Saccharum spontaneum, 4–6 m in height, which is a major forage plant. Aboveground 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, unpubl. data). Less frequently used are tall grasslands on higher terraces of the flood plain, dominated by mixed or near monospecific stands of 5–7-m-tall *Narenga porphyracorma*, *Saccharum benghalensis*, or *Themeda arundinacea* (Lehmkuhl 1988, Dinerstein 1989). Interspersed among flood plain grassland associations are patches of riverine forest dominated by *Trewia nudiflora*, *Ehretia elliptica*, and *Bombax ceiba*. During the cool season (Nov–Feb), rhinoceros heavily browse the understory shrubs and saplings common in most riverine forest stands (*Callicarpa macrophylla*, *Litsea monopetala*, *Mallotus philippinensis*, and *Murraya paniculata*) (Gyawali 1986).

Grasslands and riverine forests used by rhinoceros account for only 30% of the Park's 1,038-km^2 area. In contrast, nearly 70% of the Park is covered by sal (*Shorea robusta*) forest (Laurie 1978), an evergreen association on upland, well-drained slopes, that rhinoceros rarely use.

METHODS

Estimation of Abundance

We identified 4 subpopulations that were isolated by physical barriers (rivers and low mountains) or by ecological boundaries (extensive tracts of sal forest or cultivation): the Sauraha, the West, the Bandarjhola-Narayani River, and the South (Fig. 1). The Sauraha was the largest subpopulation (Laurie 1978) and was surveyed most intensively. It spanned the grasslands east of Kagendramali to the edge of the sal forest near Kasara in the west (Fig. 1). Laurie (1978) separated the Kagendramali and Sauraha populations, but we combined them after discovering frequent movement of animals between the 2 areas.

The Sauraha population was separated from the West population by nearly 12 km of unbroken sal forest, which we and Laurie (1978) 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 confluence of the Reu, Rapti, and Narayani rivers (Fig. 1). The rhinoceros population on Bandarjhola Island and along the Narayani River flood plain was separated from the West population by several kilometers of agricultural land and the Narayani River. Other populations were separated from the Sauraha population by extensive sal forest and a low mountain range (the South population), or by extensive sal forest, a highway, and cultivation.

We subdivided the Sauraha population into census blocks to examine habitat–density relationships (Fig. 1 inset). We used aerial photos to map the area of each block covered by *Saccharum spontaneum* and riverine forest, the 2 habitats most frequently used by rhinoceros (Laurie 1978). We censused mainly during the 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 in the open. After May, grass obscured newborn calves, and recognizing and sexing individuals was difficult.

We used photographs and sketches to identify individuals. Irregularities in skin folds and ear cuts provided the most striking and unambiguous characters for rapid field identification (Dinerstein In Press). All individuals were uniquely identified in our registry.

Between 1984 and 1988 we visited 95% of the Park and adjacent forests where rhinoceros were known to be found. Within each population, we located, identified, and photographed animals from domesticated elephants trained for this task. Searches were confined to morning and late afternoon, when animals were most active. Habituation of many individuals to close approach by elephants increased our ability to obtain detailed photographs. When individuals were less cooperative, they were surrounded by 4 elephants and herded toward the elephant supporting the photographer.

We estimated the minimal time required to find and identify every individual in our study blocks with results from a pilot study on 8 radio-collared animals (2 M and 6 ad F with calves) in the Icharni block. On 5 different days, we determined the number of radio-collared individuals that escaped visual detection during each of 2 searches. We found that about 16 hours of search time with 5 elephants (80 elephant-search hr) were needed to find all 39 animals in the 3.2-km^2 area. We then estimated search time in the other blocks in the Sauraha population by projecting the Icharni results on an area basis ($80/3.2 = 25$ elephant-search hr/km^2). In actuality, we spent far more time between 1985 and 1988 surveying blocks containing high population densities in the Sauraha population than the minimum estimate we computed because we conducted census work and photo-registration while doing other research activities.

We conducted censuses annually, and population sizes were adjusted to account for animals missed from 1 year to the next. Discovery of new animals, other than calves <1 year old, dropped from 10 to <1% from the first census year to the fourth year (also see Laurie 1978).

Sex and Age Criteria and Breeding Status

We determined the sex of animals by observing external genitalia, body size, size of neck folds (which are more pronounced in M), urination, and presence of calves. Also, adult males have wider horns at the base than adult females (Dinerstein In Press). Sex of calves <1.5 years old was difficult to determine and was recorded only if determination had been made by >3 observers or on 3 occasions by 1 observer. Laurie (1978) showed that a significant proportion of calves were incorrectly sexed and that initial sightings were biased towards males. Thus, we cautiously listed a large number of young calves as sex undetermined.

We classified animals in the Royal Chitwan NP population as calves (<4 yr), subadults (4–6 yr), or adults (>6 yr). Age categories were more specific for the intensively studied Sauraha population: calves (0–1, >1–2, >2–3, >3–4 yr); subadults (>4–5, >5–6 yr); young adults (6–12 yr, i.e., breeding F and nonbreeding M); intermediate-aged 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 were known. Subadults could be distinguished from adults by body size and horn size (Dinerstein In Press). We based our age classification for subadults on the potential for animals to breed. Because captive females and males show signs of reproductive activity by 6 years of age, we considered the subadult category to consist of animals between 4 and 6 years 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 (Dinerstein In Press). Young adult males lacked pronounced secondary neck folds. Individuals in the 12–20-year-old category were distinguished by moderate wear on the molars, horn size and wear, increased amount of facial wrinkles, size, scars, development of secondary neck folds in males, size of outer incisors, and for females, the birth of >1 calf. Individuals in the >20-year-old category had extensive wear on the molars and often displayed a combination of extensive facial wrinkles; major scars on the anal skin folds; torn or notched ears; broken, deeply grooved or eroded horns; and in males, extensive development of secondary neck and shoulder folds (Dinerstein In Press). Differences between age and sex classes were tested using Chi-squared analysis, with significance judged at the 0.05 level.

We identified males 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. Breeding males often squirt urine when closely approached, possess extensive secondary neck folds and large procumbent mandibular incisors, and are aggressive toward subordinate males (Laurie 1978, Dinerstein In Press).

Fecundity and Mortality Rates

We estimated interbirth interval in the Sauraha population by monitoring the period between births for 87 registered breeding-age females. Gestation in greater one-horned rhinoceros has been determined in zoos to be about 15.7 months (Laurie et al. 1983). Birth dates were assigned (±1 calendar month) to calves born during the study period in the Sauraha population. We calculated birth rates annually for each age class by dividing the number of live births within a female age class by the total number of females within that age class. For both age-specific fertility and survival, we used data for the entire Sauraha population, calculated these rates each year for all individuals in each class, and averaged them over all years. Our fecundity schedule is based on age-specific births of female offspring.

Mortality data for the Sauraha population was obtained from our searches and from official records of His Majesty's Government. Rhinoceros are considered property of the King, and all mortalities must be accounted for by an official inquest conducted by the Park warden. Animals most frequently died close to river banks, and their carcasses attracted large flocks of vultures, aiding location of dead animals. Drivers frequently grazed their elephants in the same areas. It is unlikely that deaths, other than newborns, escaped detection. We calculated age-specific mortality by dividing the number of individuals dying within an age class by the total number within that class.

Population Growth Rate

We used 2 methods for estimating population growth rate: (1) regression analysis on population estimates to give the observed rate of increase, and (2) instantaneous rate of increase (Caughley's [1977:108] r_s), calculated from survival and fecundity tables. We assumed that the observed vital rates were fixed and that these rates had persisted long enough for the population to stabilize. The validity of these assumptions is examined in more detail in our discussion section.

Habitat–Density Relationships

We recorded habitat selection, feeding, and wallowing behavior by 24-hour activity watches, direct observations recorded during >5,000 locations of 21 radio-collared individuals, and anecdotal observations during censuses. However, only 1988 data were used to compare densities within blocks with habitat variables because 2 of the variables, percent cover of *S. spontaneum* within the block and distance to river bank, were subject to marked annual variation due to siltation and flooding. We determined dominant plant associations within each block and percent cover by *S. spontaneum* by aerial photographs and ground surveys. We measured the distance from the edge of croplands to the center of the highest rhinoceros population density within a block (i.e., the part of the block containing the most frequent sightings of animals) on an aerial photograph. Because blocks ranged in size from 1.05 to 4.76 km^2, we tested to determine if density was positively correlated with block size. We used Spearman rank correlation analysis to test for correlations between rhinoceros densities and habitat variables associated among blocks.

RESULTS

Abundance

Sauraha Population.—The Sauraha population contained 228 registered individuals, 60.0–63.5% of the total estimated population for the Royal Chitwan NP in 1988 (Table 1). We added 3 calves to the 1988 cohort because we missed, on average, 3 births per year, which were subsequently registered in the following census year. This oversight was the result of births occurring after our last month of census work of the year. We also subtracted 15 animals from the subadult cohort registered by 1988. These subadults were registered as 4-year-old calves while still with their mothers, but most likely were re-registered as subadults in subsequent years. Laurie (1978) also adjusted his total estimate to account for this problem.

Royal Chitwan Population.—We estimated that the rhinoceros population in the Park totaled at least 358 individuals in 1988 (Table 1). Because we only censused the West and Bandarjhola-Narayani populations in 1986, we used our estimate for population growth between 1986 and 1988 in the Sauraha as a basis for projecting expected numbers in 1988 in these areas. We also corrected the West and the Bandarjhola-Narayani estimates to account for animals we likely missed: fresh dung and tracks in a few areas indicated the presence of animals we failed to register in both populations. From our data on the Sauraha population, we estimated we missed 7% of subadults and adults during the 1986 census which were subsequently added to the census in the following 2 years of searching (1987–88).

Translocations.—Twenty-four individuals were transferred from Royal Chitwan NP between 1986 and 1988 (Table 1); 17 adults and subadults were translocated to 2 reserves (4 subad F to Dudhwa Natl. Park, India; 5 M and 8 F to Bardia Natl. Park, Nepal). Seven calves were sent to zoos. All of these 24 animals came from the Sauraha population as did another 10 calves sent to zoos between 1978 and 1983. Calculation of vital rates and population growth rates between 1984 and 1988 did not include translocated adults.

Sex and Age Structure and Breeding Status

In the Sauraha population sex ratios for calves, subadults, young adults, and old adults were not significantly different from parity ($P > 0.05$) (Table 2). Intermediate-aged adult females (12–20 yr) were significantly more numerous than males ($\chi^2 = 4.3$, $P < 0.05$). No significant differences in sex ratio were found among adults in the West and Bandarjhola-Narayani populations. Subadults accounted for only 8% of the registered West population but 30% of the Bandarjhola-Narayani population.

Table 1. Total population estimate (N) of greater one-horned rhinoceros in the Royal Chitwan National Park, Nepal population, April 1988, excluding 34 animals translocated between 1980 and 1988.

Area	N
Sauraha and Kagendramali	252
Relocated animals (1986–88)	24
Subtotal	228
West population (1986)	61
Animals assumed to have been missed (7%) during 1986	4
Estimated population increase between 1986 and 1988	7
Adjusted subtotal West population	72
Bandarjhola Island and Narayani River	34
Animals assumed to have been missed (7%) during 1986	2
Estimated population increase between 1986 and 1988	4
Adjusted subtotal Bandarjhola Island and Narayani River	40
Outlying areas (Ramoli, Tikoli, Botesimra)	18
Total min. estimate for 1988	358

Compared with Laurie's (1978) age distribution in 1975, there appears to be a higher percentage of females with calves in 1975 than in 1978. However, if adult females >6–7 years old are excluded in calculating the 1988 data, then the proportion of females with calves is the same (Table 3). Also, subadults represent a smaller percentage of the Sauraha population in 1988, whereas the opposite is true for adults. These differences in age structure for the populations in 1975 and 1988 largely result from Laurie's (1978) designation of subadults as 3–9 years old, whereas we placed them between 4 and 6 years. If we reclassified our data into the same categories Laurie (1978) used, then age structure was the same in 1975 and 1988.

Male Breeders.—We estimated that 48% of adult males in the Sauraha population (n = 28) mated during the study period. Based on measurements and physical condition of all presumed breeders, we estimated that all but 1 breeding male was >15 years old. Old males (>20 yr) that remained close to high concentrations of breeding females were frequently attacked by younger, stronger males (Laurie 1978). In at least 5 instances during our study such attacks proved fatal. Another 5 breeding males presumed to have bred suffered serious wounds in fights and retreated to blocks with low densities of breeding-age females or to blocks where females and the most aggressive males were uncommon.

Fecundity and Mortality Rates

Seasonality of Births.—Fifty-three calves were born during the study period in the Sauraha population (Fig. 2). We could detect no significant difference in the distribution of births over the calendar year (χ^2 = 2.3, 11 df, P >

Table 2. Sex and age structure of greater one-horned rhinoceros populations in 3 areas in Royal Chitwan National Park, Nepal, April 1988.

	Sauraha						West				Bandarjhola and Narayani River			
Age category (yr)	M	Relocated M	F	Relocated F	Sex unknown	Total	M	F	Sex unknown	Total	M	F	Sex unknown	Total
Calves														
(0–1)	4		2	1	8	15								
(1–2)	3	2	2	3	4	14								
(2–3)	4	1	3	1	9	18								
(3–<4)	5		3	1	2	11								
(0–<4) combined	19		16		23	58	1	1	6	8	2	1	2	5
Subad														
(4–5)	9		3	1	3	16								
(5–<6)	3	1	7		6	17								
(4–<6) combined	13		11		9	33	1	1	2	4	3	4	3	10
Ad														
(6–12)	23	3	37	5	0	60	9	6	7	22	3	1	1	5
(12–20)	16		28	2	0	46	2	9	2	13	2	5		7
(>20)	19	2	22	1	0	44	3			3	7			7
Ad combined	63		95		0	158	14	15	9	38	12	6	1	19

Table 3. Sex and age composition of greater one-horned rhinoceros in the Sauraha subpopulation of Royal Chitwan National Park, Nepal, during 1975 (Laurie 1978) and April 1988.

Parameter	1975	1988
Ad sex ratio (% M)	34.1	39.9
Subad sex ratio (% M)	55.3	54.2
Subad and ad combined sex ratio (% M)	41.0	41.8
Ad as % of N	50.9[a]	63.5
Subad as % of N	22.8[a]	13.3
Ad F as % of N	33.5[a]	38.2
Ad F with calves as % of N	26.3[a]	20.9
Ad M as % of N	17.3[a]	25.3
% of ad M known or assumed to have bred during study period		48.3
% of ad F with calves	78.6	59.8
% of ad F with calves excluding F 6–7 yr old		77.0
% of ad F (6–12 yr) with calves		54.1
% of ad F (7–12 yr) with calves		90.9
% of ad F (12–20 yr) with calves		64.3
% of ad F (>20 yr) with calves		63.6
% of N <12 yr old		62.0

[a] Laurie (1978) classified subadults as 3–9 years old whereas we classified subadults to be 4–6 years old.

