AFRICAN RHINOCEROSES IN CAPTIVITY

The white rhinoceros
Ceratotherium simum (Burchell, 1817)

The black rhinoceros
Diceros bicornis (Linnaeus, 1758)

by

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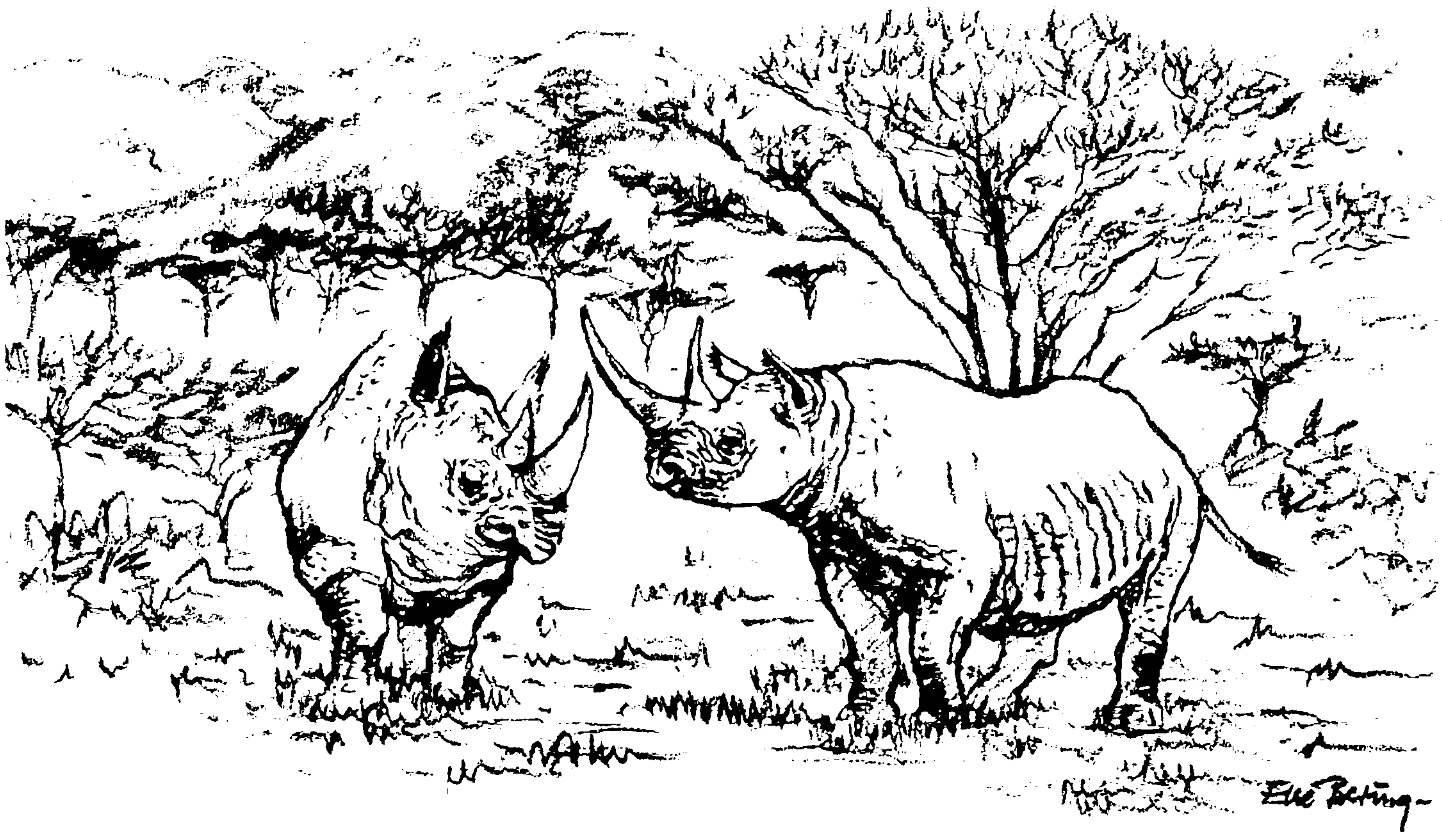

I had followed two Rhinos on their morning promenade, when they were sniffing and snorting in the air of the dawn, – which is so cold that it hurts in the nose, – and looked like two very big angular stones rollicking in the long valley enjoying life together.

Karen Blixen in Out of Africa

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SUMMARY

Rhinos are now so scarce in many areas in the wild, that breeding sanctuaries have to be considered. The aim of this study has been to compile existing data on reproduction of the two African species, the white rhino, Ceratotherium simum and the black rhino, Diceros bicornis in captivity, supported by information from the wild. Such data will not only provide useful information for future breeding projects, but will also complement studies in the wild.

For this purpose questionnaires were mailed to 156 zoos, worldwide, keeping African rhinos. 104 replied, representing 42 collections keeping 105 black rhinos and 83 collections keeping 300 white rhinos.
Based on the questionnaires and on information from the Studbook and the literature, reproduction parameters such as sexual maturity, oestrus and mating, gestation period and intervals between calves for both species, have been examined and summarized. Also juvenile mortality and artificial rearing of calves have been investigated.
The factors affecting the success of keeping and breeding the African rhinos in captivity have been examined, and it is concluded that:

1. Captive breeding and rearing of white rhinos is indeed feasible,
2. size of enclosure does not in itself affect breeding success of white rhinos,
3. keeping white rhinos in single pairs is not conducive to successful breeding,
4. intermale competition seems to have a positive influence on breeding success in white rhinos,
5. single pairs of black rhinos are as successful as multiple couples, but other factors influence the reproduction, such as the practice of keeping solitary animals,
6. more than one third of the adult females are not breeding because they are either kept single or are incompatible with their mate,

7. juvenile mortality is still a major unsolved problem in the black rhino,
8. the main cause of loss of juvenile black rhinos seems to be disease. This needs further investigation.

Based on 145 black rhinos that died in captivity, a demographic survey of the black rhino population in captivity has been carried out, and from this it is concluded that:

1. The present population of black rhinos in captivity can only be sustained if survival and/or fertility is improved,
2. the black rhino population is decreasing by approximately seven percent per year,
3. management practices should aim at a) including a larger part of the unproductive animals into the breeding stock, b) improving the overall survival. The former might be the easier to achieve.

Also, the implications of inbreeding and the problems of maintaining the subspecies in captivity are discussed, and it is concluded that:

1. inbreeding should be discouraged,
2. the practice of keeping white rhinos in herds, which is commendable from a breeding point of view, could cause inbreeding problems later on, as usually only the dominant male has the opportunity to reproduce,
3. management practice should aim at increasing the number of breeding animals in both species (which decreases inbreeding). With regard to the white rhinos the addition of breeding males is especially advantageous. This could be achieved by substituting some of the reproducing males with males that are not breeding at the present,
4. it seems impossible to maintain the genetic integrity of the subspecies of the black rhino in captivity.

1. GENERAL INTRODUCTION

BACKGROUND

Many species are endangered because their natural environment is disappearing. Through recorded history loss of habitat has also been the main reason for the declining numbers of rhinos in Africa, but it is hardly the primary problem today. Lately, the decline of rhinos has been due to poaching, the horn having great commercial value (Martin 1979).
Poaching accelerated in the beginning of the seventies, and between 1972 and 1978 a minimum of 7.75 tons of rhino horn was yearly brought on the world market, representing approximately 2580 dead rhinos every year. Well over 90 percent of the international trade of rhino products originated from the African species, for the simple reason that there are ten times as many rhinos living in Africa as in Asia (Martin 1979).

The two African species are the white or square-lipped rhinoceros Ceratotherium simum (Burchell, 1817) and the black or hook-lipped rhinoceros Diceros bicornis (Linnaeus, 1758). There are two recognized subspecies of the white rhino, the northern white rhino Ceratotherium simum cottoni (Lydekker, 1908) and the southern white rhino Ceratotherium simum simum (Burchell, 1812). The two subspecies are separated by more than 2000 km (Map 1.).
The black rhino populations have been contiguous until recently (Map 2.), with a certain geographic variation. The seventeen subspecies described by Zukowsky (1964) have been re-interpretated by Groves (1967) and he suggests seven subspecies.

While the northern white rhino with fewer than one thousand individuals left in the wild, is severely endangered (IUCN 1972 & Table 1.1.), the southern white rhino has been removed from the list of endangered animals, thanks to effective conservation measures in South Africa. Indeed, southern white rhinos have now become so plentiful in certain protected areas that they are a potential danger to their habitat (Owen-Smith 1982), and this in spite of the translocation programmes which developed during the 1960s (Player 1967). Between 1961 and 1980 more than 2600 white rhinos have been moved from South Africa, 616 of these to zoos and safari parks outside Africa (Natal Park Board, pers. comm.). Today there are about 2500 white rhinos in South Africa, and their numbers are increasing by approximately nine percent per year (Owen-Smith 1982).

Although the black rhino is still the more numerous and widespread of the two African species, with a total population of 10-15,000 in 17 or 18 countries (IUCN 1981, Table 1.1.), it is also the one that has been most severely decimated recently. In the last ten years, approximately 90 percent of the black rhinos in Kenya, Uganda and Northern Tanzania have been killed (Hillman & Martin 1979). Overall, black rhinos are decreasing in 11 to 13 of the 18 countries where they still exist (Table 1.1.). The cause of this elimination is the growing demand for rhino horn in the Far East for alleged medical purpose and in North Yemen for dagger handles. In the four years 1976-79 prices have increased 2000 percent. In South East Asia the minimum wholesale price was US $675 a kilo in late 1979 (Martin 1979). In comparison, Huxley (1961) wrote twenty years ago: "Rhino horn in Kenya commands the fantastic price of US $27 a kilo".

With prices escalating, the temptation becomes even greater for poachers. These are now well organised, well equipped and ruthless (Borner 1981).
The only way to ensure a long term survival of rhinos in the wild, would be to arrest the international trade in rhino products. Martin (1979) has made a number of recommendations to this effect. For example, to encourage interest in the producing, consuming and trading countries to join the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

SUMMARY OF THE RHINO POPULATIONS OF AFRICA
IUCN/NYZS/WWF African Rhino Survey, August 1981

Black Rhino (Diceros bicornis.L.)

Country	Estimated Nos.	Trends	Data base
Angola	low hundreds	decreasing	C
Botswana	low tens	"	C
Cameroun	less than 100	"	C
C.A.R.	1000-3000	"	B/C
Chad	possibly 0	"	
Ethiopia	less than 20	probably decreas	C
Kenya	less than 1500	decreasing	C
Malawi	± 40	stable/increasing	B/C
Mozambique	200-300	decreasing	B/C
Namibia	± 345	"	B
Rwanda	20-40	increasing	B
Somalia	low hundreds	unknown	C
South Africa & Bophuthatswana	± 625	increasing	A
Sudan	less than 300	decreasing	B/C
Tanzania	3000-4000	"	A/C
Uganda	low tens	"	C
Zambia	2500-3000	increasing	B/C
Zimbabwe	± 1400	stable/increasing	A/B/C
Total (rounded)	10,000-15,000	DECREASING	

Northern White Rhino (Ceratotherium simum cottoni, Lydekker)

Country	Estimated Nos.	Trends	Data base
C.A.R.	possibly a few	unknown	C
Sudan	less than 400	decreasing	B/C
Uganda	possibly 0	"	C
Zaire	less than 400	"	B
Total (rounded)	1,000	DECREASING	

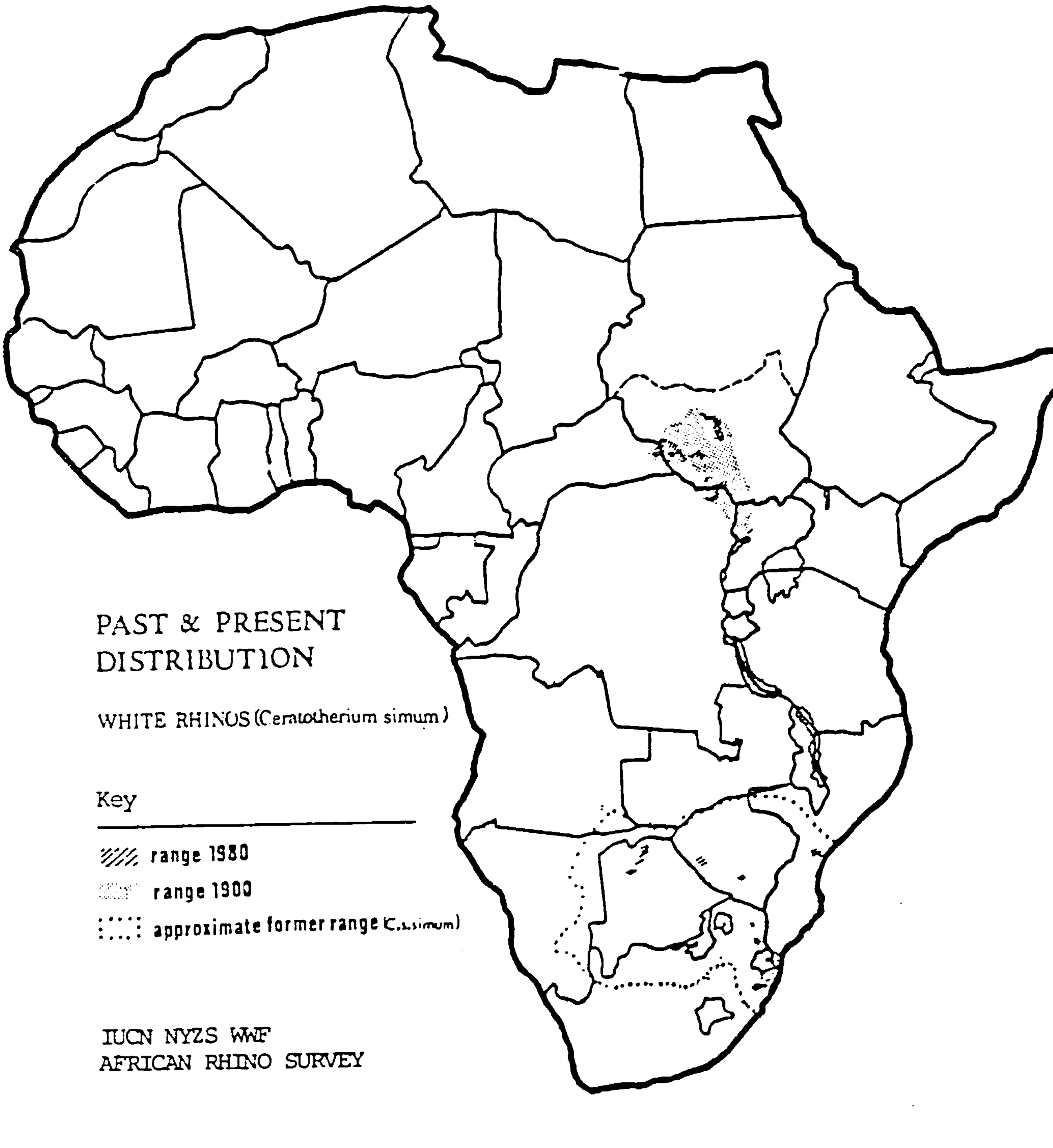
Southern White Rhino (Ceratotherium simum simum, Burchell)

Country	Estimated Nos.	Trends	Data base
Botswana	60-90(re-introduced)	increasing	B
Kenya	27(introduced)		A
Mozambique	22-36(re-introduced)	decreasing	B
Namibia	± 150(re-introduced)		B
South Africa & Bophuthatswana	± 2500	increasing	A
Swaziland	60(re-introduced)	"	A/B
Zimbabwe	± 180(re-introduced)	"	A/B
Zambia	6 (re-introduced)		A
Total (rounded)	2,995-3,033	INCREASING	

KEY: Data base: A: Estimates based on census figures or other detailed information reliable for rhinos.
B: Census information less reliable for rhinos, or extrapolations from good knowledge of an area.
C: Educated guesses.

Table 1.1.
From: IUCN/SSC African Rhino Group: The Action Plan (1981) for conservation of African rhinos.

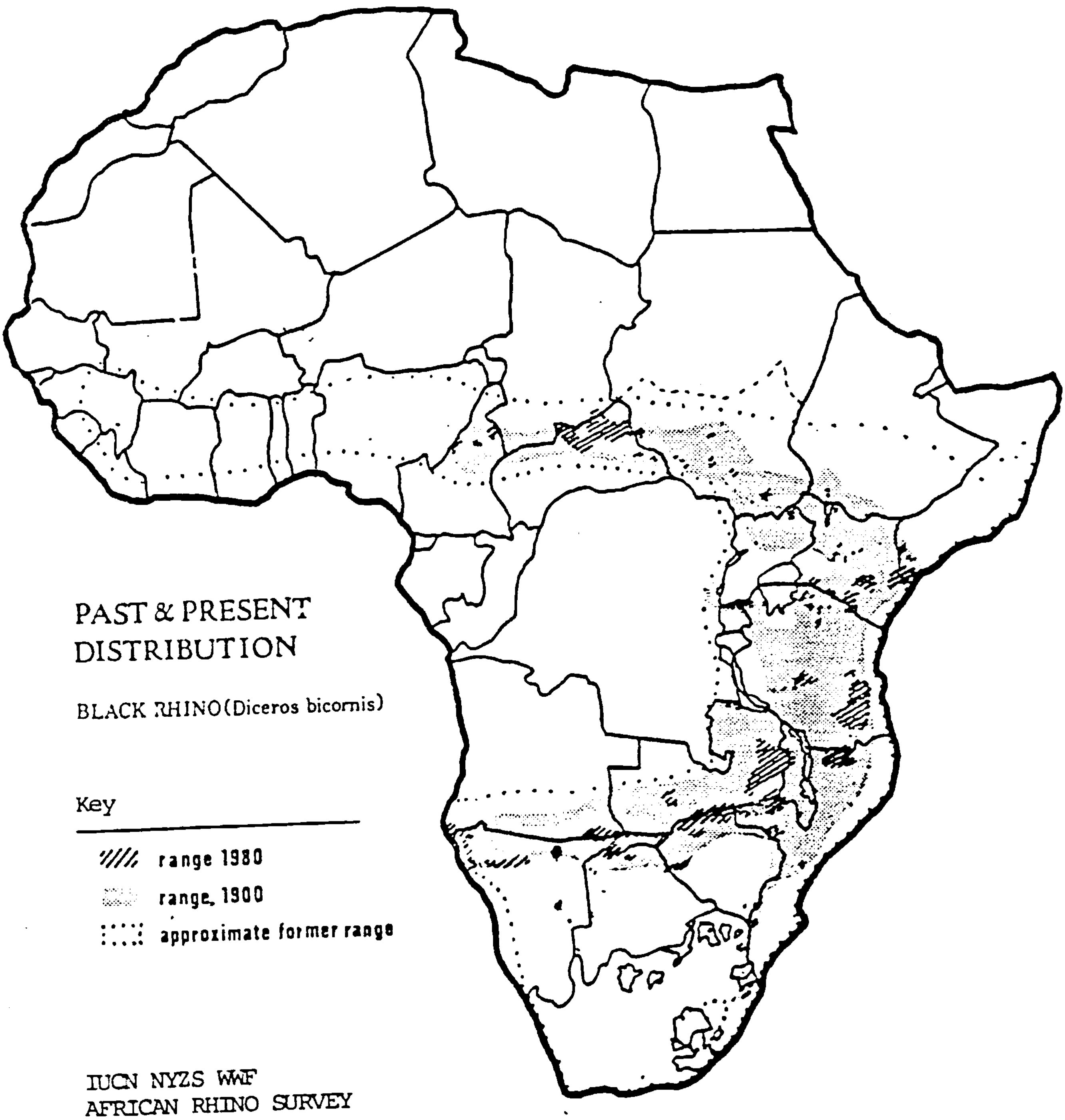
White rhino, Ceratotherium simum, distribution in the wild



Map 1.

After: African Rhino Group, Action Plan
IUCN (1981)

Black rhino, Diceros bicornis, distribution in the wild



Map 2.

