Table 3. Status of black rhinos in Africa.

	1980	1984	1987	% of total 1987 rhino population
Tanzania	3 795	3130	270	7%
C.A.R.	3 000	170	10?	0.2%
Zambia	2 750	1650	110	3%
Kenya	1 500	550	520	14%
Zimbabwe	1 400	1 680	1 760	46%
South Africa	630	640	580	15%
Namibia	300	400	470	12%
Sudan	300	100	3	—
Somalia	300	90	?	—
Angola	300	90	?	—
Mocambique	250	130	?	—
Cameroon	110	110	25?	0.7%
Malawi	40	20	25	0.7%
Rwanda	30	15	15	0.4%
Botswana	30	10	10	0.2%
Ethiopia	20	10	?	—
Chad	25	5	5?	—
Uganda	5	—	—	—
TOTAL	**14 785**	**8 800**	**3 800**	

tion strategy, and has been producing annually-revised action plans for the conservation of rhinos and elephants.

In discussing the draft strategy, an emphasis that emerged from the workshop was the need for interactive management of wild and captive populations in order to maintain genetic variability. However, it was agreed that *ex situ* breeding programmes should avoid mixing rhinos from different regions of Africa in order not to destroy probable adaptations to particular environmental factors in these ecologically divergent regions. The numbers of remaining rhinos in the four regional groups that were identified for separate genetic management are shown in Table 4.

Table 4. Estimated numbers of black rhinos in regional units.

Regional conservation unit	**Number**
Southwestern	500
Southern/Central	2 600
Eastern	600
Northern/Western	50

STATUS OF BLACK RHINOS IN CAPTIVITY

Tables 5 and 6 summarize the current status of black and other rhinos in captivity at the time of the workshop. Figures differ slightly from those used by Lynn Maguire and Robert Lacy in their analyses in these proceedings—owing to different sources of information—but not to a significant extent. There appears to be captive habitat in zoos for about 700-800 rhinos, using current collections as a crude estimate. Black rhinos are currently allocated about 20% of these spaces, while white rhinos occupy a disproportionate 60% (owing largely to their ready availability from South Africa). The black rhino population in North America, now under management of the AAZPA Species Survival Plan (SSP), has been increasing slowly over the last five years at a rate of about 2% per annum (Table 7). Birth rates have been quite encouraging (in contrast to the white rhinos, which have not reproduced well as a probable consequence of this species' inclination to breed better in group situations than when kept as pairs). Death rates in black rhinos have been high, largely because of the haemolytic anaemia syndrome discussed later in these proceedings. intensive research to resolve this problem is in progress and some hopeful insights have already been obtained, especially in terms of possible vitamin E deficiencies.

Table 5. Current populations of rhino in captivity. Sources are AAZPA Species Survival Plans (SSP), the international Species Inventory System (ISIS), International Zoo Yearbook (IZY), and the International Studbooks for African Rhinos (Zoo Berlin) and Indian Rhinos (Basel Zoo).

Species	**North America**	**World** IZY	**World** Studbook
Black	30/38 =68	68/80 = 148	82/98 =180
White			
Southern	70/93 = 163	177/215 = 392	313/357 = 670
Northern	1/0 = 1	6/5 = 1	6/5 = 1
Indian	16/12 = 28	44/35 = 79	44/35 = 79
Sumatran	0	3/6 = 9	3/6 = 9
Javan	0	0	0
TOTAL	117/143 = 260	298/341 = 639	448/501 = 949

Table 6. Estimated captive capacity or habitat (space and resources) for rhinos in the world's zoos.

Species	**North America**	**World**
Black	125	200-250
White	100 (+25?)	200-250
Indian	75	150
Sumatran	75	150
Javan	?	?
TOTAL	375-400	700-800

Table 7. Performance of North American zoos with black rhinos, 1982-1986.