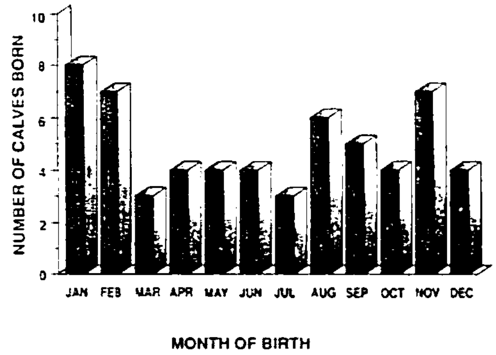

Fig. 2. Greater one-horned rhinoceros calf births by month in the Sauraha population between 1984 and 1988, Royal Chitwan National Park, Nepal.

0.99). We arranged our calf birth data in the same bimonthly format as Laurie (1978) used for the period between 1972 and 1975; the combined data set (n = 113) revealed no seasonality to parturition, either (χ^2 = 8.0, 5 df, P > 0.10). However, 43% of all calf births during the 8-year period occurred between 1 November and 28 February.

Age at First Reproduction.—We estimated that the mean age at first birth for 2 known-age females in the Sauraha population was between 7.0 and 7.5 years. An additional 15 (40%) adult females in the 6–12-year-old category (n = 37) had not given birth to their first calf by the end of our study. Of these, 13 were classified as between 6 and 7 years old, 1 between 7 and 8 years old, and 1 >8 years old. 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 the age of these 3 females by body size and classified them to be 6 years old when the births occurred, but they may have been younger.

Interbirth Interval.—We discovered either 2 sequential births, or estimated the subsequent calving of a female that was first registered with a calf <6 months old for 16 of 87 adult females. Three females gave birth again at 17, 22, and 31 months. However, each had extenuating circumstances surrounding the subsequent birth: a dominant bull trampled the first calf of 1 female, another calf was captured for shipment to a zoo, and the third calf was thought to have died or been separated from its mother. All 3 incidents apparently shortened the interbirth interval. The interbirth interval based on 13 animals whose calves survived to independence was 45.6 ± 1.8 months (range = 34–51 months). For 6 females with interbirth intervals longer than 48 months, one was 12–20 years old and five were >20 years old.

We estimated much longer interbirth intervals (60.9 ± 3.4 months, range = 48–88 months) for an additional 12 females. They were accompanied by calves of an advanced age and did not give birth during our 48-month study period. Six were categorized as 12–20-year-olds and six as >20 years old. Some of the oldest females may no longer have been reproductively active. Some may have aborted or given birth to a calf that died before it was registered, but this was probably rare. We predict that the mean interbirth interval for rhinoceros in 1988 in the Royal Chitwan NP will likely exceed 48 months, in contrast to Laurie's estimate of 42 months during 1975.

Age-Specific Birth Rate.—Intermediate-aged adult females (12–20 yr old) had higher birth rates than young or old adults (Table 4). Annual variation in birth rate for young adults was 4 times that for intermediate-aged females. Mean annual number of births recorded for the 95 registered adult females (including relocated animals) was 16.3 ± 1.0 calves per year during the study period (Table 4), or an annual birth rate of 7.6 ± 0.8%.

Mortality.—Twenty-eight animals died in the Sauraha population during our study (Table 5). As expected for a long-lived giant herbivore,

Table 4. Age-specific birth rates for adult females, Sauraha subpopulation of greater one-horned rhinoceros, Royal Chitwan National Park, Nepal.

Age category (yr)	Census yr 1984–85	1985–86	1986–87	1987–88	$\bar{x}$	SE
6–12	0.179	0.310	0.138	0.048	0.169	0.048
12–20	0.167	0.233	0.167	0.167	0.183	0.015
>20	0.208	0.130	0.130	0.087	0.139	0.022
No. calves born/yr	13	18	16	18	16.3	1.025

mortality for all age classes was low. The annual mortality rate for calves was 2.8 ± 0.9%, for subadults 2.2 ± 0.7%, and for adults 2.9 ± 0.5%. All calf mortality occurred during the first year of life when calves were prey for tigers. Beyond this age a rhinoceros is largely unaffected by predation. The disproportionate number of mortalities among male adults (15 of 18) suggests that competition for mates may be the most important contributor to deaths of males.

Population Growth Rate

The population growth rate calculated from regression analysis for the Sauraha population between 1984 and 1988 indicated an annual increase of 4.8% (Fig. 3). The population growth rate estimated from schedules of fecundity and survivorship for the same period indicated an annual increase of 2.7% (Table 6). We also combined Laurie's (1978) data from 1975 with our data and used regression analysis to estimate that the growth rate of the Sauraha population from 1975 to 1988 was 2.5% (r^2 = 0.961, $P <$ 0.01).

Habitat–Density Relationships

The highest rhinoceros densities in the Sauraha area coincided with blocks including large tracts of *Saccharum spontaneum* grassland (Table 7) (r_s = 0.7750, n = 9, $P < 0.05$). The correlation would have been stronger if translocated and relocated animals had been included. In 1986, prior to the removal of 17 animals for translocation, density in the Icharni block exceeded 10.5/km². Blocks covered mainly by *Narenga porphyracorma* grassland, the most common grassland association in the Park (Lehmkuhl 1988), supported lower densities. Dense stands of *Themeda arundinacea* along the edge of sal forest in the Jarneli, Simalchaur-Kachwani, and Bansbari blocks, were avoided.

High densities were not related to proximity to agriculture (r_s = 0.0297, n = 9, $P > 0.50$). 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, >3 km from the edge of cultivation. However, densities in blocks bordering agricultural areas may fluctuate seasonally in response to ripening of rice, corn, wheat, and lentils. During the rice harvest in October 1987, densities in the Badreini-Kharsar were 8.3/km² and declined to 3.0/km² by February 1988 after the beginning of grass fires in the Park. New shoots became abundant within 2 weeks after the fires, and most animals vacated the Badreini-Kharsar block to feed on the flush of new growth in *S. spontaneum* grasslands.

Table 5. The numbers and causes of mortalities for greater one-horned rhinoceros by sex and age class in the Sauraha subpopulation, Royal Chitwan National Park, Nepal, 1984–88.

	Ad						Subad			Calves		
	6–<12 yr		12–<20 yr		>20 yr		4–<6 yr					
Cause of death	M	F	M	F	M	F	M	F	Sex unknown	0–<1 yr	1–<4 yr	Total
Poaching			2					1	1			4
Tiger predation										4		4
Intraspecific fighting					5	1	1			1		8
Separation from F										1		1
Flood or quicksand	1				1					1		3
Cause undetermined		1	4	1	2							8
Total	1	1	6	1	8	1	1	1	1	7	0	28

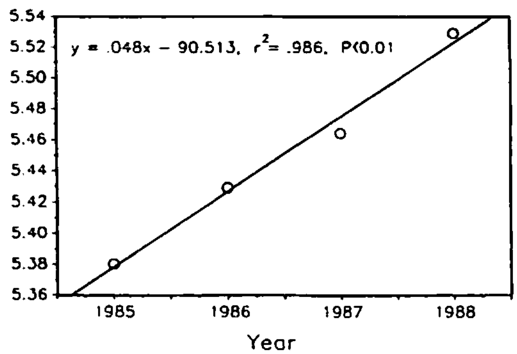

Fig. 3. Population growth of greater one-horned rhinoceros in the Sauraha subpopulation between 1984 and 1988, Royal Chitwan National Park, Nepal.

Table 6. Abridged life table for female greater one-horned rhinoceros in the Sauraha subpopulation, Royal Chitwan National Park, Nepal, based on mean mortality rates (after Caughley 1977).

Age interval (yr)	l_x[a]	p_x[b]	q_x	m_x[c]
0–1	1.000	0.889	0.111	0.0000
1–4	0.889	1.000	0.000	0.0000
4–6	0.889	0.950	0.050	0.0000
6–12	0.802	0.988	0.012	0.0845
12–20	0.746	0.992	0.008	0.0915
20–35	0.700	0.989	0.011	0.0695
35[d]	0.593	0.000	1.000	0.0000

[a] l_x refers only to survivorship to beginning of an interval.
[b] p_x is the average survivorship within an interval.
[c] m_x is the number of female offspring per female per time unit.
[d] Estimated mean maximum age based upon captive animals; females probably do not continue to breed in the wild beyond 35 years.

Blocks with the lowest densities (Simalchaur-Kachwani) lay farthest from the Rapti River and included the most sal forest. In other blocks, rhinoceros concentrated near the Rapti River. Densities were not correlated with the size of blocks ($r_s = 0.3333$, $n = 9$, $P > 0.20$).

DISCUSSION

Population Trend

The increase in number of greater one-horned rhinoceros since the late 1960's demonstrates that populations can rebound vigorously from heavy poaching when provided with sufficient habitat and protection. After declining from an estimated 1,000 animals in 1950 to 60–80 animals by 1962, when land clearing following malaria eradication and heavy poaching decimated the population, the Royal Chitwan NP population has increased by at least 311 individuals during the last 20 years (Caughley 1969; Laurie 1978; H. Mishra, King Mahendra Trust for Nat. Conserv., pers. commun.). Apparently, strict protection is responsible for reversing the decline.

Laurie (1982) 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 animals from the Kagendramali area), and he estimated the rate of increase to be between 2 and 6% per year. If we include all animals relocated after Laurie's study and during our study and assume that all individuals would have survived, then the Sauraha population has increased by 86 animals (48.9%) over a 13-year period.

The annual rate of increase estimated by regression analysis between 1975 and 1988 and the one between 1984 and 1988 derived from fecundity and mortality tables are similar. However, use of the life table for calculation of r assumes that observed vital rates are fixed and that these rates have persisted long enough for the population to stabilize. A lack of annual data on vital rates between 1976 and 1984 hinders attempts to determine the validity of the first assumption, and in particular, fixed mortality rates among older age classes. The longevity of rhinoceros and the difficulty of assigning animals to annual or biennial rather than broad age classes inhibit our effort to properly evaluate the assumption of a stable age distribution. However, circumstantial evidence that the second assumption holds is derived from several observations: (1) similarity in age structure of the Sauraha population in 1975 and 1988; (2) mortality rates for subadults and adults are the same; and (3) similarity in birth rates between 1972 and 1975 and between 1984 and 1988. Laurie (1978) estimated birth rates with a different method, but his maximum estimate (8.9%) is close to our estimate of 7.6%. Continued census efforts in Sauraha will determine the validity of assuming a stable age distribution.

In contrast to Sauraha, the West population (Fig. 1) has increased by only 22% since 1975, for a mean annual rate of increase of 1.7%/year. Comparisons were not possible for the Bandarjhola because we estimated population size by photo-registration whereas Laurie (1978) used dung piles and prints.

We predict that the Royal Chitwan NP population will continue to increase by at least another 100 individuals to a population size exceeding 500 by the year 2001. Several large tracts of *Saccharum spontaneum* grasslands,

Table 7. Greater one-horned rhinoceros densities (N/km^2) and some habitat characteristics of blocks censused in Royal Chitwan National Park, Nepal, April 1988. Estimates do not include relocated animals and are from the period when crops were not available in blocks adjacent to farmland.

Area and block	Size (km^2)	Rhinoceros 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
Bansbari	1.8	1.1	0.0	3.0	*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	30.54	6.4			
Kagendramali	6.84	4.7		1.0	
West	60.18	1.2		3.0	
Bandarjhola and Narayani	13.33	3.0		3.0	

suitable to maintain high densities, 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 (e.g., Ghatgain, LamiTaal) and in the West population are underused. In LigLige and LamiTaal, harassment by cattle herders may have kept rhinoceros from occupying these areas, which as of 1988 were managed strictly for wildlife.

The only comparable data on recovery of other rhinoceros populations comes from South Africa (Owen-Smith 1981). The Umfolozi white rhinoceros (*Ceratotherium simum*) population grew at a constant rate of 9.5%/year over a 13-year interval. High natality rates and short interbirth interval ($\bar{x}$ = 2.2 yr) accounted for this high rate of increase. The interbirth interval for the Umfolozi white rhinoceros population is half that of the Chitwan one-horned rhinoceros population even though the white rhinoceros is slightly larger in body mass.

Habitat Relationships

Densities were positively correlated with the percentage of the block covered by *Saccharum spontaneum* grassland. Along stream banks, *S. spontaneum* can account for >90% of above ground biomass by dry mass (E. Dinerstein, unpubl. data). Not surprisingly, *Saccharum* is a staple in rhinoceros diets; it normally exceeds 50% of the diet each month (Gyawali 1986; E. Dinerstein, unpubl. data). *Saccharum spontaneum* is unique among the common tall perennial grasses of the Park in that new shoots sprout soon after cutting, grazing, or inundation by floods. Other species do not sprout again until the next growing season regardless of these manipulations. New shoots of *S. spontaneum* also provide nutritious forage. Nitrogen content in regrowth is twice that of mature leaves and 10 times that of stems (E. Dinerstein, unpubl. data.).

Laurie (1978) argued that rhinoceros in the Royal Chitwan NP reached highest densities in areas supporting the greatest habitat diversity. He assessed habitat diversity qualitatively by counting the number of different habitat types in a given area. However, we contend that the highest densities are not related to degree of habitat diversity but rather to the abundance of *Saccharum spontaneum* which forms near-monospecific associations within each block. The other common association in the high density blocks is patches of riverine forest (see Dinerstein and Wemmer 1988). This forest association also exhibits low within-habitat diversity where 2 species, *Trewia nudiflora* and *Ehretia elliptica*, dominate 77% of the canopy (Dinerstein and Wemmer 1988).

Long-Term Prospects for Conservation

Severe monsoon floods, disease, and heavy poaching pose major threats to current greater one-horned rhinoceros populations. During the devastating flood of the Brahamaputra River Valley in 1988, about 70% of the Kaziranga National Park remained under 2.7–4 m of water for several weeks. At least 41 animals, including 23 calves, perished (Anonymous 1988). Recent land clearing has limited access to upland forested areas above the flood plain in the Kaziranga sanctuary. If rhinoceros and other vertebrates become isolated from upland forests, floods that 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 programs in Nepal and India to move animals to parks that historically harbored rhinoceros populations, are now well-protected from poachers, and contain suitable habitat (Mishra and Dinerstein 1987). Translocated populations have been established in Dudhwa National Park, Uttar Pradesh, India, and in Royal Bardia National Park, western Nepal. 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.

LITERATURE CITED

ANONYMOUS. 1988. Kaziranga under water. Himal Mag. Nov.-Dec.:33.

BLANFORD, W. T. 1888. The fauna of British India including Ceylon and Burma; Mammalia. Taylor and Francis, London. 617pp.

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

———. 1977. Analysis of vertebrate populations. Wiley & Sons. New York, N.Y. 234pp.

DINERSTEIN, E. 1989. The foliage-as-fruit hypothesis and the feeding behavior of South Asian ungulates. Biotropica 21:214–18.

