UNGULATE POPULATIONS IN CHITAWAN VALLEY, NEPAL

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ABSTRACT

The population composition and density of wild and domestic ungulates in selected areas of Chitawan Valley, Nepal, are estimated and compared with other regions. Species considered include Axis axis, Axis porcinus, Cervus unicolor, Muntiacus muntjak, Sus scrofa, Rhinoceros unicornis, *and domestic cattle, water buffalo, sheep, and goats.* Rhinoceros *constituted the bulk of the wild ungulate biomass in the riverine forest and grassland within the Royal Chitawan National Park. Species differed in their occurrence in various vegetation types and these differences afforded a degree of ecological separation. Counts indicated that juvenile mortality for most wild ungulates was high and seemed related to both nutritional and predatory factors. Suggestions for increasing the precision of counts of wild ungulates in monsoonal forest areas are included and conservation implications are discussed.*

INTRODUCTION

The dense, tangled vegetation, which makes direct observation of even the largest mammals difficult and time-consuming, and the absence of a concentrated birth season, pose difficult problems in monitoring population parameters of wild ungulates in the terai and dun valleys of India, Nepal and Bhutan. Light aircraft, employed in census work in the open areas of North America and East Africa, are of little use over most of this region. The lack of roads and trails in many important areas curtails censusing from a vehicle or on foot. Domestic elephants were used successfully in grassland areas of this region by Schaller (1967) and Spillett (1967). The range of habitats over which domestic elephants could be effectively utilised had not been determined when this work began.

Studies were initiated to establish population and behavioural parameters and habitat utilisation trends of the ungulates in the Royal Chitawan National Park and

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in some adjacent forest tracts in 1973 as part of an investigation of the ecology and behaviour of the tiger (*Panthera tigris*) and leopard (*Panthera pardus*). My approach was to develop and refine methods as the work progressed, as opposed to depending entirely on a single sampling scheme which might have proved inadequate. I employed a number of independent methods to assess different parameters and which could be used as cross-checks to determine the accuracy of the various estimates. This included observations from elephants and on foot made while going about other tasks, systematic observations made from platforms in trees (*machans*), line-transects made through a range of habitats, using elephants, and the standard plot technique successfully used by Eisenberg & Lockhart (1972) and Mueller-Dombois (1972) in Sri Lanka for estimating the relative intensity of animal activity with respect to different physiognomic classes of vegetation.

In this paper, I summarise observations made between November 1973 and April 1974 to provide preliminary estimates of activity and habitat utilisation, population structure, and density and biomass for the ungulates occurring in the northeast corner of the Park and in some adjacent areas. I am no longer involved in this project and my objective is to make these baseline data available to responsible managers and to provide guidance for maximising the efficiency of future census work in the terai.

CHITAWAN VALLEY

The intermediate zone between the outermost Himalayan ranges and the Gangetic Plain, the terai and associated valleys in the foothills, such as Chitawan (Fig. 1), were shunned by both the hill and plains people during all but the cool winter season because of the prevalence of malaria. In Nepal, this belt remained unsettled except for scattered villages of the indigenous Tharus. Important as strategic barriers to the hill areas, the malarious Chitawan jungles were given further protection by a government policy discouraging settlement and clearing (Rose, 1971; Burkhill in Stainton, 1972). Until 1950 the region received special consideration as a favourite shooting reserve of the Rana Prime Ministers (Smythies, 1942).

In 1955, with the pressing need for new agricultural lands due to growing populations in the hills, and the means of controlling malaria (at least temporarily) in hand, this rich jungle area was selected for one of Nepal's first large-scale agricultural development programmes. Much has changed in the last two decades, but with protection provided by a system of Royal hunting reserves, a rhino sanctuary, and a timely resettlement programme, the area which became the Royal Chitawan National Park in 1973, and many of the adjacent forest tracts, remain relatively intact. There are many problems, but they constitute a key area for the preservation of many of the large mammals in the Nepal terai (Gee, 1963; Mishra, 1974).

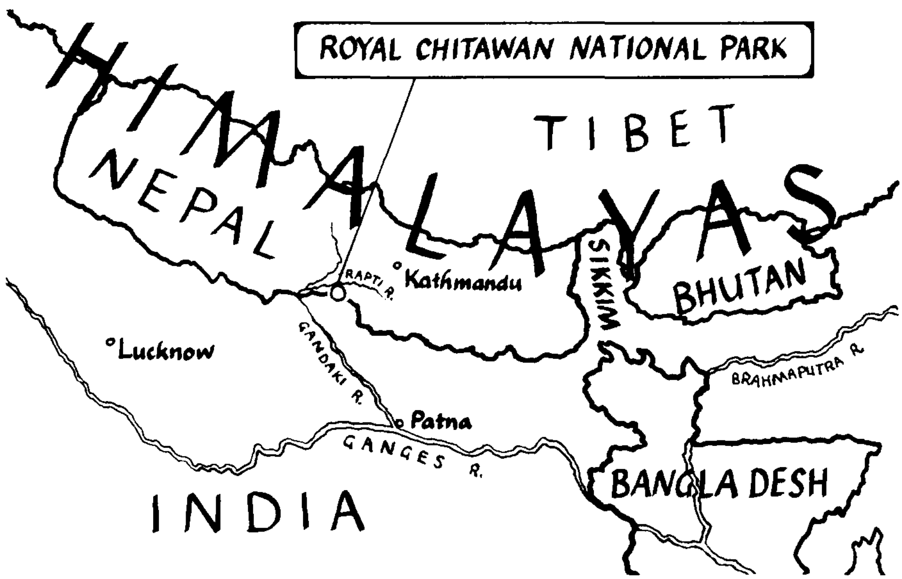

Fig. 1. The Royal Chitawan National Park, located at the base of the outermost Himalayan ranges, is one of a series of parks and sanctuaries in the terai zone which have been set aside by the governments of Nepal, India and Bhutan, primarily for the conservation of large mammals.

Under financial and manpower constraints, intensive work was confined to the northeast corner of the Park near the village of Sauraha and to some of the adjacent forest areas (Fig. 2). This region is a mosaic of riverine forests and tall grass areas bounded on the south by *Shorea* forests which extend over the Churia Hills and on the north by the Rapti and other large streams. Open areas under cultivation extend north and east from the boundaries of the Park (Fig. 2). The elevation is approximately 150 m.

Average monthly maximum temperatures range from 24 °C in January to 38 °C in May and minimum temperatures from 11 °C in January to 26 °C in June. The climate is monsoonal. Average yearly rainfall is more than 230 cm; nearly 200 cm fall during the rainy season from June through September (HMG, 1968).

Soils in the valley are deep and rich. Surface water is well distributed and available all year around. This contrasts with the porous, alluvial soils and scarcity of surface water that characterise the usual Himalayan–Plain juncture (Gee, 1963; Stainton, 1972).

