Zoo Biology 11:375–383 (1992)

RESEARCH ARTICLES

Management Parameters Affecting the Reproductive Potential of Captive, Female Black Rhinoceros, *Diceros bicornis*

Russell L. Smith and Bruce Read

San Antonio Zoological Gardens and Aquarium, San Antonio, Texas (R.L.S.), and St. Louis Zoological Park, St. Louis, Missouri (B.R.)

With deterioration of the wild population over the last two decades, captive reproduction of black rhinoceros has become a high priority for zoological gardens. Several reproductive parameters of female black rhinoceros were analyzed with data from the international studbook, and compared to data from field studies. These analyses yielded comparisons for ages of females at first calving, length of birth intervals, and span of reproductive life. The implications for rhino productivity are discussed, and some suggestions for increasing productivity are presented.

Key words: birth interval, captive breeding, Species Survival Plan, birth rate, natality

INTRODUCTION

With the decline in numbers of the wild black rhinoceros, *Diceros bicornis*, from an estimated 60,000 animals in 1970 to less than 3,500 today [Brooks, 1991], the zoological community has placed more emphasis on the establishment of a self-sustaining captive population [du Toit et al., 1987]. Such a population will have to be able not only to sustain its current numbers, but to grow to the designated carrying capacity without significant supplementation by animals from the wild [Conway, 1980a; Senner, 1980; Soulé, 1980; Seal, 1986]. The Black Rhinoceros Species Survival Plan of the American Association of Zoological Parks and Aquariums has proposed a carrying capacity of 150 animals for North America [Maruska, 1987]. The estimated world captive carrying capacity is 200–250 black rhinos [Cumming, 1987]. As of 31 December 1990, the North American captive population is 85 black rhinos, and the captive world population is 204 [Klös and Frese, 1991]. The establishment of

Received for publication August 5, 1988; revision accepted September 18, 1992.

Address reprint requests to Russell L. Smith, San Antonio Zoological Gardens and Aquarium, 3903 North Saint Mary's Street, San Antonio, TX 78212.

a self-sustaining population requires that it be capable of reaching the carrying capacity with the desired genetic representation. The population then needs to be stabilized with regard to founder representation, sex ratios, and age distribution [Foose, 1980]. To accomplish this, the captive management of the black rhino should be analyzed to determine what factors affect population growth.

Unfortunately, the captive population for black rhinos has not been able to sustain itself without recruitment from the wild. "As many as half of the animals have never reproduced, and birth rates approximately equal death rates" [Lacy, 1987]. The studbook keepers, Klös and Frese, have commented on the declining captive population for years [1983, 1987]. "The average birth rate of six individuals is opposed by a death rate of nine annually" [Klös and Frese, 1987]. Although medical and nutritional problems exist [Jones, 1979; Miller and Boever, 1982; Ott et al., 1982; Dierenfeld et al., 1988; Miller et al., 1990], those problems have not been demonstrated to directly affect reproduction. The authors here address the less publicized problem of breeding management. In addition to the demographic problems inherent with a low birth rate, genetic diversity can be lost. In general, the faster the growth to carrying capacity, the less genetic diversity is lost [Conway, 1980b; Senner, 1980; Foose, 1987].

Three basic factors characterize the reproductive performance of the female black rhinoceros: the age when she produces her first calf, the intervals between births, and the span of her reproductive life. Once these have been determined, the manager can build a breeding program that attempts to achieve the maximum production from each female in the population. By comparing what has been observed in the wild and in captivity, a manager can determine if captive breeding and breeding in the wild are equally productive. If not, a review of data may indicate how captive reproduction may be improved.

METHODS

Reproductive data on the 78 female black rhinos that have reproduced in captivity were obtained from the *International Studbook of the Black Rhinoceros* and the *International Studbook of African Rhinoceros* [Klös and Frese, 1981, 1983, 1987, 1991]. These data yield information on the age at which females produced their first calf (Table 1), the length of birth intervals (Fig. 1), and the span of reproductive life.

RESULTS

In order to eliminate the estimated ages of wild caught animals, we looked at the age at first parturition for captive born females. The average age at which a captive-born female (N = 22) produced her first calf was 8.8 years (Table 1). This is late compared to data from the wild where the average age at first parturition in wild females was determined to be 4.75–5.25 years [Schenkel and Schenkel-Hulliger, 1969], 6.25 years (with adequate males available), and 8.9 years (with one or no adult males available) [Hall-Martin, 1986], 7.5 years (at Umfolozi), and 12 years (at Hluhluwe) [Hitchens and Anderson, 1983].

