# Population Size and Trend of Greater One-Horned Rhinoceros in Nepal

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ABSTRACT

Greater One-horned rhinoceros were censused in Royal Chitwan National Park, Nepal between 1984-8 by maintaining a register of photographed individuals. By April 1988 the total current Chitwan population was estimated to be between 355-376 individuals excluding 24 relocated animals. In an intensively monitored subpopulation of rhinoceros in the central and eastern part of Chitwan (the Sauraha population), numbers have increased by 49% since 1975 for an average annual rate of increase of 3.8%. Between 1984-8 it was estimated that the Sauraha population increased on average by 4.6%/yr. This population included 87 adult females and 58 breeding-age males of which only 28 bulls were thought to have been breeding during the study period. Annual calf production averaged 7.6% (sd=1.6%) between 1984-8. No distinct season of parturition was detected. Predation by tigers accounted for over half of all calf mortality and all calves which died during the study period were <8 mo. Mean annual mortality within the calf, subadult, and adult age categories was estimated to be 2.8%, 2.0%, and 2.5%, respectively. Poaching had been a significant source of

mortality until the mid-1970's but during the study only 4 individuals were poached and none from mid-1987 to mid 1988.

<u>Rhinoceros unicornis</u> reached maximum densities of 13.3/$km^2$ in riverine forest/<u>Saccharum spontaneum</u> grassland mosaics occurring along the Rapti River. Local densities in areas dominated by <u>Narenga porphyracorma</u> and <u>Themeda arundinacea</u> grasslands were on the order of 1.7-3.2/$km^2$. Annual severe disturbance, in the form of monsoon floods, altered the spatial distribution of these successional grasslands but maintained prime grazing habitat and high <u>Rhinoceros</u> densities.

Populations of Greater One-Horned Rhinoceros (<u>Rhinoceros unicornis</u>, hereafter referred to as <u>Rhinoceros</u>) have declined drastically over the last 400 years as a result of land-clearing and poaching pressure (Blanford 1880). By 1988 only two populations contained more than 80 individuals: Royal Chitwan National Park (Chitwan) and Kaziranga National Park, Assam, India (Dinerstein and McCracken MS). This paper documents the current status of the Chitwan population, one of the few populations of rhinoceroses to have increased over the last decade. Here, we provide data on total population size, sex and age composition, seasonality of births, birth rate, intercalving interval, survivorship, mortality, and population growth rate. We also investigate the relationship between proximity to agriculture, the size of flood plain grasslands, and population densities of <u>Rhinoceros</u>. Finally, we evaluate the importance of annual monsoon floods as a means of maintaining prime grazing habitat and supporting high population densities of this endangered ungulate.

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PARK HABITAT

Rhinoceros and other large mammals occur in highest densities along the flood plain grasslands and riverine forests bordering the Rapti, Narayani, Reu, Dungre, and Icharni Rivers (Figure 1) (Seidensticker 1976, Laurie 1978, Sunquist 1981, Mishra 1982, Dinerstein (in press), Dinerstein and Wemmer (1988), and Dinerstein and McCracken MS). The most critical habitat for Rhinoceros is a riverine grassland association dominated by the 4-6 m Saccharum spontaneum. Above ground dry biomass of S. spontaneum in this association accounted for 92.0, 99.0, and 99.5% of plant matter sampled during October (end of monsoon), January (cool season), and April (hot season), respectively (E. Dinerstein, pers. obs.). Tall grasslands on higher terraces of the flood plain were dominated by mixed or near monospecific stands of 5-7 meter tall Narenga porphyracorma, Saccharum benghalensis, or Themeda arundinacea and are also used by Rhinoceros (Dinerstein in press; Lehmkuhl 1988). Interspersed among flood plain grassland associations are patches of riverine forest dominated by Trewia nudiflora, Ehretia elliptica, and Bombax ceiba. The understory shrubs and saplings common in most riverine forest stands (Callicarpa macrophylla, Litsea monopetala, Mallotus philippinensis, and Murraya paniculata) are heavily browsed by Rhinoceros during the cool season (November-February) (Gyawali 1986, E. Dinerstein pers. obs.). Grasslands and riverine forests account for only 30% of Chitwan's 1038 $km^2$. In contrast, Rhinoceros rarely used sal (Shorea robusta) forest (Laurie 1978, E. Dinerstein, pers. obs.), an evergreen association on upland, well-drained slopes, that covers roughly 70% of the park.

## METHODS

### Estimation of population size and density

Laurie (1978) found that photo registration, although time consuming, provided the only method to accurately estimate the numbers of Rhinoceros. Individuals are readily distinguishable from each other by a combination of characters: horn length and shape, grooves or rings on horn, cuts, scars, irregular bumps on cross body folds, breaks in skin folds, double folds, pigmentation patterns, ear nicks, and tail length (entire, bent, or missing the tip), size, age, and for adult females, age of calf. Irregularities in skin folds and ear cuts provided the most striking and unambiguous characters for rapid field identification.

Areas containing Rhinoceros were treated and searched as distinct regions. These were often defined by physical barriers (rivers and low mountains) or by ecological boundaries (extensive tracts of sal forest or cultivation) (Figure 1). Our intensive study area (hereafter the Sauraha area) spanned the grasslands east of Kagendramali to the edge of the sal forest near Kasara in the west. It contained the largest subpopulation of Rhinoceros (Laurie 1978, E. Dinerstein, pers. obs.) and was searched most frequently. Laurie (1978) treated the Kagendramali and Sauraha populations as separate but we combined them when we discovered animals frequently moving between the two areas.

The Sauraha area was separated from the West population (Laurie's Tiger Tops population) by nearly 12 km of unbroken sal forest, which we and Laurie regarded as a partial migratory barrier limiting extensive movements between areas. Most of the animals in the West population were concentrated within a 3 km radius of the Tiger Tops Hotel facilities. Rhinoceros on Bandarjola Island and along the Narayani River flood plain were separated from the West population by several km of agriculture and the Narayani River. Other areas searched were separated from the Sauraha population by extensive sal forest and a low mountain range (the South population), or extensive sal forest, a highway, and cultivation (e.g. Tikoli/Lunkar Line, Botesimra, Ramoli).

We further subdivided the Sauraha population into blocks in order to examine possible differences in densities related to habitat (Figure 1). We used aerial photos to map the area of each block covered by Saccharum spontaneum and riverine forest, the two habitats most frequently used by Rhinoceros (Laurie 1978). We concentrated census efforts during the long hot-dry season (Feb-May), after the tall grass layer had been burned off, when visibility was at a maximum, and when Rhinoceros grazed for long periods out in the open. After May the grass grows tall enough to obscure new born calves and sexing and recognizing individual animals becomes increasingly difficult. Thus, we decided to designate a field census year to correspond with the Nepali calendar which begins in mid-April.

Techniques for photographing Rhinoceros and recording data followed Laurie (1978). Our study differed in: 1) use of 4-5 elephants per search and 4-5 observers with binoculars rather than one; 2) habituation of many Rhinoceros to close approach by elephant by 1988; 3) vehicle transport of supplies to remote field camps (e.g. Kagendramali, Bandarjola Island), which enabled us to photograph Rhinoceros where Laurie estimated numbers by transect counts of tracks and dung piles; and 4) calibration of search effort using radio-collared animals. During our study, 23 Rhinoceros had been fixed with radio-collars as part of a long-term study on movements and social organization (Dinerstein et al. MS). Most of the radio-collared individuals lived on an island visited frequently and were part of a population where individuals could be recognized quickly by our staff. We used radio-collared animals to calibrate the search time required to find and identify every individual in the area by sweeping through it and determining the time required to find the entire population. This exercise was repeated 5 times. Total search time varied depending upon the time of observation (Rhinoceros are more active and thus more visible while feeding in the late afternoon than in the morning). On average, a 3.2 $km^2$ area consisting of a riverine forest/grassland mosaic required about 16 hours of search time using 5 elephants to find all 39 Rhinoceros using the area. This estimate was used as a minimum guideline for searching the rest of the study area. In actuality, we spent far more time between 1985-8 searching blocks containing high Rhinoceros densities in the Sauraha area. To compute density estimates per block within the Sauraha area, we spent at least two weeks/yr searching each block. Some blocks, such as the Icharni, Darampur, and Patch 1 and 2 blocks were searched almost daily. Over the 4 yr period we recorded >5,000 direct observations of Rhinoceros, and monitored the movements of the 23 radio-collared individuals in the Sauraha population. However, density estimates reported in the text are based upon direct observations of Rhinoceros observed in each block between Jan-April 1988, the last four months of the 1987-8 census.

