PAPER III

all significantly smaller than those of the translocated animals. Annual ranges (females, N = 4) and 3.3 km² (1 adult male) and seasonal ranges between (females) and 1.1 and 2.0 km² (male) were all > 8 times smaller than in Bardia and seasonal home ranges in Bardia were due to larger shifts in seasonal occ and more extensive movement within seasonal ranges than in Chitwan. In B between seasonal occupancy centers varied from 2.2 km (females) to 4 compared to 0.5 km and 0.5 km in Chitwan, respectively. Seasonal range lengt distance at about 50 hours intervals) averaged 2.7 km (females) and 3.2 km (m and 0.6 km and 0.4 km in Chitwan, respectively. Because Bardia animals distances per unit time than those in Chitwan, their seasonal home ranges overl (41 to 75 %) as those in Chitwan (58 to 79 %), despite larger spacing of seaso centers.

In Bardia, habitat preferences varied between seasons and between sex Khair-Sissoo forest was mostly exploited during winter, Riverine forest during winter seasons and Tall Grassland during the monsoon. In the hot-season, femal Sissoo and Tall Grassland more than males, during winter males used Riveri than females, and during the monsoon females used Riverine forest more than

The differences in spacing behavior were not due to non-settled behavi translocated Bardia animals, as seasonal home range sizes did not decrease fro the next. In Bardia, a highly skewed breeding sex ratio (1 male/8 females) and density (0.3 animals/km² in Bardia versus 8-10 animals/km² in Chitwan) may more extensive movement in search for conspecifics. Although productivity of th plant, *Saccharum spontaneum*, may be lower in Bardia than in Chitwan, compet probably did not occur due to the very low number of animals. Rather, a distribution and small patch size of seasonlly preferred habitats and less access compared with Chitwan were probably the main reasons for the different spac observed.

RANGING BEHAVIOR AND HABITAT PREFERENCE BY A TRANSLOCATED POPULATION OF GREATER ONE-HORNED RHINOCEROS (*RHINOCEROS UNICORNIS*) IN LOWLAND, NEPAL

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KEY WORDS: Greater one-horned rhinoceros, *Rhinoceros unicornis*, ranging behavior, habitat preference, Nepal.

ABSTRACT

Ranging behavior and habitat preferences of a newly translocated population (Bardia) were studied during 1990-1993, and movement pattern was compared with that of the donor population (Chitwan) based on monitoring daytime movement of radiomarked animals. Five years after translocation, the annual home range sizes were 25.1±9.3 km^2 and 41.8±4.4 km^2 for adult females (N = 8) and males (N = 2), respectively ($p < 0.05$). Range sizes of four social groups did not vary between seasons, but during the hot season and the monsoon females with young calves (< 1 year old) had smaller ranges than single females and females with older calves. Seasonal home range size of males varied with social status; when a younger male with a smaller range size displaced an older male with a larger range and became the dominant breeder, his seasonal ranges expanded whereas those of the former dominant's decreased in size.

Annual and seasonal home ranges of animals in the Chitwan donor population were

preferences of this and the donor population have been reported elsewhere (Jnawali, in ms). In another preliminary study, the home range sizes of the Bardia population were found to be much larger compared to the donor population in Chitwan (Wegge and Jnawali 1993). Another purpose of this study was, therefore, to compare the ranging behavior of the translocated founder population with the dense donor population and to examine the reasons for the different spacing pattern observed.

STUDY AREA

The Bardia translocation habitat of about 70 km^2 is located in the south-western corner of Royal Bardia National Park (81° 20' E and 28° 35' N) (Fig. 1). It consists basically of a narrow strip of alluvial floodplain along Geruwa river. About one third of the area extends between the park boundary and the Indo-Nepalese border in the south. Topographically, the area is flat with elevations between 100 m and 200 m a.s.l. The floodplain is intersected by a large number of small riverlets originating from Geruwa river. The climate, soils, fauna and flora is described earlier (Dinerstein 1979a and 1979b).

The Bardia study area consists of ten distinct habitat types (Table 1). Sal forest, dominated by *Shorea robusta* and *Buchhania latifolia*, covers the drier upland in the north-eastern section (Fig. 1). Riverine forest, dominated by *Mallotus phillippinensis* and *Syzigium cumini*, grows on poorely drained soils along the riverlets. The floodplain is composed of patches of Tall Grassland dominated by *Saccharum spontaneum*, and successional Khair *Acacia catechu* - Sissoo *Dalbergia sissoo* forest. Phantas (previously cultivated fields) and Wooded Grasslands are dominated mainly by short grasses such as *Imperata cylindrica* (Pokharel 1993). Mixed Hardwood forest occupies a small portion of the study area intermingled with Riverine forest, Khair-Sissoo forest and Wooded Grassland in the northern section of Khauraha island. Bushy pastures are heavily grazed areas along the village boundary outside the park and are mostly located in the southern section. A detailed description of these habitat types is also available elsewhere (Dinerstein (1979a), Jnawali in ms).

In Chitwan, mainly five habitat types are found, viz. Riverine forest, Sal forest, Tall Grassland, Bushy Pasture and cultivated land. The latter four are similar to those found in

reported elsewhere (Jnawali, in ms). Bardia, but Riverine forest differs in species composition. In Chitwan, this vegetation t
the Bardia population were found t is richer and dominated by *Trewia nudiflora* with abundant *Bombax ceiba* and *Li*
Chitwan (Wegge and Jnawali 1993) *monopetala*. Besides, two important browse species, *Murraya paniculata* and *Co*
mpare the ranging behavior of the *bengalensis*, grow only in Chitwan (Jnawali in ms).
opulation and to examine the reasons

Large tracts of intensively cultivated land and less preferred Sal forest occur outs
the boundaries of both study areas. During a two-week period in early winter, seve
thousand local villagers are permitted to cut grass inside the parks, which, combined w
widespread grass burning, reduces the density and cover in the floodplains.

The fauna in both parks is similar, except for nilgai *Boselaphus tragocamelus* a
swamp deer *Cervus duvaceli* being confined only to Bardia and gaur *Bos gaurus* only
Chitwan. Large mammals common to both areas besides rhinoceros include tiger *Panthe*
tigris, leopard *P. pardus*, sloth bear *Melursus ursinus*, wild boar *Sus scrofa* several speci
of deer (*Axis axis*, *A. porcinus*, *Cervus unicolor*, and *Muntiacus muntjack* and transient wi
elephants *Elephas maximus*.

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MATERIALS AND METHODS

The Bardia founder population, consisting of 2 adult males, 5 adult females, 3 subadul
females, and 3 subadult males, were captured near Sauraha in Chitwan and translocated and
released at the same site in the upper Karnali floodplain, about 10 km north of the Park
headquarter (Fig. 1). During 8 years after release in 1986, 9 animals died and 11 calves were
born. In late 1994, the population consisted of 15 individuals (3 males, 8 females and 4
calves, estimated at a density of approximately 0.3 animals/km^2 (Jnawali and Wegge, in ms).

Data from Chitwan used in the present comparison were taken from a subpopulation
residing near Sauraha in the northeast part of the park. This population has been intensively
studied by Laurie (1978 and 1982) and Dinerstein and Price (1991), and consists of > 100
animals in prime habitats along the Rapti river, estimated at a density of 8-10 animals/km^2
(Dinerstein and Price 1991).

In 1990, nine of the 10 founders then alive in Bardia were captured and equipped with
radio transmitters in the 142 Mhz frequency range. In addition, one subadult female born in
Bardia was also radio instrumented in 1992. All animals were immobilized using the same

drugs and techniques as described by Dinerstein et al. (1990). The drug dose was increased to 2.5 - 3 mg of M99 and 1.5 mg of acepromazine to ensure rapid immobilization. Animals were tracked during day-time, using a portable receiver and two element antennas, and located by triangulation, cross bearings or by direct approach. Tracking was carried out by elephants during the monsoon and by car and bicycle during the dry season. On average, all animals were tracked 3 times per week. The tracking periods were divided into three seasons - winter season (November-February), hot season (March-June) and Monsoon (July - October).

In Bardia, a total of 1641 locations from 10 rhinoceros were obtained between February 1990 and March 1993. In Chitwan, data (N = 652) were obtained from five animals (1 male and 4 females) tracked during 1985-87. Locations were plotted on aerial photos (1:35000 in Bardia and 1:30000 in Chitwan) and later transferred to topographic maps. In both study areas, composition of vegetation types were identified and mapped based on transect sampling and later measured by a digital planimeter (Jnawali, in ms).

Both seasonal and annual home ranges were drawn as convex polygons using the "modified minimum area method" (Harvey and Barbour 1965) as modified by Wegge and Larsen (1987): the distance between the two widest locations was divided in half. A line was then drawn clockwise between all successive outermost points that were spaced shorter than this half maximum distance. Locations further away than the maximum distance were defined as excursions and were excluded in the estimate of home range sizes. The size of a home range is a function of sample size (Voigt and Tinline 1980). In the present study an asymptotic relationship between home range size and number of location was obtained after 28 day locations. Hence, animals with less than 28 locations were excluded from the analysis of seasonal home ranges.

In Bardia, > 95% of the consecutive locations of each individual animal were spaced at intervals of 48 hours or more. Thus, autocorrelation was not considered a problem with the Bardia data set. In Chitwan, animals were tracked more frequently. To avoid autocorrelation and make data comparable with Bardia, only locations between 48 and 51 hours intervals were used.

The occupancy center (OC), or geographical center of a home range, was defined as the intersection of the average distance of locations measured along the x and y coordinates (Wegge and Larsen 1987). 50% of the day locations nearest to the occupancy center were used to estimate the core area of each seasonal home range. The size of home range and core

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areas was measured by a digital planimeter. Home range stability was determined calculating overlap of successive seasonal home ranges and core areas. Range length, defi as the minimum distance moved by an animal during a given time interval, was estim using the method described by Wegge (1985). In this study, an interval of 50 hrs (3 days) used to estimate and compare movement pattern within home ranges.

Habitat preferences were examined at three levels: (a) comparing freque distributions of animal location on habitat types with distribution of habitats within the t study area, (b) comparing frequency distribution of habitats within seasonal core areas w frequency distribution of habitats within total study area, and (c) comparing frequen distribution of animal locations on habitat types with frequency distribution of habitats with seasonal home ranges of each individual animal. For the latter, each animal's frequen distribution on each of the three main habitat types, viz. Tall Grassland, Khair-Sissoo, a Riverine forest, was plotted against the frequency of the same habitat within the animal home range. Plots on the 45° median line indicated that the animal made no active selecti for that particular habitat (Kolstad et al. 1985).

Preference for particular habitats was determined by Bonferroni confidence interva (Neu et al. 1974, Byers et al. 1984). Ivlev's Electivity Index (IEI) was employed to estima the degree of preference or avoidance of each habitat types (Ivlev 1961). Seasonal habita preferences by individual animals were determined by the relative proportion of individu animal "plots" which fell on each side of the median line and were analyzed by the Wilcoxo matched pair signed-rank test.

RESULTS

Home range

Average annual home range sizes of females and males of the translocated population in Bardia were estimated at 25.1±9.3 km^2 and 41.8±4.4 km^2, respectively, whereas in Chitwan they were only 2.9 km^2 (females) and 3.3 km^2 (males) (Table 2). Similarly, seasonal home ranges of females and one male in Chitwan were < 10% that of Bardia animals. The corresponding core areas of Bardia animals were also considerably larger than those of

Chitwan animals.

In Bardia, annual home range size of females with calves were not different from that of single females (Wilcoxon rank-sum test, $W_s = 8$, n1 = 2, n2 = 6; $p > 0.05$) . The annual home range size of males was significantly (Wilcoxon rank-sum test, $W_s = 19$, n1 = 2, n2 = 8; $p < 0.05$) larger than the average annual home range size of single females and females with calves lumped together (Table 3).