———. In Press. Sexual dimorphism in greater one-horned rhinoceros. J. Mammal.

———, AND G. F. MCCRACKEN. 1990. Endangered greater one-horned rhinoceros carry high levels of genetic variability. Conserv. Biol. 4:417–422.

———, AND C. WEMMER. 1988. Fruits *Rhinoceros* eat: dispersal of *Trewia nudiflora* in lowland Nepal. Ecology 69:1768–1774.

GYAWALI, S. R. 1986. Diet analysis of greater one-horned rhinoceros by fecal analysis. M.S. Thesis, Tribhuvan Univ. Kathmandu, Nepal. 34pp.

LAURIE, W. A. 1978. The ecology of the greater one-horned rhinoceros. Ph.D. Thesis, Cambridge Univ. 450pp.

———. 1982. The ecology of greater one-horned rhinoceros. J. Zool. Soc. London. 196:307–341.

———, E. LANG, AND C. P. GROVES. 1983. *Rhinoceros unicornis*. Mamm. Species. 211:1–6.

LEHMKUHL, J. 1988. The ecology of a South Asian tall-grass community. Ph.D. Thesis, Univ. Washington, Seattle. 195pp.

MISHRA, H. R. 1982. The ecology and behavior of chital (*Axis axis*) in the Royal Chitwan National Park, Nepal. Ph.D. Thesis, Univ. Edinburgh, Scotland. 240pp.

———, AND E. DINERSTEIN. 1987. New zip codes for resident rhinos in Nepal. Smithsonian Mag. 18:66–73.

OWEN-SMITH, N. 1981. The white rhino overpopulation problem and a proposed solution. Pages 129–150 *in* P. A. Jewell and S. Holt, eds. Problems in management of locally abundant wild mammals. Academic Press, New York, N.Y.

SEIDENSTICKER, J. 1976. Ungulate populations in Chitwan Valley, Nepal. Biol. Conserv. 10:183–210.

Received 3 October 1989.
Accepted 4 January 1991.
Associate Editor: DeYoung.

Endangered Greater One-horned Rhinoceros Carry High Levels of Genetic Variation

ERIC DINERSTEIN*

Smithsonian/Nepal Terai Ecology Project
Conservation and Research Center
National Zoological Park
Front Royal, VA 22630, U.S.A.

GARY F. MCCRACKEN

Department of Zoology
Graduate Programs in Ecology and Ethology
University of Tennessee
Knoxville, TN 37996, U.S.A.

Abstract: *The population of* Rhinoceros unicornis *in the Chitwan Valley, Nepal, was reduced to an estimated effective population size (N_e) of 21–28 individuals (60–80 total animals) in 1962. Protein electrophoresis shows that heterozygosity remains very high in this population (H_o = 9.9%) despite its near extinction. We attribute this high heterozygosity to large N_e's prior to the population bottleneck, the recent occurrence of the bottleneck, and long generation time. These results illustrate the importance of considering historical demography and life history parameters when evaluating the possible genetic effects of bottlenecks in wild populations. They also offer support to recent arguments that the erosion of genetic diversity attributed to bottlenecks may be overemphasized.*

Resumen: *La población de* Rhinoceros unicornis *en el Valle Chitwan en Nepal, fue reducida a un tamaño de población efectiva estimada (Ne) en 21–28 individuos (60–80 total de animales) en 1962. La electroforésis de proteínas muestra que la heterosidad permanece muy alta en esta población (H_o = 9.9%) a pesar de estar a punto de extinguirse. Atribuimos esta heterosidad al gran Ne's anterior al cuello de botella en la población, a la reciente ocurrencia del cuello de botella y al largo tiempo generacional. Estos resultados ilustran la importancia de considerar el historial demográfico y los parámetros biológicos cuando se estén evaluando los posibles efectos de cuello de botella en las poblaciones silvestres. Los resultados también apoyan las recientes discusiones de que la erosión de la diversidad genética, debido a los cuellos de botella, puede estar siendo sobreenfatizada.*

Introduction

The genetic consequences of near extinction are a major concern in conservation (Franklin 1980; Frankel & Soulé 1981; Schonewald-Cox et al. 1983; Allendorf & Leary 1986; Allendorf 1986; Lande & Barrowclough 1987). The concern arises because severe reductions in population size (bottlenecks) result in losses of heterozygosity, allelic diversity, and polymorphism. This may lower the fitness of individuals and jeopardize the long-term survival and evolutionary potential of their populations (Franklin 1980; Allendorf 1986). The lack of genetic diversity in populations of numerous rare and

Paper submitted October 27, 1989; revised manuscript accepted March 20, 1990.

* *Present address: World Wildlife Fund, 1250 24th St. NW, Washington, D.C. 20037.*

endangered species has been attributed to bottlenecks (Bonnell & Selander 1974; Pemberton & Smith 1985; O'Brien et al. 1987; O'Brien et al. 1985; O'Brien & Evermann 1988), and because of the attention given to bottleneck effects the preservation of genetic diversity has been a focus in designing recovery plans for some species (Lande 1988).

However, the conclusion that a population carries low diversity because it has experienced one or more bottlenecks is inferential. Genetic analysis of all species cited in the above references was conducted only after their populations had been reduced; therefore, cause and effect between low diversity and small population size has not been demonstrated. We can estimate present levels of variability, but low diversity at present does not indicate how much diversity a population had in the past.

Although the consequences of losing genetic diversity are serious for normally variable populations, several authors have questioned whether the genetic effects of bottlenecks are being overemphasized in conservation literature. Bottlenecks must be very small and repeated or sustained over several generations for major erosion of heterozygosity (Nei et al. 1975; Chakraborty et al. 1980; Allendorf 1986; Lande & Barrowclough 1987). Moreover, the probability of extinction is high when population size is very small (Goodman 1987; Lande 1988; Pimm et al. 1989). Thus, the loss of genetic diversity due to bottlenecks may be less of a problem than current literature suggests because most small populations probably will go extinct before losing a substantial portion of their existing variability (Lande 1988; Pimm et al. 1989).

It is improbable that pre- and post-bottleneck genetic surveys will be conducted for many wild populations, and the relationship between current genetic diversity and past demographic events will remain inferential in most cases. However, we can evaluate the strength of this inference by considering demographic features of populations (e.g., mating systems, dispersion and dispersal patterns) that affect levels of variation and by obtaining the best data available on historic population sizes. If we can estimate current and past effective population sizes (N_e), we can calculate expected erosion rates of pre-bottleneck genetic diversity (Lande & Barrowclough 1987) to assess the plausibility of the bottleneck scenario for explaining the levels of diversity observed in current populations. Even approximate estimates of N_e will allow calculations that could be important to the inferential arguments on which this controversy centers.

Here we use this approach to evaluate data on the genetic diversity observed in a wild population of the greater one-horned rhinoceros, *Rhinoceros unicornis*. *R. unicornis* is one of the world's most endangered large mammals and persists today in only two populations exceeding 80 individuals (Laurie 1978; Dinerstein & Wemmer 1988; Dinerstein & Price, in press; Fig. 1). Both of these populations approached extinction within this century, but have recovered substantially in recent years. The population in what is now Royal Chitwan National Park, Nepal, was reduced to an estimated effective size of 21–28 (60–80 total individuals) in the early 1960s but recovered to almost 400 animals by 1988 (Dinerstein & Price, in press). The population in Kaziranga National Park, Assam, India, was reduced to less than 100 individuals in ca. 1912 (Laurie 1978), but now has an estimated 1,500 animals (E. Martin, personal communication).

Methods

In 1986–87, we obtained blood and dermal tissue samples from 23 Chitwan *R. unicornis* (about 6% of the current total population) immobilized as part of a larger field study and translocation program (Dinerstein et al., 1990; Dinerstein & Price, in press). Plasma and red blood cells were separated and all samples frozen in liquid nitrogen. After their arrival in the laboratory, sam-

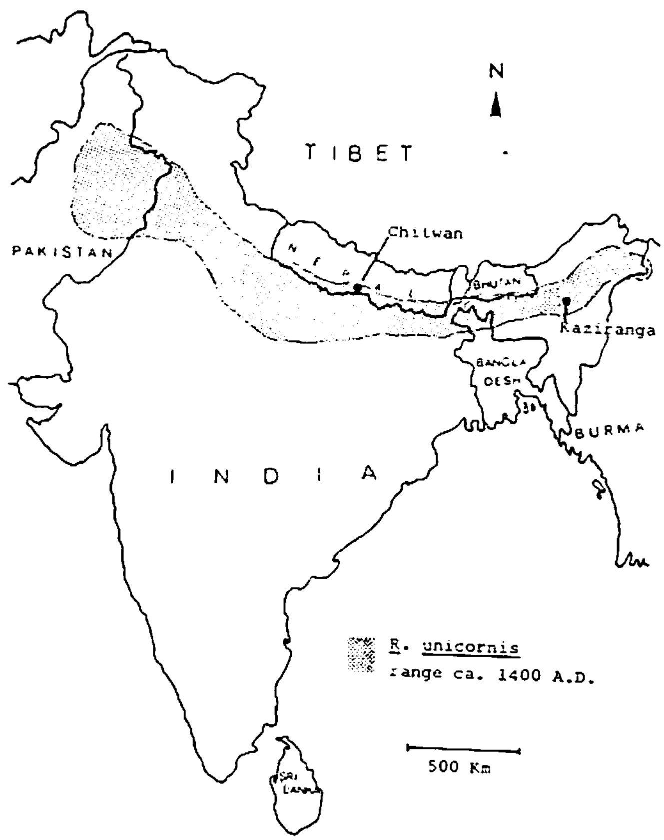

Figure 1. The geographic range of Rhinoceros unicornis, *ca. 1400* A.D., *with the locations of Royal Chitwan National Park and Kaziranga National Park indicated.*

ples were prepared for protein electrophoretic studies as described in McCracken and Wilkinson (1988). Horizontal starch-gel electrophoresis following the techniques of Selander et al. (1971) was used to examine 29 presumptive, protein-encoding loci: 17 loci from dermal tissue (Aat, Es-1, 2, 3, 4, Fum , G3pdh, Gpi, Lap-1, 2, Ldh-1, 2, Me, Pgm-1, 2, Pmi, and Sod), 7 from red blood cells (Dia-1, 2, G6pdh, Hb, Mdh, Pep, 6Pgd), and 5 general proteins (Gp-1, 2, 3, 4, 5) from blood plasma. Aat, Mdh, Me, and Pmi were resolved using tris maleate buffers; Dia-1, 2, G6pdh, Gp-1-5, and Hb using lithium hydroxide buffers; Es-1-3, Fum, G3pdh, Lap-1, 2, and Ldh-1, 2 using tris-citrate buffers (pH 8.0); Es-4 and 6Pgd using tris versene borate buffers; and Gpi, Pep, Pgm-1, 2, and Sod using Poulik discontinuous buffers (Selander et al. 1971). Protein stain recipes are from Selander et al. (1971) and Harris and Hopkinson (1978).

Results

Nine of the 29 presumptive loci examined were polymorphic. Genotype frequencies at each polymorphic locus conformed to Hardy-Weinberg expectations (Levene 1949). Allele frequencies for each of the polymorphic loci are listed in Table 1, and Figure 2 illustrates the variability seen at three of the loci. The overall heterozygosity (H_o) measured from this suite of loci (Hedrick et al. 1986) was 9.9 ± 4.5%.

Table 1. Allele frequencies at the polymorphic loci examined in *Rhinoceros unicornis*.*

	Polymorphic Loci		
Locus	*Allele*	*Frequency*	*No. of Individuals Examined*
Es-3	a	0.05	21
	b	0.59	
	c	0.36	
Es-4	a	0.84	22
	b	0.16	
G6pdh	a	0.50	20
	b	0.50	
Gp-3	a	0.11	19
	b	0.89	
Gpi	a	0.80	23
	b	0.20	
Hb	a	0.93	23
	b	0.07	
Ldh-1	a	0.48	23
	b	0.52	
6Pgd	a	0.02	23
	b	0.04	
	c	0.94	
Pgm-2	a	0.17	23
	b	0.83	

* *Dia-1 also was variable with a single rare allele at 0.02.*

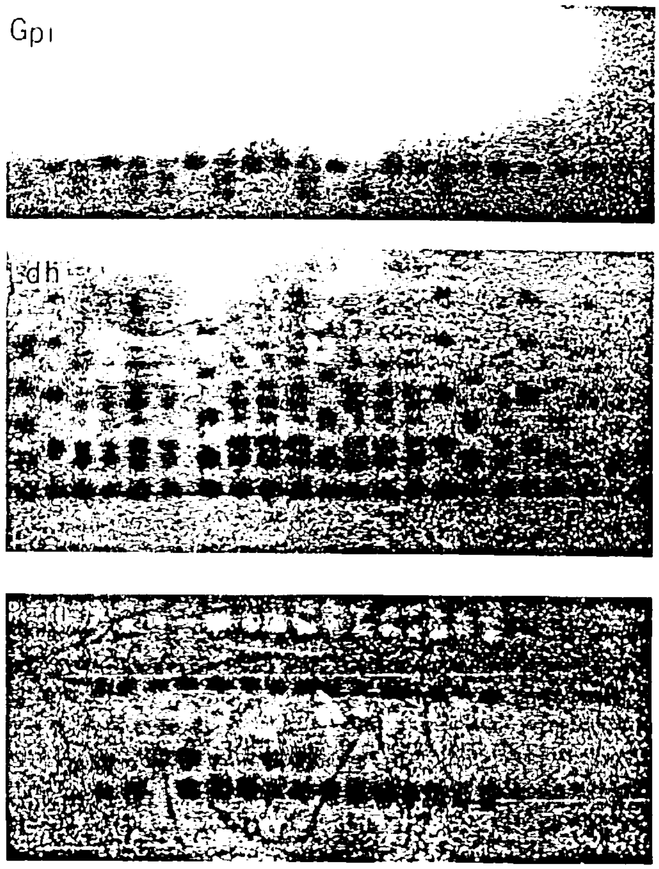

Figure 2. Electrophoretic variation observed in Rhinoceros unicornis *at Gpi, Ldh, and Pgm.*

Discussion

The heterozygosity documented in the Chitwan population of *R. unicornis* is in striking contrast to the much lower heterozygosities that have been reported for populations of other species that have experienced near-extinction (Bonnell & Selander 1974; Pemberton & Smith 1985; O'Brien et al. 1987; O'Brien et al. 1985; O'Brien & Evermann 1988). This observed heterozygosity is also at the extreme high end of values observed in over 140 other mammal species which have been examined using similar techniques, and an exception to the generalization that large mammals have low heterozygosity (Nevo 1978; Wooten & Smith 1985). To account for these results we must address two questions (1) How did such high levels of genetic variability accumulate in these mega-mammals prior to their reduction in numbers? and (2) how has this variability persisted through the bottleneck? In our attempt to answer these questions we will outline the historical demography of the Chitwan population of *R. unicornis* and consider life history characteristics that are relevant to the loss or preservation of genetic variability.