Closer to estimates from the field, a survey of captive females yielded an average estimated age at sexual maturity of 5.25 years (range 3–10 years). A female

TABLE 1. Age at first parturition of known age, captive born females

Studbook number	Birthdate	Date of first calf	Age at first parturition (years)[a]
6	10 Dec. 58	11 Nov. 69	10.9
29	1 Aug. 60	9 Jul. 69	8.9
55	27 Jul. 61	1 May 68	7.8
101	2 May 65	20 May 75	10.1
119	22 Mar. 62	23 Apr. 73	11.1
126	20 Jan. 68	7 Nov. 78	10.8
139	20 Feb. 70	4 Jan. 78	7.8
150	27 Aug. 70	18 Sep. 78	8.1
163	6 Jan. 71	25 Aug. 77	7.7
165	20 Oct. 71	3 Feb. 80	8.3
180	21 Mar. 70	3 Nov. 77	7.6
183	1 Feb. 72	21 Jul. 83	11.5
190	26 Nov. 69	29 Mar. 79	9.3
212	9 Nov. 75	6 Nov. 86	11.0
239	15 Oct. 76	12 Jul. 87	10.7
244	2 Oct. 77	15 May 84	6.6
267	16 Sep. 76	25 Aug. 85	8.9
270	25 Jul. 78	21 Oct. 85	7.3
282	5 Jul. 78	26 Aug. 86	8.2
284	12 Sep. 79	3 Mar. 86	6.5
298	23 Dec. 81	12 Oct. 90	8.8
317	29 Sep. 82	21 May 89	6.7
		mean for 22 females =	8.8 years

[a]Standard deviation: 1.6 years; range: 6.5–11.5 years; median: 8.3 and 8.8 years; mode: 7.8 and 8.9 years.

at 3.75 years [Maruska et al., 1986]. Schenkel and Schenkel-Hulliger [1969] determined the age of sexual maturity for females in the wild to be 3.5–4 years by observing females of that age being with sexually motivated males. Hall-Martin [1986] determined the age at conception of six known age cows by subtracting the length of the gestation period, 15 months, from their age at first parturition. The average was 6.3 years with a range of 3.8–9.1 years. Sexual behavior was first noted at 7–8 years in Hluhluwe, Natal [Hitchens and Anderson, 1983].

The average of 122 captive birth intervals was 40.4 months (Fig. 1), as compared to averages of 26 months [Joubert and Eloff, 1971], 27 months [Goddard, 1967], 32 months [Hall-Martin, 1986], and 30–39 months [Schenkel and Schenkel-Hulliger, 1969] for birth intervals in the wild. However, 25 (20%) of the captive birth intervals were 24 months or less (Fig. 1), with the shortest interval being 16 months. The shortest recorded birth intervals from wild females are 24 [Hall-Martin, 1986], 25 [Goddard, 1967], and 26 months [Joubert and Eloff, 1971].

Schenkel and Schenkel-Hulliger [1969] estimated that a wild female black rhino produces at least seven and at most 12 calves over a reproductive life span that ends between 30 and 35 years of age. Owen-Smith [1988] estimated a life span of 40 years, with a maximum of 18 and a mean of 14 calves produced. Longevity into the thirties and sometimes forties is not unknown in captivity, with one female living to be an estimated 48 years of age (45 years were in captivity) [Klös and Frese, 1983].