Year	**Births**	**Deaths**	**Dispersed**	**Imported**
1982	1/3	2/2		1/1
1983	2/2	0/1		2/0*
1984				
1985	2/5	3/2	0/1	
1986	4/3	3/3		
TOTAL	9/13	8/8	0/1	3/1

*Captive born in Japan

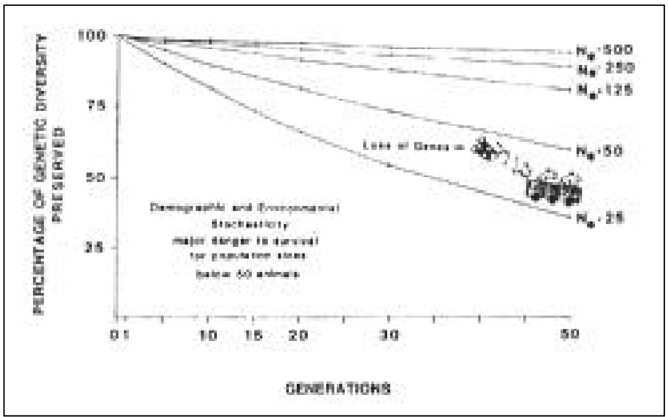
LONG-TERM MANAGEMENT OF SMALL RHINO POPULATIONS

Thomas Foose (American Association of Zoological Parks and Aquariums).

Overview of concerns

As discussed by Lynn Maguire in the preceding session, and elaborated by Robert Lacy in the following presentation, the trend towards very small and fragmented populations in the wild (i.e. towards the situation of rhinos to captivity) makes these populations vulnerable to extinction for genetic and demographic reasons. Small populations lose genetic diversity rapidly at the population level (Fig. 3) as well as at the individual level. At the population level, genetic diversity Is

Figure 3. The decline of genetic diversity (measured as average heterozygosity in the total population) over 50 generations for various effective population sizes (Ne), possible for a total population (N) of 250.



vital to permit adaptation to continually changing environments. At the individual level, genetic diversity is required to maintain the “vigour” of the animals; loss of diversity in individuals is known as inbreeding and a consequent decline in survival and fecundity rates is inbreeding depression.

Conservation biologists have suggested that genetically effective population sizes (Ne’s) of 50 or more are necessary for the shorter term (5-10 generations) mainly to counteract inbreeding depression, while Ne’s of 100-500 or even more may be necessary over the longer term to maintain adaptability. The vulnerability of small populations to demographic risks (disease epidemics, natural disasters, uneven sex ratios, etc.) imposes a further minimum limit to desirable population size: conservation biology—models suggest that populations must be no smaller than 25-50 total individuals to survive unpredictable (stochastic) demographic risks.

To preserve a species against these genetic and demographic risks, it is therefore necessary to establish some *minimum viable population size* (MVP). The actual MVP that is recommended will depend on the defined objectives for the species at risk as well as the biological characteristics of that species (Soule *et al.,* 1986). The major relevant concerns are as follows.

1.) The probability of survival of the population. No finite population size will completely insure a species against stochastic extinction, but It is sometimes possible to specify population sizes that will insure some probability of survival (e.g. 50%; 90%). For some given period of time, the higher the stipulated probability of survival, the larger the MVP required. 2.) The level of genetic diversity to be preserved. Obviously, the top objective would be to retain all the genetic diversity. However, with the restricted populations possible (In the wild or captivity), something less than all may have to be accepted for some period of time. Preserving rarer alleles (i.e. specific varieties of genes) will require larger MVP’s than merely maintaining average heterozygosity (some variation of any, non-specific kinds). Preserving 95% of average heterozygosity will require an MVP twice as large as’90% will. Population geneticists are not certain how much genetic diversity is enough but levels of at least 90% of average heterozygosity have been strongly suggested.