In the fifteenth century, before extensive human settlement within its range, *R. unicornis* occurred along the flood plains, oxbows, and feeder streams of major rivers from northwestern Burma, across the Gangetic plain, to the Indus River Valley in northern Pakistan (Fig. 1) (Laurie 1978). *R. unicornis* can be abundant in their prime habitat, the tall grasslands along major rivers. Average densities in the Kaziranga National Park currently approach 4 ind/km^2 (Martin et al. 1987) and in Chitwan, peak densities reach 13.3 ind/km^2 (Dinerstein & Wemmer 1988; Dinerstein & Price, in press). The area of prime habitat within *R. unicornis*'s historic range was approximated as a 4-km-wide band along major rivers. Conservatively, 35,800 km^2 of such habitat existed. This area multiplied by current Chitwan densities in prime habitat provides a minimal total population estimate of 476,140 individuals, ignoring individuals in less-than-prime habitat. *R. unicornis* also are highly vagile; even within their very restricted current range, individuals have moved linear distances of over 60 km within a year (G. Singh, personal communication). This vagility, coupled with their wide distribution and probable high density, all suggest that, in ca. 1400, *R. unicornis* could easily have had N_e's of tens of thousands. High levels of genetic diversity can accumulate in populations of this magnitude provided that the large effective population size is sustained over many generations (Soulé 1976; Nei 1987). Fossils of *R. unicornis* date from the Middle Pleistocene, and fossils also demonstrate a broader prehistoric distribution for this species than is estimated for ca. 1400 (Laurie et al. 1983). Therefore, it is likely that *R. unicornis* persisted in very large numbers for at least 100,000 rhinoceros generations. It also seems probable that much of the accumulated genetic diversity in this species was distributed throughout its range, with little or no structuring among regions.

By the late nineteenth century extensive land clearing and hunting fragmented their range and eliminated *R. unicornis* from all areas but the Chitwan Valley, lowland Bhutan, the Teesta Valley, West Bengal, and the Brahmaputra Valley in Assam, India (Blanford 1888). In the Chitwan Valley at least 1,000 individuals of *R. unicornis* persisted until about 1950, when poaching and land clearing after malaria eradication caused their decline to an estimated low of 60–80 survivors in 1962 (Laurie 1978; H. Mishra, personal communication). Precise calculation of N_e during this period is problematic because we lack necessary life table statistics and full information on the variance in individual reproductive success (Lande & Barrowclough 1987). However, we do have sufficient information from field studies to approximate N_e. Of 251 Chitwan rhinoceros monitored in 1984–1988, 87 were breeding females and 51 breeding-age males. All mature females produce one calf approximately every 4 years, and variance in female reproductive success appears low. Throughout the study period, only 28 of the 51 adult males showed evidence of breeding activity (Dinerstein & Price, in press). The remaining 23 adult males never attained dominance, were not allowed to approach estrous females, and showed none of the behavioral and morphological characteristics obvious in breeding males. Assuming discrete generations and that the variance in progeny number equals the mean number produced per individual (excluding nonreproductives), we calculate that $N_e = 85$, or about 35% of the total population (Lande & Barrowclough 1987). *R. unicornis* clearly violates both of the above assumptions, but we cannot presently evaluate the net effects of these violations on N_e. Therefore, we use $0.35 \times N$ (N = total population size) as the best estimate of N_e. Our conclusions will not be qualitatively affected even if this estimate is incorrect by a factor of two (see below).

The rate of decay of heterozygosity resulting from small population size is known to approximate $1/(2N_e)$ per generation (Allendorf 1986; Lande & Barrowclough 1987). Our estimate of average generation time in free-ranging *R. unicornis* is ca. 12 yrs., which is lower than that calculated for other rhinocercatids (T. Foose, personal communication). Because prior to 1950, Chitwan maintained a population of no less than 1,000 individuals ($N_e > 350$), we can calculate that the population should have lost no more than 6.4% of its original heterozygosity during the approximately 46 *R. unicornis* generations going back to 1400 A.D. After 1950, the rate of loss of heterozygosity would have accelerated. However, because only about three *R. unicornis* generations have elapsed since the population's precipitous decline, and because recovery has been rapid (i.e., in 1962, N_e = 21–28; in 1975, N_e = 95; in 1988, N_e = 133; Dinerstein & Price, in press), we also calculate that further erosion of heterozygosity should not have exceeded an additional 3%. Therefore, the current population in Chitwan should retain approximately 90% of the heterozygosity present when *R. unicornis* was still widespread and common. If N_e's were actually half our estimates, approximately 82% of the original heterozygosity should as yet be preserved, whereas if N_e's were twice our estimates, over 95% should still be present. These estimates of the heterozygosity preserved are probably conservative because (1) the Chitwan population undoubtedly exceeded 1,000 individuals between 1400 A.D. and recent times; and (2) our estimate of length of generation time is probably too low.

Although Chitwan *R. unicornis* retain high heterozygosity we observed relatively low allelic diversity, with three alleles at two loci and two alleles at all other polymorphic loci (Table 1). High allelic diversity is an expected result of sustained large N_e's (Chakraborty et al. 1980; Nei et al. 1975), and loci with multiple alleles are common in studies of organisms with apparently large N_e's (e.g. Ayala et al. 1972; McCracken 1984). Many of these alleles are at low frequencies and contribute little to overall heterozygosity (Allendorf 1986; Chakraborty et al. 1980); Nei et al. 1975; Lande & Barrowclough 1987; Fuerst & Maruyama 1986). Rare alleles are lost quickly during bottlenecks (Allendorf 1986; Fuerst & Maruyama 1986), and this could explain the relatively low allelic diversity observed in *R. unicornis*. However, with a sample of 23 individuals we expect to see only about 20% of all alleles at frequencies of 0.001–.01, and about 70% of those at frequencies of 0.01–.05. Therefore, small sample size may preclude our detecting any loss of allelic diversity resulting from reduced population size.

Finally, our results are in contrast to the only other published electrophoretic study of *R. unicornis*. In a recent paper Merenlender et al. (1989) report no observed variation among three individuals derived from the Kaziranga population. As the authors suggest, more individuals from that population must be examined to determine if the Chitwan and Kaziranga populations vary in the amount of genetic variation present.

Conclusion

We conclude that high heterozygosity persists in this population of *R. unicornis* because the population size remained large prior to 1950, the genetic bottleneck occurred recently, and average generation time is long. The observation of high genetic variability in the Chitwan rhinoceros population was surprising initially, and is in contrast to the results of several other studies on genetic variability in rare and endangered species. However, our results can be explained by considering the distributional history, demography, and life history parameters of these animals. We believe that this study illustrates the need for considering these factors when appraising possible genetic impacts of population bottlenecks in other species.

Chitwan *R. unicornis* provide an example of a population that almost went extinct while still carrying high genetic diversity. From this perspective, we believe that the situation with Chitwan rhinoceros will prove not to be exceptional. Given the accelerating rate of extinction (Meyers 1979), other threatened species like *R. unicornis* that were until recently common and widespread, may yet retain a substantial proportion of their original heterozygosity.

Acknowledgments

The Chitwan *R. unicornis* population would surely have gone extinct without the timely and aggressive efforts to protect them instituted by His Majesty's Government of Nepal, and in particular the efforts of the Department of National Parks and Wildlife. We thank C. Wemmer and the Conservation and Research Center, National Zoological Park, R. Simons and D. Challinor of the Smithsonian Institution, for providing funding for the project. We thank M. Bush and J. Block for logistical assistance. The study also was supported by the World Wildlife Fund, by the USAID Asia Near East Program for Biological Diversity, and by the University of Tennessee, Knoxville. We especially acknowledge the assistance of B. Bunting from WWF and K. Saterson from USAID in developing this project. H. Mishra, B. N. Upreti, S. Shrestha, and the staff of the Smithsonian/Nepal Terai Ecology Project, King Mahendra Trust for Nature Conservation, and the Department of National Parks and Wildlife Conservation, His Majesty's Government of Nepal, made blood and tissue collection possible. We thank P. Brussard, J. Gittleman, S. Pimm, K. Ralls, and C. Wemmer for their comments on the manuscript. Mr. B. M. Shrestha of the Kumaltar Agriculture Station, Kathmandu, maintained levels of the liquid nitrogen tank.

Literature Cited

Allendorf, F. W. 1986. Genetic drift and the loss of alleles versus heterozygosity. Zoo Biology 5:181–190.

Allendorf, F. W., and R. F. Leary. 1986. Heterozygosity and fitness in natural populations of animals. Pages 57–76 in M. E. Soulé, editor. Conservation biology: the science of scarcity and diversity. Sinauer Associates, Sunderland, Massachusetts.

Ayala, F. J., J. R. Powell, M. L. Tracey, C. A. Mourao, and S. Perez-Salas. 1972. Enzyme variability in the *Drosophila willistoni* group. IV. Genic variation in populations of *Drosophila willistoni*. Genetics 70:113–139.

Blanford, W. T. 1888. The fauna of British India, including Ceylon and Burma; Mammalia. Taylor and Francis, London, England.

Bonnell, M. L., and R. K. Selander. 1974. Elephant seals: genetic variation and near extinction. Science 184:908–909.

Chakraborty, R., P. A. Fuerst, and M. Nei. 1980. Statistical studies on protein polymorphism in natural populations. III. Distribution of allele frequencies and the number of alleles per locus. Genetics 94:1039–1063.

Dinerstein, E., and L. Price. Demographic characteristics of greater one-horned rhinoceros in Nepal. Journal of Wildlife Management. In press.

Dinerstein, E., S. Shrestha, and H. R. Mishra. 1990. Capture, chemical immobilization, and radio collar life in greater one-horned rhinoceros. Wildlife Society Bulletin. 18:36:41.

Dinerstein, E., and C. Wemmer. 1988. Fruits *Rhinoceros* eat: dispersal of *Trewia nudiflora* in lowland Nepal. Ecology 69:1768–1774.

Frankel, O. H., and M. E. Soulé. 1981. Conservation and evolution. Cambridge University Press, New York.

Franklin, I. R. 1980. Evolutionary change in small populations. Pages 135–149 in M. E. Soulé and B. A. Wilcox, editors. Conservation biology: an evolutionary-ecological perspective. Sinauer, Sunderland, Massachusetts.

Fuerst, P. A., and T. Maruyama. 1986. Considerations on the conservation of alleles and genic heterozygosity in small managed populations. Zoo Biology 5:171–179.

Goodman, D. 1987. The demography of chance extinction. Pages 9–43 in M. E. Soulé, editor. Viable populations for conservation. Cambridge University Press, Cambridge, England.

Harris, H., and D. A. Hopkinson. 1978. Handbook of enzyme electrophoresis in human genetics. North-Holland Publications, Amsterdam, Netherlands.

Hedrick, P. W., P. F. Brussard, F. W. Allendorf, J. A. Beardmore, and S. Orzack. 1986. Protein variation, fitness and captive propagation. 1986. Zoo Biology 5:91–99.

Lande, R. 1988. Genetics and demography in biological conservation. Science 241:1455–1460.

Lande, R., and G. F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pages 87–123 in M. E. Soulé, editor. Viable populations for conservation. Cambridge University Press, Cambridge, England.

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

Laurie, W. A., E. M. Lang, and C. P. Groves. 1983. *Rhinoceros unicornis*. Mammalian Species 211:1–6.

Levene, H. 1949. On a matching problem arising in genetics. Ann. Math. Stat. 20:91–94.

Martin, E. B., C. B. Martin, and L. Vigne. 1987. Conservation crisis—the rhinoceros in India. Oryx 21:212–218.

McCracken, G. F. 1984. Communal nursing in Mexican free-tailed bat maternity colonies. Science 223:1090–1091.

McCracken, G. F., and G. S. Wilkinson. 1988. Allozyme techniques and kinship assessment in bats. Pages 141–155 in T. H. Kunz, editor. Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, D.C.

Merenlender, A. M., D. S. Woodruff, O. A. Ryder, R. Kock, and J. Vahala. 1989. Allozyme variation and differentiation in African and Indian rhinoceroses. J. Heredity 80:377–382.

Meyers, N. 1979. The sinking ark. Pergamon Press, New York.

Nei, M., T. Maruyama, and R. Chakraborty. 1975. The bottleneck effect and genetic variability in populations. Evolution 29:1–10.

Nei, M. 1987. Molecular evolutionary genetics. Columbia University Press, New York.

Nevo, E. 1978. Genetic variation in natural populations: patterns and theory. Theoretical Population Biology 13:121–177.

O'Brien, S. J., and J. F. Evermann. 1988. Interactive influence of infectious disease and genetic diversity in natural populations. TREE 3:254–259.

O'Brien, S. J., M. E. Roelke, L. Marker, et al. 1985. Genetic basis for species vulnerability in the cheetah. Science 227:1428–1434.

O'Brien, S. J., D. E. Wildt, M. Bush, T. M. Caro, C. Fitzgibbon, I. Aggundey, and R. E. Leakey. 1987. East African cheetahs: evidence for two population bottlenecks? Proceedings of the National Academy of Sciences of the United States of America 84:508–511.

Pemberton, J. M., and R. H. Smith. 1985. Lack of biochemical polymorphism in British fallow deer. Heredity 55:199–207.

Pimm, S. L., J. L. Gittleman, G. F. McCracken, and M. E. Gilpin. 1989. Plausible alternatives to bottlenecks to explain reduced genetic diversity. TREE 4:176–178.

Schonewald-Cox, C. M., S. M. Chambers, B. MacBryde, and L. Thomas, editors. 1983. Genetics and conservation: a reference for managing wild animal and plant populations. Benjamin/Cummings, London, England.

Selander, R. K., M. H. Smith, S. Y. Young, W. E. Johnson, and J. B. Gentry. 1971. Biochemical polymorphism and systematics in the genus *Peromyscus*. I. Variation in the old field mouse. Pages 49–90 in Stud. Genet. VI., University of Texas Publication No. 7103, Austin, Texas.

Soulé, M. E. 1976. Allozyme variation: its determinants in space and time. Pages 60–77 in F. J. Ayala, editor. Molecular evolution. Sinauer Associates, Sunderland, Massachusetts.

Wooten, M. D., and M. H. Smith. 1985. Large mammals are genetically less variable? Evolution 39:210–212.

INDONESIAN RHINO CONSERVATION WORKSHOP

BRIEFING BOOK

SECTION 7 - BLACK RHINO DATA

INDONESIAN RHINO CONSERVATION WORKSHOP

BRIEFING BOOK

SECTION 8 - INDONESIA RHINO REFERENCE MATERIAL

l'Alliance mondiale pour la nature
The World Conservation Union

Secrétariat de l'UICN
IUCN Headquarters

MAR

MEMORANDUM

To: Bill Conway, Tom Foose, Mohamed Khan bin Momin khan, Ed Maruska, Douglas Myers, George Rabb, Charles Santiapillai, Rudi Schenkel, Ulie Seal, Nico van Strien, Warren Thomas, Ron Tilson

From: Simon Stuart Ref: SSG/M26

Subject: Approval from President Soeharto for the Points of Agreement reached at the Bodor Meeting

Date: 19th March 1990

Some good news! We have now received formal support from President Soeharto for the Points of Agreement we reached at the meeting in Bogor. This came as a result of a letter sent to the President by Prince Philip. I enclose copies of the correspondance, as well as of the agreements reached at Bogor. I think this allows us to proceed with various rhino conservation projects in Indonesia on a more sure footing.