Sex and age criteria

Sex of animals was determined by observation of external genitalia, body size, size of neck folds (more pronounced in males), urination, and presence of calves. Adult males have wider horns at the base than adult females (Dinerstein MS). Sex of calves <1.5 yr was difficult to determine and only was recorded if determination had been made by at least three observers or on three occasions by a single observer. The sexing of subadults was easier but was not possible for all of them; where sex of calves or subadults could not be determined accurately, individuals were listed as sex unknown.

We recorded 29 measurements on 41 individuals (i.e. @ 10% of the population) (Dinerstein MS), including several on repeated occasions, which were immobilized for research purposes, translocation, and capture for export to zoos (calves only) (Dinerstein et al MS). Data from immobilized and dead animals enabled us to correlate visually the most obvious features (head and body length, neck girth, shoulder height, horn length, scars, protrusion of bones, and facial wrinkles) with a relative criterion for age (i.e. tooth wear (adults) and eruption patterns). These observations provided criteria to confidently place Rhinoceros observed, but not captured by us, into discrete age categories (Dinerstein MS).

We classified the animals recorded from the Sauraha population into the following age classes and sub-classes: calves (0-1, 1-2, 2-3, 3-4 yr); subadults (4-6 yr); young adults (6-12 yr i.e. breeding females but non-breeding adult males); adults (12-20 yr); older adults (>20 yr). Calves and subadults could be aged accurately because the birth years of all calves and nearly all subadults was known. Subadults could be distinguished by body size and horn size (Dinerstein MS). Our rationale behind age classification for subadults was based upon the potential for animals to breed. Because captive females and males show signs of reproductive activity by year 6, we considered the subadult category to consist of animals 4-6 yr old. Young adults had molars with little wear, small lower incisors, short horns with little wear, few scars or body marks, and were small in size. Young adult males lacked pronounced secondary neck folds. Individuals in the 12-20 yr category were distinguished by moderate wear on the molars, horn size and wear, increased amount of facial wrinkles, size, cuts, development of secondary neck folds in males, size of outer incisors, and for females, the knowledge that she had given birth to at least one calf. Individuals in the >20 yr old category had extensive wear on the molars and often displayed a combination of extensive facial wrinkles, major scars on the rear, torn or notched ears, broken, deeply grooved or eroded horns, and in males extensive development of secondary neck folds (bibs).

For calculation of sex and age ratios for the entire registered population in Chitwan, we placed animals into three general categories: calves, subadults and adults.

Intercalving interval was estimated in the Sauraha population by monitoring the period between births for registered females.

Males were identified as breeders by observing: 1) copulations (n=7); 2) tending of estrous females; 3) the outcome of fights among dominant males; and 4) behavioral and morphological features (Laurie 1978). Breeding males often squirt urine upon close approach by an observer on elephant back, possess extensive secondary neck folds, large lower outer incisors (Dinerstein MS), and are aggressive towards subordinate males. Fourteen (50%) of those males showing dominant behavior or observed engaged in reproductive activities were immobilized, measured, and radio-collared during various periods of this study (Dinerstein MS).

Mortality data

Mortality data was obtained from our own searches and from official records of His Majesty's Government; Rhinoceros are considered to be property of the King and all mortalities must be accounted for in an official inquest conducted by the park warden. Rhinoceros died most frequently close to river banks and carcasses attracted large flocks of vultures, aiding location of dead animals. Drivers frequently graze elephants in the same areas so it was rare for other than a newborn to die and go undetected.

RESULTS

Total population size

Between 1984-1988 we visited 95% of the park and adjacent forests where Rhinoceros are known to occur. The Sauraha area contained the largest population among blocks searched, accounting for 228 registered individuals or 60.0-63.5% of the total estimated current population (Table 1). To derive this estimate we first subtracted 15 subadults from the total number of animals registered by 1988. These subadults were registered as 4 yr old calves while still with their mothers, but most likely re-registered as subadults in subsequent years. Laurie (1978) also adjusted his total estimate to account for this same problem. Second, we added 3 calves to the 1988 cohort because we observed that we missed on average the births of 3 calves/yr which were subsequently registered in the following census year. This oversight was the result of a female near parturition giving birth close to the end of a census year and after we had conducted our last sweep through the block the cow inhabited.

The West population was the second largest with 61 individuals encountered during our census in 1986. Thirty four Rhinoceros on Bandarjola Island and in the Narayani River flood plain were registered in the same year. However, tracks and other sign indicated that some animals in the West population and in the Bandarjola area had escaped registration. To obtain a total estimate for these two areas which were not searched after 1986, we adjusted these totals in the following manner. First, we determined from the Sauraha data that 7% of subadults and adults missed during the 1986 census, were subsequently added to the census in the following two years of searching (1987-8) (Table 1). Second, we assumed that we failed to register Rhinoceros in each area in equal proportion to those found. Third, we then multiplied this percentage (7%) by the original estimate for 1986 for the West population and Bandarjola. Finally, we assumed that the West and Bandarjola populations increased at the same rate as the Sauraha population, and added animals which would have been born during the 1987-8 census periods to obtain a total estimate for the West and Bandarjola populations in April 1988. These steps raised the estimated total of Rhinoceros assumed to be present in 1988 in the West population to be 72 animals and 40 animals in the Bandarjola area (Table 1). Estimates for outlying areas included 8 animals in the Tikoli/Lunkar Line area, 4 from Ramoli, and 6 from Botesimra.

Between 1986-8, 24 Rhinoceros were relocated to other reserves or zoological parks. Twenty-one of these individuals came from Sauraha and three from the edge of Sauraha and Tikoli. An additional 10 calves were relocated from the Sauraha population between 1978-1983. Adjusting the total in the Sauraha population would yield an estimate of at least 262 Rhinoceros in 1988, assuming that all relocated animals would have survived had they not been removed. In sum, our estimate for the park and its environs, including the relocated population, would be 392-413 animals in April 1988.

Distribution and densities

The highest Rhinoceros densities coincided with blocks including large tracts of Saccharum spontaneum grassland (Table 2) ($r_s$ N=9 = 0.7750 P<0.05). The significance of this correlation would have been even stronger had density estimates from 1985 rather than 1988 been used. After 1985 17 individuals were relocated from the Icharni block, the block with the highest density of Rhinoceros prior to 1985 and the most extensive S. spontaneum grasslands. In contrast, blocks covered mainly by Narenga porphyracorma grassland, the most common in the park (Lehmkuhl 1988) supported lower densities (Jarneli; Simalchaur/Kachwani (Table 2). Rhinoceros avoided dense stands of Themeda arundinacea along the edge of the sal forest within these two blocks.

