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# Habitat selection and use movements and home range of Malayan gaur (Bos gaurus hubbacki) in central Pahang Malaysia

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HABITAT SELECTION AND USE, MOVEMENTS, AND HOME RANGE OF MALAYAN GAUR (*Bos gaurus hubbacki*) IN CENTRAL PAHANG, MALAYSIA

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The ecology of the Malayan gaur in the rapidly developing Lepar River Valley was investigated from September 1977 to May 1979. An adult bull, yearling female, and yearling male were radio-collared and their movements and habitat use monitored. The population was estimated at 62 animals in 7 herds during July 1978 track surveys. The adult:calf ratio was 100:24. Groups sizes ranged from 1 to 15 with a mean of 5.0. Aggregates of 2-5 and 6-10 accounted for 35 and 34% of observations, lone animals 23%, and groups larger than 10, 8%. Calves were born throughout the year. One instance of poaching of a juvenile gaur was detected. Parasites found in and on gaur were Seteria sp.; Eimeria sp. oocysts; ova of Fasciola hepatica, F. gigantica, and unidentified nematodes; and Apponomma sp. and Boophilus microphilus ticks. The home range of the adult bull was 7018 ha, the female 5218 ha, and the yearling male 2989 ha. Home range size and configuration was strongly influenced by physiographical features. Mean daily movements for the 3 animals were 1505, 1218, and 663 m. The more important habitat use patterns of the gaur were heavy use of the man-modified habitats of secondary forests and agricultural estates, and lowland riverine areas. The adult bull and female selected against areas within 500 m of major roads and zones of very high disturbance, but the yearling male selected for both categories. A direct relationship between the creation of favorable foraging conditions and levels of disturbance was detected. Agricultural development fragmented the population into 2 groups on opposite sides of the River Valley. Feeding site examinations identified 87 species in the diet. Paspalum conjugatum, Mikania chordata, and Centrosema pubescens were important food items. Nutrient quality of forage was at or slightly above maintenance requirements, but may be lacking in crude protein and phosphorus for optimum reproduction and growth of calves. Population fragmentation, low calf recruitment, human disturbance, and habitat loss to agricultural development were identified as conservation problems. Management recommendations include: create wildlife reserves; improve gaur habitat; increase law enforcement activities; plan logging operations to benefit gaur; locate roads away from gaur use areas; close roads following logging; and leave forested corridors between separated subpopulations.

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# CHAPTER I

## INTRODUCTION

The Malayan gaur (Bos gaurus hubbacki), known locally as the seladang, is a species of wild cattle found in the tropical evergreen rainforest of Malaysia and southwest Thailand. Adult bulls can measure over 1.8 m at the shoulder and weigh over 900 kg (Hubback 1937). Coloration in adults varies from redish brown to the more typical black, white stockings below the knee, and a white boss on the forehead. Gaur associate in herds of up to 30 animals, but more commonly in groups of less than 10. A forest edge animal, gaur browse and graze on early seral vegetation. Captive Indian gaur (B. g. gaurus) first calved at 2 and produced a single calf yearly (pers. comm., Oklahoma City Zoo, USA). Tigers (Panthera tigiris) are natural predators on juveniles, sick, and old animals (Foenander 1952).

Three subspecies of gaur are recognized; the Indian gaur, found in India and Nepal; the Burmese gaur, (B. g. readei) found in Burma, Thailand, Laos, Kampuchea, and Vietnam; and the Malayan gaur. The status of the gaur has declined throughout its range (Schaller 1967, Stevens 1968, Lekagul and McNeely 1977).

In 1969, the Malayan subspecies was listed in the IUCN Red Data Book as critically endangered (Simon 1969). Khan (1977) estimated the population at about 400 animals in 1977. At that time, gaur were found in appreciable numbers only in localized areas in the West

Malaysian states of Pahang, Perak, Kelantan, and Trengganu; and in national parks and wildlife reserves (Stevens 1968, Conry 1977). The decline in the gaur population was attributed to habitat loss, poaching, and inadvertent poisoning with sodium arsenite herbicide, incidental to human activities (Kitchener 1961, Stevens 1968, Khan 1973). The projected extensive development of the lowland forests (Aiken and Moss 1975) promised further gaur-human conflicts with predictable disastrous results for the gaur (Kitchener 1961). Conry (1977) investigated the status of 6 gaur herds outside of parks or wildlife reserves and found that all 6 were already affected or threatened in the near future by agricultural development, hydro-electric dam projects, human settlement, or extensive logging. Concern for the fate of gaur herds faced with such situations initiated the present study. The Lepar River Valley was selected as the study site because it was in the early stages of rapid economic development and it held a sizeable gaur population.

The goals of this study were to investigate aspects of gaur ecology in an environment undergoing economic development and to monitor impacts of the development activities on gaur. Objectives of the study were: (1) to determine the numbers of the population; (2) to determine the home range, movements, and habitat use and selection of individuals in different herds in the population; (3) to collect quantitative data on gaur food habits and natural history; and (4) to monitor the impact of human activities on the gaur.

# CHAPTER II

## DESCRIPTION OF STUDY AREA

### Location

The Lepar River study area is located in interior east-central Malaysia, Kuantan District, Pahang, approximately 200 km east of the capital city of Kuala Lumpur. The area is bounded between $3^{o}$ 35' N and $4^{o}$ 00' N latitude and $102^{o}$ 40' E and $103^{o}$ 00' E longitude.

### Physiography

The study area encompasses approximately 620 $km^2$ and was formed by the upper and middle watersheds of the Lepar and Luit rivers (Fig. 1). The two adjacent valleys are roughly oriented in a NW-SE direction, and are separated by a range of low hills, 122 m high. Together, the Lepar and Luit rivers form a wide valley 32 km long and 25 km wide. The ridge line of the watersheds form the study area boundary to the north, east, and west, while the Kuantan-Maran road forms the boundary on the south.

The Lepar River is the dominant land form in the study area and its watershed comprises the major portion of the total area. The River is segregated into four major streams of comparable size, the Upper Lepar, Rami, Belayar, and Berakit.

The terrain varies from gentle rolling hills in the valley bottoms to steep mountains. Elevations range from 46 m in the River bottom to 1,079 m at the watershed boundary. The rock base of the area

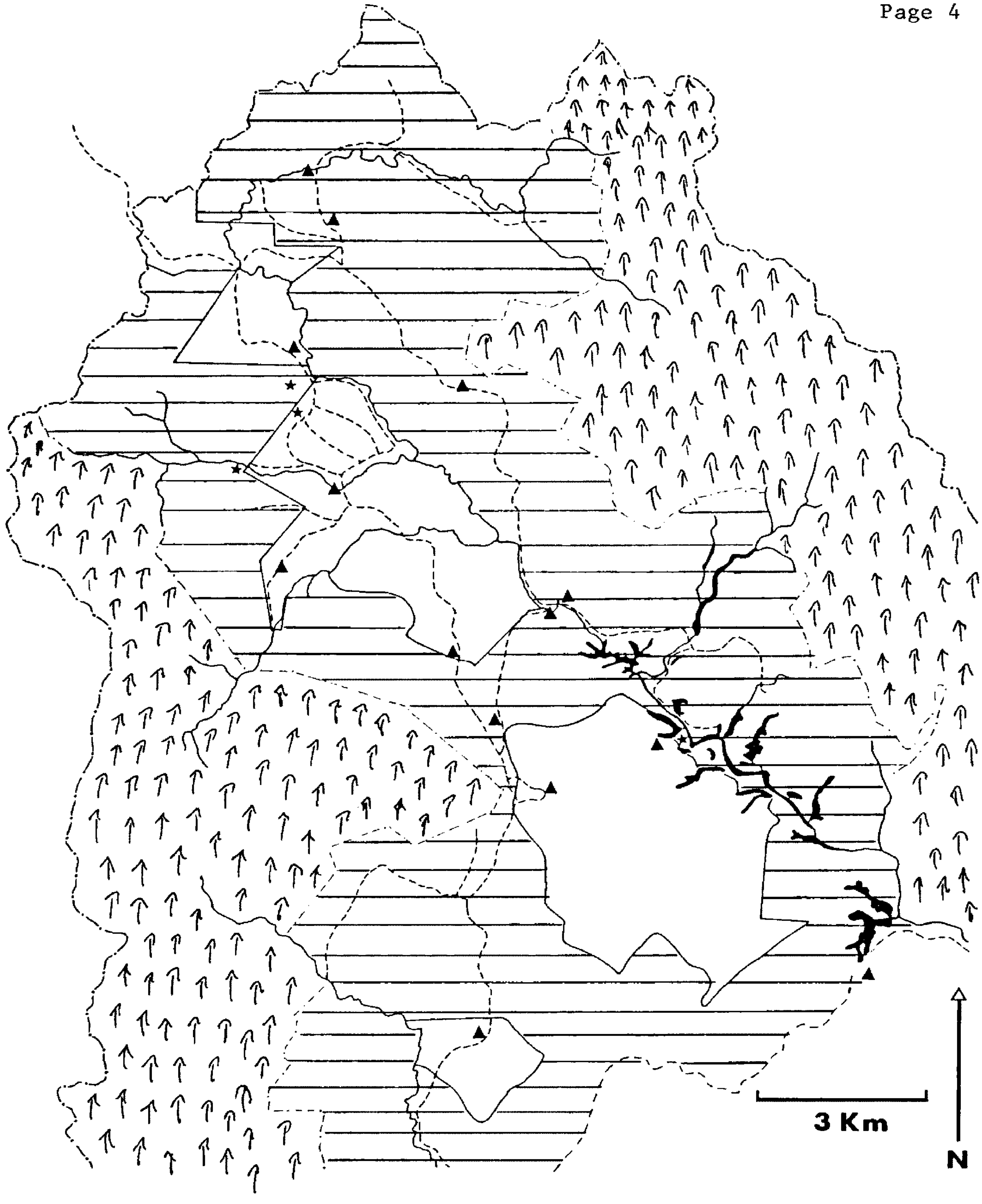


Fig. 1. Map of Lepar River study area showing distribution of habitats (primary forest-trees, secondary forest-horizontal lines, agricultural estate-open, human habitation-triangles, mineral lick-stars, and roads-dashed lines).

is upper paleozoic undifferentiated marine sediments which form shale facies and limestone formations in localized areas. The eastern ridge is composed of igneous pregranite rock (Gobbett and Hutchinson 1973).

## Climate

Malaysia has a tropical maritime climate strongly influenced by the surrounding Indian and Pacific oceans (Whitmore 1975). The atmospheric temperature over Malaya is uniformly high year round with a mean annual temperature of $27^{\circ}$ C (Dale 1963) and a mean annual relative humidity of 85% throughout the lowland areas. By day, the humidity varies between 55 and 70%, and at night it rises above 95% over most of the country. No alteration of summer and winter occurs nor is it easy to divide the year up into distinct wet and dry seasons. Heavy rainfall may be experienced anywhere at anytime of the year and short dry spells may occur, but they are not of sufficient length to qualify as "dry seasons".

The climate of Malaya does, however, have a subtle rhythm of monsoonal winds and rains divided into four periods, 2 monsoonal and 2 intermonsoonal or transitional periods. November to March is the time of the north-east monsoon, followed by the first transitional period from April to May. June to September is the south-west monsoon, followed by the second transitional period from October to mid-November. The rainfall maximums and minimums vary over the seasons throughout the country.

The Lepar Valley study area is in the interior of the country, and receives a mean annual rainfall of approximately 250 cm (Dale 1959).

A rainfall station monitored the precipitation for 1978 and 1979 at 215 cm, somewhat lower than the mean annual figure (Information on file, National Weather Bureau, Malaysia). The area received its greatest monthly precipitation (46.5 cm) during my study in December 1978 coinciding with the NE monsoon and its lowest precipitation (6.53 cm) in March 1978 (Fig. 2). Precipitation was sufficient during December, 1978, that the Lepar River flooded low lying areas.

## Vegetation

The natural vegetation of the study area is a tropical lowland evergreen rain forest of the Indo-Malayan Rain Forest Formation (Richards 1952, Whitmore 1975). Whitmore (1975) considers it the most luxuriant of all plant communities on earth; dense, evergreen, over 45 m in height, and characterized by a large number and variety of plants. The Malaya peninsula is estimated to have about 7900 species and 1500 genera of seed plants. Variation is high within the forest with as many as 210 species of trees, 0.3 m in girth or larger, found on a 1.6 ha plot (Wyatt-Smith 1966). Gregarious dominants (Consociations) are uncommon, 2/3 or more of the upper canopy trees occur at frequencies of 1 per 1.5 ha plot. However, the rain forests of Malaya display a general preponderance of species from the family Dipterocarpaceae and are classified as lowland dipterocarp rain forests.

Wyatt-Smith (1964) classified the forests of Malaysia into 3 major groups: (1) lowland vegetation; (2) hill and mountain vegetation; and (3) swamp and low-lying vegetation. According to Wyatt-Smith, lowland vegetation occurs on undulating land and foothills

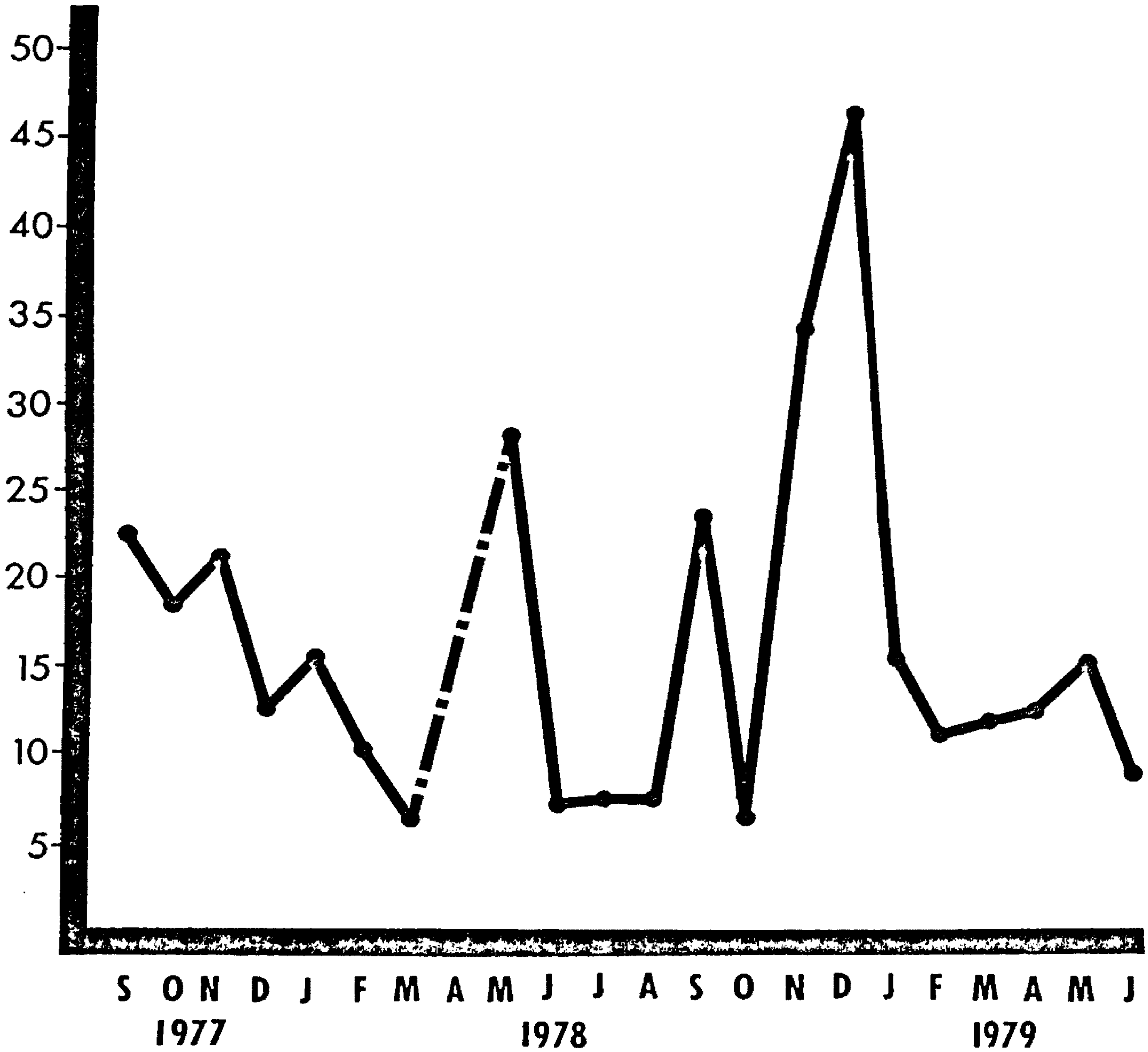


Fig. 2. Monthly precipitation (cm) on the Lepar River study area during the study period. Data not available for April, 1978.

up to an elevation of about 305 m and he termed such forests lowland dipterocarp forests. Wyatt-Smith divided lowland dipterocarp forest into primary forest and secondary forest, with the primary forest further subdivided into types on the basis of large economic trees. Hill and mountain vegetation were classified as: hill dipterocarp forest, occurring on inland ranges between the altitudinal limits of 305 and 762 m; upper dipterocarp forest, occurring on higher hills at elevations between 762 and 1220 m; montane forests, above 1220 m; and as specialized sites such as limestone vegetation. Swamp and low-lying vegetation were classified as fresh water swamp forest, mangrove swamp forest, peat swamp forest, and riparian fringes.

A 1972 Malaysian Federal Forestry Department classification of broad forest types identified forests in the Lepar Valley as a lowland dipterocarp forest of moderate to good productivity (Broad Forest Types Map, Fed. Forestry Headquarters, Kuala Lumpur). Good and moderate dipterocarp forests occur in rolling to hilly terrain up to approximately 1000 m and have the major timber species of red meranti (Shorea sp.), keruing (Dipterocarpus sp.), seraya (Shorea curtisii), balau group (Shorea spp.), kelat (Eugenia sp.), kempas (Koompassia sp.), and kendongdong (Dacryodes sp.) in densities of 1-9 trees of 60+ cm diameter per ha. Though not classified as such, hill dipterocarp and upper dipterocarp forests (elevational range of 305-1220 m) possibly occur on the upper slopes of the highest peaks. Limestone forests may also occur on the limestone formations found in the study area. These vegetation types, if they occur, would have limited range and little importance for gaur use. Riparian fringes, used by gaur, occur as narrow strips with variable widths along the banks of the rivers of the study area. However, without aerial photographs, riparian fringes were impossible to delineate. Of greatest relevance to gaur ecology is the variation in lowland dipterocarp rainforest, particularly successional stages associated with human disturbance. I mapped the study area according to the 3 identifiable successional stages to account for gross variation in vegetation structure and composition; primary forest, secondary forest, and agricultural estate. A brief description of these 3 habitats follows.

Primary forest. In this study, I use the term "primary forest" for any virgin forest unexploited by man. Primary forest covers 26,305 ha comprising 38% of the study area, and is found only at high elevations, on steep slopes, or in inaccessible regions. The upper watersheds of the rivers and the high mountains are the only remaining areas still in primary forest on the study area.

The primary forest is stratified into 5 layers; an emergent discontinuous tree layer dominated by the Dipterocarpaceae; a lower layer of continuous main stratum trees; a center layer of immature emergent trees mixed with smaller shade-tolerant trees; the fourth layer, 4 m high and consisting of shrubs, palms, and young trees; and the fifth layer, a ground layer 1-2 m high of widely scattered tree seedlings, herbs, forbs, and ferns of variable densities. The majority of vegetative work done in the tropics is oriented toward forestry, and as a result, information on the understory community is very limited.

The primary forest has a growth cycle as trees grow up, die, and fall to the ground forming gaps in the canopy into which other trees grow. As such, the primary forest consists of a mosaic of patches at different stages of maturity; from gaps, through stands of small sapplings or poles, to mature high forests, with the phases of the growth cycle existing in a state of dynamic equilibrium. The gap phase is filled by existing seedlings and sapplings on the forest floor or by seeds germinating in the gap. Pioneer species or seral species, used by gaur, can occur in the gap phase of primary forest. Poore (1968) found that 10% of the primary forest of the Jengka Valley was in the gap phase of the growth cycle.

Secondary Forest. In general, the term secondary forest refers to any sere of primary forest (Ricklefs 1979). However, in tropical secondary succession a distinction has been made between secondary forests following clear-felling and selective logging: clear-felling produces a secondary forest, and selective logging produces a depleted forest (Richards 1952, Whitmore 1975). Most selective logging operations produce a situation intermediate between the bare earth of clear-felling and the closed canopy of primary forest; selective logging usually results in a mosaic of closed canopy forest, broken canopy forest, and small openings for log collection yards and extraction routes. In this paper, any natural regrowth of vegetation following disturbance is termed secondary forest.