After: African Rhino Group, Action Plan
IUCN (1981)

INTRODUCTION

The need for a survey of African rhino in captivity emerged as rhinos have now become so scarce in many areas in the wild, that breeding sanctuaries ought to be considered in indigenous areas.
It was felt, that much valuable information was available from rhinos in captivity. Not only would such data provide useful background information for possible future breeding projects, but it would also complement studies in the wild (IUCN 1981).

For the two species of African rhino, the white rhino (Ceratotherium simum) and the black rhino (Diceros bicornis), the International Studbook (Klös and Frese 1981) records certain information (see International Registration). However, it was felt, that additional biological data was available from the individual zoos. So, it was decided in cooperation with Dr Kes Hillman, Chairman of the IUCN/SSC +) African Rhino Group, to collect as detailed information as possible on zoo-kept rhinos, such as breeding success in different situations, gestation period, intercalf-interval and mortality of young. For this purpose questionnaires were sent out to zoos and safari parks, worldwide, which keep African Rhinos.

The overall aim of the present survey has been, based primarily on information from the Studbook, the literature and from the questionnaires:

1. to compile existing data on reproduction of African rhinos in captivity, supported by information from the wild,
2. and based on this information to work out the optimal conditions for keeping captive rhinos for breeding purpose.

+) IUCN: International Union for Conservation of Nature and Natural Resources.
SSC: Species Survival Commission

Furthermore a demographic survey of the black rhino in captivity has been carried out, but is dealt with separately.
The implications of inbreeding are also discussed as well as the problems of maintaining the subspecies in captivity.

2. ABOUT THE SURVEY

INTERNATIONAL REGISTRATION

Captive rhinos are registered independently by three International Agencies, from which data can be acquired.

1. International Zoo Yearbook (Int. Zoo Yb.) has every year since 1962 (Vol III) listed zoos keeping rhinos in: Census of Rare Animals in Captivity. Besides the number of animals kept by each zoo, Int. Zoo Yb. also states how many of these are born in captivity. Numbers for 1979 and 1980 are shown in Table 2.1.

2. The International Studbook for the two African species was initiated in 1967 (Klös and Frädrich 1970) in cooperation with IUCN. The Studbook keeper is professor H.G. Klös, director of Zoologischer Garten, Berlin. Rules and procedures for future policy and responsibilities of the Studbook keepers were amended at an International Symposium on the Use and Practice of Wild Animal Studbooks, held in Copenhagen on 19th and 20th of October 1979 (Int. Zoo Yb. 1980). The author attended this meeting.
The Studbook gives the following information:
Sex, date and place of birth and death, place of origin, present and previous place of location and date of arrival. For animals born in captivity : sire and dam.
A full version of the Studbook was published for the first time in 1981 (Klös and Frese).
Table 2.2. gives the number of African rhinos registered by the Studbook, for each year since 1969, as well as the yearly number of births and deaths.

3. International Species Inventory System (ISIS), records information on the same line as the Studbook, but is computerised (Seal et al. 1976, 1977).

Year	Total numbers	Animals born in captivity	Number of collections
a. Southern white rhino			
1979	359 (167,192)	60 (37,23)	113
1980	365 (170,195)	81 (45,36+)	114
b. Northern white rhino			
1979	19 (8,11)	1 (0,1)	7
1980	11 (4,7)	1 (0,1)	4
c. Black rhino			
1979	151 (70,81)	50 (26,24)	64
1980	137 (62,75)	55 (26,29)	58

Table 2.1.

From Census of rare animals in captivity, International Zoo Yearbook , Vol 20 (1980) and Vol 21 (in press).

Figures cover the numbers in captivity on 1st of January of the year stated.

Year	Number of births	Number of animals caught in the wild	Number of deaths	Number of animals registered on Dec. 31st.
a. White rhinos				
1969	1,0	5,3	-	95 (48,47)
1970	1,0	23,34	0,1	152 (72,80)
1971	2,0	30,71	0,1	254 (104,150)
1972	4,1	24,34	-	317 (132,185)
1973	4,4	18,25	1,4	363 (153,210)
1974	8,6	25,31	3,2	428 (183,245)
1975	3,2	17,24	6,3	465 (197,268)
1976	10,7	7,10	1,6	492 (213,279)
1977	9,7	6,8	0,1	521 (228,293)
1978	11,6	5,4	3,4	540 (241,299)
1979	16,11	o,1	1,5	562 (256,306)
1980	3,5	-	6,6	558 (253,305)
b. Black rhino				
1969	4,2	2,0	6,3	142 (73,69)
1970	2,9	1,1	6,6	143 (70,73)
1971	2,3	7,10	3,8	154 (76,78)
1972	3,5	1,3	5,3	158 (75,83)
1973	1,2	4,7	4,2	166 (76,90)
1974	1,3	4,4	6,6	166 (75,91)
1975	3,4	5,6	4,3	177 (79,98)
1976	2,3	1,1	3,3	178 (79,99)
1977	7,2	-	5,4	178 (81,97)
1978	5,2	-	5,7	173 (81,92)
1979	3,4	-	5,4	171 (79,92)
1980	2,0	-	5,1	167 (76,91)

Table 2.2.

Figures from the International Studbook (Klös and Frese 1981)

MATERIALS AND METHODS

The present survey was initiated in February 1980, and is based on information from: The Studbook, questionnaires, personal visits and the literature.

The Studbook

In 1980 the Studbook registered 283 black rhinos and 541 white rhinos (both figures include deceased animals) when questionnaires were sent out.

The questionnaires

Questionnaires were mailed to 156 zoos and safari parks listed by the Int. Zoo Yb. (1979), and supplemented from the Studbook, since some zoos register with the Studbook but not with Int. Zoo Yb., and vice versa. ISIS's distribution lists were checked, but all rhinos registered by ISIS were also in the Studbook.

To reduce the zoos' work and to avoid asking for information that was already available from the Studbook, the questionnaires were filled in prior to mailing, with regard to the number of animals kept by the individual zoo, and the number of progeny that was known from the Studbook.
Appendix I lists names and country of all zoos and parks to which questionnaires were sent, and the number of rhinos kept by the individual zoo. The distributed questionnaire and the accompaning letter is enclosed as Appendix II.
Reminders were sent to zoos of special interest, e.g. zoos with a large number of rhinos, or if specific information was required. In cases where answers were doubtful or needed further investigation, I have corresponded further with the involved zoo.

The returned questionnaires cover 42 collections keeping 105 black rhinos at the time, and 83 collections keeping 300 white rhinos (see Appendix I).

Personal visits

Much valuable information has been gained by personal visits to zoos and safari parks, both in England, Holland and Denmark (marked in Appendix I).
Many details on the animals kept by the Zoological Society of London were obtained from the records at Whipsnade.

Also, a visit to the Studbook keeper's office in September 1981 proved to be extremely valuable. Here it was possible to obtain information, e.g. some stillbirths and abortions that are not registered in the Studbook. When referring to the studcards, it means information gained from the cards kept by the Studbook keeper on each individual animal.

In other words, information on the individual animal has been obtained from several sources. Thus the information kept by the Studbook covers all the animals, whereas information on breeding success in different situations, mortality of calves, gestation period and hand rearing of young is only available for the animals included in the questionnaires.
In each of the following sections it will be stated how many animals are involved and if relevant, where the information originated from.

Literature

Furthermore, literature dealing with all aspect of rhinos in captivity as well as literature on reproduction in the wild has been reviewed in order to collate and compare the scattered information concerning the two situations.

Regarding the subspecies

No distinction has been made between the two subspecies of the white rhino, since the Northern white rhino (Ceratotherium simum cottoni) is so scarcely represented in captivity (Table 2.1.). However, as the status of this subspecies in the wild causes great concern, the few specimens in captivity are of special interest. Table 2.3. gives details of all known northern white rhinos in captivity.

As far as the black rhino in captivity is concerned the information available is insufficient to establish the subspecific status.

The statistics

When nothing else is stated, a Chi-square test has been applied (2×2 contingency table), with Yates' correction as sample size is usually small (Campbell 1974) and the degree of freedom is one. Values of Chi-square has been taken from Siegel (1956).

The Demographic Survey

This study also includes a demographic survey of the black rhino population in captivity with its own introduction, method and conclusion. The same thing has not been done for the white rhino, as data on deseased animals are limited, besides, the southern white rhino is not an endangered animal, and importation from the wild is possible.

For the sake of convenience, zoo in the following will designate either a zoo proper or a safari park.

Northern white rhinos(*Ceratotherium simum cottoni*) in captivity.

Studbook number	Sex	Date and place of birth		Location	Date of arrival
16	f	1948	Sudan	Antwerpen	7. 4.1950
19	m	1950	Sudan	London	25.7.1955
54	m	1960	Sudan	Khartoum	April 64
55	f	1963	Sudan	"	"
74	m	1952	Sudan	San Diego Zoo	2.8.1972
347	m	?	Sudan	Khartoum	April 1970
348	m	?	Sudan	"	March 1973
351	f	?	Uganda	Prescot	1971
372	m	1973	Sudan	Ostrava	30.10.1974
373	m	1972	"	Dvur Kralove	19.9. 1975
374	f	1974	"	"	"
375	f	1973	"	"	"
376	f	1972	"	"	"
377	f	1972	"	"	"
378	f	1969	Uganda	"	27.8. 1977
476	f	11.11.77	Dvur Kralove	"	11.11.1977
630	m	8.6.80	"	"	8.6. 1980

Table 2.3.

Details about the northern white rhino in captivity.
NB: both 476 and 630 are offspring of 378.

Response to questionnaires

The questionnaire was filled in and returned by 99 zoos of the 156 (63%). Four additional zoos have answered by letter, two informing that they have discontinued keeping rhinos, and two saying that they were not able to fill in the questionnaire, for various reasons. One zoo returned the questionnaire without any information, and another only returned half the questionnaire.
The total response was 104 communications out of 156 possible (67%). See Appendix I for details.

During my visit to zoos and safari parks in England I personally handed over the questionnaire to the person in charge, if the particular zoo had failed to return the questionnaire. Even then, two out of the three zoos in question neglected to answer,

Nevertheless, many zoos did express their willingness to cooperate by offering further information if required. However, two zoos disregarded such a renewed approach.

Though the great majority of zoos were asked to return the questionnaire by the 15th of March 1980, answers were still coming in by September 1980.

Discussion of the response

Zoos have in several connections maintained the importance of making data available for research (Conway 1967, Jarvis 1967, Kear 1977). Of the eight well established zoos with scientific ambitions mentioned by Jarvis (1967), seven were asked to fill in the rhino questionnaire. Five replied, but one gave but scanty information and one reacted only after several reminders and a personal visit from a fellow worker.

It applies to many of the questionnaires that the information given is casual and inaccurate. In one case the offered information contradicts previously published material about the animals in question.
It remains to be said that a few zoos took the extra trouble it is to give detailed information, and gave more information than was asked for.

Zoos have often stressed the obligation they have towards science and conservation (Curry-Lindahl 1965, Conway 1967, Jarvis 1967, Scott 1967). The topic of breeding endangered species in captivity has been the theme of three world conferences (Martin 1975, Int. Zoo Yb. 1977, 1980). Everything considered, it seems disappointing that so many zoos are reluctant to cooperate.

Some zoos accuse conservationists for a tendency to condemn rather than supporting zoological institutions (Conway 1967), while conservationists have been known to blame zoos for a lack of self-criticism (Pinder & Barkham 1978). A more satisfying mutual climate might be the result, if zoos would accept the responsibility and extra work it no doubt is, to make accurate records, without which even the most careful research will not yield the result, which surely in the end will also be of benefit to the zoos.

3. WHITE RHINO, *Ceratotherium simum*

WHITE RHINOS, *Ceratotherium simum*

Keeping requirement.

During the last ten years white rhinos have become very popular in zoos and safari parks and numbers here have increased more than threefold. Partly, this is due to a South African surplus being available (Player 1967, Owen-Smith 1973) and partly because white rhinos are easier to keep than black rhinos. They can be exhibited in larger groups which are more impressive, and they are compatible with other species (Plate I) such as gnu, hartebeest, zebra, ostrich and hippopotamus (Gewalt 1972, Toovey 1979).
Though reproductive males in their natural habitat keep mutually exclusive territories (Owen-Smith 1971) some zoos are able to have two or more reproductive males together in the same enclosure. However, many zoos have to let their males out in turn to avoid severe fighting, especially when a female is on heat.

White rhinos do not require a complicated diet. In fact they will thrive on grass only. At Whipsnade 16 animals (including calves) are kept on 14 ha (Toovey 1979), but to prevent overgrazing, cut grass or hay is fed in addition. Some zoos feed concentrate all year, others only during winter. The kind of food given by individual zoos varies quite a lot, but usually amounts to between one and five kg of concentrates pr day - usually commercial horse cubes - plus various vegetables and hay, totalling 25-60 kg a day (Eriksen 1977, Jones 1979). One zoo gives a winter feed of 34 kg of cattle rolls a day for three adult rhinos plus rolled oats and bran (5.5 kg) and two bales of hay. In one place the keeper disclosed to me that the white rhinos ate all the left-overs from the fastidious species.

As long as sufficient food is available a relatively simple fence will keep white rhinos from trespassing (Toovey 1979, Plate I). At Whipsnade an electric fence was tried out, but as soon as the rhinos experienced the

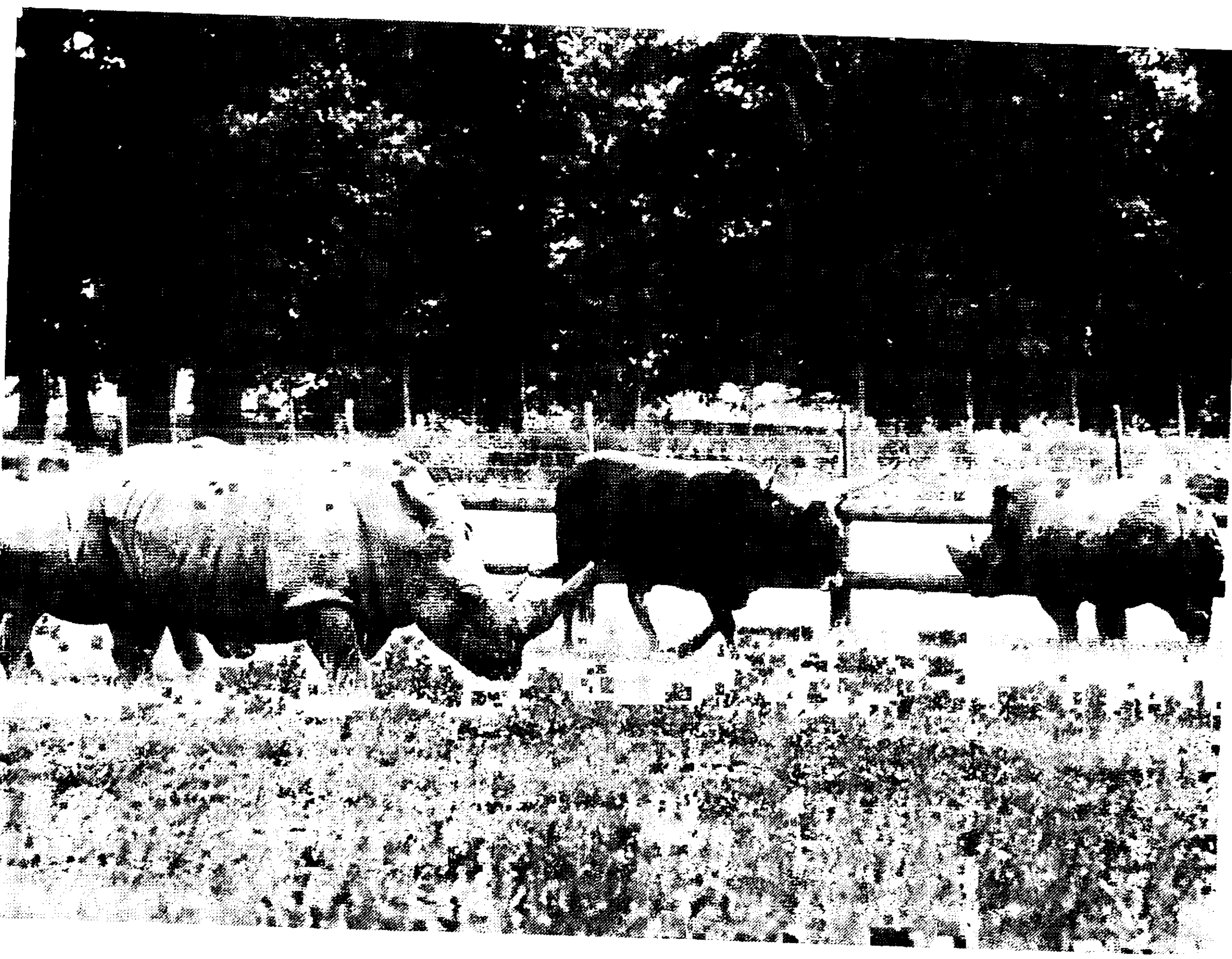


PLATE I

White rhinos with Watusi bull at Longleat, U.K.

electric charge, they pulled down the wires. The current was disconnected and now there is no trouble keeping the white rhinos inside their enclosure (Plate II)

The indoor accommodation at Whipsnade is not heated, but temperature rarely falls below 4^{o} C during winter (Toovey 1979), and there is no substantial evidence that heating is necessary as long as a dry and draught-proof shelter is provided, and that temperature does not fall below 5^{o} C for long periods (Jones 1979). Some places have floor-heating, and the animals are therefore given no straw. Under these circumstances an alternative area with a softer surface should be provided during the day, as the relatively soft sole of the rhinoceros foot is easily damaged by highly abrasive surfaces (Jones 1979).

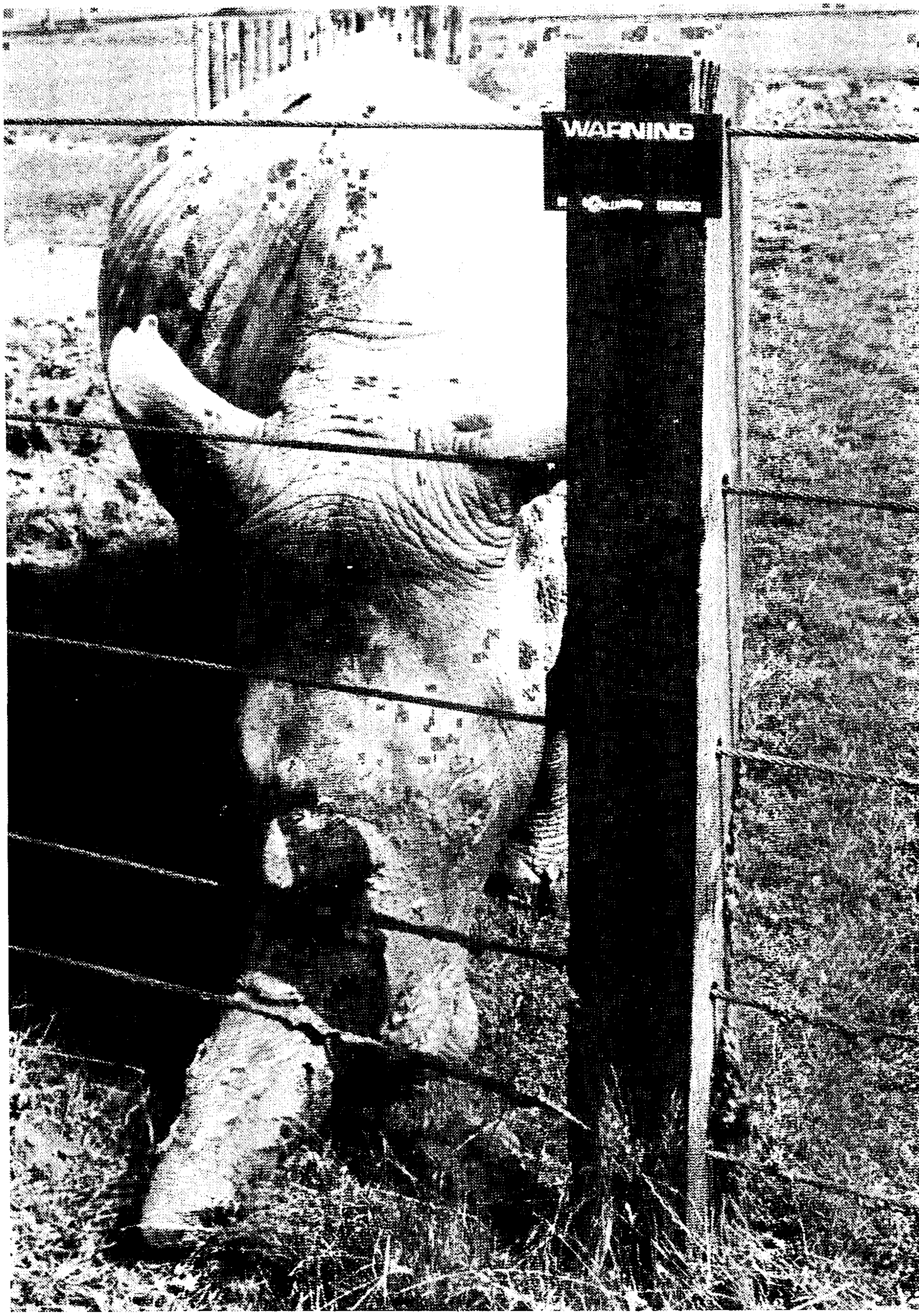


PLATE II

White rhino at Whipsnade,
the current has been disconnected.