High densities were not related to proximity to agriculture ($r_s$ N=9 = 0.0297 P>0.50). Densities in Dumria, Ghatgain, and Patch 3/Baaghuwaghera exceeded or equaled densities in blocks bordered by croplands. Rhinoceros also reached locally high densities around the Tiger Tops Lodge in the West population, also >3 km from the edge of cultivation. Densities in the Badreini/Kharsar block and in Darampur fluctuated seasonally with the ripening of rice, corn, wheat, and lentils grown in the adjacent fields. During the rice harvest in 1987 (October), densities in Badreini/Kharsar were 8.3/km$^2$ and declined to 3.0/km$^2$ by February 1988 after the beginning of grass fires in the park. New shoots became abundant within two weeks after the fires and most Rhinoceros vacated the Badreini/Kharsar block to feed on the flush of new growth in S. Spontaneum grasslands. Estimates in Table 5 represent density estimates for the period when crops were not available (late-Feb-May 1988).

The blocks with the lowest density of Rhinoceros (Simalchaur/Kachwani and Jarneli) lay the farthest from the river edge and included the most sal forest. Within the other blocks, Rhinoceros concentrated in the section closest to the river. High local densities of Rhinoceros were not correlated with the size of a block (Spearman rank correlation $r_S$ N=9 = 0.3333 P>0.20).

Sex and Age Structure in the Sauraha population

Laurie (1978) observed that it was difficult in all instances to determine the sex of young Rhinoceros. He showed that a significant proportion of calves were reclassified upon successive observations and that initial sightings are biased towards assigning most calves as males. This is probably the result of confusing the penis with the protruding navel of a female calf, a mistake easy to make in poor light, when vision is partly obscured, or if the calf is running away. Thus, our caution in sex determination for young calves explains the large number listed as sex undetermined. Assuming, however, that the sex ratio of undetermined calves was equal, there is no evidence to suggest departure from an even sex ratio at birth for animals between 0-4 years (Table 3). Sex ratio among subadults registered in the Sauraha population was not significantly different from 50:50.

Young adult females (6-12 yr) outnumbered males but not significantly (Chi-square = 3.765 P <0.10). Intermediate-aged females (12-20 yr) were significantly more numerous than males (Chi-square = 4.261 P<0.05). Among old animals (i.e. > 20 yr) the numbers of males and females were equal in Sauraha but variable elsewhere (Table 3).

In the West population the ratio of adult males to females was equal whereas in the Bandarjola population twice as many adult males as females were found (Table 3). Moreover, subadults accounted for only 8% of the registered West population but 30% of the Bandarjola population. Tall grasslands in the Bandarjola area are smaller than in other parts of the West area. Similarly, the Jarneli block and the Kharsar section of the Badreini/Kharsar block of the Sauraha area contained mostly subadult males, supported no S. spontaneum grassland, and was mostly covered by sal forest. These differences in sex and age composition suggested that largely forested areas such as Bandarjola and Jarneli will be occupied mainly by non-breeding males and subadults, with breeding females and males concentrating in riverine patches dominated by S. spontaneum grasslands.

Comparison of Age structure between 1975 and 1988

Differences between age structure in 1975 and 1988 are largely the result of Laurie's decision to designate subadults as between 3-9 yr old whereas we placed them between 4-6 yr. Thus, subadults represent a smaller percentage of the population in 1988 than in 1975 whereas the opposite is true for adults (Table 4). Laurie's data also indicate that more females were with calves in 1975 than in 1988. However, this is partly the result of removing 7 calves from the Sauraha population in the last two years and our decision to include 6 yr old females as adults. Removing this single year cohort and recalculating the percent of adult females with calves from our data reveal no difference between 1975 and 1988.

## Reproductive Biology

### Seasonality of births

We were able to assign birth dates within one calendar month to 53 calves born during the study period (Figure 2a). Laurie (1978) assigned 60 births to bimonthly periods between 1972-5. Arranging our data in the same bimonthly format Laurie used, we found the distribution of births over the calendar year to be the same as during his study (chi-square = 2.3254 df =5, P > 0.75). The combined data set (N=113) revealed that parturition was aseasonal (Figure 2b).

### Age at first reproduction

Forty percent of the adult females in the 6-12 yr category (N=37), had not yet given birth to their first calf or were pregnant. Of this group of 15 females, 13 were classified as between 6-7 yr old, one female between 7-8 yr, and one female > 8 yr. Three adult females would have been classified as subadults, based upon horn size, body size, and lack of marks or wrinkles, had they not been observed with young calves. We estimated age of these three females to be just over 6 years when the calf births occurred. These data indicated that mean age at conception was about 6 yr in the Sauraha population.

Gestation in *Rhinoceros* has been determined in zoos to be about 15.7 months (Laurie and Groves 1981). Thus, mean age at first reproduction was more likely to be between 7.0-7.5 yrs. Laurie (1978) estimated age at first reproduction to be 7.1 years for females. A more accurate estimation of this parameter will require following several cohorts of registered calves from birth through age at first reproduction. In captivity, estrous may be observed as early as 4 years.

Intercalving interval

We closely monitored the reproductive behavior of 87 breeding-age females. For 16 females we either registered two sequential births or estimated the subsequent calving of a female first registered with a calf < 6 mo age. Three of the 16 females, F014, F004, and F031, gave birth again at 17 mo, 22 mo, and 31 mo, respectively, after the birth of the previous calf. Each had extenuating circumstances surrounding the subsequent birth: a dominant bull trampled the new born calf of F014, the calf of F004 was captured for shipment to a zoo, and the calf of F031 was thought to have died or been separated from its mother, prompting, in all three cases a shortening of the ICI. Thus, we excluded these three examples when calculating ICI and used only 13 animals. For the latter group the mean interval was 45.6 months (sd=6.4 range = 34-51). For the 6 females that exceeded a 48 mo ICI, only 1 was placed in the 12-20 yr category whereas 5 were aged at >20 yr.

We estimated much longer ICI's for an additional 12 females that did not give birth during the 48 mo study period (x = 60.9 mo sd= 11.9 mo range = 48-88 mo). These estimates were based upon the advanced age of their calves at first registration of the females. Six of these females were placed in the 12-20 yr category and the other half were estimated to be > 20 yr. Thus, some of these latter females may represent very old females no longer reproductively active. Some may have aborted or given birth to a calf which died before we could register it but this is probably only a small percentage of the 12 females. Before assuming, however, that older females are no longer breeding it should be noted that the percentage of females with calves was the same for cows in the 12-20 yr and > 20 yr age classes (Table 4). Data from the Chitwan population indicate that the mean ICI for Rhinoceros in 1988 will likely exceed 48 mo in contrast to Laurie's estimate of 42 mo (3.5 yr) during 1975.

Age Specific Birth Rate

The age specific birth rate for females in the 12-20 yr category was calculated to be higher than for either young adults (6-12 yr) or old adults (>20) (Table 5). Annual variation in the birth rate of young adults was 4 times that of intermediate aged females.

Reproductive activity of adult males

Based upon the criteria listed earlier, we estimated that 48% of the adult males within the Sauraha population (N = 28) mated during the study period. Half of these males were measured and after examining extent of wear on the molars, large size of the lower, outer incisors, obvious scars, and wrinkles, we estimated that all but one appeared to be > 15 yr old. For the remainder of suspected breeders not examined, body size, scars, and other features suggested that these individuals, too, were > 15 yr.

Older males which were no longer dominant in the various blocks but remained in patches close to high concentrations of breeding females were frequently attacked by younger, stronger males (Laurie 1978, E. Dinerstein, pers. obs.). In at least five instances between 1984-8 such attacks proved fatal. Five breeding bulls (two of which were radio-collared) retreated to blocks with low densities of breeding-age females or where females and dominant males were mostly absent after suffering serious wounds in fights.

Dispersal

Skew in the sex ratio for 6-12 year and 12-20 year age classes suggests that some non-breeding adult males dispersed outside the Sauraha area and that we failed to register them. Thus, the total number of young adult males in the entire Chitwan population may be slightly higher than that reported here. However, these animals were certainly not part of the breeding population in the Sauraha area during the study period.