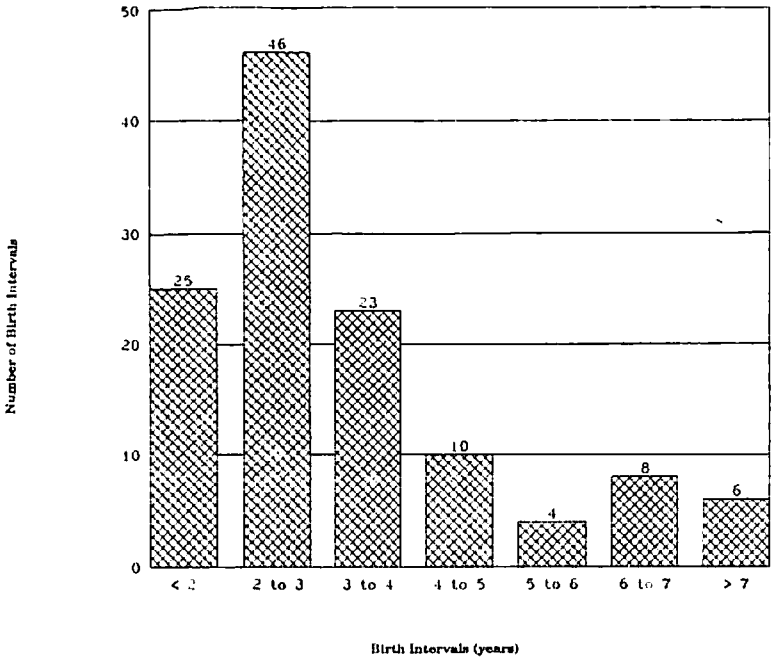

Fig. 1. Distribution of individual birth intervals of black rhinoceros in captivity.

However, females in captivity have demonstrated a shorter reproductive life than has been estimated for wild females. The studbook keeper has noted that breeding ceases at about 20–25 years [Klös and Frese, 1987]. Since then, two females have calved at 28 years of age, although 11 previously reproducing females have lived or are living past that age. The earliest a captive female of known age has produced a calf is 6.5 years (Table 1). The reproductive life of a captive, female black rhino, as determined by the data, is from her 6th to her 28th year.

Recruitment due to natality has been demonstrated to be higher in wild black rhinos than in captives. The birth rate of captive black rhinos, as a percentage of the entire population, from 1970 through 1990 is an average 4.4% per year (Table 2). Birth rates in some wild populations have been demonstrated to be 7.0% and 7.2% [Goddard, 1967], 9.0% and 9.6% [Hall-Martin, 1986], and 5.3% and 11.0% [Hitchins and Anderson, 1983]. The birth rate in captivity, as a ratio of young/year/adult females, is 11.4% (Table 3), as compared to 25% in a wild population [Goddard, 1967].

DISCUSSION

By building a management program, based on a female's first parturition at 6 years of age and birth intervals of 2 years, the lifetime reproductive potential of captive females could parallel the estimated production of wild females. Since most captive females have failed to reach this level of reproduction, the question of how current management practices affect the reproductive potential of black rhinos must

TABLE 2. Birth rates and death rates in the captive population of black rhinoceros, 1970–1990

Year	Population (31 December)	Births	Birth rate	Deaths	Death rate
1970	143	11	7.7%	13	9.0%
1971	156	5	3.2	12	7.7
1972	161	8	5.0	9	5.6
1973	170	4	2.4	7	4.1
1974	171	4	2.3	13	7.6
1975	183	7	3.8	7	3.8
			3.3%		5.7%
1976	186	6	3.2	6	3.2
1977	187	10	5.4	10	5.4
1978	181	7	3.9	13	7.2
1979	179	9	5.0	12	6.7
1980	172	7	4.1	12	7.0
			4.3%		5.9%
1981	174	9	5.2	6	3.5
1982	180	9	5.0	10	5.6
1983	182	8[a]	4.4	9	5.0
1984	180	6	3.3	6	3.3
1985	181	10	5.5	6	3.3
			4.7%		4.1%
1986	175	11	6.3	12	6.9
1987	179	3	1.7	7	3.9
1988	176	9	5.1	5	2.8
1989	197	11[b]	5.6	7	3.6
1990	198	10[a]	5.1	7	3.5
			4.8%		4.1%
Average 1970–1990:			4.4%		5.1%

[a]One calf conceived in wild.
[b]Two calves conceived in wild.

As a reproductive goal, we consider that the production of a calf every 2 years from the time she is 6 years old, to be optimal reproduction. Since most captive females have not reached the end of their reproductive lives, an evaluation of reproductive production can be made by comparing age of reproducing females and the number of calves produced against the hypothetical optimal production. Most captive females fall short of the optimum, but several females in different institutions located on different continents have come close. This does raise the question: Is our hypothetical optimal production possible? The female, Studbook #213, has kept up with the hypothetical optimal production, with eight calves produced [Klös and Frese, 1990]. Her 9th calf was born July, 1991, after a birth interval of 19 months [M. Sulak, pers. comm.].