Shifting cultivation, abandoned estates, or selective logging are the usual causes of secondary forest in Malaysia. Secondary forest altered from primary lowland dipterocarp rain forest is generally poor in species composition, with trees smaller in basal diameter and lower in height (Richards 1952). Secondary forest is further characterized by an irregular structure where patches of undisturbed primary forest are adjacent to open gaps or patches of vegetation in various seral stages. Tree composition differs greatly between secondary and primary forests; the families Euphorbiaceae, Urticaceae, Myrtaceae, Rhizophoraceae, and Lauraceae are most abundant in secondary forest, while the families Dipterocarpaceae and Rubiaceae are most abundant in primary forest.

Secondary forest species are light demanding and rapid growing. With efficient seed dispersal, secondary species are quick to colonize openings (Richards 1952). The presence or availability of seeds and seedlings determines the specific course of secondary succession. Variability within secondary forests is very high. For example, in some instances logging operations cause a vigorous outburst of growth in the understory, while in other instances, openings are colonized by new invader species. Early seral stages are often dominated by forbs, grasses, and shrubs that can form remarkably uniform and homogeneous stands.

The extent that logging opens the canopy for propagation by secondary species is directly related to intensity and duration of logging. Burgess (1971) found that modern intensive methods of selective logging harvested 10%, and in the extraction process, destroyed an additional 55% of the standing crop of trees over 10 cm in diameter, leaving pockets and gaps where tree crowns had fallen interwoven with extraction tracks. Repeated logging causes further damage, with species composition becoming progressively richer in secondary weed species, short lived pioneers, and bamboo (Dendrocalamus pendulus and Gigantochloa scortechinis; Whitmore 1975). The combined clear-felling and scraping of the ground layer at log collection yards and along extraction routes often causes the succession of a grass association (Paspalum conjugatum or Imperatata cylindrica) that hinders tree seedling establishment.

Human activity in the Lepar Valley transformed large tracts of primary forest into secondary forest that covered 26,300 ha (38%) of the study area. Logging was the main cause of the secondary vegetation with 2 additional small areas altered by shifting cultivation and a mining operation. Selective logging was the usual practice; however, clear-felling was used prior to agricultural development. Logging started in the early 1960's and has continued since (Pers. comm., Pahang State Forestry Dept.). All areas at low elevations and with easy access were logged, and reentry logging has occurred in many areas. "Skid logging" techniques were the usual methods used, with a corresponding use of heavy equipment and an extensive network of roads to service the area. It is unknown whether any techniques were used to reduce soil compaction or scarification.

Agricultural development. Agricultural development converted over 16,000 ha (23% of the study area) of lowland dipterocarp forest to cultivated crops. Large-scale estate agriculture was practiced in the

Lepar Valley, with both privately owned and government sponsored estates in operation. Agricultural expansion occurred as a continuous process throughout the study period, and plans call for the cultivation of an additional 24,000 ha in the near future. The major estates are 4000 to 6000 ha in size and the monocultural crops produced are rubber (Heavea brasiliensis) and oil palm (Elais guineensis).

Agricultural lands are located on gentle terrain at low elevations adjacent to the major rivers. The development process involved removal of saleable timber, clear-felling of all remaining trees, burning the slash, and planting and fertilizing the monoculture crops. In some estates, cover crops (Leguminoseae) were planted or native secondary grass species were allowed to colonize the bare ground and act as erosion control. During the early growth stages of the tree crop, the open canopy allowed a lush growth of grasses and legume cover crops in the fields. As the trees matured, the canopy closed and the undergrowth was eventually shaded out.

Depredation by wildlife, elephants (Elephas maximus) in particular, is a major problem affecting agriculture in the Valley. As agriculture expanded into the lowlands, elephants were displaced from their original habitat and occupied the secondary forest surrounding the estates. At night, the animals enter the estates and feed on the young crops, supplementing their natural diet (Monroe and England 1978). The crop is destroyed and replanted a number of times until the agriculturalist concedes or the animals are killed. On one estate, this replanting-destruction cycle has been going on for over 5 years

(Pers. comm., Manager Pahang Oil Palm Estate).

As a by product of this man-elephant conflict, vast acreages of fringe agricultural lands periodically went fallow and were not tended by the field workers. These abandoned fields grew lush with natural grasses and the legume cover crops provided an abundant, palatable, and nutritious food source for wildlife that utilized it.

Human Population Centers.

The human populace involved in the development of the Lepar River Valley was distributed in 14 small settlements. Three all-weather roads penetrate the Valley and connect with an extensive network of estate and logging roads (Fig 1). In the Lepar valley, the development process was accompanied by a large influx of human population. Permanent logging camps were built and occupied year round and, on the agricultural estates, small towns were established to house the estate workers.

# CHAPTER III

# METHODS AND PROCEDURES

## Marking and Telemetry Techniques

An immobilization team composed of 2 to 4 Department of Wildlife personnel and the author conducted radio-collaring operations intermittently from October 1977 to March 1979. Gaur were stalked on foot to within 20 m and darted with a Palmer Cap-Chur gun and darts (4 and 7 cc; Palmer Chemical and Equipment Co.; Inc.) filled with a mixture of Immobilon and Rompun. Five gaur were equipped with radio transmitters (154.2-154.5 MHz). Four of the transmitters were manufactured by Telonics Inc., powered by lithium batteries, and hermetically sealed. The fifth, was an AVM Instrument Co. transmitter reassembled from an elephant collar and equipped with new lithium batteries and an antenna, dipped in bees wax, and set in dental acrylic. All transmitter packages were mounted on 5-cm, 4-ply, rubberized belting, wrapped with waterproof colored plastic tape for identification, and bolted on the immobilized animal's neck.

From 26 October 1977 to 7 May 1979, 176 locations of 3 gaur (adult bull, yearling female, and yearling male) were obtained (Table 1). Using an AVM receiver, I located collared animals by radio telemetry from a Cessna 172 aircraft with a double, 4-element, directional yagi antenna bolted onto the wing struts. Maximum tracking

Table 1. Sex, age, and the date of monitoring of radio-collared gaur, and the number and method of location.

| Gaur | Sex | Age | Number and method of location | | | | Monitoring period |
|---|---|---|---|---|---|---|---|
| | | | Aerial | Ground | Triangulation | Total | |
| 1 | M | 5+ | 32 | 5 | 1 | 38 | 10 Jan 78 - 23 Nov 78 |
| 2 | F | 1 | 70 | 11 | 10 | 91 | 16 Oct 77 - 16 Dec 78 |
| 3 | M | 1 | 12 | 22 | 13 | 47 | 8 Nov 78 - 7 May 79 |
| Total | | | 114 | 38 | 24 | 176 | |

distance was approximately 25 km from 660 m elevation. Ground tracking locations were made with a single, 4-element, hand-held yagi antenna or by ground triangulation from base stations equipped with a dual-antenna, null-peak system mounted on a rotating 6 m shaft and situated on high points in the study area. Signal reception on the ground was greatly affected by terrain with the contact distance ranging from less than 1 to 5 km. Locating animals from the ground was very time consuming, often unproductive, and disturbing to the gaur. Locations by ground triangulation from base stations were restricted to specific areas of the range because of rough terrain and poor reception. Consequently, gaur were monitored primarily by aerial tracking. Numerous visual sightings were made during tracking (48 of 176, 27%), and verified the accuracy of the locations. The sex, age, and date of monitoring of the 3 radio-collared gaur are shown in Table 1. Gaur were aged by tooth eruption and wear of the incisors. The average periods of eruption and wear of the teeth of domestic cattle (Ensminger 1976) were used as criterion for age estimation.

Population Census

In the early stages of the study, I explored the study area observing gaur distribution and abundance. Based on that initial knowledge, I established and periodically traveled a series of track survey routes, foot trails and vehicle routes, to observe gaur distribution, group spatial relationships, group size, and census the population. Both visual and animal sign observations were made on the track surveys. However, the dense vegetation and minimal visibility greatly limited observations; as a result, animal sign provided the predominant source of data. Track sign was carefully examined to distinguish group size and then measured for classification into age categories.

A comprehensive census was conducted from 18-20 July 1978 by 4 teams that combined ground track surveys with aerial tracking of radio-collared animals. The short, 3-day census and location of known groups (radio-collared animals) eliminated the confusing effects of group movements, and helped to establish the social structure of the population. As much as possible of the study area was covered, but at best, the census results represent a minimum population estimate.

Criteria used for age and sex classification of visually observed animals were based on measurements and a pictorial record of immobilized animals and known-age captive Indian gaur at the Oklahoma City Zoo, Oklahoma, USA. Gaur seen were classified into 4 age classes; 0-6 months, new born calf, golden colored; 6-12 months, older calf, brown colored with stockings, horn length to 30 cm; yearling, 3/4 adult size, horn length 30-45 cm; adult, dark brown to black, full size, well developed incurved horns. When possible, sex classification was made on the basis of external genitalia and morphology. The female horns are sharply incurved with thin basal diameters. The tips almost meet in very old cows. Females show slight muscular development of the neck and shoulders. The male horn grows out and up with thick basal diameters. Bulls show massive muscular development of the neck and shoulders. Calves and yearlings were difficult to age by external morphology.

Track data were classified into 3 age classes according to track length. Criteria for the age classes were established from hoof measurements of immobilized animals handled during capture and collaring operations and additionally from track measurements of calves seen in the field. The 3 age classes discernable from track data were: calf, <8.0 cm; yearling, 8.0 to 9.0 cm; and adult, >9.0 cm. If front and rear track measurements varied and fell into 2 age classes, the animal was classified as an adult if the larger track was >9.0 cm and as a calf if the smaller track was <8.0 cm. Adult females could occasionally be identified by their association with calves.

Movements, Home Range, and Habitat Use

Gaur telemetry locations were identified on a standard gridded topographic map (series L7010, 1:63360, printed by the Director of National Mapping, Malaysia). Locations were recorded as 3 digit, east and north coordinates, corresponding to the standard numerical reference on the map. For each location, habitat use was noted by type and a visual sighting attempted.

Home range size of each animal was determined by the minimum area method (Mohr 1947). Locations of the animals were plotted on a gridded topographic map with the outermost locations connected by straight lines to include all other locations. The home ranges were convex polygon shaped and the inclusive areas were determined using an Apple Computer. The boundaries were traced onto a digitizing plate and the computer calculated the polygon area.

Locations were examined in chronological order to detect activity and movement patterns. The distance moved between consecutive 24 hour locations or consecutive activity period locations was measured and indicated the extent of gaur minimum daily movements (MDM).

Gaur telemetry locations were used to quantify habitat use. A topographic map showing habitat types, salt licks, major roads, and human dwellings was used as the data base on which to categorize locations. Each location was plotted on the map and categorized using the following 12 habitat parameters:

1. Habitat type: Primary forest, secondary forest, agricultural estate, or open water.
2. Distance to major river.
3. Horizontal diversity index: The number of habitat types (1 above) accessible within 500 m of the location.
4. Elevation.
5. Distance to mineral lick.
6. Distance to ecotone.
7. Distance to primary forest habitat.
8. Distance to secondary forest habitat.
9. Distance to agricultural estate habitat.
10. Distance to major road.
11. Distance to human habitation.
12. Disturbance zone: Very high, high, moderate, or low disturbance according to the disturbance potential of any given site.

Food Habits

Feeding site observations, inspection of dung piles, and cursory observations were used to quantify percentage composition and occurrence of forage items in the gaur diet. Feeding sites were located in the 3 habitat types from observations of animals feeding, or more frequently, from the distinctive sign of gaur hoof prints and feeding. Only fresh feeding sign, 1-2 days old was examined. At each feeding site, instance of use, or bites, were recorded for each plant species. A leaf of 12 X 8 cm size or a combination of twigs and leaves of comparable size were considered 1 bite of a browse item and a clump of grass 10 cm in diameter was considered 1 bite of grass. Unknown plant species were tagged and collected for later identification by personnel of the Forest Research Institute and University Pertanian. Feeding site data were summarized by species and forage class, by habitat types, and by total diet. The percentage composition of each species and forage class in the primary forest, secondary forest, agricultural estate, and total diet was calculated.

The occurrence of additional food items in the diet were detected by cursory observations and inspection of fecal materials, and were included in the gaur forage item list. Seeds found in dung piles were collected for identification. An inspection for parasite ova and seeds were made of 32 fecal samples. The samples were washed through a filter, the seeds separated out, and the items identified.

Important food items from secondary forest and agricultural estate habitats were analyzed for nutrient content. I collected 2 samples of grasses (predominantly Paspalum conjugatum) from secondary forest and an agricultural estate, a mixed grass-legume sample (P. conjugatum and Centrosema pubescens) from an agricultural estate, and 1 fruit sample (Dillenia ovata) from secondary forest for analysis. The samples were sun dried for 4 days and later oven dried. Personnel at the University Pertanian analyzed the samples for dry matter, protein, fat, crude fiber, carbohydrate, ash, phosphorus, and gross energy. The nutrient contents of the grass samples from the 2 habitats were compared.

Sample of Habitat Availability

A nonmapping random point method (Marcum and Loftsgaarden 1980) was used to determine the availability of habitat parameters within the home ranges of the 3 gaur. With this method, the availability of hard to map habitat parameters can be estimated and several mutually exclusive habitat parameters can be handled simultaneously for each sampling point. Briefly, I generated by computer random sampling points within each home range using the 3 digit, east and north, map coordinates. The random sampling points were plotted and characterized according to the 12 habitat parameters; habitat type, elevation, horizontal diversity index, etc., as was previously done for telemetry locations, using the same base map. These sampling data were summarized by computer runs in cumulative groups of 40 sample points (runs of the first 40, 80, 120 points per group). When relatively small differences were obtained between groups (less than 5% differences in means for most parameters), the sample size was considered adequate (Marcum 1975). The sample size used for sampling each home range was 149, 153, and 136 random points. The proportionate availability of habitat parameter categories was calculated by the number of random points falling in a habitat category, divided by the total number of random points in that home range sample. This proportionate availability was compared with proportionate use to determine habitat selection.

## Statistical and Computer Procedures

Data summarization and analysis were done with the aid of a DECSYSTEM-20 computer. SPSS (Statistical Package for the Social Sciences; Nie et al. 1975) and BMDP (Biomedical Computer Programs:P Series; Dixon and Brown 1979) statistical computer packages and graphics programs from the system library of canned programs were used for data manipulation, summarization, analysis, and presentation. A text formulating program was also used in the preparation and editing of the manuscript.

Habitat selection. Gaur selection for or against habitat parameter categories was tested with a Chi-squared test of homogeneity. The hypothesis tested was that gaur use each habitat category in proportion to its occurrence in the home range. If this hypothesis was accepted at the P=0.10 level of significance, I then concluded that no selection occurred and no further analyses were performed. If the hypothesis was rejected, I concluded that selection occurred and identified the specific categories. This was accomplished by calculating 90% simultaneous confidence intervals for the difference in proportionate use and availability for each habitat category (Marcum and Loftsgaarden 1980). For additional clarity in examining the results of tests for selection, I calculated the Z-value for the difference between proportions of use and availability for each individual category and looked up its probability level in a Z-table (Schefler 1979). The formula used to calculate the Z-value was:

$$Z=(Pu - Pa)/[Pu(1 - Pu)/Nu + Pa(1 - Pa)/Na]^{1/2}$$

where Nu equals the number of gaur locations, Pu equals the proportionate use of that habitat category, Na equals the number of random sampling points, and Pa equals the proportionate availability of that habitat category in the home range.

Each gaur's habitat selection was analyzed separately.

The 90% simultaneous confidence intervals, as constructed for a habitat parameter with 4 categories, required an individual confidence interval of 97.5% for each habitat category. The 90% simultaneous confidence intervals assure, with a probability of 0.90, that the 4 individual categories simultaneously include the true parameter values.

Multivariate analyses of habitat use. A principal components analysis (Morrison 1967, James 1971, Smith 1977), using the BMDP principal components analysis computer program (Dixon and Brown 1979), was conducted on the gaur habitat data. This technique is useful for descriptive purposes, as I use it here, because it summarizes the information (variance) from the complex multivariate data set in a few new independent dimensions (components) accounting for known proportions of the total variance. The identity of the derived components is interpreted from the correlations of the original variables with the components, and the size of the coefficients indicate the relative importance of each variable in the component. Furthermore, the importance and usefulness of the component to represent the information in the multivariate system is measured by the proportion of the total variance attributed to it. Principal components analysis detects the relationships of the measured variables, without an a priori assumption of dependence or importance, that may lead to the recognition of functional complexes not readily discernable and to a greater understanding of the phenomenon studied. A major utility of principal components analysis is that for descriptive purposes, the data need not meet the stringent assumptions of a multivariate normal distribution (as is often the case with biological data), unless used with statistical tests (Morrison 1967, Neff and Marcus 1980).

Five principal component analyses were run on standardized data (mean of 0 and variance of 1), with the components extracted from the correlation matrix. The 12 habitat variables listed above were included in the analyses with the discrete variables coded for biological relevance. The categories in the discrete variable "habitat type"; primary forest, secondary forest, and agricultural estate; were coded as 1,2, and 3 representing a gradient of improving forage availability (grasses and legumes). Likewise, the discrete variables "disturbance zone" and "horizontal habitat diversity" were coded to reflect increasing disturbance and diversity with the increasing numerical sequence.

For these analyses, habitat type, horizontal habitat diversity, distance to ecotone, and distance to river were interpreted as representing a gradient of favorable foraging sites. My rationale for this was that various authors have described gaur foraging sites as jungle clearings, forest fringe, riverine areas, abandoned and shifting cultivation, and other areas of seral vegetation (Hubback 1937, Stevens 1968, Weigum 1972, Medway 1978). The variables "distance to road", "distance to human habitation", and "disturbance zone" reflect disturbance effects. "Distance to primary forest", "distance to secondary forest", and "distance to agricultural estates" reflect both a foraging and disturbance effect. Separate principal components analyses were run for the combined gaur, individual animal, and combined random habitat sample data.

## CHAPTER IV

## RESULTS

### Population Status and Distribution of Gaur in the Lepar Valley

I periodically traversed survey routes along river courses, logging roads, and plantation fringe areas collecting information on gaur distribution and group size. Group size and age composition were estimated from animal sightings and sign, track and bed counts, and track measurements. A July 1978 census, conducted by 4 teams, combined aerial tracking of radio-collared animals and ground track surveys to cover as much of the study area as possible in a 3-day period. The short duration of the census eliminated the confusing effects of group movements. The results from the census provided an estimate of the minimum population size in the Valley.

Population census. The July 1978 census revealed at least 62 animals in 7 herds identified by locality. Small groups and lone individuals in a general locality were combined to arrive at the figure for herd size (Table 2). The radio-collared adult bull and female were located in the Belayar and Berakit river herds, respectively. The organization depicted in Table 2 is based on the concurrent census. However, over 125 track surveys throughout the study period consistently located groups in these localities.

Table 2. Size and age composition of 7 gaur herds found on the Lepar River study area during a 3-day census, 18-20 July 1978.

| Locality | Herd size | Age composition | | | Remarks |
|---|---|---|---|---|---|
| | | Adult | Yearling | Calf | |
| Luit River | 10 | 8 | 1 | 1 | groups of 6 & 4 |
| Belayar River | 12 | 7 | 2 | 3 | groups of 8 & 4 |
| Rami River | 7 | 5 | 2 | 0 | |
| Upper Lepar River | 14 | 8 | 2 | 4 | |
| Hok River | 8 | 8 | 0 | 0 | groups of 5,2 & 1 |
| Berakit River | 7 | 4 | 1 | 2 | |
| Lower Lepar River | 4 | 2 | 2 | 0 | |
| Total | 62 | 42 | 10 | 10 | |

<u>Distribution</u>. Fig. 3 illustrates the distribution and spatial relationships of the 7 herds found on the study area. In addition to the Lepar and Luit valleys, gaur were found in the adjoining watersheds of the Tekum and Jempot rivers. Presence of gaur in the Jempot watershed was attributed to the travels of the radio-collared adult male.

The distributional limits of gaur to the north of the Lepar Valley are unknown; however, movement data indicated that steep, mountainous terrain did not prohibit travel between adjacent watersheds. The presence of domestic water buffalo (<u>Bubalus bubalis</u>) delimited the distributional range of the gaur in the lower Lepar Valley. Both track data and telemetry locations indicated that the gaur traveled up to and no further than the range of the domestic herds from the village of Kampong Rambutan.