In Bardia, no statistical differences were detected between size of seasonal home ranges of four different social groups (Kruskal-Wallis test, $p > 0.05$, all groups) (Table 4). In the hot and monsoon seasons, the size of home ranges of females with older calves (> 1 year) and single females were both significantly larger than the females with small calves (< 1 year) (Wilcoxon rank-sum test, $p < 0.05$, all), but no such differences were observed in winter. In all three seasons, mean home range sizes of males were larger than that of females with big calves and single females combined, but non of them were statistically significant (Wilcoxon rank-sum test, $p > 0.05$, all). Among the two males, size of home ranges changed with social status (Table 4). When the younger, subadult male (337) replaced the older, dominant breeder (275) in the monsoon, home range sizes of both changed in opposite directions.

Females tracked in consecutive seasons (hot = 5, monsoon = 4 and winter = 2) were used to detect changes in home range size from one year to the next. In general, ranges increased slightly (8.6%) in consecutive seasons, but none of the changes were statistically significant (Wilcoxon matched pair signed-rank test, $p > 0.05$, all) (Table 5).

All instrumented animals remained mainly within a narrow strip of the floodplain along Geruwa river with remarkable overlap in seasonal home ranges (Table 6). For females, the mean seasonal home range overlap ranged from 54.9% to 74.8%, whereas for males it ranged from 41.2% to 51.3%. The seasonal core area overlap ranged from 21.6% to 43.8%

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(females) and from 18.6% to 21.6% (males). Overlap was largest during the hot/monsoon, smallest during monsoon/winter seasons. Seasonal overlap of males was consistently small than that of females (Table 6).

In Bardia all radio marked animals shifted their occupancy centers between seasons (Fig. 2), in spite of large seasonal overlap in home ranges (Table 6). For males the mean distances between OCs ranged from 3.3 km to 6.2 km, whereas for females they ranged from 1.1 km to 3.1 km. The difference between sexes were significant in the winter/hot and hot/monsoon seasons (Wilcoxon rank sum test, $p < 0.05$, both) but not between the monsoon and winter (Wilcoxon rank sum test, W_s = 13, n1 = 2, n2 = 8, $p > 0.05$).

In Bardia, animals moved extensively within their home ranges (Fig. 3). Mean linear distance within ca 50 hours intervals ranged from 2.3 km to 4.1 km for males and 2.5 to 2.9 km for females (Table 6). Thus, within few days animals traversed most of their home ranges. For example, one female made a journey of about 11 km (location 23 to 24) in < 35 hours (Fig. 3). On average, males tended to move longer than females, but the difference was only significant in the hot season (Wilcoxon rank sum test, W_s = 13, n1 = 2, n2 = 5 $p < 0.05$).

With smaller annual and seasonal home ranges in Chitwan, distances between seasonal OCs and range lengths were also much smaller there than in Bardia (Table 6). However, movement in relation to home range size was almost as large; animals moved less but covered nearly the same proportion of their home range within the same time interval. Compared with Bardia, extent of seasonal home range overlap was larger among Chitwan females, except for the hot/monsoon season. The male here had larger overlaps in all three seasons.

Habitat use

Bardia animals preferred Khair-Sissoo forest, Riverine forest and Tall Grassland and avoided Sal forest, Wooded Grassland, and River and Riverbeds (Table 7). Mixed Hardwood forest was used according to availability. Among preferred habitat types, highest preference was observed for Riverine forest (IEI = 0.44). Sal forest was the most avoided (IEI = - 0.93), and animals were not located in Bushy pastures, Phanta and Agricultural lands during daytime.

Riverine forest was preferred in all three seasons by females (Table 8 and Fig. 4), whereas males preferred this habitat only during the hot and winter seasons (Table 8). When seasonal use of habitats was tested on an individual animal level, this habitat was used significantly more in the hot and winter seasons (Wilcoxon matched pair signed-rank test, $t = 55$ and 54, respectively, $n = 10$, $p < 0.01$, both) (Fig. 5).

Khair-Sissoo forest was also preferred in all three seasons by females (Table 8, Fig. 4), whereas males preferred this habitat type only during winter. Test for seasonal use by individual animals confirmed that this type was preferentially used mainly during winter (Wilcoxon matched pair signed-rank test $t = 51$, $n = 10$, $p < 0.01$) (Fig. 5). This was also reflected in the composition of habitat types in the seasonal core areas. Highest proportion ($\bar{x}$ = 40.4±5.4SD) of Khair-Sissoo forest was recorded during winter (Table 9).

Tall Grassland was preferred during hot and monsoon seasons by females whereas males preferred this habitat type during the monsoon only (Table 8). Both sexes used very little of this habitat during winter (Table 8). Test for seasonal use by individual animals also disclosed that this habitat was preferentially used during the monsoon and hot seasons (Wilcoxon matched pair signed-rank test, $p < 0.01$) (Fig. 5). Furthermore, core areas contained the highest proportion of this habitat during the monsoon ($\bar{x}$ = 32.3±2.9SD), confirming that

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Tall Grassland was especially important during this season (Table 9).

There were some notable differences between the habitat use of males and females (Fig. 6). Most pronounced differences were observed in the hot season. Females used significantly more Khair-Sissoo and Tall Grassland than males, whereas males used more Riverine forest than females (Chi Square tests, $p < 0.05$, all). In winter, Khair-Sissoo was much preferred by both sexes with no differences between males and females. However, Riverine forest was then used more by males. In the monsoon, Tall Grassland was much preferred by both sexes, but with differential usage between males and females. In this season Riverine forest was used more by females ($\chi^2 = 9.37$, $p < 0.05$).

DISCUSSION

Ranging pattern

Five years after translocation to Bardia, the average annual home range of individual animals was estimated at about 28.5 km^2. The annual home range size of animals in the Chitwan donor population was 3.0 km^2, or only 1/9 of that. In Chitwan, radio instrumented animals basically remained in the prime habitat of Icharni island. However, occassionally they excursed across the Rapti river in the west and to Bushy pastures and cultivation in the northeast. These areas are not included in the home ranges in the present study. Their inclusion would increase the home range size by a maximum of 20-30 percent, which still make the Chitwan home ranges much smaller than in Bardia. Laurie (1982) also estimated a smaller mean home range size of 4.3 km^2 for Icharni animals.

The discrepancies between home range size in Bardia and in Chitwan may be due to

non-settled ranging behavior, lower animal density or poorer habitat quality in Bardia. Because data on ranging behavior was collected only five years after translocation, animals in Bardia may not yet have settled down. However, seasonal home ranges did not decrease from 1990/91 to 1991/92. In fact, they tended to increase (Table 5), although large individual differences were observed. Seasonal ranges were also spatially quite stable from one year to the next, and suppplementary data collected in 1993 supported the general pattern that individual animals continued to roam over the same large areas in which they had settled in 1990.

Kiwia (1989) and Pienaar et al. (1993) found an inverse relation between the home range size and density of black *Diceros bicornis* and white *Ceratotherium simum simum* rhinoceros, respectively. In high density areas, movement of individual animals may be restricted by animals in neighbouring areas, as found among African buffaloes *Syncerus caffer* (Funston et al. 1994). Here, the borders of home ranges of individual herds were dictated mainly by the proximity of neighbouring herds. But rhinoceros are basically non-territorial and solitary animals (Laurie 1978). Hence, the size of home ranges is not expected to be influenced by the presence of other conspecifics.

However, the extremely low animal density in Bardia (ca 1 animal per 5 km^2) may have triggered extensive movement unrelated to habitat quality per se. The highly skewed sex ratio of only one mature male/8 breeding age females and a widely spaced distribution pattern of females may have induced movement by both sexes searching for mates. Indirect evidence of ovulations not leading to conception indicates that females, on occassion, did not make contact with the dominant male when in estrous (Jnawali and Wegge in ms). The pronounced increase in movement by the younger male after he became the dominant breeder also suggests that mating behavior may have affected space use.

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In general, home range size is likely to increase when large numbers of animals exploit the same resources (Damuth 1981). Thus, assuming a similar resource base in both areas, home range of Chitwan animals is expected to be larger, and not smaller, than those of Bardia animals. Based on resource requirements, home ranges of rhinoceros are probably determined by productivity, availability and distribution of seasonal foods and access to habitats for shelter, heat avoidance and wallowing. Tall Grasslands and Riverine forests are the critical habitats for the greater one-horned rhinoceros (Laurie 1978, Dinerstein and Price 1991, and this study). Besides, agricultural crops become an important component of their diet late in the monsoon and during the early part of the dry season (Laurie 1978, Jnawali 1989). In Chitwan, continuous blocks of Riverine forest surrounded by large tracts of grassland combined with closely located agriculture reduce animals movement (Fig. 7). Unlike in Chitwan, in Bardia the preferred habitats are fragmented in small patches unevenly distributed throughout the north-south elongated floodplain (Fig. 7). This probably leads not only to larger shifts in location of seasonal occupancy centers but also to more extensive movements within each season. Hitchens (1969) and Larter and Gates (1993) also observed larger home ranges of black rhinoceros and wood bison *Bison bison*, respectively, in areas where food resources were more dispersed, and Owen-Smith (1973) reported that white rhinoceros extended their ranges during winter when water was in short supply.

Moe and Wegge (1995) stated that the fine grained habitat pattern in Bardia compared to Chitwan reduced the home range size of axis deer *Axis axis*, in spite of a much higher animal density there. But habitats preferred by rhinoceros differ from those preferred by axis deer. The daily food intake by rhinoceros of about 15-20 kg of organic matter (Foose 1982, cited in Owen-Smith 1988) is extremely high compared to small ungulates. In Bardia, individual patches of preferred habitat are probably too small to supply sufficient quantity of

high quality food for an extended period of time. As a result, animals need to move from one patch to the next in order to meet their high daily food requirement.

However, habitat quality may also be poorer in Bardia. The productivity of the staple food plant - *Saccharum spontaneum* - is probably lower than in Chitwan. Although no productivity study has yet been made in Bardia, indirect evidence indicates that this may be the case. Compared to Chitwan the floodplain in Bardia is drier, probably leading to less vigorous sprouting of *Saccharum* during the dry season, with animals exploiting proportionally less grasses and more browse than Chitwan animals during this time (Jnawali in ms). This may explain the larger home ranges in Bardia during the dry season, but not in the monsoon.

All seasonal home ranges of Bardia animals were larger than those of the donor population in Chitwan. Tall Grassland was the most preferred habitat type during the monsoon. In Bardia, this habitat is scattered in small patches ($\bar{x}$ = 10.4 ha) along the river and riverlets, spaced on average 0.99 km apart, in contrast to Chitwan where Tall Grasslands occur in large blocks (Fig. 7). More extensive movement during the monsoon by Bardia animals may therefore be explained by smaller patch size and lower relative proportion of this preferred habitat type in Bardia, rather than inferior quality during this period.

Riverine forest was preferred during the hot season in Bardia. Like with Tall Grassland, Riverine forest is also dispersed in fragmented patches (mean 35 ha) about 2.7 km apart compared with Chitwan where patches are much larger. Furthermore, Riverine forests in Chitwan are richer in preferred food plants (Jnawali in ms.), which probably also contributes to more extensive movement and larger home ranges during the hot season in Bardia.

Less access to cultivated lands probably also increases the home range of Bardia

animals. The Sauraha donor population occupies a concentration of naturally highly preferre habitats close to cultivated lands. In Bardia, access to agriculture is limited by the Geruwa river in the west and large tracts of less preferred Sal forest in the east. Accessible cultivated lands occur mostly in the southern section which triggers animal movement southwards during winter when crop raiding becomes prevalent.

Like in black rhinoceros (Kiwia 1989), average annual home range size of Bardia males was significantly larger than the average annual home range of females. This was mainly because their seasonal home ranges were more spaced than those of females. However, the seasonal home ranges of males were also larger, probably due to males' extensive movement in search of females. Furthermore, larger home ranges among males may also be explained by differences in areas needed to fulfill metabolic requirements (McNab 1963), as adult males are 20-25% larger than femles (Laurie 1982).

Only during the monsoon was home range size of females with calves smaller than other female social groups. The flooded riverlets may have limited more extensive movement of young calves during this season.

Habitat use

In Bardia, Riverine forest was heavily utilized during winter and hot seasons (Fig. 6). *Mallotus phillippinensis* and *Syzigium cumini* are dominant tree species in this habitat type, of which *Mallotus* constitutes an important part of the diet (Jnawali in ms). *Calamus tenuis*, a climbing palm also basically confined to the Riverine forest, was also exploited mainly during the hot and winter seasons. Furthermore, Riverine forest with unpenetrable bushes of *Calamus*, particularly in the southern section of the study area, also provides good shelter during winter when animals raid crops during night-time.