With this information in mind, managers should determine if their management of the animals is consistent with their reproductive goals. If the goal is to achieve rapid increase in the captive population to reach the carrying capacity set for the population, then animals should be manipulated to achieve maximum reproduction.

TABLE 3. Births/adult female black rhinoceros in the captive population, 1970–1990

Year	Calves born	Adult females (6–28 years)	Calves/year/ adult female
1970	2.9	52	21.2%
1971	2.3	53	9.4
1972	3.5	50	16.0
1973	1.3	53	7.5
1974	1.3	58	6.9
1975	3.4	62	11.3
	10.18	276	10.1%
1976	4.2	69	8.8
1977	7.3	75	13.3
1978	5.2	80	8.8
1979	5.4	77	11.7
1980	4.3	78	10.0
	25.14	379	10.3%
1981	4.5	79	11.4
1982	3.6	77	11.7
1983	5.3[a]	77	10.4
1984	4.2	68	8.8
1985	5.5	70	14.1
	21.21	371	11.3%
1986	6.5	69	15.9
1987	2.1	67	4.5
1988	4.5	72	12.5
1989	4.7[b]	75	14.7
1990	5.5[a]	74	13.5
	21.23	357	12.3%
Overall average:			11.4%

[a]One calf conceived in the wild.
[b]Two calves conceived in the wild.

Once this has been accomplished, the management strategy can be adjusted to maintain the desired rate of reproduction.

Introductions of reproductively mature rhinos has produced anxiety for the managers of those animals. Although wild, male rhinos are not aggressive during precopulatory behavior [Goddard, 1966], wild females have been known to be [Ritchie, 1963; Goddard, 1967]. Captive animals of both sexes have shown aggressive behaviors during introductions. It seems probable that the failure to introduce animals or the termination of introductions to reduce the possibility of injuries has impeded reproduction. Jones [1979] suggests that introductions be made while the animals are separated by bars or a fence. He also suggests giving the animals as much room as possible to allow for chasing and mock fighting. Facility design and the management of animals have not always met the biological needs of the rhinos. As with any other captive wildlife, there is no substitute for the manager's knowledge of the individual animals involved, thoughtful decisions, and deliberate action.

Two suggestions follow for achieving a desirable rate of reproduction.

1. Move female calves approaching 3 years of age into situations where they can be bred, preferably with a proven breeding male. This would insure that young females are bred as early as possible, thus entering into the reproducing population earlier. Species such as rhinos, with a prolonged prereproductive period, suffer a dramatic reduction of reproductive potential if the age at first parturition is increased [Cole, 1954]. Conversely, "Growth of the population as a whole accentuates the reproductive value of the first batch of young over later batches" [Horn, 1978].

2. Make a concerted effort to keep birth intervals as close to 2 years as possible. This will involve re-introducing the breeding pairs earlier than is commonly done. Three strategies for early reintroduction are outlined below.

1. At the St. Louis Zoological Park, calves are weaned at about 6 months of age. This is done gradually to reduce stress. A calf born 6 November 1986 was separated from its dam and kept in a stall for 1 hour per day starting the first week of May 1987. During the second week of May, the time of separation was extended to 2 hours for 3 days and then extended to the entire morning. During the third week of May, the calf was separated from its dam from morning until 4:00 p.m. This was continued until the staff was satisfied that the calf was eating well on its own. Complete separation took place on 19 June. The calf was then familiarized with a shipping crate and was sent to another zoo on 14 July. The female was introduced to a male, who shared two pens with her 24 hours a day. The female was bred back on 22 July, 258 days after giving birth.

2. At the San Antonio Zoological Gardens and Aquarium, calves became accustomed to being separated from the dam for about 1 hour, while the pen was being cleaned. This was started at 3–4 months of age. Calves may temporarily exhibit weaning distress, but no calf has injured itself. When the male begins to show interest in the cow, the calf can be separated while the male and female are introduced. This routine can be continued for as long as the male exhibits interest in the female (standing by the gate of the female's enclosure, vocalizing, penile erection, etc.). Calves have been totally separated from the dam at about 1 year of age. Mating has occurred on this schedule as early as 107 and 116 days postpartum.