Agricultural estates in the Valley separated the population into groups occupying the foothills to the east and west of the estates. Forested corridors running between the estates connected the forested foothill sections and were used by both groups.

<u>Age composition</u>. Track size was used to determine the age of individuals. Of the 62 gaur identified in the census, 42 were classified as adults, 10 as yearlings, and 10 as calves (Table 2). The data produced a ratio of 100:24:24 adults to yearlings to calves in the population.

Because of limitations inherent in "track measurement data", I present these findings as an index of reproductive success rather than

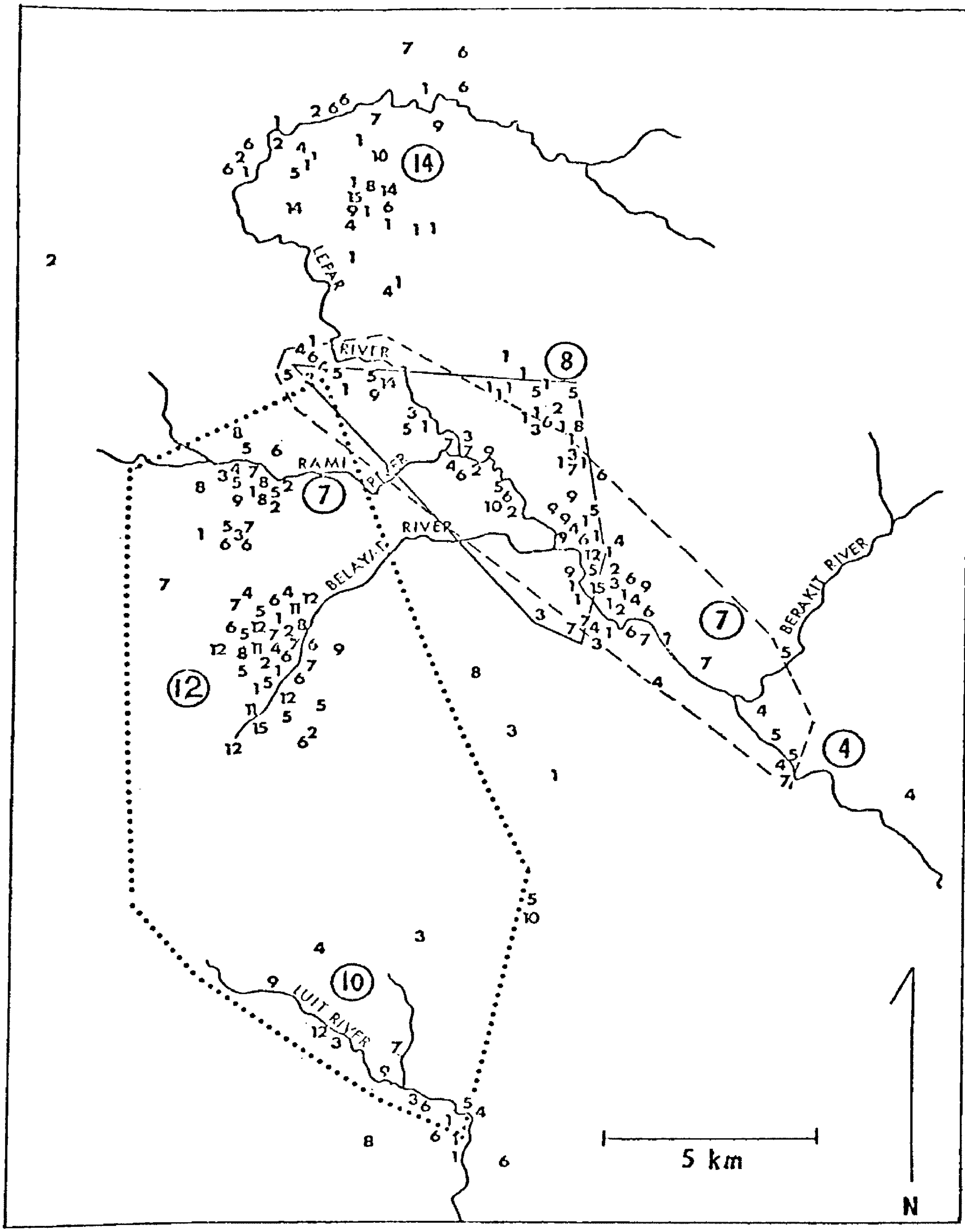


Fig. 3. Distribution and spatial relationship of gaur herds in the Lepar Valley (large numbers-results of 7/78 census, small numbers-track counts 1977-1979, dotted line-home range of adult bull, dashed line-home range of yearling female, solid line-home range of yearling male).

an enumeration of age class composition in the population.

Group size and cohesion. Gaur group size observed on the study area ranged from 1 to 15 (a local villager reported seeing 20 animals in the upper Lepar herd). In 212 observations, the mean group size was 5.0 animals. Aggregates of 2-5 and 6-10 animals were the most frequently encountered groups, accounting for 35 and 34% of the observations. Lone animals accounted for 23% of the observations, and aggregates greater than 10 accounted for 8% of the observations.

Gaur groups were not strongly cohesive. Large groups, encountered at clearings, salt licks, and agricultural estates, frequently split upon entering the forest. Fig. 3 graphically presents the spatial relationship between the groups of various sizes and indicates the loose cohesion of gaur groups. This figure also includes the home ranges of the 3 monitored gaur and the population structure data from the July 1978 census.

When disturbed, groups usually broke into smaller subgroups or family units and individuals. The smallest cohesive unit was the cow-calf group. Large groups of 12 to 15 animals were encountered during capture operations and would eventually disintegrate into groups of 1 or 2 animals as we pursued them throughout the day.

Life history. Calves were born throughout the year and hence no seasonality was detected in the breeding season. Visual observation and track measurement data provided a rough estimate of the calving period; tracks 6.5 cm or less indicated a calf less than 4 months old.

Tracks of new calves, or observations of golden colored calves, were made during 9 months of the year, January to May, July, and October to December. Five cm was the smallest track observed, and tracks 5.0 to 5.5 cm in length were encountered in March, May, July, and December. An additional visual sighting of a golden calf (2-3 months old) was made in March and a lactating female accompanied by her calf of less than 4 months (tracks measured 5.8 cm in length) was immobilized in July.

Two gaur were collared as calves and their relationship with the herd provided information on dispersal of young. A female collared at 6-9 months of age accompanied a group throughout the 14 month monitoring period. This contrasts with the male collared at 12 months that was located on its own 6 months later. However, the young bull continued to interact with a group, 9 days later it was relocated with a group of females.

The cow-calf bond was the strongest bond within a group; yet, even it broke down under disturbance such as encounters with humans on foot or in automobiles. Escape behavior usually included the disintegration of the group with animals fleeing in various directions. This may have resulted in separation and abandonment of calves. On 2 occasions a golden calf (thought to be the same animal) was seen standing at the edge of a logging road when no other herd members were in the area. Possibly the calf was momentarily separated from the herd, was abandoned by the cow, the cow was dead, or the calf was left in hiding while the female was foraging. What ever the explanation, the calf was vulnerable to predation and poaching.

_Mortality_. One case of poaching was discovered on the study area. The skeletal remains of a young gaur was found in an abandoned logging camp. On an other occasion, a logging truck knocked down a young gaur crossing the logging road and the animal fled with unknown injuries. Tigers and leopards (_Panthera pardus_) both were found on the study area, but, no evidence of tiger or leopard predation was found.

Additional potential causes of mortality existed. Sodium arsenite was used to kill grasses on a number of oil palm estates. Khan (1973) documented the demise of a herd of gaur at Kuala Lompat after eating grasses sprayed with this poison. In addition, I found a number of wire leg hold snares set for wild pigs (_Sus scrofa_) by poachers. These illegal devices could cause the death or permanent injury of a gaur if it stumbled into one.

_Disease_. The gaur examined during collaring operations were well nourished with no external signs of disease. Blood samples from 2 animals were negative for blood diseases. However, internal and external parasites were found in and on the animals. Appendix A lists the parasitic infestation found on gaur. Twenty-eight of 94 (30%) dung samples inspected for parasitic ovum were infected. Two species of tick were collected from immobilized animals, but, were of no known medical significance.

The presence of domestic animals in the Lepar Valley presents a danger of disease transmission to the gaur. In 1978, an epidemic of Foot-And-Mouth disease was reported in northern Malaysia; however, no cases were reported for gaur or domestic stock on the study area.

## Home Range and Movements

Home range size and configuration. The home range size of the monitored gaur varied considerably with the yearling male occupying the smallest range and the adult bull the largest. Physiographical features greatly affected home range shape and size.

The adult bull was monitored for 10 months and located 38 times. Its range included the upper and middle watersheds of the Rami, Ruil, and Luit rivers. The home range size as determined by the minimum area method (convex polygon) (Mohr 1947) was 13,730 ha. However, the range of the adult bull contained 2 distinct concentrated-use areas separated by mountainous terrain. Travel between the 2 areas was up the drainage systems, crossing over the mountains at a low point on the watershed boundary, and down the adjacent drainage system. The rugged mountainous area appeared to be used only as a travel corridor.

For analyses of the adult bull's range, the minimum area method greatly over estimates actual area used. A modification of this method, excluding the mountainous terrain and dividing the home range into 2 separate use areas connected by a travel corridor, better represents the range of the adult bull (Fig. 4). The 2 resulting polygons measured 2829 ha and 4189 ha. The combined areas totaled 7018 ha.

Shape of the home range was greatly influenced by physiographical features. The home range was oblong with 20.8 km between the most widely separated locations. The northern edge of the range was located in the vicinity of a mineral lick and jungle clearing

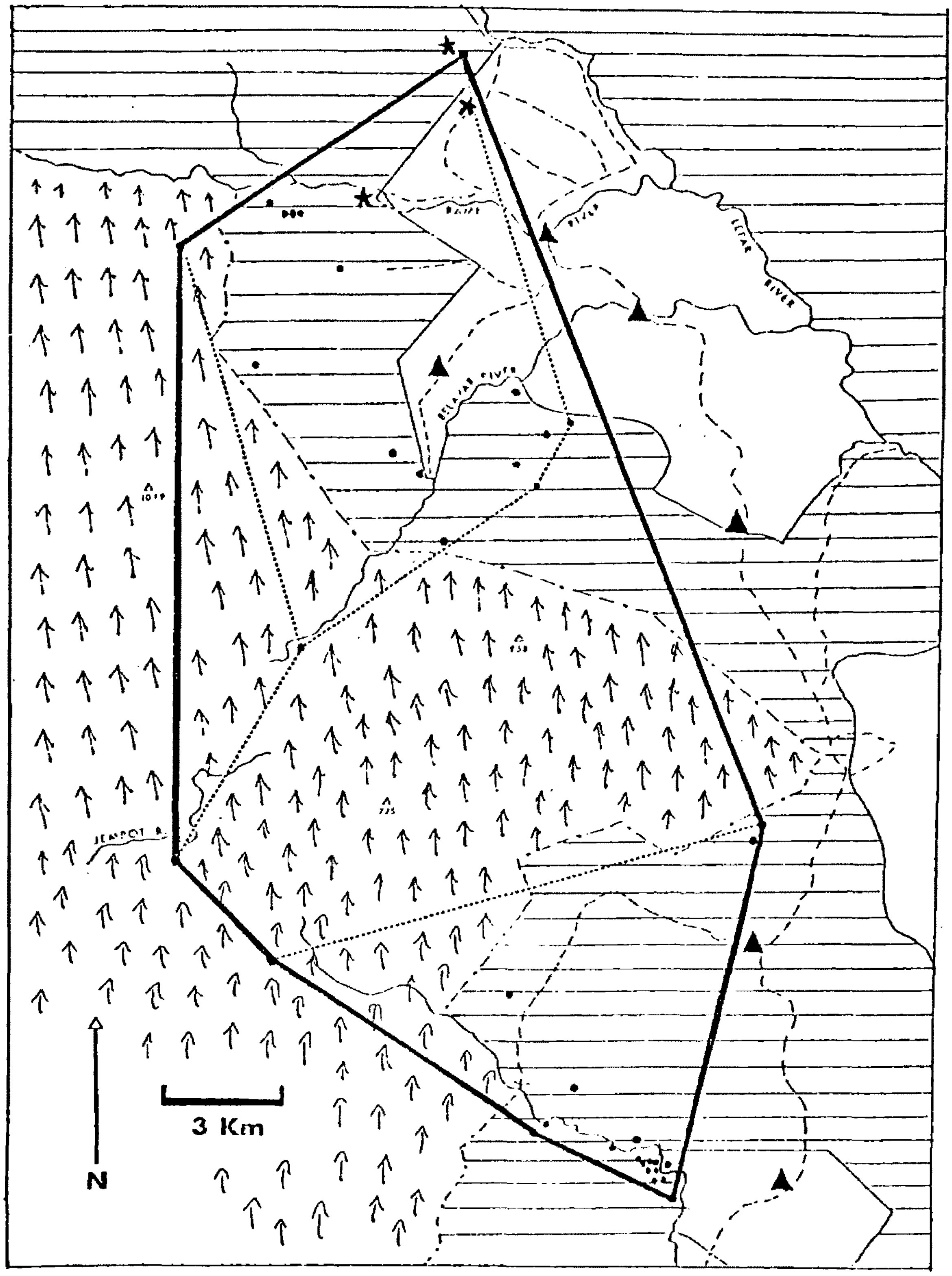


Fig. 4. Home range of adult bull gaur showing habitats (primary forest-trees, secondary forest-horizontal lines, agricultural estate-open, human habitation-triangles, mineral lick-stars, roads-dashed lines).

and the southern extreme bordered an agricultural estate. Both concentrated-use blocks were located in the lowland areas of the drainage systems. Borders of the home range were determined by agricultural estate boundaries or steep mountainous terrain. Primary forest, secondary forest, and agricultural estate habitats were available in the home range.

The female, monitored for 12 months and relocated 91 times, occupied a home range of 5213 ha (Fig. 5). The home range was long and thin, adhering to the Lepar River and agricultural estate boundary. The maximum distance between any two points in the range was 17 km.

Mineral licks were located at both the southern and northern extremes of her range and influenced range shape. A great portion of her western boundary was within agricultural estates, but no discernable physiographical barrier inhibited range expansion on the east. Agricultural estate and secondary forest habitats were available within the home range.

The yearling male was monitored for 7 months and relocated 47 times. Its home range measured 2989 ha and was triangular. The long axis of the range adhered to the Lepar River and agricultural estate boundary (Fig. 6). The greatest distance between any 2 locations was 10.1 km.

A mineral lick was located in the extreme NW corner of his range and influenced the northern boundary. The southern limits of the range was associated with the boundary of an agricultural estate. The range extended east into a forested area with no apparent

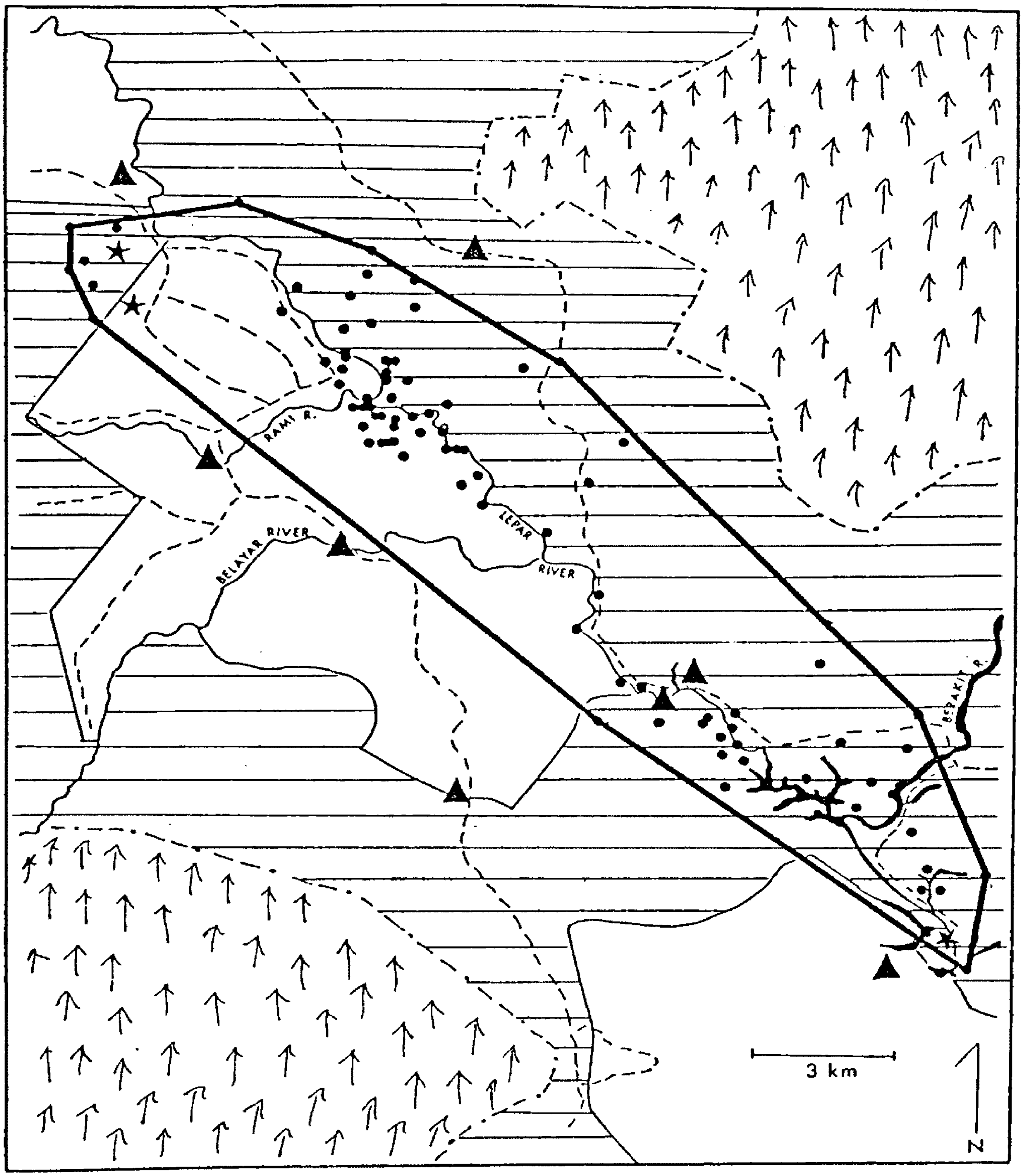


Fig. 5. Home range of yearling female gaur showing habitats (primary forest-trees, secondary forest-horizontal lines, agricultural estate-open, human habitation-triangles, mineral licks-stars, roads-dashed lines).

