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METAPOPULATION WORKSHOP

BRIEFING BOOK

SECTION 3
SMALL POPULATION BIOLOGY OVERVIEW

INTRODUCTION

An endangered species is (by definition) at risk of extinction. The dominant objective in the recovery of such a species is to reduce its risk of extinction to some acceptable level - as close as possible to the background, "normal" extinction risk all species face.

The concept of risk is used to define the targets for recovery, and is used to define recovery itself. Risk, not surprisingly, is a central issue in endangered species management. Unfortunately, there is ample reason to suppose that we (as humans) are not "naturally" good at risk assessment. Recovery will be more often successful if we could do this better. There is a strong need for tools that would help managers deal with risk. We need to improve estimation of risk, to rank order better the risk due to different potential management options, to improve objectivity in assessing risk, and to add quality control to the process (through internal consistency checks). Among the risks to be evaluated are those of extinction, and loss of genetic diversity.

In the last several years such tools have been developing. The applied science of Conservation Biology has grown into some of the space between Wildlife Management and Population Biology. A set of approaches, loosely known as "Population Viability Analysis" has appeared.

These techniques are already powerful enough to improve recognition of risk, rank relative risks, and evaluate options. They have the further benefit of changing part of the decision making process from unchallengeable internal intuition to explicit (and hence challengeable) quantitative rationales.

In the following sections, Jon Ballou, Tom Foose, and Bob Lacy each describe aspects of Population Viability Analysis (PVA). The text, adapted from that used in other PVAs (Ballou et al. 1989, Lacy et al. 1989), provides an overview of some of the population biology concepts that form the foundation of Population Viability Assessment. Each contributor approaches the subject from their own expertise and experience, so the contributions differ somewhat in perspective and content. There is some overlap, which may help the newcomer by occasionally repeating a point in different language.

SMALL POPULATION OVERVIEW (J. Ballou)

The primary objective of single-species conservation programs is to reduce the risk of population extinction. A first step in doing this is to identify those factors that can potentially cause extinction in the population. The most fundamental threat is, of course, declining population size. If a population is declining in numbers, and no action is taken to reverse the trend, then extinction is imminent. However, if the population is not declining, its fate is less certain and predicting its future more complicated.

The foremost problem facing the conservation of small populations is that these populations are still highly vulnerable to extinction even through they may be maintaining their size or even increasing in number. Small populations are challenged by a number of factors that increase the likelihood of the population going extinct simply because the population is small.

CHALLENGES TO SMALL POPULATIONS

Challenges to small populations can be roughly categorized as demographic and/or genetic in nature. Beginning with demographic challenges, at the most basic level, the level of the individual, the population is threatened by Demographic Variation. Demographic variation is the normal variation in the population's birth and death rates and sex ratio caused by random differences among individuals in the population. The population can experience fluctuations in size simply by these random differences in individual reproduction or survival. These randomly caused fluctuations can be severe enough to cause the population to go

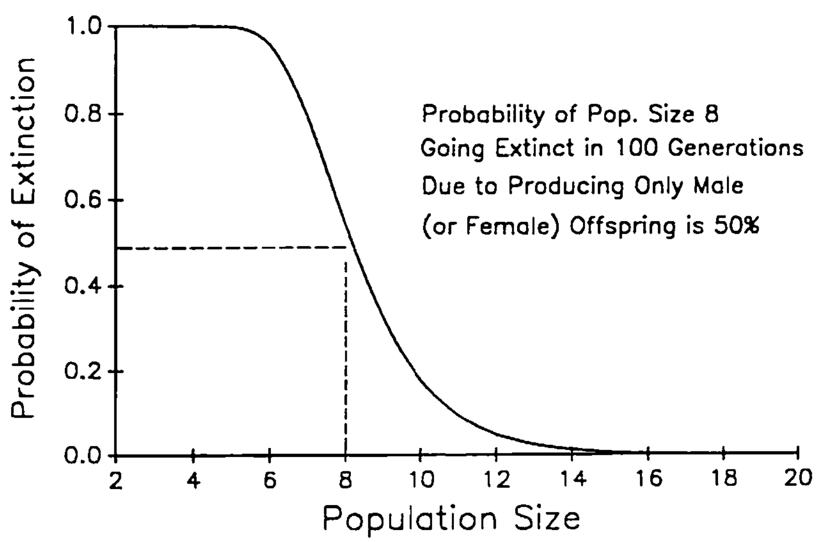

Figure 1. Example of demographic variation: Probability of extinction by 100 generations due solely to producing only one sex of offspring during a generation.

extinct. For example, one concern in extremely small populations is the possibility that all individuals born into the population
during one generation are of one sex, resulting in the population going extinct. Figure 1 illustrates the probability of this occurring over a 100 generation period in populations of different size. There is a 50% chance of extinction due to biased sex ratio in a population of size 8 sometime during this time period.

Similar consequences could result from the coincidental effects of high death rates or low birth rates. However, these risks are practically negligible in populations of much larger size. In general, the effect of any one individual on the overall population's trend is significantly less in large populations than small populations. As a result, demographic variation is a relatively minor challenge in all but very small populations (less than 20 animals).

A more significant threat to small populations is Environmental Variation. Variation in environmental conditions clearly impact the ability of a population to reproduce and survive. Populations susceptible to environmental variation fluctuate in size more than less susceptible populations, increasing the danger of extinction. For example, reproductive success of the endangered Florida snail kite (Rostrhamus sociabilis) is directly affected by water levels, which determine prey (snail) densities: nesting success rates decrease by 80% during years of low water levels. Snail kite populations, as a result, are extremely unstable (Bessinger 1986).

Another level of threat to small populations are Disease Epidemics and Catastrophes. Epidemics and catastrophes are similar to other forms of environmental variation in that they are external to the population. However, they are listed separately because we are just beginning to appreciate their role as recurrent but difficult to predict environmental pressures exerted on a population. They can be thought of as relatively rare events that can have devastating consequences on the survival of a large proportion of the population. Less devastating diseases and parasites are a natural accompaniment of all species and populations that may act to decrease reproductive rates and increase mortality.

Epidemics can have a direct or indirect effect. For example, in 1985 the sylvatic plague had a severe indirect effect on the last, remaining black-footed ferret population by affecting the ferrets prey base, the prairie dog. Later that same year, the direct effect of distemper killed most of the wild population and all of the 6 ferrets that had been brought into captivity (Thorne and Belitsky 1989).

Catastrophes are one-time disasters capable of totally decimating a population. Catastrophic events include natural events (floods, fires, hurricanes) or human induced events (deforestation or other habitat destruction). Both large and small populations are susceptible to catastrophic events. Tropical deforestation is the single most devastating 'catastrophe' affecting present rates of species extinction. Estimates of tropical species' extinction rates vary between 20 and 50% by the turn of the century (Lugo 1988).

Small populations also are susceptible to genetic challenges. The primary genetic consideration is the loss of genetic variation. Every generation the genes that get passed on to offspring are a random sample of the genes of the parents. In small populations, this random sample of genes is a small sample and may be unrepresentative of the genes of the parental generation. Some of the genetic variation present in the parents, may not, just by chance, get passed on to the offspring. This genetic variation is then lost to the population. This process is called genetic drift because the genetic characteristics of the population can drift or vary over time. In small populations, genetic drift can cause rapid loss of genetic variation - the smaller the population, the more rapid the loss of variation.