3. At the San Francisco Zoological Gardens, a very trustworthy male was separated from the female immediately prior to parturition and reintroduced to the female and calf 3–6 weeks postpartum. These rhinos are kept in separate stalls at night, but share a yard during the day. The eight birth intervals for this female average 24 months.

During the last decade, there has been a rise in the birth rates, whereas the mortality rate has decreased (Table 2). It remains to be seen what the reasons for these trends are, or if they will continue. These positive trends have occurred since the initiation of organized captive management plans for black rhinoceros by the American Association of Zoological Parks and Aquariums Species Survival Plan (SSP), the Europäisches Erhaltungszucht Programm (EEP), the Species Survival Committee of Japan (SSCJ), the Joint Management of Species Group (JMSG), and Australasian Captive Management Programme (ACMP). It is our contention that more effort in management will result in increased productivity, and it seems as though this process has begun.

It is an oversimplification to speak of maximizing reproduction in captivity, given the finite space available, as well as the need to equalize founder representation

[Foose, 1980]. In reality, we realize that population increase should proceed in parallel with demographic and genetic considerations. However, the ability to maximize reproduction is a management option that could be called on when needed, as when building a new population or producing surplus for release. Should we be placed in the enviable position of succeeding too well, the population can easily be stabilized, as our recent history over the last two decades has shown.

CONCLUSIONS

Simple management decisions have long-term effects on captive populations. More intensive management has been proven to increase production, especially in mammals with lengthy gestation and birth intervals [Read, 1986]. By comparing the data from captivity with the data from the field, we can partially evaluate current captive management. If the goal of expanding the captive population of black rhinos is going to be reached as rapidly as possible, current management strategies need to be improved. Managers need to manipulate the population to achieve the maximum reproduction of females.

ACKNOWLEDGMENTS

This work has been improved by the comments of reviewers and colleagues. The international studbook keepers not only regularly published pedigree and demographic data, but were among the first to emphasize management in their studbook.

REFERENCES

Brooks, M. Black rhino conservation plan adopted. THE RHINO CONSERVATION NEWSLETTER 1(2):3, 1990.

Cole, L.C. The population consequences of life history phenomena. THE QUARTERLY REVIEW OF BIOLOGY 29:103–137, 1954.

Conway, W.G. Where do we go from here? INTERNATIONAL ZOO YEARBOOK 20:184–189, 1980a.

Conway, W.G. An overview of captive propagation. Pp. 199–208 in CONSERVATION BIOLOGY, AN EVOLUTIONARY-ECOLOGICAL PERSPECTIVE. Soulé, M.E. and B.A. Wilcox, eds. Sunderland, Sinauer, 1980b.

Cumming, D. Small population management of black rhinos. PACHYDERM 9:12–15, 1987.

Dierenfeld, E.S.; du Toit, R.; Miller, R.E.; Dolensek, E.P. Vitamin E in captive and wild black rhinoceroses. JOURNAL OF WILDLIFE DISEASES 24:547–550, 1988.

du Toit, R.F.; Foose, T.J.; Cumming, D.H.M. Recommendations: Proceedings of African Rhino Workshop. PACHYDERM 9:1–3, 1987.

Foose, T.J. Demographic management of endangered species in captivity. INTERNATIONAL ZOO YEARBOOK 20:154–166, 1980.

Foose, T.J. Long-term management of small rhino populations. PACHYDERM 9:13–15, 1987.

Goddard, J. Mating and courtship of the black rhinoceros, *Diceros bicornis* L. EAST AFRICAN WILDLIFE JOURNAL 4:69–75, 1966.

Goddard, J. Home range, behaviour, and recruitment rates of two black rhinoceros populations. EAST AFRICAN WILDLIFE JOURNAL 5: 133–150, 1967.

Hall-Martin, A.J. Recruitment in a small black rhino population. PACHYDERM 7:6–8, 1986.

Hitchens, P.M.; Anderson, J.L. Reproduction, population characteristics and management of the black rhinoceros, *Diceros bicornis minor*, in the Hluhuwe/Corridor/Umfolozi Game Reserve Complex. SOUTH AFRICAN JOURNAL OF WILDLIFE RESEARCH 13:78–85, 1983.