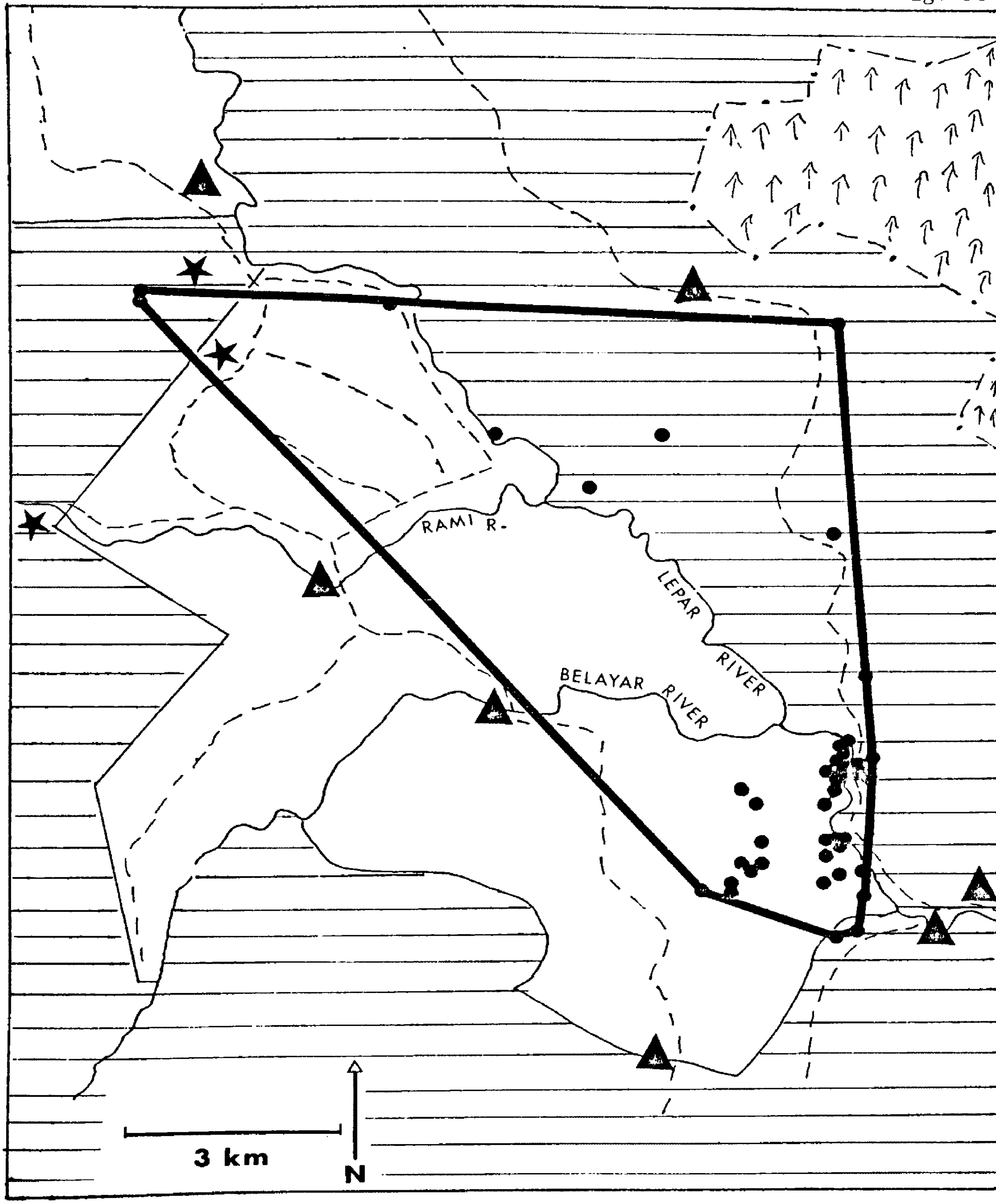


Fig. 6. Home range of yearling male gaur showing habitats (primary forest-trees, secondary forest-horizontal lines, agricultural estate-open, human habitation-triangles, mineral lick-stars, roads-dashed lines).

physiographical barrier limiting expansion. Agricultural estate and secondary forest habitats were available in the home range.

The only area of home range overlap between all 3 animals occurred in the area of mutually shared mineral licks (Fig. 3). However, there was virtually complete overlap of the yearling male's range by the female. The majority of radio locations of the yearling male were made during 1979 after failure of the female's transmitter. Consequently, concurrent movements of the 2 animals were detected only once at a mineral lick.

Movements. Gaur telemetry locations and back tracking provided information on daily movements and general range use. Back tracking and successive 24 hour telemetry locations indicated the magnitude of daily movements. The mean and range of minimum-distance-moved (MDM) between successive 24 hour locations or activity periods for the 3 gaur are reported in Table 3.

Mean MDM varied from 660 m for the yearling male to 1500 m for the adult male and was highly correlated with home range size ($r=+0.997$, $P<0.05$). MDM ranged from 0.0 m recorded for both the yearling male and female to 4150 m movement recorded for the adult bull when it was traveling between the north and south sections of its home range. Both telemetry locations and back tracking indicated that gaur often selected a use area and remained in its general locality for extended periods. The proportion of MDM less than 1.0 km was 0.5 or greater for all 3 gaur (Table 3). Back track data supported this finding, gaur repeatedly used the same agricultural estates and established pastures for days at a

Table 3. Mean and range of minimum daily movements (m) and proportion of minimum daily movements less than 1.0 km for 3 radio-collared gaur on the Lepar River study area.

| Gaur | n | Daily movement* | | |
|---|---|---|---|---|
| | | Mean | Range | Proportion <1.0 km |
| Adult Bull | 10 | 1565 | 170-4150 | 0.50 |
| Female | 36 | 1218 | 0-3900 | 0.50 |
| Yearling Male | 12 | 663 | 0-2600 | 0.83 |

*Minimum distance moved between telemetry locations on consequtive days or activity periods.

time.

Gaur movements were examined for correlations with general weather patterns; MDM's were compared with the daily rainfall and 3-day rainfall averages for trends. Only 1 significant trend was detected, MDM of the yearling male was directly related to 3-day average rainfall. However, it was at such a low predictability that the validity of the relationship is questionable (r=+0.539). In general, no apparent association was evident between distance an animal moved in a day and the quantity of rainfall.

Long movements between areas of concentrated use and (assumed) movements to mineral licks were detected in all 3 animals. The adult bull traveled 4.0 km (straight line) on 2 consecutive days in transit between concentrated use areas. This animal shifted between the northern and southern portions of its bi-portioned range at least 7 times during the 11 months it was monitored. The female also made numerous shifts in her range, moving between mineral licks, forest areas, and agricultural estate feeding areas. Seven long-distance shifts in her range were detected.

Gaur readily used logging roads during their movements, in addition to the more traditional routes along river drainages. We tracked a group of gaur for more than 5 km along a major access logging road before it entered the forest. We often tracked gaur groups as much as 20 km in a single day before giving up the chase.

Movements to mineral licks by all 3 animals were detected. The adult bull was located within 1500 m of a mineral lick 3 times, although its principle range use area was 18 km distant. A number of the shifts this animal made in its range use were, I believe, associated with movement to mineral licks. Both the female and yearling male were detected in the vicinity of licks as well. The female was detected within 1000 m 9 times, and the yearling male twice. The frequent location of track sign at mineral licks confirmed their popularity.

### Gaur Habitat Use and Selection

Three gaur were monitored, and their use of 12 habitat parameters was compared to the availability of parameters in their home ranges. The hypothesis that gaur used each habitat parameter category in proportion to its availability was tested with a Chi-squared test of homogeneity at the P=0.10 level. Habitat parameters for which selection occurred were further analyzed with a simultaneous confidence interval (Marcum and Loftsgaarden 1980). Selection occurred in all the habitat parameter categories with the exception of "distance to agricultural estate" and "distance to human habitation" by the female and yearling male, and "habitat type" by the yearling male.

In reporting the results of the test for selection, I followed the terminology of Marcum (1975). "Selected for" indicated that use of a habitat parameter category was significantly greater than its availability, "Selected against" indicated that use was significantly less than availability. "No significant difference" referred to the case where no significant difference was detected between gaur use of the habitat parameter category and its proportionate availability.

<u>Habitat type</u>. Both the adult bull and the yearling female gaur exhibited selection in their use of the habitat types available in their home range, whereas the yearling male used its habitat in proportion to availability. Of the 4 habitat types found on the study area, the adult male's home range included primary forest, secondary forest, and agricultural estate. The female and yearling male occupied home ranges that included secondary forest, agricultural estate, and open water in the form of lakes or the lower stretches of the Lepar River. All 3 gaur used the habitat types available to them in different ways.

The adult bull selected for secondary forest habitat. More than 86% of his total use occurred in this habitat, whereas secondary forest comprised only 62% of the available area. Agricultural estate and primary forest habitat were selected against, but selection against primary forest was not highly significant ($z=-1.95$, $P=0.051$; Table 4). This animal was the only 1 of the 3 monitored that used the primary forest habitat. This habitat was only available at high elevations on steep slopes (areas unsuitable for logging), and it was used during travel between discontinuous sections of secondary forest and for sanctuary from disturbance.

The female gaur exhibited no significant difference between use of the 2 terrestrial habitat types in her home range and their availability. Secondary forest received the heaviest use (65%) followed by agricultural estates with 35% of total use. Approximately 7% of her home range was covered by open water, but no use was recorded. Thus,

Table 4. Percentages of gaur use and home range availability of habitat types and results of statistical tests of selection.

| | (N) | Primary forest | Secondary forest | Agricultural estate | Open water |
|---|---|---|---|---|---|
| **Adult bull** | | | | | |
| Use % | 37 | 10.8 | 86.5 | 2.7 | |
| Availability % | 149 | 22.8 | 62.4 | 14.8 | |
| 90% SCI Test* | | NSD | + | - | |
| *z* Value | | -1.95 | +3.49 | -3.05 | |
| Prob. of *z*** | | 0.051 | 0.0005 | 0.002 | |
| **Yearling female** | | | | | |
| Use % | 91 | | 64.8 | 35.2 | 0 |
| Availability % | 153 | | 65.4 | 27.5 | 7.2 |
| 90% SCI Test | | | NSD | NSD | - |
| *z* Value | | | -0.10 | +1.10 | -3.46 |
| Prob. of *z* | | | 0.92 | 0.27 | 0.0005 |
| **Yearling male** | | | | | |
| Use % | 46 | | 39.1 | 60.9 | 0 |
| Availability % | 136 | | 49.3 | 48.5 | 2.2 |

*90% Simultaneous confidence interval test compares gaur use of habitat parameter categories with availability to denote preference. In reporting results the symbol + or - indicates use significantly greater or less than availability and NSD indicates no significant difference between use and availability.

**Probability of obtaining, by chance alone, a difference between the proportions of use and availability as great as the observed difference given the null hypothesis of use equal to availability.

open water habitat type was selected against. Open water habitat types could be important for activities such as wallowing or bathing, however, gaur do not wallow.

The female was never monitored using the primary forest habitat, even though such habitat was within 1500 m of her home range. This distance was easily within the range of the animal's daily movements (the average minimum distance moved per 24 hour period was 1230 m with a maximum of 3900 m). No natural barriers were evident to prohibit travel into primary forest, apparently a high degree of selection was occurring against primary forest or some factor associated with it.

The yearling male exhibited no significant difference in use of habitat types and their occurrence in his home range ($X^2$=2.78, d.f.=2, P>0.10). Therefore, no additional statistical tests for selection were made. His use of habitat types and their availability are reported in Table 4. Unlike the adult bull and female, he used the agricultural estate habitat to a greater extent than all other types. The agricultural estate habitat received 61% of total use versus 39% use in secondary forest habitat. As was the case with the female, open water occurred but was not used. The young male was never monitored as using primary forest habitat, even though it was available within 900 m. Evidently, this animal also exercised some selection against primary forest habitat or some factor associated with it.

*Proximity to riparian zones*. The Luit, lower Lepar, and 3 major tributaries of the upper Lepar River sectioned the study area and the home ranges of the 3 animals monitored. The gaur used a range of distances from 10 to 6200 m from major rivers.

All 3 gaur selected areas within 250 m of rivers. Use of this zone accounted for over 45% of each gaur's total use; 46, 63, and 52%, respectively, for the adult bull, female, and yearling male. Areas more than 250 m from major rivers were either selected against, or their use did not differ significantly from availability (Table 5).

Horizontal habitat diversity. Gaur locations and random sampling points were assigned a horizontal habitat diversity index rating according to the degree of diversity of habitat types accessible from that location. The diversity index was determined by the number of habitat types found within 500 m of a location. Diversity index ratings ranged from a low of 1, representing a location well within the perimeter of a homogeneous habitat type, to a high of 3, representing a location near a second habitat type and a river.

In general, gaur selected for areas of high diversity (DI=3) and against areas of low diversity (DI=1; Table 6). Areas of intermediate diversity (DI=2) were used in proportion to their availability by the adult male and female, and were selected against by the yearling male. Areas with a diversity rating of 3 represented the smallest proportion of the home ranges of the adult male and female, yet received the largest proportionate use, 41 and 48% use versus availability of 21 and 27%.

Table 5. Percentages of gaur use and home range availability of distance classes to the nearest major river and results of statistical tests for selection.

| | | Distance to nearest major river (m) | | | |
|---|---|---|---|---|---|
| | (N) | 0-250 | 251-750 | 751-1250 | 1250 |
| **Adult bull** | | | | | |
| Use % | 37 | 45.9 | 24.3 | 16.2 | 13.5 |
| Availability % | 149 | 18.1 | 25.5 | 18.8 | 37.6 |
| 90% SCI Test* | | + | NSD | NSD | - |
| _z_ Value | | +3.17 | -0.15 | -0.38 | -3.50 |
| Prob. of _z_** | | 0.002 | 0.881 | 0.704 | 0.0005 |
| **Yearling female** | | | | | |
| Use % | 91 | 62.6 | 22.0 | 8.8 | 6.6 |
| Availability % | 153 | 37.9 | 32.0 | 17.6 | 12.4 |
| 90% SCI Test | | + | NSD | NSD | NSD |
| _z_ Value | | +3.86 | -1.72 | -2.05 | -1.57 |
| Prob. of _z_ | | 0.0001 | 0.085 | 0.04 | 0.116 |
| **Yearling male** | | | | | |
| Use % | 46 | 52.2 | 19.6 | 17.3 | 10.9 |
| Availability % | 136 | 27.9 | 34.6 | 19.1 | 18.4 |
| 90% SCI Test | | + | NSD | NSD | NSD |
| _z_ Value | | +2.93 | -2.11 | -0.30 | -1.30 |
| Prob. of _z_ | | 0.003 | 0.035 | 0.764 | 0.194 |

*See footnote Table 4.

**See footnote Table 4.

Table 6. Percentages of gaur use and home range availability in relation to horizontal habitat diversity and results of statistical tests for selection.

| | | Horizontal habitat diversity Index*** | | |
|---|---|---|---|---|
| | (N) | 1 | 2 | 3 |
| Adult bull | | | | |
| Use % | 37 | 21.6 | 37.8 | 40.5 |
| Availability % | 149 | 45.6 | 33.6 | 20.8 |
| 90% SCI Test* | | - | NSD | + |
| z Value | | -3.04 | +0.47 | +2.26 |
| Prob. of z** | | 0.002 | 0.638 | 0.024 |
| Yearling female | | | | |
| Use % | 91 | 17.6 | 34.1 | 48.4 |
| Availability % | 153 | 41.8 | 30.7 | 27.5 |
| 90% SCI Test | | - | NSD | + |
| z Value | | -4.32 | +0.55 | +3.27 |
| Prob. of z | | 0.000 | 0.583 | 0.001 |
| Yearling male | | | | |
| Use % | 46 | 32.6 | 8.7 | 58.7 |
| Availability % | 136 | 48.5 | 19.9 | 31.6 |
| 90% SCI Test | | NSD | NSD | + |
| z Value | | -1.96 | -2.07 | +3.27 |
| Prob. of z | | 0.05 | 0.038 | 0.001 |

*See footnote Table 4.

**See footnote Table 4.

***Diversity index was determined by the number of habitat types found within 500 m of the location.

Elevation. Elevation on the study area ranged from 46 m along the lower reaches of the Lepar River to 1049 m at the highest point on the watershed boundary. The guar used a range of elevations from 46 m to 381 m.

The adult bull used the broadest range of elevations, from 46 to 381 m, with the highest elevations used during travels from 1 watershed to the next over the dividing mountain ridge. Use of elevations between 61 and 381 m did not differ significant from availability. Low elevations, 61 m or less, received over 43% use and were selected for (Table 7).

The female and yearling male used the lower areas of the study area, avoiding the high elevations altogether. More than 95% of their use occurred at elevations of 91 m or less while the highest elevations used were 122 and 107 m. Both animals selected for elevations less than 61 m and against elevations above 122 and 107 m. No significant difference was detected between use and availability of intermediate elevations (61-91 m).

On the study area, elevation was generally related to slope steepness. Areas at elevations selected for by gaur were generally gentle terrain of low undulating hills. The steeper slopes were found at high elevations and avoided by 2 of the 3 animals monitored and used during travel between low elevation areas by the adult bull.

Proximity to mineral licks. Four natural mineral licks were discovered in the Lepar River study area (Fig. 1). Three were located within 3.5 km of each other on the northern extreme of the 3 gaur's

Table 7. Percentages of gaur use and home range availability of various elevations and results of statistical tests for selection.

**Adult bull** — Elevation (m)

| | (N) | 46-61 | 61-91 | 92-122 | 122-152 | >152 |
|---|---|---|---|---|---|---|
| Use % | 37 | 43.2 | 18.7 | 16.2 | 10.8 | 10.8 |
| Availability % | 149 | 10.0 | 33.6 | 30.2 | 12.1 | 14.1 |
| 90% SCI Test* | | + | NSD | NSD | NSD | NSD |
| *z* Value | | +3.91 | -1.96 | -1.96 | -0.22 | -0.56 |
| Prob. of *z*** | | 0.000 | 0.05 | 0.05 | 0.826 | 0.575 |

**Yearling female** — Elevation (m)

| | (N) | 46 | 46-61 | 61-77 | 78-91 | >91 |
|---|---|---|---|---|---|---|
| Use % | 91 | 4.4 | 47.3 | 29.7 | 13.2 | 5.5 |
| Availability % | 153 | 11.1 | 27.5 | 32.7 | 14.4 | 14.4 |
| 90% SCI Test | | NSD | + | NSD | NSD | - |
| *z* Value | | -2.01 | +3.09 | -0.50 | -0.27 | -2.41 |
| Prob. of *z* | | 0.044 | 0.002 | 0.617 | 0.787 | 0.016 |

**Yearling male** — Elevation (m)

| | (N) | 46-61 | 61-77 | 77-91 | >91 |
|---|---|---|---|---|---|
| Use % | 46 | 56.5 | 28.3 | 13.0 | 2.2 |
| Availability % | 136 | 28.6 | 38.2 | 21.3 | 11.8 |
| 90% SCI Test | | + | NSD | NSD | - |
| *z* Value | | +3.36 | -1.27 | -1.36 | -2.74 |
| Prob. of *z* | | 0.001 | 0.204 | 0.17 | 0.006 |

*See footnote Table 4.

**See footnote Table 4.

ranges and the fourth was located on the southern extreme of the female's range. The home range of the adult bull contained 3, that of the female 3, and that of the yearling male 2 mineral licks. Track surveys indicated frequent use of mineral licks by gaur on the study area.

The adult bull used areas situated the farthest from a mineral lick. This animal traveled 19 km from the southern edge of its home range (Luit River agricultural estate) to the mineral licks located in the north. When on their home ranges, the female and yearling male were within 7.2 and 7.5 km of a mineral lick (Table 8).

The 3 animals used the habitat differently in relation to mineral licks. The adult bull and female used as available areas within 2000 m of a mineral lick, but, the yearling male used those areas less than available. Selection for areas at distances greater than 2000 m from a mineral lick probably represents an interaction with another factor in those localities, rather than some influence of the mineral lick.

Proximity to ecotones. Areas adjacent to ecotones were selected for, with over 40% or more of each animal's use concentrated in zones within 250 m of an ecotone (Table 9). However, selection of this zone by the adult bull was slightly less (z=-1.99, P=0.047) than is required for significance of the individual confidence interval in the 90% simultaneous confidence interval test for selection (Marcum and Loftsgaarden 1980). The yearling male used areas near ecotones the most, 57% of his use occurred within 250 m and 44% was within 100 m.

Table 8. Percentages of gaur use and home range availability in relation to distance to the nearest mineral lick and results of statistical tests for selection.

| | Distance to nearest mineral lick (m) | | | | |
|---|---|---|---|---|---|
| | (N) | 0-2000 | 2001-7000 | 7001-15000 | >15000 |
| Adult bull | | | | | |
| Use % | 37 | 8.1 | 35.1 | 16.2 | 40.5 |
| Availability % | 149 | 16.1 | 43.6 | 27.5 | 12.8 |
| 90% SCI Test* | | NSD | NSD | NSD | + |
| z Value | | -1.48 | -0.94 | -1.60 | +3.26 |
| Prob. of z** | | 0.139 | 0.347 | 0.110 | 0.001 |
| | (N) | 0-2000 | 2001-4000 | 4001-6000 | >6000 |
| Yearling female | | | | | |
| Use % | 91 | 14.3 | 45.1 | 35.2 | 5.5 |
| Availability % | 153 | 18.9 | 30.1 | 26.1 | 24.8 |
| 90% SCI Test | | NSD | + | NSD | - |
| z Value | | -0.95 | +2.34 | +1.49 | -4.56 |
| Prob. of z | | 0.342 | 0.019 | 0.136 | 0.000 |
| | (N) | 0-2000 | 2001-4000 | 4001-6000 | >6000 |
| Yearling male | | | | | |
| Use % | 46 | 4.3 | 6.5 | 2.2 | 87.0 |
| Availability % | 136 | 16.2 | 20.6 | 32.3 | 30.8 |
| 90% SCI Test | | - | - | - | + |
| z Value | | -2.70 | -2.82 | -6.50 | +9.37 |
| Prob. of z | | 0.007 | 0.005 | 0.000 | 0.000 |

*See footnote Table 4.