Khair-Sissoo forest was also preferentially used during winter. With a dense and abundant understorey vegetation, consisting mainly of *Murraya koinigii*, *Pogostemon bengalensis* and *Callicarpa macrophylla*, this habitat type provides suitable shelter when the Tall Grassland becomes more open after grass cutting and burning in early winter. Furthermore, *Callicarpa* is an important food plant during this season. Females preferred Khair-Sissoo forest also during the hot season and the monsoon. During the hot season animals voraciously exploit *Dalbergia sissoo* and *Callicarpa macrophylla* (Jnawali in ms). Monsoon use of Khair-Sissoo forest was probably related to shelter to escape from blood sucking tabanid flies *Tabanus sp..*, which are prevalent in Tall Grassland during that part of the year.

Tall Grassland in the floodplain was highly preferred by both male and females during the monsoon, when animals mainly exploit grasses common in this habitat. Preferred *Saccharum spontaneum*, *S. bengalensis*, *Arundo donax* and *Erianthus ravennae* make up about 70% of the diet in this season (Jnawali in ms). Tall Grassland also attracts animals during the hot season when new flush becomes available after the first rains late in the hot season.

Other habitats in Bardia - Sal forest, Mixed Hardwood forest and Wooded Grassland - received very little use. These habitats are of little importance in terms of food plants. Common grasses in the latter two habitats (*Imperata cylindrica* and *Desmostachia bippinata*) receive some use only during the early sprouting stages, and sal seedlings were not eaten (Jnawali, in ms). Also, with an open understorey vegetation neither of these habitats provide good shelter. River and riverbeds were used relatively more during the hot season when animals wallowed frequently to escape from the heat. Animals were never located in Phanta and Bushy pastures during daytime. Phantas are devoid of both preferred food plants and good shelter. No use of Bushy pastures during the day was mainly due to disturbances, as all

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Bushy pastures lie outside the park boundary and are used for livestock grazing.

Five years after release in Bardia, spacing behavior showed that the translocated animals had settled in established home ranges. Large size of annual and seasonal ranges and more extensive movement compared with the donor population in Chitwan were mainly due to low animal density combined with different spatial distribution of preferred habitats. Although Tall Grassland may be less productive in Bardia, this is unlikely to explain the larger space use there, because animal density was too low to induce competition for food. Unlike in Chitwan, in Bardia the preferred Riverine forest and Tall Grasslands are fragmented and distributed in small patches which contribute to more extensive seasonal movements. In addition, the huge Geruwa river and large tracts of unattractive Sal forest limit access to agricultural crops, leading animals to move sowthwards during winter. In Chitwan, large tracts Riverine forest surrounded by Tall Grassland combined with nearby agriculture probably reduces animals' movement to obtain seasonal foods.

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REFERENCES

Anstey, D. 1987. Report on stage two of the reintroduction of the greater one horned rhinoceros to th0e Royal Bardia Wildlife Reserve, Nepal. report, DNPWC/KMTNC. 12 pp.

Bhattacharya, A. 1993. The status of the Kaziranga rhino population. Tiger Paper 20:1-6.

Bauer J.J. 1988. A priliminary assessment of the reintroduction success of the Asian one-horned rhinoceros (*Rhinoceros unicornis*) in Bardia wildlife reserve, Nepal. Tiger Paper, October-December:26-32.

Byers, R.C., Steinhorst, R.K., and Krausman, P.R. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage. 48:1050-1053.

Caughley, G. 1969. Wildlife and recreation in the Trisuli Watershed and other areas in Nepal. HMG/FAO/UNDP Trisuli Watershed and Development Project. Project Report No. 6. Kathmandu. 54pp.

Damuth, J. 1981. Home range, home rnage overlap, and species energy use among herbivorous mammals. Biol. J. Linn. Soc. 15:185-193.

Dinerstein, E. 1979a. An ecological survey of Royal Karnali-Bardia Wildlife Reserve, Nepal. Part I: Vegetation modifying factors, and successional relationships. Biol. Conserv. 15:127-149.

Dinerstein, E. 1979b. An ecological survey of the Royal Karnali-Bardia wildlife reserve, Nepal. Part II: Habitat/animal interactions. Biol. Conserv. 18: 5-38.

Dinerstein, E., and Price, L. 1991. Demography and habitat use by a Greater One-horned rhinoceros in Nepal. J. Wildl. Manage. 55:401-411.

Dinerstein, E., Shrestha, S., and Mishra, H.R. 1990. Capture, chemical immobilization, and radio-collar life for greater one-horned rhinoceros. Wildl. Soc. Bull. 18:36-41.

Foose, T.J. 1982. Trophic Strategies of ruminant vs nonruminant ungulates. Ph.D. dissertation. University of Chicago.

Funston, P.J., Skinner, J.D., and Dott, H.M. 1994. Seasonal variation in movement patterns, home range and habitat selection of buffaloes in a semi-arid habitat. Afr. J. Ecol. 32:100-114.

Gurung, K.K. 1989. The Indian rhinoceros. Pp 87-89. In: Indian wildlife (Israel and Sinclair eds.). APA Publications, Singapur. 380pp.

Harvey, M.J., and Barbour, R.W. 1965. Home range of Microtus ochrogaster as determined by a modified minimum area method. J. Mammology 46:398-402.

Hitchins, P.M. 1969. The influence of vegetation types on sizes of home ranges of black rhinoceros in Hluhluwe game reserve, Zululand. The Lammergeyer 10:81-85.

Ivlev, V.S. 1961. Experimental ecology of the feeding fishes. Yale University Press, New Haven, Conn.

Jnawali, S.R. 1989. Park-people conflict: Interaction between greater one-horned rhinoceros and people adjacent to the Royal Chitwan National Park in Sauhara area. M.Sc. thesis. Agri. Univ. of Norway. 86pp.

Jnawali, S.R., and Wegge, P. 1993. Space and habitat use by a small re-introduced population of greater one-horned rhinoceros (*Rhinoceros unicornis*) in Royal Bardia National Park in Nepal - A preliminary report. Pp. 208-217. In: Rhinoceros Biology and Conservation (O.A. Ryder, ed.). Proceeding of an International Conference, Zool. Society, San Diego, USA.

Jnawali, S.R., and Wegge, P. 1991. Is there room for endangered large mammals in a developing country? Preliminary results from a field study on the conservation of greater one-horned rhinoceros (*Rhinoceros unicornis*) in Royal Bardia National Park in Nepal. Faginfo 123:145-160.

Khan, M.K. bin., and Foose, T.J. 1994. Chairman's report: Asian rhino specialist group. Pachyderm 18:3-8.

Kiwia, H.Y.D. 1989. Ranging patterns of the black rhinoceros (Diceros bicornis) in Ngorongoro Crater, Tanzania. Afr. J. Ecol. 27:305-312.

Kolstad, M., Bø, T., and Wegge, P. 1985. The habitat and ecology of black grouse (Tetrao tetrix L.) during spring and summer in east Norway. Medd. Norsk Viltforskn. 13:1-46.

Larter, N.C., and Gates, C.C. 1994. Home-range size of wood bison: Effects of age, sex, and forage availability. J. Mammalogy 75:142-149.

Laurie, W.A. 1978. The ecology and behavior of the greater one-horned rhinoceros. Ph.D. dissertation. Cambridge University. 450pp.

Laurie, W.A. 1982. Behavioral ecology of the Greater One-horned rhinoceros (*Rhinoceros unicornis*). J. Zool., Lond. 196: 307-341.

McNab, B.K. 1963. Bioenergetics and the determination of home range size. Am. Nat. 97:133-140.

Mishra, H.R. 1982. Balancing human needs and conservation in Nepal's Royal Chitwan National Park. Ambio 11:246-251.

Mishra, H.R., and Dinerstein, E. 1987. New zip codes for resident rhinos in Nepal. Smithsonian Magazine 18:67-73.

Moe, S.R., and Wegge, P. 1995. Spacing behaviour and habitat use of axis deer (Axis axis) in lowland Nepal. Can. J. Zoology. In Press.

l large mammals in a

on the conservation of

l Bardia National Park

rhino specialist group.

(Diceros bicornis) in

of black grouse (Tetrao

orsk Viltforskn. 13:1-46.

. Effects of age, sex, and

horned rhinoceros. Ph.D.

l rhinoceros (*Rhinoceros*

ge range size. Am. Nat.

epal's Royal Chitwan

esident rhinos in Nepal.

e of axis deer (Axis

Nepal, S.K., and Weber, K.E. 1993. Struggle for existence: Park-people conflict in the Royal Chitwan National Park, Nepal. Asian Institute of Technology, Thailand. 199pp.

Neu, C.W., Bayers, C.R., and Peek, J.M. 1974. A technique for analsis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Owen-Smith, N. 1973. The behavioural ecology of the white rhinoceros. Ph.D. dissertation. University of Wisconsin.

Owen-Smith, N. 1988. Megaherbivores: Influence of very large body size on ecology Cambridge Univ. Press, New York. 396pp.

Pelinck, E., and Upreti, B.N. 1972. A census of rhinoceros in Chitwan National Park and Tamaspur forest, Nepal. HMG/FAO/UNDP National Park and Wildlife Conservation Project, Internal Report, Kathmandu. 10pp.

Pienaar, D.J., Bothma, J.D.P., and Theron, G.K. 1993. White rhinoceros range size in the south-western Kruger National Park. J. Zool., Lond. 229:641-649.

Pokharel, S.K. 1993. Floristic composition, biomass production, and biomass harvest in the grassland of the royal Bardia National Park, Bardia, Nepal. M.Sc. thesis, Agricultural University of Norway, Ås, Norway. 66pp.

Sale, J.B. 1986. Rhinos re-established in Utter Pradesh. Indian Forester, October:945-948.

Sale, J.B., and Singh, S. 1987. Reintroduction of greater Indian rhinoceros into Dudhwa National Park. Oryx 21:81-84.

Sharma, U.R., 1991. Park people interactions in Royal Chitwan National park, Nepal. Ph.D. dissertation. Univ. of Arizona. 274pp.

Sinha, S.P., and Sawarkar, V. B. 1993. Management of the reintroduction greater one-horned rhinoceros (*Rhinoceros unicornis*) in Dudhwa National Park Uttar Pradesh, India. Pp. 218-227. In: Rhinoceros Biology and Conservation (O.A. Ryder, ed.). Proceeding of an International conference, Zool. Society, San Diego, USA.

Vigne, L., and Martin, E.B. 1994. The greater one-horned rhino of Assam threatened by poachers. Pachyderm 18:28-43.

Voigt, D.R., and Tinline, R.R. 1980. Strategy for radio tracking data. Pp. 387-404. In: A hand in biotelemetry and radio-tracking, C.J. Amlaner and D.W. McDonald (eds.). Pergamon Press Ltd., Oxford.

Wegge P. 1985. Spacing pattern and habitat use of capercaillie hens in spring. Int. Symp on Grouse 3:499-513.

Wegge, P., and Larsen, B.B. 1987. Spacing of adult and subadult male Common Capercaillie during the breeding season. The Auk 104:481-490.

Wegge, P., Jnawali, S.R., and Moe, S.R. 1990. Bardia Conservation Research Program: Progress report 1990. Department of Biology and Nature Conservation, Agricultural University of Norway, King Mahendra Trust for Nature Conservation, Nepal, and Department of National Parks and Wildlife Conservation, Nepal. 37pp.

ction greater one-horned

Uttar Pradesh, India. Pp.

der, ed.). Proceeding of

of Assam threatened by

a. Pp. 387-404. In: A

D.W. McDonald (eds.).

s in spring. Int. Symp on

le Common Capercaillie

n Research Program:

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Conservation, Nepal, and

lepal. 37pp.

Table 1. Size (km²) and description of the habitat types of the study area in Bardia.