Horn, H.S. Optimal tactics of reproduction and life-history. Pp. 411–429 in BEHAVIOURAL ECOLOGY, AN EVOLUTIONARY APPROACH. Krebs, J.R. and Davies, N.B., eds. Sunderland, Sinauer, 1978.

Jones, D.M. The husbandry and veterinary care of captive rhinoceros. INTERNATIONAL ZOO YEARBOOK 19:239–352, 1979.

Joubert, E.; Eloff, F.C. Notes on the ecology and behaviour of the black rhinoceros, *Diceros bicornis*, Linn.1758 in South West Africa. MADOQUA 1:5–53, 1971.

Klös, H.G.; Frese, R. INTERNATIONAL STUDBOOK OF THE BLACK RHINOCEROS. Berlin, Zoologischer Garten Berlin, 1981.

Klös, H.G.; Frese, R. INTERNATIONAL STUDBOOK OF AFRICAN RHINOCEROS. Berlin, Zoologischer Garten Berlin, 1983.

Klös, H.G.; Frese, R. INTERNATIONAL STUDBOOK OF AFRICAN RHINOCEROS. Berlin, Zoologischer Garten Berlin, 1987.

Klös, H.G.; Frese, R. INTERNATIONAL STUDBOOK FOR AFRICAN RHINOCEROSES. Berlin, Zoologischer Garten Berlin, 1991.

Lacy, R. Further genetic and demographic analyses of small rhino populations. PACHYDERM 9:16–19, 1987.

Maruska, E. SSP MASTERPLAN FOR BLACK RHINOCEROS. Cincinnati, AAZPA Species Survival Plan for Black Rhinoceros, 1987.

Maruska, E.J.; Dresser, B.L.; Barden, B.D. BLACK RHINOCEROS INTERNATIONAL MANAGEMENT SURVEY. Cincinnati, AAZPA Species Survival Plan for Black Rhinoceros, 1986.

Miller, R.E.; Boever, W.J. Fatal hemolytic anemia in the black rhinoceros: Case report and survey. JOURNAL OF THE AMERICAN VETERINARY MEDICAL ASSOCIATION 181:1228–1231, 1982.

Miller, R.E.; Cambre, R.C.; deLahunta, A.; Brannian, R.; Spraker, T.; Johnson, C. Encephalomalacia in three black rhinoceros, *Diceros bicornis*. JOURNAL OF ZOO WILDLIFE MEDICINE 21:192–199, 1990.

Ott, J.E.; McDonald, S.E.; Robinson, P.T.; Wright, F.H. Ulcerative stomatitis in a black rhinoceros, *Diceros bicornis*. Pp. 68–71 in PROCEEDINGS OF THE AMERICAN ASSOCI TION OF ZOO VETERINARIANS, 1982.

Owen-Smith, R.M. MEGAHERBIVORES: TH INFLUENCE OF VERY LARGE BODY SI ON ECOLOGY. Cambridge, Cambridge Univ sity Press, 1988.

Read, B. Breeding and management of the M layan tapir, *Tapirus indicus*, at St. Louis Zo INTERNATIONAL ZOO YEARBOOK 24/ 294–297, 1986.

Ritchie, A.T.A. The black rhinoceros. EAST A RICAN WILDLIFE JOURNAL 1:54–62, 196

Schenkel, R.; Schenkel-Hulliger, L. ECOLOG AND BEHAVIOUR OF THE BLACK RH NOCEROS (DICEROS BICORNIS L.) FIELD STUDY. Hamburg, Verlag Paul Par 1969.

Seal, U.S. Goals of captive propagation progra for the conservation of endangered species. I TERNATIONAL ZOO YEARBOOK 24/ 174–179, 1986.

Senner, J.W. Inbreeding depression and the s vival of zoo populations. Pp. 209–224 in CO SERVATION BIOLOGY, AN EVOLUTIO ARY-ECOLOGICAL PERSPECTIVE. Sou M.E. and B.A. Wilcox, eds. Sunderland, S auer, 1980.

Soulé, M.E. Thresholds for survival: Maintaini fitness and evolutionary potential. Pp. 151–1 in CONSERVATION BIOLOGY, AN EVOL TIONARY-ECOLOGICAL PERSPECTIV Soulé, M.E. and B.A. Wilcox, eds. Sunderla Sinauer, 1980.