**See footnote Table 4.

Table 9. Percentages of gaur use and home range availability in relation to distance to the nearest ecotone and results of statistical tests for selection.

| | Distance to nearest ecotone (m) | | | | |
|---|---|---|---|---|---|
| | (N) | 0-250 | 251-750 | 751-1500 | >1500 |
| Adult bull | | | | | |
| Use % | 37 | 43.2 | 32.4 | 16.2 | 8.1 |
| Availability % | 149 | 25.5 | 31.5 | 34.6 | 9.4 |
| 90% SCI Test* | | NSD | NSD | - | NSD |
| *z* Value | | +1.99 | +0.10 | -2.55 | -0.26 |
| Prob. of *z*** | | 0.047 | 0.92 | 0.011 | 0.795 |
| | (N) | 0-250 | 251-750 | 751-1750 | >1750 |
| Yearling female | | | | | |
| Use % | 91 | 39.6 | 25.3 | 29.7 | 5.5 |
| Availability % | 153 | 17.0 | 26.1 | 42.5 | 14.4 |
| 90% SCI Test | | + | NSD | NSD | - |
| *z* Value | | +3.97 | -0.14 | -2.14 | -2.40 |
| Prob. of *z* | | 0.000 | 0.889 | 0.032 | 0.016 |
| | (N) | 0-250 | 251-750 | 751-1250 | >1250 |
| Yearling male | | | | | |
| Use % | 46 | 56.5 | 15.2 | 21.7 | 6.5 |
| Availability % | 136 | 22.8 | 27.9 | 28.7 | 20.6 |
| 90% SCI Test | | + | NSD | NSD | - |
| *z* Value | | +4.14 | -1.94 | -0.97 | -2.81 |
| Prob. of *z* | | 0.000 | 0.052 | 0.332 | 0.005 |

*See footnote Table 4.

**See footnote Table 4.

All 3 animals used intermediate distances to ecotones (251-750 m) approximately equal to availability. Areas at distances greater than 750 m were used either approximately equal to availability, or less than available.

Proximity to primary forest. The adult bull was the only animal monitored that used primary forest or came within 500 m of it (Table 10). The minimum distance the female and yearling male were observed from primary forest was 1500 and 900 m. Areas adjacent to primary forest were used approximately equal to availability by the adult male and female and used proportionately less than their availability by the yearling male. Less than 10% of the female and yearling male use was concentrated in this closest distance class. The important use pattern evident was that some gaur completely avoided zones adjacent to primary forest. Areas relatively close to primary forest were available, yet received use approximately proportional to or less than their availability. Areas far from primary forest received the heaviest use, probably representing an interaction with some other factor in those localities.

Proximity to secondary forest. Secondary forest comprised a major portion of the gaur habitat. When not in secondary forest, gaur selectively used various distances from it.

The adult bull rarely used other habitat types and was found outside secondary forest on just 5 of 37 occasions (Table 11). Three of the 5 locations were in primary forest at distances greater than 2 km

Table 10. Percentages of gaur use and home range availability in relation to distance to the nearest primary forest habitat and results of statistical tests for selection.

| | Distance to nearest primary forest habitat (m) | | | | |
|---|---|---|---|---|---|
| | (N) | 1-1000 | 1001-2000 | 2001-3000 | >3000 |
| Adult bull | | | | | |
| Use % | 33 | 33.4 | 18.2 | 42.4 | 6.0 |
| Availability % | 116 | 33.6 | 29.3 | 22.4 | 14.7 |
| 90% SCI Tests* | | NSD | NSD | NSD | NSD |
| z Value | | -0.02 | -1.39 | +2.12 | -1.65 |
| Prob. of z** | | 0.984 | 0.165 | 0.034 | 0.099 |
| | (N) | 501-2000 | 2001-3000 | 3001-4000 | >4000 |
| Yearling female | | | | | |
| Use % | 91 | 8.8 | 15.4 | 68.2 | 7.7 |
| Availability % | 153 | 13.7 | 27.5 | 34.0 | 24.8 |
| 90% SCI Test | | NSD | - | + | - |
| z Value | | -1.21 | -2.33 | +5.53 | -3.80 |
| Prob. of z | | 0.226 | 0.02 | 0.000 | 0.000 |
| | (N) | 501-1500 | 1501-2500 | 2501-4000 | >4000 |
| Yearling male | | | | | |
| Use % | 46 | 4.3 | 2.2 | 69.6 | 23.9 |
| Availability % | 136 | 14.7 | 13.3 | 44.1 | 27.9 |
| 90% SCI Test | | - | - | + | NSD |
| z Value | | -2.42 | -3.08 | +3.19 | -0.54 |
| Prob. of z | | 0.016 | 0.002 | 0.001 | 0.589 |

*See footnote Table 4.

**See footnote Table 4.

Table 11. Percentages of gaur use and home range availability in relation to distance to the nearest secondary forest habitat and results of statistical tests for selection.

| | Distance to nearest secondary forest habitat (m) | | | | |
|---|---|---|---|---|---|
| | (N) | 1-250 | 251-1250 | >1250 | |
| **Adult bull** | | | | | |
| Use % | 5 | 20.0 | 20.0 | 60.0 | |
| Availability % | 56 | 33.9 | 50.0 | 16.1 | |
| 90% SCI Test* | | NSD | NSD | NSD | |
| *z* Value | | -0.73 | -1.57 | +1.96 | |
| Prob. of *z*** | | 0.465 | 0.116 | 0.05 | |
| | (N) | 1-250 | 251-500 | >500 | |
| **Yearling female** | | | | | |
| Use % | 32 | 65.6 | 21.9 | 12.5 | |
| Availability % | 53 | 35.8 | 18.9 | 45.3 | |
| 90% SCI Test | | + | NSD | - | |
| *z* Value | | +2.79 | +0.33 | -3.64 | |
| Prob. of *z* | | 0.005 | 0.741 | 0.000 | |
| | (N) | 1-250 | 251-750 | 751-1250 | >1250 |
| **Yearling male** | | | | | |
| Use % | 28 | 60.7 | 7.2 | 25.0 | 7.1 |
| Availability % | 70 | 21.4 | 31.4 | 22.9 | 28.6 |
| 90% SCI Test | | + | - | NSD | - |
| *z* Value | | +3.74 | -3.27 | +0.22 | -2.95 |
| Prob. of *z* | | 0.000 | 0.001 | 0.826 | 0.003 |

*See footnote Table 4.

**See footnote Table 4.

from secondary forest during travel between 2 concentrated use areas. Another location was in primary forest just 600 m from secondary forest, and the fifth location was 100 m inside an agricultural estate.

Habitat use by the female and yearling male was restricted to secondary forests and agricultural estates. Therefore, the measurement of distance to secondary forest depicts the animals' tendency to venture into more open areas of the agricultural estates. Both animals selected for areas within 250 m of secondary forest, concentrating 66 and 61% of their respective use in zones adjacent to it. The female did not venture beyond 650 m from secondary forest with intermediate distances (251-500 m) used as available and distances greater than 500 m selected against. The yearling male penetrated the agricultural estates the farthest, venturing up to 1750 m from secondary forest. Distances greater than 1250 m were used significantly less than in proportion to their availability.

Proximity to agricultural estates. Gaur locations were classified relative to distance from the nearest agricultural estate habitat. Locations within the agricultural estates were assigned to the 0 distance class and were not included in the computations (use of habitat types is reported separately under the Habitat Type section). Therefore, this habitat parameter represents gaur use in relation to agricultural estates when not in such estates. The distance class adjacent to agricultural estates received the heaviest use by gaur (Table 12). The adult and yearling males concentrated 47 and 67% of their use within 500 m of schemes while 34% of the female's use occurred

Table 12. Percentages of gaur use and home range availability in relation to distance from the nearest agricultural estate habitat and results of statistical tests for selection.

| | Distance from nearest agricultural estate habitat (m) | | | | |
|---|---|---|---|---|---|
| | (N) | 1-500 | 501-1500 | 1501-2500 | >2500 |
| <u>Adult bull</u> | | | | | |
| Use % | 36 | 47.2 | 19.5 | 19.5 | 13.9 |
| Availability % | 127 | 11.0 | 23.6 | 22.8 | 42.6 |
| 90% SCI Test* | | + | NSD | NSD | - |
| <u>z</u> Value | | +4.11 | -0.54 | -0.44 | -3.99 |
| Prob. of <u>z</u>** | | 0.000 | 0.589 | 0.66 | 0.000 |
| | (N) | 1-500 | 501-1000 | 1001-1500 | >1500 |
| <u>Yearling female</u> | | | | | |
| Use % | 59 | 33.9 | 17.0 | 25.5 | 23.7 |
| Availability % | 111 | 27.9 | 26.1 | 15.3 | 30.6 |
| | (N) | 1-500 | 501-1000 | 1001-1750 | >1750 |
| <u>Yearling male</u> | | | | | |
| Use % | 18 | 66.7 | 16.7 | 11.1 | 5.5 |
| Availability % | 70 | 38.6 | 24.3 | 15.7 | 21.4 |

*See footnote Table 4.

**See footnote Table 4.

in this zone.

However, when use was compared to availability, only the adult bull selectively used distance classes from agricultural estate habitat, selecting for areas within 500 m, against areas greater than 2500 m, and using intermediate distance classes approximately proportional to their availability. The results of the Chi-squared tests for homogeneity of use and availability indicated that both the female and yearling male used distance classes from agricultural estates in approximate proportion to their occurrence in their home ranges. Therefore, no further tests for selection were made. Their proportionate use and availability of distance classes to agricultural estates are reported in table 12.

The majority of gaur locations were determined by aerial telemetry between 0830 and 1830, when gaur may avoid the open agricultural estates for the security of the neighboring jungle. Track surveys and visual observations detected night use and daytime avoidance of agricultural estates. If locations within 500 m of an agricultural estate were considered as representing probable use of the estate the preceeding morning or following night, the use and importance of this habitat increased considerably. Agricultural estates and fringe areas accounted for 49, 57, and 87% of use by the adult bull, female, and yearling male, respectively.

## Disturbance

During the study period, the Lepar Valley was in progressive stages of logging and agricultural development, subjecting the gaur to continuous human disturbance. Early in the study, 1977 through June 1978, disturbance was relatively light with limited logging activity and little traffic on the major access road east of the Lepar River (less than 20 one-way trips per day). With the progression of time, logging, road construction, forest clearing, traffic, and human settlement increased dramatically. The opening of the North-Lepar logging concession in July 1978, prompted bridge and road construction followed by heavy logging activity. During the heaviest road construction period monitored, 292 one-way trips crossed the access bridge over the Lepar River on 27 October 1978. Heavy logging activity and traffic continued east of the River throughout the duration of the study. In addition, commencing in September 1978 and continuing through 1979, large tracts of secondary forest used by the gaur were cleared for agricultural expansion. Each increase in work activity was accompanied by an influx of human population and the potential for human disturbance. Three habitat parameters were measured to monitor gaur reaction to disturbance: distance to the nearest major road; distance to the nearest human habitation (small town, barracks, logging camp, or any permanent dwelling); and proportionate use of disturbance zones.

Distance to nearest major road. Major access roads that were passable year round serviced the agricultural estates and logging operations in the Lepar Valley (Fig. 1). Gaur locations were classified by distance from the nearest major road. Chi-squared results indicated that the animals selectively used areas in relation to distance from roads.

The adult bull and female used areas within 500 m of roads significantly less than their proportionate availability (Table 13). Distances classes greater than 500 m from a road were used significantly greater than their availability, or used equal to availability.

The yearling male differed dramatically from the use pattern of the adult bull and female. He used areas adjacent to major roads (0-500 m) significantly more than their proportionate availability, and used intermediate areas (501-1000 m) as available. In addition, this animal was monitored during heavier stages of development than either the adult bull or female.

Distance to human habitation. Only the adult bull selectively used distances classes from habitation. He used areas within 1000 m of human habitation significantly less than their availability. Distance classes greater than 1000 m from human habitation were used significantly greater than availability or equal to availability (Table 14). Both the female and yearling male used distance classes to the nearest human habitation in proportion to their availability. Therefore, no further statistical tests were performed.

Disturbance zones. Gaur locations were classified according to the disturbance potential of any given site. Areas within 500 m of major roads or human habitation were classified as very high disturbance zones, areas within agricultural estates were classified as high disturbance zones, areas in secondary forest were classified as moderate disturbance zones, and areas in primary forest were classified as low

Table 13. Percentages of gaur use and home range availability in relation to distance to the nearest major road and results of statistical tests for selection.

| | | Distance to nearest major road (m) | | | |
|---|---|---|---|---|---|
| | (N) | 0-500 | 501-2000 | 2001-4000 | >4000 |
| Adult bull | | | | | |
| Use % | 37 | 0 | 40.5 | 37.8 | 21.6 |
| Availability % | 149 | 3.4 | 20.1 | 37.6 | 38.9 |
| 90% SCI Test* | | - | + | NSD | NSD |
| z Value | | -2.30 | +2.34 | +0.02 | -2.22 |
| Prob. of z** | | 0.021 | 0.019 | 0.998 | 0.026 |
| | (N) | 0-500 | 501-1000 | 1001-1500 | >1500 |
| Yearling female | | | | | |
| Use % | 91 | 15.4 | 22.0 | 38.5 | 24.2 |
| Availability % | 153 | 30.7 | 22.9 | 14.4 | 32.0 |
| 90% SCI Test | | - | NSD | + | NSD |
| z Value | | -2.89 | -0.16 | +4.16 | -1.33 |
| Prob. of z | | 0.004 | 0.873 | 0.000 | 0.184 |
| | (N) | 0-500 | 501-1000 | >1000 | |
| Yearling male | | | | | |
| Use % | 46 | 73.9 | 19.6 | 6.5 | |
| Availability % | 136 | 50.0 | 32.4 | 17.6 | |
| 90% SCI Test | | + | NSD | - | |
| z Value | | +3.06 | -1.80 | -2.27 | |
| Prob. of z | | 0.002 | 0.072 | 0.023 | |

*See footnote Table 4.

**See footnote Table 4.

Table 14. Percentages of gaur use and home range availability in relation to distance to the nearest human habitation and results of statistical tests for selection.

| | Distance to nearest human habitation (m) | | | | | |
|---|---|---|---|---|---|---|
| | (N) | 0-1000 | 1001-2500 | 2501-4000 | 4001-5500 | >5500 |
| **Adult bull** | | | | | | |
| Use % | 37 | 2.7 | 54.0 | 24.3 | 8.1 | 10.8 |
| Availability % | 149 | 11.4 | 33.6 | 33.5 | 16.2 | 5.4 |
| 90% SCI Test* | | - | + | NSD | NSD | NSD |
| *z* Value | | -2.35 | +2.25 | -1.14 | -1.50 | +1.00 |
| Prob. of *z*** | | 0.019 | 0.024 | 0.254 | 0.134 | 0.317 |

| | (N) | 0-1000 | 1001-2000 | 2001-3000 | >3000 |
|---|---|---|---|---|---|
| **Yearling female** | | | | | |
| Use % | 91 | 9.9 | 42.9 | 42.9 | 4.4 |
| Availability % | 153 | 20.9 | 37.3 | 36.6 | 5.2 |

| | (N) | 0-500 | 501-1500 | 1501-2500 | >2500 |
|---|---|---|---|---|---|
| **Yearling male** | | | | | |
| Use % | 46 | 0 | 39.1 | 56.5 | 4.4 |
| Availability % | 136 | 5.9 | 35.2 | 47.8 | 11.0 |

*See footnote Table 4.

**See footnote Table 4.

disturbance zones. Only the adult bull used all 4 disturbance zones, the female and yearling male used the 3 higher disturbance zones (Table 15).

Both the adult bull and female selected against areas of very high disturbance. The adult bull selected for moderate disturbance zones and used as available the low disturbance zones. The female selected for high disturbance zones and used as available moderate disturbance zones. Moderate disturbance zones received the most use by both the adult bull and female (87 and 57%).

The yearling male used very high, high, and moderate disturbance zones. He selected for very high disturbance zones and against moderate disturbance zones, concentrating 91% of his total use in high or very high disturbance zones. No significant difference was noted between use and availability of high disturbance zones.

Multivariate Analyses of Habitat Use

A principle component analysis (PCA) was conducted on the data for the individual animals (AM, F, JM, in Table 16), combined gaur (CG in Table 16), and combined random habitat samples (RS in Table 16). The combined gaur PCA identified the characteristics of the habitat that best described gaur habitat use. The first principle component (PC-I) of the combined gaur data is highly correlated with most of the original variables (Table 16). Empirically, PC-I represents a gradient of increasingly favorable forage conditions directly related to disturbance and inversely related to elevation. PC-I accounts for 43% of the total variance in the data set. A habitat site with a large value on PC-I was

Table 15. Percentages of gaur use and home range availability in relation to zones of disturbance and results of statistical tests for selection.

| | | Disturbance zones | | | |
|---|---|---|---|---|---|
| | (N) | Very High | High | Moderate | Low |
| **Adult bull** | | | | | |
| Use % | 37 | 0 | 2.7 | 86.5 | 10.8 |
| Availability % | 149 | 6.0 | 8.7 | 62.4 | 22.8 |
| 90% SCI Test* | | - | NSD | + | NSD |
| *z* Value | | -3.08 | -1.70 | +3.50 | -1.95 |
| Prob. of *z*** | | 0.002 | 0.089 | 0.001 | 0.051 |
| **Yearling female** | | | | | |
| Use % | 91 | 15.4 | 30.8 | 53.8 | |
| Availability % | 153 | 30.7 | 11.1 | 58.2 | |
| 90% SCI Test | | - | + | NSD | |
| *z* Value | | -2.88 | +3.60 | -0.67 | |
| Prob. of *z* | | 0.004 | 0.000 | 0.503 | |
| **Yearling male** | | | | | |
| Use % | 46 | 73.9 | 17.4 | 8.7 | |
| Availability % | 136 | 50.0 | 23.5 | 26.5 | |
| 90% SCI Test | | + | NSD | - | |
| *z* Value | | +3.08 | -0.91 | -3.17 | |
| Prob. of *z* | | 0.002 | 0.363 | 0.002 | |

*See footnote Table 4.

**See footnote Table 4.

Table 16. First principal component correlation coefficients of the 12 habitat parameters extracted from the correlation matrix of the adult male (AM), female (F), yearling male (YM), combined gaur (CG), and combined random habitat sample (RS) data.

| Habitat parameter | AM | F | YM | CG | RS |
|---|---|---|---|---|---|
| Habitat type | -0.86 | -0.80 | -0.07 | -0.64 | -0.80 |
| Horizontal diversity | -0.53 | -0.81 | -0.95 | -0.51 | -0.29 |
| Distance to ecotone | 0.88 | 0.85 | 0.90 | 0.75 | 0.17 |
| Elevation | 0.81 | 0.43 | 0.61 | 0.75 | 0.65 |
| Distance to river | 0.05 | 0.57 | 0.82 | 0.30 | 0.44 |
| Distance to primary forest | -0.72 | -0.37 | 0.07 | -0.68 | -0.89 |
| Distance to secondary forest | -0.87 | -0.58 | -0.63 | 0.57 | -0.17 |
| Distance to agricultural estate | 0.95 | 0.91 | 0.40 | 0.93 | 0.89 |
| Distance to mineral lick | -0.24 | -0.19 | -0.27 | 0.12 | 0.58 |
| Distance to road | 0.91 | 0.27 | 0.68 | 0.78 | 0.77 |
| Distance to habitation | 0.93 | 0.02 | 0.22 | 0.79 | 0.74 |
| Disturbance zone | -0.86 | -0.59 | -0.52 | -0.61 | -0.75 |
| Variance explained (%) | 59.3 | 35.5 | 34.7 | 43.1 | 41.8 |

located in a block of primary forest habitat far from the nearest ecotone, agricultural estate, roads, and human habitation; an area of little or no horizontal diversity in habitats, poor forage potential, and no human disturbance. A site with a small score on PC-I was located in secondary forest habitat within 200 m of an agricultural estate and human dwelling; 50 m from a road; an area with good forage potential, high horizontal habitat diversity, and high human disturbance.

The second principal component (PC-II) accounts for an additional 13% of the variance in the data set (Table 17). Horizontal diversity has a high positive correlation and distance to the river has a high negative correlation. Empirically, this component appears to represent a gradient of increasing horizontal habitat diversity (favorable foraging conditions) inversely related to distance from a major river. On the study area, habitat boundaries often followed rivers.

The similarities in high correlations for PC-I and PC-II between the combined gaur and the random habitat samples (CG and RS in Tables 16 and 17) indicated that the gaur population as a whole was responding directly to the existing habitat conditions. However, the greater differences between correlations of the random habitat sample PCA and the individual gaur PCA indicated that the different groups in the population selected special habitat conditions. The differences in correlations between the individual PCA's also identifies areas of partitioning and overlap in habitat space within the population as a whole.