BREEDING SUCCESS IN RELATION TO SIZE OF ENCLOSURE.

In 1970 and 1971 respectively, Whipsnade and San Diego Park each received a herd of white rhinos, and the "sudden" success of breeding the white rhino in captivity started. Before then, successful breeding had only been achieved at Pretoria Zoo, and it is notable that breeding in this group started with the birth of a calf that was conceived in the wild (Smith 1968). Pretoria also produced the first calf conceived in captivity.

Based on the experience at Pretoria, Whipsnade and San Diego, where animals were kept in large enclosures, it was suggested that the crucial factor for breeding the white rhino in captivity is sufficient space and a large number of females (Klös and Frese 1978). Rawlins (1979) claims that space is more important than the number of animals. But as breeding has occurred in both Copenhagen and San Antonio, where the animals are kept in small enclosures (540 and 900 m^2 respectively), it is more probable that white rhinos will breed under very modest condition (Eriksen 1977)

Response on the questionnaires shows that breeding does take place in enclosures of all sizes from 540 m^2 to 100 ha. It is interesting to note, that there are several places with no propagation, though the animals are kept in large enclosures (up to 12 ha), indicating that size of enclosure has no effect on breeding success.

To test this (Chi-square test, Campbell 1974), a limit between large and small enclosure was set at 4000 m^2 (Table 3.1.), because that is sufficient space to allow several rhinos to move around, and there will be room for trees and a wallow.

Only zoos with three or more rhinos are included, as in zoos with a single pair only, successful breeding is rare (Figure 3.1.), possibly for other reasons.

To make sure that this limit had not been chosen too small, tests (Chi-square) were also carried out for limits of 12000 m^2 and 40000 m^2 (10 acres). In none of these cases were there any statistically significant difference - indicating that it is not the size of the enclosure that is the crucial factor in breeding white rhinos in captivity.

White rhinos, Ceratotherium simum

Enclosure / No. of Zoos	Large enclosure (more than 4000 m^2 =1 acre)	Small enclosure (less than 4000 m^2 =1 acre)
+ Breeding	10	8
- Breeding	6	9

Table 3.1.

Breeding success in relation to size of enclosure ($X^2 = 0.292$, $0.5 < p < 0.7$)

BREEDING SUCCESS IN RELATION TO NUMBER OF ANIMALS

Figure 3.1. shows the influence of the number of animals in each collection on the breeding result. It is notable that the chances of breeding with a single pair are small. Breeding has only occurred in three cases, and in two of these the female was already pregnant on arrival. The third case has a special story. Of the pair the zoo (Memphis) owned from 1961, the female died in 1973. A new female arrived in April 1976, and mating took place shortly after, on 14th of June, indicating that a previously paired animal might mate with a new partner. The two cases where females were pregnant on arrival also support this, as breeding has continued with a new male (square in Figure 3.1.), althougt it is difficult to say if breeding here is due to the change of animals or the fact that breeding is easier to achieve once a female has had the first young.

Both Whipsnade and San Diego case-histories support the view that a pair will loose interest in each other, if they are kept together all the time. At both places the resident bull was put out with a new herd, and sired most of the calves, though both males had been with an adult female for years, probably without even mating (Rawlins 1979). The average time spent together for 36 of the 40 pairs that have not bred, is 11 years so it is not because of lack of time, that breeding has not taken place. So, it must be concluded, that being a single pair of white rhinos in a zoo - whether in a large or small enclosure - is a very unfavourable condition for breeding. Since this is an unnatural situation in the wild, it emphasizes the need to examine the natural conditions when keeping animals in captivity.

Klös and Frese (1978) maintain that it is important to have several females for successful breeding of white rhinos. I have not been able to show this, as breeding only occurred in three of the 14 zoos having two or more females with one male, and that is insufficient for a test.

It would not be correct to include zoos with a single pair, as breeding here is so unsuccessful (Figure 3.1.).

However, this study does indicate that the number of males has an influence on breeding success. Comparing the zoos holding one male plus two or more females with the zoos holding two or more males plus two or more females (Figure 3.1.), there is a significant difference (x^2=4.783, $p < 0.05$) between zoos having bred and zoos that have not. Adding zoos where mating has occurred, as breeding, there is also a significant difference (X^2= 5.723, $p < 0.02$), indicating that it is an advantage to have more than one adult male. The following examples also support this view:

1. Copenhagen changed their only male, a youngster, for an adult in June 1972 (Eriksen 1977). The new male got very excited when entering the pen, running round sniffing at all the sites where the younger male had spray-urinated (S.Rasmussen, pers. comm.), suggesting that in spite of his young age (five years in 1972), he must have been able to leave markings, which influenced the behaviour of the older male. Shortly after (Sept. 1972) mating attempts were observed, although successful copulation did not take place until the following year (Eriksen 1977).

2. A safari park in Japan bred five calves in 1978, all sired by the same bull, though they had three adult males at the time. Due to fighting, one male was sold, and unfortunately the sire of the calves died shortly after, leaving one adult male, which could be expected to breed. But since then there have been no mating (Oct. 1981).

3. Jacksonville zoo gives the information that they had no successful propagation from 1967 to 1979, at which time pairs became groups, and successful breeding occured. (It must be noted, that size of enclosure was increased at the same time).

White rhinos, Ceratotherium simum

♀ \ ♂	1	2 or more
1	△ ■ ■ ● ○ ○	
2 or more	△ △ △ △ △ △ △ △ △ ▲ ▲ ▲ ○ ○	△ △ △ ▲ ▲ ▲ ▲ ▲ ▲ ▲ ▲ ▲ ▲ ▲ ▲ ○ ○ ○

Figure 3.1.

Breeding-success in relation to number of animals

Each symbol represents one Zoo keeping white rhinos (N=77).

- ▲ Breeding
- ● Breeding, but special story (see text)
- ■ Breeding, but female pregnant on arrival
- ○ Matings, but no breeding
- △ No matings or breeding

REPRODUCTION

Sexual maturity

Females.

The first second-generation captive born white rhino was born on 12th of October 1979 at Toronto. The dam was born on 3rd of February 1973, which gives an age at first calving of 6 years 8 months. Deducting a gestation period of 16 months, gives the age of conception as 5 years 4 months. This corresponds well with an age of 6½-7 years at first calving for females living in the wild (Owen-Smith 1973).

Usually the Studbook gives only the year of birth for wild caught rhinos, but for some animals the day of birth has been estimated to within one month. For such females the mean age at first calving is 5 yrs 10 months (N=6, range: 5 y 1 m - 6 y 2 m), i.e. conception took place at 4 years 6 months on average (N=6, range: 3 y 9 m - 4 y 8 m).

It could be presumed that this lower age at first calving results from a mistaken estimation of the animals' true age. This view might be supported by the fact that one zoo has supplied mating dates for a pair of white rhinos supposed to be 3 years 4 months old at the most. The rhinos are alleged to have been born in 1965, arriving at the zoo in August 1966. So, even if they had been born on the first day of 1965, they were still fairly young when mating (Copulating) occurred in April 1968. Should however the alleged age be the true one, this would make the pair the youngest copulating white rhinos dealt with in this study.

In addition information on 16 females is at hand, both from the Studbook and questionnaires. For these the age at first calving is 8 years on average (range: 6 - 11 yrs) with an uncertainty factor of one year, age being based on the year of birth.

The reason why the age of the latter 16 females is not estimated too low could be that they arrived in captivity at an older age, all being more than two years old (11 being more than 4 years). The previously mentioned 6 females on the other hand, were all under two years (three estimated to be less than one year) when purchased.
Thus, it must be concluded: the younger the animal the greater the tendency to underestimate its age.

Males.

The questionnaires give but scarce information about the males. In one case, a male estimated to be born in November 1971, sired a calf born on October 2nd 1979; conception took place when he was approximately 6½ years old. Apart from the male, mentioned before, alleged to be no more than 3 years 4 months at the most, the youngest mating (copulating) age is 5½-6 years (N=2). Here again the age is based on the year of birth i.e. with an uncertainty factor of one year.

One male sired his first calf when he was 17 years old. For seven years he had lived with a female without mating but two months after the arrival of a new female, mating took place.

In the wild, males do not mature socially, i.e. keep a territory, until they reach the age of 10-12 years. Since only territorial bulls have access to females, subordinate bulls do not mate. (Owen-Smith 1973).
The data concerning captive animals suggests that males - not unexpectedly - are able to reproduce years before their opposite numbers in the wild have the opportunity.

Oestrus and mating

As information on the duration of oestrus and copulation or intervals between oestrus, were not asked for specifically, only three zoos gave such information spontaneously:

a. Duration of oestrus was observed to be one day (N=6), two days (N=3) and three days (N=1) in two pairs of white rhinos. This is based on observations on mating behaviour (mounting), copulation took place only once. Intervals between oestrus in these two females varied between 66 and 346 days.

b. Duration of copulation is informed to be 30 and 40 minutes (N=4) in one pair, while it lasted 10 and 30 minutes (N=2) when the same bull copulated with another female.

c. Copulation lasted five to twelve minutes (N=6) in the only pair kept by this zoo. Intervals between oestrus were 29 and 33 days (N=5). Once copulation took place on two consecutive days.

However, mating dates were asked for, and are available for 29 females. This information gives certain indications of the duration of oestrus. It is assumed that oestrus only lasted one day, when only one mating date is supplied (N=89). This assumption might not be correct. If two consecutive days are given, oestrus is said to have lasted two days (N=4). Where two matings have taken place with one day in between, oestrus is assumed to have lasted three days (N=2). In one case three matings took place over a seven days period.

It has to be noticed that the questionnaire asked for mating dates, so it might be that some zoos have given dates of mating behaviour as well, disregarding whether copulation took place. In most cases, however, the meaning is not in doubt.

Owen-Smith (1973) claims that oestrus only lasts about one day in wild living females, and is terminated by a successful mating. This survey could support his figure on the duration of oestrus since oestrus usually lasts one day (N=95), but in some cases two days (N=7), and have been reported to last three days (N=3). However, copulation can take place more than once in an oestrus period (N=12). In addition one zoo gave the information that matings took place six or seven times at each oestrus with the strongest male, but no dates are provided. So, from the present information it cannot be concluded that a successful copulation will terminate oestrus.

For females having bred, the average number of copulations before conception is 2.3 (N=31, range: 1-12).

Copulation lasts from 5 to 40 minutes (N=12).

It must be emphasized that the data concerning oestrus and matings may be somewhat unreliable, since zoos may not have given all oestrus and/or mating dates, or may not have observed/recorded all dates, which can be difficult especially where rhinos are kept in herds in large enclosures. Thus, the information on duration of oestrus, number of copulations before conception and intervals between oestrus are minimum figures, as matings and/or oestrus may have passed unnoticed.

Intervals between oestrus appeared to be 30 days in the wild (Owen-Smith 1973), but according to the information from questionnaires varies between 27 and 346 days in captivity. It is notable, however, that intervals between oestrus often are a multiplum of about 30 days (e.g. 67 days, 92 days). If this is taken into account, the information could support the 30 days claimed by Owen-Smith (1973). Reliable information (c. page 32) does support a cycling period of approximately 30 days.

The great variation in lenght of intervals between oestrus could also be due to the fact, that for some reason females suspend cycling for some time. This is found in wild living females (Owen-Smith 1973), where cycling can be suspended due to unfavourable conditions, e.g. dry weather.
It is worth noting that many zoos with only one male and one female remarked on the fact, that they observed no oestrus in their females.

Gestation period

In literature data on gestation period varies from 16 months (Smith 1968) to 17-18 months (Rawlins 1979). A gestation period of 16 months has been reported from the wild (Owen-Smith 1973) and from white rhinos kept in large enclosures in Krüger National Park, South Africa (Owen-Smith, pers. comm.).

Figure 3.2. gives the result from the questionnaires. The large range, however, might be due to recording-error. This is supported by the fact that several females have calved again after 524 to 545 days (see: intervals between calves). In one case the interval between two calves is as low as 515 days. 20 of the 30 (67%) reported gestation periods lies within 482 and 511 days. It is worth noting that a gestation period over 510 days can be explained by deducting 30 or 60 days (assuming a cycling period of about 30 days), meaning that females could have been in oestrus after the recorded copulation, conception taking place one or two oestrus later. This could be the case, since a great proportion of the calves are bred at the "big places", where white rhinos are kept in herds, making it more difficult to observe all matings.

For one gestation period only (496 days) is the sex of the calf unknown. In the remaining cases the average gestation period is 522 days for male-calves (N= 17, range: 470-584 days, s= 32.2) and 501 days for female-calves (N=12, range: 482-580 days, s=26.3). However, there is no significant difference ($0.05 < p < 0.10$, 2 sided t-test).
Only including gestation periods between 480 and 510 days, the average gestation period is <u>496 days</u> (N=19); being 499 days for male-calves (N=7, s=8.8) and 494 days for female-calves (N=11, s=8.9). There is no significant difference($0.2 < p < 0.3$, 2 sided t-test).

In cattle and buffaloes there is a positive relation between gestation length and birth weight, whereas the sex of the calf has less or no influence on length of gestation (Andersen and Plum 1965).
It could be assumed that male rhino calves at birth are heavier than female calves and hence have a longer gestation period, but this does not seem to be the case.

It must be concluded that the gestation period for white rhinos is 480 to 510 days.

White rhino, Ceratotherium simum, in captivity

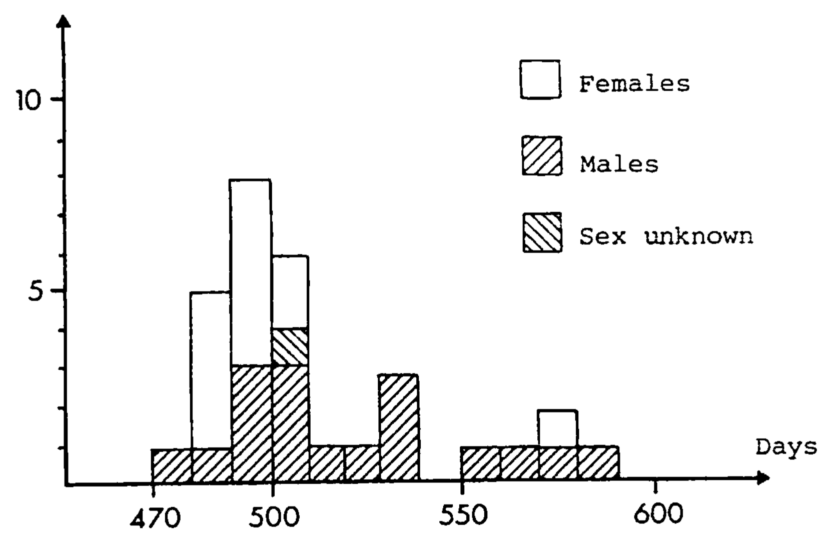


Figure 3.2.

Gestation period for the white rhino.
N = 30 (from 24 different females)

Intervals between calves

Table 3.2. gives the intercalf-interval for 30 females having produced two or more calves each. The mean intercalf-interval is 24 months (range: 17-43½ months). The Studbook (Klös and Frese 1981) gives an intercalf-interval of 27 months. This disparity must be due to the information gained from the questionnaires on stillborn calves or calves that died before being registered by the Studbook.

Owen-Smith (1973) gives an average of 30 months between calves for wild living females. This indicates that captive females can be very prolific breeders, when they are kept under the right conditions. (It is significant that no breeding is taking place in single-pair collections. Figure 3.1.). Indeed, one of the females at San Diego Wild Animal Park gave birth to six calves in 7½ years with an average intercalf-interval of 18½ months (554 days, range: 533-573 days).

From San Diego Wild Animal Park several intervals (N=9) as low as 17½-18 months (524 to 545 days) have been reported, one intercalf-interval being only 515 days. This indicates that conception can take place shortly after parturition, in some cases as early as one month after. The reason why the females at San Diego Wild Animal Park have such short intercalf-intervals as compared to females kept elsewhere, could be a result of the practice of not isolating a female with young.

White rhino, Ceratotherium simum, in captivity

Zoo	Intercalf-interval (months) mean	range	Number of intervals	Number of births	Number of females
1. Whipsnade	29½	18-43	11	17	6
2. San Diego Wild Animal Park	19½	17-24	29	37	8
3. Others	28	18-43½	21	37	16
1 + 2 + 3	24	17-43½	61	91	30

Table 3.2.

Intercalf-intervals for females in captivity.

MORTALITY OF CALVES AND JUVENILES

The questionnaires give information about a total of 112 births. Of these 14 were stillborn or died shortly after birth (within 24 hours). Table 3.3. This makes an early post-natal loss of 12.5 percent. Of the remaining 98 calves six died during their first year (6.1%), three died when between one and two years (3.3%) and two when they were between two and three years (2.2%). Early pre- and post-natal losses is assumed to be eight percent in the wild and calf-mortality(excluding post-natal mortality) is assumed to be 3.5 percent per annum (Owen-Smith 1973)

Six of the 19 (31.6%) that died (Table 3.3., not including stillborn calves) were killed by other members of the group, a hazard that follows the otherwise commendable practice of keeping white rhinos in herds. Several zoos have commented on the fact that members of a herd may become aggressive towards females with young. Many zoos isolate mother and young, some as long as six months.

At Whipsnade two male calves aged 9 and 15 months respectively, were both maltreated in one day by an adult male (V.J.A. Manton, pers. comm.). It is not clear whether this was because they were males, or because they happened to be in the way at feeding time. Both died from shock and injuries. It is noteworthy, that all juveniles killed by other members of the herd were males, excluding only calves but a few days old.

However, the high mortality rate of males is not specific for animals in captivity: In the wild a considerable excess of male-calves are born, while the sex-ratio in adulthood has become even, suggesting a higher mortality among males. Most deaths seem accidential or resulting from fights among males (Owen-Smith 1973).

It is worth noting, that also in captivity more male than female calves are being born (60% males, 40% females, figures from Table 2.2.). Although more males are being injured (exclusively males), the overall loss of juveniles is equal for the two sexes (Table 3.3.)

It should be mentioned, that one zoo euthanased a healthy male calf as soon as it was born (not included in Table 3.3.) because of the difficulties of disposing of males later on.

White rhinos, Ceratotherium simum, in captivity

No. and sex		Age at death	Cause
6	2m,4f	-	stillborn
1	f	1 day	trauma, impaction, infection in urogenial tract
1	?	day of birth	crushed by dam
1	?	day of birth	injured by other member
1	m	day of birth	trauma
1	f	1 day	not known
1	m	1 day	starvation, hypotermia
1	f	1 day	neonatal weakness
1	m	1 day	euthanased
1	m	5 days	not known
1	m	8 days	euthanased, trauma due to injury possible born premature
1	f	32 days	salmonellosis
1	f	6 weeks	born weak, tentative diagnosis: valvular endocarditis, nephritis
2	m	9 months 15 months	both killed by other male
1	f	7 months	malnutrition (hand-raised)
1	f	18 months	lymphadenitis, pneumonia
1	m	22 months	injuries and shock
1	m	33 months	enteritis
1	m	36 months	killed by dam

Table 3.3.