All subadult males (N = 10) which were born in the Icharni block during this study left this block after separation from the cow. These males either remained on the periphery of these blocks in scrub jungle habitat or left the block completely. Subadult females, in contrast, remained in the core area of these blocks

(E. Dinerstein, pers. obs.).

Mortality

Twenty-eight animals died in the Sauraha population during the 4 yr interval (Table 6). Seven of these were first year calves < 8 months old; no other mortalities were recorded within the other calf age classes (1-2;2-3;3-4 yr). Mean annual mortality of calves < 1 yr was 11.9%/yr (sd = 7.4%) during the study period. We calculated mean annual mortality by including relocated calves from each of the four cohorts. Overall calf mortality (i.e. calves representing all calf age classes from 0-4 yr) during the study period was 11.3% or an average of 2.8%/yr.

Mortality of subadults was low, accounting for only 10.7% of the total. Assuming a stable population composition and mortality rate for subadults during the study period we calculated a mean mortality rate for subadults as 2.0 %/yr.

Fifteen of the eighteen adults which died during the study period were males. Among the 6-12 yr class, only two animals died, a male and a female. Six of seven mortalities in the 12-20 year category and 8 of 9 mortalities in the > 20 year category were males. Again assuming that the composition of adults was stable, annual adult mortality averaged 2.5% during the study period.

It remains unclear if the age distribution of males and females in the >20 yr category is the same. Longevity in wild Rhinoceros is not known but captive animals have reached 47 years. However, mortality data collected during this study (see below) and during Laurie's study indicate that females probably outlive males.

Causes of mortality

Four out of seven calves that died before reaching 1 yr were killed by tigers (Table 6). One other calf was trampled and killed by a radio-collared dominant bull who did not breed the mother. We know of one female that aborted or gave birth and soon lost its calf during our study period and we estimate that perinatal mortality has been underestimated. Three calves died after being separated from their mothers; two separations followed mating chases between the mother and a dominant bull, and one was separated during a major flood.

Five males and one adult female in the Sauraha population died from wounds suffered during intraspecific fighting. In the West population another adult female apparently died from injuries sustained from a dominant bull. Intraspecific fighting accounted for most of the mortality for the entire Chitwan population. Two adults died after becoming stuck in quicksand.

Population trend

The Chitwan population declined from an estimated 1000 animals in 1950 to a low of 60-80 animals by 1962 when land clearing following malaria eradication and heavy poaching decimated the population (Caughley 1969, Laurie 1978, H. Mishra pers. comm.). Strict protection reversed this decline. Laurie (1978) conducted the first total count of Chitwan Rhinoceros and estimated the population to have increased to 270-310 individuals by 1975 (Figure 3).

The age structure of the Sauraha population is indicative of a large herbivore population still in the expansion phase (Table 7). Survivorship was high in all age classes as might be expected in a long-lived giant herbivore, which after the first year is largely unaffected by natural predation (Table 8). By April of 1988, 62% of the Sauraha population was under 12 yr (Table 7). Most young adult females were accompanied by calves as were intermediate-age and old females. Mean annual number of births recorded for the 95 registered adult females (including relocated animals) was 16.3 calves/yr (sd=2.04) during the study period, or an annual birth rate of 7.5% yr (sd= 0.79%) (Table 7). Adjusting this figure for annual mortality during each year of the census yielded a net annual increase of 4.6% (sd =1.06%).

Laurie (1978) estimated that the Sauraha population in 1975 contained 176 animals (adjusted by us to account for more accurate data on poaching and including Laurie's estimate of Rhinoceros from the Kagendramali area) and estimated the rate of increase to be between 2-6%/yr. If we include all animals relocated after Laurie's study and during this study and assume that all individuals would have survived, then the Sauraha population has increased by 86 animals (48.9%) over a 13 yr period for an average annual rate of increase of 3.76%/yr (Figure 3).

In contrast, the West population has increased by only 22% since 1975 for a mean annual rate of increase of 1.7%/yr.

Direct comparisons between the 1975 data and this study for Bandarjola are not possible because we estimated population size by photo-registration whereas Laurie used indirect sign.

## DISCUSSION

### Dynamics of the Chitwan population

The increase in the number of *Rhinoceros* since the late 1960's demonstrates that *Rhinoceros* populations will rebound vigorously from episodes of heavy poaching when provided sufficient habitat and protection by armed guards. The Chitwan population has increased by at least 311 in 20 yr. Even within blocks, increased numbers of *Rhinoceros* are apparent. In 1975, *Rhinoceros* were not common in the Icharni block (A. Laurie, pers. comm.). Prior to the removal of 17 animals for relocation in 1986, the density of *Rhinoceros* in the Icharni block exceeded $10.5/km^2$.

We predict that the Chitwan population will continue to increase by at least another 100 individuals. Several large tracts of *Saccharum spontaneum* grasslands suitable to maintain high densities of *Rhinoceros* are currently underpopulated (e.g. LigLige in the East and Chamka in the West). Even patches of *S. spontaneum*/riverine forest mosaic within the Sauraha population (Ghatgain, LamiTaal) and in the West population appear underutilized. In Liglige and LamiTaal, harassment by cattle herders may have kept *Rhinoceros* from occupying these areas which are now managed strictly for wildlife.

In the eastern part of the park, poaching may have artificially reduced _Rhinoceros_ densities. However, some of these grasslands are bordered by sal forest, a habitat offering little forage for _Rhinoceros_ and other large ungulates (Gyawali 1986, Dinerstein 1987). It remains doubtful if these areas will support increased numbers of dispersing subadults and non-breeding adults. Where tall riverine grasslands abut sal forest, densities will probably not reach the same levels in comparison with areas where the adjacent woodland is composed of riverine trees, saplings, and shrubs which are heavily browsed in winter by _Rhinoceros_ (Gyawali 1986). Alternatively, low rates of recolonization of former habitats may be a demographic feature of a population of large slow breeders decimated by disease or heavy poaching.

The only comparable data on recovery of other rhinoceros populations comes from South Africa (Owen-Smith 1981). The Umfolozi white rhinoceros population expanded at a constant rate of 9.5%/yr over a 13 yr interval. High natality rates and short intercalving interval ($\bar{x}$= 2.2 yr) accounted for this high rate of increase. It is interesting that despite being considerably larger in body mass than _Rhinoceros_, intercalving interval among the Umfolozi white rhinoceros population was virtually half that of the Chitwan population.

_Habitat selection, population densities, and habitat disturbance_

Avoidance of heat stress, nutritional requirements, and the densities of predators constrain habitat selection in large ungulates. Twenty-four hour activity watches conducted during the study period revealed that Rhinoceros may average 8 hr/d in wallows or streams during August and September, the period of peak daily relative humidity (E. Dinerstein, pers. obs.). Wallowing occurs for at least 1 hr/d in every month except December and January. Not surprisingly, Rhinoceros remain close to open water for most of the year.

We showed that Rhinoceros densities were significantly positively correlated with the percent of the block covered by Saccharum spontaneum grassland. Along stream banks, S. spontaneum may account for over 90% of the dry-weight above ground biomass. Thus, large herbivores must eat S. spontaneum or avoid this habitat. Not surprisingly, Saccharum is a staple in Rhinoceros diets, normally exceeding 50% of the diet each month, an observation determined by fecal analysis (Gyawali 1986) and by direct observation of habituated, radio-collared individuals during 24 activity watches (E. Dinerstein, pers. obs.). Saccharum spontaneum is unique among the common tall perennial grasses of Chitwan because plants sprout new shoots soon after cutting, grazing, or inundation by floods. Nitrogen content in regrowth is twice that of mature leaves and 10 X that of stems (E. Dinerstein unpubl. data).

The dominance of Saccharum is a function of annual habitat disturbance, i.e., the severity and periodicity of monsoon floods (Dinerstein 1987, Lehmkuhl 1988). Monsoon floods deposit silt on the S. spontaneum grasslands bordering major rivers and after receding create favorable germination sites. Seeds of

Saccharum spontaneum are wind and water-dispersed and plants set seed during the flood season before any other tall perennial grass species.