Table 17. Second principal component correlation coefficients of the 12 habitat parameters extracted from the correlation matrix of the adult male (AM), female (F), yearling male (YM), combined gaur (CG), and combined random habitat sample (RS) data.

| Habitat parameter | AM | F | YM | CG | RS |
|---|---|---|---|---|---|
| Habitat type | -0.14 | 0.13 | 0.68 | 0.18 | 0.08 |
| Horizontal diversity | 0.63 | -0.22 | 0.03 | 0.70 | -0.83 |
| Distance to ecotone | 0.15 | -0.11 | 0.02 | -0.23 | 0.78 |
| Elevation | -0.10 | 0.58 | -0.15 | 0.05 | -0.01 |
| Distance to river | -0.70 | 0.61 | -0.37 | -0.62 | 0.61 |
| Distance to primary forest | 0.45 | -0.61 | 0.83 | -0.09 | 0.09 |
| Distance to secondary forest | 0.36 | 0.17 | 0.59 | 0.30 | 0.34 |
| Distance to agricultural estate | -0.02 | -0.11 | -0.86 | -0.03 | 0.19 |
| Distance to mineral lick | 0.66 | 0.60 | 0.10 | 0.48 | -0.00 |
| Distance to road | 0.15 | -0.74 | 0.44 | 0.28 | -0.33 |
| Distance to habitation | 0.14 | 0.16 | -0.17 | 0.42 | -0.24 |
| Disturbance zone | -0.14 | 0.50 | -0.27 | 0.03 | 0.23 |
| Variance explained (%) | 14.7 | 19.8 | 22.6 | 13.0 | 17.1 |
| Cummulative variance (%) | 74.1 | 55.3 | 57.3 | 56.1 | 59.0 |

## Food Habits

Forage use. Over 87 species of plants in 73 genera and 32 families were identified as gaur food items in feeding site examinations, inspection of dung piles, and cursory observations (Appendix B). The diet included 13 grass, 12 forb, and 53 browse species; 7 fruits; and 7 cultivated plants. Evidence of feeding was observed in a wide variety of locations, pristine primary forests, river banks, natural openings, secondary forests, along logging roads, agricultural estates, man made habitat improvement pastures, and village gardens. Feeding sites in the primary forest included river banks and small gaps, areas of seral vegetation.

Grasses comprised the largest proportion of the diet in primary forest and agricultural estate habitats and browse (mostly leaves) accounted for the largest proportion of the diet in the secondary forest habitat (Table 18). Forb consumption made up a major proportion of the diet in the agricultural estate habitat and was approximately equal to browse consumption in primary forest habitat. The grass Paspalum conjugatum and the herbaceous vine Mikania chordata were important food items across all habitat types. Crytococcum oryphylum, C. accresens, Cyperus exaltatus, and Imperata cylindrica were important grass species as well (Table 19). Important browse items included plants of the genus Macaranga, Trema, and Ficus. The herbaceous vine, Centrosema pubescens, planted as a cover crop in agricultural estates, was the most important forb in the diet, followed in importance by M. chordata and Poulzolzia zeylandica.

Table 18. Percentage composition of forage classes by habitat type in the gaur diet* as identified by bite counts at 18 feeding sites. Number of samples are in parenthesis.

| | Habitat types | | | |
|---|---|---|---|---|
| Forage class | Primary forest (3) | Secondary forest (5) | Agricultural estate (10) | All types (18) |
| Graminoids | 45 | 27 | 55 | 41 |
| Forbs | 29 | 3 | 42 | 23 |
| Browse | 26 | 70 | 3 | 36 |

*See Appendix B for a complete list of the diet.

Table 19. Percentage composition of plant species accounting for 2% or more of the gaur diet in primary forest, secondary forest, and agricultural estate habitats as identified by bite counts at 18 feeding sites. See Appendix B for the complete list of the diet.

| Plant species | Forage class | % composition |
|---|---|---|
| PRIMARY FOREST | | |
| *Paspalum conjugatum* | grass | 32.1 |
| *Mikania chordata* | forb | 18.8 |
| *Cyrtococcum oxyphylum* | grass | 12.0 |
| *Ficus* spp. | browse | 11.0 |
| *Lasianthus* spp. | browse | 4.3 |
| *Schindapus pictus* | forb | 2.6 |
| *Colocasia esculentum* | forb | 2.2 |
| *Peliosanthes violacea* | forb | 2.0 |
| Total | | 85.0 |
| SECONDARY FOREST | | |
| *Paspalum conjugatum* | grass | 19.4 |
| *Macaranga heynei* | browse | 14.7 |
| *Trema augustifolia* | browse | 9.1 |
| *Macaranga hosei* | browse | 7.4 |
| *Trema tomentosa* | browse | 6.2 |
| *Stylocoryna adpressa* | browse | 5.4 |
| *Mikania chordata* | forb | 3.7 |
| *Cyrtococcum accresens* | grass | 2.6 |
| *Cyperus exaltatus* | grass | 2.4 |
| Total | | 70.9 |
| AGRICULTURAL ESTATE | | |
| *Paspalum conjugatum* | grass | 43.7 |
| *Centrosema pubescens* | forb | 34.7 |
| *Cyrtococcum accresens* | grass | 9.3 |
| *Poulzolia zeylanica* | forb | 3.5 |
| *Mikania chordata* | forb | 3.4 |
| Total | | 94.6 |

Track sign and the occurrence of seeds in gaur feces provided evidence that fruits were occasionally taken from the forest floor. *Ficus* spp., *Dillenia indica*, *D. ovata*, and *Parkia javanica* were sought by the animals.

Examination of dung piles revealed seeds from 7 plant species, including the 4 mentioned above. In examining 32 dung piles for seeds, *Paspalum conjugatum* seeds were found in all 32, seeds of *Eleusine indica* in 12, *P. orbiculare* seeds in 8, and *Ficus* spp. seeds in 7.

*Nutritional quality of selected forage species*. The lush grasses and legume cover crops found in the agricultural estates were a particularly strong attractant to the gaur. Forage was superabundant in both secondary forest and agricultural estate habitats, with legumes available in the agricultural estates and grasses available in both types. The mean percentage cover of grasses at secondary forest and agricultural estate sites was 28 and 39%, and for legumes at the same sites, 0.4 and 31%. Fertilization of the agricultural estates and the presence of legume cover crops potentially produced forage of higher nutritional quality in the agricultural estates than in secondary forest prompting the heavy gaur use of these areas.

Lack of laboratory facilities prohibited extensive nutrient analysis of plant samples, and hence the small sample size is not appropriate for statistical tests. However, the results provide a rough index of the nutrient quality of the vegetation from both habitat sites. Two samples each of grasses (predominantly *P. conjugatum*) from agricultural estate and secondary forest sites and a mixed sample of legumes and grasses (*P. conjugatum* and *C. pubescens*) from an agricultural estate site were analyzed for nutrient content (Table 20). The average crude protein content of grasses collected from the secondary forest habitat site was greater than the grass sample from the agricultural estate. However, values for percentage dry matter, fat, crude fiber, carbohydrates, ash, gross energy, and phosphorus were comparable. As expected, the single mixed grass-legume sample had a higher protein and phosphorus content than any of the grass samples and comparable values for the other nutrient measures.

Table 20. Nutrient content of mixed grass and mixed grass and legume plant samples from secondary forest and agricultural estate sites.

| Sample | Percentage of dry matter | | | | | | |
|---|---|---|---|---|---|---|---|
| | Crude protein (Nx6.25) | Fat | Crude fibre | Carbohy drates (NFE) | Ash | Phospho rus | Gross energy (kcal/g) |
| Mixed grass from secondary forest | | | | | | | |
| 1 | 7.3 | 1.3 | 30.3 | 44.7 | 7.6 | 0.13 | 4.2 |
| 2 | 7.6 | 1.7 | 27.6 | 46.9 | 7.5 | 0.11 | 4.2 |
| Mixed grass from agricultural estate | | | | | | | |
| 1 | 7.4 | 1.9 | 26.5 | 46.2 | 9.5 | 0.17 | 3.9 |
| 2 | 7.0 | 1.4 | 27.7 | 47.9 | 7.3 | 0.14 | 4.3 |
| Mixed grass and legume from an agricultural estate | | | | | | | |
| 1 | 11.9 | 2.6 | 28.9 | 40.9 | 7.3 | 0.19 | 4.3 |
| Fruit (<u>Dillenia ovata</u>) | | | | | | | |
| 1 | 5.1 | 3.1 | 14.6 | 60.4 | 5.3 | 0.18 | 4.0 |

## CHAPTER V

## DISCUSSION

Recent investigations on the status of gaur throughout Malaysia reported herds of 10 to 12 gaur in the Selai River Valley, Johore; 7 in the Jengka River Valley, Pahang; 20 in the Soak River Valley, Trengganu (Conry 1977); 38 animals in 5 herds along the Tembling, Atok, Tahan, and Terengan rivers of the Malaysian National Park (pers. obs.); and 86 animals in 10 herds in Perak (Khan 1973). An earlier survey of the Malaysian National Park in 1969 reported 51 animals in 5 herds (Weigum 1972). Khan (1977) estimated the country-wide population at 400 animals.

The population of at least 62 gaur on the Lepar study area makes it one of the largest populations in Malaysia. This population estimate is a minimum figure based on track survey data collected by 3 teams covering the 620 $km^2$ study area in a 3 day period. We traversed the usual haunts of the animals such as agricultural fringe areas and river systems, but no doubt, some animals went undetected. During a 1980 survey of the area, 96 animals were found (pers. comm., Ebil bin Yusof, Research Officer, Department of Wildlife and National Parks, Malaysia, 1981), with the population difference attributed to recruitment and the identification of new groups.

The fragmentation and isolation of the Lepar gaur population may present a serious threat to their welfare. Splitting the Lepar population of 60 or 100 animals into east and west subpopulations essentially creates 2 populations of 30 to 50 animals. Although 50 animals is probably one of the larger populations in the country, it may be dangerously near or below the lower bounds on population size compatible with long-term survival. Small, isolated populations are susceptible to genetic deterioration that could result in short-term inbreeding depression and, over the long-term, in a loss of genetic variability and adaptability (Franklin 1980, Senner 1980, Soule 1980). Small populations are also susceptible to stochastic events such as disease, flooding, accidental poisoning, and other catastrophes, driving them to extinction (Soule 1980, Terborg and Winter 1980). Inbreeding can have a very deleterious effect on survival and reproduction (Franklin 1980, Senner 1980, Soule 1980). Soule reviewed the literature and concluded that even a small amount of inbreeding typically undermines fecundity and viability; a 10% increase in homozygosity (inbreeding rate) may reduce total reproductive performance by as much as 25%. Ralls et al. (1979) reported higher juvenile mortality for inbred young than noninbred young in 15 of 16 species of captive ungulates. However, the gaur may not be so drastically affected at low population levels as reported above. Its high level of evolution and behavior may allow it to cope with changing conditions and demands to a far greater extent than less highly evolved species. In addition, the time interval between generations for the gaur (3-5 years) is so long that the effects of inbreeding may not be felt for 50 years.

The preventive therapy for low population maladies is adequate population size and gene flow. The effects of inbreeding depression and stochastic extinctions can be minimized by immigrations between subpopulations. Losses to stochastic extinctions can be replaced by new colonists as long as an outside source is available, and inbreeding depression can be countered by occasional immigrations. Franklin (1980) reported that immigration rates of 1 or 2 individuals per generation into an inbred population reduces the level of inbreeding dramatically. To ensure adequate gene flow, travel corridors should be left between fragmented subpopulations, and for completely isolated groups, artificial migration may be necessary. The Lepar population represents a major proportion of the estimated 400 remaining animals in the country (Khan 1977). Preservation of this genetic stock is essential to maintain the genetic variability of the country-wide population. The situations calls for the immediate and continuous management of the genetic fitness of the population.

My finding on gaur habitat use and selection indicated that, although gaur did use a variety of habitat conditions within the lowland dipterocarp rain forest, a large proportion of their use was concentrated within a narrow range of habitat conditions. In the course of this study, a number of habitat conditions were identified that were selected for by gaur. Habitat conditions selected for were: (1) secondary forests; (2) areas within 250 m of a major river; (3) elevations below 61 m from an available range of 46 to 1049 m; (4) areas within 500 m of agricultural estates; (5) areas within 250 m of secondary forests; (6) areas within 250 m of an ecotone; and (7) areas of high horizontal habitat diversity.

In addition to the above habitat conditions, some habitat situations were heavily used by gaur but because of their high availability within the home range, they were not used in excess of availability. By definition, such habitat conditions are not selected by the animals. However, this does not necessarily mean they are unimportant to them. A number of investigators have recognized the importance in careful interpretation of the results of habitat use and selection studies. Marcum and Loftsgaarden (1977) caution, "care must be used in interpretation of the results of utilization-availability studies." They noted that habitat conditions which receive little regular use may be critically important to survival during brief periods. Johnson (1980) also pointed out that determining preference (selection) from measurements of use and availability data depends on how the researcher determines the availability of habitat components. In this study, availability was determined from habitat found within the specific animals' home range as determined by the minimum area method, and incorporates the bias inherent with this methodology.

As in Marcum's (1975) habitat use study on elk (Cervus elaphus), I found habitat not selected for receiving heavy use. Such habitat should be identified as important. Additional important habitat conditions were: (1) agricultural estates; (2) areas within 750 m of rivers; (3) elevations below 92 m; (4) forested areas adjacent to agricultural estates (500 to 1500 m); and (5) areas within 750 m of ecotones.

Marcum and Loftsgaarden (1977) also caution that conceivably a situation could exist where a habitat condition is selected against, yet may actually be important to survival. In such situations, the conclusion that those habitat conditions are not useful or are detrimental to the welfare of the species is not always true. I identified 3 such situations where gaur use was significantly less than availability but the habitat appeared to provide an essential need. Those situations were: (1) areas adjacent to salt licks were selected against by the yearling male; (2) the adult bull selected against agricultural estates; and (3) the adult bull selected against primary forests. Two mineral licks were located in the home range of the yearling male yet were rarely used. Salt licks were reported as an essential component of gaur habitat, important for the health of the animals and in determining distribution of herds (Thom 1934, Hubback 1937, Foenander 1952, Kitchener 1961, Stevens 1968, Weigum 1972, Khan 1973). The adult bull selected against both primary forest and agricultural estate habitats. However, primary forests were important to the herds on the west side of the Valley as a sanctuary from disturbance. Agricultural estates were important not only as a source of nutritious forage, but as a site for social interactions as well. Different herds mixed at the agricultural estate feeding sites. In short, all 3 of the above listed habitat conditions were selected against in general, but, were important to gaur survival on a periodic basis or added to the viability of the population.

In summary, the more important habitat use patterns of the gaur were: very heavy use of habitat modified areas, 89 to 100% of individual use occurred in logged secondary forests and newly created agricultural estates; 70 to 85% of individual use occurred within 750 m of a major river, and 45 to 63% was within 250 m; 62 to 98% of individual use occured in lowland areas at elevations less than 92 m; and 49 to 87% of individual use concentrated along agricultural estate fringe. In addition, gaur tended to associate with areas of high horizontal habitat diversity, 43 to 56% of individual use occurred within 250 m of an ecotone and in areas easily accessible to a number of different habitat conditions.

The results on gaur habitat use found in this study were consistent with the habitat use commonly reported for the gaur. Numerous authors have described habitat used by gaur (Hubback 1937, Fetherstonhaugh 1952, Foenander 1952, Ogilvie 1954, Kitchener 1961, Stevens 1968, Wharton 1968, Weigum 1972, Khan 1973, Harrison 1974, Khan 1977, Lekagul and McNeely 1977, Medway 1978). While informative, their reports on habitat use are of a general nature and are not readily comparable to the results of this study. Therefore, only general comparisons will be made between this study and earlier reports.

Hubback (1937) and others (Foenander 1952, Kitchener 1961, Weigum 1972, Medway 1978) reported the habitual use of jungle clearings, abandoned fields of shifting cultivators, and the forest fringe by gaur. Weigum appropriately described the gaur as a creature of secondary vegetation. The gaur is believed to be a recent invader of the forested environment of Malaya. Chasen (1940) identified the gaur as an immigrant from the north of an Indo-Chinese (Himalayan) origin. Medway (1972) believed that the gaur was a recent invader of Malaya in the wake of neolithic man and dependent on his forest clearings. He stated (1965) that gaur are not true forest mammals but favor the banks of large rivers, abandoned clearings of shifting cultivation, forest glades, and other open situations where grazing is available. Kitchener (1961), Stevens (1968), and Wharton (1968) associated the present distribution of the gaur with the abandoned clearings of the shifting cultivators. Foenander (1952) went as far as to state, "one might with a certain amount of confidence say that where there are Sakai [shifting cultivators]...there will seladang be found." Both he and Hubback (1937) found gaur in their largest numbers when associated with the clearings of agriculturalists. The reported prosperity of gaur when associated with early agricultural activities, the predominant use of seral vegetation, and the dependence on man to produce such conditions in appreciable quantities, indicates that a historical and prehistorical commensal relationship existed between gaur and man.

On the Lepar study area, the man-modified habitats of secondary forests and agricultural estates received 100% of the use of 2 animals and 89% of the third animals. The historical habitat components of abandoned agricultural clearings, jungle gaps, and the forest fringe have been replaced by the logging roads, log collection yards, and tree gaps of the logged secondary forest and the newly cleared fields of the oil palm and rubber estates. On this study area, the developmental activities did not, as is often believed, push the gaur into the hills and primary forests. On the contrary, gaur use was concentrated around developmental activities and the seral vegetation produced. Favorable foraging conditions were abundantly available in the agricultural estates and secondary forests while limited in the primary forests.

My data illustrates the necessity for an active habitat management program for important gaur populations in wildlife reserves, parks, and other areas. Habitat within reserves, parks, and secure areas must be adequate to meet the needs of the gaur, or else they will be drawn out of the protected areas into the encroaching developed areas. Weigum (1972) reported such behavior by the Kuala Tahan herd in the Malaysian National Park. That herd spent a significant portion of its time foraging outside the Park in the surrounding secondary forests. A non-interference management policy towards gaur habitat in the tropical rain forest will, by default, require the gaur to use the man-modified environments of the developing areas. Habitat improvement projects should emulate the foraging conditions found in the agricultural fringe areas that are so heavily used by the Lepar herds.

My study documented the importance attributed to the lowland river valleys as gaur habitat by various authors (Hubback 1937, Stevens 1968, Medway 1978). Seventy per cent or more of each gaur's use was within 750 m of a major river. I also found that gaur selected for low elevations, with elevations of 61 m or less accounting for as much as 98% of gaur use. The highest elevation used by gaur was 381 m, well below the 610 m limit reported by Hislop (1966) and above the 305 m limit reported by Medway (1965). Hubback (1937) stated that gaur were not mountain animals, although in wandering, solitary bulls went far into the mountain country, herds did not. However, on a number of occasions I followed herds from lowland areas up into steep hilly country. The adult bull, accompanied by a herd, traversed mountainous terrain moving between feeding areas.

Areas near ecotones and areas of high habitat diversity were selected for indicating the importance of interspersions of habitats to gaur. My findings support the earlier reports that the gaur is a forest edge animal (Hubback 1937, Kitchener 1961, Medway 1978). Kitchener's description of gaur habitat as being the cool forest during the heat of the day and the open clearings and jungle edges during the night applies equally well to the gaur on my study area. The interspersion of secondary forest, riverine, and agricultural estate habitats was very heavily used by the animals providing the necessities of food, water, and shelter.

Employing the investigational techniques of radio-telemetry, the large range use of the gaur was delineated. The adult bull had a home range of 7018 ha, the female 5213 ha, and the yearling male 2989 ha. The size and shape of each home range was greatly affected by physiographic features. The location of mineral licks, river systems, jungle clearings, and agricultural estates appeared to determine boundaries.

Movements in an animal's range often progressed from 1 area of concentrated use to another. Heavy disturbance in 1 area of the range initiated movement to areas of lesser disturbance. Once in an area of concentrated use, such as an agricultural estate, the general tendency was to remain for an extended period before moving to another area of concentrated use. The high correlation between mean daily distance moved and home range size indicated that the larger the home range size and the more dispersed the resources, the more time spent traveling.

Home range areas delineated in this study were 2.3 to 5.4 times larger than the 1300 ha ranges reported by Weigum (1972) for the Kuala Tahan herd in the Malaysian National Park. The Lepar gaur ranges were also larger than the 1275 ha range reported for a male tapir (Tapirus indicus) by Williams (1978) and comparable to the 3200 to 16,700 ha range reported by Olivier (1978) for the Asiatic elephant, 2 co-inhabitants of the Malayan rain forest.