Habitat type	Size	Percentage of study area	Broad description
Sal forest	7.68	11.2	Upper dry land dominated by *Shorea robusta* and *Buchana latifolia*.
Riverine forest	6.81	9.9	Poorely drained mixed forest dominated by *Mallotus pllipp Syzigium cumini* and *Ehretia laevis*.
Khair-Sissoo forest	13.54	19.6	*Acacia catechu* and *Dalbergia sissoo* dominated forest gro the old riverbeds
Mixed Hardwood forest	0.98	1.5	*Oegenia dalbergiodes* and *Schleichera trijuga* intermixed l
Tall Grassland	8.19	11.9	Tall grassland communities on the floodplain dominated by *Saccharum spontaneum* and *S. bengalensis*. *Arundo donax* dominates the banks of riverlets.
Wooded Grassland	3.13	4.5	*Imperata cylindrica* dominated grassland with sparsely distr tree species, e.g. *Bombax ceiba*, *Bahunia racemosa* and *Ma phillippinensis*.
Phanta	0.95	1.4	Old cultivated open dry fields dominated by *Imperata cylin*
Bushy Pasture	4.80	6.9	Heavily grazed meadows dominated by *Imperata cylindrica*, *Chrysopogon aciculatus* and *Cyanodon dactylon* with scatte bushes of *Ziziphus mauritiana* and *Callicarpa macrophylla*.
River and riverbed	21.4	31.1	River, riverlets and seasonally flooded bare river beds cover with sand and boulders.
Cultivated land	1.4	2.0	Seasonally irrigated paddy fields and dry corn fields.

Table 2. Seasonal and annual home ranges (HR) and core areas (CA) of Bardia and Chitwan animals (in km^2±SD) in 1990-1993.

	Females				Males*			
	Bardia		Chitwan		Bardia		Chitwan	
	HR	CA	HR	CA	HR	CA	HR	CA
Winter	15.6±4.5	2.9±1.7	1.2±0.4	0.2±0.1	20.7±10.3	2.6±0.6	1.1	0.1
Hot	13.3±4.9	3.1±1.4	1.1±0.4	0.2±0.1	21.2±11.1	3.7±0.9	2.0	0.6
Monsoon	14.4±7.1	2.7±1.0	1.3±0.5	0.3±0.1	14.4± 7.1	2.9±0.2	1.4	0.4
All year	25.1±9.3	8.5±2.5	2.9±0.9	0.6±0.2	41.8± 4.4	9.3±3.9	3.3	0.9

* Only 2 males in Bardia and 1 male in Chitwan

of Bardia and Chitwan

Males*		
	Chitwan	
CA	HR	CA
2.6±0.6	1.1	0.1
3.7±0.9	2.0	0.6
2.9±0.2	1.4	0.4
9.3±3.9	3.3	0.9

Table 3. Average annual home range size of three social groups of rhinoceros in Bardia.

Sex	Annual home range size			
	Mean	sd		
Single females (2)	22.1	3.7		
Females with calf (6)	26.1	10.7	$W_s = 8$	ns
Males (2)	41.8	5.1	$W_{s\ m,f} = 19$	$p<0.05$

Table 4. Seasonal home ranges of different social groups of Bardia animals in 1990-1993.

Sex	Hot n	$\bar{X}$	sd	Monsoon n	$\bar{X}$	sd	Winter n	$\bar{X}$	sd	H	p
Females with small calves[a]	2	8.8	1.7	4	6.6	3.8	2	13.3	4.5	2.46	ns
Females with older calves[b]	4	14.4	3.2	3	18.6	11.2	3	20.9	9.4	2.17	ns
Single females	5	13.1	4.7	4	15.9	2.9	3	15.1	4.5	2.39	ns
Males (275: 29.0_D; 337: 13.3_{SD})	2	21.2	11.1	2 (9.2_{SD}; 30.4_D)	20.8	10.3	2 (13.5_{SD}; 28.0_D)	20.8	8.4	0.32	ns

a = calves < 1 year, b = calves 1-5 years, D = dominant, SD = sub-dominant, H = Kruskal-Wallis test

a animals in 1990-1993.

Winter				
n	$\bar{X}$	sd	H	p
2	13.3	4.5	2.46	ns
3	20.9	9.4	2.17	ns
3	15.1	4.5	2.39	ns
2	20.8	8.4	0.32	ns

ıb-dominant, H = Kruskal-Wallis

Table 5. Seasonal changes in home ranges of females* in Bardia

Seasons	n	% change	t**	p
Hot season	5	+ 0.9	10	ns
Monsoon season	4	+38.1	4	ns
Winter season	2	-31.1	both decreasing	
All season	11	+ 8.6	41	ns

* Females with calves < 1 year excluded in comparison,
** Wilcoxon matched pair signed-rank test

Table 6. Mean percent overlap in seasonal home ranges (HR) and core areas (CA), mean distance between seasonal occupancy centers (km) and mean range lengths (km/48 hrs) for Bardia and Chitwan animals.

	Bardia				Chitwan			
	Females		Males		Females		Males*	
Seasonal overlap	HR	CA	HR	CA	HR	CA	HR	CA
Hot/Monsoon	74.8	43.8	51.3	21.6	65.6	27.6	75.3	9.8
Monsoon/Winter	54.9	21.6	41.2	20.4	67.1	29.4	79.1	44.7
Winter/hot	59.6	25.4	46.3	18.6	61.1	26.5	58.5	0
Distance between OC								
Hot/Monsoon	1.1±1.4		6.2±1.6		0.5±0.2		0.5	
Monsoon/winter	3.1±1.8		3.3±0.9		0.4±0.2		0.3	
Winter/hot	2.5±1.3		4.9±1.4		0.6±0.1		0.6	
Range length								
Hot	2.5±0.3		4.1±2.2		0.5±0.1		0.5	
Monsoon	2.9±1.4		2.3±1.3		0.4±0.2		0.4	
Winter	2.8±1.2		3.3±1.6		0.8±0.1		0.3	

* Only 1 male in Chitwan

areas (CA), mean distance
18 hrs) for Bardia and

Chitwan			
Females		Males*	
HR	CA	HR	CA
65.6	27.6	75.3	9.8
67.1	29.4	79.1	44.7
61.1	26.5	58.5	0
0.5±0.2		0.5	
0.4±0.2		0.3	
0.6±0.1		0.6	
0.5±0.1		0.5	
0.4±0.2		0.4	
0.8±0.1		0.3	

Table 7. Utilization-availability data for habitat types in the Royal Bardia National Park, Nepal, 1990-93.

Habitat types	Total area km²	Expected proportion of usage	Actual proportion of usage	Bonferroni intervals	Ivlev's Electivity *Index*
Sal forest	7.68	0.112	0.004	$-0.001 \leq p \leq 0.009$*	-0.93
Khair-Sissoo forest	13.54	0.197	0.411	$0.376 \leq p \leq 0.446$*	+0.35
Riverine forest	6.81	0.099	0.257	$0.226 \leq p \leq 0.288$*	+0.44
Mixed Hardwood forest	0.98	0.014	0.013	$0.003 \leq p \leq 0.021$	-0.07
Tall Grassland	8.19	0.119	0.218	$0.189 \leq p \leq 0.247$*	+0.29
Wooded Grassland	3.13	0.045	0.009	$0.002 \leq p \leq 0.016$*	-0.67
Phanta	0.95	0.014	0.0	0	0.0
Bushy Pasture	4.80	0.070	0.0	0	0.0
Agriculture	1.40	0.020	0.0	0	0.0
River and riverbeds	21.40	0.311	0.088	$0.069 \leq p \leq 0.108$*	-0.56

* difference at 0.05 level of significance.

Table 8. Habitat use by Bardia rhinoceros (% locations in each habitat) in hot, winter and monsoon seasons compared with the habitat composition of the study area.

Habitat types	% available	Hot		Monsoon		Winter	
		M	F	M	F	M	F
Sal forest	11.2	0	0.3^{ns}	0	1.2*	0	0
Khair-Sissoo forest	19.6	25.0^{ns}	35.1*	33.1^{ns}	30.5*	47.0*	50.7*
Riverine forest	9.9	32.7*	22.7*	16.7^{ns}	24.4*	41.2*	32.0*
Tall Grassland	11.9	19.2^{ns}	26.4*	36.3*	28.5*	11.8^{ns}	12.9^{ns}
Mixed Hardwood forest	1.4	1.9^{ns}	1.5^{ns}	2.8^{ns}	2.0^{ns}	0	0.4^{ns}
Wooded Grassland	4.5	0	1.4*	0	0.5*	0	0.9*
Phanta	1.4	0	0	0	0	0	0
Bushy Pasture	7.0	0	0	0	0	0	0
Cultivated land	2.0	0	0	0	0	0	0
River and riverbeds	31.1	21.2^{ns}	12.6*	11.1*	12.9*	0	3.1*

* difference at 0.05 level of significance.

tat) a hot, winter
study area.

Winter	
M	F
0	0
47.0*	50.7*
41.2*	32.0*
11.8ns	12.9ns
0	0.4ns
0	0.9*
0	0
0	0
0	0
0	3.1*

Table 9. Composion (in percent) of habitats in the whole study area and in the seasonal core areas in Bardia in 1990-1993.

Habitat types	Composition of study area	Composition of core areas		
		Hot	Monsoon	Winter
Sal forest	11.2	0	0.1±0.2	0
Khair-Sissoo forest	19.6	30.3±2.9	28.6±4.0	40.4±5.4
Riverine forest	9.9	14.3±1.2	7.6±1.8	14.6±3.7
Tall Grassland	11.9	21.7±2.4	32.3±2.9	8.2±3.9
Mixed Hardwood forest	1.4	4.1±1.7	3.2±1.3	1.4±0.7
Wooded Grassland	4.5	4.1±0.9	4.0±1.5	9.0±3.6
Phanta	1.4	0	0.2±0.2	0
Bushy Pasture	7.0	0	0	0
Agriculture	2.0	0	0	0
River and riverbeds	31.1	25.5±1.7	24.0±1.3	26.4±0.8

