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Population Characteristics and Management of Black Rhinoceros *Diceros bicornis minor* and White Rhinoceros *Ceratotherium simum simum* in Ndumu Game Reserve, South Africa

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ABSTRACT

The population sizes, sex and age structures, home range sizes and overlap were determined for black rhinoceros Diceros bicornis minor *and white rhinoceros* Ceratotherium simum simum *in Ndumu Game Reserve by repeated sightings of known individuals and groups. The black rhino population in June 1986 was estimated to be 42, of which 10% were juveniles and with an adult sex ratio not differing significantly from parity. Their home range varied between 4·3 km² for a mixed group of animals and 13·8 km² for an adult female with calf. Home range overlap varied from 12 to 80%. The white rhinoceros population in June 1986 was estimated to consist of 57 animals of which 14% were juveniles. Adult sex ratio did not differ significantly from parity. Home range size varied from 2·5 to 22·9 km² and overlapped extensively for both sexes. Both populations of rhino in Ndumu are below the proposed minimum effective population size of 50. Consequently, for both species we recommend that in conjunction with the sustained removal of animals from the population, individuals from the parent populations should be periodically introduced into the reserve to increase the effective population size.*

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INTRODUCTION

Sixteen black rhinoceros *Diceros bicornis minor* were re-established into Ndúmu from Mkuzi, Hluhluwe and Umfolozi Game Reserves between 1962 and 1970 (Hitchins, 1984) and have apparently flourished. Twenty white rhinoceros *Ceratotherium simum simum* were re-established in Ndumu between 1961 and 1963 with similar success.

If these populations were allowed to achieve an unassisted equilibrium at ecological carrying capacity, their population increase rates would be zero (Caughley, 1976). There still remain numerous conservation areas where these two species could be re-established; thus it would be in the interests of conservation to maintain these populations in a productive state.

Since their re-establishment in Ndumu, individuals from both populations have been translocated to other areas. However, these removals were undertaken with little knowledge of the size, structure or rates of increase of the Ndumu populations. Consequently, the objectives of this investigation were to:

1. establish the population size and distribution of both black and white rhino;
2. establish the sex and age structure of each population;
3. calculate the extent of the home range, and overlap for each species;
4. make management recommendations that would improve the probability of long-term survival of these two species in Ndumu.

This study was commenced in July 1984 and field work was suspended at the end of June 1986.

STUDY AREA

Ndumu is a small game reserve (*c.* 116 km^2) situated at the confluence between the Usutu and Pongolo Rivers on the Mozambique coastal plain (26° 52′ S and 32° 15′ E). The climate is hot and humid in summer and warm and dry in winter. The mean annual rainfall is 630 mm, with lower and upper extreme values of 276 and 1160 mm respectively. 79% of the rainfall occurs between October and March.

Detailed descriptions of the vegetation and soils have been documented by De Moor *et al.* (1977). For the purpose of this paper, it is sufficient to recognise the following ecological units:

(i) Flood plain communities on recent alluvial soils. These occupy approximately 29% of the reserve and consist of riparian fringing forest, *Phragmites* reed beds, and *Echinochloa/Cynodon* grasslands.

(ii) Woodland, forest and thicket on recently deposited sandy soils covering approximately 16% of the reserve.
(iii) Bushland and thicket on yellow to orange calcareous clay soils—locally called Mahemane thicket and occupying 35% of the reserve.
(iv) *Acacia tortilis* woodland on ancient red dune sands covering approximately 11% of the reserve.
(v) Mixed *Acacia nigrescens* wooded grassland occupying 5% of the reserve area.

The remaining 4% of reserve area is taken up by open water, pans and rivers.

In addition to black rhino and white rhino, 14 other large herbivore species occur in the reserve. The most important of these are buffalo, hippo, impala, nyala and zebra. The total large herbivore biomass in the reserve is estimated as 70 kg ha^{-1} (Goodman, 1987).

METHODS

Population size

The density of vegetation in Ndumu is a considerable obstacle in estimating the population size of both species of rhino. The density of the woody plant canopy and understorey renders both aerial and ground sample population estimation techniques unfruitful. Consequently, the known individual or group method was employed. The reserve was subdivided into six patrol areas, a portion of which was traversed each day by game guards stationed in the area. In this method attempts were made by ourselves with the assistance of the game guard sightings to recognise every individual or group in the population by various features unique to each. For example, the ear tears, ear notches or horn shape of individuals, or sex and age structure and area occupancy of groups. A register was built up of all known individuals or groups. When no new individuals or groups were encountered, all individuals in the register were summed to give an estimate of the population.