With best wishes,

Yours sincerely,

Lilette Humphry

pp Simon N. Stuart Ph.D.,
Species Programme Officer
Species Survival Commission

Enclosure: as mentioned

cc. Call
C. Hirdi
A. Ferrhout (for
Betts
Tahija
Djojohadikusumo
Dr. Holdgate
E Kemf.

Copy for JNS
7 MARS 1990

WWF World Wide Fund
For Nature

WWF International

CH-1196 Gland, Switzerland
Telephone: (022) 64 71 81
Telegrams: Panda, Gland
Telex: 419 618 wwf ch
Telefax: (022) 64 42 38

24th October 1989

Your Excellency,

I am delighted to have this opportunity to re-visit Indonesia for the first time since the State Visit by The Queen in 1974. On this occasion I am visiting in my capacity as President of WWF, the World Wide Fund for Nature. WWF is involved in a number of important conservation projects in Indonesia and it works very closely with IUCN - The World Conservation Union.

I enclose a copy of the report of the Inter-Organizational Meeting that was held at the BIOTROP Institute in Bogor in June this year between "IUCN - The World Conservation Union" and "The Directorate General of Forest Protection and Nature Conservation (PHPA)" to discuss plans for the protection of the Javan and Sumatran species of Asian rhinoceros.

You will see that in his message to the meeting, Ir Hasjrul Harahap, Minister of Forestry, said "... both species are endangered in Indonesia and the prospect for their long-term survival appears to be grim but not entirely hopeless." He then went on to say "... it is necessary that action be taken at the highest level to decide upon policies to ensure the long-term survival of viable populations of the two species in Indonesia." He concluded his message with these words "This meeting is itself proof that international organizations are seriously concerned about the plight of Asian rhinos and are prepared to extend their help..."

The section entitled "Points of Agreement" summarises the most important conclusions, and technical and scientific details are to be found in the Annexes. These include a detailed "Population Viability Analysis".

LETTER TO THE PRESIDENT OF INDONESIA

...2/

WWF World Wide Fund
For Nature

WWF International

CH-1196 Gland, Switzerland
Telephone: (022) 64 71 81
Telegrams: Panda, Gland
Telex: 419 618 wwf ch
Telefax: (022) 64 42 38

My purpose in writing is to ask you to give your support to the "Points of Agreement" so that the necessary steps can be taken to put the recommendations into action and so that international financial support for the program can be mobilized. WWF is anxious to become involved and there are a number of zoos in Europe and North America that are already showing an interest in cooperating. A positive sign of your approval would greatly assist in generating substantial funding for the program.

With sincere good wishes

Philip

Dr. Hoogijcke

PRESIDEN
REPUBLIK INDONESIA

Jakarta, 25 Januari 1990

Sri Paduka;

Surat Sri Paduka tanggal 24 Oktober 1989 sungguh menggembirakan hati saya; karena telah dapat memperbaharui pengenalan dan pertukaran pikiran dengan Sri Paduka.

Saya sepenuhnya menyokong pokok-pokok persetujuan beserta rekomendasinya tentang penyelamatan Badak Jawa dan Sumatera.

Saya juga telah meminta kepada Menteri Kehutanan untuk mengambil langkah-langkah yang diperlukan dan kepada Menteri Negara Kependudukan dan Lingkungan Hidup untuk mengkoordinasikan usaha-usaha kami dalam menyelamatkan dan meningkatkan populasi badak.

Dengan bantuan Sri Paduka, saya berharap usaha kami tidak hanya terbatas pada upaya penyelamatan badak dari kepunahan, tetapi juga dapat menunjukkan kepada dunia suatu contoh kerjasama internasional di bidang lingkungan hidup.

Akhirnya, perkenankan saya untuk menyampaikan ucapan Selamat Tahun Baru.

PRESIDEN REPUBLIK INDONESIA

SOEHARTO

Sri Paduka
PANGERAN EDINBURGH
Presiden "The World Wildlife Fund For Natures"
CH-1196 Gland

UNOFFICIAL TRANSLATION

26 FEV. 1990

PRESIDEN
REPUBLIK INDONESIA

Jakarta, January 25, 1990

Your Royal Highness;

In acknowledging your letter of October 24th, 1989, it gives me great pleasure to renew our acquaintance and to exchange ideas with you.

I fully support the "Points of Agreement" with its recommendations to save the Java and Sumatra Rhinos.

I have requested the Minister of Forestry to take the necessary steps and the Minister of State for Population and Environment to coordinate our efforts in saving and enhancing our Rhino population.

With your cooperation, I hope that our endeavor will not only serve to save the Rhinos from extinction, but also provide the world with an example of international cooperation in the field of the environment.

Allow me to convey to you a Happy New Year.

PRESIDENT OF THE REPUBLIC OF INDONESIA

Sgd.

SOEHARTO

His Royal Highness
THE DUKE OF EDINBURGH
President of the World Wildlife Fund for Natures
CH-1196 Gland
SWITZERLAND

REC: 23 FEV. 1990

	ACT	
DGO		
OD		MWH
PPD		SNS
FIN		
CMC		
CH[illegible]		

THE CONSERVATION OF RHINOS IN INDONESIA

An inter-organizational meeting convened by

IUCN - The World Conservation Union

and the

Directorate General of Forest Protection and Nature Conservation

held at the BIOTROP Institute, Bogor, 5-7 June 1989

Report of the Meeting

The impetus for this meeting was the finalization of the Action Plan for the Conservation of Asian Rhinos, which was prepared on behalf of IUCN and its members by the IUCN/SSC Asian Rhino Specialist Group. The Action Plan identifies conservation action on behalf of the Javan and Sumatran rhinos in Indonesia as being a particularly high priority. The purpose of the meeting was to explore how the recommendations of the Action Plan can be put into effect within Indonesia. The meeting concentrated mainly on the Javan rhino, since many of the more difficult issues surrounding the Sumatran rhino had been addressed in earlier meetings. However, the points of agreement by the meeting, and the rhino conservation programme that is now recommended, cover both species. For this programme to move ahead, and for donor participation to be sought, the conclusions of the meeting now await formal endorsement by the Government of Indonesia.

The consensus reached during the meeting is summarised in the "Points of Agreement". Further details are provided in the relevant Annexes. The biological basis for the recommendations made is provided in the population viability analysis in Annex 2.

It was the unanimous conclusion of the meeting that the current opportunity to save the Javan and Sumatran rhinos, and to restore them to healthy population levels, should not be lost. The recommendations made by the meeting provide the most effective means to convert this desire into reality.

Message from the Hon'ble Minister of Forestry

Distinguished guests,

I am pleased to welcome you to this meeting convened by the INternational Union for Conservation of Nature and Natural Resources (IUCN) and the Directorate General of Forest Protection and Nature Conservation (PHPA) on Asian rhinos. This meeting has been specifically organized to implement the action plan prepared by IUCN to conserve the rhinos in Asia. Given that two of the three species of Asian rhinos occur in Indonesia, it ia also a meeting where our participation becomes all the more important and invaluable. International concern has always been focused on the plight of the Asian rhinos, especially the two species that occur in Indonesia - the Javan rhino and the smaller Sumatran or wooly rhino - ever since poaching and habitat loss led to a drastic reduction in their numbers. At present a viable population of the Javan rhino is to be found in just one locality in Indonesia, i.e. the Ujung Kulon National Park in West Java. The Sumatran rhino on the other hand, enjoys a wider distribution in Sumatra. It is also, in comparison to the Javan rhino, more numerous. But there is no room for complacency. Both species are endangered in Indonesia and the prospect for their long-term survival appears to be grim but not entirely hopeless.

Increasing human population and increasing agricultural land use have considerably reduced the land available to the wildlife in Indonesia since the turn of the century. The animals that are most affected by the continued contraction of their range are the large mammals such as the elephant, rhino, and tiger which need relatively large areas to survive. For this reason alone, it is necessary that action be taken at the highest level to decide upon policies to ensure the long-term survival of viable populations of the two species of rhino in Indonesia.

Purely from a commercial point of view, a rhino is more valuable dead than alive when its horn, hide, and even blood are sold to wholesalers in south-east Asia. There has been a continuous whittling away of rhino populations in Indonesia to provide rhino products in Chinese medicine. Poaching has been identified as the one agency that represents an over-riding threat to the Javan rhino.

The long-term survival of rhinos in Asia depends on man and his willingness to share with them the resources of the land. We need to formulate conservation policies in the light of the prevailing socio-economic conditions and their development plans. But since conservation is of world-wide importance, as well as of National benefit, the International Community too has a responsibility to provide assistance, which may in the form of funds, equipment, or technical collaboration, as well as cooperating in controlling international trade in rhino products.

This meeting itself is proof that international organizations are seriously concerned about the plight of the Asian rhinos and are prepared to extend their help to where the rhinos occur to enhance the long-term survival of the species in their natural habitat.

We look forward to a fruitful collaboration on our joint efforts to safeguard the species from becoming extinct in Asia. May I wish you all every success at your deliberations.

THE CONSERVATION OF RHINOS IN INDONESIA

IUCN/PHPA

Points of Agreement

GENERAL POINTS

1. The recovery of the populations of the Javan and Sumatran rhinoceroses to levels that would ensure their long-term survival is among the highest conservation priorities in Indonesia.

2. The responsibility for saving these species and their natural environments rests with the authorities and people of Indonesia. However, the survival of these species are of importance and interest to the whole world and hence the international community should also contribute to the conservation of these species and their habitats.

JAVAN RHINOCEROS

3. The long-term goal is to save the Javan rhino in its former and present natural habitat. This will entail the establishment of a total population of at least 2000 rhinos distributed over 10 to 20 viable populations (i.e., populations of 100 animals or more) in secure areas throughout the former range of the species (including in countries outside Indonesia). This means identifying and adequately protecting natural forests in advance of reintroductions or translocations.

4. To achieve this goal, the first priority is to provide strict protection for the surviving population in Ujung Kulon National Park, ensuring that the level of poaching is zero. Methods for bringing this about are given in Annex 1.

5. Another priority is to identify and protect potential forest sites for re-establishment of rhino populations in the future.

6. However, the population of rhinos in Ujung Kulon is not, and never can be, of sufficient size to secure the species for the long-term. It is too small for long term viability in ecological, demographic, and genetic terms. Plainly, it is vulnerable to catastrophic events or circumstances. In short, the Javan rhino is now in the process of becoming extinct and will be extinct unless we take action now.

7. It is likely that the population in Ujung Kulon is at, or is approaching, carrying capacity of the environment, and cannot be expected to increase much further.

8. The response to this dilemma by removal of animals from Ujung Kulon to establish other populations can be supported by decision analysis, and population viability analysis indicates the level of removal that can be sustained without impairing the survival of the Ujung Kulon population. As a matter of high priority, it is therefore recommended that two additional populations be set up in Indonesia as soon as feasible by removing animals from Ujung Kulon. The biological and management arguments are given in Annex 2. The capture protocol is given in Annex 3.

9. The greatest concern for the genetic and demographic survival of the species is to increase rapidly its numbers and to establish populations in other locations. This means that a closely managed situation is preferable initially, and therefore a captive breeding program is indicated. One of the initial captive propagation sites could be situated in or adjacent to a prime translocation or reintroduction site in Sumatra. The other captive propagation site should be located near Bogor based upon a detailed site analysis. The full list of candidate sites for captive management is given in Annex 4.

10. Before removal of animals from Ujong Kulon can take place, it is essential that the receiving sites be adequately prepared, and that all the necessary aspects of protection are in place.

11. Identification, preparation, and protection of additional proposed relocation and reintroduction sites should be started as soon as possible, otherwise such sites might be lost, thereby jeopardizing the long-term goals of the recovery programme. A preliminary assessment of such sites is given in Annex 5, and protocols for reintroduction are given in Annex 6.

12. Based on a risk analysis of advantages and disadvantages of potential sites, the first removals and transfers to the receiving sites should take place in 1990, provided advance rehabilitation and protection of these sites is carried out. Removals and transfers should continue in 1990 and 1991 until the required numbers of animals are obtained. Procedures for capture and captive management are given in Annexes 3 and 7.

13. Additional captive breeding facilities should be considered in relation to the conservation needs of the species as the captive bred population expands (see Annex 4).

14. All aspects of the conservation work on the Javan rhino should be accompanied by appropriate monitoring and research, including monitoring of the Ujung Kulon, captive, translocated, and reintroduced populations. Guidelines for research are given in Annex 8.

15. Similarly, all conservation projects on the Javan rhino should include a training component, including captive breeding projects. Guidelines for training are given in Annex 9.

SUMATRAN RHINOCEROS

16. The long-term goal for the species in Indonesia is to secure viable populations in the wild amounting to at least 1000 animals in Sumatra and 300-500 animals in Kalimantan.

17. The top priority is to enforce strict protection and anti-poaching measures in Kerinci-Seblat, Gunung Leuser and Barisan-Selatan National Parks. The guidelines given in Annex 1 for the Javan rhino apply to the Sumatran rhino as well, except that specific anti-poaching units are needed in addition to normal reserve guards.

18. Surveys are needed to locate additional viable populations for protection in Sumatra (perhaps in northern Aceh and Gunung Patah), and in Kalimantan (perhaps along the border with Sarawak).

19. The existing capture programme for doomed animals for captive breeding should be continued until such time as sufficient founder animals are available for zoos, both in Indonesia and in the United States and the United Kingdom. The current status of the capture programme is outlined in Annex 10.

20. The captive breeding programmes should not only secure the total population adequately for long term survival, but also to provide animals for selective reintroductions, and a programme for such reintroductions should be developed as appropriate.

21. The Sumatran Rhinoceros conservation programme has similar training, monitoring, and research needs to the Javan Rhinoceros Programme. Training, in particular, should be an integral part of each project (see Annexes 8 and 9).

22. If no viable population can be found in Kalimantan, a long-term activity would be to enter into an agreement with Malaysia to seek animals from the Sabah captive breeding programme.

CLOSING POINTS

23. A Rhinoceros Conservation Unit should be established within the PHPA to have responsibility for all operational aspects of rhino management in Indonesia.

24. The effectiveness of protection measures for important rhinoceros populations is closely related to the attitude of the local people towards the protected areas. Similarly, education and awareness programmes are needed in all parts of Indonesia, emphasizing the country's importance and responsibility for both species of rhinoceros.

25. Appropriate rural development projects in the buffer zones around the reserves are an important means of avoiding and resolving conflicts over resource use.