Floods have probably always been a predictable and frequent phenomenon in this ecosystem because of the steep mountain chain to the North and heavy precipitation concentrated in a 4 month wet season. The silt layer deposited along the major rivers also contains topsoil washed from the foothills and mountains of the outer Himalaya. This process recharges the nutrient levels of the flood plains and provides the high productivity characteristic of this habitat. Large herbivores which feed heavily in these dense near-monotypic stands would be expected to reach high local densities. Viewed on a regional scale, Rhinoceros populations probably spread along the flood plains at the base of the world's highest mountain range because of the presence of the highly productive but low diversity grassland community (see Lehmkuhl 1988) that flanked South Asia's major river systems (Dinerstein and McCracken MS).

It is unclear to what extent recent deforestation in the Himalayan has intensified floods. Aerial photographs from 1968 offer little resemblance to the current distribution of river courses, channels and grasslands along the Narayani River (C. MacDougal, pers. comm.). As a result of severe floods in 1984 and 1986 patches of S. spontaneum grasslands in the Sauraha area > 0.5 $km^2$ were buried under .3 m of silt. Most areas silted over during the monsoon revert to tall S. spontaneum within 1 growing season and provide large herbivores with abundant, nutritious forage.

Laurie (1978) argued that Rhinoceros in Chitwan reached highest densities in areas supporting the greatest habitat diversity. Habitat diversity was assessed qualitatively by counting the number of different habitat types in a given area. We have shown that high Rhinoceros densities in Chitwan are not related to degree of habitat diversity and in fact occur in blocks with extremely low within and between habitat diversity (see also Lehmkuhl 1988). Furthermore, the other common association within the high density blocks is riverine forest, an assocation where 77% of the canopy is dominated by two species, Trewia nudiflora and Ehretia acuminata (Dinerstein and Wemmer 1988 and E. Dinerstein, pers. obs.).

Differences between blocks in the sex and age distribution of Rhinoceros

Several blocks showed significant skew in the distribution of sex and age categories. Most striking was the difference between the Icharni block and the Patch 1 and 2 block in 1986 where competition among dominant males for reproductive females influenced sex and age composition. For example, during most of 1986 the middle and lower part of the Icharni block contained 39 resident individuals: 2 adult males, 15 adult females with calves, 1-2 barren females, 3 subadult males, and 3 subadult females (Dinerstein et al. 1988). In contrast, the Patch 1 block contained 13 adult and subadult males and no breeding age females. The Icharni block was separated from the Patch 1 block by the Rapti River, crossible throughout the year by Rhinoceros. However, during 1986 none of the 13 males (4 of which were radio-collared) crossed the Rapti into the Icharni block while the dominant male was present.

Another obvious feature observed in 1986 within the Icharni block was that 11 of 15 adult females were accompanied by calves < 1 yr and 13 of 15 had calves < 2 yr. In contrast, females in areas >2 km from agriculture were typically followed by calves > 2 yr. One explanation for interpreting Icharni as a calving and nursery area for Rhinoceros is that Icharni is bordered on 3 sides by agriculture and by eating crops, lactating females ingest more nutritious forage than in natural grasslands. Another explanation, not mutually exclusive, is the absence of predators; during 1986, we rarely observed signs of tigers on Icharni. Laurie (1978) also found that calves < 1 yr are vulnerable to tigers. Two tigers, an adult male and female, were radio-collared near Icharni, but monitoring revealed that neither used the block during 1986.

Long-term prospects for conservation

Severe monsoon floods, disease, and heavy poaching loom as major threats to current Rhinoceros populations. During the devastating flood of the Brahamaputra River Valley in 1988, about 70% of the entire Kaziranga reserve remained under 2.7-4 m of water for several weeks, and at least 41 Rhinoceros (including 23 calves) perished (annon. 1988). The Kaziranga sanctuary was demarcated on a flood plain but until recently, Rhinoceros had access to upland forested areas above the flood plain. If Rhinoceros and other vertebrates become cut off from upland forests as a result of land clearing, than floods which normally serve to increase the productivity of critical grasslands and Rhinoceros populations could become a major source of calf mortality.

The threat of epidemics and poaching have instigated translocation programs in Nepal and India to parks which are now well-protected from poachers, contain suitable habitat, and historically harbored Rhinoceros populations (Mishra and Dinerstein 1987). Translocated populations have been established in Dudhwa National Park, Uttar Pradesh, India (4 females from Chitwan and 6 from Kaziranga) and in the Royal Bardia Wildlife Reserve in western Nepal (13 individuals from Chitwan in 1986). Still lacking is a comprehensive plan for conservation of Greater one-horned rhinoceros among nations supporting free-living populations (India, Nepal, and Bhutan), international conservation groups, and specialists in captive management.

The longevity of Rhinoceros will require long-term monitoring to track the Chitwan, Kaziranga, and other recently translocated populations to understand more completely the demography of megafaunal species. With the exception of harvesting operations for African elephants and Owen-Smith's work on white rhinoceros in South Africa, such data are largely unavailable for long-lived large mammals. This study along with Laurie's (1978) effort provides managers with several data points to gauge the tempo of recovery for *Rhinoceros unicornis* and other large herbivore species.

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Figure 1. Map of Royal Chitwan National Park and environs showing major features, areas, and blocks referred to in the text.