Population sex and age structure

The sex and age structure of the population was determined by classification of all individuals in each population through incidental observation by reserve staff. An attempt was then made to confirm all of these observations by one of us (A.J.C.) during the study period. Three age classes were distinguished, namely; juvenile (<1 year), yearling (1–<2 years) and subadult and adult (2 years and more). Criteria used for the field recognition

of these age classes were according to Hitchins (1970) for black rhinoceros and line drawings made from photographs of known-aged individuals subsequently published in Hillman-Smith *et al.* (1986) for white rhinoceros. All classified groups were entered into a register and each sex within each class was summed on the termination of the study.

Home range size and overlap

The localities of individually recognisable animals were noted by reference to a six-figure grid system with a resolution of 100 m covering the reserve. Normally, only a single observation per individual was made on any one day, but if an animal was seen to move significantly in the same day then a further fix would be recorded. Each observation for each individual was plotted on a 1:50 000 map and at the end of the data collection phase the peripheral localities for each individual were joined, and the area so enclosed then measured using a planimeter. We have considered ten localities per group recorded throughout the study period, the minimum necessary for a reasonable estimate of home range size and overlap. Overlap in home ranges was assessed by overlaying individual home ranges on a single map and measuring the area that each individual's home range overlapped with another.

RESULTS

Black rhinoceros

Population size and density

Based on a total of 440 sightings, 18 black rhino individuals or groups were identifiable. This accounted for a total of 19 animals. In addition to this, there were a further 18 individuals or groups that could be recognised on the basis of the sex and age composition of the groups, or their spatial separation from other similar groups. We estimated that they contributed a further 23 individuals to the total population, which was estimated to be 42. Of this total population, 7 individuals occupied the floodplain and sandveld woodland and thicket to the east of the Pongolo river, while the remaining 35 individuals were found west of the Pongolo (Fig. 1). Only on infrequent occasions when the river level was very low did individuals from the two sub-populations make contact with one another.

The mean density for black rhino in the whole of Ndumu was 0·38 km^{-2}. The density of rhino east of the Pongolo river was 1·64 km^{-2}.