26. Continued vigilance is needed to eliminate the illegal trade in rhinoceros products, and to bring offenders to justice. Increases of penalties and other appropriate actions are recommended to enhance the enforcement of the laws pertaining to these crimes.

27. International cooperation on rhinoceros conservation with other Asian countries should be pursued, with a view to sharing information and uncovering illegal trading routes.

28. An international awareness and fund-raising programme on the conservation needs of Indonesia's rhinos should be launched as soon as possible.

INDONESIAN RHINO INTER-ORGANIZATIONAL MEETING
BOGOR - 5-7 JUNE 1989

MONDAY - 5 JUNE - AM

Attendance: Sutisna, Betts, Rabb, Effendi, Van Strien, Clark, Thomas, Nardelli, Foose, Schenkel, U. Seal, M.Seal, Rubini, Syafi, Khan, Stuart, Santiapillai, Widodo, Tilson, Harudin, Parkinson, PHPA staff, students, Dinerstein, Fujita, Dr. Linda, Sukianto

Stuart: Indonesia the only nation with two extant species of Asian rhino.

Effendi: Very brief but advocates/invites action plan.

Schenkel: Chronicle of last 25 years on Javan rhino.

1967: Facilities and staff conditions very bad. Poaching occurred. Lindberg instrumental in arranging for U.S. WWF money for project. Widodo first Schenkels' assistant, then director of Ujung Kulon.

Is possible to protect rhino in ujung kulon effectively. Govt. must decide to save rhino from extinction; must provide full support to project. Should appoint competent and committed field man to lead the project. Must be effective manager of field team. Exhorts Govt. to appoint person of integrity as well as competence. Criticizes IUCN/WWF for not actively promoting an Asian rhino campaign.

1989: Conditions still not satisfactory. WWF disengaged in 1978-79. Govt. wanted to assume control of project. No plan or implementation thereof. Equipment and support for guards inadequate. Director is administrator; needs to be a field man. War leader. Must consider practical plan for protection in addition to analyses of population viability. Advocates protection of Ujung Kulon population can contribute so rhino can recover to 'optimal' level; then other alternatives can be considered.

Widodo: Results of recent survey. Survey team of 12. U.K. and immediately east thereof. Tracks of 24-36 cm. Should be 14-40? Estimate 52-62 animals. Contends represents slight increase over last survey. Rhinos reoccupying areas again from which absent since 1982, esp. in east, on isthmus, and around lighthouse. Distribution now over most of U.K. Recommend another survey in Oct./Nov.

Thomas: Delivers report on status of captive propagation projects. Two females recently moved to North America adjusted very well.

Table 1. Sumatran rhino capture statistics.

	Captured	Died	Born	Surviving
Indonesia	4/6	0/1		2/2
W. Malaysia	2/9	2/1	0/1	1/7
Sabah	3/1	2/0		1/1
United States				0/2
United Kingdom		0/1		1/1
Thailand		0/1		
Total	9/16	4/4	0/1	5/13

Table 2. Current Locations

Facility	Number
Indonesia:	
Jakarta	1/1
Surabya	1/0
Bogor Safari Park	0/1
West Malaysia:	
Malacca Zoo	1/7
Sabah:	
Sepilok	1/1
North America:	
Cincinnati	0/1
Los Angeles	0/1
United Kingdom:	
Port Lympne	1/1
Total	5/13

Santiappil. Inquires if female from Bogor and male from Surabya be placed together?

Thomas: Yes.

Khan: Can accommodate 8 at Malacca; 12 at Sungei Dusun. Haven't captured any for 1 year but will resume again soon. Clarifies other points about program in Malaysia.

Schenkel: Discusses behavioral aspects of managing Indian rhinos for reproduction. Emphasizes aggression that occurs if animals kept together for prolonged periods. Also inquires if any signs of estrus or sexual behavior.

Thomas: Hormonal studies indicate cycles, but no behavioral sings. Affirms zoos aware of management problems.

Khan: Comments on some aggression among females kept together.

Santiap: Acknowledges there are 3 viable populations. May be animals in Benkulu, but habitat destruction occurring rapidly. Even protected areas will be under pressure. Emphasizes importance of Kerinci. Govt. doesn't have resources to protect effectively. Funds needed from outside. However, the $1.2 million in field `conservation over last 20 years, but 85% to ex patriate salaries. Cites Malaysia as model. Encourages international funding agencies consider this problem. Also laments lack of training that has occurred in conjunction with captive propagation project. Recommends reorienting to provide such training. Already have enough ecological information; now need actual management.

Khan: Acknowledges the Schenkels as progenitors of action plan. Presents highlights of Action Plan. Mentions Javan Rhino in Vietnam and advocates possibility of captive breeding. For Sumatran Rhino in Sumatra, verbalizes inability to protect smaller fragmented groups. Losses may be 10% in Sumatra. Poaching heavy in Sabah.

Indian Rhino: About 1700. Goal is 2000 rhinos in at least 5 areas. Establish and expand areas. Captive propagation.

Javan Rhino: Rarest large mammal in world. < 100 in world; most in Java; a few in Vietnam. Cites recommendation for captive propagation and also establishment of new wild populations.

Sumatran Rhino: Not as critically endangered as Javan but is probably experiencing the most serious poaching and habitat destruction problems. Cites high mortality of animals moved abroad.

MONDAY - 5 JUNE - PM

Attendance: Rabb, Effendi, Van Strien, Clark, Thomas, Foose, Nardelli, Schenkel, U. Seal, M.Seal, Syafi, Khan, Stuart, Santiapillai, Widodo, Tilson, Harudin, Parkinson, PHPA staff, students, Dinerstein, Fujita, Dr. Linda, Sukianto

Seal: To perform PVA, must agree on some goals and objectives
Seal advises everyone that everyone can express their opinions and thoughts. If don't, can't complain. Also if want contributions accurately documented in record, submit in writing to Seal.

JAVAN RHINO

1. Ultimate goal is species survival

2. How do we desire it to survive:

   a. As an evolving species - population large enough for natural selection and mutation to counteract drift. May need 2000.

   b. As a holding action, e.g. 90% for 200 years. May need 200.

   Much discussion from Schenkel about need to preserve rhino as component of co-evolved ecosystem. Clark contends that 2a is end; 2b a means.

3. Current resource:

   a. Ujung Kulon population 50-70.

   b. Vietnam population

   Widodo inquires about genetic diversity.

1900	10^3
1937	25
1967	25
1977	45
1987	55

Best case scenario is that there have been 3 generations (20 years) since 1930's. If N_e = 20, loss of diversity about 2.5% per generation or about 7.5% total. If N_e = 10, then loss would be 5% per generation or about 15% for the 60 year period. Dinerstein notes estimate of N_e/N ratio for Indian rhino is about .4.

Seal moves through handout sheets. Polygamous. First reproduction: females at about 7: males at about 15 years. Discussion of inter-birth interval, hence age-specific fertility of rhinos. Schenkel suggests Amman's data might not be valid because of likelihood of not detecting young calves. Agree that estimates of mortality plausible. Carrying capacity: U.K. = 300 km^2; but is suggestion that rhino habitat only 100 km^2; density = 1/5-10 km^2. Carrying capacity = 70-100 (Schenkel, etc.) Observation: population seems to have stabilized at about 50-60 animals for last decade. Explains 2 population models. Then discusses consequences of removing 3.6 adults.

Foose: Demography primer interlude.

Seal: Possible goal is to restore to historic range, perhaps/obviously not in original numbers.

Santiap: How long would it require for Javan rhinos in zoos to increase from 20 to 1000 as Indian rhino has in Kaziranga.

Foose: Rate of increase in Kaziranga about 5% per year. This rate would be required in captivity or wild. Annual rate of increase of Indian rhino in captivity over the last 15 years has been about 4.5%

Dinerstein: About same rate of increase under optimal conditions in wild in Nepal.

Schenkel: Discusses relative risks and problems of translocation versus captivity.

Effendi: Proposes combination of captive propagation and translocation. Also Javan rhino belongs to world not just Indonesia. Proposes gen pool concept for "Ujung Kulon".

Thomas: Very encouraged by words. Need to consider all options. Protection of Ujung Kulon and exploration of translocation sites. Also interested in statements about captive propagation. Suggests that if are going to remove animals from Ujung Kulon for captivity or translocation, must consider number, sex, age of animals to be removed and over what period of time.

Seal: Short-term objective is to establish 2 more populations immediately.

Clark: Proposes applicability of decision analysis to this question. Recommends invite Lynn Maguire to contribute paper to proceedings of workshop.

Rabb:	Can we assemble data pertinent to good decision analysis, e.g. poaching intensity?
Schenkel/ Santiap:	Can't really estimate rate of poaching from field data.
Seal:	Data indicates losing about 5 adults total per year.
Stuart:	What are consequences of various levels of poaching.
Seal:	Will calculate more; but indications now are that loss of 3 more adults per year will be intolerable.
Foose:	Long-term optimism versus short-term pessimism. Can only expect poaching pressure to intensify over short-term as populations of other rhinos disappear elsewhere.
Syafi:	From discussion, pessimistic about prospects of translocating rhinos. Habitat may not be available. Advocates captive propagation better alternative.
Stuart	For both species, need to identify present and potential viable populations. Also need estimate of resources required to reduce poaching.
Dinerstein	Nepal does demonstrate populations if protected will expand, assuming habitat not at carrying capacity. Value of presence of research activity in reducing poaching.
Widodo	Can improve protection.
Schenkel	Nature self-regulating.
Fujita	Would captivity preserve genetic diversity better than translocation.
Seal	Also high-tech possibilities.

TUESDAY - 6 JUNE - AM

Attendance: Rabb, Effendi, Van Strien, Clark, Thomas, Foose, Schenkel, U. Seal, M. Seal, Rubini, Khan, Stuart, Santiapillai, Widodo, Tilson, Harudin, Parkinson, PHPA staff, students, Sukianto, Fujita, Dr. Linus

Schenkel: Agree should protect Ujung Kulon. Also agree should establish second population, ideally in forested area large enough to accommodate viable number of animals.

Presentation on protection of Ujung Kulon.

Seal: Continues Javan Rhino PVA

Points/Objectives of Agreement

- Long-term:
  - Total (meta)population of 2000 animals distributed over 10-20 subpopulaions distributed over historic range of species.
- Short-term:
  - Protect Ujung Kulon
    - Interlude on drift versus selection. In populations < 100, drift will predominate over selection unless selection very (abnormally) intense. In Ujung Kulon, estimates of loss due to drift over last 60 years are 10-15%.
    - Rabb: Even if protected, Ujung Kulon population is so small (< 100), that is already on way to extinction.
    - Schenkel contends that selection will have produced fittest animals
    - Tilson and Fujita emphasize that dominance and fitness not well correlated
    - Foose presents simple 2-locus example.
  - Need to establish 2 more populations as soon as possible:

- Translocated populations

- Captive populations

  - Captive population will permit approximately twice retention of diversity as randomly breeding translocated population.

  - Ultimate goal is to return animals from captivity to wild as soon as possible (ideally 2 or 3 generations at most).

  - Can expand population more rapidly because:

    - Reduction of inter-birth interval

    - Decrease in mortality (protection from poachers, disease, etc.)

- Need to decide what combination of captive and translocated populations are optimal.

  - Discussion of semi-reserves as compromise.

Seal describes new sets of analyses performed. (Refer to attached sheets)

TUESDAY - 6 JUNE - PM

Attendance: Rabb, Effendi, Van Strien, Clark, Thomas, Foose, Schenkel, U. Seal, M. Seal, Rubini, Khan, Stuart, Santiapillai, Widodo, Tilson, Harudin, Parkinson, PHPA staff, students, Sukianto, Fujita, Dr. Linus, Syafi, Harudin, Nardelli

Seal — Consider general characteristics of captive situation and translocation site:

Analyses suggest Ujung Kulon population could tolerate a 1 time loss of half (about 10) of animals under 7 years and 3.6 animals over 7 years. Must distinguish this kind of removal from a continuing reduction, e.g. due to poaching, which population will not be able to sustain.

Schenkel — Concern about age of animals to be removed, in terms of their dependance on mothers and their adaptability to new sites.

Khan/Thomas — Discussion of selection criteria for animals.

Thomas — Proposes capture protocol

Try for the 3.6 adults

No aged animals;

No calves with mothers unless keep parent

No lactating females

Retain any animals under 7 acquire as are accumulating adults

Et alia — Discussion of stochasticity (unpredictability) of age and sex structure of captured animals.

Foose — Need more flexible guidelines in terms of various combinations of adults and subadults that could be removed. Inquires if analyses don't indicate that population can sustain removal of 6.12 regardless of age. Also `need to consider minima in terms of founder base for new populations.

Seal — Need to better define boundaries, i.e. maxima and minima, for numbers to be captured.

Clark — Should collect as much data from all animals.

Van Strien — Should also suggest sex ratio of subadults. Also must consider time span of captures

Seal — Yes. Based on what know about sex ratios, proposes 3-4 males and 6-7 females. In terms of time span, removal of all animals over short period of time the worst case scenario.

Khan — Recommends that capture occur in all parts of reserve so that sample is representative.

Dinerstein — Comments that operationally may be impossible to distinguish ages of animals.

Widodo — Recommends that intensive monitoring.

Foose: — Inquires if animals that might be captured and then released back into Ujung Kulon should be followed by radiotelemetry.

Schenkel: — Must be preparations and plan for release.

Seal: — Are there suggestions of guidelines for timetable for capture.

Parkinson — Should not have more than 2 traps activated at a time. Would expect that could capture an animal every 5 or 6 weeks.

Seal — Minima

Foose — Suggests 20 as minima if there are two new populations established. 10 if only one population. 10 founders will be expected to represent 95% of the average heterozygosity.

Clark — Suggests that demography more important than genetics for establishing minima.

Seal — Suggests 10 as a minima.

Seal — Now consider translocation site or captivity situation.

- Translocation and Translocation Sites:
  - Appropriate habitat
  - Sufficient area
    - 100 or more as population size
    - Hence 600-1000 km^2
  - Adequate protection
  - Natural boundaries
  - Within Historic Range of Species
  - Geographic separation from Ujung Kulon
  - Distance from human activity
  - Predator free
  - Competition free
  - Political approval
  - Site preparation

Widodo Suggest Way Kambas and Barisan Selatan as candidates.

Seal List of potential sites:

Way Kambas

Barisan Selatan

Pulau Panaitan

Newly created reserve

Kalimantan

Stuart Some assignments for components of workshop document:

Will be a short, general statement of recommendations

Protection: Schenkel, Widodo, and Van Strien

Protocols for Removal of Animals: Thomas and Parkinson

Captive Management: Khan & Foose

Reintroduction: Dinerstein

Priority Areas for Species: Effendi

Surveys, Monitoring, Research: Rubini and Fujita

PVA: Seal, Foose

Training: Santiapillai

Seal: Captive situations

- Adequate facilities (to accommodate and manage original animals and expansion)
    - 6-12 animals optimal
- Experienced Staff (with rhinos)
    - Curatorial
    - Veterinary
    - Nutritional

- Multiple sites (Far enough for stochastic security but close enough for ready exchange of animals)
- Coordinated Plan (SSP)
- General Accessibility
- Security
- Funding
- Official Approval
- Cooperation, Technology Transfer, Training
- Proximity to Human Centers of Activity so can serve educational purposes
- Research Capabilities

Candidate sites

- New site near Ujung Kulon
- New site close to Bogor
- Zoos with Sumatran rhinos
- Other zoos
- New site near Way Kambas
- Sungei Dusun
- New Site near proposed translocation sites.