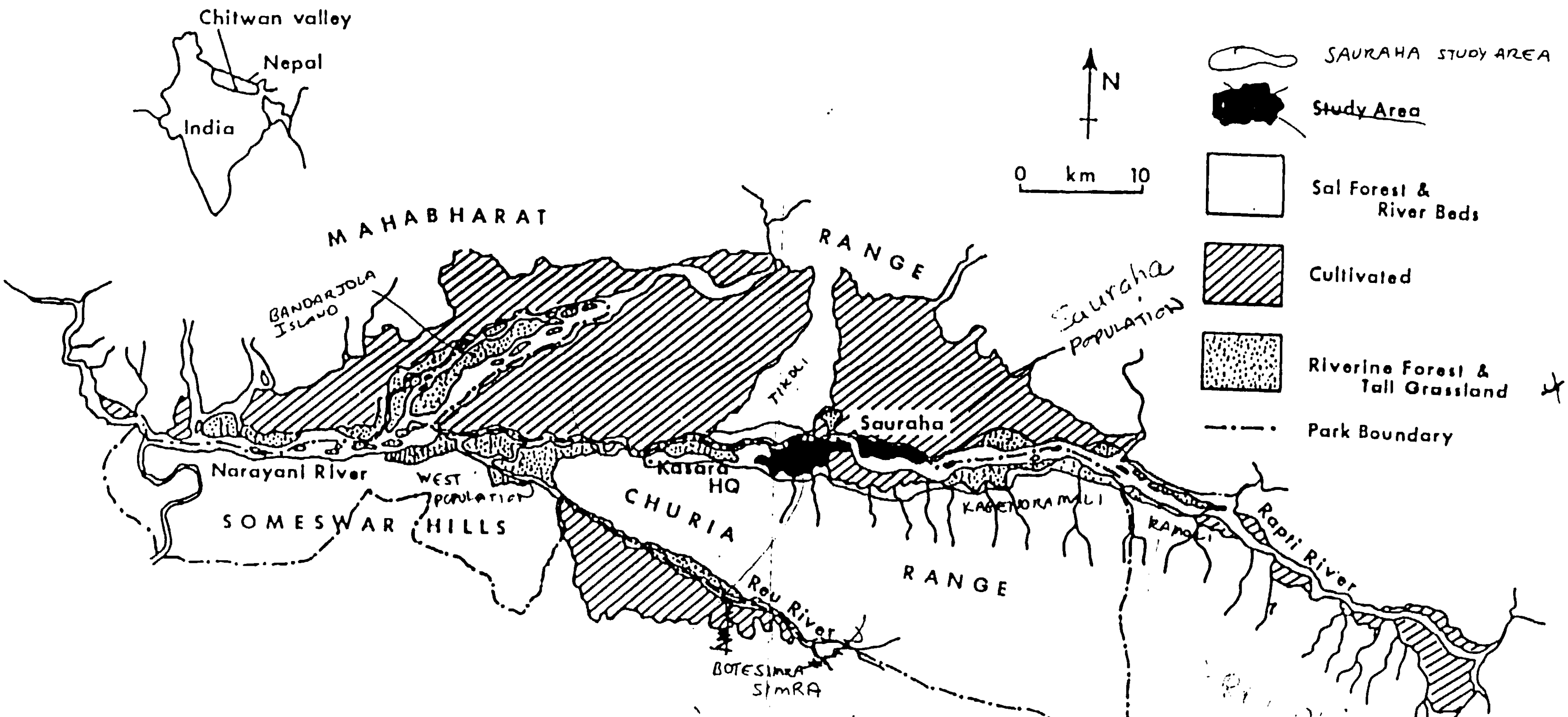


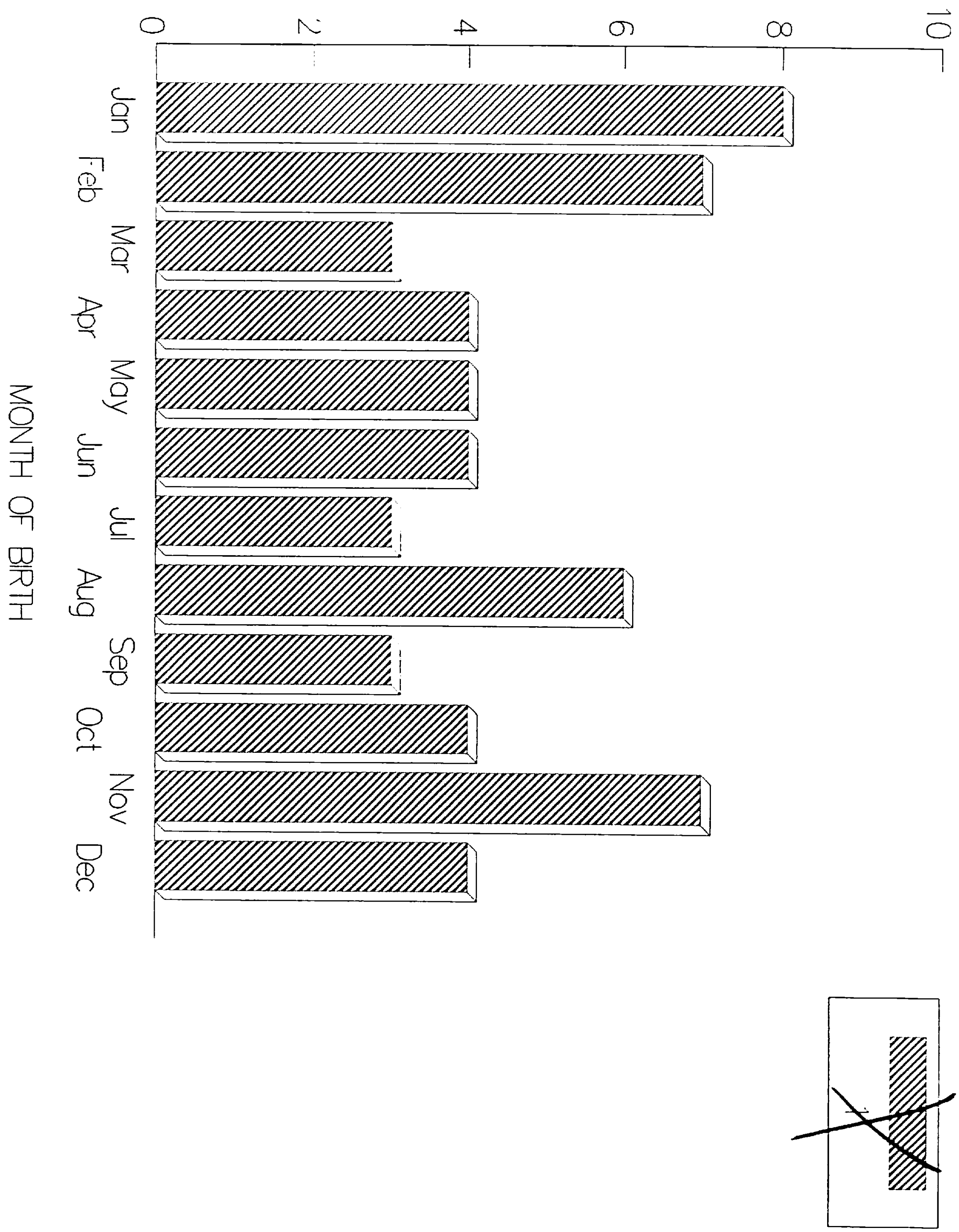

Fig. 1. Map of Chitwan valley, Nepal, showing location of Royal Chitwan National Park, research study area, general plant cover, and land use. (Base map modified from Laurie 1978/and Lehmkuhl 1988.)

KAGENDRAMALI

Figure 2a. Calf births by month in the Sauraha study area between 1984-1988.

Figure 2b. Pooled data from 1975 study (Laurie 1978) and this study for calf births assigned to 2 month intervals.