Inbreeding (matings between relatives) can also cause populations to lose genetic diversity. In small populations, all the animals quickly become related; they share common alleles. Offspring produced from related parents are inbred and because the parents are related, the offspring can get the same alleles from its mother and father. Inbred individuals are therefore more homozygous than non-inbred individuals and have lower levels of genetic diversity than animals born to unrelated parents.

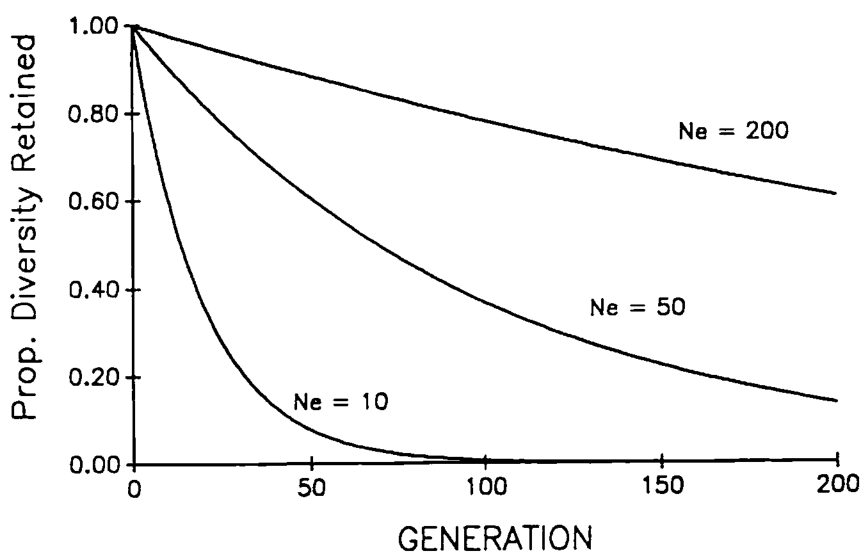

Figure 2. Loss of genetic diversity over 200 generation in populations with different effective sizes (Ne).

The loss of genetic variation in populations of different size is shown in Figure 2. The rate of loss is a function of the effective size of the population (Ne; the percent of diversity lost each generation is 1/2Ne). Technically, a population's effective size is the size of an ideal population that loses genetic diversity at the same rate as the real population. There is extensive literature on how to estimate a population's effective size (Lande and Barrowclough 1987); however, the number of animals contributing to the breeding pool each generation can be used as a very rough estimate of the effective size. The effective size of the population is therefore much less than the actual number of animals; estimates suggest that Ne is often only 10 to 30% of the total population. Seemingly large populations will lose significant levels of genetic diversity if their effective sizes are small.

Conservation programs include the maintenance of genetic diversity as a primary goal for several reasons. If species are to survive over the long-term, they must retain the ability to adapt to changing environments (i.e. evolve). Since the process of natural selection requires the presence of genetic variation, conservation strategies must include the preservation of genetic diversity for long-term survival of species. In addition to long-term evolutionary considerations, the presence of genetic diversity has been shown to be important for maintaining the fitness of the population. A growing number of studies show a general, but not universal, correlation between genetic diversity and various traits related to reproduction, survival and disease resistance (Allendorf and Leary 1986). Individuals with lower levels of genetic variation often have higher mortality rates and lower reproductive rates than individuals with more diversity.

Data on the effects of inbreeding in exotic species also show the importance of maintaining genetic diversity. Numerous studies have shown that inbreeding can significantly reduce reproduction and survival in a wide variety of wildlife (Ralls and Ballou 1983; Wildt et al, 1987; Figure 3). Inbreeding depression results from two effects: 1) the increase in homozygosity allows deleterious recessive alleles in the genome to be expressed (whereas they are not in non-inbred, more heterozygous individuals); and 2) in cases where heterozygotes are more fit than homozygostes simply because they have two alleles, the reduced heterozygosity

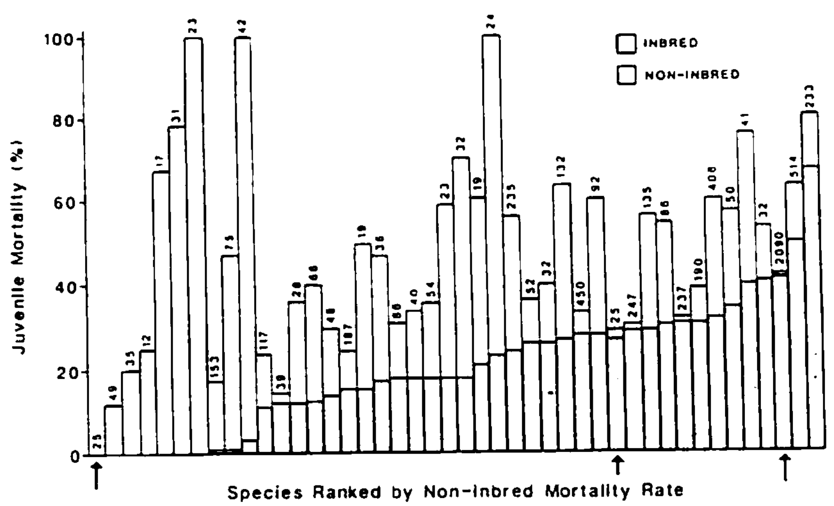

Figure 3. Effects of inbreeding on juvenile mortality in 45 captive mammal populations (From Ralls and Ballou, 1987).

caused by inbreeding reduces the fitness of the inbred individuals (overdominance). In both cases, the loss of genetic variation due to inbreeding has detrimental effects on population survival.

Small isolated populations, with no migration from other populations, lose genetic diversity and become increasingly inbred over time. Their long-term survival potential is jeopardized since they gradually lose the genetic diversity necessary for them to evolve and their short-term survival is jeopardized by the likely deleterious effects of inbreeding on survival and reproduction.

The genetic and demographic challenges discussed above clearly do not act independently in small populations. As a small population becomes more inbred, reduced survival and reproduction are likely: the population decreases. Inbreeding rates increase and because the population is smaller and more inbred, it is more susceptible to demographic variation as well as disease and severe environmental variation. Each challenge exacerbates the others resulting in a negative feedback effect termed the "Extinction Vortex" (Gilpin and Soule, 1986). Over time the population becomes increasing smaller and more susceptible to extinction (Figure 4).