Shorea robusta (Fig. 3) dominates in the Churia Hills, frequently with a relatively open grass or low shrub/grass understory; this type constitutes the majority of the land area included in the Park. The dominants in the riverine forest (Fig. 4) are *Trewia nudiflora* and *Bombax malabaricum*. *Callicarpa macrophylla* and

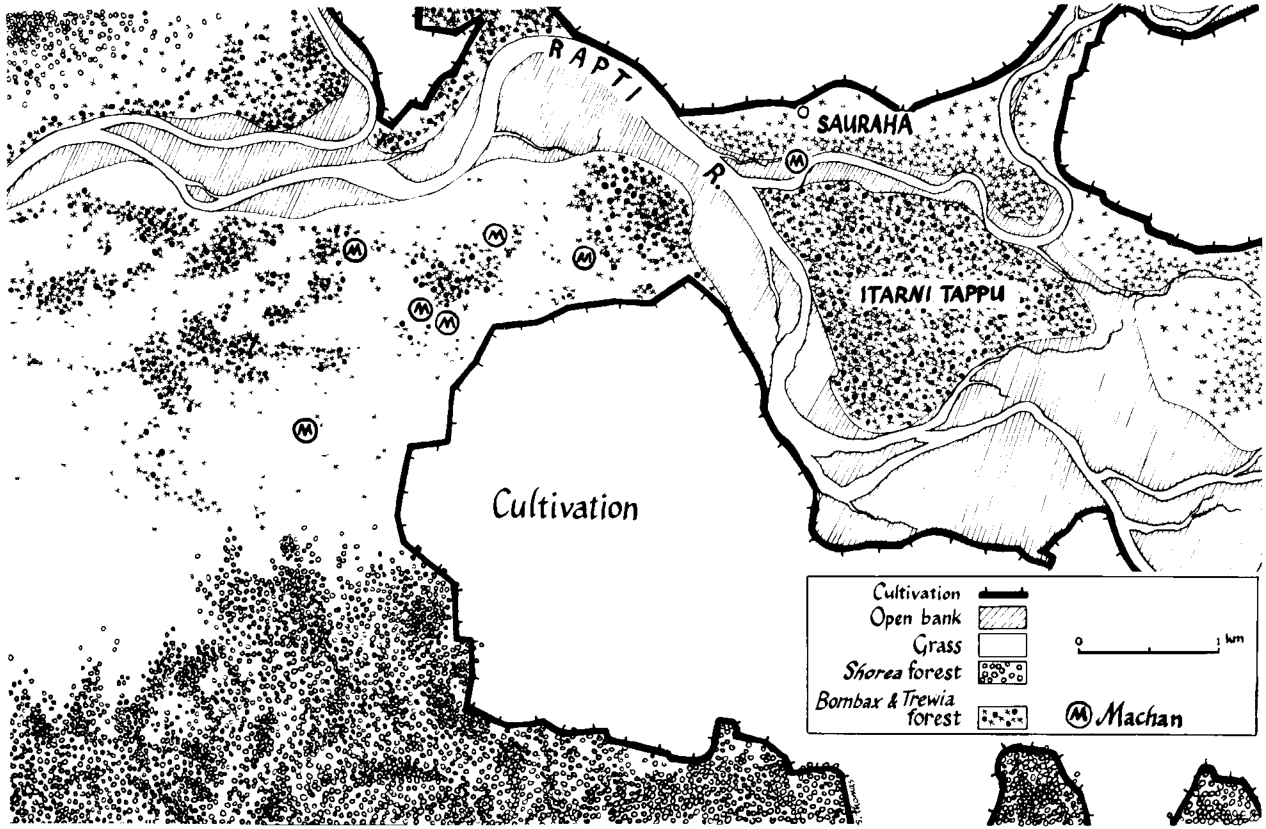

Fig. 2. A vegetation map of the Sauraha area in the northeast corner of the Royal Chitawan National Park. The National Park lies south of the Rapti River, adjacent to the cultivated areas. North of the Rapti, only Itarni Tappu is included within the National Park; other forest areas are under Forest Department and National Parks and Wildlife Conservation Office administration.

Fig. 3. An axis deer stands in the *Shorea* forest which has a fairly open understory.

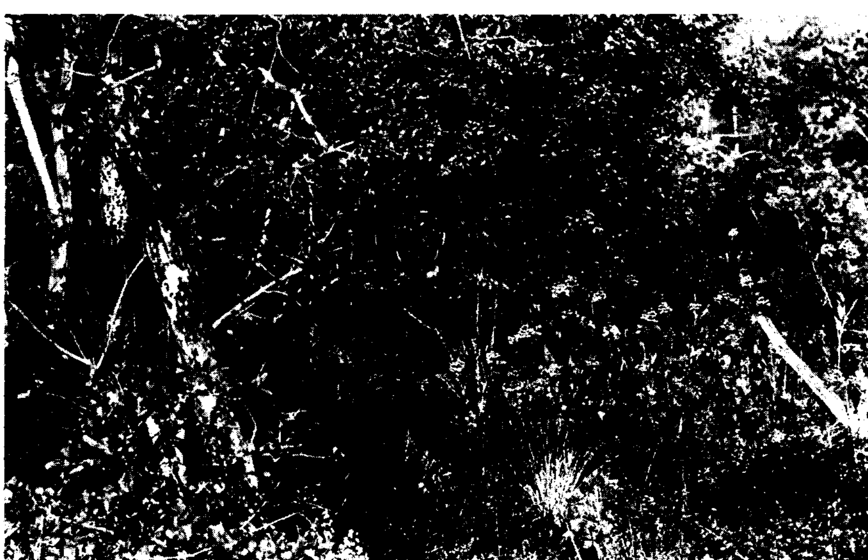

Fig. 4. The riverine forest with a dense shrub understory. A sambar is just visible in the centre of the picture.

Fig. 5. (a) The tall grass area. Grass usually grows 3 5 m in height. February 1974. (b) A tall grass area after the fires. April 1974.

Fig. 6. Open banks of the Rapti River after the monsoonal high water has receded.

Phyllanthus emblica are common shrub understory species. The grasslands are complex; in the Sauraha area alone, 40 species have been found by A. Laurie (in prep.). *Saccharum* sp. and *Phragmites karka* are frequently encountered; tall grass stands are usually over 3 m in height (Fig. 5a). The banks are mostly open (Fig. 6); outside the rainy season, the grass is grazed short.

This is the juncture of two faunal realms. The mountains that rise to the north buttress the main Asian land mass; the plants and animals only a few airline kilometres away are predominantly palaearctic forms. At the base of the mountains, the flora and fauna have their affinities with the Gangetic Plain and the south. The large ungulate fauna includes axis deer (*Axis axis*), hog deer (*Axis porcinus*), sambar (*Cervus unicolor*), barking deer (*Muntiacus muntjak*), wild swine (*Sus scrofa*) and great Indian one-horned rhinoceros (*Rhinoceros unicornis*). There is a small population of gaur (*Bos gaurus*) restricted to the hills. Very infrequently a wild elephant (*Elephas maximus*) will roam through the Churia Hills. Nonmenclature for mammals follows Ellerman & Morrison-Scott (1951) and Stainton (1972) for plants.