Seal Evaluation of translocation sites

Way Kambas:

estimated carrying capacity 100-200
habitat similar to Ujung Kulon
distant from Ujung Kulon
protectability: intermediate
easily accessible
tigers & clouded leopards
near people

Barisan Selatan:

estimated carrying capacity 100-120
distant from Ujung Kulon
similar to Ujung Kulon
protectability: logistically most difficult
difficult access
tigers & clouded leopards

Pulau Panaitan:

estimated carrying capacity is no more than 30 animals

and is not sufficiently separated from Ujung Kulon

20 km of sea

protectability: least difficult (Widodo) but poorly protected at moment (Schenkel)

no fresh water

intermediate access

no predators

Relegate next two to later consideration when trying to locate the 10-20 sites.

Newly created reserve
protected site away from people in central Sumatra

Kalimantan
not within historic range

specific site not identified

distant from Ujung Kulon

WEDNESDAY - 7 JUNE - AM

Attendance: U. Seal, M. Seal, Rabb, Foose, Tilson, Fujita, Rubini, Schenkel, Syafi, Clark, Betts, Santiapillai, Widodo, Effendi, Van Strien, Khan, Thomas, Stuart, Nardelli, Dinerstein, Harudin

Seal More on captive propagation option.

Point: Are wild caught animals for captive propagation be retained within Indonesia or can foreign facilities be considered.

Thomas First step is to consider if animals out of wild must be retained within Indonesia

If they must, can/should progeny from wild-caught animals be moved abroad

Indonesians must decide.

Rubini Should commence in Indonesia, then progeny can move abroad.

Effendi Realize that rhinos doesn't just belong to Indonesia. However, protection of rhino must be first priority. Captive propagation should be commenced in Indonesia. Later can decide if progeny can move abroad. With Sumatran rhino, why not consolidate existing animals, then can determine if additional animals are needed.

Schenkel Discusses captive sites

Options on captive sites:

1. Near translocation sites
   A. Way Kambas
   B Barisan Selatan
   C. Pulau Panaitan

2. Bogor

3. Elsewhere

Thomas Is it possible to insure protection of another in situ site.

Santiap If establish captive facility at Way Kambas, would it not be possible/advisable to have ex patriot experts.

Thomas Don't need to have captive facility at release site. Need to have captive facility where best support resources are.

Schenkel Captive facility at Way Kambas would facilitate and motivate better protection at Way Kambas.

Rabb — Agrees in part with Schenkel, but primary objective of captive propagation should be to maximize production of animals and preservation of gene pool. To achieve these objectives, captive propagation needs to be where existing expertise, resources, and facilities are.

Tilson — Not good idea to have captive facility where wild is because of the stochastic problems.

Foose — Agree with and will extend Tilson's comments. For this reason, Effendi's suggestion that consolidate all Sumatran rhinos in captivity at single site would not be advisable. Moreover, don't yet have enough Sumatran rhinos in captivity to constitute a genetically viable foundation. Likewise, should be multiple captive sites.

Schenkel — Will try to synthesize. Would prefer translocation to Way Kambas. But realizes that perhaps need to commence with captive propagation. But would it not be possible to commence with 2 captive propagation sites: 1 in Way Kambas and 1 elsewhere.

Widodo — If establish 1 captive facility, should have ex patriot expertise.

Rabb — What about Bogor as second facility.

Thomas — Should not return animals to the wild until captive population is secure and self-sustaining so can produce sustainable harvest. Suggests California condor as model.

Schenkel — Why not utilize Safari Park in Bogor as one site and Way Kambas as the other site.

Rabb — Tries to reconcile the Schenkel and Thomas/Rabb positions.

Thomas — Concern about Safari Park is the high traffic of animals in and out because of disease dangers.

Stuart — Perceives a consensus emerging, i.e. for 2 captive populations with translocation deferred until later. But must remember that there are other considerations beyond just the biology. Must preserve the natural habitat. Might even consider consolidating

Effendi — Provide assurance that Govt will protect Way Kambas. Has just been declared a national park. Thinks idea of locating a captive facility at Way Kambas is good. Is already an elephant training facility there. Also approves of Bogor.

Seal	Inquires about possibility of a rhino specialist team?
Effendi	Yes, moving in that direction. Widodo now species conservation officer for PHPA. Using this office as a base, will try to establish a rhino specialist unit.
Rabb	Would this rhino unit have management authority with respect to rhino reserves.
Effendi	PHPA is organized into functional (advisory) units and management units.
Seal	After much discussion (Refer to Maryalice's notes), consensus seem to be that Way Kambas best translocation sites. (Refer to evaluation matrices).
Thomas	(Accepted as part of consensus by Seal). Do captive propagation first a 2 sites before attempt translocation.
Seal	Two sites recommended are Way Kambas and Bogor.

MONITORING AND RESEARCH PRIORITIES: JAVAN RHINOS

I. Stock Population At Ujung Kulon

All research and monitoring activities are assigned priorities with respect to applied importance for translocated populations.

1) Describe the status and demographic profile of the present population; refine and improve current census techniques.
- use trip cameras to identify individuals (build up photo register)
- establish a grid system of trails for censuses
- assess variation among sampling periods and sampling effort
- information needed: number, sex, age

2) Compare availability of preferred browse plant species (e.g. study by Hartmann) with relative abundance of rhinos in the twelve areas within Ujong Kulon.
- identify browse plant species diversity within the areas
- describe phenological patterns of browse species within the areas
- collect rhino scats in areas for fecal analysis to determine percent of browse vs. graminoids in diet (and consider more refined methods to determine nutrition obtained from food sources [e.g.bomb calorimetric studies] and nutritional studies of browse species)

3) As the capture program proceeds:
- radio collar individual animals that are to be released to obtain information on ranging patterns and habitat use, wallowing behavior, activity budgets, feeding ecology, social organization, etc.
- develop immobilization procedures using other rhino species, and ensure that the immobilization of Javan rhinos is conducted by only very well-trained and experienced personnel
- on all captured animals, obtain age correlates, blood samples for genetic analysis, screen for diseases, collect ectoparasites, weights, morphometric data, establish criteria for aging animals by dentition, (if female) collect saliva for reproductive endocrinological studies, individually mark hoofs for track surveys

As more accurate census data becomes available provide this for refinement/adjustments of PVA.

II. Translocated Population (n= 8 to 10 animals)

This section assumes site preparation has already been performed and that translocated animals have been handled as little as possible so as to retain their wild state (i.e. no excessive exposure to humans, minimal stress and holding time).

The appropriate agencies/institutions that will carry out the monitoring and research activities described below should be identified as soon as possible.

It is also strongly suggested that a Javan Rhino translocation team be established within PHPA with assistance from appropriate organizations, both national and international, to carry out the monitoring/research program.

In general, research priority should be to establish how well translocated animals have adapted to their new habitat. A review of the existing literature on Javan rhinos should be conducted prior to initiation of research in order to decrease any redundancy of efforts.

Research and monitoring priorities for reintroduction biology were not specifically considered here (e.g. studies on rehabilitation and behavioral changes upon release), but are an important component of the long-term goals of the Javan rhino conservation program.

All animals should be radio-collared to permit the following research [Note: collars for subadults should be expandable to allow for growth of animal]:

1) Develop protocol for data collection, storage and analysis

2) Characterize vegetation of translocated area prior to animal reintroduction (along similar lines of Unjung Kulon study for comparative purposes)

3) The key research objectives of the monitoring/research program for the translocated population are:

-establish how animals locate and harvest food

-establish how animals recognize and avoid predators

-establish how animals move and orient in space (home range)
-determine dispersal distance from initial site of release
-determine whether correlates exist in movement patterns in relation to human settlements

-determine how animals interact with conspecifics and other herbivores

-determine thermoregulation behavior

-conduct post-release evaluation to secure data on mortality, reproductive success, disease susceptibility and demographic structure

4) Identify and conduct surveys of other areas to examine the suitability of these areas as future reintroduction sites (especially with regard to the Sumatran rhino)

PROTECTION OF UJUNG KULON: PRIORITY ASPECTS

OUTLINE

1) Housing, equipment (and maintenance)

2) Functioning at the protection front, leadership and management

3) Relationship with human communities adjacent to Ujong Kulon

4) Support by PHPA as the link to the top levels of the Government

5) Support by the top level of the Indonesian Government

6) Assistance by international organizations (IUCN/WWF)
    - financial assistance
    - other assistance

7) Creating public awareness
    - in Indonesia
    - on an international level

8) Care of tourism

1. HOUSING, EQUIPMENT, MAINTENANCE

Housing: guardposts, shelters, guard center

Equipment of buildings: lamps, tools (axe, saw, etc.), kitchen equipment, office equipment, etc.

Firearms: ammunition, compass, map, rucksacks, etc.

Personal equipment: uniforms, shoes, torch, golog, etc.

Vehicles for patrolling: motorboats (Haudenleum, Peucang), dugouts, motorcycles

Vehicles for logistics: car (Bogor/Jakarta/Tamanjaya), motorboat (Badak)

Telecommunications:

Maintenance: regular inspection, regular service, repair, tools for specialist

2. FUNCTIONS AT PROTECTION FRONT (leadership and management)

"Front leader":

-education/training of field staff, emphasis on practical in Ujong Kulon

-preparing and instructing working program for field staff: patrolling, surveying, reporting

-inspection of guard work in the field, status of housing and equipment

-taking care of recruitment and promotion on the basis of the character (reliability, collaboration, motivation)

-dismissal of unfit people within field and office staff

-employment and supervision of specialist(s) for maintenance, servicing, repair of technical equipment

In coordination with "assisting manager":

-organization of logistic service, transport of people (care of sickness)

-taking care of economic situation of the staff; applications to superiors...WWF

-financial administration

3. TO CREATE GOODWILL IN HUMAN POPULATION TOWARDS NATIONAL PARK

Establish contacts with local authorities

Explain aims and meaning of nature conservation, its benefits to mankind

Practical aspects: interest of water household, employment of local people as guards for additional work in the context of tourism

Information of village people on Ujong Kulon, its natural values, its rhinos, aims of nature conservation

PROTOCOL ON REMOVAL OF ANIMALS FROM SOURCE POPULATION

Using the agreed number and sex ratio of animals to be removed from the parent population of 3 male and 6 female adults and one half of the young under 7 years of age, we would suggest that the plan of action should be to make every effort to catch the targeted number and ratio of adults. Those young of the agreed age range and sex ratio caught in the process would be kept until the adult quota is achieved. That accomplished, would constitute the group to be removed. To continue on past this point would be economically unsound and not really necessary!

Obviously, aged animals caught should be rejected as well as lactating females unless the existing baby can be caught as well. Because of the expenditures of money and time, we feel that the catching operation should be done all at one time. We caution that only very experienced personnel should be used.

CAPTIVE MANAGEMENT

1. Protocol for removal of rhino from trap and transport to captive facility.

2. Captive facility:

   A. Should be constructed on a sound design.

   B. The facility at the Malacca Zoo and the new one being constructed at Sungei Dusun could serve as models. (Plans to be attached).

   C. Facility should include individual outside paddocks and inside stalls for each animal; there should also be several other unoccupied stalls that can be used for shunting animals for cleaning and other routine husbandry.

   D. Each inside stall should have troughs/dispensers for food and water.

   E. There should be gates interconnecting all inside stalls and outside paddocks

   F. The outside paddocks should be relatively large (.25 - .5 hectare?); there should be a two tiers of outside paddocks: the smaller one just described connecting with larger ones (1 hectare or more).

   G. All enclosures inside and outside should have good drainage.

   H. Floors should be tile to minimize foot abrasion

I. The outside paddocks should contain trees to provide shade.

J. The outside paddocks must have wallows covered by shade.

K. Physical restraint facilities (squeeze chutes) should be constructed into each facility.

L. Inside stalls should have vertical grills far enough apart to provide good visibility of animals.

M. There should be space for storage of food, medicines, and other supplies.

N. The facility must have good running water and electricity.

3. Routine animal husbandry

A. Animals should be moved into individual stalls at night.

B. Nutrition/Diets

a. If natural vegetation is to be used, selection should be based on best available information about diets in the wild.

b. If animals are to be converted to more conventional zoo diets, there must be an adequate acclimatization/adjustment process and period.

C. Good hygiene is critical to prevent disease; enclosures must be well cleaned each day.

4. Staff

A. Good keepers must be available to care for the animals.

B. Keepers should be knowledgeable about animals, interested in rhinos, and should receive basic training in captive husbandry of rhinos (e.g. at zoos with rhinos or through training provided on site by visiting or resident zoo professionals).

C. In Indonesia, PHPA rangers that are trained in fundamentals of captive husbandry would be good candidates. (this source has been used successfully in Malaysia).

D. The number of keepers will depend on the number of animals. However, considering the need for shifts and absences, a good guide might be 1 keeper per every 2 animals.

E. A good on-site supervisor/curator should be responsible for the operation.

F. Clear and specific instructions and protocols (written) must be provided to guide the keepers.

G. Keepers must be adequately paid.

5. Veterinary Care:

A. A veterinarian with rhino experience must be permanently assigned to the facility and project.

B. Regular parasite control programs must be implemented.

C. Other disease prophylaxis programs should also be applied.

6. Data collection:

7. Behavioral Management

8. Propagation Management

A. Placement of animals together for reproduction should be guided by a coordinated population management plan based on genetic and demographic analyses and objectives.

B. A studbook must be maintained for the species.

TRANSLOCATION PROGRAM FOR JAVAN RHINOCEROS

The design and implementation of reintroduction programs are critical for the long-term viability of endangered species. The Javan rhino is among the most rare of free-ranging large mammals, and it is agreed that translocation to another reserve in Sumatra is highly desireable in the near future. However, no such translocation program has been attempted to date in Indonesia involving rare species. Fortunately, translocation programs already underway in Nepal and India concerning the closely related Greater One-horned rhinoceros provide some valuable guidelines and field experience in shaping the reintroduction program in Indonesia.

The most important initial step is for the responsible agency to appoint a Javan rhino translocation team (JRTT). The Nepal and India experiences clearly illustrated that translocation requires detailed planning, site surveys, dry-runs, and political cooperation and cooperation of law enforcement officers between districts before any translocation can take place. The leader of the team must be a high-ranking official to assure access to decision-makers and sound planning.