3.) How long this level of genetic diversity must be preserved. The optimal answer is indefinitely, i.e. the species could then continue to evolve as environments change. But again, there may have to be compromises. Hopefully, intensive programmes will be needed only through the present ““demographic winter”’ (the period extending for the next 200 to 500 years, during which human population growth and development will continue and intensify disruption of natural systems). However, the winter may vary on a species-by-species and area-by-area basis.

Biological characteristics that influence MVP sizes include the following:

1.) The generation time of the species. Genetic diversity is lost generation by generation, not year by year. Thus some given period of time, e.g. 200 years, represents more generations, hence more opportunity to lose diversity, for a species like a galago than it does for a species like a rhino.

2.) The Ne/N ratio of the population. Loss of diversity does not depend simply on total population size, but rather on the genetically effective size (which reflects how the animals are actually reproducing to transmit genes to the next generation). Very generally, the genetically effective size of a population depends on:

— the number of animals actually reproducing;
— the sex ratio of the reproducing animals;
— the relative lifetime number of offspring (i.e. family size of animals in the population).

Since Ne is normally less (often much less) than the census number (N), MVP’s must be larger than the population sizes prescribed by genetic calculations since these prescriptions are always in terms of Ne.

3.) The number of founders that establish a population. Founders are animals out of a wild population that are used to establish a captive or a new wild population (or augment a recovering wild population). Conversely, they could be animals from captivity that are used to re-establish a species in the wild. in general, the larger the number of founders, the smaller the MVP needed for some genetic objectives. However, there is a point of diminishing returns so that usually 20-30 founders may be adequate.

4.) The reproductive rate or recovery potential of the population. Much genetic diversity can be lost either as the population grows from its foundation size to carrying capacity or during recovery from periodic reductions. in general, the higher the reproductive rate and hence growth or recovery to carrying capacity, the less genetic diversity is lost.

5.) The degree of subdivision or fragmentation in the population. If a species is fragmented into a number of subdivisions which are Isolated from one another, animals may not be able to move around for breeding and hence exchange of genetic material. Such situations can cause loss of genetic diversity. On the other hand some subdivision may assist retention of some kinds of genetic diversity. The important point is that conservationists must analyze the genetic processes in the species under consideration and develop an appropriate management plan that may include artificial movement or manipulation of animals, to synthesize many separate smaller populations into a so-called metapopulation capable of greater long-term viability.

Clearly, there is no single MVP figure that will apply to all species or to all situations for any given species. Rather, MVP’s will vary depending on the objectives of the program and the circumstances of the species. Detailed explanation and expansion of the MVP concept are provided by Gilpin and Soule (1986), Shaffer (1987) and Soule (1987). The process of determining the size of a population that is required to achieve some level of genetic and demographic security has come to be known as *population viability analysis (PVA).*

PVA attempts for black rhinos

Table 8 represents some initial attempts at prescribing MVP's for both wild and captive black rhinos. These analyses were performed using microcomputer software developed by Jon Ballou of the National Zoological Park in Washington, DC, and are extremely tentative. To refine the PVA models and their data inputs, there needs to be more collaboration between conservation biologists and field managers of black rhinos. However, since there is an urgent need for management guidelines, a number of preliminary recommendations based on these rough analyses have been generated for consideration.

An Ne = 500 is proposed for each regional conservation unit of black rhinos. This represents a number sufficiently high to ensure maintenance of genetic diversity (e.g. 90% average heterozygosity for 50 rhino generations) and demographic security.

An Ne/N ratio of 0.25 to 0.5 is proposed as a further operational guideline in formulating conservation strategies for black rhinos. With management, especially in captivity, it may be possible to improve this ratio. Simple arithmetic indicates that to achieve an Ne = 500 with a worst case situation of Ne/N = 0.25, an MVP of 2 000 would be required for each conservation unit of rhinos.