ACTIVITY AND HABITAT UTILISATION

The frequency of encountering wild ungulates in different vegetation types indicates trends in habitat utilisation (Table 1). My search time in grassland, riverine forests and banks was roughly comparable to the relative proportion of each type occurring

TABLE 1
FREQUENCY OF ENCOUNTERING GROUPS OF WILD UNGULATES IN DIFFERENT VEGETATION TYPES IN THE ROYAL CHITAWAN NATIONAL PARK, NEPAL, NOVEMBER 1973–APRIL 1974

N	Shorea *forest*	*N*	*Riverine forest*	*N*	*Tall grass*	*N*	*Banks*
17	*A. axis*	77	*A. axis*	152	*A. porcinus*	18	*A. axis*
5	*Cervus*	67	*Cervus*	113	*Rhinoceros*	12	*Rhinoceros*
3	*Muntiacus*	45	*Rhinoceros*	34	*A. axis*	8	*Sus*
2	*A. porcinus*	43	*Muntiacus*	27	*Sus*	7	*Muntiacus*
1	*Sus*	36	*Sus*	16	*Cervus*	6	*Cervus*
0	*Rhinoceros*	15	*A. porcinus*	10	*Muntiacus*	0	*A. porcinus*

in the flood plain, but I spent much less time in the *Shorea* forest. Nevertheless, comparison with the *Shorea* forest types is useful and can be related to the others. Each species utilised a variety of vegetation types, yet a considerable degree of separation occurred (Table 1). Of the ungulates living in Chitawan, the hog deer showed a high degree of preference for the grassland areas, the sambar and barking deer for the forest areas and the rhino for the riverine flood plain types. The axis deer and wild swine were ubiquitous.

Frequency of encounter data permits only the gross aspects of habitat utilisation trends to be considered. By utilising standard plots located in different physiognomic classes of vegetation, I attempted to gain insight into the fine-grained trends that were occurring. The usefulness of this technique for estimating animal activity in the lowland dry scrub jungle of Sri Lanka has been demonstrated by Eisenberg & Lockhart (1972), but it remained to be determined if this method would be useful in the mesic riverine types in Chitawan.

A description and a preliminary assessment of the technique and difficulties encountered have been presented in a report to His Majesty's Government (Newbry & Seidensticker, 1974). Briefly, animal activity is discerned by noting on half-hectare plots characteristics such as faecal piles, evidence of grass and branch feeding, height of branch feeding, extent of cover, game trails, location and size of termite mounds, size of tracks, or ground disturbance as the result of digging, scraping or wallowing. Of the indirect evidence gathered, the most useful in determining habitat utilisation trends was the number of faecal piles for each species counted on each plot. The rhino is well known for its propensity of defecating at fixed locations and could not be included. It was difficult to separate accurately the faecal piles of all the cervids by size and shape alone; here I have included counts of faecal piles I was reasonably sure were those of axis deer or sambar.

Table 2 includes the results obtained from 11 plots that were located throughout the study site. Useful comparisons both within (plots no. 1, 2, 3, 4, 6, 7, 9, 10) and outside the National Park (plots no. 5, 8, 11) can be made. The plot in the riverine forest outside the Park showed less use than those inside the Park by both axis deer and sambar, although the plot in the *Shorea* forest outside the Park showed more use by axis deer than the *Shorea* forest plots in the Park.

TABLE 2

HABITAT UTILISATION TRENDS AS INDICATED BY NUMBER OF FAECAL PILES PER ½-HA PLOT, LOCATED IN THE CHITAWAN VALLEY, NEPAL

Vegetation class	*Plot no.*	*Domestic cattle and buffalo*	Lepus nigricollis	Sus scrofa	Cervus unicolor	Axis axis
Open bank	8	291	79	21	6	139
Tall grass	10	0	3	37	22	117
Low grass	1	0	13	14	29	150
Grass-shrubs	3	0	9	15	39	110
Riverine forest, open understory	4	0	1	4	84	68
Riverine forest, thick shrub understory	6	0	0	0	108	132
Scattered *Bombax*, *Zizyphus jujuba* understory	7	2	9	29	82	76
Scattered *Bombax*, thick shrub understory	5	125	15	10	13	6
Shorea forest, open understory	2	0	2	2	5	28
Shorea forest, low grass understory	9	0	0	0	60	62
Shorea forest, short grass understory	11	13	0	4	19	73

Habitat utilisation trends within the Park, as judged from these sample plots, showed the same general trends as those determined from frequency of encounter: a greater use of the forest than the grassland by sambar, and the axis deer and wild swine fairly well distributed among all types. Wild swine, axis deer and sambar, however, used the riverine types more heavily than the *Shorea* forest.

Both axis deer and sambar used the low grass sites more heavily than the tall grass areas. The scattered areas of low grass were under cultivation until a resettlement programme a decade ago; the dominant species (*Imperata cylindrica*) is interspersed with occasional clumps of the tall *Saccharum* sp. Most frequented by sambar were the grasslands with a strong shrub component, and open forests with a thick understory of *Zizyphus jujuba*; the axis deer showed less use of these areas. Both these large deer were recorded in the dense riverine forests with thick shrub understories, but in the riverine forests with more open understories, sambar prevailed.

Inside the Park, observations were made from a series of six *machans*, maintained

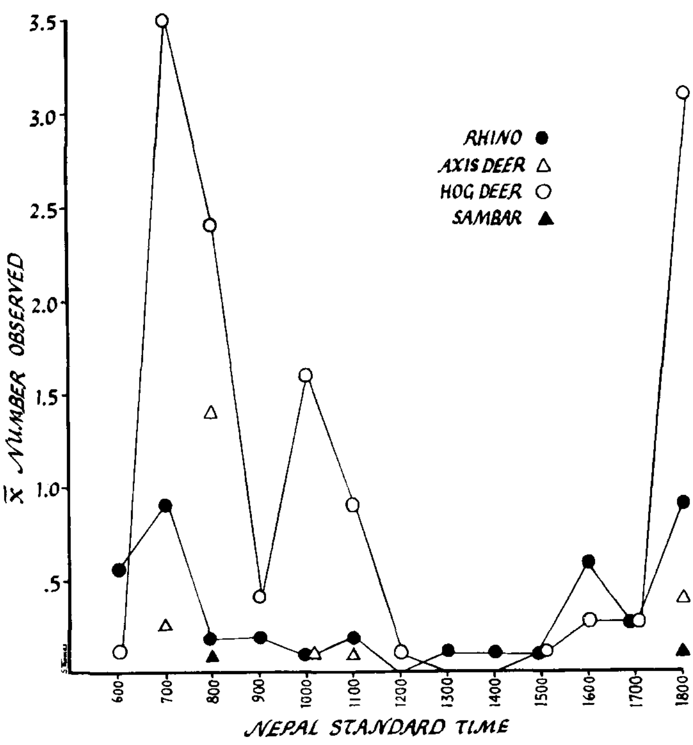

Fig. 7. Composite of observations made from a system of six *machans* overlooking a tall grass area in the Royal Chitawan National Park, Sauraha area.

in cooperation with A. Laurie, which were situated to give coverage of a large area of grassland near the eastern boundary of the Park (Fig. 2). Four-hour observation periods were systematically alternated so that the region received equal coverage for a total of 128 hours in February and March (Fig. 7).

By February, many of the tall grass areas had been burned by fires started by local people and Park personnel, making it possible to see animals (Fig. 5b). The new growth appeared almost immediately after the burning; by mid-April, observational opportunities from *machans* were limited by the new growth.

All species were observed in these burned grassland areas, but the barking deer and wild swine were only infrequently seen. Most frequently observed were hog deer, axis deer and rhino. Sambar occasionally were seen at the forest edge or in the shrub/grassland areas. These data show two major activity peaks: at 0700 h and at 1800 h. An additional peak for both axis and hog deer occurred later in the morning at 1000–1100 h. Evening observations were not possible due to National Park regulations.