Juvenile mortality, of animals born in captivity.
Sex, age and cause of death for calves that died before 3 years of age.

Hand-rearing of calves

Seven white rhino calves have been hand-raised at San Diego Wild Animal Park. Three died due to medical problems, but the remaining four were successfully hand-reared and presently two have been reintroduced to the herd (L.E. Killmar, pers. comm.).

Calves were fed equal parts of fresh non-fat milk and fresh low-fat milk plus KARO for a sugar additive (2 tablespoons per 0.5 l of milk). Calves will consume 3 liter (100 oz: U.S. measures)per feeding, once every two hours, not exceeding 14.8 l (500 oz) per day for about 3 to 3½ months, when weaning can begin. At five months of age the amount will be reduced to 1.9 l (64 oz) per day. Under this schedule the calf should gain 45-57 kg (100-125 pounds) per month.
During the weaning period a cooked mixture of rice and barley may be needed to begin the transfer to solid foods. Also hay and grain is introduced on a free choice basis.

Another zoo bottle-fed a calf for a couple of days with milk from its mother, which might not have been necessary as the calf was later accepted.

One zoo reared a male calf from six months of age. He was given 20 l of milk-powder solution in addition to multivitamins and fresh grass.

Others have reported on successful hand-rearing from one week of age (Bigalke et.al. 1950, 1975) and from 21 days (Wallach 1969).

In the wild weaning onto grass commences at two months of age, and by four months of age a calf is spending much time grazing and can be regarded as weaned, though it continues to nurse much longer, usually until it is over a year old (Owen-Smith 1973).

Longevity and disease factors

The oldest known living white rhino in captivity is a female, Zuluana at Pretoria zoo, born in July 1946. She was hand-reared from one week of age (Bigalke et.al. 1950, 1975). Owen-Smith (1973) assumes a potential life span of 45-50 years for white rhinos in the wild.

Assuming that all deaths are reported to the Studbook, which might not be the case, the mean annual mortality-rate is calculated to be 1.4 percent (range: 0.2 - 2.1%) for the years 1973 to 1980 (figures from Table 2.2.). Early post-natal losses are not included in this figure, as these are seldom reported to the Studbook (see: mortality of calves).
Owen-Smith (1973) calculated the mortality-rate for the wild living white rhino population in Natal in 1969 as being 2.7 percent. As early post-natal losses in the wild usually go unobserved, his estimate is comparable to the figure calculated for the captive population.

Many zoos are reluctant to give information about the cause of death of their animals. Jarofke and Klös (1979) note that of 26 reported deaths, the cause was only given in 11 cases: Three died of disease in the digestive system, one of pneumonia, two of circulary insufficiens, one of disease in the urinary system, two of accidential trauma, one of shock and one of poisoning.

When questioned whether disease played any role in lack in breeding success, 76 zoos gave a negative answer. Only in a single case was a penis prolapse a hindrance for copulation.
Jones (1979) summarizes the present knowledge on pathology and medicine with regard to captive rhinoceroses.

It must be concluded that the death-rate for the captive white rhino population as a whole is not high, although early post-natal losses are higher in captivity that they presumably are in the wild. However, enough young are born annually in captivity to compensate for the loss of deceased animals.

4. BLACK RHINO, *Diceros bicornis*

BLACK RHINOS, *Diceros bicornis*

Keeping requirement

Black rhinos are usually kept in the traditional way, one or two individuals in a small enclosure. The size of the pen ranges from 130 m^2 to 1 ha (2½ acres). However, black rhinos at San Diego Wild Animal Park in U.S.A., have 50 ha (125 acres) at their disposal.

Only four of the zoos that have returned questionnaires have been able to keep a male and two females simultanously, one had even had two males and two females on show together, but this is rare. To prevent fighting many zoos separate their animals except when the female is on heat. Some have observed that the animals will fight when re-introduced, but presume it is part of their courtship. In their natural habitat black rhinos very rarely fight during courtship (Goddard 1966). Zoos naturally handle their rhinos individually, depending on the character of the animals. San Diego Wild Animal Park keep their black rhinos with other species, but no other information on this aspect has come to hand.

Black rhinos are mainly browsers, but will thrive on a diet calculated for the domestic horse (Jones 1979). They are fed concentrates the whole year round in addition to hay and vegetables and browse, if available (Crandall 1964, Jones 1979). Some zoos admit that their black rhinos do not get as much browse - if any - as they would like them to have.

At Port Lympne, U.K. I saw black rhinos being fed a meal of tomatoes, cucumbers, lettuce, apples and other vegetables, all prime quality. This zoo also keeps its rhinos in an enclosure with a fence built of vertical posts only, preventing the rhinos from damaging themselves (Plate III).

PLATE III

Black rhino at Port Lympne, U.K.
Note the construction of the fence.

BREEDING SUCCESS

It has been suggested that the main reason why the black rhinos have such a poor breeding record is due to the practice of keeping the animals in couples; since the black rhino in its natural habitat is solitary, it is supposed that their mutual sexual interest will decline adversely when they are forced to live together for years (Klös and Frädrich 1970). This study suggests that this is probably true with regard to the white rhino. Nothing, however, indicates that zoos with a single pair of black rhinos have poorer breeding records than zoos with more animals. One zoo reported that their only female had bred with one male, but was incompatible with a second male. It seems that if a pair is in harmony, they will go on breeding even if they are kept in proximity in a small enclosure (Klös and Frese 1978).

Of the 75 collections registered with the Studbook keeper in 1980, 26 kept a single animal and 4 collections have animals of the same sex only. This means that 40 percent of the collections (about 20% of the captive population) is debarred from breeding because of the lack of a mate.

From the Studbook (Klös and Frese 1891) one might get the impression that breeding is less productive that is actually the case. This is due to the fact, that calves that are stillborn or die shortly after birth are not always reported to the Studbook. Of the 146 females in the Studbook only 54 (37%) have bred. However, when information from both the questionnaires and from the studcards is considered as well, the result is 65 (44%) breeding females. The disparity is ascribable to the fact that the questionnaires include two breeding females not previously registered and one female that was registered as not breeding but has in fact bred. Furthermore, questionnaires include eight females (12% of all breeding females) that did produce, but the progeny was not registered due to an early death. This indicates that the problem might not only be a question of breeding but also how to avoid getting so many

calves that are born weak and how to improve survival in general.
It should be noted, that five of the eight cases where females had dead progeny only, this was their only calf. Two females have each had two calves that both died, and one female has had three calves that all died.

Of the 94 living females (Figure 4.1.), 46 (49%) have bred and 48 (51%) have not. Of the non-breeding females 20 are considered too young (born after 1973, see sexual maturity), leaving 28 adult females that are not breeding. This means, that 30 percent of all females, or 38 percent of the adult females are not breeding. It must be noted, that of the 40 black rhino females that died after the age of eight, only 19 (48%) have bred, indicating that the ratio of non-breeding/ breeding females has been even greater.

As half the number of the animals kept in single collections are females, this accounts for approximately 20 percent of the females that have never bred. The remaining non-breeders might be victims of infertility or incompatibility with their mate. Infertility has not been reported in wild living females, on the contrary, there is evidence that black rhinos will continue to reproduce into very old age (Goddard 1970a). Hence, it is most likely, that the lack in breeding success - where adult males and females are kept together - is due to incompatibility.
The alarming thing is, that more than 1/3 of all adult females might never contribute to the next generation. The consequence of this will be discussed later.

Lack in breeding in the second generation has been reported in Orang-utan (Pinder and Barkham 1978). To test if non-breeding rhinos belong to a certain group, e.g. captive born, a chi-square test was carried out. Of the 28 living non-breeding adult females mentioned above, 17 are wild born and 11 captive born. Comparing these with the 46 breeding females of which 36 are wild born and 10 captive born, there is no significant difference between the reproduction-success in the wild-born females and females born in captivity. ($X^2 = 1.843$, $0.10 < p < 0.20$).

Black rhino, Diceros bicornis, in captivity

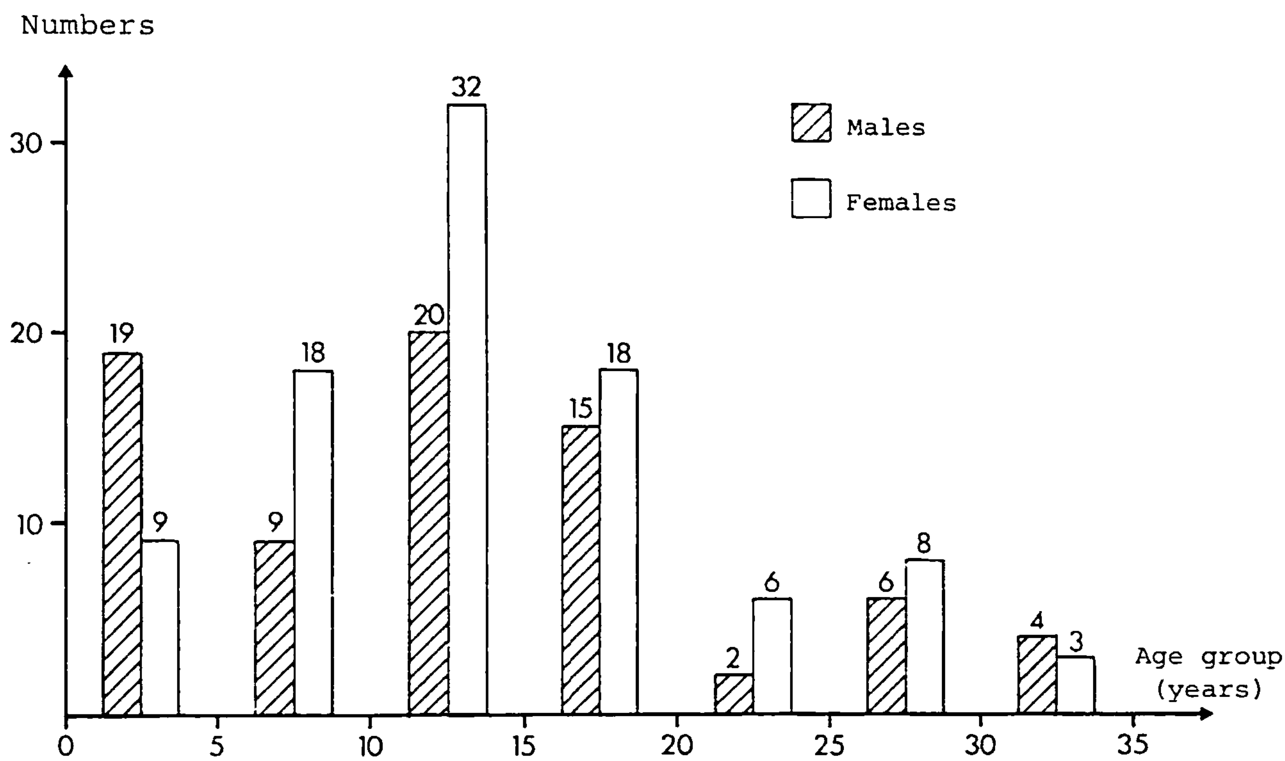


Figure 4.1.

Age distribution of the black rhino population in captivity, 1981.
N = 169 (75 males, 94 females).

REPRODUCTION

Sexual maturity

Females

As more second generation females produce calves, the exact age at first calving can be established. For 13 captive born females the mean age at first calving was 8 years 4 months (range: 6 y 8 m - 11 y 1 m). Deducting a gestation period of 15 months, conception took place at 7 years 1 month on average. However, 10 of the 13 females (77%) calved before 9 years of age giving a mean age at first calving of 7 years 10 months (N=10, range: 6 y 8 m - 8 y 11 m), conception taking place at 6 years 7 months on average. A couple of zoos gave the dates of first matings, though these did not result in conception. In one case the female was just 5 years and in another 6½ years. Jones (1979) reports on a black rhino calf born to a female 4½ years and a male 3½ years, both captive bred. I have not been able to trace these animals, but there is no indication (in literature or in this study) that black rhino females are able to conceive when only 3 years 3 months. According to the questionnaires, the youngest a captive born female calved was 6 years 8 months. However, one wild born female supposed to have been born in 1971, calved in February 1976, meaning that she could at the most be 5 years 2 months at first calving. This case might merely support the view, that dealers have a tendency to fancy their animals younger than they actually are.

This study suggests that females in captivity reach sexual maturity (are able to conceive) at the age of 5½ - 6½ years.

Males

The mean age at which captive males became a parent was 7 years 7 months (N=6, range: 5 y 8 m - 9 y 1 m) which infers that the average age at first copulation resulting in conception was 6 years 2 months.

The captive born male previously mentioned (Jones 1979) was reported to be only 2 years 1 month when he sired a calf, but this is exceptional. The youngest known age at first copulation in this study is a male nearly three years old. He was born on January 3rd 1958, and observed copulating in December 1960.
In another case a male was reported to have copulated for the first time at 4 years 2 months, with a 7½ years old female.
One zoo mentioned that their 6 years old male was too small to be introduced to the females, he would not be put with the females until he was seven years old.

Although there is wide range in the age at which black rhino males are able to copulate, the data from this study suggests that black rhino males are not able to sire until the age of 4½ years at the earliest.

Sexual maturity in the wild

Goddard (1967, 1970a) suggested that factors affecting recruitment rates, such as age of sexual maturity and intervals between calves, were density-dependent. High density will delay sexual maturity and increase intervals between calves.

This is supported by the black rhino populations in Natal, South Africa, as described by Hitchins and Anderson (1980). For the dense, stable population in Hluhluwe (0.7 rhino/km^2) the age at sexual maturity is higher than for the thinner, increasing population in Umfolozi (0.1 rhino/km^2).

Table 4.1. summarizes the age at sexual maturity of females. However, a few results are also available for males. Goddard (1970b) observed a single male of known age mating at the age of 4.3 years (in Ngorongoro). In the same population he gives the age at sexual maturity in females as 3.8-5.7 years. Hitchins and Anderson (1980) claim that in Natal no male less than nine years of age was observed holding a territory or mating, although physiological maturity is reached at the age of eight (spermatogenesis had not commenced in a seven years old male, but was present in a male eight years old). Though it is not stated if these males originated from the Hluhluwe or the Umfolozi subpopulation, it must be concluded that although the age of sexual maturity varies between populations, it does not vary significantly for males and females within a population. Sexual maturity is not only a matter of being physiologically mature, but can be affected by other factors, such as crowding. (See also the section on recruitment).

Black rhino, *Diceros bicornis*

Locality	Age at first mating	Age at first parturition	Reference
Tsavo	-	4.75-5.25 y	Schenkel & Schenkel-Hulliger 1969
Ngorongoro	4.7-5.7 y	6-7 y	Goddard 1970b
"	3.8-5.0 y	5-6 y	"
"	4.5	5 y 9 m	"
Addo	4 y 7 m	8 y 5 m	Hall-Martin & Penzhorn 1977
"	-	8 y	"
"	4 y 6 m	-	"
Hluhluwe	7.1 y	not calved by 10.6 y	Hitchins & Anderson 1980
"	8.2 y	not calved by 12.2 y	"
Corridor/ Umfolozi	-	6.5 y	"
"	-	8.5 y	"
Captivity	5.0-6.5 y	7 y 10 m	This study

Table 4.1.

Black rhino females, sexual maturity
Age at first mating and age at first parturition.

Oestrus and mating

Information from the questionnaires suggests that black rhinos mate frequently without conception taking place. Greed (1967) reported on mating behaviour in a pair of black rhinos copulating regularly for several years before conception took place. For three pregnancies (in 2 females) the average number of copulations per pregnancy was 12.3 (range: 8-20). Another zoo has reported on a pair copulating regularly for five years without conception taking place.

Only one zoo gave information about the duration of coitus, which lasted from five minutes to one hour (N=14), but in most cases (N=10) from 10 to 30 minutes. In this pair copulation took place up to four times in one day. Greed (1967) mentions copulation lasting from 2 to 55 minutes. Hitchins and Anderson (1980) observed 47 copulations in the wild, which lasted from 12 to 43 minutes.

When zoos have given detailed information on mating-dates it is possible to work out the periods between oestrus. One female conceiving in November, was cycling regularly from June, with an interval of 25 days (N=7, range: 22-28 days). Another female was cycling regularly from May to December with an interval of 31 days (N=7, range: 20-83 days). From December to the following March no mating dates are reported, implying that cycling had been suspended, but from March to November she was cycling with an interval of 24 days (N=9, range: 5-46 days). Conception took place in November.

One zoo gave information on cycling periods for a female observed over a period of five years. This female suspended cycling from two to five months, at least once a year (6 times in 5 years) but not the same time of the year. Not including these long periods up to 165 days, the average interval between oestrus was 32 days (N=37, range: 9-67 days, s=12.0). In the pair mentioned by Greed (1967) the female suspended cycling for 172 days.

Hitchins and Anderson (1980) observed intervals between oestrus in wild living females that varied between 26 and 46 days (N=10). They also claim that oestrus (duration of receptivity) only lasts one day. However, in the wild a female is attended by a bull for 6 or 7 days before copulation takes place. In several cases in captivity copulations takes place on two consecutive days, suggesting that oestrus (receptive period) may last two days.

Gestation period

Others have reported gestation periods for black rhinos to be 419 & 438 days (Greed 1967), 458 days (Gowda 1967), 465 days (Yamamoto 1967), 454, 457 & 463 days (Hays 1967) and 469 days (Dittrich 1967).
The 419 days reported by Greed (1967), may not be the true gestation length, as mating also occured three weeks before, in which case the gestation period would be 441 days.

Figure 4.1. shows the results from this study.
Of the total of 30 pregnancies, the sex of the calves are known in 26 cases (17 males and 9 females). The mean gestation period for male-calves is 458 days (range: 438 - 493 days, s=18.5) and 457 for female-calves (range: 430-487, s=18.7). There is no significant difference between gestation periods for male and female progeny ($0.70 < p < 0.80$).

Gestation periods for black rhinos in the wild are reported to be 446 & 478 days (Goddard 1967) and 455 days in a semi-wild female (Hall-Martin and Penzhorn 1977).

Our present knowledge leds to the conclusion that the gestation period for black rhinos is about 450 days or 15 months.

Black rhino, Diceros bicornis, in captivity

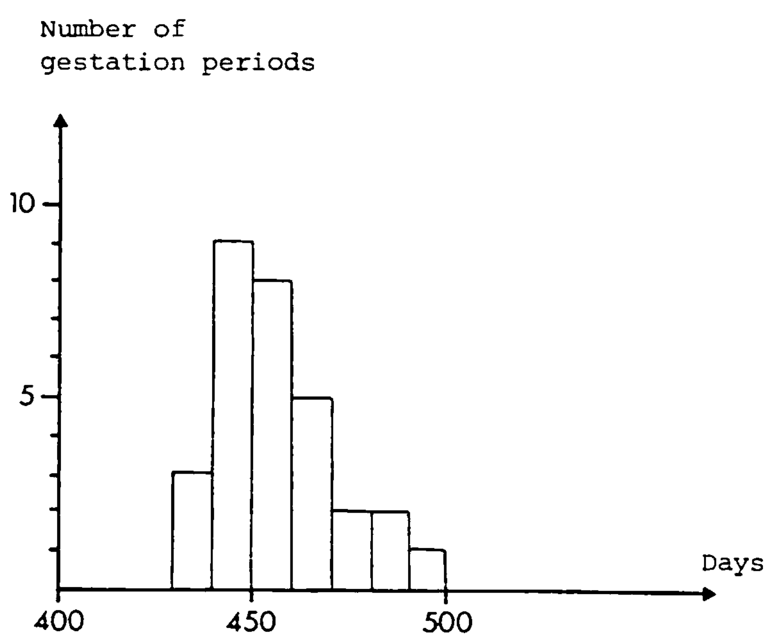


Figure 4.2.