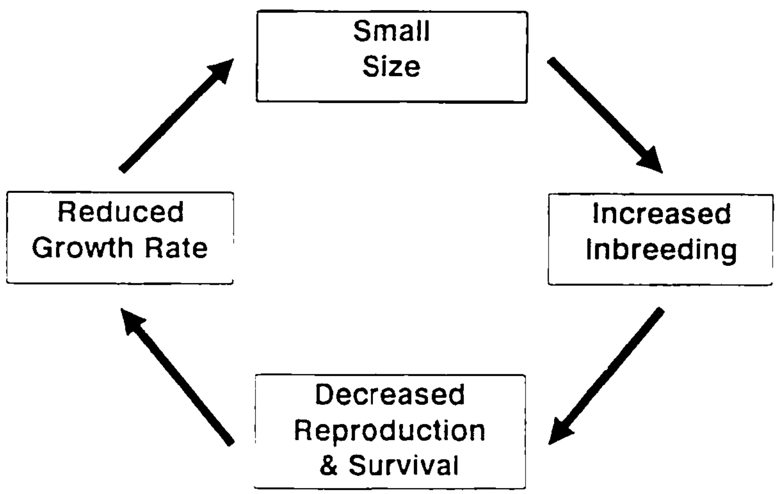

Figure 4. "Extinction Vortex" caused by negative feedback effects of inbreeding in small populations.

POPULATION VIABILITY ANALYSES

Many of the challenges facing small populations are stochastic and are result from random unpredictable events. Many can generally be assumed to decrease the likelihood of long-term survival of the population. However, because of their stochastic nature, their exact effects on population extinction and retention of genetic diversity can not be predicted with total accuracy. For example although inbreeding depression is a general phenomenon, its effects vary widely between species (Figure 3) and it is not possible to precisely predict how any one population will respond to inbreeding.

Nevertheless, conservation strategies that address these unpredictable issues of extinction and loss of genetic diversity must be developed and implemented. The process that has been developed over recent years to assess extinction probabilities and loss of genetic diversity is called Population Viability Analysis (PVA; Soule 1987). PVA is defined as a systematic evaluation of the relative importance of factors that place populations at risk. It is an attempt to identify those factors that are important for the survival of the population. In some cases, this may be easy - habitat destruction is often a critical factor for most endangered species. But at other times, the effects of single factors, and the interaction between factors, are more difficult to predict.

To try to gain a more quantitative understanding of the effect of these factors, computer models have been developed that apply a combination of analytical and simulation techniques to model the populations over time and estimate the likelihood of a population going extinct and the loss of its genetic variation. The model is first provided with information describing the life-history characteristics of the population. Depending on the model used, this includes data on age of first reproduction, litter size distribution, survival rates, mating structure and age distribution as well as estimates of the variation associated with each of these variables. A number of different external factors may also be considered. This may include levels of environmental variation, change in carrying capacity and severity of inbreeding depression. Models also allow consideration of threats facing the population: probability of catastrophes and their severity, habitat loss and disease epidemics (Figure 5). The models use the life-history variables, the external factors and the potential threats to project the population into the future,

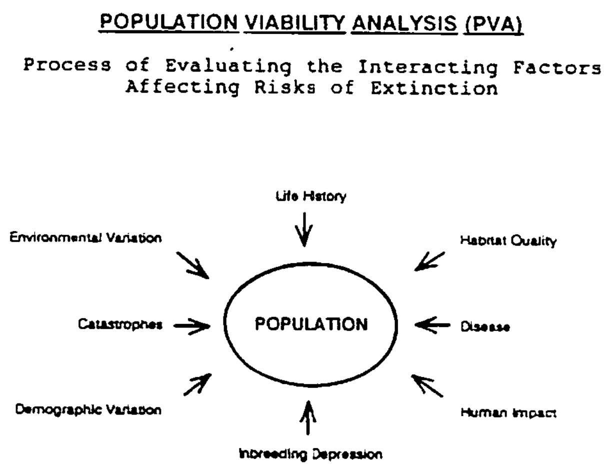

Figure 5. Population Viability Analyses (PVA) model the effects of different life-history, environmental and threat factors on the extinction and retention of genetic diversity in single populations.

measuring the level of genetic variation that is retained over time and recording if and when the population goes extinct (population size goes to zero). The simulations are repeated, often thousands of times, to provide estimates of the statistical variation associated with the results. The probability of extinction at any given time is measured as the number of simulations that the population had gone extinct by that time divided by the total number of simulations run (Figure 6). The levels of genetic variation are recorded as the percent of the original heterozygosity and number of original alleles retained in the population at any particular point.

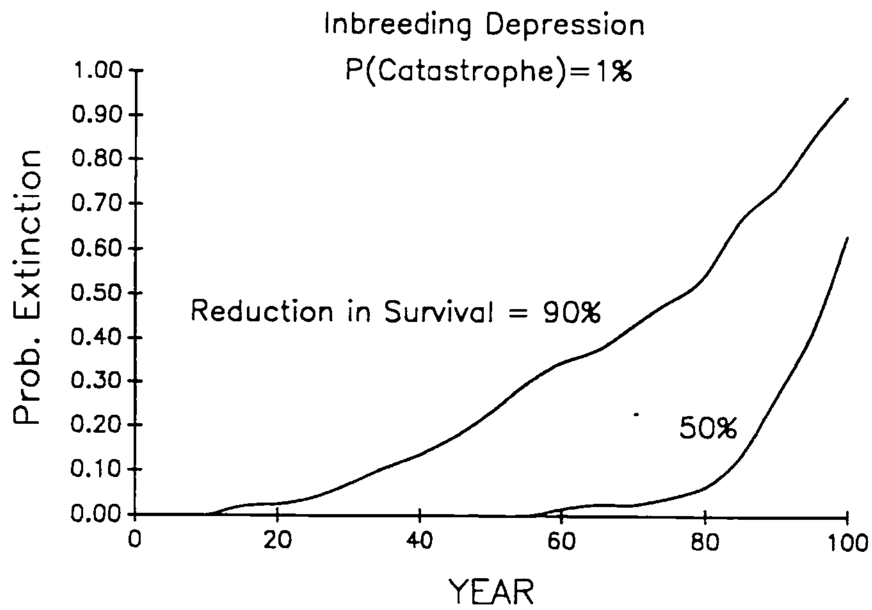

Figure 6. Hypothetical example of population extinction results from the VORTEX PVA model. The model includes negative effects of inbreeding and a catastrophe probability of 1%. The probability of extinction is shown over time for two different levels of catastrophe severity: a 90% reduction in survival vs 50% reduction in survival.

A number of population viability models have been developed. The model used by the Captive Breeding Specialist Group of the IUCN is VORTEX, written by Robert Lacy (Chicago Zoological Society). This model has been used extensively to develop conservation strategies for a number of species including the Black-footed ferret, Florida panther, Puerto Rican Parrot, Javan rhino and the four species of lion tamarins.

The true value of the model is not in trying to examine the effects of all variables simultaneously in the population. The interactions between these many factors is too complex to attempt to interpret the results of population projections based on more than just of few of these considerations. We can gain far more insight into the dynamics of the population by examining only one or two factors at a time - and picking those factors that we believe have an impact on the population and ignoring those that don't.

The primary use of the model in developing conservation strategies is its use in conducting "what if" analyses. For example 'what if' survival were decreased in the wild population as a result of a disease outbreak? How would that effect the extinction of the population and retention of genetic diversity? These 'what if' analyses can also be used to evaluate management recommendations. For example, how would the probability of population extinction change if the carrying capacity of the reserve holding the animals were increased by 10%?