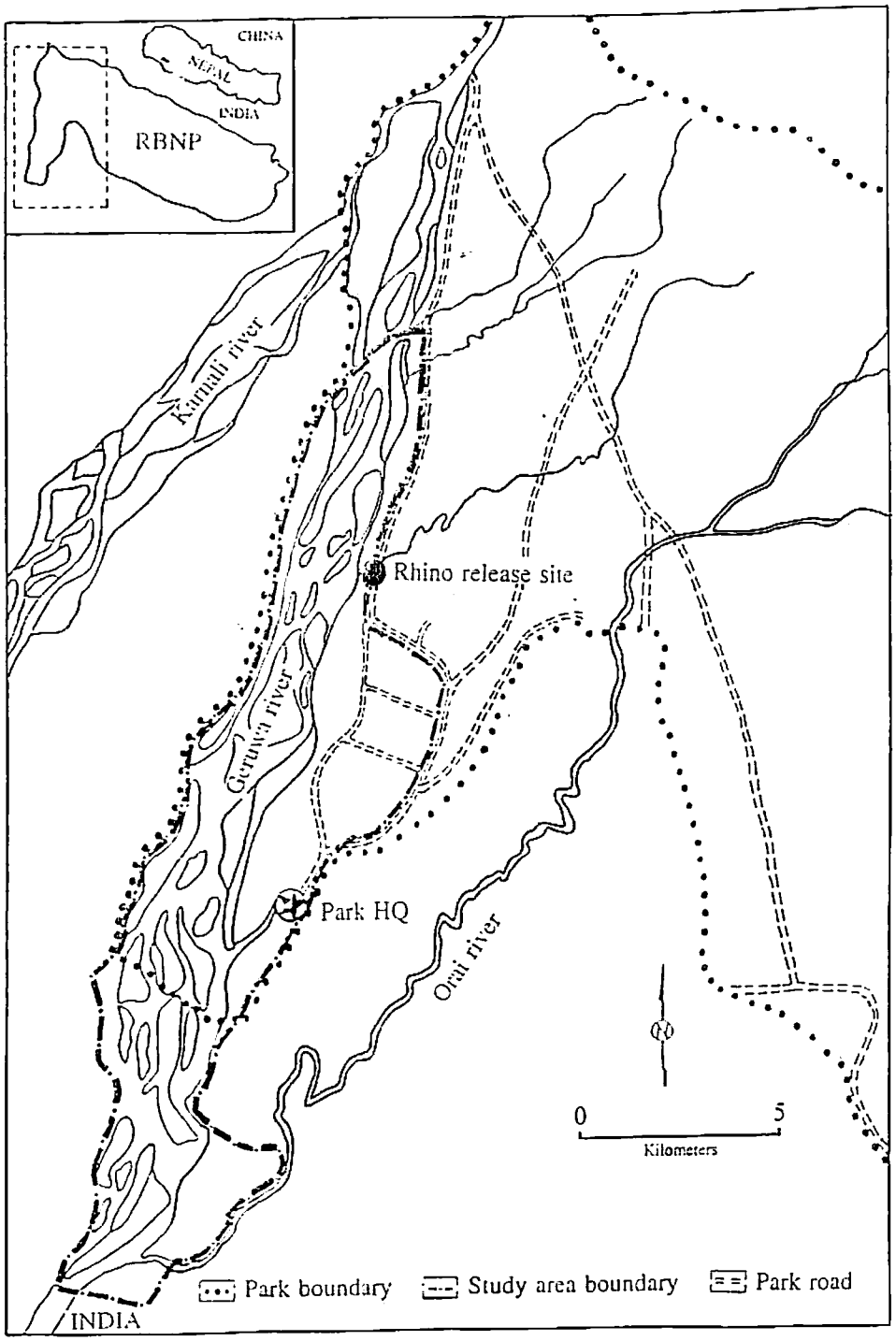
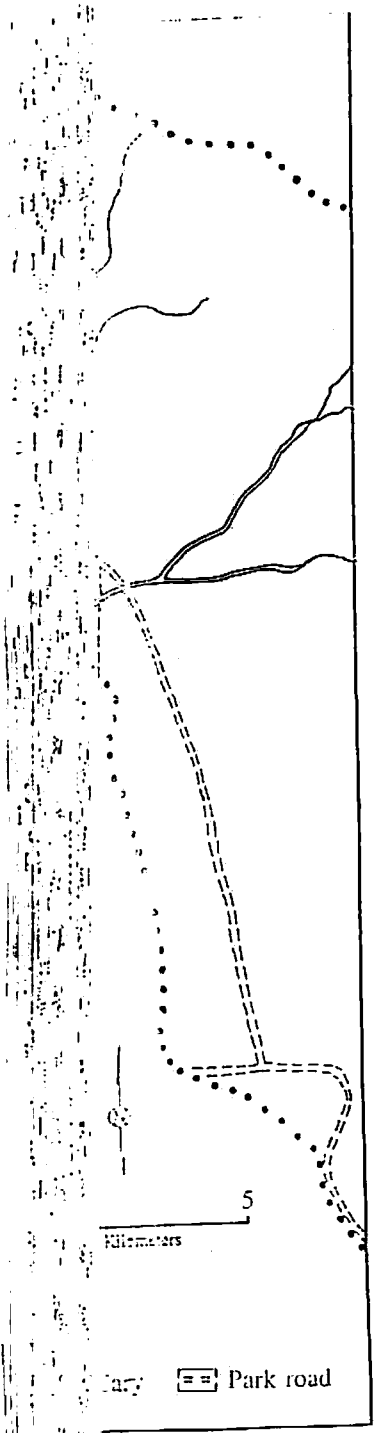


Figure 1. Map of the western section of Royal Bardia National Park showing study area.



...k showing study area.

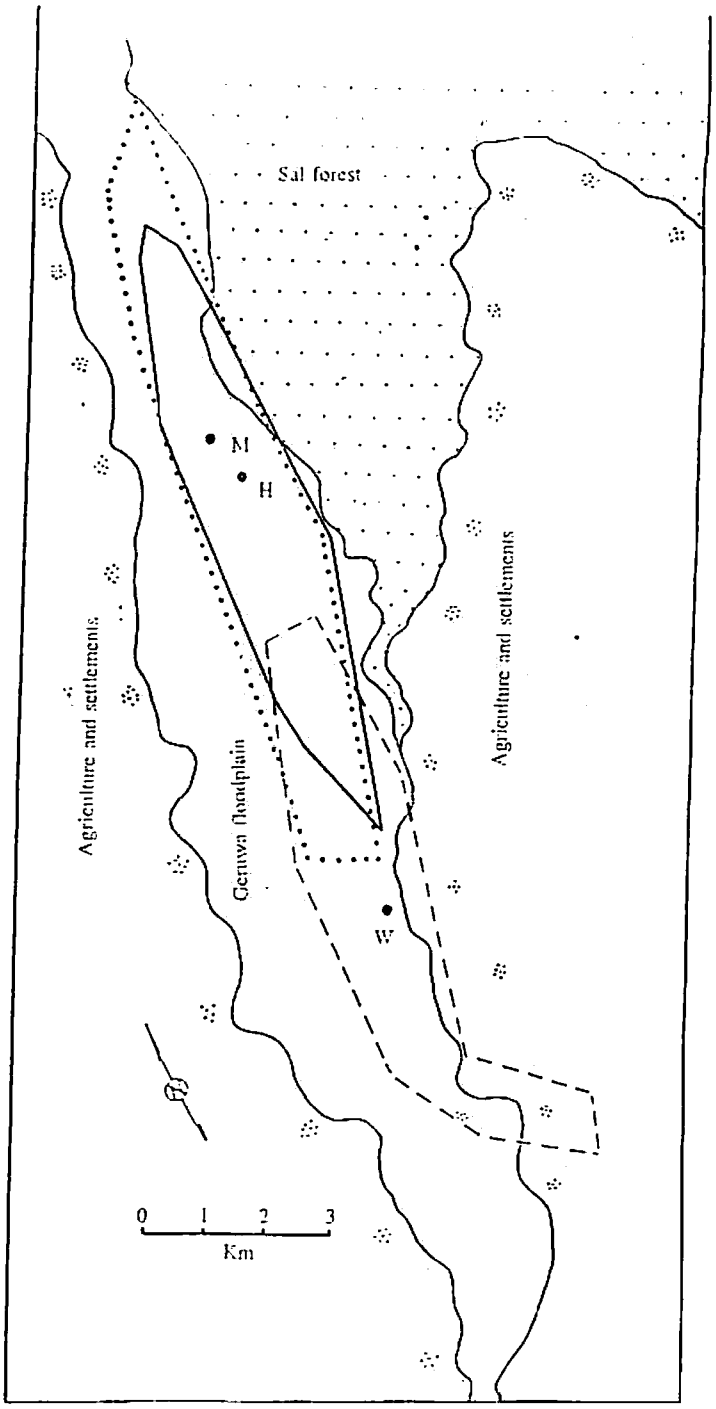


Figure 2. Seasonal home range and occupancy center of one adult female *Rhinoceros unicornis* in 1990/91.
Dotted line = monsoon (M), solid line = hot (H) and stipled line = winter (W). Floodplain consists of a mosaic of different habitat types (see text).

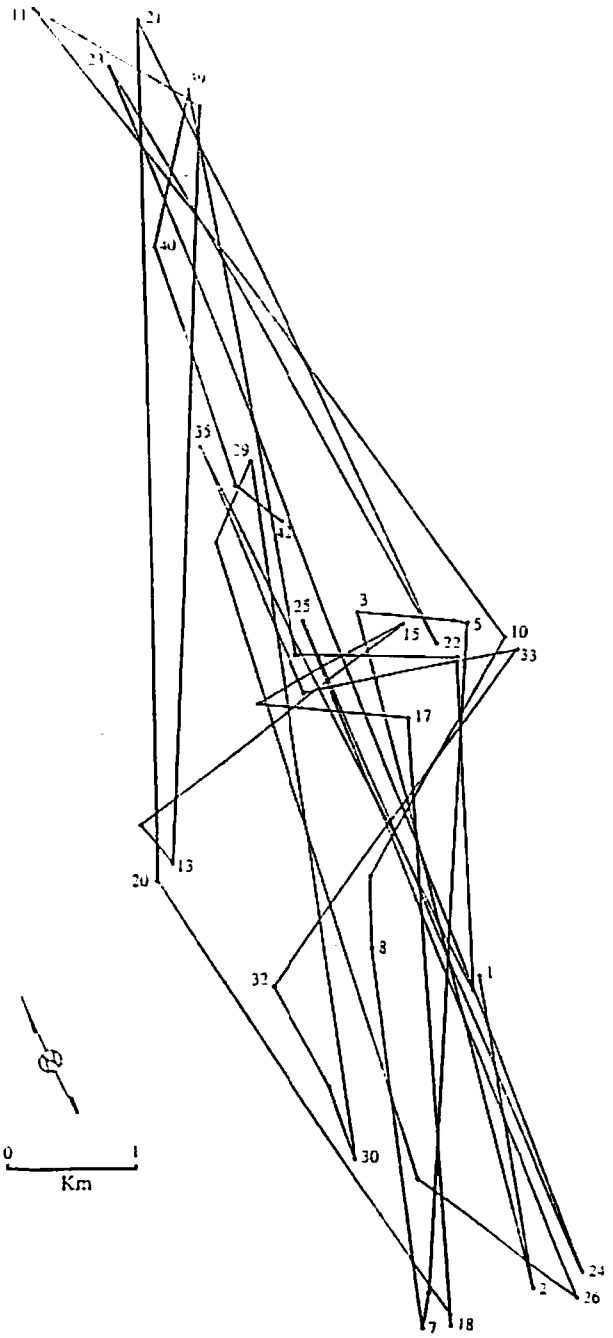


Figure 3. Range length of one adult female *Rhinoceros unicornis* during winter season, Royal Bardia National Park, 1990-1991.

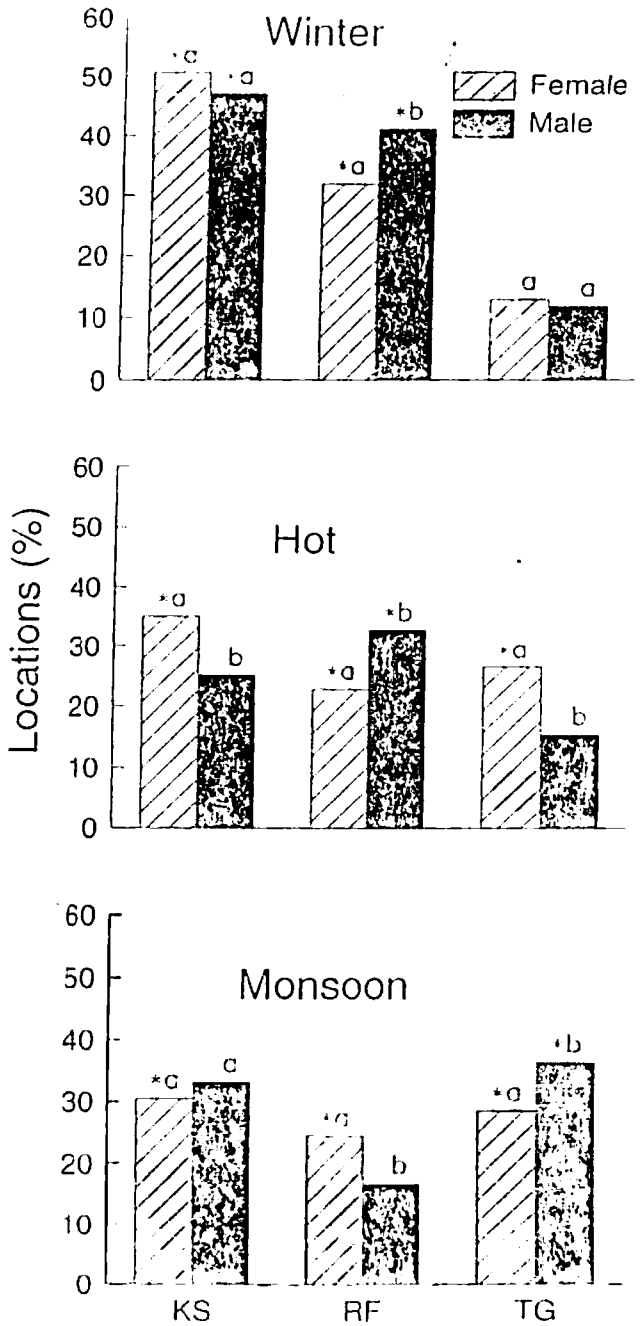


Figure 6. Seasonal distribution of animal locations (in %) on three main habitat types in Bardia. * denotes significant preference by each sex (Bonferroni intervals) and non-maching letters denote a significant difference in habitat between sexes in each season.

inoceros unicornis during

990-1991.