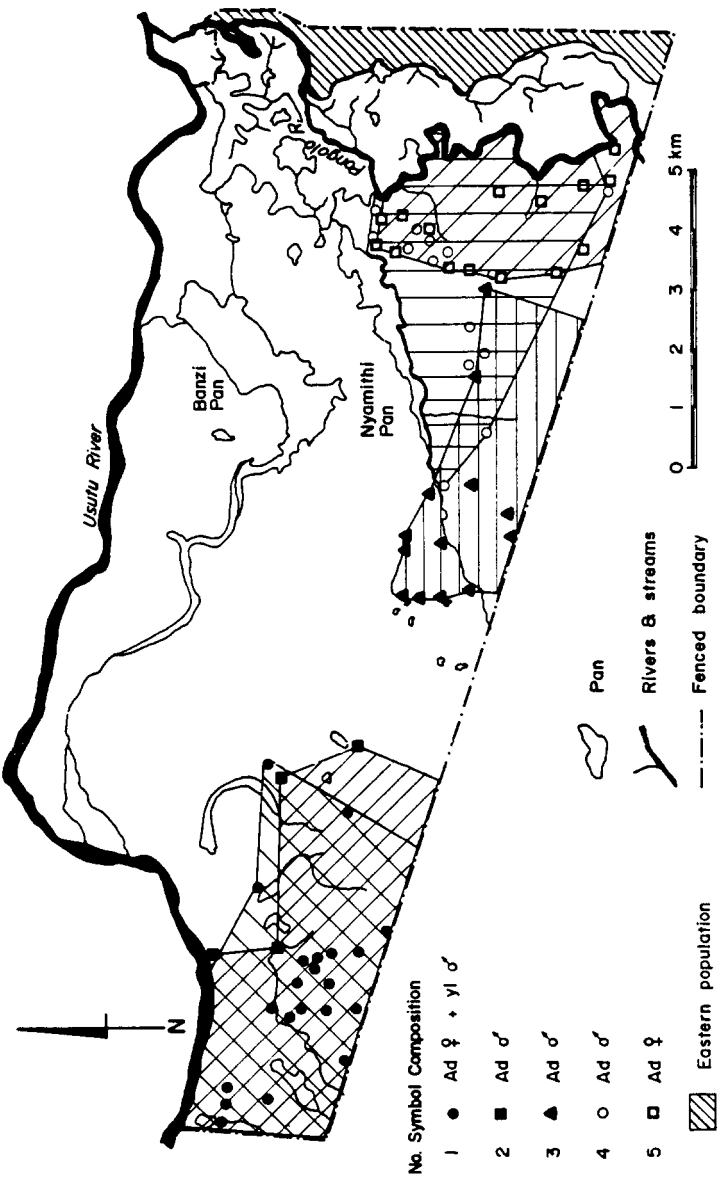

Fig. 1. Ndumu Game Reserve showing individual sighting localities and home range boundaries of six known black rhino individuals and group.

TABLE 1
Sex and Age Classification of Black Rhinoceros

Age	*Sex*	*Number*	*Age totals*	*Age ratio*
Adult and subadult	Male	15	33	0·79
	Female	18		
Yearling	Male	3	5	0·12
	Female	1		
	Unclassified	1		
Juvenile	Male	2	4	0·10
	Female	1		
	Unclassified	1		
Total		42	42	

Age totals are the sum of all individuals in each age class. Age ratio is the ratio of individuals in each age class to the total population.

Sex and age structure

The population consisted of 33 adults and sub-adults (79%), 5 yearlings (12%) and 4 juveniles (10%) (Table 1). Of the adults and sub-adults, 15 were males and 18 females, which does not differ significantly from a sex ratio of 1:1 (chi-square = 0·27, $0{\cdot}5 < P < 0{\cdot}7$). The numbers of yearling and juvenile animals in the population were too small to test regarding their sex ratio, in addition to which there was one sexed individual in each age class.

Home range size and overlap

Of the 18 known groups, five were sighted on more than ten occasions. In addition, the seven animals found to the east of the Pongolo river occupied a restricted area between the floodplain and the eastern boundary fence (Fig. 1), which we took to be their maximum home range. At the outset of data analysis, it became obvious that many observations of certain individuals, in particular those occupying denser thickets, were only made along well-established roads and tracks. In addition, although in principle we used the minimum convex polygon method for home range estimation, certain non-negotiable obstacles such as major rivers, pans and fences slightly reduced the estimate of some of the home ranges. Furthermore, other evidence such as known drinking points influenced us to extend some home range boundaries to a more logical limit.

Finally, a large adult male was tracked passively for two days prior to being captured and translocated to another area. The extremities of the animal's movements over this period were mapped and an estimate of

14·3 km^2 for its home range was obtained. This animal had the largest home range recorded for any individual in Ndumu (Fig. 1, individual number 2).

The minimum estimate for home range was 4·3 km^2 and was for the group of animals east of the Pongolo river (Fig. 1). Since this area was shared by seven individuals which included two adult males and two adult females, this is likely to be an over-estimate of minimum home range.

The four estimates based on known individual sightings were 8·3 km^2 (adult male, individual 3), 12·3 km^2 (adult male, individual 4), 8·3 km^2 (adult female, individual 5) and 13·8 km^2 (adult female and yearling male calf, group 1) (Fig. 1) giving a mean estimate for home range of 11·4 km^2. Measurements of home range overlap were obtained for a single male/male (individuals 3 and 4) and two male/female pairs (groups 1 and 2, 4 and 5) (Fig. 1). These were 12·4% for the former and 79·5% and 48·8% for the latter.

White rhinoceros

Population size and density

Based on a total of 951 sightings, the number of recognisable white rhino individuals or groups was 26, representing a total of 35 animals. In addition to these, a further 16 groups or individuals could be recognised on the basis of the sex and age composition of the groups, or their spatial separation from other similar groups. We estimated that they contributed a further 22 animals to a total population consisting of an estimated 57 individuals. No white rhino were found permanently in the area of the reserve to the east of the Pongolo river (Fig. 2). Only one observation was made of a group of three individuals crossing the Pongolo into this area and returning shortly afterwards.