The investigation of gaur food habits identified a wide variety of food items eaten by the species. Over 87 plants in 73 genera and 32 families were identified. With further investigations, a great many more will no doubt be added to the list. Graminoids were the most important forage class in primary forest and agricultural estate habitats and browse (mostly leaves) was the most important class in secondary forest habitats. The high occurrence of grasses in the primary forest diet, usually a habitat of limited grass availability, reflects the selectivity gaur exercised in choosing feeding sites. In primary forest, feeding sites were usually in areas of seral vegetation; along stream banks and in natural forest gaps, where typical gaur food items occurred. Gaur appeared to select for feeding sites in secondary forest and agricultural estates as well. In secondary forest, feeding sites were often located in logging yards and along roads where grasses and a wide variety of shrubs were plentiful. Seral browse items, such as the plants of the genus Macaranga and Trema, were primarily found in secondary forest and comprised a major proportion of the diet there. The mixed diet of grasses and browse in the secondary forest diet illustrates the combined browsing and grazing habit of the guar.

Grasses and forbs were a major proportion of the diet in agricultural estates. The herbaceous legume Centrosema pubescens, planted as a cover crop in agricultural estates, was the most important forb in the diet. Feeding in agricultural estates and on the legumes growing there may also reflect selection of feeding sites and nutritious food items by gaur. In illustration, the Belayar River herd consistently used 1 field (Block B, Asia Oil Palm) for feeding. This repeated use had a cyclic "mowing" effect, continuously turning back the growth stage of the forage. The legume cover crop and the early growth stages of grasses are highly nutritious and palatable, more so than the mature stage (Sinclair 1977). The repeated use of such areas may be selection for forage of high nutrient content and palatability. Selection for feeding sites and forage nutrients by ungulates is not uncommon. Marcum (1975) reported that elk select for mesic feeding areas in late summer, and Klein (1970) reported that mule and white tailed deer (Odocoileus hemionus and O. virginianus) select for forage of high nutrient content.

As with habitat use, my findings are fairly consistent with the food habits commonly reported for the gaur. Weigum (1972) identified 89 plant species in the diet of the gaur in the National Park, of which 96% occurred in the early seral vegetation of river banks, clearings, secondary forest, and abandoned agricultural estates. He identified P. conjugatum and M. chordata as the most important food items, comprising 43.8 and 17.5% of the diet versus the 31.3 and 6.5% values I found. Weigum lists Eupatorium odoratum as an important food item, although, I only found it in trace amounts in the diet. A number of authors (Hubback 1937, Foenander 1952, Khan 1973) reported general observations on gaur food habits. They noted a variety of grasses and a number of woody plants and fruits as occurring in the diet. All the reports identified areas with grasses as preferred feeding sites. The greatest discrepancy between earlier reports and my findings was the occurrence and importance of the legume cover crop C. pubescens in the diet of the Lepar herds.

The habitats most heavily used by gaur, secondary forests and agricultural estates, provided unlimited quantities of the grass P. conjugatum. The legume C. pubescens was available in large quantities in agricultural estates. The logging roads, clearings, and gaps in the secondary forest also provided a large quantity and variety of shrubs. The important food items were abundantly produced. Conservatively, the foraging conditions in terms of important food item production were excellent. The perplexing question is why there were not more animals?

Although limited to just 2 important species, the nutrient analysis of mixed grass and grass and legume plant samples provided an indication of the nutrient quality of the diet. Crude protein content for the mixed grass samples from both the secondary forest and agricultural estate habitats varied from 7.0 to 7.6% and phosphorus levels varied from 0.11 to 0.17%. These levels are right at or below minimum maintenance requirements recommended for a number of ruminants. Dietz and Nagy (1976) reported 8% crude protein as a minimum requirement for mule deer and Murphy and Coates (1976) also listed 7% crude protein as a minimum for deer. Sinclair (1977), after reviewing the literature, selected 5% crude protein as the minimum maintenance requirement for African buffalo (Syncerus caffer). The National Resource Council (NRC; 1976) recommended minimum crude protein requirements of 5.8 to 10.9% for domestic cattle depending on age, sex, and physiological requirements. Minimum maintenance requirements of phosphorus for domestic cattle were reported as 0.18% (NRC 1976) and 0.17% for mule deer (Dietz and Nagy 1976).

Growth, reproduction, and lactation require additional nutrients above minimum maintenance levels (Maynard and Loosli 1969). The nutrient requirements of developing young are especially high. Domestic calves growing at a rate of 1.1 kg/day required feed with a crude protein content of 18% and phosphorus content of 0.70% (NRC 1976). Dietz and Nagy reported requirements of 14 to 16% crude protein and 0.50% phosphorus for young mule deer and lactating does.

Both protein and phosphorus are essential nutrients for growth, development, and reproduction. Deficiencies of either protein or phosphorus led to reductions in appetite, growth, reproduction, and milk production in domestic cattle (Maynard and Loosli 1969, NRC 1976). The major sign of protein shortages in diets of breeding females was an irregular or delayed estrus. Also, continuous phosphorus privation resulted in severe ricketts in young; bone deformities, disease, and fractures; and breakdown of teeth.

The mixed grass and legume sample had an appreciably higher nutrient content of 11.9% crude protein and 0.19% phosphorus. The addition of legumes in the diet may provide enough nutrients to raise the protein content above the minimum and improve the phosphorus levels. If so, this greatly increases the importance of C. pubescens and the habitats where it is found.

Additional work on the nutrient content of the gaur diet merits investigation. A thorough nutrient analysis of the 5 most important food items from the different habitats is recommended. Pending those results, the general indications are that the nutritional quality of the forage is at or slightly above maintenance levels, although it may be lacking in both crude protein and phosphorus for optimum reproduction and growth of calves. Nutrient intake can be improved by providing nutrient blocks high in phosphorus and other mineral content at new or established mineral licks, and by increasing the availability of the legume C. pubescens. Seeds or clippings of this plant are readily available and can be planted in pastures developed for habitat improvement or in the numerous clearings and along the logging roads of the secondary forest.

The age composition of the Lepar population indicated low calf recruitment. The adult to calf ratio of 100:24 was markedly below the 100:62 ratio observed by Weigum (1972) in the Malaysian National Park at a comparable season of the year. Weigum attributed the high adult to calf ratio to high natality and low mortality with no evidence of tiger predation or poaching. Schaller (1967) reported cow to calf ratios for Indian gaur in kanha Park, India. His ratio of bulls to cows to calves was recalculated as adults to calves yielding a ratio of 100:29. He attributed the low adult to calf ratio to a high mortality rate of 50% for calves and yearlings. Applying Schaller's population parameters of 80 bulls to 100 cows adult sex ratio and birth rate of 90% to my data, I calculated a cow to calf ratio of 100:43. If accurate, this ratio indicates a mortality rate of 52% for the calf age class.

Captive Indian gaur first calved at 2.5 years and had an average lag between births of 13.3 months (pers. comm., Oklahoma City Zoo, USA). Weigum also reported natality rates and calf survival of 100% for the Kuala Tahan herd. Under similar conditions, it is a reasonable assumption that the Lepar herds can achieve comparable recruitment. Dahmer (1978) reported an adult:calf ratio of 100:37 for wild Asian buffalo in Chitwan National Park, Nepal. At present, unknown factors are drastically reducing calf production or inflicting heavy mortality, or both.

Various decimating factors were identified on the study area that could have affected juvenile survival. Tigers and leopards both inhabited the area. Hubback (1937) and Foenander (1952) reported that tiger predation was heavier on the juvenile age classes than on adults. Schaller (1967) reported a 50% mortality rate from predation on the juvenile age classes versus a 5% rate for adults. Tiger sign was not abundant on the study area and the level of predation was unknown.

A number of human disturbance factors could have inflicted additional juvenile specific mortality. Poachers armed with shotguns can more easily kill and process a juvenile than an adult. One case of poaching of a juvenile animal was detected on the Lepar study area. Also, the increased human traffic in the area has increased human-gaur encounters. Such encounters usually elicit escape behavior and often the splitting of the group and cow-calf pairs. Once separated, the chance of mortality from tiger predation, human poaching, or permanent abandonment increases. Hubback (1937) reported the desertion of calves in mad stampedes following disturbance, and he suspected heavy tiger predation on the calves left behind. During this study, a solitary calf was observed, lending credence to the abandonment reports.

The low recruitment rate may also be attributed to low ovulation or aborted gestations. Poor nutrition can cause a cessation of ovulation, gestation, or the birth of weak calves unable to survive. Klein (1970) reviewed the literature on deer nutrition and concluded that poor nutrition can lower conception rates, increase in utero mortality, and increase mortality of new-born fawns. Poor nutrition following parturition in domestic cattle caused reduced milk production in cows and the resultant weakening of calves. Weaned calves had an increased susceptibility to disease and other mortality (Maynard and

Loosli 1969). The low nutritional quality of forage on the study area may have affected the recruitment in such a manner. Heavy disturbance associated with human activities may also have increased stress and reduced the ovulation rate of the gaur. Morrison (1960) reported that captive elk failed to ovulate when penned in an area of heavy disturbance. When moved to a more secure area, they resumed ovulation. Conceivably, the low calf recruitment could also be from inbreeding depression. Inbreeding causes a decrease in both fecundity and survival of young (Soule 1980, Franklin 1980). Ralls et al. (1979) reported lower survival rates for inbred young than noninbred young in 15 of 16 captive ungulates.

The low recruitment of juvenile animals into the population was probably the result of a number of factors acting to decrease natality and juvenile survival. Poor nutrition, predation, poaching, inbreeding depression, accidental death, and heavy human disturbance were possible contributing factors to the low recruitment. More work needs to be done to determine the causes of low recruitment in the Lepar population. Until then, any potential factors decreasing recruitment should be managed to minimize adverse effects. Management programs such as increased law enforcement to deter poaching and minimize harassment of the animals, habitat improvement to augment nutrition, or maintaining migration routes to promote gene flow could all help to achieve such goals.

Throughout my study, the reactions of gaur to human disturbance were monitored. Two animals, the adult bull and female, were monitored during periods of light disturbance whereas the yearling male was monitored during the latter stages of the study when disturbance levels were considerably greater. Generally, disturbance levels increased over time on the study area, and associated with this, the trend in gaur use patterns reversed. The adult bull and female avoided disturbance, selecting against areas within 500 m of major access roads and areas of very high disturbance. The adult bull also selected against areas within 1000 m of human habitation. Both animals selected for areas with intermediate disturbance levels in their home ranges. Their selection against areas adjacent to roads was a reaction to the human activity (traffic, noise, and human presence), rather than to the presence of the road. Logging roads closed to traffic or lightly traveled were readily used by the animals for both travel lanes and as feeding sites. The open conditions on old logging roads produced lush grass cover.

The complete reversal in reaction of gaur to disturbance was recorded following a period of very heavy road building and bridge construction during my study period. The yearling male was collared in the same month that road traffic reached 300 trips per day down the main access road. This reversal of gaur use patterns between the period of light and heavy disturbance can be interpreted in a number of ways. One interpretation is that the yearling male had become partially habituated to man's presence and disregarded the disturbance associated with the road. Another possible explanation is that his behavior is indicative of a dispersing yearling bull, and is not representative of a cow-calf group. The young bull may have left the cow-calf group and occupied the habitat on the fringe of their range in the heavily disturbed areas. Both explanations may apply. The yearling male's behavior did not diverge completely from that of the cow-calf group he often accompanied. This group gradually became accustomed to disturbance and disregarded traffic on a number of occasions. In addition, dispersing young may use heavily disturbed areas to a greater extent than cow-calf groups.

A number of other examples of the animals habituating to disturbance were noted. Gaur fed and rested in open agricultural fields during the daylight hours. Animals were also observed feeding along heavily traveled logging roads and in clearings adjacent to such roads. On 2 occasions, the yearling male's group ventured to within 100 m of our permanently occupied camp. The gradual acceptance of noise disturbance was displayed in the animal's loss of fear of the low flying aircraft.

Habituation to man by the gaur presents alarming possibilities. Today the population is well armed and, I fear, not as innocuous as the Sakai of old. One instance of poaching was detected during the study period, and without continuous protection, the newly habituated animals may be shot.

The hazardous relationship between human activities and gaur habitat use was identified in the principal components analysis. The first principal component was interpreted as a gradient of increasingly favorable forage conditions directly related to disturbance levels and inversely related to elevation. These data indicated that in the usual development process, as in the Lepar Valley, the heaviest development occurred in the typical gaur habitat. Also, highly favorable foraging conditions were created in the development process, but they were associated with the areas of highest disturbance. To take advantage of the favorable foraging conditions, the gaur must also accept an increase in disturbance levels. The heavy use of disturbed areas by the female and yearling male indicated that the animals did so. Kitchener (1961) accurately predicted this sequence of events when he wrote, "as cultivation is extended, it is inevitable that the few remaining herds will be brought into closer and more frequent contact with the human economy. This can only result in further decimation of their already depleated numbers and eventually their complete extinction...." He went on to recommend the creation of wildlife reserves to protect the animals and initiation of habitat improvement projects to create favorable foraging conditions in the reserves to draw the animals away from development.

The habitat use described earlier for the gaur poses problems for long-term conservation of the species. The principle gaur habitat, river valleys at elevations below 150 m in the lowland dipterocarp rain forest, is also the land resource with the greatest value for economic exploitation (Aiken and Moss 1975). Lands with gentle terrain and good soils below the steep line boundary of 183 m have been classified as agricultural lands of Classes II and III in the Malayan Land Capability Classification system (Panton 1965). Forty-eight per cent of the total land area in West Malaysia of 13.2 million ha is classified as suitable for agricultural development. As of 1975, just 2.5 million ha remained undeveloped to meet present and future needs of an expanding population. The Malaysian Government's 5-year economic plan (Third Malaysian Plan; Anonymous 1976) placed a great deal of emphasis on agricultural expansion and logging to provide land and jobs. At the present rate of development of 500,000 ha every 5 years, all remaining arable land of agricultural classes II and III (gaur habitat) will be developed in 20 years. The bulk of development is planned for the states of Pahang, Johore, Trengganu, and Kelantan; the states that harbor most of the remaining gaur populations (Stevens 1968, Conry 1977). With such high demand for agricultural lands, preserving wildlife habitat will undoubtably take a low priority.

The apparent large range requirements of the gaur, up to 7000 ha of lowland riverine areas suitable for agricultural development, make the task of preserving the existing ranges extremely difficult. One approach to this problem is to request smaller areas for reserves and to try and concentrate gaur use within smaller areas. The location of mineral licks and feeding areas, and disturbance factors appeared to affect range use of the 3 animals monitored in the Lepar study. Through intensive management, perhaps the requirements of the animals can be provided in a reduced area. Attempting to alter range use by strategically locating salt licks and feeding areas in secure habitat is certainly worth the effort. Ogilvie (1954) and Weigum (1972) reported modification of a herds range use after the introduction of an artificial salt lick. Likewise, gaur use of newly abandoned clearings of shifting cultivators (Foenander 1952, Khan 1973) further supports the contention that range use can be modified.

The extensive development of the lowland forests that is projected in the next 20 years, will have a number of detrimental impacts on the gaur. Development of all agricultural lands below the steep line boundary of 183 m will convert all existing gaur habitat to monoculture. In rubber and oil palm estates, the favorable foraging conditions created in the initial development process are short lived; the grasses and the legumes are gradually shaded out by the growing tree crops, rendering the estates unusable by gaur. Such complete habitat elimination will leave the gaur to subsist on the dwindling agricultural fringe and steep hill forests. Development of the lowland river valleys will also fragment and isolate the remaining gaur populations. This occurred in the Lepar Valley, agricultural development separated the gaur population into 2 subpopulations inhabiting the opposite forested hills of the Valley. Human activities incidental to development processes can also have an adverse impact. Disturbance levels, harassment, and poaching of animals often increase with an increase in human population.

A decline in gaur populations often follows developmental activities. Kitchener (1961) reported the extirpation of the Chior River herd following the cultivation of land and the destruction of salt licks. He also noted the decline of a number of herds that used agricultural fringe, attributing the losses to heavy poaching and poisoning with sodium arsenite herbicide. Stevens (1968) reported the elimination of a population of 70 gaur in the Segamat Wildlife Reserve, Malaysia, following land clearing and human disturbance. He addressed the problem of habitat elimination when he wrote, "If that habitat [lowland rain forest] is entirely forfeited to agricultural and urban development the rich faunal heritage of the country will be lost." He went on to recommend the creation of new wildlife reserves to preserve lowland habitat and protect the animals from harassment.

With low population levels and continuing extensive habitat elimination, the gaur in Malaysia is at a critical junction in time. However, the prospects for its conservation are not totally bleak. Dependent on seral vegetation stages, the gaur can benefit from a management program incorporating habitat improvement. If human activities such as poaching and harassment can be minimized, the early seral vegetative stages of agricultural estates and logged forests will benefit the animal. However, these benefits are short-term, the long-term solution to save the gaur is the preservation of lowland forests. I believe the most effective way to accomplish this is to preserve all or part of existing gaur ranges as wildlife reserves. As wildlife reserves, areas can be given full protection from human disturbance and the habitat can be continuously managed to provide all the animals' needs. In areas where agricultural development has displaced herds, providing legume and grass pastures in nearby forested areas would help to lessen the impact of habitat elimination. Preservation of adequate lowland habitat is perhaps the most difficult yet urgent conservation measure needed to save the gaur in Malaysia.

# CHAPTER VI

## MANAGEMENT RECOMMENDATIONS

The current status of the gaur in the Lepar Valley, the changing environmental conditions there, and the selective habitat utilization of the gaur prompted the following management recommendations for the Lepar population. These guidelines, while formulated for the Lepar population, are applicable to populations in other areas of the country in similar situations (Conry 1980).

1) Recommendation: Establish a wildlife reserve to protect important gaur habitat on the east and west sides of the Lepar Valley.

Rationale: Preservation of important gaur use areas as wildlife reserves will protect gaur habitat from conversion to agricultural estates or urban development (Kitchener 1961, Conry 1980). The establishment of a wildlife reserve will allow the Department of Wildlife and National Parks to regulate human access, construct ranger stations, and implement habitat improvement projects on site (Anonymous 1972).

2) Recommendation: Improve gaur habitat by making a series of 10 ha pastures in which important forage item production is increased and maintained at a high level. Locate the pastures in secure areas, 1000 m apart, and in low lying areas adjacent to small streams or rivers. Make pastures rectangular in shape with a width of 150 to 200

m. Include or create a number of mineral licks in the area of habitat improvement.

Rationale: Providing secure foraging sites would improve forage availability in surroundings free from human harassment. Availability of such habitat may concentrate use within smaller home ranges than presently used by the Lepar herds and reduce exposure to human activities. Foenander (1952), Kitchener (1961), and Weigum (1972) also recommended habitat improvement projects to conserve the gaur in Malaysia.

3) Recommendation: Plant the legume cover crop *Centrosema pubescens*, in clearings, log collection yards, gaps, unused logging roads of secondary forest, and in the pastures of recommendation 2 to improve the quality of forage. Also provide nutrient blocks with high phosphorus content at established and new mineral licks.

Rationale: Study results on the nutrient content of 2 important food items indicate inadequate quantities of both phosphorus and crude protein in the diet, possibly effecting reproduction and survival of young (Maynard and Loosli 1969). Providing legumes, which are high in protein and phosphorus content (National Research Council 1976), and high phosphorus content mineral blocks would improve nutrition.

4) Recommendation: Increase law enforcement activities on the study area.

Rationale: Poaching and human harassment are possible causes of low recruitment. Increased law enforcement would deter such activities.

5) Recommendation: Plan logging operations to maximize benefits to and minimize adverse impacts on the gaur population. Compartmentalize operations so that disturbance is localized and nonactive compartments can serve as refuge areas. All operations should be completed in one compartment before proceeding to the next. Centralize worker habitation in 1 camp located in the compartment being logged. Reseed clearings, gaps, and unused logging roads with legumes and grasses.

Rationale: The habitat modifications caused by logging operations produce abundant quantities of grasses and shrubs that benefit the gaur. Consequently, logged areas receive heavy use. Reseeding logged areas with legumes and grasses will further enhance these benefits.

6). Recommendation: Locate permanent access roads away from rivers and major streams and gaur concentrated-use areas as far as possible. Following logging operations, close all nonessential roads with bulldozed sections, barricades, or control gates.