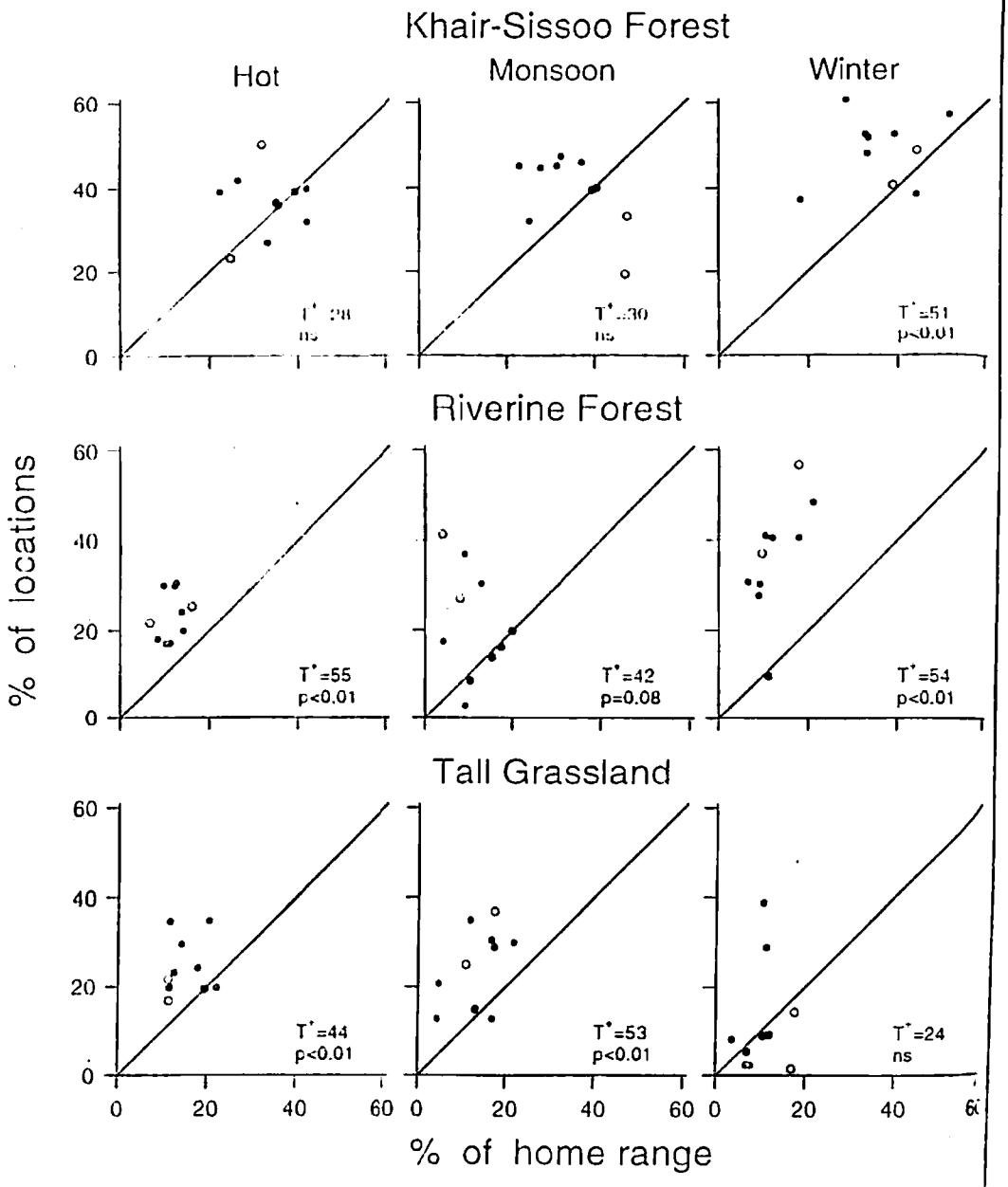
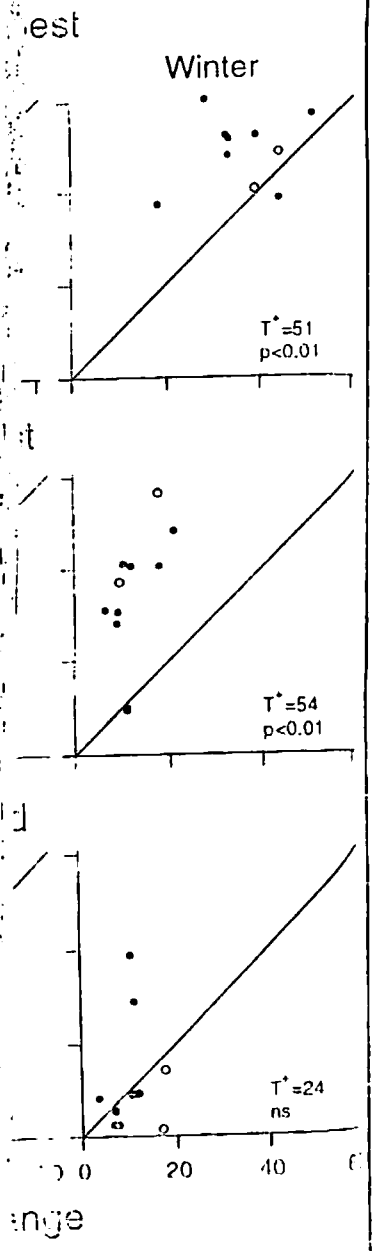


Figure 5. Percent of locations in the individual home ranges compared with habitat composition of the home ranges. Filled circles are females, and open circles are males.



...s compared with habitat
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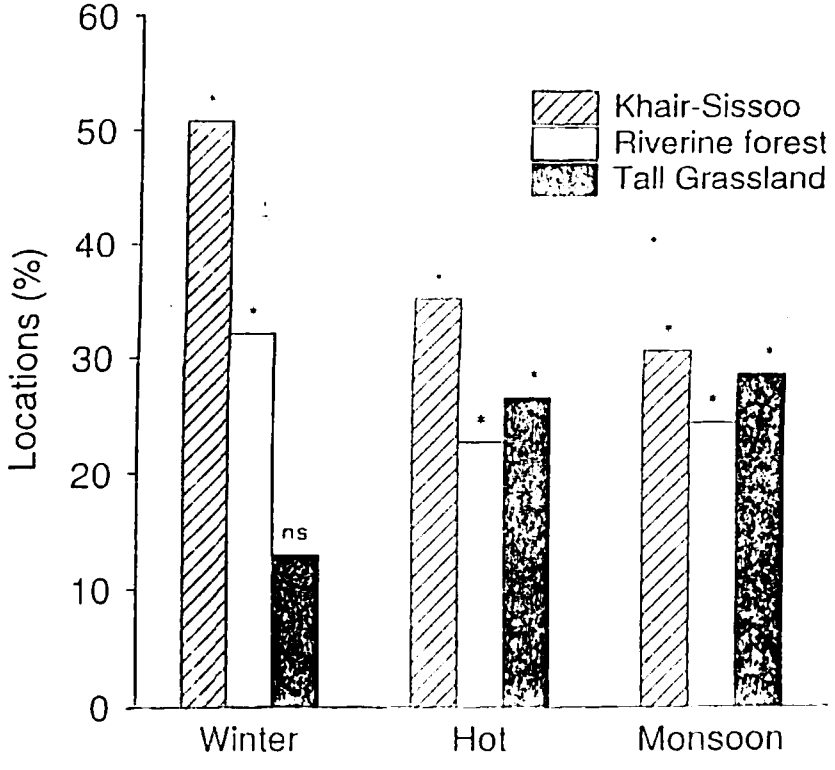

Figure 4. Proportion of female locations in three habitat types in three seasons (χ^2 test: *, $p < 0.05$, ns = not significant)

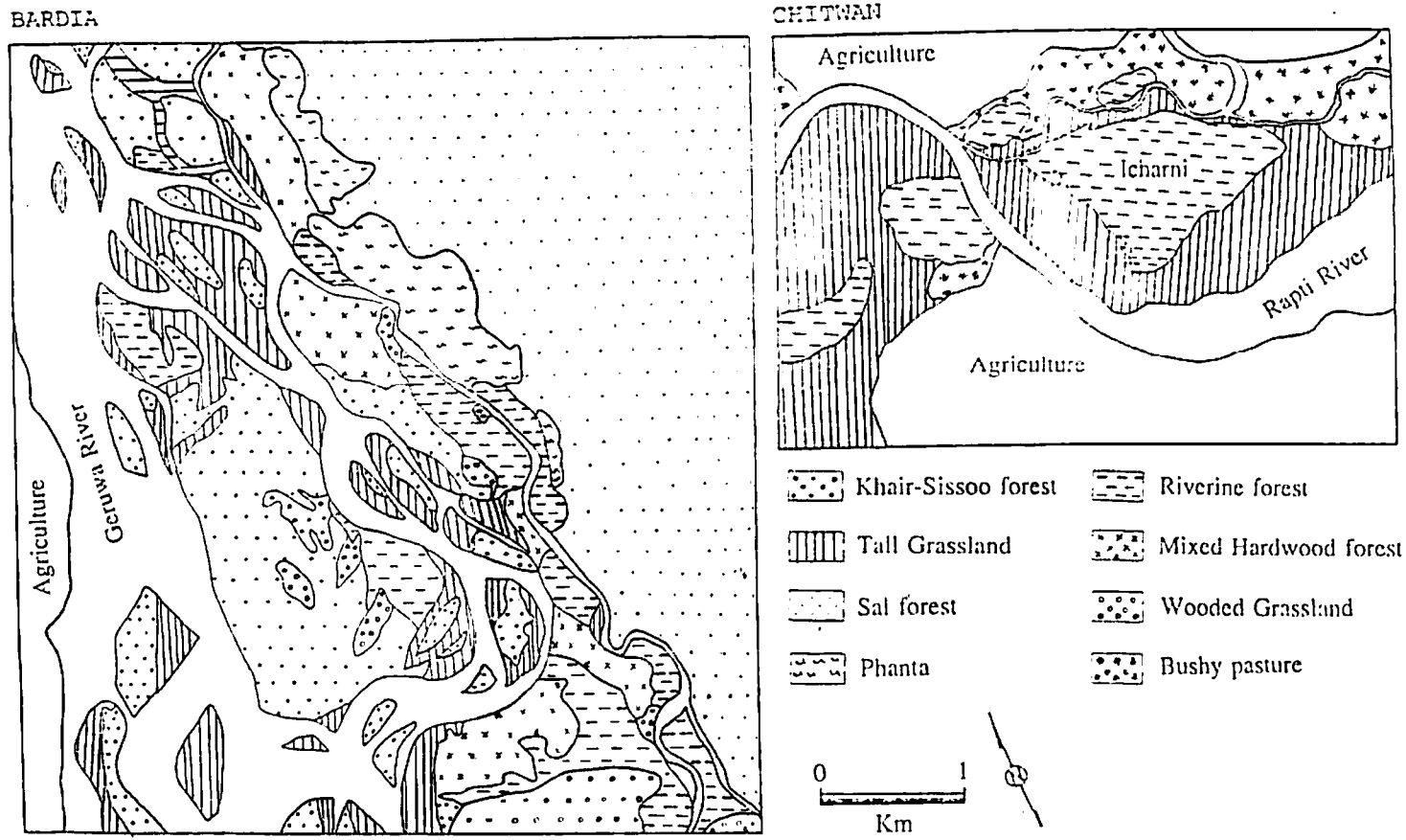

Figure 7. Map of two study areas in Royal Bardia NP (middle section) and Royal Chitwan NP showing distribution of different habitat types.