Since black rhino populations will be fragmented and resources for conservation limited, it also seems advisable to suggest a size for individual populations of black rhinos within each conservation unit. The number roughly indicated by analyses so far is 100-200. This guideline does not dictate that populations smaller than this size are worthless but that they should probably receive lower priority for conservation efforts than larger ones. Realistic cost-benefit analyses need to be performed on each of the rhino populations of limited viability to determine if intensive and interactive management in feasible in both logistic and economic terms, it should be emphasized that the figure suggested here applies not to actual current population, but to potential size of the population in the given area if rhinos can be adequately protected to reach carrying capacity.

Finally, it should be realized that individual populations of 100-200 are not likely to be genetically and demographically viable by themselves over periods of time in the order of centuries. There will need to be interchange between separate populations to create the so-called "metapopulations" for each conservation unit. Where natural migration is not possible between separate populations, management will have to artificially move animals for genetic and demographic reasons as suggested by appropriate PVA analyses.

Because of the limited space and resources available in ex *situ* facilities, MVP's may have to be, and probably can be, even more precisely defined for captive than for wild populations. An objective for captive propagation of preserving 90% of average heterozygosity for 200 years is a common recommendation of conservation biologists considering principles of population genetics (i.e. inbreeding) and demography as well as the likely period of time that human pressures will be most intense on wildlife. To achieve objectives of preserving a significant fraction (90%) of the wild gene pool for 200 or so years, a number of combinations of ultimate carrying capacity, initial founder numbers, and population growth rates will produce the desired results (as demonstrated in Table 8).

As a result of these preliminary analyses, the zoo community is proposing to develop captive populations of 150 each for at least two of the conservation units of black rhinos; the North American AAZPA SSP will attempt captive populations of 75 for each of these two units. The constraints imposed by the biological characteristics of the species will prescribe a critical minimum for the number of founders (i.e. animals out of the wild) that will be needed to establish the captive population. For black rhinos, 20-25 effective founders for each conservation unit maintained seems desirable.

Table 8. Minimum viable populations required to preserve 90% average heterozygosity for various periods, in several demographic situations.

A. GENERATION TIME = 15 YEARS.
POPULATION GROWTH RATE = 1.03/YEAR
Ne/N Ratio = 0.5

		YEARS						
		75	150	225	300	450	600	750
EFFECTIVE	10	–	–	–	–	–	–	–
NUMBER	20	62	131	236	367	603	8911	134
OF	25	50	121	189	273	459	641	832
FOUNDERS	30	50	103	170	241	393	551	712
	50	50	100	156	203	319	439	561
	75	50	100	150	193	297	404	513
	100	50	100	150	193	289	392	495

B. GENERATION TIME = 15 YEARS. POPULATION GROWTH RATE = 1.06/YEAR
Ne/N Ratio = 0.5

		YEARS						
		75	150	225	300	450	600	750
EFFECTIVE	10	115	292	534	786	1310	1842	2384
NUMBER	20	50	115	187	261	414	568	727
OF	25	50	106	170	235	369	505	642
FOUNDERS	30	50	102	160	221	345	471	598
	50	50	100	147	200	308	417	527
	75	50	100	150	193	293	397	501
	100	50	100	150	193	289	389	489

C. GENERATION TIME = 15 YEARS.
POPULATION GROWTH RATE = 1.06/YEAR
Ne/N Ratio = 0.25

		YEARS						
		75	150	225	300	450	600	750
	10	230	583	1069	1573	2621	3685	4769
EFFECTIVE	20	101	231	374	522	829	1136	1451
NUMBER	25	100	212	339	470	737	1010	1284
OF	30	100	204	320	442	689	942	1195
FOUNDERS	50	100	200	295	400	615	835	1054
	75	100	200	295	386	589	794	1001
	100	100	200	295	386	579	778	997

FURTHER GENETIC AND DEMOGRAPHIC ANALYSES OF SMALL RHINO POPULATIONS

Summary of presentation by Robert Lacy
(Chicago Zoological Society)

This work is quite preliminary, providing initial insights and possible directions for future analysis, not definite conclusions or recommendations about rhino populations. The