Gestation period for the black rhino.
N = 30 (from 15 different females)

Intervals between calves

For a total of 35 females that gave birth to 103 calves, the mean intercalf-interval is 35 months (N=68, range: 17-112 months). All intervals are calculated within one month, but it should be noted that the shortest interval of 17 months in fact is 16 months 20 days.

It is worth noticing that the mean intercalf-interval is significantly shorter ($p < 0.01$) if the previous calf was stillborn or died shortly after birth. In this case the mean interval is 25.2 months (N=16, s=6.7) compared to a mean interval between calves of 36.5 months (N=51, s=11.6) where young survived. In a semi-captive population in Addo in South Africa the shortest calving interval (24 months) also occured when a calf was killed. Otherwise the mean intercalf-interval in Addo National Park was 36 months (N=7).
Goddard (1967) claims that the onset of oestrus does not appear to be closely associated with reduced lactation. The female may apparently develop regular oestrus cycles within a few weeks of parturition but the calving-conception interval is relatively long. Four intervals of 25, 28, 29 and 38 months respectively are given for the Ngorongoro population, Tanzania. These are the shortest intervals reported from the wild (Table 4.2.).
As the recruitment rate of one calf per female every four years did not correspond with the observed intercalf-interval of 28 months, it was suggested (Goddard 1967) that the populations in Ngorongoro and Olduvai were being controlled by a self-regulating mechanism, such as reduced fertility rates. This also seems to be the case for the South African populations described by Hitchins and Anderson (1980). They found a mean calving interval of 63 months in the stable population in Hluhluwe, and 42 and 36 months respectively for the increasing populations in the Corridor and Umfolozi (Table 4.2.). The population density and its influence on recruitment is also discussed in the section on sexual maturity.

The prolonged intercalf-interval found in some cases in captivity is probably a result of the practise of isolating females with young for quite a long time: in one zoo for as much as three years. However, it could also be due to a shortage of males. For example, it is difficult at the present to find an adult male (for breeding purpose) in Europe.

It should be mentioned, that five females (of 51) calved again within two years although they had a young at the time of conception.

The shortest interval between two calves in this study is 16 months 20 days (the previous calf died after 11 days), the female having conceived approximately six weeks after partuition. However, a female with a surviving young also conceived again shortly after birth, about two months, as she calved with an interval of 17 months.

One female had five calves in eight years with an average intercalf-interval of 23½ months, but four of her calves died before the age of three months.

It must be concluded that females that are breeding regularly might conceive again within 9 months of birth, some even before, suggesting that it would be an advantage for reproduction if females with young were not isolated longer than is necessary for the safety of the calf.

Black rhino, Diceros bicornis

Locality	Mean calving interval (months)	Recruitment calves/year/ adult female	Reference
Ngorongoro	28 (N=4)	0.25	Goddard 1967
Olduvai	-	0.26	"
Tsavo	30-39	-	Schenkel & Schenkel-Hulliger 1969
Tsavo	30	0.30	Goddard 1970 a
Etosha	26 (N=1)	-	Joubert & Eloff 1971
Amboseli	48	0.25	Western & Sindiyo 1972
Addo	35 (N=8)	-	Hall-Martin & Penzhorn 1977
Serengeti	40 (N=2)	-	Frame 1980
Hluhluwe	63	0.19	Hitchins & Anderson 1980
Corridor	42	0.28	"
Umfolozi	36	0.33	"
Captivity	35 (N=68)	0.11	This study

Table 4.2.

Intervals between calves and recruitment-rates for black rhinos in the wild, and in captivity.

Recruitment

Recruitment can be calculated as the mean number of calves per year/number of adult females (Goddard 1967).

In Table 4.2. recruitment in captivity has been calculated by using the average number of calves produced per year, in the three years 1978 to 1980, divided by the mean number of adult females.

According to the Studbook (Table 2.2.) a total of 16 calves were born in the years 1978, 1979 and 1980, which gives an average of 5.3 calves per year. However, from the questionnaires, information on 7 calves born in that period but not registered, has come to hand (3 were born in 1980, 3 in 1979 and 1 in 1978). Including these, the average number of calves amount to 7.7 per year. The average number of adult females in the years 1978 to 1980 was 70. Hence the recruitment rate is 7.7/70 = 0.11, meaning that each female in captivity on average has one calf every nine years. Table 4.2. summarises the recruitment-rates for black rhino populations in the wild. It must be noticed that the recruitment-rates for Hluhluwe, the Corridor and Umfolozi are calculated from the observed intervals between calves, implying that all adult females in the population are breeding. Looking at the locations in Table 4.2. it is clear that the recruitment rate does not always correspond with the observed intercalf-interval, particularly not for black rhinos in captivity. If the recruitment-rate for animals in captivity was based on the 35 months calving interval, it would amount to 0.34 calves/year/adult female. The difference between the 0.11 and the 0.34 calves/year/adult female is due to the fact that about 38 percent (see breeding success) of the adult females are not producing at all.

Recruitment can also be measured as the mean number of calves/the total population size (Goddard 1967).

As the Studbook (Table 2.2.) gives the total number of animals for each year , recruitment can be worked out as a percentage of the whole population. The mean number of calves born in the six years 1975 to 1980 is 8.6 (this figure includes 15 calves not registered in the Studbook). The mean population size amount to 174 for the years 1975 to 1980 (see Table 2.2.). Hence the recruitment-rate of 8.6/174 = 0.049 or 4.9 percent per year. Goddard (1967) estimated the annual recruitment for black rhino populations in the Ngorongoro and at Olduvai to be 7.0 and 7.2 percent respectively in 1962-66.

More important than the actual size of the recruitment is the question: Does recruitment equal mortality? Which it does not for black rhinos in captivity. The annual mortality amounts to 8.2 animals (in 1975-80, see Table 2.2.b.) according to the Studbook, but adding the 15 calves that were born between 1975-80, but died, the mean annual loss is 10.7 animals, which is a death-rate of 10.7/174 = 0.061 or 6.1 percent per year.

This is also discussed in the Demographic status of the captive black rhino population.

Mortality of calves and juveniles

Of the 131 births (not including abortions) in captivity, 7 were stillborn, 9 died within their first week of life and 10 died between one week and one year of age (Table 4.3. for more details).
Altogether 26 calves (19.8%) died in their first year. However, excluding perinatal (stillborn or young that died same day) deaths, the loss in the first year amounts to 16 calves or 12.2 percent.

It has been suggested that the high mortality rate for juvenile black rhinos is the result of youngsters being transported from their birthplace to another zoo when they are about two or three years old, and so directly or indirectly falling victim to the stresses of transport (Klös and Frese 1978). However, there is no significant difference between the number of deaths amongst animals that were moved as compared to animals that were not moved ($X^2=0.0550$, $0.80 < p < 0.90$). Thirty-five black rhinos were moved between the age of 7 months and 4 years, of these 11 died. Twenty-five rhinos were not moved and of those 8 died before reaching the age of 4 years.
This indicate that the risk of dying is not greater for an animal that is moved than it is for one that is not moved.

The cause of death is known for 13 of 21 (62%) animals (Table 4.4.) that were born alive but died within two years of life. Of these 8 (61.5%) died of disease. Assuming that the rate of death due to disease is similar for the eight animals where cause is unknown, i.e. five died of disease, this will give a total of 13 of 21 rhinos (62%) that could have died from disease.
Looking at the age group two to three years (Table 4.5.), seven or eight (depending on whether poisoning is regarded as disease.) died of disease (54 - 62%).

Overall, for both groups (Table 4.4. & 4.5.) 15 of the 26 (58%) where cause of death is available, died of disease.

Of the rhinos that died accidentially, two were killed by a sire and one drowned, suggesting that better management could have prevented some of the deaths.

It must be concluded that the main loss (50-60%) in juvenile black rhinos is due to disease.

Black rhino, Diceros bicornis, in captivity

Numbers and sex	Time of death
2	abortions (nearly full time)
7 (2,2)+3	stillborn
3 (1,2)	died same day
6 (3,3)	between 1 day and 1 week
4 (3,1)	" 1 week and 1 month
4 (0,4)	" 1 month - 6 months
2 (0,2)	" 6 months - 1 year
2 (2,0)	" 1 year - 2 years
13 (6,7)	" 2 years - 3 years
1 (1,0)	" 3 " - 4 "
1 (1,0)	" 4 " - 5 "
1 (1,0)	" 5 " - 6 "
1 (1,0)	" 6 " - 7 "

Table 4.3.

Age distribution of juvenile mortality,
of 133 births in captivity.
Numbers in bracket: (males, females) + not known

Black rhino, Diceros bicornis, in captivity

Sex	Age at death	Cause
f	1 day	aspiration pneumonia
f	2 days	? was bottle fed for 2 days
f	4 "	pneumonitis
m	11 "	killed by male
m	12	killed by male
m	1 month	peritonitis
f	1½ months	polioencephalomalacia
f	3 "	aspiration pneumonia
f	4½ "	was bottle fed (mother died)
f	6 "	drowned
f	8 "	euthanised (rectal prolaps)
f	9 "	ulcer of skin and stomach
m	15 "	low grade infection

Table 4.4.

Calf-mortality.
Cause of death is given for 13 animals (of 21) that were born alive but died before 2 years of age.

Black rhino, Diceros bicornis, in captivity

Sex	Age at death (months)	Cause
f	24	Intoxication
m	25	cardiac arrest
m	26	acute hemolytic crisis with severe hemoglobinura possible
f	26	haemorrhagic enteritis
(m)	26	not known
(m)	27	damage of spinal cord
(f)	27	muscular dystrophy
f	28	not known
m	29	not known
f	29	not known
m	32	hemorrhages in stomach and kidneys
f	33	not known
f	35	hemorrhages in stomach and kidneys (passing blod in urine) poisoning?

Table 4.5.

Juvenile mortality, of animals born in captivity. All animals that died between two and three years are listed. Animals in bracket were not moved, all others were.

Hand-rearing of calves

Both Cincinnati zoo and San Diego Wild Animal Park have successfully hand-reared a black rhino calf. The calf at San Diego was removed from its mother when it was 28 days old, but the calf at Cincinnati was hand raised from birth. The feeding plan, including formula, amount etc., is enclosed as Appendix III.

Another zoo reared a calf from six months of age by giving it extra concentrate.

Others have reported on the composition of black rhino milk (Greed 1961), and on the changes during lactation (Gregory et al. 1965).

Two zoos report on having tried to hand-rear black rhinos, but in both cases the calf died, one after two days,the other after 4½ months (Kreag 1966).

Longevity and disease factors

A female black rhino, Mary, at Chicago zoo, reached the advanced age of 48, before she was euthanased. She had been at the zoo for 45 years. Goddard (1970a) estimated a maximum life span of 35-38 years for black rhinos in their natural habitat.

Mean expectation of life (e_x) at birth has been calculated to be 12.2 years in captivity (Table 5.1.) as compared to 8.4 years for black rhinos in the wild (Goddard 1967). Only nine animals (of 145) survived the age of 30, indicating that few black rhinos in captivity die of old age.

Jarofke & Klös (1979) summarise the cause of death for 40 black rhinos. However, in several cases they give more than one cause per animal (54 causes for 40 animals). The main feature is, that no single cause of death prevails.

The Studbook (Klös and Frese 1981) summarizes the cause of death for animals reported to them. For 33.3 percent of the females and 40 percent of the males, no reason for death was given. 50 percent of the females died of Gastro-intestinal disease. 30 percent of the males died of diseases in various organs, of which 13.3 percent was in the Gastro-intestinal system. 26.7 percent of the females and 30 percent of the males died from accidents or other cause.

Juvenile mortality and disease factors are discussed in another section.

When asked, if disease played any role in breeding failure, 28 zoos returned a negative answer, while seven zoos answered yes, of which six gave reason for death of their animals. One zoo had lost three black rhinos in one year. In another case a female calved prematurely, because she had suffered from haemoglobinuria 2½ months previously. Two cases of severe Cutaneous granulomata was successfully treated at Maiduguri zoo. The treatment was based on Young (1966).

5. DEMOGRAPHIC SURVEY OF THE BLACK RHINO IN CAPTIVITY

DEMOGRAPHIC STATUS OF THE CAPTIVE BLACK RHINO POPULATION

Introduction

There is a growing awareness that rare and endangered species in captivity should not be managed as solitary collections, but as an entire population to which demographic methods can be applied (Foose 1980). The result of this would be that more species in captivity achieve self-sufficiency. Pinder and Barkham (1978) assess that only twenty-six species of rare mammals - of the 229 species being exhibited by zoos - can be considered self-sustained, and only eight have achieved this status between 1970 and 1976. Unfortunately, there has been a lack of accurate analysis of zoos overall contribution to conservation and also of serious self-criticism (Pinder and Barkham 1978).

However, in recent years several attempts have been made to describe and recommend on management of endangered species in captivity, both demographically (Foose 1977, 1980, Goodman 1980) and genetically (Benirschke 1977, Flesness 1977, Chesser et al. 1980, Senner 1980). It seems though, that zoos are inclined to emphasize the few species they have actually managed to save, neglecting those where trends have been unfortunate - the black rhino being only one of many.

Demographic methodology has long been used to describe wild populations. Survival curves for elephant populations in two parks in Uganda were constructed by Laws (1966). Goddard (1970) did the same thing for black rhinos in Tsavo National Park, Kenya. The difficult and time consuming part in constituting life tables for wild populations is the age determination. This is a minor problem with captive animals as the age of individuals in general is available from the respective studbooks.

It is evident from the birth- and death rates in the International Studbook of the black rhinoceros (Table 2.2.) that the captive population is decreasing. Since 1969 when recording started there have been a few years where the number of birth have been in balance with deceased animals but the overall picture is one of a decreasing stock. To work out the rate of decrease and how to improve propagation a demographic analysis has been carried out.

Until 1977 it was possible to replace the deficit with importations of wild animals, but since the black rhino has become an endangered animal (Hillman and Martin 1979) such importations will be difficult to justify in the future. Therefore, it seems necessary that the black rhinos in captivity are managed with the aim of making the population self-sufficient, if black rhinos are to remain in captivity.

The black rhino population in captivity is decreasing by approximately 7 percent per year. If this trend is allowed to continue, in ten years time the number will only be half of what it is today.

Materials and Methods

From the Studbook supplemented with data from the guest-tionnaires, information is available on 145 black rhinos that died between 1969 and 1980. In 12 cases the age at death had to be estimated on the basis of the date of arrival at the zoo.

The material has been divided into age groups (d_x in Table 5.1.) as described by Krebs (1978) and survival can be calculated: $l_{x+1} = l_x - d_x$.

Since it is of special interest to know the chances of survival in the first few years of life, and detailed information is available as most of the young animals have been born in captivity, an age interval of one year has been chosen for the first five years, after which a five-years interval is used. All columns have as legend the letters normally used in ecology (Krebs 1978):

x: age interval

n_x: number of survivors at start of age interval x

l_x: proportion surviving to start of age interval x

d_x: number dying during the age interval x to x+1

q_x: rate of mortality during the age interval x to x+1

e_x: mean expectation of life, or mean life time remaining to those alive at start of interval x

m_x: number of offspring of the same sex as the parent, expected from an individual age x, per time unit (here: 5 years)

Other parametres used are:

R_o: net reproductive rate = $\sum_0^\infty l_x m_x$

r_m: innate capacity of increase (or decrease)

G: generation-time = mean period between the birth of a parent and the birth of a progeny

λ: annual rate of change = e^{r_m}

Usually life-tables start with a complete survival at birth (Krebs 1978), but in this study an additional group 0' is included, consisting of 10 animals that were either stillborn or died shortly after birth (within 24 hours), Table 5.1.

One method of predicting how a population will change is to combine reproduction and mortality in the net reproductive rate, R_o.

$$R_o = \sum_{o}^{\infty} l_x m_x$$

Therefore, it is necessary to know the number of offspring an animal will produce within a certain age-group (m_x), as well as the probability of surviving to that age (l_x). If survival was complete, R_o would be the sum of the m_x column (Table 5.4. & 5.5.). In practice m_x is found by dividing the number of female-births in each age group (Figure 5.1.b.) by the number of females in the same age group (Figure 5.1.a.).
Figure 5.2. is an example on how to count the animals in each age group. No birth has been reported in animals younger than five years, so females younger than five years are not included. If a female (e.g. 293 in Figure 5.2.) is 11 years, she will count 1/5 only in the age group 10 to 15 years. Figure 5.1.a. includes all females (not only those shown in Figure 5.2.) some of which have died.

As the sex-ratio at birth is equal (of 131 births, 65 were males, 63 females, 3 unknown sex) all births are counted and divided by two, to get the number of female births. Similarly m_x is worked out for males (Table 5.5.b. & Figure 5.3.a. & b.). It must be noted, that m_x for males is not as accurate as for females, because in 17 cases the sires of the calves were unknown. In those cases the births were distributed proportionally, the known births having been assigned to their sires age-group.

Therefore, the m_x-value used in Table 5.4. is the one for females (female offspring per female). This is also the usual procedure, as demographers typically view populations as females giving birth to more females (Krebs 1978).

The l_x-value for the whole population (Table 5.1.) includes three calves with unknown sex, and hence is the most complete, and therefore used in calculating the $l_x m_x$ product (Table 5.4.). However, the l_x value here is the proportion surviving to the midpoint of the age class (pivotal-age) and not as in Table 5.1. the proportion surviving to the start of the age-interval.

R_o is the multiplication rate per generation. A generation-time (G) is defined as the mean period between the birth of a parent and the birth of a progeny. G is only of mathematically interest, as offspring are not born all at once but over a period of time.
The generation-time is crudely estimated from the formula:

$$G = \frac{\sum l_x m_x x}{R_o}$$

Another way to work out how a population will change, is to use the parameter r_m, which is the innate capacity of increase (or decrease) for <u>that particular environment</u>, in this case the conditions in zoos.

When generations overlap, r_m is determined by the equation:

$$\sum_{x=0}^{\infty} e^{-r_m x} l_x m_x = 1$$

The annual rate of change is defined as:

$\lambda = e^{r_m}$, $e = 2.71828$ (base of nat. log.)

Result and discussion

Values for d_x, n_x, l_x, and q_x are given for the population as a whole (Table 5.1.) and for males and females separately (Table 5.2. & 5.3.). Mean expectation of further lifetime (e_x) is calculated for each age group (Table 5.1.). The survivorship curve for the captive population is shown in Figure 5.4.

R_o, G, r_m, and λ have been calculated both for males and females separately and for the population as a whole (Table 5.7.). The black rhino population in captivity is decreasing ($R_o < 1$, $r_m < 0$, $\lambda < 1$). The decrease is approximately seven percent per year ($\lambda = 0.9281$). A twenty-five years projection of the decrease is shown (Figure 5.7.).

Foose (1980) claims, that it is important to treat the sexes separately as survival and fertility often differ significantly for males and females. This is not the case for the black rhino in captivity. There is no significant difference between the sexes in the number dying (d_x in Table 5.2. & 5.3., Figure 5.5.a., Kolmogorov-Smirnov two sample test, $p > 0.05$). Fertility for the two sexes (m_x in Table 5.5.a. & 5.5.b.) cannot be compared, as the value for males are not accurate (see method). Figure 5.6. shows the fertility (m_x) and the reproductive values (V_x) from Table 5.5.

It seems that the m_x value for males between 30 and 35 years is greater than m_x for males between 25 and 30 years (Figure 5.6.a.). The high value for males between 30 and 35 is merely a result of the small sample size in this group. One young was born to a male in that age group, but as all births were counted and divided by two, only 0.5 birth is listed (Figure 5.3.b.). Since only two males survived to that age-group (Figure 5.3.a.) the m_x-value gets disproportionally high.

It is not surprising that R_o is less than one (the population is decreasing). This was expected from the birth- and death-rates from the Studbook (see introduction), and partly due to the fact that more than 1/3 of the adult females are not contributing to the next generation.

However, to answer the question whether it is at all feasible to breed the black rhino in captivity, one will have to look exclusively at the 64 females that have bred (marked in brackets in Figure 5.1.a.). If the breeding females are not able to produce sufficient offspring to secure the future of the species, nothing else will.