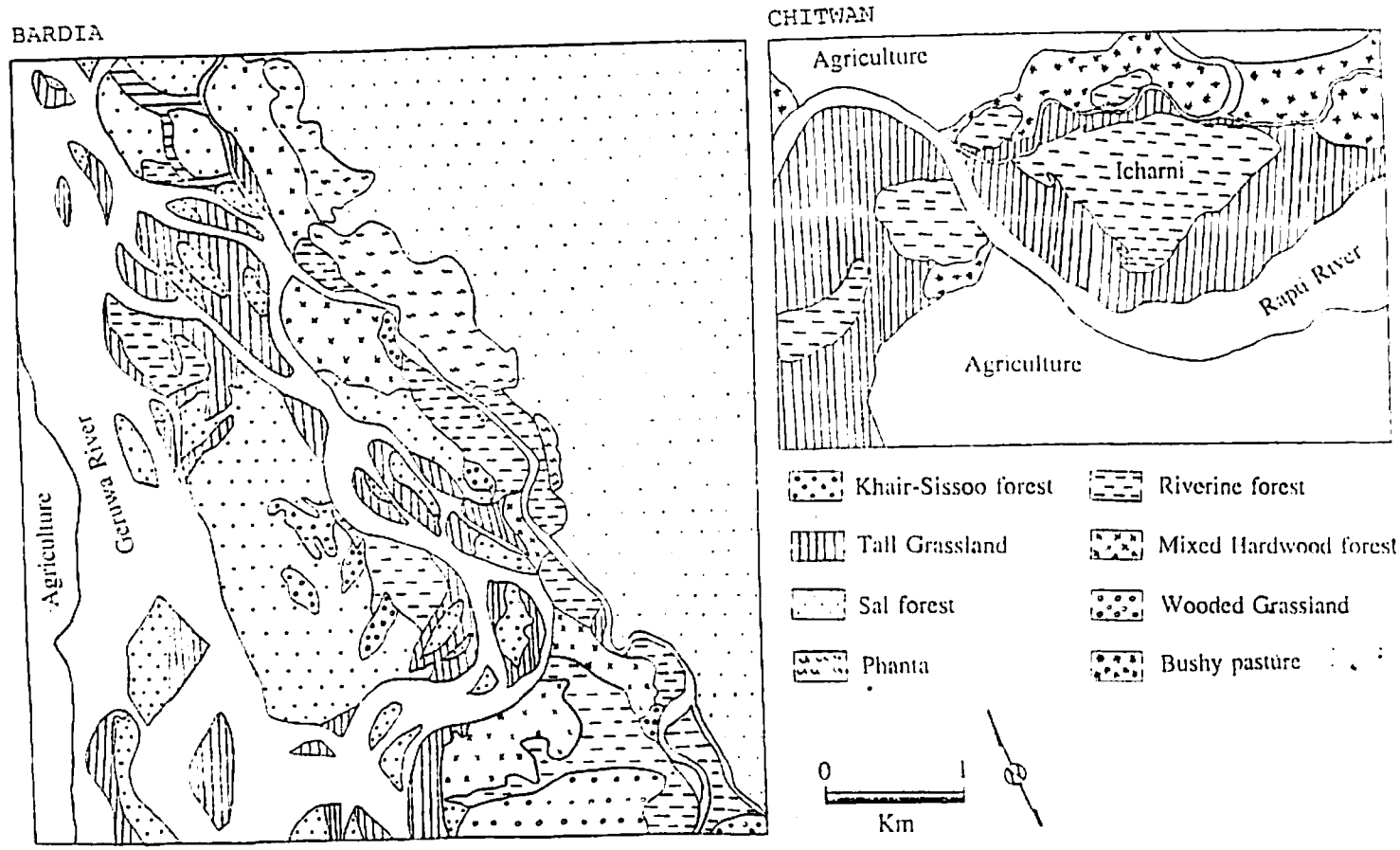

Figure 7. Map of two study areas in Royal Bardia NP (middle section) and Royal Chitwan NP showing distribution of different habitat types.

Figure 7. Map of two study areas in Royal Bardia NP (middle section) and Royal Chitwan NP showing distribution of different habitat types.

PAPER IV

PERFORMANCE OF A TRANSLOCATED POPULATION OF GREATER ONE-HORNED RHINOCEROS IN NEPAL

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KEY WORDS: Greater one-horned rhinoceros, *Rhinoceros unicornis*, translocation, Nepal

ABSTRACT

In 1986 13 rhinos (5 males and 8 females) were translocated from Royal Chitwan to Royal Bardia National Park in lowland Nepal. Following erratic and extensive movements by some individuals during the first few years (up to 100 km loop outside the park), in 1990 animals were settled in large home ranges (mean ca 28 km^2) within 20 km of the release site. Eight years after translocation, 15 animals were spread over an area of 70 km^2. Of the original transplants, six died due to injuries contracted during transport (1 male), poaching (1 male and 1 female), fighting (1 male), natural death (1 female, presumably during calf birth) and unknown cause (1 male). A total of 11 calves were born, 10 from the original female group

and 1 by a female calf born in 1987. One or two females of breeding age did not conceive during the 8 year period, probably due to social incompatibility and/or temporay lack of breeding males. Mean calving interval (N = 4) was 52 months (4.3 years), and age at first parturition of one female was 6 years, both similar to the donor population in Chitwan. One male bred at maximum age of 10 years, a younger age than reported in Chitwan. Two of the calves (18%) died within one year due to tiger predation (1) and loss of mother (1). In addition, 1 female was poached at age of 5 years. Growth of the Bardia founder population was depressed mainly due to direct and indirect effects of poaching: since release in late 1986 to end of 1994 (8 years) number of animals increased from 13 to 15. In the absence of poaching and other irregular deaths, breeding and net recruitment would have been close to the maximum potential of the species, indicating that the habitat in the Karnali floodplain is of adequate quality to sustain a small population of this endangered species.

INTRODUCTION

The world population of the greater one-horned rhinoceros (*Rhinoceros unicornis*) numbers less than 2000 animals, distributed mainly in two national parks, one in Kaziranga in India, the other in Royal Chitwan in Nepal (Khan and Foose 1994). To safeguard the species against eradication from disease or other calamaties, animals have been translocated from Chitwan to Dudhwa NP in India (Sale and Singh 1987) and to Bardia NP in Nepal (Mishra and Dinerstein 1987, Bauer 1988, Jnawali and Wegge 1993). No field study has yet been conducted which accurately describes the fate of animals after their release in a new environment. Such information is valuable when designing future translocations of large

Dispersal and settlement

Dispersal following release has been described by Bauer (1988) and Jnawali and Wegge (1991, 1993). One of the two adult males died after one week 0.5 km from the release site probably due to injuries contracted during transport. Six of the remaining 12 founders made extensive movements after release, whereas the others moved only a few km and settled with activity centers within 10 km of the release site. Longest trek was made by an adult female, the "Indian nomad": within 5 days she moved about 40 km SE through mainly cultivated fields and settlements to near the airport of Nepalgunj town, whereupon she turned back to enter the floodplain south of the Indian border, about 25 km south of the release site. Three years later, she appeared in the central part of the floodplain and was radio-collared. She gave birth to a male calf in the monsoon 1990 and remained in the southern section of the study area until she moved back permanently to the south of the Indian border in November 1991. One subadult male dispersed about 30 km SW near the Indian border, stayed there nearly two years, then moved 40 km northwards where it was poached. Another subadult male first moved 20 km southwards and established a temporary home range there. Three years later he moved north and was radio-collared shortly south of the release site. Soon thereafter, he moved south again and remained near the border until mid 1990. He then moved north and established a new home range in the central part of the floodplain. Two of unknown sex and age travelled 15 km north, spent two years near the Karnali gorge and then returned to near the release site, probably disturbed by bridge construction activities. The last animal to make erratic movement was another adult female: following release she moved eastwards 8 km out of the park, gave birth and remained there for two years, then returned

to the floodplain shortly south of the original release site.

Three of the six "dispersers" did not track preferred habitat during initial dispersal: instead of moving within and along the floodplain of similar habitat as in their original environment in Chitwan, they travelled directly across unsuitable sal forest, cultivated fields and populated areas, only resting temporarily in remnant patches of degraded forest. When failing to find suitable and undisturbed habitat, they returned back to the general area of the release site.

One of the subadult males probably dispersed out of the Park. During the first few years, unsubstantiated reports indicated his presence in the floodplain, but since 1989 we have no reliable information of his whereabouts or destiny. It is assumed that he died from unknown causes.

Five years after the initial release, the surviving 10 animals had spread out and settled in an area of about 70 km^2 (Fig. 2). Home ranges were large, ranging from ca 12 km^2 (smallest female range) to 45 km^2 (largest male range), which was about ten times larger than in the donor population (Jnawali and Wegge 1993). During the next two years seasonal and annual home ranges did not decrease in size, indicating that ranging behaviour was site specific, reflective of different composition and dispersion of preferred habitats and lower population density than in Chitwan (Jnawali and Wegge, in ms). With the loss of three males, the adult sex ratio was highly skewed, consisting in 1990 of 2 males and 8 females (Table 2).

Breeding and reproduction

Two of the adult females were pregnant when translocated and calved in Bardia the following year. Subsequently, 9 calves were born. Four females calved twice with calving

interval ranging from 48 to 58 months (mean 52 months or 4.3 years). The sex of seven calves was 4 male and 3 female. The first born female calf gave birth at the age of 6 years, assuming a gestation period of 16 months (Dinerstein and Price 1991). *Following the death* of one of the two adult males shortly after release, the other adult was dominant and mated most females until early 1990. He occupied the northern and central part of the floodplain and sired three of the first four calves born. An original subadult male who resided in the extreme southern part, bred the "Indian nomad" in winter 1989, at a maximum age of 10 years. In 1990 he moved north and challenged the older dominant male. After injuring him badly and displacing him to the northern part, he killed him in early winter 1992. Since then, he has been the dominant breeder and sired all subsequent 6 calves born to the population.

Nearly all breeding age females have calved within expected time intervals. Among the 3 nonpregnant adults translocated in December 1986, one calved in September 1988 and one in the monsoon (July-August) 1989, indicating that they conceived during one of their first estrous cycles. The third adult ("Indian nomad") did not breed before winter 1989, presumably because she occupied the southern part of the floodplain where only the subadult male was then present. Once he became sexually mature (and later "took over" the floodplain), she mated with him. Among the three originally subadult females, one calved in 1991 at an estimated age of 10-11 years. At least one of the two remainders have not yet given birth. A recently born calf (1994) may have been born to the last original subadult or to a female calf born in 1987.

Most calves were born during the monsoon: seven of nine calves were born during July-October, and two late in the hot season. With a gestation period of 16 months, mating appears to have been concentrated to the early part of the dry season (December-March).

Losses

Of the original founder population of 13 animals, seven died during the 8 year period. In addition, 2 of the 11 new calves died. Poaching was the most important mortality factor, responsible for a minimum of 3 of the known deaths. As a young adult, one original subadult male was killed west of the park near settlements while he was expanding his home range northwards, presumably in search of settled females. One adult female was poached near park headquarter inside the park 6.5 years after release, shortly after having given birth to her second calf. Her orphaned calf died a few weeks later, presumably due to starvation or malnutrition. Her first calf, a 5 year old female, was poached the year before just outside the park border.

Another adult female colonizer was found dead in sal forest outside the periphery of her home range with an unborn, fullterm calf. Circumstantial evidence indicated that she may have died from complications during late pregnancy or calf birth.

The only successfully established adult male was killed by a younger male in 1992. The fight took place west of Geruwa river, the park border, near cultivation and settlements. It started late in the evening and lasted until early morning. The loser may have been physically weakened from previous interactions with the same male, as ten months earlier he was seriously injured in another fight with the younger male. The location of the fight was 20 km north of the latters previous activity center near the Indian border.

In spite of a dense tiger population (Støen 1994), predation by tiger has killed only one calf so far. The calf was less than 6 months old. Hence, 10 of 11 calves survived tiger predation during their first 6 months of life.

DISCUSSION

After 8 years, the translocation of 13 individuals has led to the establishment of a seeemingly healthy, well-producing population of 15 animals in the Karnali floodplain. Breeding and reproduction has been "normal", with animals performing according to the biological potential of the species: the observed calving interval of 52 months and age at first reproduction of 6 years compare quite closely with an interval of at least 48 months and 6-7 years recorded in the donor population in Chitwan (Dinerstein and Price 1991). Also, male breeding at maximum 10 years of age was quite young compared to Chitwan, where all except one out of 28 breeders were estimated to be $\geq$ 15 yrs (Dinerstein and Price 1991) The unusual situation in Bardia probably explains this rapid breeding recruitment: due to very dispersed animal distribution, the dominant male was spatially out of contact with the female when she went into estrous and she accepted the 10 year old male for mating.