Because the models don't examine all factors potentially contributing to extinction, the model results usually underestimate a population's probability of extinction. However, it is important to stress that the purpose of the PVA is not to estimate exact extinction probabilities but to identify the relative importance of the various factors being considered and to evaluate the effect of a range of management recommendations on the survival of the population.

IMPLICATIONS OF PVA ON MANAGEMENT GOALS

The concepts of population extinction and loss of genetic diversity are based on probabilities rather than certainties. The results from the PVA models provide us with information on the probability of extinction given certain assumptions about the biology and status of the population. As a result, we can not predict or guarantee what will happen to these populations with any absolute certainty.

This has some fairly strong implications when we are trying to develop conservation strategies to reduce the risks of extinction in the populations. We must be able to recognize that we will not be able to formulate and implement recommendations that will guarantee the survival of any population. We can only formulate and implement recommendations that will decrease the likelihood of extinction in populations over a given time period.

A common approach is to develop management strategies that assure a 95% chance of the population surviving for 100 years and maintaining 90% of its genetic variation over the same time period (Shaffer 1987; Soule et al, 1986). This would assure a high probability of survival and retain a large proportion of the population's ability to genetically adapt and evolve to changing environments. This approach defines the Minimum Viable Population (MVP) size to achieve these management objectives. Management strategies can only be fully evaluated if both degree of certainty and time frame for management are specified.

METAPOPULATIONS

The discussion to this point has focused on the extinction and genetic dynamics of a single population. However, often managers are faced with a species distributed over several interacting populations. When this is the case and animal movement (migration) between populations is high enough that the dynamics (extinction or genetic) of any single population is affected by dynamics of other nearby populations, the group of interacting populations is called a Metapopulation (Figure 7). The understanding of metapopulation dynamics has become increasingly important for the development of conservation strategies.

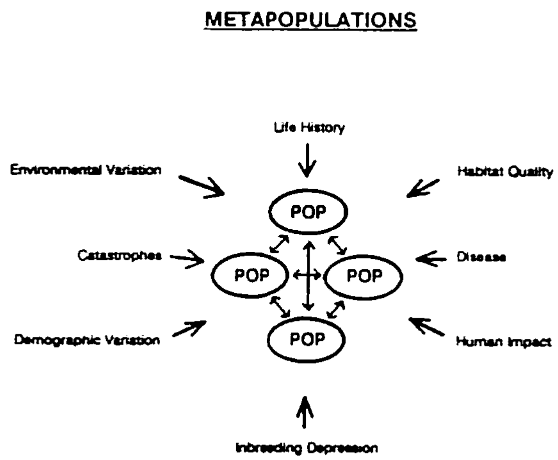

Figure 7. The interaction between population 'patches' results in a Metapopulation structure. Conservation strategies must consider the spatial distribution of the patches and its effect on correlated extinctions and recolonization between patches.

Metapopulation management focuses on the spatial distribution of the populations and how that influences both the genetic and demographic dynamics of the system. The metapopulation system can be thought of as a grouping of populations ('patches') of different sizes and distances from each other, with some patches periodically going extinct and being recolonized by migrants from other patches. The most important conservation considerations are rates of extinction for the individual patches and the re-colonization rates between patches (Gilpin 1987).

As we have discussed above, the extinction dynamics of any single patch is affected by any number of factors including size of population, rate of population recovery following a population decline, etc. From a metapopulation perspective, the simplest level is when patch extinction rates are uncorrelated with each other: the probability of extinction of any one patch is independent of any other patch. Environmental variation and catastrophes increase the extinction correlation between patches and this increases the likelihood of the entire metapopulation going extinct. So considerations of the spatial distribution between patches, and what that means in terms of how similarly they react to environmental variation and catastrophes is an important part of developing management strategies.

On the other side of the coin is the effect of spatial distribution on recolonization rates between patches. The closer patches are to each other, the higher the probability of a patch being recolonized following an extinction by migrants from a neighboring patch. Thus, distances between patches is positively correlated with recolonization and long-term survival of the metapopulation.

Patch extinction and recolonization also effect the retention of genetic diversity in the metapopulation. Small, fragmented and isolated populations rapidly lose genetic diversity. However, with migration between patches, gene flow among patches can be increased and the effective size of the total metapopulation is significantly increased. However, if recolonization following extinction repeatedly involves a very limited number of individuals (one pair or a pregnant female), then individual patches can be genetically invariant as a result of the recurrent founder effects.

The interaction between the positive aspects of recolonization and the negative effects of correlated patch extinction complicate the understanding of metapopulation dynamics, both at the genetic and demographic level. Unfortunately, computer models that combine aspects of single-population extinction and genetic considerations discussed above with considerations of metapopulation theory are not yet available for developing conservation management strategies.

Nevertheless, managers should be cognizant of the complexities of metapopulation systems. In general, populations distributed over several populations are more secure over the long-term than one population located at a single site. This is particularly true if there is gene flow between patches (either natural or through management intervention) and the patches are not susceptible to the same catastrophic threats. In many cases, a captive population can serve as a secure patch that can be used as a source to recolonize other patches through reintroduction efforts and as a reservoir for genetic diversity.

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Interactive Management of Small Wild and Captive Populations (T.J. Foose)

Introduction

Conservation strategies for endangered species must be based on viable populations. While it is necessary, it is no longer sufficient merely to protect endangered species *in situ*. They must also be managed.

The reason management will be necessary is that the populations that can be maintained of many species under the pressures of habitat degradation and unsustainable exploitation will be small, i.e. a few tens to a few hundreds (in some cases, even a few thousands) depending on the species. As such, these populations are endangered by a number of environmental, demographic, and genetic problems that are stochastic in nature and that can cause extinction.

Small populations can be devastated by catastrophe (weather disasters, epidemics, exploitation) as exemplified by the case of the black footed-ferret and the Puerto Rican parrot, or be decimated by less drastic fluctuations in the environment. Demographically, small populations can be disrupted by random fluctuations in survivorship and fertility. Genetically, small populations lose diversity needed for fitness and adaptability.

Minimum Viable Populations

For all of these problems, it is the case that the smaller the population is and the longer the period of time it remains so, the greater these risks will be and the more likely extinction is to occur. As a consequence, conservation strategies for species which are reduced in number, and which most probably will remain that way for a long time, must be based on maintaining certain minimum viable populations (MVP's), i.e. populations large enough to permit long-term persistence despite the genetic, demographic and environmental problems.

There is no single magic number that constitutes an MVP for all species, or for any one species all the time. Rather, an MVP depends on both the genetic and demographic objectives for the program and the biological characteristics of the taxon or population of concern. A further complication is that currently genetic and demographic factors must be considered separately in determining MVP's, although there certainly are interactions between the genetic and demographic factors. Moreover, the scientific models for assessing risks in relation to population size are still in rapid development. Nevertheless, by considering both the genetic and demographic objectives of the program and the biological characteristics pertaining to the population, scientific analyses can suggest ranges of population sizes that will provide calculated protection against the stochastic problems.

Genetic and demographic objectives of importance for MVP

Probability of survival (e.g., 50% or 95%) desired for the population;

Percentage of the genetic diversity to be preserved (90%, 95%, etc.);

Period of time over which the demographic security and genetic diversity are to be sustained (e.g., 50 years, 200 years).