I can identify only tentatively the determinants acting to produce this pattern of activity. The abrupt change of activity in the early morning suggests that the daily activity pattern is initiated with sunrise for the axis and hog deer, though this is not true for the rhino. The next peak in activity for the axis and hog deer seems associated with an endogenous feeding rhythm (Geist, 1963; Jarman & Jarman, 1973); an initial feeding period in the morning was followed by a period of rumination, followed again by a period of feeding in the open at 1000 h–1100 h. The greatly reduced activity in midday and early afternoon is in response to the hot midday sun. Feeding began again in the late afternoon and probably extended into the middle of the night (extrapolated from Fig. 8). The hog deer were active again beginning at 1500 h, but the axis deer were not usually active in the grasslands until 1800 h, although they could have been feeding in the forest areas out of view earlier in the afternoon.

Figure 8 is based on observations made from a *machan* located on the north bank of the Rapti River on the Park border. From this vantage point, an observer could monitor a 75-ha short-grass/sand bank area separating the densely wooded island, Itarni Tappu, and a strip of scrub forest adjacent to the cultivated areas (Fig. 2). A total of 84·5 h of observations were made between 0600 h and 2200 h from 1 January to 28 February; mean number observed was calculated by counting the number of different individuals seen during each one-hour period and dividing by the number of observation periods. Night observations were made with a night-vision device.

The activity of domestic stock, including cattle, buffalo and domestic elephants, and people was strictly diurnal, beginning at 0600 h and extending until 1700 h, with an activity peak at 1400 h. The wild ungulates seen in this border area, listed in order of frequency of occurrence, included axis deer, rhino, wild swine, sambar, barking deer and hog deer. Rhesus monkeys (*Macaca mulatta*) and leopards were also observed.

The activity peaks at 0800 h and 1700 h for the wild ungulates correspond with their movements between the forest areas and the strip of scrub forest. In the afternoon these animals would move rather quickly across the open banks from Itarni Tappu to the strip of forest, moving into the cultivated areas after sunset; they would return in the morning. Later in the evening, after the domestic stock had been moved back into the village areas, axis deer, barking deer, sambar and rhino would come out onto the open banks and graze. The rhino occurred more frequently through the early afternoon than the other species.

Contrast Fig. 8 with Fig. 7, which is based on observations made from *machans* overlooking grassland areas within the Park. Note in Fig. 7 the occurrence of the ungulates in the open areas extending well into the morning and beginning again in the early afternoon; these activity peaks are not as constricted as those of ungulates

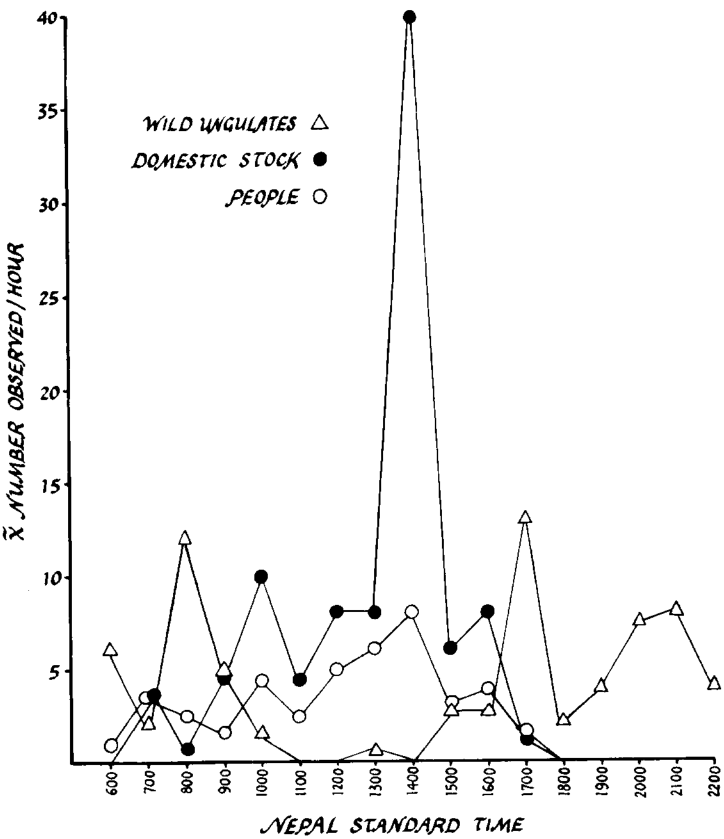

Fig. 8. Observations made from a single *machan* overlooking an open bank area north of Itarni Tappu on the boundary of the Royal Chitawan National Park, Sauraha area.

occurring in the areas which are shared with domestic stock and people.

The use of shade appears to be an important part of the thermo-regulatory strategies of all these wild ungulates, and thus the restricted activity in the open, exposed areas at midday. With dense vegetation restricting observational opportunities in the Park, this border area has great potential for tourist viewing. Restriction of the activity of people and domestic stock (including elephants) would increase its utility.

POPULATION STRUCTURE

Ungulates observed were classified according to sex and age whenever possible, using the criteria described by Spillett (1967), Schaller (1967) and Eisenberg & Lockhart (1972). Sex of adults was determined for rhinos through relative body size and characteristics of the face, which were pointed out by A. Laurie. In this preliminary analysis, the yearling or subadult cervids and wild swine were included with the adults. The sex of subadult rhinos is very difficult to determine, and subadults were not included with the adults.

In the thick vegetation, one usually obtained only a fleeting glimpse before the animal moved off. Sambar, barking deer and hog deer, because they occur more frequently singly or in small groups, were easier to classify than the wild swine and axis deer. The wild swine were particularly difficult to see clearly enough to classify in the tall grass or forest understory. Single and small groups of axis deer presented no problem, but large groups occurring in the forest undergrowth did. In these situations, we attempted an estimate of group size and scored it as mixed composition, mostly males, or mostly females with young.

TABLE 3
AGE AND SEX RATIO OF LARGE HERBIVORES IN THE ROYAL CHITAWAN NATIONAL PARK, NEPAL, FROM DECEMBER 1973–APRIL 1974

Species	*Adult* ♂♂	*Adult* ♀♀	*Young*
Rhinoceros	38	100	83
Axis axis	115	100	28
Cervus unicolor	102	100	50
Axis porcinus	51	100	24
Muntiacus muntjak	74	100	11
Sus scrofa	30	100	38

Table 3 gives the adult sex composition of the wild ungulate populations, as determined from both ground and *machan* observations. A higher percentage of females than males was found in all except the axis deer. There is considerable variation in the adult sex ratio of ungulates as reported from other regions (Spillett, 1967; Schaller, 1967; Hoogerwerf, 1970; Berwick & Jordan, 1971; Eisenberg &

Lockhart, 1972; Barrette, 1975). The numbers of ♂♂: 100 ♀♀ for axis deer range from 35–79 (N = 11, $\bar{x}$ = 64), sambar 30–127 (N = 4, $\bar{x}$ = 61), hog deer 75–103 (N = 4, $\bar{x}$ = 89), barking deer 91–86 (N = 2), wild swine 44–133 (N = 2). Spillett (1967) reported 81 ♂♂ per 100 ♀♀ for rhinos in the Kaziranga Sanctuary (India). The rhino is currently under intensive investigation by Laurie (1973), who found the adult sex ratio, based on individually recognisable animals, was about 60 ♂♂ to 100 ♀♀ in the Sauraha area. My estimate of the adult sex ratio of this species based on frequency of encounter is biased in favour of females; this is related to difficulties of identification. My estimates of the ♂♂ : 100 ♀♀ proportion of hog deer, barking deer, and wild swine fell below estimates from other areas; those of axis deer are above, and the sambar estimate fell within the range from previously reported studies.