Mean density of white rhino in Ndumu west of the Pongolo river was 0·57 km^{-2}. However, most of the population was centered on the western half of the reserve since much of the remainder consisted of dense thicket and was not suitable habitat for white rhino. The mean estimate of density for the former area was 1·75 km^{-2}. However, when prime grazing conditions prevailed, the most westerly third of this area supported mean densities of 2·68 rhino km^{-2} for periods of up to five months.

Sex and age structure

The population consisted of 45 adult and sub-adults (78%), 4 yearlings (7%) and 8 juveniles (14%) (Table 2). Of the adults and subadults, 18 were males and 27 were females. This does not differ significantly from a sex ratio of 1:1 (chi-square = 1·80, $0{\cdot}1 < P < 0{\cdot}2$). The numbers of both sexes in the yearling and juvenile age classes were too small to test statistically.

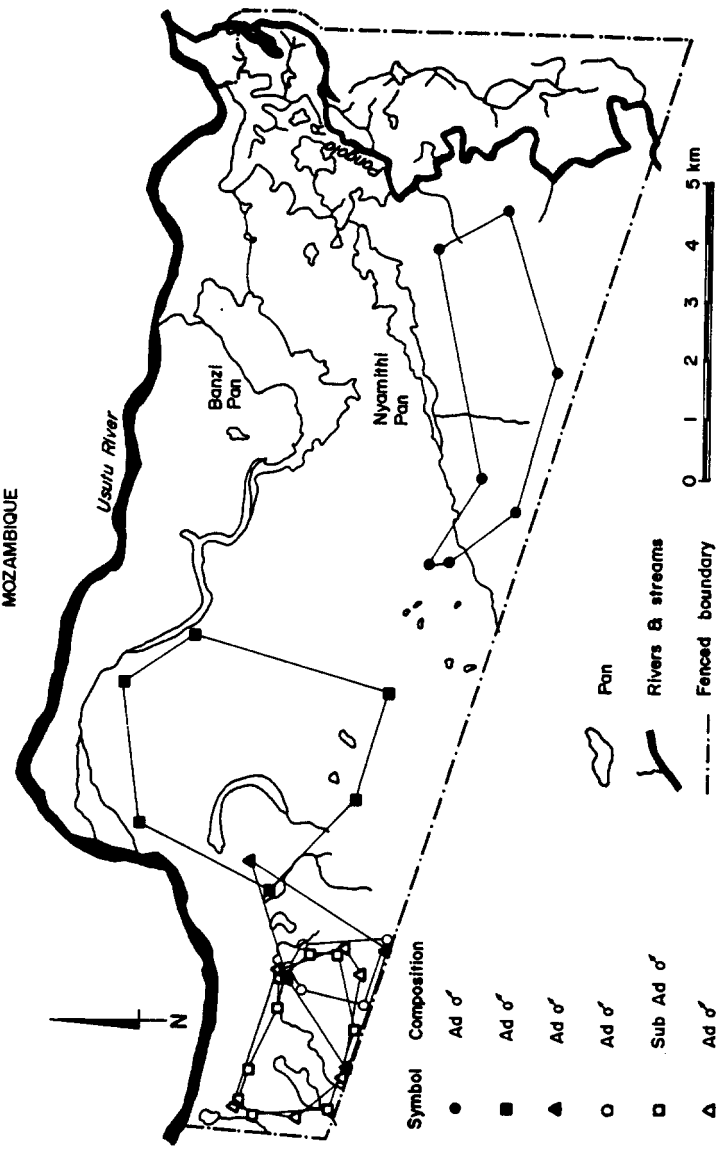

Fig. 2. Ndumu Game Reserve showing sightings of the most extreme observations, and thus home range limits, for six known adult and subadult male white rhino.

TABLE 2
Sex and Age Classification of White Rhinoceros

Age	*Sex*	*Number*	*Age totals*	*Age ratio*
Adult and subadult	Male	18	45	0·78
	Female	27		
Yearling	Male	1	4	0·07
	Female	3		
Juvenile	Male	3	8	0·14
	Female	5		
Total		57	57	

Age totals are the sum of all individuals in each age class. Age ratio is the ratio of individuals in each class to the total population.