In terms of demographic and environmental problems, for example, the desire may be for 95% probability of survival for 200 years. Models are emerging to predict persistence times for populations of various sizes under these threats. Or in terms of genetic problems, the desire may be to preserve 95% of average heterozygosity for 200 years. Again models are available. However, it is essential to realize that such terms as viability, recovery, self-sustainment, and persistence can be defined only when quantitative genetic and demographic objectives have been established, including the period of time for which the program (and population) is expected to continue.

Biological characteristics of importance for MVP

Generation time: Genetic diversity is lost generation by generation, not year by year. Hence, species with longer generation times will have fewer opportunities to lose genetic diversity within the given period of time selected for the program. As a consequence, to achieve the same genetic objectives, MVP's can be smaller for species with longer generation times. Generation time is qualitatively the average age at which animals produce their offspring; quantitatively, it is a function of the age-specific survivorships and fertilities of the population which will vary naturally and which can be modified by management, e.g. to extend generation time.

The number of founders. A founder is defined as an animal from a source population (the wild for example) that establishes a derivative population (in captivity, for translocation to a new site, or at the inception of a program of intensive management). To be effective, a founder must reproduce and be represented by descendants in the existing population. Technically, to constitute a full founder, an animal should also be unrelated to any other representative of the source population and non-inbred.

Basically, the more founders, the better, i.e. the more representative the sample of the source gene pool and the smaller the MVP required for genetic objectives. There is also a demographic founder effect; the larger the number of founders, the less likely is extinction due to demographic stochasticity. However, for larger vertebrates, there is a point of diminishing returns (Figure 1), at least in genetic terms. Hence a common objective is to obtain 20-30 effective founders to establish a population. If this objective cannot be achieved, then the program must do the best with what is available. If a pregnant female woolly mammoth were discovered wandering the tundra of Alaska, it would certainly be worth trying to develop a recovery plan for the species even though the probability of success would be low. By aspiring to the optima, a program is really improving the probability of success.

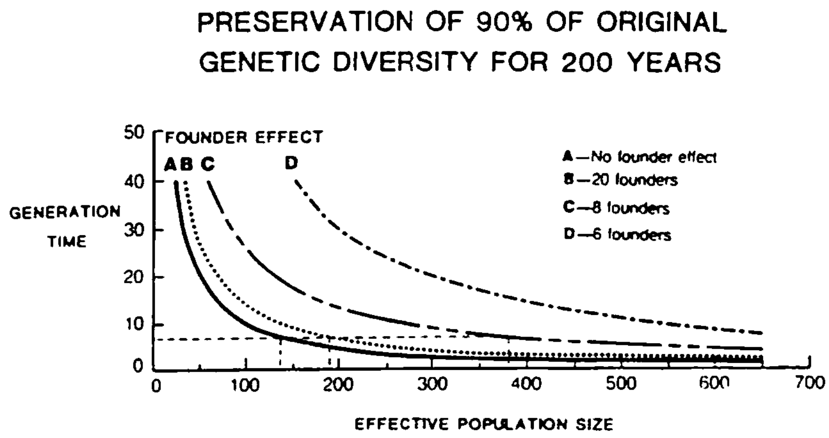

Figure 1. Interaction of number of founders, generation time of the species, and effective population size required for preserving 90% of the starting genetic diversity for 200 years.

Effective Population Size. Another very important consideration is the effective size of the population, designated N_e. N_e is not the same as the census size, N. Rather, N_e is a measure of the way the members of the population are reproducing with one another to transmit genes to the next generation. N_e is usually much less than N. For example in the grizzly bear, N_e/N ratios of about .25 have been estimated (Harris and Allendorf 1989). As a consequence, if the genetic models prescribe an N_e of 500 to achieve some set of genetic objectives, the MVP might have to be 2000.

Growth Rate. The higher the growth rate, the faster a population can recover from small size, thereby outgrowing much of the demographic risk and limiting the amount of genetic diversity lost during the so-called "bottleneck". It is important to distinguish MVP's from bottleneck sizes.

Population viability analysis

The process of deriving MVP's by considering various factors, i.e. sets of objectives and characteristics, is known as Population Viability (sometimes Vulnerability) Analysis (PVA). Deriving applicable results in PVA requires an interactive process between population biologists, managers, and researchers. PVA has been applied to a number of species (e.g., Parker and Smith 1988, Seal et al. 1989, Ballou et al. 1989, Lacy et al. 1989, Lacy and Clark, in press).

As mentioned earlier, PVA modelling often is performed separately with respect to genetic and demographic events. Genetic models indicate it will be necessary to maintain populations of hundreds or thousands to preserve a high percentage of the gene pool for several centuries. Recent models allow simultaneous consideration of demography, environmental uncertainty, and genetic uncertainty.

MVP's to contend with demographic and environmental stochasticity may be even higher than to preserve genetic diversity especially if a high probability of survival for an appreciable period of time is desired. For example, a 95% probability of survival may entail actually maintaining a much larger population whose persistence time is 20 times greater than required for 50% (i.e., average) probability of survival; 90%, 10 times greater. From another perspective, it can be expected that more than 50% of actual populations will become extinct before the calculated mean persistence time elapses.

Species of larger vertebrates will almost certainly need population sizes of several hundreds or perhaps thousands to be viable. In terms of the stochastic problems, more is always better.

Metapopulations and Minimum Areas

MVP's imply minimum critical areas of natural habitat, that will be vast for large carnivores like the Key deer. Consequently, it will be difficult or impossible to maintain single, contiguous populations of the hundreds or thousands required for viability.

However, it is possible for smaller populations and sanctuaries to be viable if they are managed as a single larger population (a metapopulation) whose collective size is equivalent to the MVP (Figure 2). Actually, distributing animals over multiple "subpopulations" will increase the effective size of the total number maintained in terms of the capacity to tolerate the stochastic problems. Any one subpopulation may become extinct or nearly so due to these causes; but through recolonization or reinforcement from other subpopulations, the metapopulation will survive. Metapopulations are evidently frequent in nature with much local extinction and re-colonization of constituent subpopulations occurring.