With the exception of sambar, with the sex ratio of adults at parity, these estimates of population structure indicate differential mortality rates between the sexes, related no doubt to differential predatory pressure and/or habitat conditions.

TABLE 4
GROUPING TENDENCIES OF THE WILD UNGULATES IN THE ROYAL CHITAWAN NATIONAL PARK, NEPAL

Species	*No. of groups*	*Group size—%*								
		1	2	3	4	5	6–10	11–20	21–30	31–40
Rhinoceros	245	54	43	2	1	0·5				
Muntiacus	68	93	7							
Cervus	107	66	23	7	2		1			
A. porcinus	269	55	24	6	4	4	6	1		0·5
A. axis	160	18	12	15	11	11	18	9	4	2
Sus	84	74	15	4	6		1			

Observations on grouping tendencies of the wild ungulates are shown in Table 4. Barking deer are nearly always found alone. In the two instances of grouping where we could determine composition, a male was with a female and a female with a juvenile, and I believe the remaining groups were also females with young. We occasionally came upon a young barking deer without the female. Eisenberg & Lockhart (1972) felt that the juveniles frequently did not accompany the female on her foraging trips, but remained concealed, and these data would support this. This results in an underestimate of the proportion of young in the population (Table 3).

The wild swine show a reduced group size from that reported in other areas. This is primarily a function of the time of year in which these counts were made and represents the high degree of mortality which occurred during their first year. The 74 % of the observations being of solitary individuals is considerably above the 38 % reported for Sri Lanka. Striped young appeared following the female in March. One female was followed by 6 young. Other groups were known to have more, but I could not obtain accurate counts. The largest group recorded between November and February was 4, which included a single female with young. The mortality pattern with swine is complicated in that, at least in the eastern end of the Park, there was an epidemic. In the Sauraha area a tigress and her two cubs were seen feeding on a pig which they may have found dead.

Sambar were frequently found alone, or in groups which included a female and her fawn or a female, fawn and yearling. We observed 2 or 3 males together in a few instances, and twice we saw 2 females and their fawns. The largest group (10) was observed at dusk in a small opening in the forest and consisted of 2 ♂♂, 4♀♀, 1 yr ♀ and 3 young. It appeared that a single young was the rule, but the female–young ratio we observed makes it unlikely that females are breeding only every other year, as those in Sri Lanka reportedly do (Eisenberg & Lockhart, 1972).

Hog and axis deer are the two representatives of the genus *Axis* inhabiting the Indian subcontinent, and differ in their utilisation of habitat. The axis deer apparently prefer the forest or forest edge, while the hog deer prefer the tall grass environs (see above). They also differ in their grouping tendencies, as shown in Table 4.

The hog deer are primarily solitary, with 55 % of the sightings made of single individuals, as compared to 18 % for the axis deer. Hog deer were rarely encountered in forest situations and our estimates of sex and age structure based on ground and *machan* observations agree closely. However, we found that there was a greater tendency to encounter young on the ground than from *machans*, which indicates that females left their young when coming out to feed in the recently burned or short grass areas. The estimated female-to-young ratio seems surprisingly low. We observed young spotted hog deer in February and March but young of various sizes were recorded over the entire observation period, possibly indicating the lack of a strong birth peak, or perhaps, two birth peaks. I feel, however, that this low female–young ratio reflects the degree of mortality which they were undergoing in their first year of life. Predation by leopards and tigers is important and nutritional factors may be involved.

Hog deer have been only casually treated by other investigators (Schaller, 1967; Spillett, 1967), so I include my observations on their social organisation and adaptations to specific habitats. Given that the more primitive cervids were rather generalised small forest-dwelling forms, we see in the axis and hog deer two quite distinct adaptive syndromes. The axis deer is a species inhabiting the forest and forest edge, but having the ability to utilise the grassland areas as well. An important habitat component in their diel cycle is the forest area (see above and Schaller, 1967). The spotted-coat patterning seems related to camouflage, but we see also the increase in size which is a characteristic morphological trend in the evolution of ungulates in the open grassland as an adaptive response to predatory pressure (Howell, 1965). The hog deer have remained relatively small, but inhabit grasslands almost exclusively; they seem specifically adapted to live in tall grass. Movement away from a source of disturbance is similar to the axis deer, as reported by Schaller (1967). In form, however, it reminds me of the forest-living barking deer's inconspicuous mode of avoiding predatory detection (Eisenberg & McKay, 1974).

This is also reflected in its solitary tendency as compared with the group-living axis deer. The only large groups of hog deer (Table 4) were seen after the burning of the tall grass or in the low thatch-grass areas where they came together in the openings to feed.

The structure of the small groups varied: groups of 2 included males, females, and male–female, but most frequently a female with young. In groups of 3 to 7, where we could record composition, 10 % were all males, 45 % were females with young and yearlings, and 45 % were of mixed composition, indicating a tendency toward the formation of unisexual groups similar to those of the axis deer. The formation of large groups in areas with low-growing vegetation may be a means of gaining protection from predators while feeding, as discussed by Vine (1971). Protection from predators while living in the tall grass, on the other hand, is through inconspicuousness which includes living spaced apart (Tinbergen *et al.*, 1967; Geist, 1974).

TABLE 5
ESTIMATES OF POPULATION COMPOSITION OF *Axis axis* BY VARIOUS METHODS

Method and area	*N*	♂♂ :	♀♀ :	*Young*
Observation from *machan* on park boundary, open bank	241	110	100	17
Machan observation of grassland area in the park	71	46	100	46
Ground observation				
Total	317	141	100	35
Tall grass	129	67	100	34
Forest	129	174	100	33
Banks	59	470	100	20
TOTAL	629	115	100	28

The population composition of the axis deer is summarised in Table 5. By including only complete classifications of groups, population composition of axis deer was estimated to be 135:100:35. Only the estimates obtained from the ground in the grassland areas are similar to those obtained from other regions. Observations made on the open banks from *machans* and from the ground indicate a preponderance of males. It appears that both differential habitat utilisation by the sexes and selective predation may occur. In Kanha National Park (India), tigers took proportionally fewer male axis deer than female (Schaller, 1967). Data from Chitawan also suggest this (Seidensticker, in press).

Note the strong disparity between estimates of female–young ratios made on the north side of the Rapti, where the riverine forest and banks were greatly overgrazed by domestic livestock, and those from the Park itself, where grazing by livestock is officially excluded. Eisenberg & Lockhart (1972) have emphasized the restricted mobility and attachment to site displayed by axis deer in Sri Lanka; here we are probably dealing with two distinct sub-populations. These different female–young ratios seem related to nutritional differences and reflect the differential way in which mortality factors are acting on the juvenile age class within even this very limited area.