Home range size and overlap

Of the 26 known groups and individuals, 15 were sighted on more than ten occasions. Home range size averaged 10·0 km^2 (range 2·5–22·9 km^2). There was no apparent relation between the number of sightings of each group and home range size for groups with more than 10 sightings ($r = 0{\cdot}002^{ns}$) and thus we may assume that factors other than this are determining our estimate of home range sizes of these animals.

Adult and subadult male home range sizes varied from 2·5 to 13·9 km^2 with a mean of 7·9 km^2 ($n = 6$). All known adult female groups were accompanied by at least one of their offspring, and their home ranges varied from 4·7 to 22·9 km^2 with a mean of 11·3 km^2 ($n = 9$). Female ranges were not significantly larger than male home ranges ($df = 13$, $t = 1{\cdot}273^{ns}$ for one-tailed test).

Known adult and sub-adult males had range overlaps varying from one extreme of being completely overlapped by the home ranges of other males in the prime white rhino habitat in the west of the reserve, to no known overlap with other males in the less suitable habitat south of Nyamithi pan (Fig. 2). In a portion of the prime white rhino habitat in the west, it was found that at least 11 adult or sub-adult male home ranges overlapped in a common area. This overlap was not associated with water or an attraction to a female in oestrus.

All known female groups had some range overlap with other female groups. This varied from 100% in at least six instances to a minimum of 77%. Again the density and amount of range overlap in the west indicated

that this area was highly favoured when compared to any other area. In a small portion of this area, at least eight known female groups shared a common area within their home ranges.

DISCUSSION

Black rhino

The mean density of black rhino in Ndumu (0·38 km^{-2}) falls well within the range of other estimates for the species in Africa (Goddard, 1970; Hitchins & Anderson, 1983). In general terms this would be regarded as being 'medium' to 'low' using the terminology of Goddard (1970). The isolated population to the east of the Pongolo River (1·64 rhino km^{-2}) has a 'very high' density (Goddard, 1970) and exceeds the previously highest recorded density of 1·1 km^{-2} found in Hluhluwe by Hitchins (1976). The high degree of soil variability (alluvium, Cretaceous clays and Quarternary dune sands) in association with past disturbance, has resulted in a vegetation cover with a high species richness and beta diversity. We are of the opinion that the maintenance of the very high density of black rhino in this area is largely due to this vegetation diversity and the free availability of permanent water. The fact that two out of the seven animals occupying the area are less than two years old would seem to indicate that this continues to be productive black rhino habitat.

The proportion of juveniles (10%) and yearlings (12%) in the whole population would indicate a juvenile recruitment in the region of 10% per annum. In the absence of emigration from the reserve, a recorded mortality of two animals in the last 6 years and the removal of two adults for relocation elsewhere, the maximum rate of increase in this population would be in the region of 9% per annum.

Home range sizes in Ndumu (4·3–14·3 km^2) were generally towards the bottom of the range recorded elsewhere. In Hluhluwe Game Reserve, Hitchins (1969) recorded home ranges of 5·0 km^2 and 3·0 km^2 in 'savanna' and thicket habitats respectively. Rhino home ranges in East Africa varied considerably. Individual home ranges in Ngorongoro Crater were from less than 2·6 km^2 to 15·4 km^2 (Goddard, 1967), 5·6 km^2 to 22·7 km^2 in the Masai Mara (Mukinya, 1973) and 43 km^2 to 133 km^2 on the Serengeti plains (Frame, 1980).

The medium to high population density, relatively high juvenile recruitment and low home range size can be explained by the availability of suitable cover (high proportion of closed woodland and thicket), the apparent abundance of palatable browse and the wide distribution of

surface water, all of which are thought to be essential components of suitable black rhino habitat (Smithers, 1983).

At present, the Ndumu black rhino population is isolated from all others in southern Africa. While the total population size is estimated at 42, the effective population size, *Ne* (Franklin, 1980) is only 29. This is well below the proposed minimum effective population sizes of 50 and 500 individuals for short- and long-term survival (Franklin, 1980; Soulé, 1980). Clearly, if this population is to retain its genetic fitness and long-term viability, appropriate management action is necessary.

Basically, two management options for increasing effective population size are available (Soulé, 1984): (a) *in situ* population and/or habitat management; or (b) creation and maintenance of artificial genetic links with other closely situated but related populations.