Unfortunately, as wild populations become fragmented, natural migration for re-colonization may become impossible. Hence, metapopulation management will entail moving animals around to correct genetic and demographic problems (Figure 3). For migration to be effective, the migrants must reproduce in the new area. Hence, in case of managed migration it will be important to monitor the genetic and demographic performance of migrants

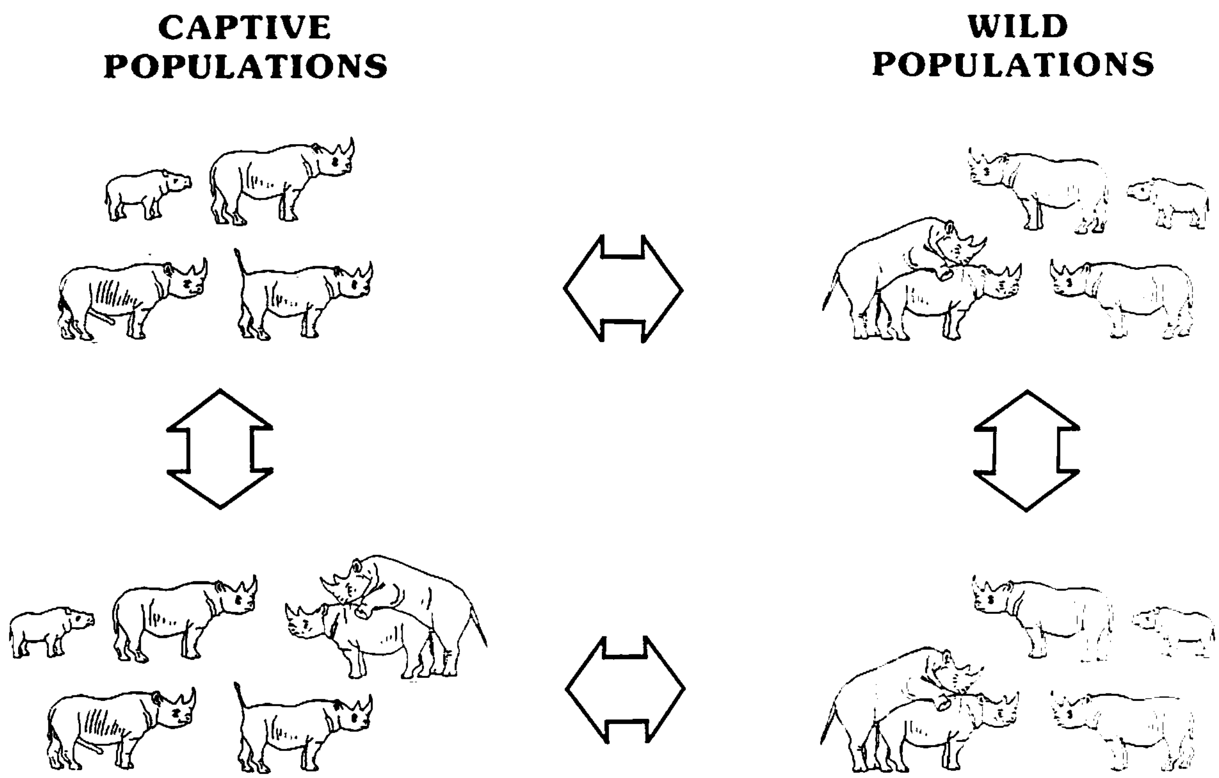

Figure 2. Multiple subpopulations as a basis for management of a metapopulation for survival of a species in the wild.

Managed migration is merely one example of the kinds of intensive management and protection that will be desirable and necessary for viability of populations in the wild. MVP's strictly imply benign neglect. It is possible to reduce the MVP required for some set of objectives, or considered from an alternative perspective, extend the persistence time for a given size population, through management intervention to correct genetic and demographic problems as they are detected. In essence, many of these measures will increase the N_e of the actual number of animals maintained.

The Key deer is already subject to intervention: animals are fed by residents, movements are obstructed and the population is being fragmented by development, and deer are killed by collisions with automobiles. Such interventions are manifestations of the fact that as natural sanctuaries and their resident populations become smaller, they are in effect transforming into megazoos that will require much the same kind of intensive genetic and demographic management as species in captivity.

MANAGED MIGRATION AMONG POPULATIONS OF RHINOS

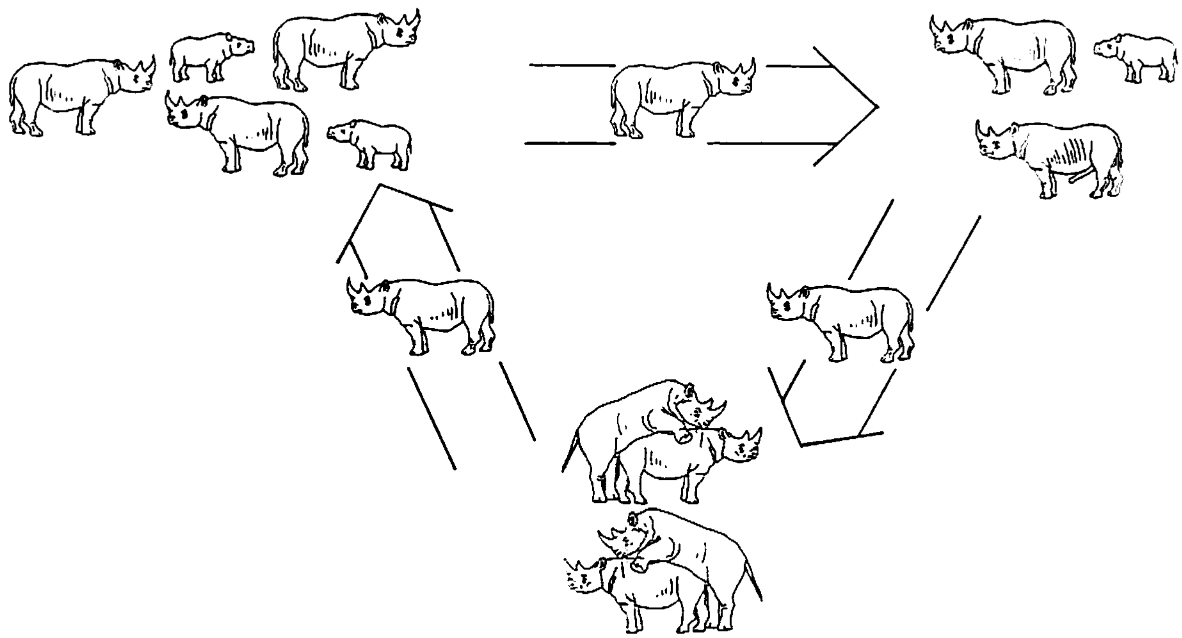

Figure 3. Managed migration among subpopulations to sustain gene flow in a metapopulation.

Captive Propagation

Another way to enhance viability is to reinforce wild populations with captive propagation. More specifically, there are a number of advantages to captive propagation: protection from unsustainable exploitation, e.g. poaching; moderation of environmental vicissitudes for at least part of the population; more genetic management and hence enhance preservation of the gene pool; accelerated expansion of the population to move toward the desired MVP and to provide animals more rapidly for introduction into new areas; and increase in the total number of animals maintained.

It must be emphasized that the purpose of captive propagation is to reinforce, not replace, wild populations. Captive colonies and zoos must serve as reservoirs of genetic and demographic material that can periodically be transfused into natural habitats to re-establish species that have been extirpated or to revitalize populations that have been debilitated by genetic and demographic problems.