NUMBERS AND BIOMASS

The riverine forests and grasslands in Chitawan Valley have long been hailed by hunters as exceptionally rich in numbers of large mammals (Smythies, 1942), but no previous attempts have been made to estimate accurately the density of any species other than the rhino (Gee, 1959; Pelinck & Upreti, 1972; Laurie, 1973).

The preliminary estimates reported here (Table 6) were derived from counts made from elephant-back using the belt-transect method of Kelker (in Jarman, 1972) over a total distance of 66·2 km. Belt widths, of course, varied with the vegetation types, the season, and with the species concerned. They were derived by summarising a sample of sightings of each species under each vegetation condition within successive 10-m belts parallel to the elephant's line of travel. From this, the belt width where sightings began to fall off was determined and calculations were made accordingly. The starting point of each transect was marked and direction of travel was determined by compass bearing, facilitating repeated counts along the same general course. All distances were calculated from aerial photographs.

Transects were made on the basis of available time and manpower. A first series was conducted at the end of January, in the *Shorea* and riverine types both within and outside the National Park. A second series of transects was conducted in early April, but only included the riverine forest/grassland within the Park. Initially, transects were attempted employing two elephants moving parallel, 50–75 m apart; voice contact was maintained to avoid any duplication in the count. This proved impractical and all April counts were conducted from a single elephant.

Usually there were three observers per elephant: the driver; his assistant, usually standing on the back; and one seated observer, recording. This number of observers proved essential for obtaining accurate records, especially in the thickest vegetation; frequently, one observer would spot an animal undetected by the others. While wild elephants are no longer a component of the wild fauna in this area, domestic elephants have been kept at the government elephant camp at Sauraha for years and, through most of the year, they are taken daily to feed in the forest and grassland areas censused. Movements along transect lines did not constitute an unusual disturbance of recent origin.

In Table 6, data for both January and April have been combined. There is a flux in the number of ungulates in the riverine forest/grassland within the Park. The estimate of rhino density from January in this area was $6{\cdot}5/km^2$, while in April this had jumped to $17{\cdot}2/km^2$, as rhinos from the surrounding areas began concentrating in the Park in response to the new grass growth after the burning and to a decrease in available food in areas surrounding the Park (Laurie, 1973). The estimates of the

TABLE 6

PRELIMINARY ESTIMATES OF NUMERICAL AND BIOMASS DENSITY OF WILD UNGULATES IN THE CHITAWAN VALLEY, NEPAL, JANUARY AND APRIL 1974

	Within the National Park				*Outside the National Park*			
	Riverine forest/tall grass		Shorea *forest*		*Riverine forest*		Shorea *forest*	
	N/km^2	kg/km^2*	N/km^2	kg/km^2	N/km^2	kg/km^2	N/km^2	kg/km^2
Rhinoceros	11·2	15792			4·7	6627		
Cervus	2	308	2·9	447	3·9	600	11·5	1771
Sus	5·8	360			4·7	291		
A. axis	17·3	951	15·4	847	1·6	88	19·2	1056
A. porcinus	35	1085			10·9	358		
Muntiacus,	6·7	94			4·7	65		
Total kg/km²		18590		1294		8029		2827

* Weights are from Schaller (1967), Eisenberg & Lockhart (1972) and Whitehead (1972) adjusted with respect to percentage of age and sex classes.

numbers of wild swine were 3·4 and 11·5/km^2 in January and April, respectively; with the birth peak in March, these data allow at least a preliminary estimate of the annual mortality rate.

My estimates of the numerical density of axis deer for the two months were 17·7 and 17/km^2 and those of sambar, 1·8 and 2·2/km^2. This small variation indicates that neither axis deer nor sambar were concentrating in this area of the Park during April.

I was interested in deriving estimates of the biomass of large prey species within the home areas of a female tiger and a female leopard which I was intensively radiotracking, and thus, I concentrated my census efforts in the riverine forest/tall grass mosaic within the Park (Seidensticker, in press). Much less effort was directed toward the *Shorea* forest or the riverine forests adjacent to the Park, but preliminary estimates for these areas have been included in Table 6 for comparison. These areas outside the Park are subject to intensive grazing by domestic stock and wild ungulate biomass in the adjacent riverine forest was less than half (8029 kg/km^2) that estimated for the riverine forest/grassland within the Park (18,590 kg/km^2). Estimates made in the adjacent forests are maximum ecological densities; the surrounding cultivation and banks upon which these animals depend for food are not included.

The reverse trend was indicated for the *Shorea* forests; my counts suggest that a greater number of axis deer and sambar were living in the old Mahendra Deer Park outside the National Park than in the *Shorea* forest at the edge of the Churia Hills within the National Park. A similar trend for axis deer was noted in the sample plots, but sambar were estimated to be more numerous within the Park than outside. Only further study will clarify this situation, but availability of surface water may be an important factor.

I think the density estimates for hog deer are too high, and those for axis deer too low in the riverine forests adjacent to the Park, based on frequency of observation in the open (see above). Within the Park, I feel that barking deer were less abundant than indicated. I felt at first that sambar were more abundant than indicated by the January estimates based on frequency of encounter, but the second census in April revealed only slightly more. While sambar are using the grassland area, they tend to do this most frequently after dusk, as indicated by observation from *machans*, and my impression of sambar abundance is related to frequency of diurnal encounter in the forest or at the forest edge. If just this forest area is considered in the calculation, the density estimate is 6/km^2.

Comparison of these density estimates with other areas are revealing. Eisenberg & McKay (1974) have provided a summary of large mammal biomass estimates from available data. In Kaziranga Wildlife Sanctuary in Assam (India), located in the flood plain of the Brahmaputra River, census data by Spillett (1967) provided an estimate of 3800 kg/km^2. Schaller (1967) estimated the biomass in Kanha National Park to be 2637 kg/km^2, while estimates from the lowland dry-zone scrub jungle of

Sri Lanka range from 766 to 886 kg/km^2 (Eisenberg & Lockhart, 1972; McKay, 1973). Using the density figures from the Sauraha area and Laurie's estimate of total rhino numbers, I calculated the crude biomass of the entire Park to be 1756 kg/km^2.

The maximum ecological density for the Sauraha area in Chitawan Valley is 18,590 kg/km^2, 15,792 of which is rhino. This compares with some areas of the Ruwenzori (Queen Elizabeth) National Park, Uganda. Field & Laws (1970) reported biomass of large mammals ranging from 5140 to 36,510 kg/km^2. The year-around standing crop biomass for large ungulates in the typical bush grassland in their four-year study period was 29,490 kg/km^2, which is the highest that has been reported.

OBSERVATIONS ON DOMESTIC LIVESTOCK

Domestic livestock provide a substantial portion of the diet of the tigers and leopards which live in the northeast section of the Park and the adjacent forests (Seidensticker, in press), and a census was conducted to determine density and age structure and to learn how husbandry practices were influencing availability of various livestock classes as prey (Fig. 9).