It is alarming, that only including breeding females (Table 5.6.) R_o is still less than one (the population is decreasing), indicating that unless either l_x (survival) or m_x (fertility) is improved, the black rhino population in captivity will not be able to reproduce itself in sufficient numbers to equal the mortality. The sum of the m_x column is 1.8 (Table 5.6.), meaning that the number would multiply 1.8 times in one generation if survival was complete.

To hope for complete survival or anything near it, would at the moment be too optimistic, but it is of the greatest consequence that survival is improved. It is more effective to increase survival rates of all reproductive age classes by a certain amount than increasing the fertility in the same classes by the same amount (Goodman 1980). However, increasing fertility might be the easier task (Foose 1980), besides it is important from a genetic point of view. Roughly, the greater the number of breeding animals the larger the effective population (N_e) and the smaller the rate of inbreeding (Inbreeding and its effects will be discussed later).

It must be concluded that the maximum breeding, both for the individual animal and for the population as a whole, should be attempted. Zoos should be asked not to keep single animals. Even pairs should be adviced against. Larger breeding groups should be favoured, since this improves the possibility of the individual to select a congenial partner, besides the risk of being left with a single animal due to death is minimized.

To give an example of the needed breeding-improvement: Of the 169 (Figure 4.1.) black rhinos alive in 1981, approximately 13 will die within one year (Table 5.8.), therefore at least 13 calves have to be produced a year to set off this loss. Of the 94 living females (Table 4.1.) 20 are too young and 11 might be too old to breed, leaving 63 females to produce 13 calves, which is 0.21 calves per year per female - or nearly twice the present rate of 0.11 calves/year/female (see section on recruitment). The intercalf-interval is 35 months (Table 4.2.), meaning that breeding females produce 0.34 calves/year/female. So, if all the 63 breeding-age females were producing calves at this rate, it would amount to 21 calves per year.

Many young rhinos die during the first year (Figure 5.5.), 18 percent including perinatal loss. This state of affair might be improved by secluding the mother when she is going to calf. Rhinos are often nervy animals with a temperament not suited to face the public when they have a newborn calf.

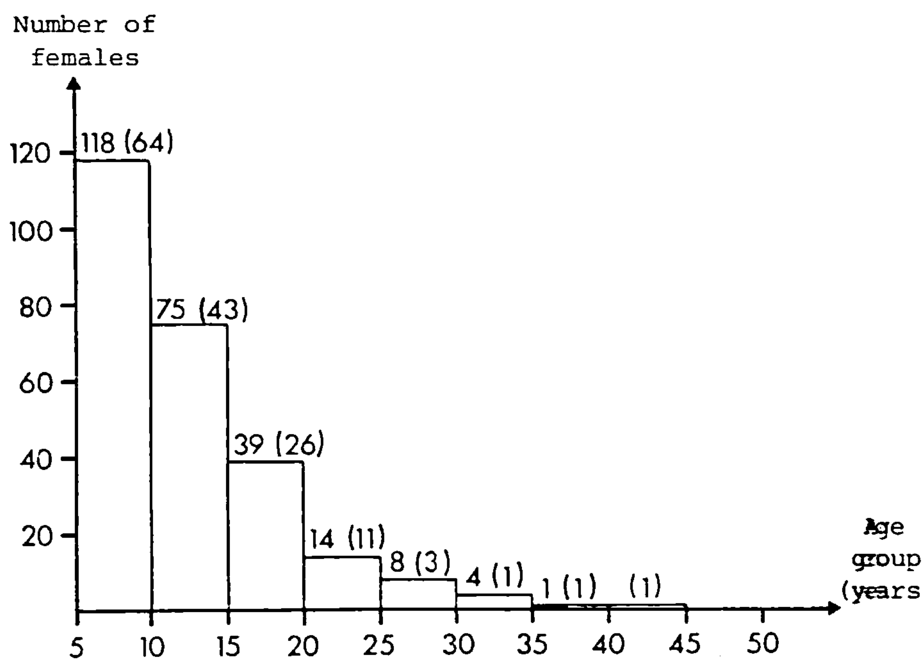
It remains to be said, that the 18 percent mortality in the first year of life is not exceptionally high compared to wild populations. Goddard (1970a) gives mortality rates of 16 percent for both the first and second year of life in the Tsavo population in Kenya. However, Conway (1980) claims, that zoos do better than nature in increasing recruitment rates and lowering death rates. Death rates in older classes is a little less in captivity as compared to the wild, but recruitment is far less in captivity than in the wild. The recruitment rate in Tsavo was 10.9 percent

(Goddard 1970a) and 7.0 and 7.2 percent per year respectively in Ngorongoro and Olduvai, Tanzania (Goddard 1967). The mean annual recruitment in captivity is 4.9 percent (1975-80, see recruitment). Said in another way, the females in Ngorongoro and Olduvai had one calf every four years on average, while the females in captivity on average have one calf every nine years.

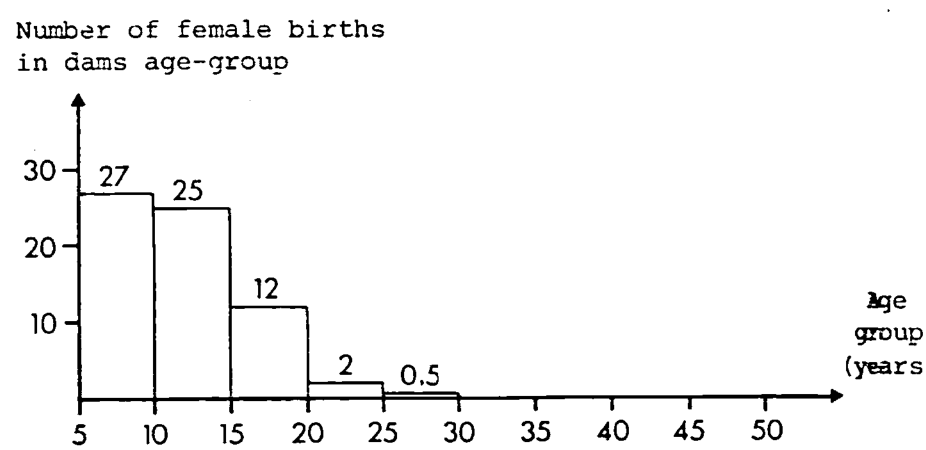
The fact that many juveniles (13%, Table 5.1. & Figure 5.5.) die when they are between two and three years old needs further investigation. In most cases these animals die from disease. It is strongly recommended that a veterinary surgeon should study the cause of death in this group in more details.

Black rhino, Diceros bicornis, in captivity

Females



a.



b.

Figure 5.1.

a. Number of females in each age group, numbers in bracket are breeding females

b. Number of female-calves in dams age group, (female calves = all calves/2)

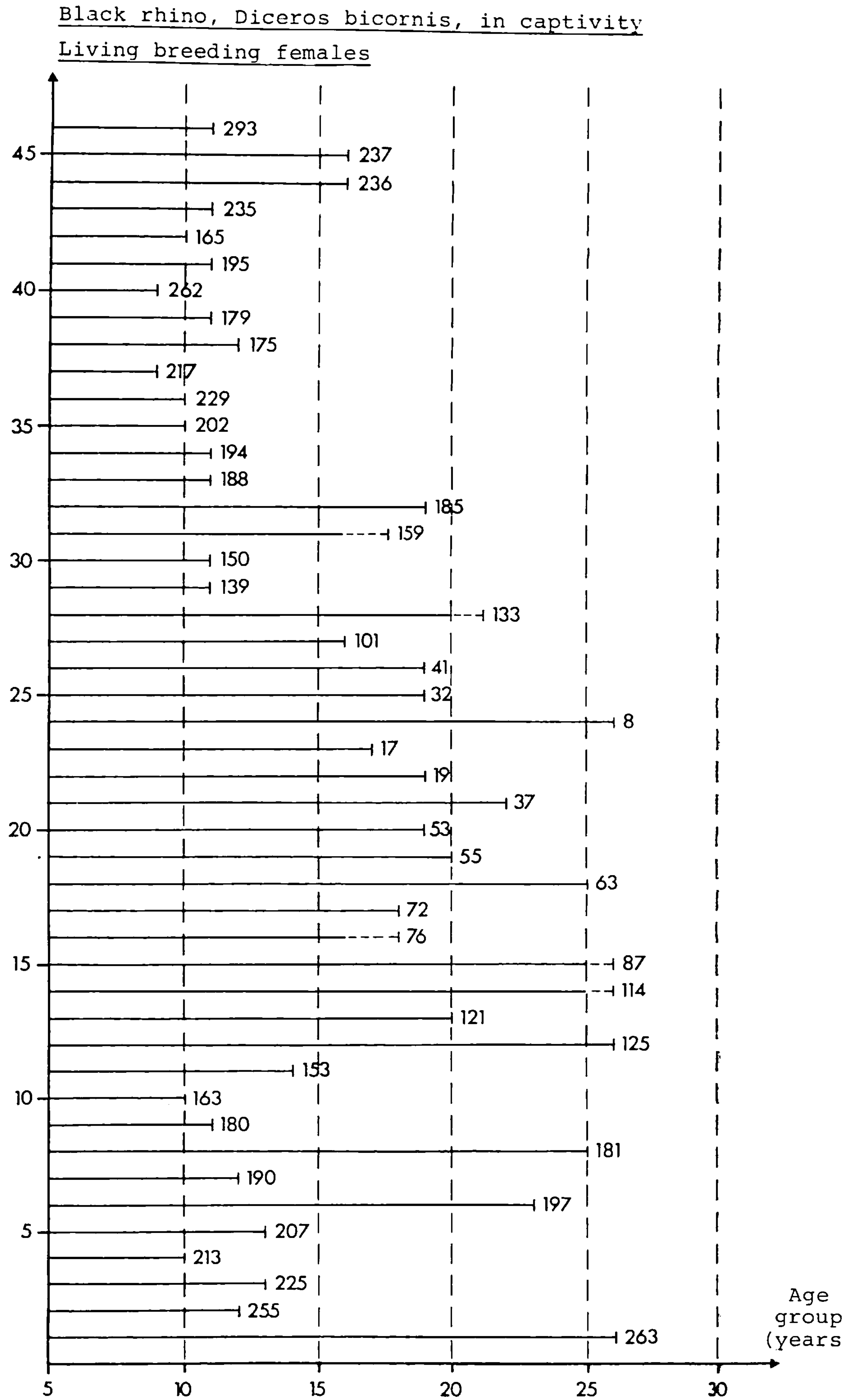
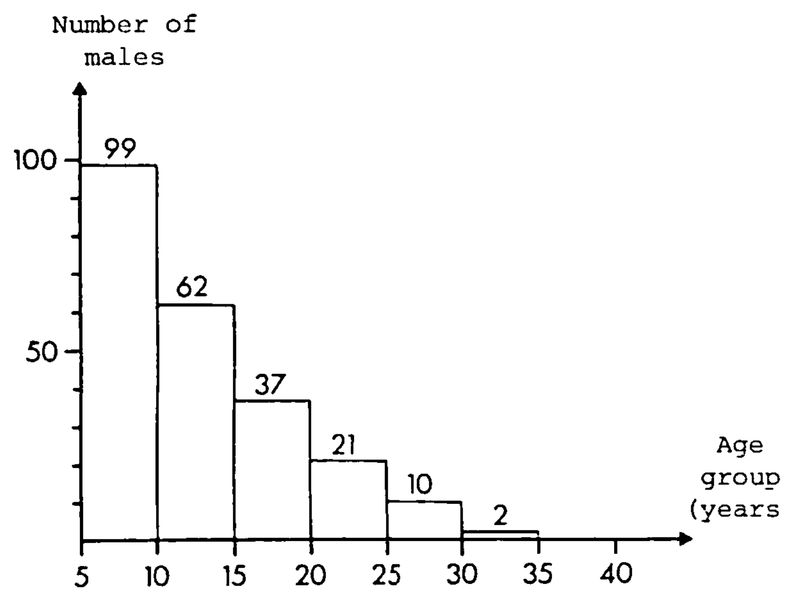


Figure 5.2.

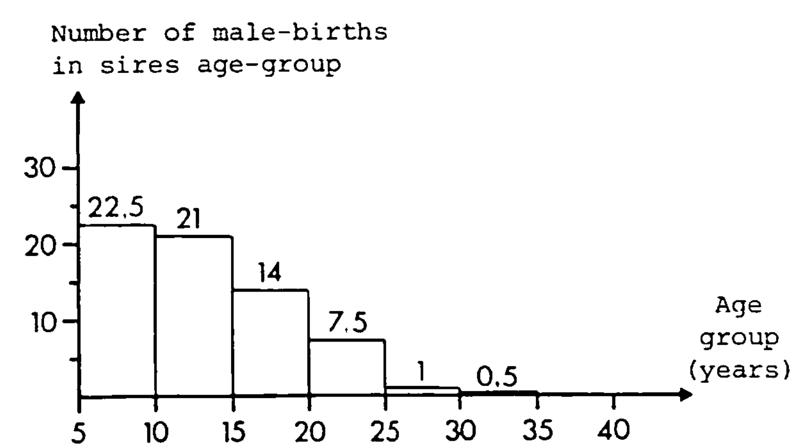
Age of females in 1981. Numbers refer to Studbook.
broken line: age is estimated, see materials & methods.

Black rhino, Diceros bicornis, in captivity

Males



a.



b.

Figure 5.3.

a. Number of males in each age group

b. Number of male-calves in sires age group, (male-calves = all calves/2).

Black rhinos, Diceros bicornis, in captivity

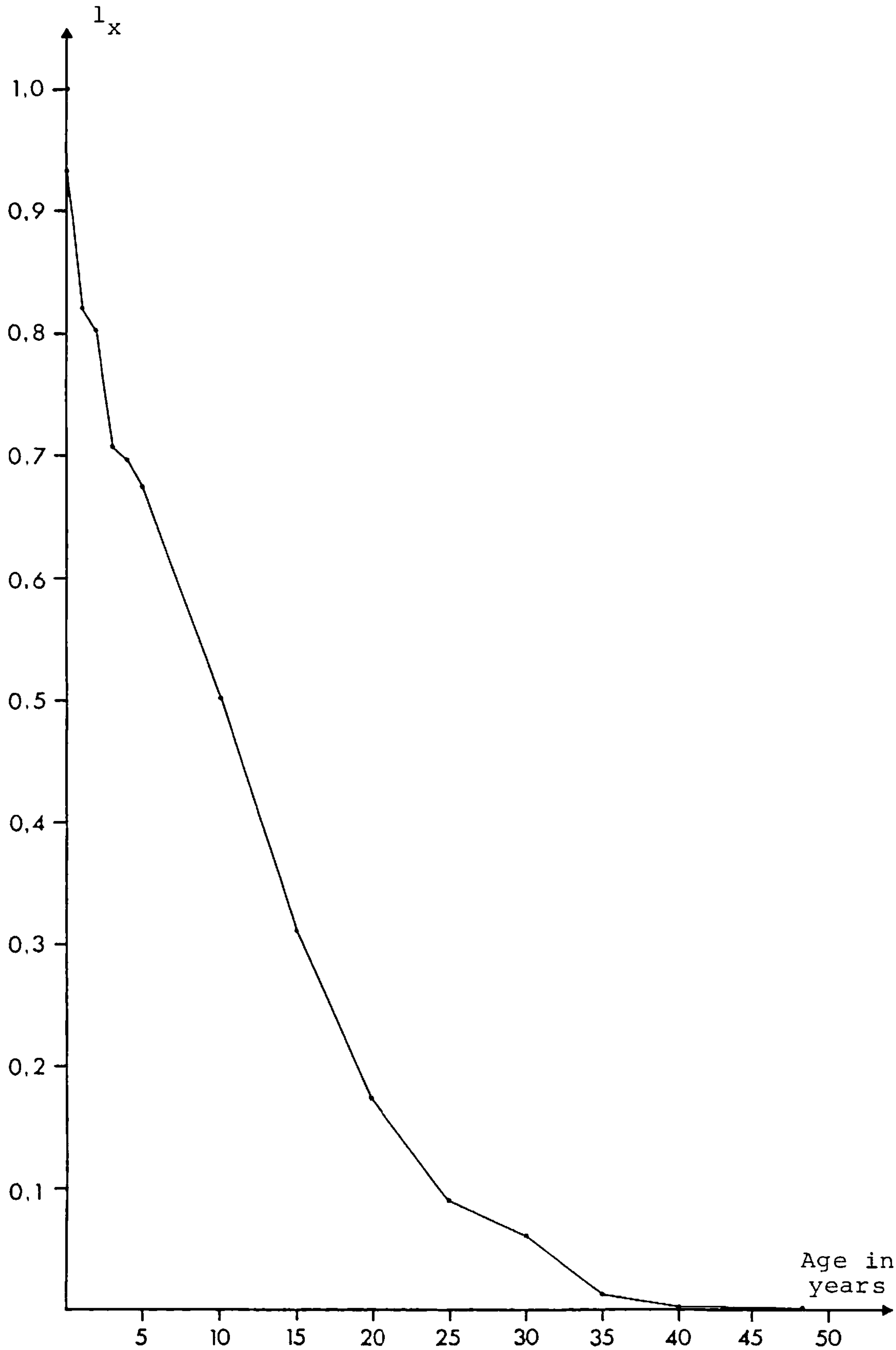


Figure 5.4.

Survivorship curve. Proportion surviving to start of each interval (Table 5.1.). Perinatal losses (stillborn and early deaths) are included, therefore the survival at birth is less than 1.0).

Black rhino, Diceros bicornis, in captivity

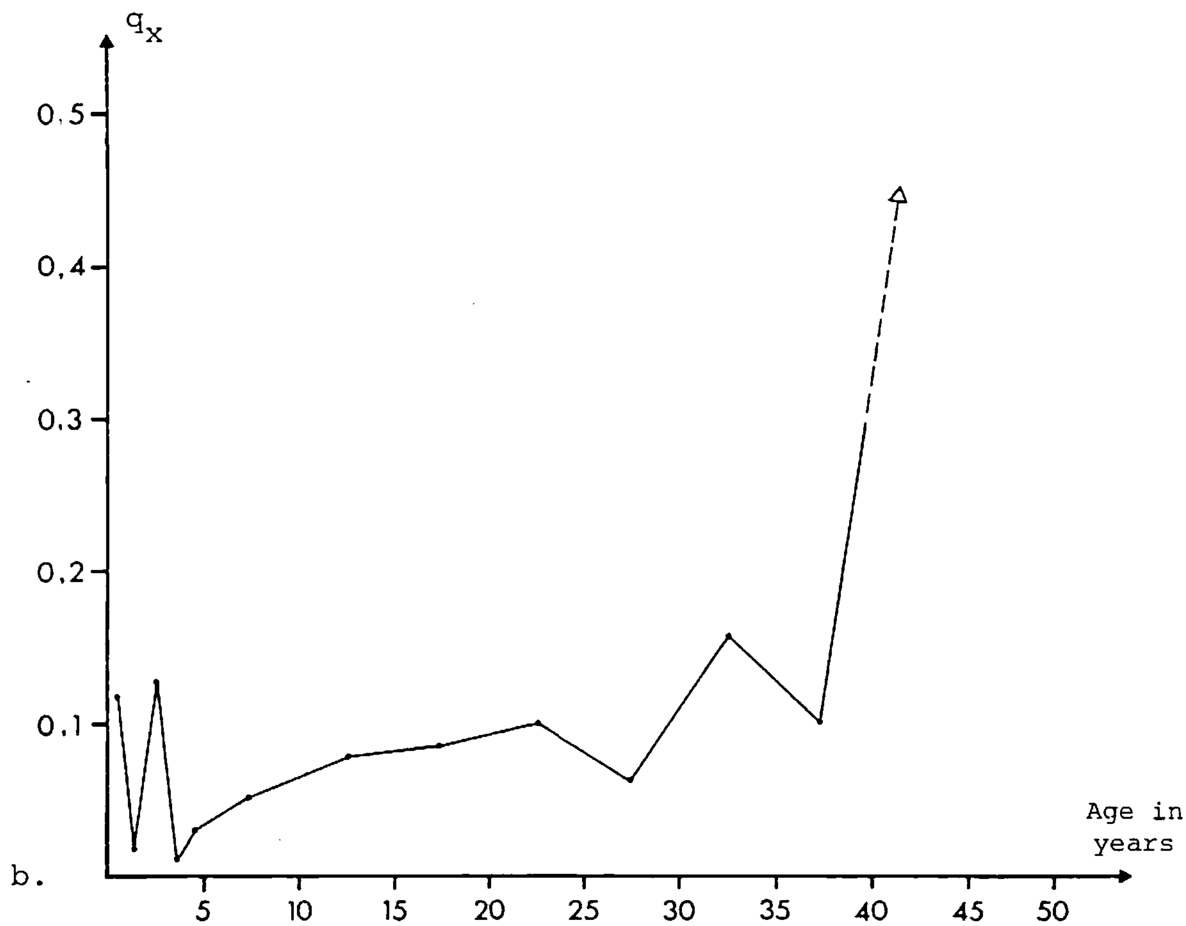


Figure 5.5.