METAPOPULATION

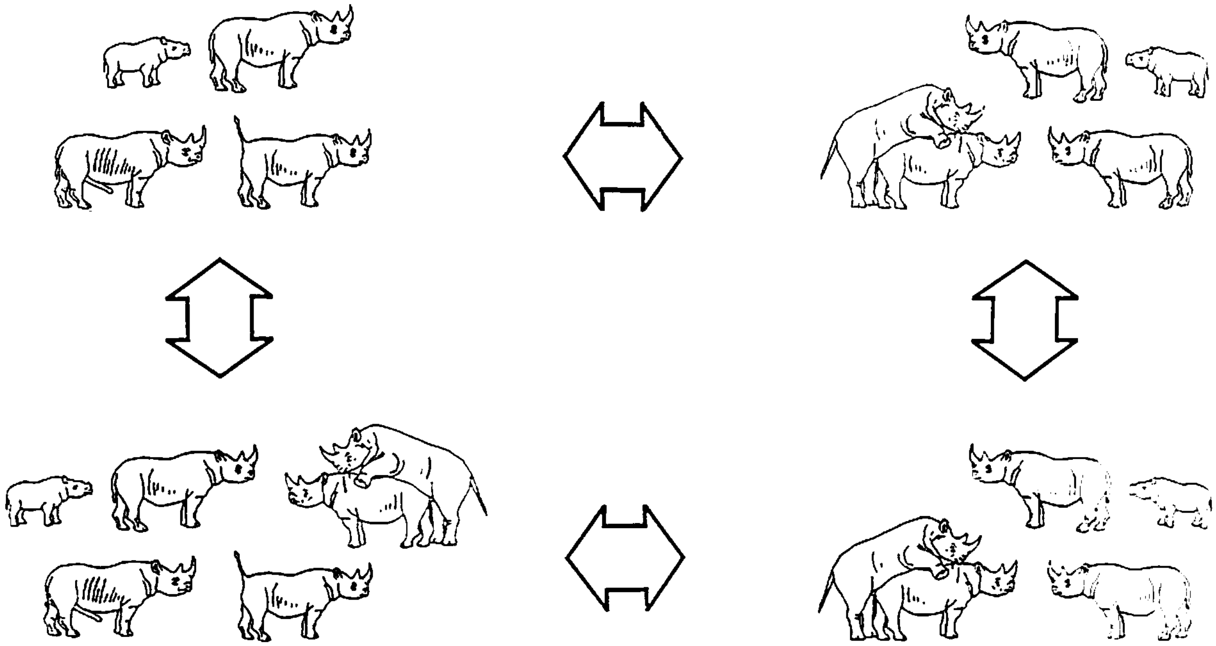

Figure 4. The use of captive populations as part of a metapopulation to expand and protect the gene pool of a species.

The survival of a great and growing number of endangered species will depend on assistance from captive propagation. Indeed, what appears optimal and inevitable are conservation strategies for the species incorporating both captive and wild populations interactively managed for mutual support and survival (Figure 4). The captive population can serve as a vital reservoir of genetic and demographic material: the wild population, if large enough, can continue to subject the species to natural selection. This general strategy has been adopted by the IUCN (the world umbrella conservation organization) which now recommends that captive propagation be invoked anytime a taxon's wild population declines below 1000 (IUCN 1988).

Species Survival Plans

Zoos in many regions of the world are organizing scientifically managed and highly coordinated programs for captive propagation to reinforce natural populations. In North America, these efforts are being developed under the auspices of the AAZPA, in coordination with the IUCN SSC Captive Breeding Specialist Group (CBSG), and are known as the Species Survival Plan (SSP).

Captive propagation can help, but only if the captive populations themselves are based on concepts of viable populations. This will require obtaining as many founders as possible, rapidly expanding the population normally to several hundreds of animals, and managing the population closely genetically and demographically. This is the purpose of SSP Masterplans. Captive programs can also conduct research to facilitate management in the wild as well as in captivity, and for interactions between the two.

A prime examples of such a captive/wild strategy is the combined USFWS Recovery Plan/SSP Masterplan for the red wolf. Much of the captive propagation of red wolves has occurred at a special facility in Washington state, but there is also a growing number of zoos providing captive habitat, especially institutions within the historical range of the red wolf.

Another eminent example of a conservation and recovery strategy incorporating both captive and wild populations is the black-footed ferret. This species now evidently survives only in captivity. Because the decision to establish a captive population was delayed, the situation became so critical that moving all the animals into captivity seemed the only option, circumstances that also applied to the California condor. Another option may have been available if action to establish a captive population had occurred earlier as was done with the Puerto Rican parrot and plain pigeon. Consideration of the survivorship pattern, which exhibited high juvenile mortality for ferrets, as it does for many mammals and birds, suggested that young animals destined to die in the wild might be removed with little or no impact on the population. The AAZPA and CBSG/SSC/IUCN are involved in these kinds of strategies and programs worldwide.

Population Viability Analysis (R. C. Lacy)

Many wildlife populations that were once large, continuous, and diverse have been reduced to small, fragmented isolates in remaining natural areas, nature preserves, or even zoos. For example, black rhinos once numbered in the 100s of thousands, occupying much of Africa south of the Sahara; now a few thousand survive in a handful of parks and reserves, each supporting a few to at most a few hundred animals. Similarly, the Puerto Rican parrot, the only psittacine native to Puerto Rico, was formerly widespread on the island and numbered perhaps a million birds. By 1972 the species was reduced to just 20 birds (4 in captivity). Intensive efforts since have accomplished a steady recovery to 46 captive and 34 wild birds at the end of 1988. In 1989, the Luquillo forest which is home to both the captive and wild flocks of Puerto Rican parrots was severely damaged by a hurricane. Apparently about half of the wild parrots were killed, most of the traditional nest trees were destroyed, the food supply was decimated, and it is unlikely that a viable population remains in the wild.

When populations become small and isolated from any and all other conspecifics, they face a number of demographic and genetic risks to survival: in particular, chance events such as the occurrence and timing of disease outbreaks, random fluctuations in the sex ratio of offspring, and even the randomness of Mendelian gene transmission can become more important than whether the population has sufficient habitat to persist, is well adapted to that habitat, and has an average birth rate that exceeds the mean death rate. Unfortunately, the genetic and demographic processes that come into play when a population becomes small and isolated feed back on each other to create what has been aptly but depressingly described as an "extinction vortex". The genetic problems of inbreeding depression and lack of adaptability can cause a small population to become even smaller --which in turn worsens the uncertainty of finding a mate and reproducing -- leading to further decline in numbers and thus more inbreeding and loss of genetic diversity. The population spirals down toward extinction at an ever accelerated pace. The size below which a population is likely to get sucked into the extinction vortex has been called the Minimum Viable Population size (or MVP).

The final extinction of a population usually is probabilistic, resulting from one or a few years of bad luck, even if the causes of the original decline were quite deterministic processes such as over-hunting and habitat destruction. Recently, techniques have been developed to permit the systematic examination of many of the demographic and genetic processes that put small, isolated populations at risk. By a combination of analytic and simulation techniques, the probability of a population persisting a specified time into the future can be estimated: a process called Population Viability Analysis (PVA) (Soule 1987). Because we still do not incorporate all factors into the analytic and simulation models (and we do not know how important the factors we ignore may be), the results of PVAs almost certainly underestimate the true probabilities of population extinction.

The value of a PVA comes not from the crude estimates of extinction probability, but rather from identification of the relative importance of the factors that put a population at risk and assessment of the value (in terms of increased probability of population persistence) of various possible management actions. That few species recognized as Endangered have recovered adequately to be delisted and some have gone extinct in spite of protection and recovery efforts attests to the acute risks faced by small populations and to the need for a more intensive, systematic approach to recovery planning utilizing whatever human, analytical, biological, and economic resources are available.