We counted and classified livestock in two areas. The first was a 36·3 km^2 area that included the area south of the Rapti, adjacent to the east boundary of the Park, the

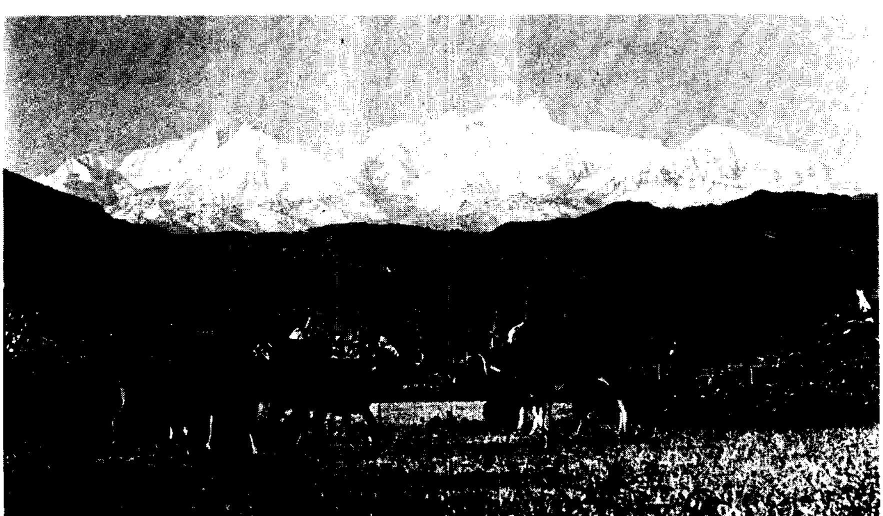

Fig. 9. A cultivated area north of the Rapti River. The first Himalayan ranges, the Mahabharat Lekh, reach as high as 2800 m in elevation. The Himalayan snow peaks, with Himalchuli (7864 m), rise 100 km in the distance. November 1973.

Shorea forest-clad Churia Hills and the area on the north side of the Rapti extending from east of Sauraha, west to include all the area in the V formed by the confluence of the Little Rapti with the main Rapti River. A second area was censused for purposes of comparison. I attempted to select an area that was as far removed as possible from the forest areas of the Valley; this was a site in the centre of the Chitawan Valley. We counted livestock in a 6·5 km^2 area surrounding and to the east of Tandi Bazaar, a small town on the Hitaura–Narayanghat Road.

These counts were made in March by several people walking simultaneously over the cultivated area which, at this time of year, was lying fallow and the domestic stock were concentrated. To avoid duplication, each observer was responsible for specific blocks, and for checking all houses and villages that lay within his blocks, to count and classify the animals which were being kept under shelter. Counts were made in the morning. Area 1 took three days to count; Area 2 was counted in one day.

Age classification was based on relative size. Being accustomed to the growth rates of livestock in the western United States, I was amazed that the young I would have judged to be a month or so old were actually 6 to 9 months old, and stock I judged to be approximately one year old were 18 to 24 months of age. Questioning owners, we found that those animals classified as young were up to one year of age and subadults, from 1–3 years, in some cases even older. We did not attempt to classify sheep and goats.

The results of these counts are presented in Table 7, which also includes the estimates of biomass. We do not have weight data for the various classes of livestock

TABLE 7
NUMBERS, DENSITY, AND SEX AND AGE COMPOSITION OF DOMESTIC LIVESTOCK IN THE SAURAHA AREA, CHITAWAN VALLEY, NEPAL

	No. recorded	*Density N/km^2*	*Sex/age ratio* ♂♂	: ♀♀	: *SA*	: *Y*		*Biomass* kg/km^2*
AREA 1 (36·3 km^2)								
Cattle	4768	131	249	100	51	49		30392
Buffalo	1345	37	43	100	44	52		10804
Sheep	942	26						295
Goats	882	24						273
							Total	41764
AREA 2 (6·5 km^2)								
Cattle	466	72	281	100	75	87		16704
Buffalo	242	37	13	100	33	54		10804
Sheep	48	7						80
Goats	173	27						307
							Total	27895

* Weights from Berwick & Jordan (1971) adjusted with respect to percentage of age and sex classes.

and we have had to rely on the weights from Berwick & Jordan (1971) from India. It is my impression that the cattle, but not the buffalo, are slightly smaller in this area than in India and future workers will have to include the collection of accurate weights to increase the precision of estimates.

Buffalo were more frequently kept under shelter than cattle; females with small young or young alone were kept more frequently than other sex–age classes. Goats were kept tied in the vicinity of houses more often than sheep. Buffalo are important in the village food economy in providing milk and the manufacture of ghee, a cooking oil; thus, the care taken in their keep. Among the other classes of stock kept under shelter were those used as draft animals; only castrated males were used, and bullocks were apparently preferred over buffalo.

The males indicated in Table 7 are nearly all castrated and there is a remarkable disparity between buffalo and cattle. This is accounted for primarily by the fact that castrated buffalo males are sold in the market; the bullocks never are. A comparison of the age structure between the two areas shows a marked difference in productivity of the population and this seems related to density, but is countered by another factor, which is accessibility to grazing lands in the adjacent forest areas. What may be occurring in Area 1 is that cattle are being brought in from surrounding regions to use the forest areas, specifically non-reproducing females and bullocks. This explains the density and age structure of the population in the area adjacent to the forest.

It is important to note that the biomass of domestic ungulates (41,764 kg/km^2) far exceeds that of the wild ungulates in the riverine forest/tall grass area in the Park (18,590 kg/km^2). However, the biomass of the domestic stock in the centre of the Valley (28,656 kg/km^2) more closely approximates that of the wild ungulate fauna. The large livestock biomass in the vicinity of the forest could be maintained only because of the availability of food in the forest tracts. This is at the expense of the wild ungulates. Laurie is looking at this in detail, specifically with the rhino and with the other large ungulates.

DISCUSSION

Accurate estimates of population structure and density and other quantitative data on the behaviour of ungulates in the monsoonal forests of Asia were difficult to obtain, and the limitations of many of the conventional methods in these environs have recently been discussed by Eisenberg & Thorington (1973). These preliminary results, obtained in a variety of vegetative types in one area of Chitawan Valley, demonstrate the usefulness of domestic elephants in conducting line-transects, and it appears feasible to expand this approach to other areas within the Royal Chitawan National Park and to other regions. It is imperative that effort be directed toward continual refinement, in line with the suggestions by Eberhardt (1968). Until detailed species studies using marked or individually recognizable animals become available, radiolocation methods, employed with selected individuals of each species, will be useful in understanding differential habitat utilisation, activity patterns, and response to observers under a range of habitat conditions. Radiolocation of selected individuals will also provide insight into the mortality factors operative on various sex–age classes (Cook *et al.*, 1971).

Apart from the problems related to censusing methods, the critical survival problems of many of the large ungulates in this region make it necessary, as Geist (1974) has pointed out, to maximise research efficiency, while minimising interference with animals. Progress toward this goal has been made by developing a comprehensive theory of the ungulates' social evolution as it relates to ecological variables (Geist, 1974). In local situations, management efficiency and precision can be continually upgraded through a periodic reassessment of the ecological and behavioural assumptions upon which conservation programmes are based.

These estimates of ungulate density and habitat utilisation in Chitawan Valley are only first approximations and I recognise their limitations. Even with the unknown biases that may be associated with these data, they are informative and useful. I placed a high priority on obtaining biomass estimates, as an integral part of my assessment of factors which determine habitat suitability, and thus influence tiger and leopard density, and for comparison with similar mammalian faunas elsewhere, to identify and provide insight into the environmental forces operating. It is important to ask what combination of factors are present which enable this particular area in Chitawan Valley to support an ungulate biomass surpassing that reported for other areas on the Indian subcontinent, Sri Lanka or, indeed, most other areas of the world.