Annual death-rate (q_x) in each age-group.

a. q_x for males and females separately, including perinatal losses.

b. q_x for the whole population, not including perinatal loss.

Black rhino, *Diceros bicornis*, in captivity

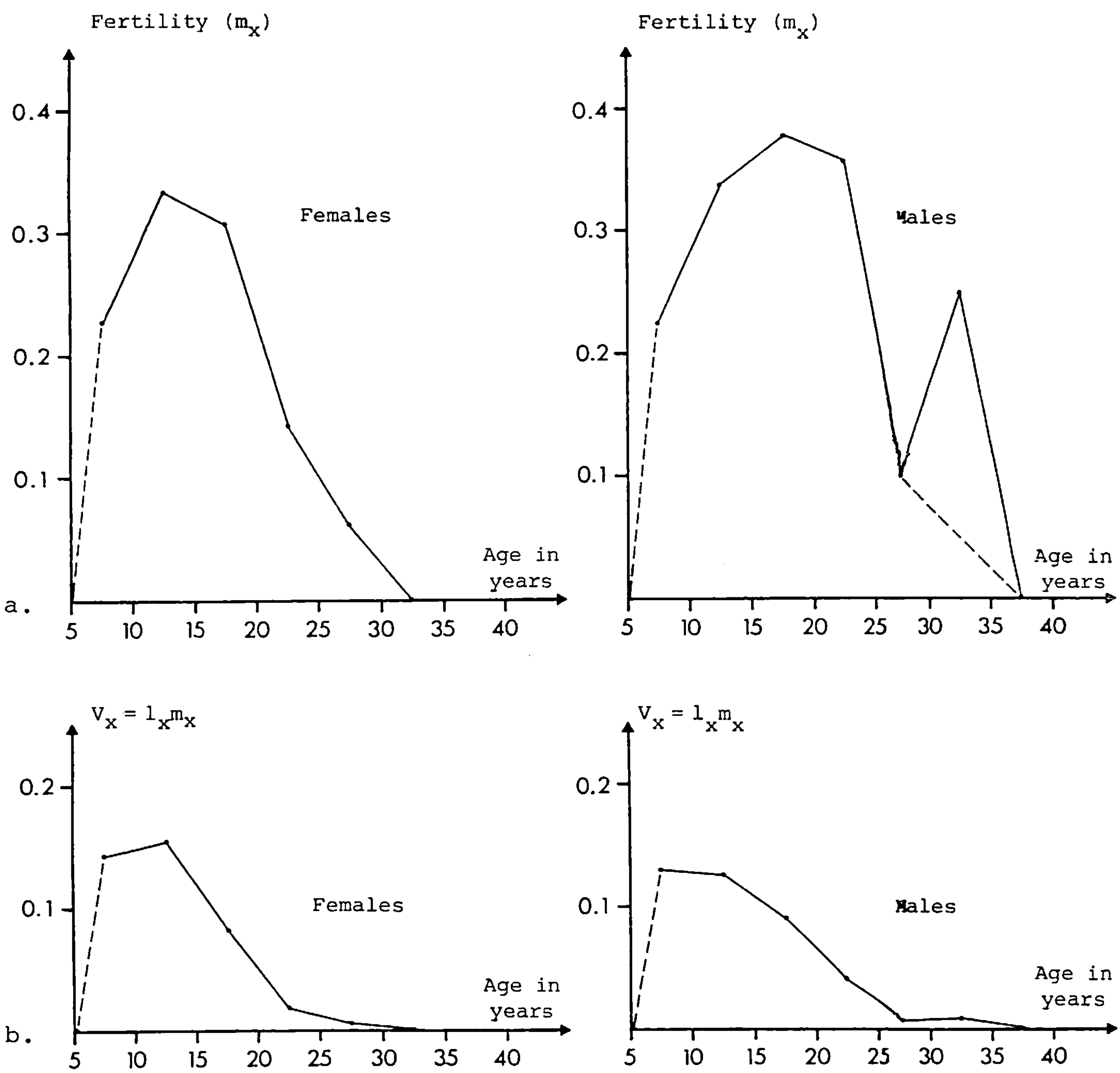


Figure 5.6.

a. Fertility (m_x): number of offspring of the same sex as the parent per age-group (here: five years)
For the high value of m_x for males between 30 and 35 years, see text.

b. Reproductive value (V_x): the $l_x m_x$ products from Table 5.5. are shown for each age group.

Black rhino, Diceros bicornis, in captivity

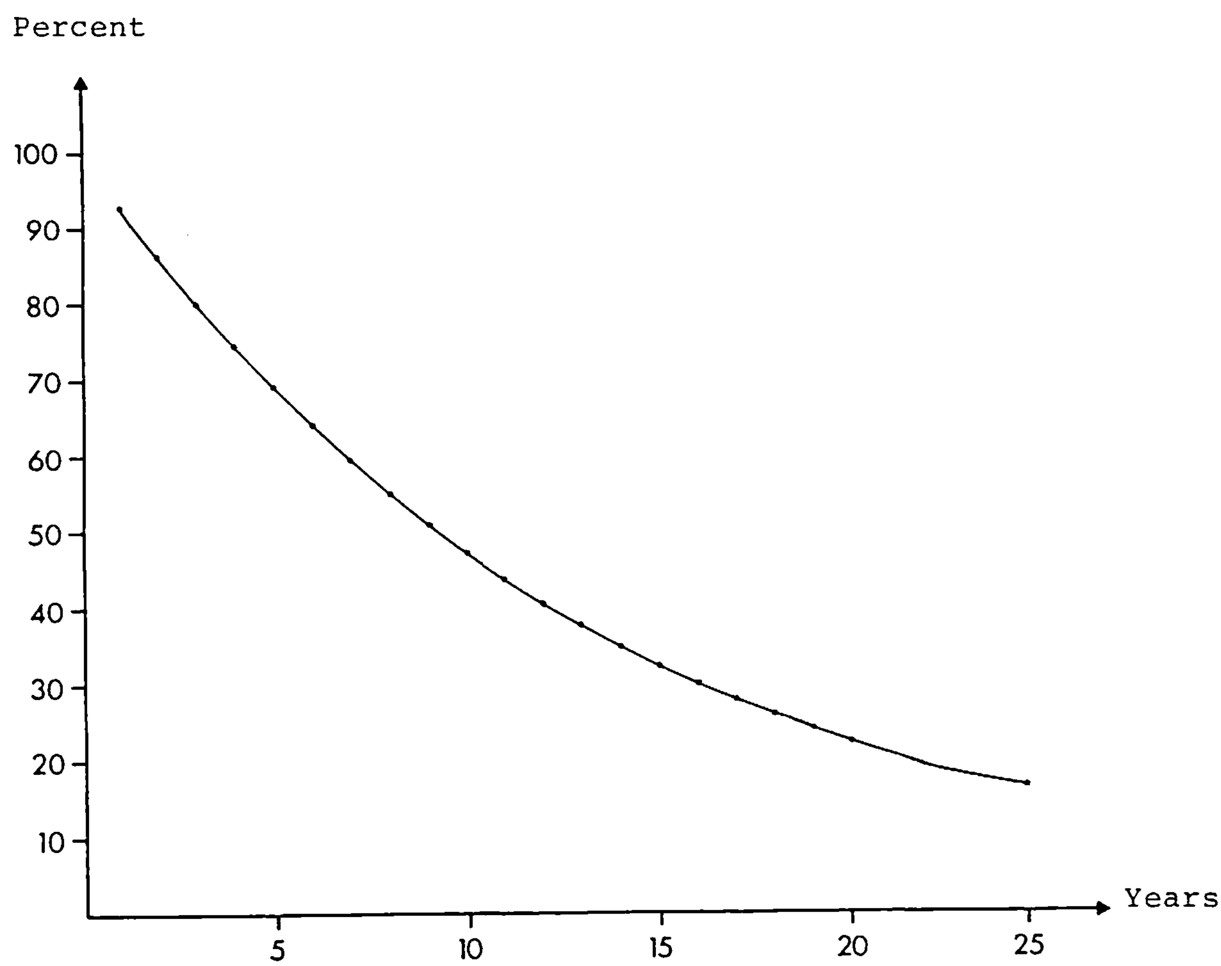


Figure 5.7.

Twenty-five years projection of the decrease in the percentage of captive black rhinos.
(with an r_m of -0.0746)

Age (years)	Number of survivors at start of age interval x,	Proportion surviving to start of age interval x,	Number dying during age interval x to x+1	Rate of mortality during age interval x to x+1	Mean expectation of further life
x	n_x	l_x	d_x	q_x	e_x
0'	145	1.000	10	0.069	
0-1	135	0.931	16	0.119	12.2
1-2	119	0.820	2	0.017	12.7
2-3	117	0.807	15	0.128	12.0
3-4	102	0.703	1	0.010	12.7
4-5	101	0.697	3	0.030	11.8
5-10	98	0.676	25	0.255 (0.051)	11.1
10-15	73	0.503	28	0.384 (0.077)	9.1
15-20	45	0.310	19	0.422 (0.084)	8.2
20-25	26	0.179	13	0.500 (0.100)	7.3
25-30	13	0.090	4	0.308 (0.062)	7.1
30-35	9	0.062	7	0.778 (0.156)	4.1
35-40	2	0.014	1	0.500 (0.100)	4.8
40-over	1	0.007	1	1.000	1.7

<u>Table 5.1.</u>

Life table for the black rhino, <u>Diceros bicornis</u>, in captivity numbers in brackets are the yearly rates.

Life table for the black rhino (Diceros bicornis) in captivity

Females only

x	d_x	n_x	l_x	q_x
0'	4	67	1.000 }	
0-1	10	63	0.940 }	0.22
1-2	0	53	0.791	0.00
2-3	8	53	0.791	0.15
3-4	0	45	0.672	0.00
4-5	0	45	0.672	0.00
5-10	6	45	0.672	0.13 (0.03)
10-15	16	39	0.582	0.41 (0.08)
15-20	11	23	0.343	0.48 (0.10)
20-25	6	12	0.179	0.50 (0.10)
25-30	1	6	0.090	0.17 (0.03)
30-35	4	5	0.075	0.80 (0.16)
35-40	0	1	0.015	0.00
40-48	1	1	0.015	1.00
48-over		0	0.0	

Table 5.2.

After 5 years, yearly mortality is shown in brackets.
All columns are symbolized as in Table 5.1.

Life table for the black rhino (Diceros bicornis) in captivity

<u>Males only</u>

x	d_x	n_x	l_x	q_x
0'	3	75	1.000 }	
0-1	6	72	0.960 }	0.12
1-2	2	66	0.880	0.03
2-3	7	64	0.853	0.11
3-4	1	57	0.760	0.02
4-5	3	56	0.747	0.05
5-10	19	53	0.707	0.36 (0.07)
10-15	12	34	0.453	0.35 (0.07)
15-20	8	22	0.293	0.36 (0.07)
20-25	7	14	0.187	0.50 (0.10)
25-30	3	7	0.093	0.43 (0.09)
30-35	3	4	0.053	0.75 (0.15)
35-40	1	1	0.013	1.00
40-over		0	0.0	

<u>Table 5.3.</u>

For explanation of symbols see Table 5.1.
After five years, numbers in brackets are the yearly mortality.

Black rhino (Diceros bicornis) in captivity

Age group	Midpoint or pivotal age	Proportion surviving to pivotal age	No of female offspring pr female aged x pr time unit (5 years)	Product of $l_x m_x$
x		l_x	m_x	V_x
5-10	7.5	0.590	0.2288	0.1350
10-15	12.5	0.407	0.3333	0.1357
15-20	17.5	0.245	0.3077	0.0754
20-25	22.5	0.135	0.1429	0.0193
25-30	27.5	0.076	0.0625	0.0048
30-35	32.5	0.038	0.0	0.0
			R_o =	0.3702

Table 5.4.

Survivorship table (l_x) and fertility table (m_x).

Black rhino (Diceros bicornis)

a. females.

Age group x	Midpoint or pivotal age	Proportion surviving to pivotal age l_x	No of female offspring pr female aged x pr time unit (5 years) m_x	Product of $l_x m_x$ V_x
5-10	7.5	0.627	0.2288	0.1435
10-15	12.5	0.463	0.3333	0.1542
15-20	17.5	0.261	0.3077	0.0803
20-25	22.5	0.135	0.1429	0.0193
25-30	27.5	0.083	0.0625	0.0052
30-35	32.5	0.045	0.0	0.0
			R_o =	0.4025

b. males.

			No of male offspring pr male aged x pr time unit	
5-10	7.5	0.580	0.2272	0.1318
10-15	12.5	0.373	0.3387	0.1263
15-20	17.5	0.240	0.3784	0.0908
20-25	22.5	0.140	0.3571	0.0410
25-30	27.5	0.073	0.1000	0.0073
30-35	32.5	0.033	0.2500	0.0083
			R_o =	0.4055

Table 5.5.

Survivorship table (l_x) and fertility table (m_x), and the product V_x.

a. females
b. males

Black rhino (Diceros bicornis) in captivity.

Age group	Midtpoint or pivotal age	Proportion surviving to pivotal age	No of female offspring pr female aged x pr time unit (5 years)		Product of $l_x m_x$
x		l_x	m_x		V_x
5-10	7.5	0.590	0.4219		0.2489
10-15	12.5	0.407	0.5814		0.2366
15-20	17.5	0.245	0.4615		0.1131
20-25	22.5	0.135	0.1818		0.0245
25-30	27.5	0.076	0.1667		0.0127
30-35	32.5	0.038	0.0		0.0
			1.8133	R_o=	0.6358

Table 5.6.

Survivorship table (l_x) and fertility table (m_x), and the product V_x. Only including breeding females.

Black rhino (Diceros bicornis) in captivity

	R_o	r_m	λ	G
males	0.4055	-0.0607	0.9411	13.7
females	0.4025	-0.0689	0.9334	12.4
whole population	0.3702	-0.0746	0.9281	12.4

Table 5.7.

For explanations of symbols see Materials and Methods.

Black rhino (Diceros bicornis) in captivity

Age class	Number in each age-class (Figure 4.1.)	Death rate. Percent from life-table (Table 5.1.)	Actual number lost in a year
0-5	28	6.2(+)	1.7
5-10	27	5.1	1.4
10-15	52	7.7	4.0
15-20	33	8.4	2.8
20-25	8	10.0	0.8
25-30	14	6.2	0.9
30-35	7	15.6	1.0
		total =	12.6

Table 5.8.

Actual number of rhinos lost pr year of the population of 169.

(+): average from 6 groups (Table 5.1.)

6. INBREEDING AND THE PROBLEM OF SUBSPECIES

INBREEDING IN CAPTIVITY

There are numerous examples of the deleterious effects of inbreeding, both in captivity (Flesness 1977, Ralls et al. 1979, 1980) and in natural populations (Soulé 1980). It is not until recently that the principles of genetic conservation in relation to wildlife management has been considered seriously. Information on this subject regarding Southern Africa has been reviewed by Greig (1979).

Inbreeding increases the probability that the offspring will receive identical genes from both parents, and hence reduce the natural variability. This increase in homozygosity is measured by the inbreeding coefficient, F (for calculations of F, see Lasley 1978). For example, a brother-sister mating will result in an inbreeding coefficient $F = 0.25$, i.e. the offspring will have 25 percent decrease in heterozygosity as compared to the non-inbred parents.

Data from natural populations suggest that relatively heterozygous individuals have greater viability and, in some cases, fecundity, than relatively homozygous individuals (Soulé 1980).

The degree of inbreeding, and hence the loss of variability (f) is inversely related to the population size.

1.) f increases by $1/2N_e$ per generation (Franklin 1980).

N_e is the effective breeding size, and is, roughly, equal to the number of breeding animals in a population with an even number of breeding males and females, and with matings at random.

With an uneven number of males and females, N_e is measured by the formula:

2.) $$N_e = 1/\left(\frac{1}{4\,N_m} + \frac{1}{4\,N_f}\right)$$

N_m and N_f are the number of breeding males and females respectively.

If N_e is 50 (equation 1. on previous page) the degree of inbreeding is 0.01 or one percent, which is the maximum allowable rate of inbreeding according to the basic rule of conservation genetics; but even so, the loss of genetic variation is appreciable after a few generations (Soulé 1980).

Soulé (1980) shows how powerful an inbreeding depression can become: "A survey of inbreeding experiments led to the generalisation that increasing the inbreeding coefficient by ten percent induces a 5 to 10 percent decline in a particular reproductive trait... A 5 or 10 percent decline in fertility might not appear to be very serious, but if the effects of inbreeding depression on the other traits (such as viability) are also considered, this amount of inbreeding can lower reproductive performance as a whole by 25 percent."
Ten percent inbreeding is equivalent to the amount that would occur - theoretically - in one generation in a population of five random breeding adults.

The Przewalski horse (Equus przewalskii) is an example of a species where inbreeding has had detectable harmful effects.With coefficients as high as 0.6, the variability has been reduced by 60 percent in some individuals. A Chi-square analysis of all except the present generation of horses, shows, that individuals with higher inbreeding-coefficients are less likely to reproduce ($p < 0.001$). If they do reproduce, they tend to have fewer offspring than individuals with lower inbreeding coeffecients ($p < 0.002$). The high level of inbreeding is due to the use of a very small number of stallions (Flesness 1977).

Black rhinos breeding in captivity at present amounts to 28 males and 46 females, which gives an effective population size, $N_e = 70$ (equation 2., previous page). Franklin (1980) claims, that an effective population size of 50 is the minimum for short-term propagation, for long term propagation he recommends 500. So, with an effective population size of 70, which is more than for many other species in captivity, the black rhino population could in theory be secure - from a genetic point of view - on a short-term basis. However, the main problem is, that this is far from being a random breeding population, but consist of a large number of small collections, where inbreeding takes place.

Inbreeding is often governed by economic considerations. It is costly to transport large animals as rhinos often over long distances, hence the temptation to breed with the animals at hand, even if they are closely related. The most common inbreeding in the black rhino is daughter-sire matings. This is due to the practise of keeping only two or three animals in a collection, so the only choice for a daughter is often her own father. Three such animals (2 males, 1 female) that are the result of a daughter-sire mating are registered in the Studbook. In addition questionnaires have revealed a female that is the result of a full-sib mating, plus another female that have produced two calves by her own sire. Both calves died, one at birth the other after two days.
Daughter-sire matings and full-sib matings both result in an inbreeding coefficient, $F = 0.25$, meaning that the genetic variability is reduced by 25 percent in one generation. The questionnaires also showed several attempts of inbreeding, but with no result as yet. In two cases mating dates were given for daughter-sire pairs.

Altogether, information on seven inbred black rhinos is at hand. Of these three died before two days of age. Comparing numbers on inbred rhinos to the 126 births of non-inbred animals, of which 23 died, there is no significant difference ($X^2=1.2277, 0.2<p<0.3$). In this study, the same limits for non-inbred animals have been used as by Ralls et al. (1979), i.e. young that survived six months were considered to have lived, whereas the died catagory consisted of young surviving less than six months, including stillbirths and young born prematurely.

The sample size of seven in the inbred group, can be argued as being too small on its own. However, Ralls et al. (1979) examined 16 species of ungulates and found, that mortality of inbred young was higher than that of non-inbred young in 15 of the 16 species. For five of their species the sample size in the inbred groups were seven or less.
If the black rhino is added to the list of Ralls et al. (1979), the black rhino would be one more species where mortality of inbred young is higher than that of non-inbred young (two-tailed sign-test, $p < 0.0003$).