NUMBER OF CALVES BORN/MONTH
1984-8



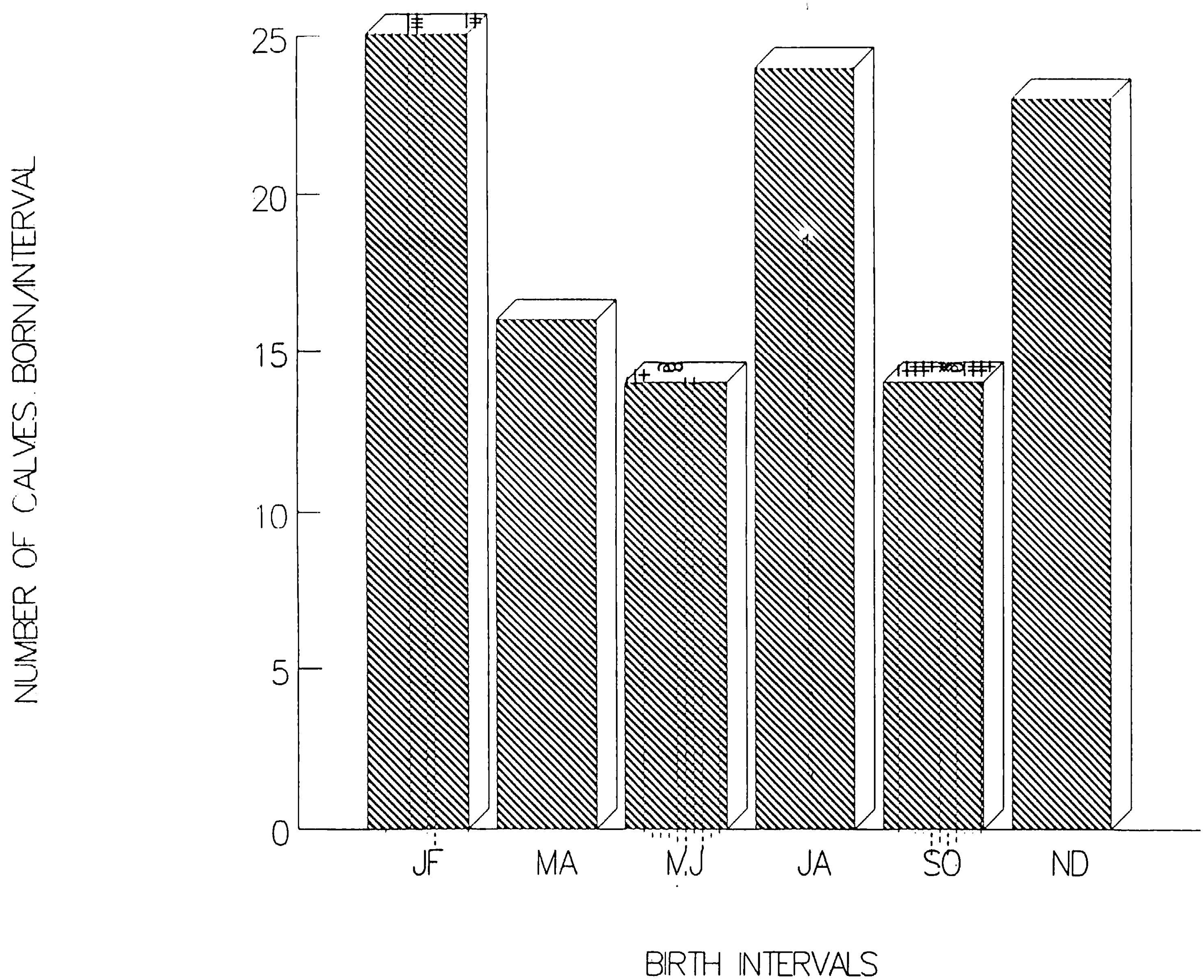

25
20
15
10
5
0
NUMBER OF CALVES BORN/INTERVAL
JF
MA
MJ
JA
SO
ND
BIRTH INTERVALS

Figure 3. Population trend of *Rhinoceros unicornis* in Royal Chitwan National Park.

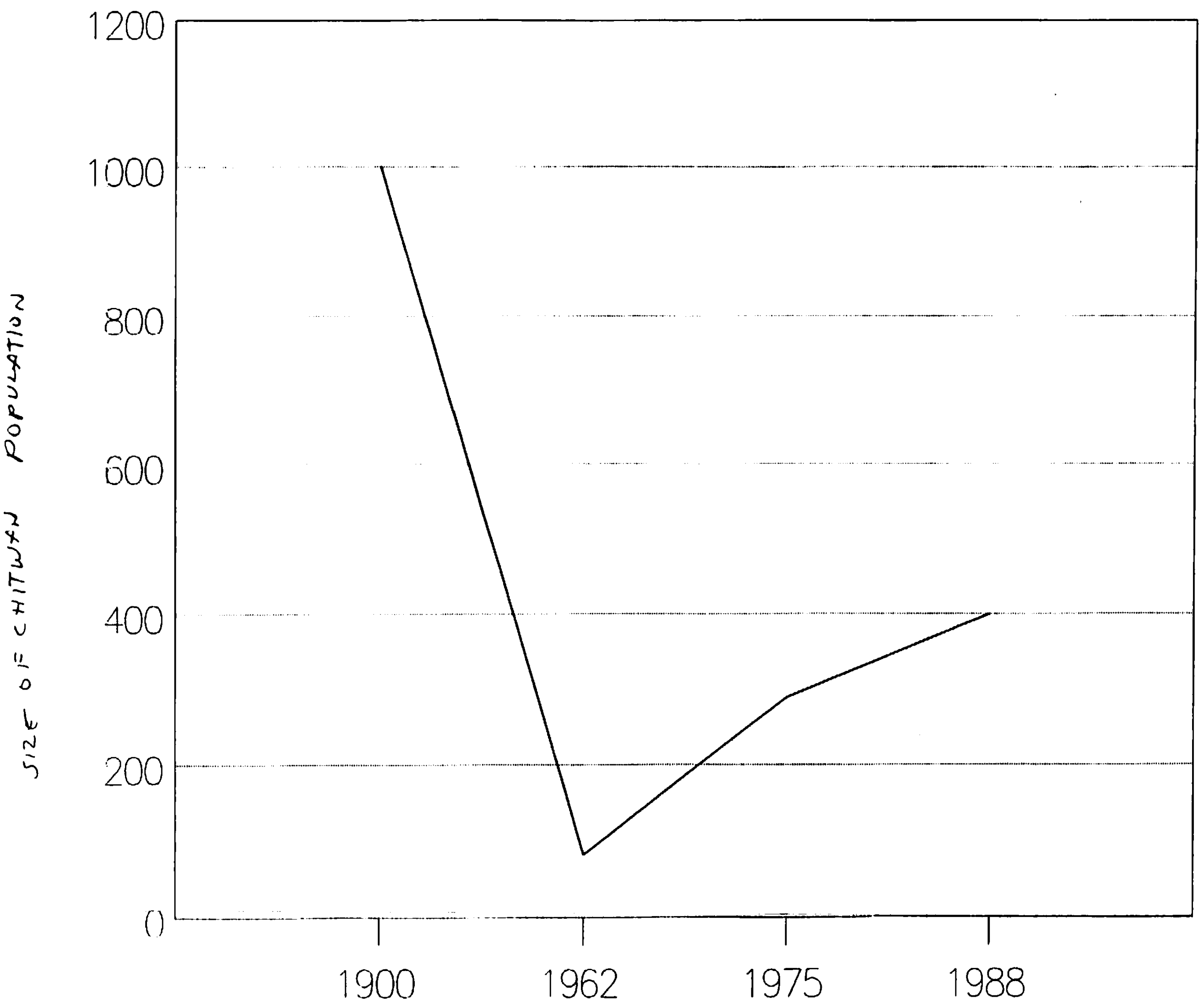

SIZE OF CHITWAN POPULATION
1200
1000
800
600
400
200
0
1900
1962
1975
1988

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Table 1. Total population estimates for the Chitwan Rhinoceros population

| population | Total 4/88 |
|---|---|
| a. Sauraha and Kagendramali | 228 |
| b. Relocated animals (1986-8) | 24 |
| c. Subtotal | 252 |
| d. West population (1986) | 61 |
| e. Animals assumed to have been missed (7%) during 1986 | 4 |
| f. Estimated population increase between 1986-8 | 7 |
| g. Adjusted subtotal West population (d+e+f) | 72 |
| h. Bandarjola Island and Narayani River | 34 |
| i. Animals assumed to have been missed (7%) during 1986 | 2 |
| j. Estimated population increase between 1986-8 | 4 |
| k. Adjusted subtotal Bandarjola and Narayani River | 40 |
| l. outlying areas (Ramoli, Tikoli, Botesimra) | 18 |
| m. Total minimum estimate for 1988 excluding translocations | 358 |
| n. Including translocations | 382 |
| o. Ten animals relocated between 1980-3 | 392 |
| p. Minimum and maximum estimate including all of Chitwan Valley | 392-413 |

Table 2. Densities of Rhinoceros in blocks searched and some habitat characteristics of those blocks. Estimates do not included relocated animals.

| Area: | Block: | Size: ($km^2$) | Density: ($n/km^2$) | % of block covered by S. spontaneum grassland | distance from croplands to center of highest density (km) | dominant plant associations in block |
|---|---|---|---|---|---|---|
| Sauraha | Icharni | 4.14 | 9.4 | 52.6 | 0.5 | S. Spontaneum, riverine forest |
| | Darampur | 4.16 | 2.2 | 0.0 | 0.5 | scrub |
| | Dumria | 3.62 | 9.4 | 29.6 | 5.0 | Narenga grassland, S. spontaneum |
| | Badreini/ Kharsar | 1.05 | 3.0 | 0.0 | 0.5 | riverine forest, scrub |
| | Patch 1 and 2 | 2.41 | 13.3 | 43.6 | 1.0 | riverine forest, S. spontaneum |
| | Patch 3/ Baaghuwaghera | 3.15 | 12.4 | 29.2 | 3.0 | riverine forest, S. spontaneum |
| | Simalchaur/ Kachwani | 4.76 | 1.7 | 0.0 | 1.0 | Narenga grassland, sal forest |
| | Jarneli | 1.96 | 3.6 | 0.0 | 3.0 | Narenga grassland, sal forest |
| | Ghatgain/ Lamitaal | 3.49 | 8.3 | 5.6 | 3.0 | riverine forest, Narenga grassland |
| | Subtotal: | 28.74 | 6.8 | | | |
| Kagendramali | | 6.84 | 4.7 | na | 1.0 | |
| West | | 60.18 | 1.2 | na | 3.0 | |
| Bandarjola and Narayani | | 13.33 | 3.0 | na | 3.0 | |