The climate in Chitawan Valley, while classed as monsoonal, is modified by the outer Himalayan range towering to the north (Fig. 9). Farther south on the subcontinent, showers occurring outside the rainy season are infrequent but, during the time I spent in Chitawan, we had one or more substantial downpours each month.

The soils over the Chitawan Valley floor are alluvial and most have a high content of very fine sand; the periodic increment of silt left by floodwaters is an important factor in many areas. As described below, the vegetational consequences of flooding and impeded drainage in the Valley can readily be seen.

The flowering of *Bombax* and the new growth from the deep-rooted grasses begins almost immediately after the burning, in January through April, indicating the availability of soil moisture is the most important determinant of plant growth in where the land lies parched and dormant during the hot season (Schaller, 1967). The availability of soil mosture is the most important determinant of plant growth in most African vegetation types (Jarman, 1974) and this seems true for the Indian subcontinent. During the hot season in Chitawan, not only is food available for the ungulates in the form of new grass leaves, but this new growth also has the most favourable protein/fibre ratio of any growth stage (Bell, 1970). Also, on the valley floor there are well-distributed sources of surface water available all year round, but in the Churia Hills to the south surface water is seasonally restricted.

No quantitative work has yet been done but, from an examination of aerial photographs and on-the-ground observations, it appears that the riverine forest/tall grass mosaic in the lower Chitawan Valley is, in large measure, a product of and maintained by, the seasonal flooding and frequent change in course of the big rivers and streams that flow through the valley. The *Shorea* forests occur on the higher ground with better drainage. The riverine forests grow in areas which are subject to occasional flooding and, in the lower areas, there is a range of tall grass associations, from those that occur in permanent water to those that are flooded only under unusual high-water conditions.

A more fine-grained assessment of the current vegetation is confounded in part by our lack of information on the influence of past and present grazing by livestock and wild ungulates. We do not know the importance of herding species that were once present, such as the elephant, wild water buffalo (*Bubalus bubalis*) and swamp deer (*Cervus duvauceli*), had in maintaining certain vegetation patterns. But even a cursory analysis in Chitawan Valley shows a differential response by *Shorea* and riverine forests to intensive grazing and browsing by domestic stock and opening of the forest canopies by wood cutters. Also, a differential response by grasslands is shown where the low-growing thatch-grass is harvested annually and where it is not (Laurie, 1973).

With man's increasingly expanding pressure threatening the survival of many large mammals, it is easy to ignore his earlier role in creating and maintaining environmental situations which were especially favourable for many species of wild ungulates (Wharton, 1968). Through grazing of livestock, cultivation, and a range of activities, from collecting thatch-grass, gathering firewood and fishing, to collecting wild fruits, edible stalks and tubers, man has been a long-standing environmental component of Chitawan Valley. But it has been only since the intensive development projects began 20 years ago that he has been the dominant factor. Just how long the aboriginal Tharus and other less-known groups have lived there is not known, but it could well have been for thousands of years. It is important to remember that the meadows of Kanha National Park and Corbett National Park in India, which are now such important centres in the lives of many large ungulates, are the products of past cultivation activities by man (Schaller, 1967). Many of the grassland areas where these censuses were conducted were intensively farmed and heavily grazed by domestic livestock before a resettlement programme only a decade ago.

Within this broad outline of environmental factors, a diversity and abundance of large ungulates can be anticipated, from the models recently advanced by Eisenberg & McKay (1974) and Geist (1974). Their models predict that the ecotone areas, or forest/savanna interface, exhibit the maximum diversity and density of ungulates for any geographical area (see also Leopold, 1933), and it is clear from the first estimates presented here that the riverine forest/tall grass areas in Chitawan Valley offer an optimal dispersion of vegetation types.

I have contrasted habitat utilisation and some aspects of sociality of the congeners, hog and axis deer. This was to emphasise the special behavioural and morphological characteristics of the hog deer, which appear closely linked with the tall grass areas. It is useful at this stage to examine all the ungulates in relation to what we know about their affinities to particular successional stages in the vegetation.

Eisenberg & Lockhart (1972) have classed the axis deer and barking deer as affiliated with intermediate successional stages in the vegetation, the sambar with a late-intermediate stage, and the hare with early successional stages. Trends indicated in Tables 1, 2 and 6 corroborate this assessment, if we can correctly assume a successional progression in the riverine type from grassland through forest, first with shrubs replacing grass in the understory. The hog deer, with its affinity for grassland, also falls into the category as affiliated with early successional stages, although coming later than the hare. The rhino seems best classed as affiliated with early to intermediate successional stages.

Two species, the wild water buffalo and the swamp deer which were once part of the Chitawan fauna (Spillett, 1967), have their habitat affinities primarily with the grassland, judging from the information available (Daniel & Grubh, 1966; Schaller, 1967; Eisenberg & Lockhart, 1972; Seidensticker & McNeely, 1975). In this riverine vegetation type, they would be classed as affiliated with early successional stages, along with the hog deer and rhino.

Both the swamp deer and the wild water buffalo are currently restricted to single isolated populations in other sanctuaries in Nepal. One conservation measure which has been proposed, to help assure survival, is their reintroduction in Chitawan. While this is a viable option, it must not be undertaken without a thorough review of habitat preferences, exact successional affiliations, and possible consequences of interspecific competition. We do not know why these species disappeared from Chitawan Valley, but habitat alteration through the agricultural development programme and diseases contracted from domestic livestock seem likely factors. One area where it is at present possible to make the comparative studies needed before reintroduction is attempted is the Kaziranga Sanctuary in Assam (India). Here elephant, rhino, swamp deer, water buffalo and hog deer occur together. I hope immediate conservation needs can transcend international boundaries.

The studies by Schaller (1967) and Eisenberg & Lockhart (1972), and the observations presented here, show that the ungulates in Chitawan Valley are ecological specialists; we could expect seemingly minor changes in the vegetation composition and structure to be manifested in their relative abundance. Considering that the riverine types are probably maintained through occasional environmental perturbations, in this case the flooding and changing of channels by the rivers during the rainy season, maintaining this diversity and abundance in the small section of the flood plain which is included in the National Park will be difficult. It is conceivable that heavy flooding in a single season or within a short span of years (Eckholm, 1975), could change the entire flood plain area within the National Park to an open bank situation (Fig. 6). When the lower valley floor was under the same vegetation regime, other areas offered refugia for the species dependent on the grasslands. Now what remains of the natural flood plain vegetation occurs only within the National Park; the other areas are under cultivation and refugial areas would be extremely limited or nonexistent (see Terborgh, 1974; Willis, 1975).

On the other hand, in the next few years the river could change course and cut through the centre of the valley, in which case, through the process of plant succession, we could anticipate gradual afforestation, creating unfavourable conditions for the ungulates with affinities for the early successional stages. All of this poses a difficult task for the managers responsible for maintaining the integrity of the Park.

Perhaps the most important point at this stage is to realise that the Royal Chitawan National Park is not an island unto itself and cannot be managed as one (Houston, 1971; Myers, 1972). Surely the greatest immediate task facing managers is to devise administrative infrastructures based on this realisation and to extend administrative considerations beyond protectionism into the realm of habitat management founded on hard ecological data.

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