Since both density and home range sizes of black rhino in Ndumu indicate that habitat is already close to optimum, habitat management is unlikely to increase effective population size to any large extent. By maintaining an equal number of offspring between mating pairs, the effective population size could be twice its currently estimated value (Soulé, 1982). For the time being, however, difficulties experienced with monitoring, let alone actual management, would preclude exercising this option until longer term records on the life history of each individual in the population become available.

The second option is clearly more appropriate to exercise at this stage. At present an average of two animals per annum are being removed to establish new populations in other suitable reserves. Our crude estimate of rate of increase would seem to indicate that this population could easily sustain this removal. In conjunction with this removal programme, genetic fitness of this population should be enhanced by the simultaneous periodic introduction of an individual from one of the parent populations, namely those in Mkuzi and the Hluhluwe/Umfolozi Game Reserves. With an estimated mean generation time of 12 years, a single successful introduction from one of the parent populations every 12 years, is likely to be an efficient means of enhancing effective population size.

White rhino

Both the mean white rhino population density in Ndumu (0·6 km^{-2}) and the density in the western half of the reserve (1·8 km^{-2}) fall in the lower portion of the range recorded in Hluhluwe/Umfolozi reserves by Owen-Smith (1973). These were from 0·4 km^{-2} in Hluhluwe to 5·7 km^{-2} for his western study area in Umfolozi.

The relatively high proportion of juveniles (14%) and lower proportion of

yearlings (7%) in the population indicates a juvenile recruitment of at least 7%. In the absence of emigration from the reserve and a recorded mortality of two animals in the last three years, the maximum rate of increase in this population would be in the region of 6%. The apparent drop in the relative proportion of individuals from juvenile to yearling age categories might be construed as an alarmingly high juvenile mortality rate. However, in a relatively small population such as this, it could also be due to random variation in conception and natality, as well as depressed natality due to the extended drought in the region, which was terminated by the Domoina flood event in February 1984.

This population is apparently still increasing. Due to the large proportion of the reserve which has a high woody plant cover, however, we are of the opinion that the habitat is less suitable than that found in the west of Umfolozi, and that the high densities apparent in Umfolozi are unlikely to be achieved over an extensive area in Ndumu. Since the area of suitable white rhino habitat in Ndumu is small, and a large number of other grazers are also supported by this area, the population size of rhino is currently being limited by management to between 50 and 60 individuals.

Female home ranges in Ndumu (mean 11·3 km^2) were generally equivalent to the annual ranges recorded for Umfolozi by Owen-Smith (1973) (mean 14·3 km^2, range 6·1–19·6 km^2). Mean annual ranges of males in Ndumu (7·9 km^2) were considerably larger than male territory sizes found by Owen-Smith (0·75–2·6 km^2). An apparent difference in male behaviour in Ndumu when compared to Umfolozi was that we were unable to find any evidence for territoriality in male rhino in the western portion of the reserve where densities were highest. This could explain the high degree of home range overlap and larger annual ranges when compared to the Umfolozi population.

As with black rhino, the white rhino in Ndumu are isolated from other white rhino populations in southern Africa. The effective population size (*Ne*) is estimated as 33 and again, this is well below the proposed short-term minimum effective population size of 50. For reasons other than genetic, the population ceiling for white rhino in Ndumu has been fixed at between 50 and 60 individuals. Genetic fitness of this population will therefore be most practically enhanced by the periodic introduction of individuals from the parent population found in the Hluhluwe/Umfolozi reserves. Mean generation time is estimated as 13 years, so the successful introduction of a single animal from the parent population every 13 years, done in conjunction with the sustained removal of animals in excess of the suggested population ceiling, would be the most efficient means of enhancing effective population size.

Finally, both black rhino and white rhino are rapidly falling victim to

poachers in many parts of Africa. Unless a proven, reliable monitoring system is adopted to determine rhino status in conjunction with poaching pressure, the rhino populations in Ndumu may suffer similar declines. Consequently, we recommend that monitoring should entail an ongoing and conscientious check on all known black rhino and white rhino individuals and groups, coupled with a continual update and analysis of poaching activity similar to that reported by Conway (1984). This would ensure early detection of any adverse activity and thus facilitate swift counteraction.

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