Under the leadership of the JRTT, a research unit should be appointed to carry out the field surveys in Way Kambas to determine the optimal release sites, establish a grid of trails for monitoring the movements of translocated, radio-collared animals, and to become familiar with telemetry and field monitoring techniques. Assuming that additional Greater one-horned rhinoceros will be moved from Royal Chitwan National Park to the Royal Bardia Wildlife Reserve in 1990, the Javan rhino research team should be invited to observe the translocation effort in Chitwan and the follow-up monitoring program in Bardia.

In practice, translocation can be expensive, time-consuming, labor-intensive, and requires dedication by a highly motivated team. The JRTT should develop a realistic timetable and budget as soon as the team is developed. This plan could be developed with technical support from individuals associated with translocations of rhinos in Asia. The Nepal experience, documented in a report to the King Mahendra Trust for Nature Conservation, revealed that Greater one-horned rhinoceros could be relocated for about US$2,000/animal. Funding sources would need to be identified early on in the project and commitments made to the translocation effort to insure swift development of the translocation program. At the same time, the in-kind contributions of the Indonesian government should be made clear. The JRTT should review available documents published by the Government of India and Nepal and adapt these programs to the local situation.

A major question remains regarding the release. How long should the translocated animals be held in Way Kambas or a different site prior to release? The decision will rest with the JRTT and may vary on the temperament and condition of the individual which has been translocated.
For research protocol on translocated animals see section 6: Surveys, monitoring and research.

The key point is that translocation cannot be considered a success until animals raise offspring in new locations. Given the low reproductive rates of rhinoceros, this will require a long-term commitment on the part of the JRTT and outside donors of a minimum of 5-6 yr.

JAVAN RHINOCEROS - SITES FOR REMOVED ANIMALS

I. TRANSLOCATION SITE CRITERIA:

- Translocation and Translocation Sites:
  - Appropriate habitat
  - Sufficient area
    - 100 or more as population size
    - Hence 600-1000 km^2
  - Adequate protection
  - Natural boundaries
  - Within Historic Range of Species
  - Geographic separation from Ujung Kulon

Distance from human activity
Predator free
Competition free
Political approval
Site preparation

List of potential sites:
- Way Kambas
- Barisan Selatan
- Pulau Panaitan
- Newly created reserve
- Kalimantan

II. EVALUATION OF PROPOSED TRANSLOCATION SITES

Way Kambas:
- estimated carrying capacity 100-200
- habitat similar to Ujung Kulon
- distant from Ujung Kulon
- protectability: intermediate
- easily accessible
- tigers & clouded leopards
- near people

Barisan Selatan:
- estimated carrying capacity 100-120
- distant from Ujung Kulon
- similar to Ujung Kulon
- protectability: logistically most difficult
- difficult access
- tigers & clouded leopards

Pulau Panaitan:
- estimated carrying capacity is no more than 30 animals and is not sufficiently separated from Ujung Kulon
- 20 km of sea
- protectability: least difficult (Widodo) but poorly protected at moment (Schenkel)
- no fresh water
- intermediate access
- no predators

III. CAPTIVE SITES CRITERIA

Criteria:
- Adequate facilities (to accommodate and manage original animals and expansion)
- 6-12 animals optimal
- Experienced Staff (with rhinos)

Curatorial
Veterinary
Nutritional
Multiple sites (Far enough for stochastic security but close enough for ready exchange of animals)
Coordinated Plan (SSP)
General Accessibility
Security
Funding
Official Approval
Cooperation, Technology Transfer, Training
Proximity to Human Centers of Activity so can serve educational purposes
Research Capabilities

Candidate sites:

New site near Ujung Kulon

New site close to Bogor

Zoos with Sumatran rhinos

Other zoos

New site near Way Kambas

Sungei Dusun

New Site near proposed translocation sites.

IV. EVALUATION OF PROPOSED CAPTIVE PROPAGATION SITES

Candidate sites:

New Site near proposed translocation sites.
- New site near Ujung Kulon
- New site close to Bogor
- New site near Way Kambas

Zoos with Sumatran rhinos

Other zoos

Sungei Dusun

Table 1. Sumatran Rhino - Capture Statistics

	Captured	Died	Born	Surviving
Indonesia	4/6	0/1		2/2
W. Malaysia	2/9	2/1	0/1	1/7
Sabah	3/1	2/0		1/1
United States				0/2
United Kingdom		0/1		1/1
Thailand		0/1		
Total	9/16	4/4	0/1	5/13

Table 2. Sumatran rhinos - current locations.

Facility	Number
Indonesia:	
Jakarta	1/1
Surabya	1/0
Bogor Safari Park	0/1
West Malaysia:	
Malacca Zoo	1/7
Sabah:	
Sepilok	1/1
North America:	
Cincinnati	0/1
Los Angeles	0/1
United Kingdom:	
Port Lympne	1/1
Total	5/13

JAVAN RHINO PVA

Javan Rhino Population simulations results. The variables were first year mortality, juvenile mortality, and adult mortality. The remaining conditions were: polygamous, 7 year first reproduction, 75% no calf, 25% one calf per year, variances set at 1, no catastrophic variance, standard population structure (2,2; 2,2; 1,2; 1,2; 1,2; 12,16). Carrying capacity of 100. 300 runs for 100 years.

Juvenile mortality = 2%

Adult Mortality%		Infant Mortality % 10	15	20	25
4	r	.029	.028	.026	.024
	T	31.0	31.0	31.0	31.0
	%J	37.2	36.6	36.0	35.4
	Surv	1.00	1.00	1.00	1.00
	N	94 ± 8.5	93 ± 8.9	92 ± 9.0	92 ± 8.6
6		.022	.020	.017	.014
		22.8	22.8	22.8	22.8
		40.5	39.8	39.2	38.3
		1.00	1.00	1.00	1.00
		90 ± 9	88 ± 10	87 ± 10	84±15
8		.012	.009	.005	.002
		18.8	18.8	18.8	18.8
		42.2	41.5	40.6	39.6
		.997	.997	.993	.987
		77 ± 19	74 ± 20	62 ± 23	52±23
10		.000	-.004	-.007	-.011
		16.6	16.6	16.6	16.6
		43.5	42.4	41.6	38.6
		.977	.957	.850	.753
		46 ± 24	35 ± 22	26 ± 18	21±16

Juvenile mortality = 4%

Adult Mortality%		Infant Mortality % 10	15	20	25
4	r	.025	.024	.022	.020
	T	31.0	31.0	31.0	31.0
	%Juv	37.1	36.9	36.3	35.5
	Surv	1.00	1.00	1.00	1.00
	N	92 ± 7.8	92 ± 8.7	90 ± 8.7	90 ± 8.9
6		.017	.014	.012	.009
		22.8	22.8	22.8	22.8
		40.6	39.7	38.9	38.1
		1.00	1.00	1.00	.997
		86 ± 11.3	83 ± 14	81 ± 16	75 ± 19
8		.005	.002	-.001	-.005
		18.7	18.7	18.7	18.7
		41.9	41.1	40.2	39.1
		.990	.983	.970	.933
		63 ± 24	54 ± 23	43 ± 24	33 ± 20
10		-.008	-.011	-.015	-.019
		16.5	16.5	16.5	16.5
		43.1	42.1	41.1	39.9
		.853	.817	.647	.620
		26 ± 18	21 ± 16	16 ± 12	14 ± 10

Juvenile mortality = 6%

Adult Mortality%		Infant Mortality % 10	15	20	25
4	r	.021	.020	.018	.016
	T	30.9	30.9	30.9	30.9
	%Juv	37.7	37.0	36.3	35.6
	Surv	1.00	1.00	1.00	1.00
	N	90 ± 9.1	90 ± 8.2	89 ± 8.8	88 ± 9.7
6		.011	.009	.006	.003
		22.7	22.7	22.7	22.7
		40.4	39.5	38.6	37.7
		1.00	1.00	1.00	.990
		80 ± 15	74 ± 19	66 ± 23	57 ± 23
8		-.002	-.005	-.008	-.011
		18.6	18.6	18.6	18.6
		42.5	40.6	39.6	
		.977	.910	.903	.843
		42 ± 23	35 ± 23	26 ± 17	21 ± 13
10		-.016	-.019	-.023	-.027
		16.3	16.3	16.3	16.3
		42.5	41.3	40.4	
		.677	.627	.437	.390
		17 ± 12	13 ± 8.9	12 ± 8.8	9 ± 5

List of Participants

A. From the ministry of Forestry/PHPA

Ir Sutisna Wartaputra (Director-General of PHPA)
Ir Sujadi Hartono (Secretary-General of PHPA)
Dr. Effendy A. Sumardja (Director of Nature Conservation)
Ir Toga Siallgan (Director of National Parks)
Mr. Widodo Sukohadi Ramono (Chief, Species Conservation)
Prof. Rubini Atmawidjaja (President, Indonesian Wildlife Fund)
Ir Muladi Widjaja (PHPA)
Ir Bambang Darmadji (Ujung Kulon NP)
Ir Mohammed Haryono (Ujung Kulon NP)

B. From IUC/SSC

Dr. George Rabb (Deputy Chm. IUCN Species Survival Commission)
Dr. Simon Stuart (Species Programme Officer, SSC Executive Office)
Mr. Mohd. Khan bin Momin Khan (Chm, IUCN/SSC Asian Rhino Specialist Group)
Ir Syaffii Manan (Deputy Chm. IUCN/SSC ARSG)
Prof. Ruedi Schenkel (Former Chm. IUCN/SSC ASRG)
Dr. Ulysses S. Seal (Chm., IUCN/SSC Captive Breeding Specialist Group)

C. From International Zoo Community

Dr. Thomas Foose (Conservation Director, AAZPA)
Dr. Warren Thomas (Director, Los Angeles Zoo; Coordinator SRT)
Mr. Francisco Nardelli (Sumatran Rhino Trust [SRT])
Dr. Tim Clark (Brookfield Zoo)
Dr. Ronald Tilson (Minnesota Zoo)
Mr. Tony Parkinson (Sumatran Rhino Trust)

D. Others
Dr. Nico van Strien
Dr. Charles Santiapillai (WWF-I)
Dr. Eric Dinerstein (WWF-US)
Dr. Marty Fujita (Smithsonian Institution)
Dr. Linda Buntaran (IPB)
Dr. Hadi Ali Korda (IPB)
Dr. Machmud Thohari (BIOTROP)
Mr. Suhianto Lusli
Mrs Marialice Seal
Mr. Haerudin Sadjuddin (UNAS)
Director of Surabaya Zoo
Dr. Linus Sumanjunta (Director, Ragunan Zoo)
Director of African Safari Park (Cisarua)
Group of 10 Students

Regrets: Hon'ble Minister of Forestry, Ir Hasjrul Harap

WWF Indonesia Programme Statement on Conservation Priorities for Javan and Sumatran Rhinos in Indonesia.

Indonesia supports the largest remaining populations of Sumatran rhinos Dicerorhinus sumatrensis (at least 400 animals) and possibly the only viable population of Javan rhinos Rhinoceros sondaicus in the world. Both species are listed as endangered in the IUCN Red Data Book and their conservation is a matter of national and international concern. Both species are legally protected within Indonesia. For both species the main conservation priority is, and must continue to be, in situ conservation of rhinos within their natural habitats.

Sumatran Rhinos

1. In-situ conservation in Protected Areas

a. Sumatran rhinos are known to occur in substantial numbers in three national parks in Sumatra: Gunung Leuser, Kerinci-Seblat and Barisan Selatan. A fourth Sumatran park, Way Kambas, may still harbour a few Sumatran rhinos. All four of these parks have been identified as areas of global conservation importance by IUCN and are centres of biodiversity. Together they protect not only the Sumatran rhino but most species of Sumatran plant and animal life.

b. In Kalimantan the Sumatran rhino is now extinct in Kutai N.P. but rhinos may still occur in Kayan-Mentarang reserve in East Kalimantan, especially in the Ulu Sembakung extension. This reserve is recognised as a major centre for biodiversity in Borneo.

Improving effective protection and management of the Sumatran rhino reserves - Gn. Leuser, Kerinci-Seblat, Barisan Selatan, (Way Kambas) and Kayan-Mentarang - is the top priority for conservation of Sumatran rhinos. The Species Heritage Programme proposed by IUCN/SSC would be a good way to raise support, funding and resources to strengthen these parks.

2.In-situ conservation outside protected areas

a. There are probably still substantial numbers of Sumatran rhinos living in forests outside reserve boundaries. Not all of these forests are designated for conversion to agriculture. The Sumatran rhino prefers hill forests and is known to occur in several protection forests (hutan lindung) e.g. Gunung Patah, Gunung Abong-Abong, Lesten Lukup. Better protection of these forests, especially the forests between Kerinci-Seblat and Barisan Selatan, and more effective management will increase their conservation value. Stricter law enforcement against poachers will also protect Sumatran rhinos in remote areas.

2. Sumatra's forests are vanishing fast, a result of clearance for logging and agriculture. There are several small populations of rhinos pocketed in isolated patches of forest as at Torgamba. These rhino polulations are unlikely to be viable in the long run and the animals have been declared 'doomed'. The present PHPA/SRT strategy is to capture these 'doomed' rhinos and remove them to captive breeding schemes in Indonesia, Britain and U.S.A.

3. **Translocation**

A cheaper, and better conservation alternative would be to translocate 'doomed' animals to other reserves within Sumatra within the animals previous range. Such reserves include Berbak and Way Kambas. Prior to any such translocation measures must be taken to improve protection and effective managment of the receiving reserves. Again <u>in situ</u> conservation of rhinos in their natural habitats will benefit both the rhino and thousands of other 'less glamorous' species.

4. **Captive breeding programmes**

'Doomed' animals are currently captured for captive breeding schemes in zoos far away from the capture site. Since the ultimate aims of such programmes are to reintroduce captive-bred animals into the wild, considerable resources must also be allocated for protection of suitable wild habitats. Reintroductions of captive-bred animals into the wild are notoriously difficult, due to the behavioural and ecological needs of the species, and the need to 'educate' captive-born animals to living wild.

a. If PHPA plans to continue with its captive breeding activities, attention should be given to the possibility of captive-breeding wild-caught translocated animals in semi-wild conditions i.e. in very large enclosures (200 hectares or more) within a suitable conservation area. Such a scheme has the advantage that animals are:

1. translocated to natural habitats, rather than zoo conditions so remain essentially 'wild'.
2. animals can be well protected but remain within natural habitat in a much larger reserve area.
3. animals are born under semi-wild conditions and are already familiar with the environment and food plants prior to release
4. such a programme is cheaper, easier and more likely to be effective than a zoo programme and subsequent reintroduction scheme.
5. resources continue to be spent on improving protection and management of the reserve as part of the breeding scheme.
6. the presence of the breeding paddock is a tourist attraction even though the paddock is sufficiently large that rhinos can avoid the attention of visitors if they wish to do so.

b. Captive breeding schemes in zoos are the least attractive option from a conservation viewpoint. Animals are removed from the wild; few zoos have adequate facilities or space to build up