Rationale: Human activities accompanying logging were detrimental. The skeletal remains of a juvenile gaur found in an abandoned logging camp verified that conclusion. Controlling access into gaur localities with road closures and habitation restrictions would decrease human activities and increase gaur security and probably survival. Marcum (1975), Flynn (1978), and Thomas (1979) recommend handling hunting and human disturbance impacts through management of public access, specifically closing or locating roads away from critical areas.

7) Recommendation: Leave forested corridors between groups separated by agricultural development.

Rationale: Agricultural development of the low elevation areas along the river systems fragmented the gaur population into groups inhabiting the forested foothills on either side of the Valley. As development progresses, the already fragmented population will be further divided into small groups in isolated pockets of habitat. MacArthur and Wilson (1963), Brown (1971), and Soule and Wilcox (1980) warned of the decline and extinction of isolated animal groups on habitat islands. Terborg (1974) recommended travel corridors between isolated habitat islands to facilitate movements and gene flow.

8) Recommendation: Continue research activities monitoring population status with emphasis on recruitment. Further investigations into the content and nutrient quality of the diet are warranted.

Rationale: Results of this study indicated that the population had low recruitment. Additional information is needed to verify that contention and identify the causes.

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# APPENDIX A

## PARASITES FOUND IN AND ON GAUR

The following incidence of internal and external parasites of gaur were detected in the examination of 6 immobilized animals, 2 necropsies, and 94 fecal samples.

| Condition | Notes |
|---|---|
| Internal Parasites | |
| *Eimeria* sp. oocysts | found in 2% of fecal samples |
| *Fasciola hepatica* eggs | found in 12% of fecal samples |
| *Fasciola gigantica* eggs | found in 1% of fecal samples |
| Unidentified nematode eggs | found in 16% of fecal samples |
| *Setaria* sp. | found in 1 animal |
| External Parasites | |
| *Apponomma* sp. (tick) | found on 1 of 8 animals examined |
| *Boophilus microplus* (tick) | found on 3 of 8 animals examined |

APPENDIX B

PERCENTAGE COMPOSITION AND OCCURRENCE OF FORAGE SPECIES IN PRIMARY FOREST, SECONDARY FOREST, AGRICULTURAL ESTATE, AND TOTAL DIET AS IDENTIFIED IN FEEDING SURVEYS AND CURSORY OBSERVATIONS.

| Forage species* | Forage class (B,F,G)** | Primary forest (%) | Secondary forest (%) | Ag. estate (%) | Total diet (%) |
|---|---|---|---|---|---|
| I. Feeding Survey Data | | | | | |
| DICOTYLEDONS | | | | | |
| ACANTHACEAE | | | | | |
| Lepidagathis sp. | B | | 0.6 | | 0.2 |
| Lepidagathis longifolia | B | | 0.7 | | 0.3 |
| ANACARDIACEAE | | | | | |
| Dracontomelum mangiferum | B | | 0.6 | | 0.3 |
| ANTONIACEAE | | | | | |
| Norrisia sp. | B | | 0.2 | | 0.1 |
| COCHLOSPERMACEAE | | | | | |
| Cochlospermum religiosum | B | | | 0.3 | 0.1 |
| COMPOSITAE | | | | | |
| Eupatorium odoratum | F | | | 0.1 | T*** |
| Mikania chordata | F | 18.8 | 3.2 | 3.4 | 6.5 |
| Veronia arborea | B | | 1.6 | | 0.7 |
| CONVOLVULACEAE | | | | | |
| Argyreia sp. | B | | | 0.7 | 0.3 |

Appendix B (Cont)

| Forage species* | Forage class (B,F,G)** | Primary forest (%) | Secondary forest (%) | Ag. estate (%) | Total diet (%) |
|---|---|---|---|---|---|
| EUPHORBIACEAE | | | | | |
| *Bridelia pustulata* | B | | 1.8 | | 0.7 |
| *Cleistanthus hirsutulus* | B | | 0.1 | | 0.1 |
| *Cnesmosa javanica* | B | | 0.4 | | 0.2 |
| *Glochidion spiciflorum* | B | | 0.7 | | 0.3 |
| *Macaranga constricta* | B | | 0.3 | | 0.1 |
| *Macaranga gigantea* | B | | 1.4 | | 0.6 |
| *Macaranga heynei* | B | | 14.7 | | 6.1 |
| *Macaranga hoseii* | B | | 7.4 | | 3.1 |
| *Macaranga hullettii* | B | | 0.3 | | 0.1 |
| *Macaranga* sp. | B | | 0.9 | | 0.4 |
| DILLENIACEAE | | | | | |
| *Tetracera scandens* | B | 1.6 | | | 0.3 |
| HYPERICACEAE | | | | | |
| *Cratoxylum formosum* | B | | 0.2 | | 0.1 |
| GUTTIFERAE | | | | | |
| *Garcinia dulcis* | B | | 0.5 | | 0.2 |
| LABIATAE | | | | | |
| *Gomphostemma* sp. | F | 0.5 | | | 0.1 |
| LEGUMINOSAE | | | | | |
| *Acacia pennata* | B | | | 1.4 | 0.5 |
| *Cassia mimosoides* | B | 0.3 | | | 0.1 |
| *Centrosema pubescens* | F | | | 34.7 | 13.3 |
| *Dialium kingii* | B | | 0.3 | | 0.1 |
| *Intsia palembanica* | B | 1.0 | 0.1 | | 0.3 |
| *Millettia albiflora* | B | 1.8 | | | 0.4 |
| *Sarca thaipingensis* | B | | 0.2 | | 0.1 |
| MELASTOMACEAE | | | | | |
| *Melastoma malabathricum* | B | | 0.4 | | 0.2 |

Appendix B (Cont)

| Forage species* | Forage class (B,F,G)** | Primary forest (%) | Secondary forest (%) | Ag. estate (%) | Total diet (%) |
|---|---|---|---|---|---|
| MORACEAE | | | | | |
| *Ficus* sp. | B | 11.0 | 4.4 | | 4.1 |
| *Ficus fistulosa* | B | | 0.3 | | 0.1 |
| *Taxotrophis ilicifolia* | B | 0.5 | | | 0.1 |
| MYRTACEAE | | | | | |
| *Eugenia aquea* | B | | 0.3 | | 0.1 |
| OPILIACEAE | | | | | |
| *Lepionurus sylvestris* | B | | 0.2 | | 0.1 |
| RHIZOPHORACEAE | | | | | |
| *Pellacalyx axillaris* | B | | 0.2 | | 0.1 |
| ROSACEAE | | | | | |
| *Rubus angulosus* | B | | 0.5 | | 0.2 |
| RUBIACEAE | | | | | |
| *Hedyotis capitellata* | B | | 0.7 | 0.1 | 0.3 |
| *Lasianthus* sp. | B | 4.4 | 0.4 | | 1.1 |
| *Pavetta graciliflora* | B | | 0.7 | | 0.3 |
| *Pavetta indica* | B | | 0.2 | | 0.1 |
| *Randia exaltata* | B | 0.3 | | | 0.1 |
| *Stylocoryna adpressa* | B | | 5.4 | | 2.2 |
| *Uncaria cordata* | B | | 0.7 | | 0.3 |
| ULMACEAE | | | | | |
| *Trema angustifolia* | B | | 9.1 | | 3.7 |
| *Trema tomentosa* | B | | 6.2 | | 2.6 |
| URTICACEAE | | | | | |
| *Poikilospermum microstachys* | B | | 1.4 | | 0.6 |
| *Pouzolzia zeylanica* | F | | | 3.5 | 1.3 |

Appendix B (Cont)

| Forage species* | Forage class (B,F,G)** | Primary forest (%) | Secondary forest (%) | Ag. estate (%) | Total diet (%) |
|---|---|---|---|---|---|
| VERBENACEAE | | | | | |
| *Callicarpa tomentosa* | B | | 1.0 | | 0.4 |
| *Clerodendron inerme* | B | 0.2 | 1.2 | | 0.5 |
| *Premna sterculifolia* | B | | | 0.9 | 0.3 |
| VIOLACEAE | | | | | |
| *Rinorea* sp. | B | | 0.3 | | 0.1 |
| VITACEAE | | | | | |
| *Tetrastigma* sp. | B | | 0.5 | | 0.2 |
| MONOCOTYLEDONS | | | | | |
| ARACEAE | | | | | |
| *Colocasia esculentum* | F | 2.2 | | | 0.4 |
| *Scindapsus pictus* | F | 2.6 | | | 0.5 |
| CYPERACEAE | | | | | |
| *Cyperus exaltatus* | G | 1.1 | 2.4 | | 1.2 |
| GRAMINEAE | | | | | |
| *Cyrtococcum accresens* | G | | 2.5 | 9.3 | 4.6 |
| *Cyrtococcum oxyphyllum* | G | 12.0 | 0.7 | 1.2 | 3.2 |
| *Imperata cylindrica* | G | | 1.2 | 0.7 | 0.7 |
| *Leptaspis urceolata* | G | | 0.1 | | T |
| *Paspalum conjugatum* | G | 32.1 | 19.4 | 43.7 | 31.3 |
| *Paspalum scorbiculatum* | G | | 0.3 | | 0.1 |
| *Phragmites karka* | G | | | 0.2 | 0.1 |
| LILIACEAE | | | | | |
| *Peliosanthes violacea* | F | 2.0 | | | 0.4 |

Appendix B (Cont)

| Forage species* | Forage class (B,F,G)** | Primary forest (%) | Secondary forest (%) | Ag. estate (%) | Total diet (%) |
|---|---|---|---|---|---|
| ORCHIDACEAE | | | | | |
| *Agrostophyllum majus* | F | 1.7 | | | 0.3 |
| PALMAE | | | | | |
| *Calamus* sp. | B | | 0.1 | | T |
| FILICALES (THELYPTERIDAE) | | | | | |
| *Abacopteris multilineata* | F | 0.9 | | | 0.2 |
| Unidentified browse | B | 4.8 | 3.1 | | 2.2 |

II. Cursory Observation Data

DICOTYLEDONS

CONVOLVULACEAE

| | |
|---|---|
| *Ipomoea batatus* | F |

EUPHORBIACEAE

| | |
|---|---|
| *Hevea brasiliensis* | B |
| *Manihot esculenta* | B |
| *Euphorbia* sp. | Fruiit |
| *Phyllanthus urinaria* | Fruit |

DILLENIACEAE

| | |
|---|---|
| *Dillenia ovata* | Fruit |
| *Dillenia indica* | Fruit |

LEGUMINOSEAE

| | |
|---|---|
| *Parkia javanica* | Fruit |

Appendix B (Cont)

| Forage species* | Forage class (B,F,G)** | Primary forest (%) | Secondary forest (%) | Ag. estate (%) | Total diet (%) |
|---|---|---|---|---|---|
| MORACEAE | | | | | |
| *Ficus* sp. | Fruit | | | | |
| ULMACEAE | | | | | |
| *Trema orientalis* | Fruit | | | | |
| MONOCOTYLEDON | | | | | |
| GRAMINEAE | | | | | |
| *Bambusa* sp. | G | | | | |
| *Digitaria* sp. | G | | | | |
| *Eleusine indica* | G | | | | |
| *Ottochloa nodosa* | G | | | | |
| *Panicum repens* | G | | | | |
| *Paspalum orbiculare* | G | | | | |
| *Perotis indica* | G | | | | |
| *Setaria* sp. | G | | | | |
| MUSACEAE | | | | | |
| *Musa* sp. | F | | | | |
| PALMAE | | | | | |
| *Elaeis guineensis* | B | | | | |

*Browse species were identified by Dr. K. Kouchummen of the Forest Research Institute, Kepong, Malaysia. Grass and seed samples were identified by Dr. I. Enoch of the University Pertanian, Serdang, Malaysia, who also proofed the nomenclature. Scientific names are according to Backer and Vanden Brink (1965), Ridley (1967), Gilliand (1971), and Whitmore (1973).

*B = browse, F = forbs, G = grass.

***T = trace amounts accounting for less than 0.05%.

# APPENDIX C

## CHEMICAL CAPTURE OF GAUR

### Chemical Immobilization.

Immobilon (Etorphine hydrochloride and Acepromazine, Reckitt and Coleman Pharmaceutical Division, Hull, United Kingdom),Rompun (Xylazine hydrochloride, Bayer, Leverkusen, Germany), and Azaperone (Azaperone, Janssen Pharmaceutica, Beerse, Belgium) were used in various combinations and doses for immobilizing gaur. With these drugs, 8 gaur were successfully immobilized (Table 21) while 7 were darted but were not immobilized (Table 22). Weigum (1972) reported attempted immobilization of gaur with M99 (Etorphine hydrochloride) with mixed results. He tried doses of 1.5-2.5 mg on adult animals with no apparent effect, but a 3.0 mg dose knocked down a young bull but did not fully tranquilize him. Etorphine hydrochloride has also been used on captive Indian gaur (Pers. comm. Dr. Jenson, Oklahoma City Zoo, Oklahoma).

All gaur immobilized were free ranging and darted from the ground with Palmer Cap-Chur guns and darts (4 and 7 cc)(Palmer Chemical and Equipment Co., Inc.). Six of the animals were immobilized in conjunction with a radio telemetry research project, while the remaining 2 were intended for captivity. Immobilized animals were treated with medications, measured, and radio-collared (if appropriate) prior to the intravenous injection of the Etorphine antagonist Revivon (Diprenorphine hydrochloride, Reckitt and Colman Pharmaceutical Division).

Table 21. Immobilizations of gaur with the drugs Immobilon (Etorphine), Rompun, and Azaperone.

| Gaur | Dose (mg) | | | | Sex | Age | Wt | Reaction time* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Etorphine | Rompun | Azaperone | Revivon | | | | F | D | R |
| 1** | 2.45 | | 100 | 3.0 | M | 0.3 | 100 | | | |
| 5** | 9.8 | | | 12.0 | F | 4.0 | 600 | | | |
| 6*** | 9.8 | | 300 | 13.5 | F | 20.0 | 700 | 5 | 35 | |
| 7 | 4.9 | 150 | | 7.5 | F | 0.7 | 250 | 10 | 40 | 5 |
| 9™ | 9.8 | 500 | | 12.0 | M | 5.0 | 950 | 90 | 45 | 10 |
| 10 | 6.13 | 150 | | 7.5 | F | 1.5 | 400 | 15 | 45 | 4 |
| 11 | 4.9° | 150 | | 6.0 | M | 2.0 | 500 | 25 | 40 | 4 |
| 12 | 6.13° | 150 | | 7.5 | M | 1.0 | 300 | 5 | 45 | 5 |

*F = time to find, D = down time, and R = recovery time in minutes.

**Animal died in captivity after 10 and 2 days respectively.

***Animal remained recumbent following immobilization and died after 8 days.

™Animal was given a second dose of 2.45 mg etorphine and 300 mg Rompun.

°Drug over expiration date by 4 and 5 months respectively.

Table 22. Unsuccessful immobilizations of gaur with the drugs Immobilon (Etorphine), Rompun, and Azaperone.

| Gaur | Dose (mg) | | | Estimate of* | | | Notes on dart operation |
|---|---|---|---|---|---|---|---|
| | Etorphine | Rompun | Azaperone | Sex | Age | Wt | |
| 2 | 4.9 | | 100 | M | 5+ | 700 | drug ejected |
| 3 | 8.58 | | 50 | M | 5+ | 700 | drug ejected |
| 4 | 6.13 | | 50 | ? | 2 | 400 | drug ejected |
| 8 | 6.13 | 150 | | F | 3 | 400 | drug ejected |
| 13 | 4.9** | 150 | | F | 5+ | 500 | |
| 14 | 6.13** | 150 | | F | 5+ | 500 | |
| 15 | 7.35** | 250 | | M | 5+ | 800 | drug ejected, needle on dart broken |

*Visual appraisal of sex, age, and weight.

**Drug over expiration date by 5,5, and 9 months respectively.

Immobilization. Initial use of Immobilon alone and an Immobilon and Azaperone mixture for immobilization of gaur was unsatisfactory in consideration of safety and animal reaction (see Drug Mortality section and Tables 21 and 22). A mixture of Immobilon and Rompun proved effective and safe and was used throughout the rest of the study. Doses in successful immobilizations ranged from 1.0 cc Immobilon (2.45 mg Etorphine hydrochloride per cc) combined with 100 mg Azaperone used on a calf (No. 1, Table 21) to 4.0 cc Immobilon mixed with 500 mg Rompun used on an adult bull (No. 9, Table 21). The mean dose of etorphine in successful immobilizations averaged 6.43 mg.

Estimated body weights were used to construct dosage rates. Body weights were estimated by visual evaluation and with a domestic cattle chest-circumference/body-weight tape. Based on body weight, the mean dosage rate of Etorphine hydrochloride was 1.6 mg/100 kg with a range of 0.98 to 2.45 mg/100 kg live body weight. The 95% confidence interval for the mean dosage rate of Etorphine hydrochloride was 1.21 to 2.0 mg/100 kg body weight.

I used either 150 or 200 mg Rompun in the drug combination in successful immobilizations of gaur (Table 21). The mean dosage rate of Xylazine, based on estimated body weight, was 46 mg/100 kg (range 30 to 60 mg/100 kg). The 95% confidence interval for the mean dosage rate of Xylazine was 31 to 61 mg/100 kg body weight.

The "time to find" is the period between the initial drug injection and the location of the animal, and provided a rough measure of induction time. The time to find was reported for 6 cases and ranged from 5 to 90 minutes with a mean of 25 minutes. The 90 minute case occurred when an adult bull was not fully immobilized and fled over 1.6 km before becoming entangled in vines. He was administered a second dose and was fully immobilized at 90 minutes.

The narcosis stage allowed easy handling and was of sufficient length for thorough processing of each animal. The mean down time, recorded on 6 animals, was 42 minutes (range 35-50 min). The temperature recorded on 2 animals was $39.0^{\circ}$ C and $39.3^{\circ}$ C.

Seven gaur were darted but did not go down (Table 22). The mean dose of Etorphine used in the unsuccessful immobilization attempts (6.30 mg) did not differ significantly from the mean dose (6.43 mg) use for successful immobilizations. However, in 3 of the 7 attempts the Immobilon was outdated.

Recovery. The manufacturer's recommended dose of 1.0 cc Revivon (3.0 mg Diprenorphine) per 1.0 cc Immobilon was administered intravenously to all 8 immobilized gaur. With 1 exception, all animals recovered quickly, mean recovery time was 5.6 minutes (range 4-10 min, Table 21). The 1 exception was a very old cow, estimated at 20 years of age, that died after 8 days recumbency (see Drug Mortality section). She revived after the administration of Revivon, stood for a few minutes on wobbly legs, then lay back down. An additional dose of 0.5 cc Revivon had no effect.

A large dose of Rompun apparently delayed the recovery of No. 9. Its recovery time was twice that of other animals, and on standing, it had woobly legs and moved off only 300 m before bedding down. This residual tranquilizing effect associated with high dosages of Rompun mixed with Etorphine was also noted by Gasaway et al. (1978) in immobilizing moose (Alces alces).

Drug Mortality. Only 1 animal died as a direct result of immobilization. The animal was darted and went down in 5 minutes and revived after the administration of the antagonist, Revivon. However, the animal remained recumbent and died after 8 days. A veterinary examination of the recumbent animal detected no medical malady and a gross post-mortem examination in the field by me found no abnormalities that could explain the condition leading to death. The pertinent finding was the advanced age of the animal, estimated at 20 years from the gum level wear of the front incisors.

Though not attributed to chemical immobilization, an additional 2 deaths occurred in captivity, 2 and 10 days following capture. Post mortem examinations of the carcasses attributed death to a combination of stress and heat stroke resulting from violent struggle during capture, transport, and confinement (Pers. comm., Letter from Dr. D. Smith, Pathologist, University Pertanian, Malaysia).

Conclusion.

Based on my experience with a limited sample size in the rain forest of Malaysia, the combination of Immobilon and Rompun was preferred and proved safe and effective for the immobilization of gaur. Dosages of from 2.0-2.5 cc Immobilon mixed with 150 mg Rompun immobilized gaur weighing up to 500 kg. Smaller dosages were used for calves and larger dosages for big bulls. The manufacturer's recommended dosage for Revivon was adequate. A great deal of individual variation was noted in the animal's responses to this drug mixture. Advantages were a deep narcosis, no problems with reguritation or respiratory distress, no hypothermia, the reversibility on demand of the Immobilon action with the antagonist Revivon, and a short recovery period.

The disadvantages of the Immobilon-Rompun mixture were individual animal variation in reaction to knock down dose (apparent failure to react to the drugs), problems with storage in the field (storage at ambient temperature exceeded manufacturer's recommendations), and reaction times of over 15 minutes in a few cases compounded the already difficult task of finding a darted animal in the dense jungle.