Table 3. Sex and age composition of the registered populations in the three main areas in Chitwan.

| Age class: (yr) | Sauraha | | | | | | | West | | | | Bandarjola and Narayani River | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Males | Relocated Males | Females | Relocated Females | Sex Unknown | Total | Total including relocations | Males | Females | Sex Unknown | Total | Males | Females | Sex Unknown | Total |
| calves: | | | | | | | | | | | | | | | |
| (0-1) | 4 | | 2 | 1 | 8 | 14 | 15 | | | | | | | | |
| (1-2) | 3 | 2 | 2 | 3 | 4 | 9 | 14 | | | | | | | | |
| (2-3) | 4 | 1 | 3 | 1 | 9 | 16 | 18 | | | | | | | | |
| (3-4) | 5 | | 3 | 1 | 2 | 10 | 11 | | | | | | | | |
| calves (0-4) | 16 | 3 | 10 | 6 | 20 | 46 | 55 | 1 | 1 | 6 | 8 | 2 | 1 | 2 | 5 |
| subadults: | | | | | | | | | | | | | | | |
| (4-5) | 9 | | 3 | 1 | 3 | 15 | 16 | | | | | | | | |
| (5-6) | 3 | 1 | 7 | | 6 | 16 | 17 | | | | | | | | |
| subadults (4-6) | 12 | 1 | 10 | 1 | 9 | 31 | 33 | 1 | 1 | 2 | 4 | 3 | 4 | 3 | 10 |
| adults: | | | | | | | | | | | | | | | |
| (6-12) | 23 | 3 | 37 | 5 | 0 | 60 | 68 | 9 | 6 | 7 | 22 | 3 | 1 | 1 | 5 |
| (12-20) | 16 | | 28 | 2 | 0 | 44 | 46 | 2 | 9 | 2 | 13 | 2 | 5 | | 7 |
| (>20) | 19 | 2 | 22 | 1 | 0 | 41 | 44 | 3 | | | 3 | 7 | | | 7 |
| adults combined: | 58 | 5 | 87 | 8 | 0 | 145 | 158 | 14 | 15 | 9 | 38 | 12 | 6 | 1 | 19 |

Table 4. Sex and age composition of the registered population in the Sauraha area during April 1988 (this study) and 1975 (from Laurie 1978) (parameters 1-8 for 1988 data include individuals relocated during the study period. Parameters 10-15 exclude these individuals).

| | 1988 | 1975 |
|---|---|---|
| adult sex ratio (% male) | 39.9 | 34.1 |
| subadult sex ratio (% male) | 54.2 | 55.3 |
| subadult and adult combined sex ratio (% male) | 41.8 | 41.0 |
| adults as % of the population | 63.5 | 50.9 |
| subadults as % of the population | 13.3 | 22.8 |
| adult adult females as % of the population | 38.2 | 33.5 |
| adult females with calves as % of the population | 20.9 | 26.3 |
| adult males as % of the population | 25.3 | 17.3 |
| % of adult males known or assumed to have bred during study period | 48.3 | |
| % of adult females with calves | 59.8 | 78.6 |
| % of adult females with calves excluding females 6-7 yr old | 77.0 | |
| % of adult females (6-12 yr) with calves | 54.1 | |
| % of adult females (7-12 yr) with calves | 90.9 | |
| % of adult females (12-20 yr) with calves | 64.3 | |
| % of adult females (> 20 yr) with calves | 63.6 | |
| % of population < 12 yr old | 62.0 | |

Table 5. Age specific birth rate for adult females in the Sauraha population

| Age: | Census year: 84-85 | 85-86 | 86-87 | 87-88 | mean | std |
|---|---|---|---|---|---|---|
| 6-12 | 0.179 | 0.310 | 0.138 | 0.048 | 0.169 | 0.095 |
| 12-20 | 0.167 | 0.233 | 0.167 | 0.167 | 0.183 | 0.029 |
| >20 | 0.208 | 0.130 | 0.130 | 0.087 | 0.139 | 0.044 |

Table 6. The numbers and causes of mortalities within each sex and age class in the Sauraha population

| | Adults | | | | | | Subadults | | |
|---|---|---|---|---|---|---|---|---|---|
| | >20 M | >20 F | 12-20 M | 12-20 F | 6-12 M | 6-12 F | M | F | Sex Unknown |
| Cause of death: | | | | | | | | | |
| Poaching | | | 2 | | | | | 1 | 1 |
| Tiger predation | | | | | | | | | |
| Intraspecific fighting | 5 | 1 | | | | | 1 | | |
| Abandonment by female | | | | | | | | | |
| Flood or quicksand | 1 | | | | 1 | | | | |
| cause undetermined | 2 | | 4 | 1 | | 1 | | | |
| Total | 8 | 1 | 6 | 1 | 1 | 1 | 1 | 1 | 1 |

Table 7. Population parameters of the Sauraha population

Population estimates for each year represent a minimum estimate

| Census year: | No. of calves born: | Population size: | Birth rate: | % annual mortality: | % annual mortality of animals > 1yr old | r |
|---|---|---|---|---|---|---|
| 1987-8 | 18 | 252 | 7.69 | 1.95 | 0.78 | 5.74 |
| 1986-7 | 16 | 236 | 7.27 | 3.28 | 2.46 | 3.99 |
| 1985-6 | 18 | 228 | 8.57 | 2.98 | 2.98 | 5.59 |
| 1984-5 | 13 | 217 | 6.37 | 3.12 | 2.23 | 3.25 |
| mean | 16.3 | | 7.48 | 2.83 | 2.11 | 4.64 |
| std | 2.05 | | 0.79 | 0.52 | 0.82 | 1.06 |

Table 8. Survivorship data for the Sauraha population excluding calves and subadults of undetermined sex

| | Census year: 84-85 | 85-86 | 86-87 | 87-88 | mean | std |
|---|---|---|---|---|---|---|
| Females: | | | | | | |
| 0-1 | 0.846 | 1.000 | 0.875 | 0.833 | 0.889 | 0.066 |
| 1-4 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.000 |
| 4-6 | 1.000 | 0.900 | 0.900 | 1.000 | 0.950 | 0.050 |
| 6-12 | 1.000 | 0.976 | 0.976 | 1.000 | 0.988 | 0.011 |
| 12-20 | 1.000 | 1.000 | 0.967 | 1.000 | 0.992 | 0.014 |
| >20 | 1.000 | 0.957 | 1.000 | 1.000 | 0.989 | 0.019 |

| | 84-85 | 85-86 | 86-87 | 87-88 | mean | std |
|---|---|---|---|---|---|---|
| Males: | | | | | | |
| 0-1 | 0.846 | 1.000 | 0.875 | 0.833 | 0.889 | 0.066 |
| 1-4 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.000 |
| 4-6 | 0.917 | 1.000 | 1.000 | 1.000 | 0.979 | 0.036 |
| 6-12 | 1.000 | 1.000 | 0.962 | 1.000 | 0.990 | 0.017 |
| 12-20 | 0.938 | 0.750 | 0.938 | 1.000 | 0.906 | 0.094 |
| >20 | 0.810 | 1.000 | 0.905 | 0.905 | 0.905 | 0.067 |