It has been claimed (Slatis 1960) that inbreeding has no detectable effect on fertility and mortality in the European Bison (Bison bonasus), and Slatis (1975) argues, that inbreeding has some advantages besides convenience, such as producing a uniform strain and detecting undesirable genes. This is well known to domestic livestock breeders, where a special form of inbreeding - linebreeding - has been practised for a long time. However, linebreeding is usually a mild form of inbreeding, directed towards a line of ancestors, which often involves half-sib matings; but parent-offspring matings are regarded as intense inbreeding and not looked upon with favour (Lasley 1978).

It might be desirable to breed a uniform strain in domestic stock, but the question still remains: Which characteristics are desirable in a wild animal?

It might be argued, that seven cases of inbreeding is not alarming, but this is a minimum figure, more might have occurred, and more will come if the present attempts are successful.

<u>The white rhino</u> has not been mentioned yet, as breeding has only just started in the second generation in captivity, but inbreeding could be a problem later on, as it is not uncommon to sell half-sibs as breeding pairs. Several such cases are known for white rhinos, but some also for the black rhino. This again reflects economics; it is cheaper to transport two rhinos from one place, than to transport two rhinos from different places. However, a serious captive breeding program should invest enough care in the acquisition phase, and only use the best founders, meaning that as many animals as possible are as unrelated as possible (Senner 1980).

The practise of keeping white rhinos in herds, without changing the dominant (breeding) male now and again, gives only a few males the opportunity to breed. This could cause inbreeding problems in the future, especially as these "big places" are producing most of the future breeding stock.
In 1980, 558 white rhinos were registered (Table 2.2.), of these approximately 20 males and 65 females were breeding, $N_e = 61$, or less than the effective population size for the black rhino in captivity. As mentioned previously, the inbreeding depression in the Przewalski horse is due to the use of a very small number of stallions (Flesness 1977). The same thing could happen to the white rhino.
Therefore, it is of importance for the future of the species to give more captive white rhinos, especially males, occasion for propagation.

Senner (1980) constructed a mathematical model of a zoo population with nine parameters representing characteristics of a species or of a management decision. He found, that the most important manipulation to increase the effective population size (which decreases inbreeding), is to equalise the genetic contribution of the parents to the next generation.

In other words, it is important to get an equal number of offspring from all animals (For mathematical derivation and treatment see Senner 1980).

It was concluded from the Demographic Survey of the black rhino in captivity, that survival had to be improved. However, according to Senner's model (1980), this is not sufficient to secure the future of the species. It is of greatest importance that more black rhinos (as well as white rhinos) get the opportunity to contribute to the next generation.

Artificial insemination seems to be the logical answer to the inbreeding problem. Although it is widely used in cattle, artificial insemination has not been practised successfully, as yet, with endangered species (Benirschke 1980). Young (1967) reports on semen extraction by manipulation technique from a black rhino.
Kleiman (1975) describes the various difficulties in this field, but also mentions that success in mammalian species such as ungulates, can be expected in the future.

A Studbook is an important tool for detecting inbreeding depressions. It is necessary, however, to record all births, including stillbirths and young born prematurely, as well as abortions. Otherwise the studbooks will be of limited value only, in spite of the great amount of work which is being put into them.

THE PROBLEM OF MAINTAINING THE SUBSPECIES

When discussing the feasibility of breeding wild animals in captivity as a means of conserving species, the questions soon arises: What do we want to conserve? Can it be achieved in practice?

It has been claimed (Senner 1980, Soulé 1980), that extinction of small populations is inevitable. Most lines that are inbred become extinct in three to twenty generations (Soulé 1980). So, it seems reasonable, as suggested by Campbell (1980), to make plans for reintroduction as soon as possible, even if the possibilities at the moment seem dim. This implies conserving as much genetic variation as possible, recognising that, in nature, heterosis is actively maintained and seems in many ways beneficial (Benirschke 1977). This means doing what is possible to minimise inbreeding.

However, with regard to the black rhino there is a major drawback. Zoos are likely to have crossed animals from different geographical areas. The Studbook does not keep records indicating the subspecies or exact geographical origin of each animal. For example, in some cases the origin given is East Africa, in other cases the origin is more specific, e.g. Kenya. But unless it is established exactly where in Kenya an individual is caught, it is difficult, if not impossible, to designate the subspecies to which it belongs, as three subspecies occur in Kenya (Groves 1967).

Conway (1967) states that in some captive propagation projects subspecific distinction in small populations would have to be ignored because of the important need to obtain as variable a gene pool as practicable, i.e. a large breeding group.
Of course one can always argue that it is better to have non-endemic rhinos, than to have no rhinos at all; but surely, wherever possible the genetic integrity of a subspecies or local population should be maintained.

This view was also taken by the IUCN/SSC's African Rhino Group, when it stated, that translocations should be limited to reintroduction to areas formerly inhabited by the species; and that individuals should belong to the endemic subspecies.

It is not only in captivity that genetic integrity has been ignored. Black rhinos from Kiboko area, Kenya (Diceros bicornis michaeli) were translocated to the Addo National Park in South Africa in 1961-62, the endemic subspecies (Diceros bicornis bicornis) having been exterminated by 1853 (Hall-Martin & Penzhorn 1977). The nearest sub-species to the endemic one would have been Diceros bicornis minor, but none were available at the time. Only later, in 1977 were D.b.minor translocated to the Addo National Park (Greig 1979).

At the African Rhino Specialist Group Meeting in August 1981 in Zimbabwe, Hall-Martin reported that the Park Board have now moved the D.b. michaeli out of Addo, and are making cromosome tests of suspect progeny. The possibility of returning individuals to Kenya was discussed. Pretoria zoo is another possibility.

The conclusion is, that it probably would be possible to preserve the black rhino in captivity if sufficient efforts are made, at least on a short term basis. However, conservation of the subspecies as biological diversity would be extremely doubtful, if we are to rely only on the present captive rhinos as genetic material.

POSTSCRIPT

Recognising the serious status of the rhinos, the International Union of Directors of Zoological Gardens (IUDZG) is holding a Symposium on the Ecology, Conservation and Captive Management of Rhinoceroses during 26-27 August 1982 at the Zoological Society of London.

The Symposium will be attended by international zoo people, and by others interested in conservation and large mammals.

APPENDIX I

	Zoos name	Country	White rhino C.simum sp	Black rhino D. bicornis
+	Aalborg	Dk	1,3	-
	Antwerpen	Ne	2,2	-
	Akiyoshidai	Japan	3,3	-
	Al Ain	U. Arab Emirates	1,1	-
	Albuquerque, New Mexico,	U.S.	1,1	
+	Arnheim	Ne	5,7(3,5)	-
	Asheboro, N. Carolina	U.S.	1,2	o,1(0,0)
	Atlanta, Georgia	U.S.	-	1,1
	Berlin, East	E. Ger	1,2	1,1
+	Berlin, West	W. Ger	1,1	1,3
	Barcelona	Spain	1,2	-
	Baton Rouge, Louisiana,	U.S.	1,2	-
	Birmingham, Alabama	U.S.	1,2	-
	Blackpool	U.K.	1,2	
	Bloemfountain	S.A.	1,1	-
	Boraas	Sweden	1,1	-
	Bristol	G.B.	-	0,1
	Brownsville, Texas	U.S.	2,2(1,1)	-
	Buenos Aires	Brazil	-	o,1
	Buffalo, N.Y.	U.S.	-	2,2(1,2)
	Cairo	Egypt	-	1,1
	Calgary	Canada	1,1	-
	Caracas (Carabobo)	Venezuela	3,4	-
	Catskill, N.Y.	U.S.	1,1	-
	Chester	G.B.	1,1	1,1
	Chester-le-Street	G.B.	1,2	-
	Cheyenne, Colorado	U.S.	-	1,2
	Chicago, Illinois	U.S.	1,1	1,3(1,2)
	Cincinnati, Ohio	U.S.	-	2,2(3,2)
	Cologne (Køln)	W.Ger	1,1	-
	Columbia, Was.D.C.	U.S.	1,2	-
+	Copenhagen	Dk	3,2(1,2)	-
	Cotswold	G.B.	1,1(1,2)	-

APPENDIX I(2)

Zoos name	Country	White rhino C.simum sp	Black rhino D.Bicornis
Dallas	U.S.	-	1,1
Denver, Colorado	U.S.	-	2,3(2,2)
Detroit, Michegan	U.S.	-	1,2
Djakarta	Indonesia	1,1	-
Dortmund	W. Ger	1,1	-
Dresden	W. Ger	1,1	-
Dublin	Ire	1,1	-
Duisburg	W.Ger	1,1	-
Dvur Kralove	Chez	3,6(2,5) C.s.cottoni 1,6(3,6)	3,8(3,6)
Edingburg	G.B.	2,1(1,2)	-
Emmen	Ne	1,1	-
Edmonton	Canada	1,1	-
Forth Worth, Texas	U.S.	1,1	-
Frankfurt	W.Ger	-	1,1
Fresno, California	U.S.	1,1	-
Fukuoka	Japan	1,1	-
+ Givskud	Dk	2,0(1,0)	-
Glaskow	G.B.	2,0	-
Habana	Cuba	2,4	-
Hanover	W.Ger	2,1	1,1
+ Hilvarenbeck(Bekse Bergen)	Ne	3,5(2,4)	-
Hiroshima	Japan	-	2,1
Hodenhagen	W.Ger	3,3	-
Honolulu, Hawaii	U.S.	1,1	-
Houston, Texas	U.S.	1,1	-
Int. Animal Exchange (Animal dealers)	U.S.	11,28	-
Jackson, Mississippi	U.S.	1,2	-
Jacksonville, Florida	U.S.	2,3(2,4)	1,1(0,0)
Johannesburg	S.A.	2,2	1,0

APPENDIX I(3)

Zoos name	Country	White rhino C.simum sp	Black rhino D.bicornis
Kano	Nigeria	-	1,1
Katowice	Poland	1,1	-
Kings Mills, Ohio	U.S.	6,3	-
Khartoum	Sudan	C.s.cottoni 3,1	-
Knoxville, Tennessee	U.S.	1,4	-
Kobe	Japan	1,1(no reply)	1,1
Knudtenborg	Dk	2,2	-
Kolmarden	Sweden	1,1	-
Krefeld	W.Ger	1,1	-
Leipzig	E.Ger	1,1	1,0(1,1)
Lesna	Cz	-	1,1
Liberec	Cz	1,1(0,1)	-
Little Rock, Arkansas	U.S.	1,1	-
+ London	G.B.	0,1 C.s.cottoni 1,0	2,1
Lisbon	Port	1,1	2,2
Los Angeles, Calif	U.S.	1,1	1,1
+ Longleat	G.B.	3,3(4,2)	-
Louisville, Kentucky	U.S.	1,1	-
Lion Country Safari, Ca	U.S.	7,8	-
Madrid	Spane	1,1	-
Maidieguri	Nigeria	-	1,2
Magdeburg	E.Ger	-	2,1
Mallorca	Spane	1,1	-
Memphis, Tennessee	U.S.	1,2	1,2(0,1?)
Miami, Florida	U.S.	-	2,1
Milwankee, Wisconsin	U.S.	1,2	-
Miyazaki	Japan	4,9(3,9)	-
Moskau	U.S.S.R.	-	1,3
Morella	Mexico	1,2	-
Monroe, Lousiana	U.S.	1,1	-
Munich	W.Ger	1,2	-
Munster	W.Ger	2,2	-
Mysore	India	-	2,2

APPENDIX I(4)

Zoos name	Country	White rhino C.simum sp	Black rhino D.bicornis
Nagoya	Japan	1,1	1,2
Naples	Italy	-	1,2
New Delhi	India	-	1,1
New Orleans,Louisiana	U.S.	2,2	-
Norfolk, Virginia	U.S.	1,1	-
Nurnberg	W. Ger	1,1	-
Oklahoma, Ohio	U.S.	1,1	3,2
Omaha, Nebraska	U.S.	1,1	-
Osaka	Japan	-	2,3(1,1)
Ostrava	Cz	2,1(1,1)	-
Paignton	G.B.	-	1,1(1,0)
Peking	China	1,1	1,3
Philidelphia, Pa	U.S.	1,1	1,0
Phoenix, Arizona	U.S.	2,1	-
Pistoia	Italy	1,1	-
Pittsburgh, Pennsylv.	U.S.	1,1	1,0(0,0)
+ Port Lympne(Bekesbourne)	G.B.	-	2,2
Prague	Cz	1,2	-
Prescot	G.B.	3,2	-
	C.s.cottoni	0,1	
Pretoria	S.A.	9,7	1,1(0,1)
Ramat-Gan	Israel	6,4(6,3)	-
Rangoon	Burma	1,1	-
Rapperswil	Switzerland	1,1	-
Rio de Janeiro	Brazil	1,1	-
Rome	Italy		1,1
Rotterdam	Ne	1,1	-
Salt Lake City, Utah	U.S.	1,1	-
San Antonio, Texas	U.S.	3,3 (2,3)	1,2(1,1)
San Diego Zoo, Calif	U.S.	4,2 (?)	1,2(1,1)
	C.s.cottoni	1,2(1,0)	
San Diego wild Animal Park	U.S.	6,17(9,9)	1,2(2,2)
San Francisco, Calif	U.S.	1,1	1,1(2,1)
Santo Domingo	Dom.Rep.	2,2	-

APPENDIX I(5)

Zoos Name	Country	White rhino C.simum sp	Black rhino D.bicornis
Sao Paulo	Brazil	1,1	-
Sedgwich, Kansas	U.S.	-	1,1
Sendai	Japan	1,1	-
Sigean	France	1,1	-
Singapore		1,1	-
Southampton	G.B.	1,2	-
St Louis, Missouri	U.S.	-	2,2(1,2)
Stuttgart	W.Ger	2,1 (0,0)	-
Surabaja	Indonesia	1,1	-
Sydney	Aust.	-	3,2(1,2)
Tampa, Florida	U.S.	1,1	2,2(1,1)
Teheran	Iran	-	2,1
Tel Aviv	Israel	-	1,1
Tokyo, Ueno	Japan	1,1	-
Toledo, Ohio	U.S.	1,1	-
Toronto	Canada	2,2	1,2(0,0)
Tuscon, Arizona	U.S.	1,1	-
Tunis	Tunesia	2,2	-
Turino	Italy	1,1	-
Verona	Italy	1,2(0,0)	-
Villiersdorp	S.A.	1,2	-
Washington, D.C.	U.S.	-	2,2(1,1)
+ Whipsnade	G.B.	5,16(3,13)	1,1(2,1)
+ Windsor	G.B.	3,5(2,4)	-
Winston, Oregon	U.S.	2,1	-
+ Woburn	G.B.	3,3(2,2)	
Wroclaw	Poland	-	1,1
Zagreb	Yugo	-	1,1
Zurich	Switzerland	1,1	2,3(3,3)

Appendix I

Alfabetic order of Zoos to which questionnaires were mailed
Key:
First letter underlined: zoo replied to questionnaire
+ in front of name: personal visit
brackets: number of rhinos changes according to questionnaire
1,0: 1 male
0,1: 1 female

IUCN/SSC NYZS°WWF
African Rhino Group
P.O.box 60642
Nairobi, Kenya
Tel : 331542

Copenhagen, 1980.

Dear Sir/Madam,

Rhinos have now become so scarce in many areas in the wild, that breeding sanctuaries must be considered in indigenous areas.

Much valuable information on many aspects of their population dynamics, behaviour and needs in captivity are only available from a captive situation. In co-operation with Dr. Kes Hillman, Chairman of the IUCN African Rhino Group, of which I am a member, I am trying to collect all available information about rhinos in captivity. Not only will this data help in any future breeding projects, but it will also complement studies in the wild. Some information has already been obtained from the respective studbook keepers. However, I would greatly appreciate if you would kindly participate by letting me have as much other information as possible. In particular, we should like to know about keeping conditions, abortions, still born calves, behavioural observations and the methods and success of any management to increase rate of reproductions, such as early weaning of calves. Without your kind help, this study will be of limited value. May I trouble you to return the enclosed questionnaire(s), as soon as possible, and not later than.........
Thanking you in advance for your kindness.

Sincerely yours,
Hanne Lindemann
Hanne Lindemann

Please return to:
Hanne Lindemann
Zoologisk Museum, 1. Afd.
Universitetsparken 15,
DK 2100 Copenhagen
Denmark.

Appendix II

The distributed questionnaire

QUESTIONNAIRE for

Date:

Name of respondant:

Zoos name and
address:

I see you keep____ Rhinos (males, females), of which the following females have bred: (if this has changed, please correct).

1. Have you had any abortions, still born calves or calves that died before being registered by the studbook? If so please give: No. and/or name and date of birth of female involved, date of birth and death of the calf, and reason for death if known.

2. Do you have any records of mating dates, if so please give: No. and/or name of rhino (both males and females), date(s) of birth(s) date of first mating, date(s) of other mating(s).

3. Problems or needs regarding mating, e. g. long time of courtship, presence of other males, etc.

4. How are the rhinos kept?
   Singly
   In pairs
   Several together
   Male separate from female(s)

5. Do you vary this, for example when females are in oestrus?

6. Please indicate rough size of pen (in m^2 or acre(s)).
If there is an inner and outer pen, please give size of both, and how long the rhinos are kept in each.

7. Have you made any management experiments to increase breeding success and survival of young? (i. e. pen size, periodic isolation of sexes, early weaning of calves, etc.).

8. Did disease play any role in lack in breeding success?
If yes, please give details.

9. Do you have any experience in hand rearing of young?
If yes, please give some details.

10. Have there been any studies done on rhinos at your Zoo?
If yes, please give references.

Please return to:
Hanne Lindemann
Zoologisk Museum, 1. Afd.
Universitetsparken 15,
DK 2100 Copenhagen
Denmark.

If further comments please use other side!

APPENDIX III(2)

Black Rhino - <u>Diceros bicornis</u> 0.1 = 9-16-78

0 days - 82# Formula- Skim milk and Calf Starter Replacer. Every 4 hours. 32 ounces per feeding. 8AM-12AM. : 84/96

5 days - Formula change- 1:1 2% Lowfat milk to skim milk. 1 ounce Vi-Sorbin and ½ tsp. Plex-sol daily 160/160

12 days - Formula change- 26 ounces 2% lowfat milk
26 ounces skim milk
3 ounces Lactose
½ ounce powdered protien

4 weeks - Finalized formula- (per bottle = 64 ounces)
850ml 2% Vitamin A&D Lowfat Milk
800ml Skim Milk
77 grams Pro-Mix(high potency whey protien supplement)
46 grams Lactose mixed with 60ml water
320/320

6 weeks -160# 1½ quarts Monogastric Diet(Anderson Feeds)
Free Choice hay - 80% timothy, 20% alfalfa

10-13 wks- Cut the number of feedings to two per day. Experienced diarrhea and weight loss.

15 weeks - Resumed feeding schedule of five bottles per day.

6½ months- Began to reduce the formula strength while keeping the total volume the same.
850ml 2% lowfat milk
200ml skim milk
600ml water
77 grams Pro-Mix
46 grams Lactose mixed with 60ml water

Subsequent cuts in strength were made about every three weeks for three months about 10% each time. The cuts were made in all the ingredients and the volume was kept approximately the same by increasing the water.

8½ months - 4 bottles every 4 hours , 8AM-8PM.
9 months - 3 bottles every 4 hours , 8AM-4PM.
10 months - 2 bottles 8AM&4PM.
11 months - 1 bottle - 8AM.
9-9-77 - weaned 500#.

Apparatus - Calf bottle and nipple.

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Many people have helped with this study in various ways. Particularly, I would like to thank Dr Kes Hillman for suggesting this survey and for her never failing interest.

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Beyond the call of duty, the exhibition department of the Zoological Museum in Copenhagen kindly provided me with office space and facilities.

Finally I should like to express my thanks to the staff of all the zoos that took the trouble to fill in the questionnaires and particularly to those I had the opportunity to visit and plague with questions.

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Elke Rehring –

ZOO 6·4·80