In Bardia, most calves were born during the monsoon, indicating some synchronization in mating. In a much larger sample in Chitwan, Dinerstein and Price (1991) reported no evidence of seasonal breeding. However, Laurie (1978) found a tendency for more births to occur during the monsoon and winter in the same population. Since our sample was quite small, it is too early to say if seasonal breeding indeed will "evolve" in the translocated population.

Breeding commenced quickly in the translocated population. Aside from two females that were pregnant during transportation and which delivered successfully some months later, the first conception must have occurred in Bardia 5-6 months after release. Although some females were not bred during their first estrous cycle, most of them conceived soon after they had settled in their new environment.

However, despite high reproductive potential, population growth has been quite slow, due mainly to poaching and stochastic events. Poaching of an adult female led to the loss of her newborn calf. The death of another female, probably due to physiological abnormalities during the terminal stage of pregnancy, also led to a loss of one calf. Further, the early death of two males may have delayed breeding among some females due to social disorder combined with a skewed sex ratio and spaced out distribution of breeding females: during the one year period when the young adult male was displacing the only adult breeding male, some females probably ovulated without conceiving because they were spaced out over a very large area.

The habitat quality of the Bardia founding population is seemingly quite adequate considering the breeding performance and survival rate of calves. Recent habitat and food studies also support this (Jnawali in ms.). However, the small population is already causing difficult problems for park management. Locally, severe crop damage problems have already developed as animals move outside the park border and forage on maturing crops of maize, rice and lentils during the latter part of the monsoon and early dry season (Bhatta 1994, and pers. obs.). The large home ranges and extensive movement of individual animals are interpreted to be a result of preferred habitats being small and dispersed, coupled with founders being recruited among habituated crop raiders in Chitwan (Jnawali and Wegge 1993, and in ms.). With strict control of poaching, the population is expected to increase more rapidly in the years to come, as the population now consists of 1 subadult and 7 adult females, and 1 adult and 2 subadult males, and 4 calves less than 4 years of age. This will enevitably lead to more crop raiding and harassment to local villagers. A major effort is therefore needed to reduce the conflicts with local communities. Since most of the "hot spots" are in localized and well-defined areas, electric fencing, combined with specially designed

trenches (Jnawali 1989), are the recommended methods to solve the management problem.

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REFERENCES

Bauer, J.J. 1988. A preliminary assessment of the reintroduction success of the Asian One-horned rhinoceros (*Rhinoceros unicornis*) in Bardia Wildlife Reserve, Nepal. Tiger Paper, October-December:26-32.

Bhatta, S.R. 1994. Beginning with buffer zone management: A case study from Royal Bardia National Park, Nepal. M.Sc. thesis. Agricultural University of Norway, Ås. 100pp.

Dinerstein, E. 1979. An ecological survey of the Royal Karnali-Bardia Wildlife reserve, Nepal. Part I: Vegetation modifying factors, and successional relationships. Biol. Cons. 15:127-150.

Dinerstein, E., and Price, L. 1991. Demography and habitat use by a greater one-horned rhinoceros in Nepal. J. Wildl. Manage. 55:401-411.

Jnawali, S.R. 1989. Park people interaction: Assessment of crop damage and human harassment by rhinoceros (*Rhinoceros unicornis*) in Sauraha area adjacent to the Royal Chitwan National Park, Nepal. M.Sc. thesis. Agricultural University of Norway. 102 pp. (unpubl.).

Jnawali, S.R., and Wegge, P. 1991. Is there room for endangered large mammals in a developing country? Preliminary results from a field study on the conservation of greater one-horned rhinoceros (*Rhinoceros unicornis*) in Royal Bardia National Park in Nepal. Faginfo 23:145-157.

Jnawali, S.R., and Wegge, P. 1993. Space and habitat use by a small re-introduced population of greater one-horned rhinoceros (*Rhinoceros unicornis*) in Royal Bardia National Park in Nepal - a preliminary report. Pp. 208-217. In: Rhinoceros Biology and Conservation (O.A. Ryder, ed.). Proceeding of an International Conference, Zool. Society, San Diego, USA.

Khan, M.K. bin., and Foose, T.J. 1994. Chairman's report: Asian rhino specialist group. Pachyderm 18:3-8.

Laurie, W.A. 1978. The ecology and behavior of the greater one-horned rhinoceros. Ph.D. dissertation., University of Cambridge, Cambridge, UK. 449pp. (unpubl.).

Laurie, W.A. 1982. Behavioral ecology of the greater one-horned rhinoceros (*Rhinoceros unicornis*). J. Zool. Lond. 196:307-341.

Lehmkuhl, J.F. 1989. The ecology of a south Asian tall grass community. Ph.D. dissertation. University of Washington, Seattle. 195pp. (unpubl.).

Mishra, H.R., and Dinerstein, E. 1987. New zip codes for resident rhinos in Nepal. Smithsonian Magazine 18:67-73

Sale, J.B., and Singh, S. 1987. Reintroduction of greater one-horned *rhinoceros into* Dudhwa National Park. Oryx 21:81-84.

Støen, O-G. 1994. The status and food habits of the tiger (*Panthera tigris*) population in the Karnali floodplain of Royal Bardia National Park, Nepal. M.Sc. thesis. Agricultural University of Norway. 41pp.

Table 1. Composition of the founder population released in the Karnali floodplain of Royal Bardia National Park in 1986.

Translocation time	Total number	Adult males	Adult* females	Subadult males	Subadult females
February 1986	4	0	1	1	2
December 1986	9	2	4	2	1
Total	13	2	5	3	3

* Two females were pregnant when translocated

Table 2. Mortality and recruitment of the founder population of 13 animals (5 males and 8 females) in Royal Bardia National Park during eight years after translocation.

Year	Mortality	Recruitment	Status end of year M a/s	F a/s	C*	Total
1986	1 ad. male from injuries		2/2	5/3	0	12
1987		2F	2/2	5/3	2	14
1988	1 young ad. male dispersed and dead	1F	3/0	8/0	3	14
1989	1 young ad. male poached	1M	2/0	8/0	4	14
1990		1M	2/0	8/0	5	15
1991		1M	2/0	8/2	4	16
1992	1 ad. male from fighting 1 ad. female natural death 1 subad. female poached 1 calf (<6 mo.) predated	1F 1	1/0	7/2	4	14
1993	1 ad. female poached 1 orphaned calf dead	1M 1	1/1	6/2	4	14
1994		1	1/2	7/1	4	15

a = adult (>6 years), s = subadult (4-6 years), C* = calves (<4 years)

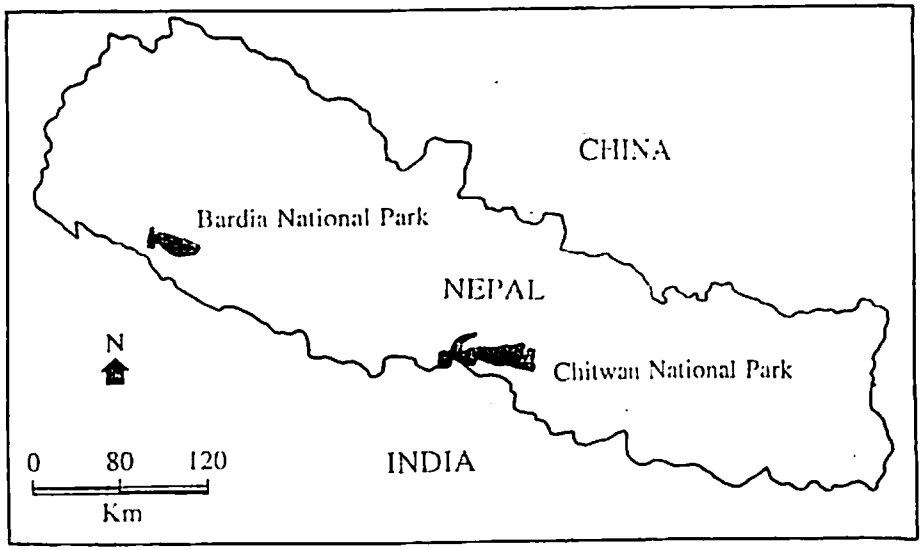

Figure 1. Map showing location of Chitwan NP (donor population) and Bardia NP (translocation) in Nepal.

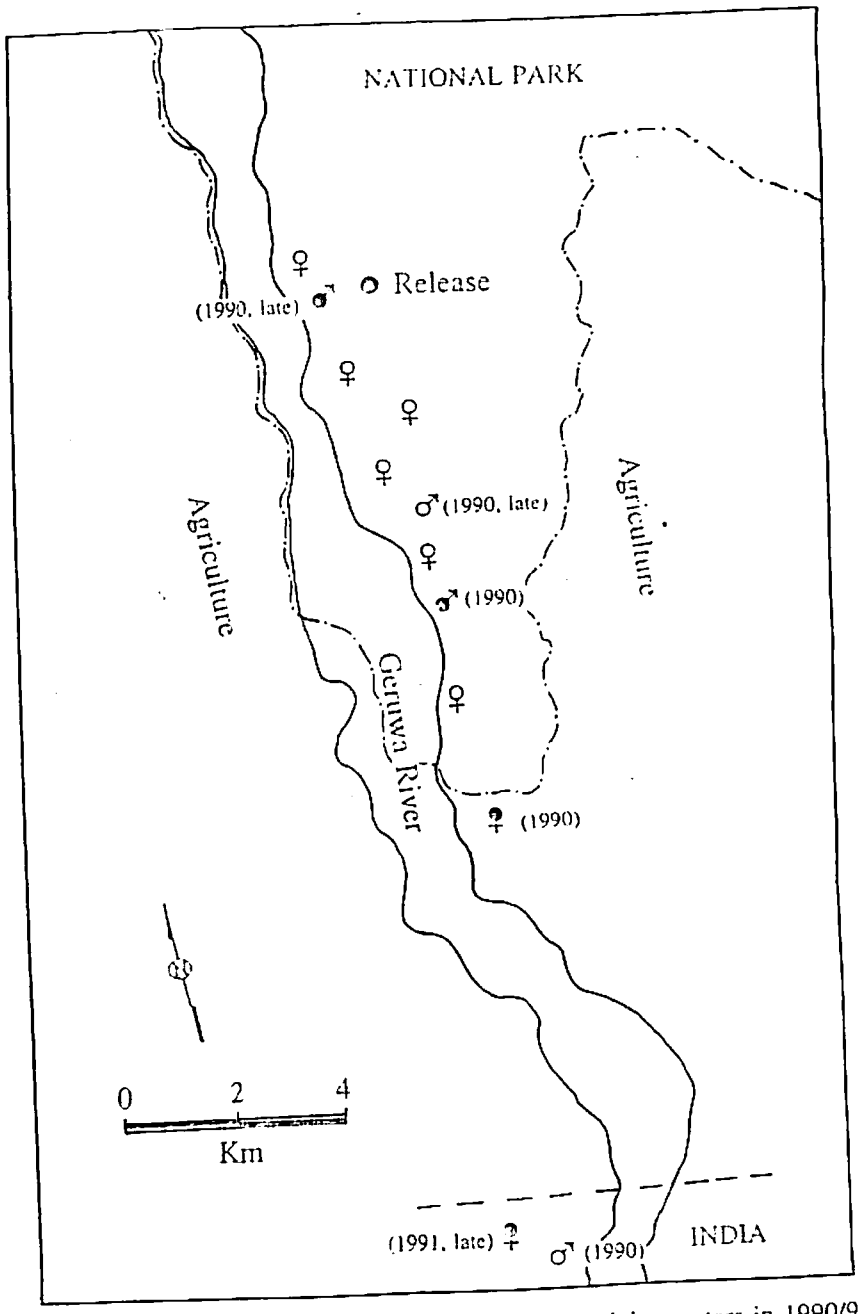

Figure 2. Release site (1986) and distribution of activity centers in 1990/91 of the translocated rhinos. ♀ Indian nomad, ♂ older male, ♂ younger male (see text).