Genetic Processes in Small and Fragmented Populations

Random events dominate genetic and evolutionary change when the size of an inter-breeding population is on the order of 10s or 100s (rather than 1000s or more). In the absence of selection, each generation is a random genetic sample of the previous generation. When this sample is small, the frequencies of genetic variants (alleles) can shift markedly from one generation to the next by chance, and variants can be lost entirely from the population -- a process referred to as "genetic drift". Genetic drift is cumulative. There is no tendency for allele frequencies to return to earlier states (though they may do so by chance), and a lost variant cannot be recovered, except by the reintroduction of the variant to the population through mutation or immigration from another population. Mutation is such a rare event (on the order of one in a million for any given gene) that it plays virtually no role in small populations over time scales of human concern (Lacy 1987a). The restoration of variation by immigration is only possible if other populations exist to serve as sources of genetic material.

Genetic drift, being a random process, is also non-adaptive. In populations of less than 100 breeders, drift overwhelms the effects of all but the strongest selection: Adaptive alleles can be lost by drift, with the fixation of deleterious variants (genetic defects) in the population. For example, the prevalence of cryptorchidism (failure of one or both testicles to descend) in the Key deer (Felis concolor coryi) is probably the result of a strongly deleterious allele that has become common, by chance, in the population; and a kinked tail is probably a mildly deleterious (or at best neutral) trait that has become almost fixed within the Key deer.

A concomitant of genetic drift in small populations is inbreeding -- mating between genetic relatives. When numbers of breeding animals become very low, inbreeding becomes inevitable and common. Inbred animals often have a higher rate of birth defects, slower growth, higher mortality, and lower fecundity ("inbreeding depression"). Inbreeding depression has been well documented in laboratory and domesticated stocks (Falconer 1981), zoo populations (Ralls et al. 1979, Ralls and Ballou 1983, Ralls et al. 1988), and a few wild populations. The male-biased sex ratio of Key deer fawens may be a consequence of inbreeding, as might the low rate of twinning.

Inbreeding depression probably results primarily from the expression of rare, deleterious alleles. Most populations contain a number of recessive deleterious alleles (the "genetic load" of the population) whose effects are usually masked because few individuals in a randomly breeding population would receive two copies of (are "homozygous" for) a harmful allele. Because their•parents are related and share genes in common, inbred animals have much higher probabilities of being homozygous for rare alleles. If selection were efficient at removing deleterious traits from small populations, progressively inbred populations would become purged of their genetic load and further inbreeding would be of little consequence. Because random drift is so much stronger than selection in very small populations, even decidedly harmful traits can become common (e.g., cryptorchidism in the Florida panther, biased sex ratio in the Key deer) and inbreeding depression can drive a population to extinction.

The loss of genetic diversity that occurs as variants are lost through genetic drift has other, long-term consequences. As a population becomes increasingly homogeneous, it becomes increasingly susceptible to disease, new predators, changing climate, or any environmental change. Selection cannot favor the more adaptive types when all are identical and none are sufficiently adaptive. Every extinction is, in a sense, the failure of a population to adapt quickly enough to a changing environment.

To avoid the immediate effects of inbreeding and the long-term losses of genetic variability a population must remain large, or at least pass through phases of small numbers ("bottlenecks") in just one or a few generations. Because of the long generation times of the

Puerto Rican parrot, the present bottleneck has existed for just one or two generations, and could be exited (successfully, we hope) before another generation passes and further genetic decay occurs. The Florida Key deer has evidently been in a bottleneck for thousands of years, perhaps 2-3 thousand generations. Although we cannot predict which genetic variants will be lost from any given population (that is the nature of random drift), we can specify the expected average rate of loss. Figure 5 shows the mean fate of genetic variation in randomly breeding populations of various sizes. The average rate of loss of genetic variance (when measured by heterozygosity, additive variance in quantitative traits, or the binomial variance in allelic frequencies) declines by drift according to:

$$V_g(t) = V_g(0) \times (1 - 1/(2N_e))^t,$$

in which V_g is the genetic variance at generation t, and N_e is the effective population size (see below) or approximately the number of breeders in a randomly breeding population. As shown in Figure 6, the variance in the rate of loss among genes and among different populations is quite large; some populations may (by chance) do considerably better or worse than the averages shown the Figure 5.

The rate of loss of genetic variation considered acceptable for a population of concern depends on the relationship between fitness and genetic variation in the population, the decrease in fitness considered to be acceptable, and the value placed by humans on the conservation of natural variation within wildlife populations. Over the short-term, a 1% decrease in genetic variance (or heterozygosity), which corresponds to a 1% increment in the inbreeding coefficient, has been observed to cause about a 1-2% decrease in aspects of fitness (fecundity, survival) measured in a variety of animal populations (Falconer 1981). Appropriately, domesticated animal breeders usually accept inbreeding of less than 1% per generation as unlikely to cause serious detriment. The relationship between fitness and inbreeding is highly variable among species and even among populations of a species, however. A few highly inbred populations survive and reproduce well (e.g., northern elephant seals, Pere David's deer, European bison), while attempts to inbreed many other populations have resulted in the extinction of most or all inbred lines (Falconer 1981).

Concern over the loss of genetic adaptability has led to a recommendation that management programs for endangered taxa aim for the retention of at least 90% of the genetic variance present in ancestral populations (Foose et al. 1986). The adaptive response of a population to selection is proportional to the genetic variance in the traits selected, so the 90% goal would conserve a population capable of adapting at 90% the rate of the ancestral population. Over a timescale of 100 years or more, for a medium-sized vertebrate with a generation time of 5 years such a goal would imply an average loss of 0.5% of the genetic variation per generation, or a randomly breeding population of about 100 breeding age individuals.

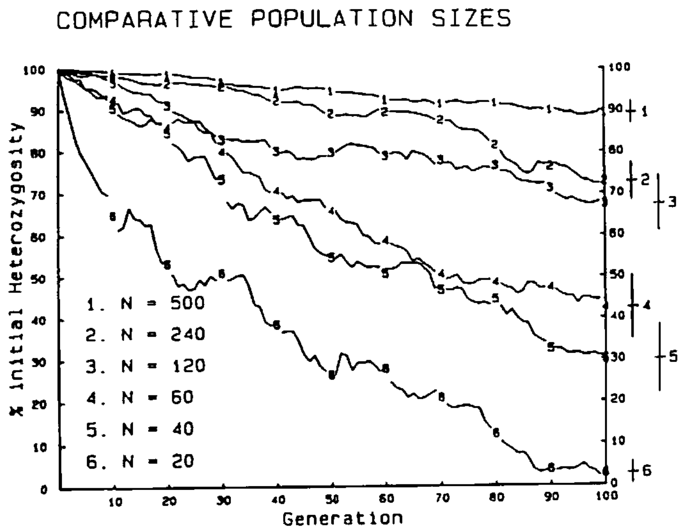

Figure 5. The average losses of genetic variation (measured by heterozygosity or additive genetic variation) due to genetic drift in 25 computer-simulated populations of 20, 50, 100, 250, and 500 randomly breeding individuals. Figure from Lacy 1987a.

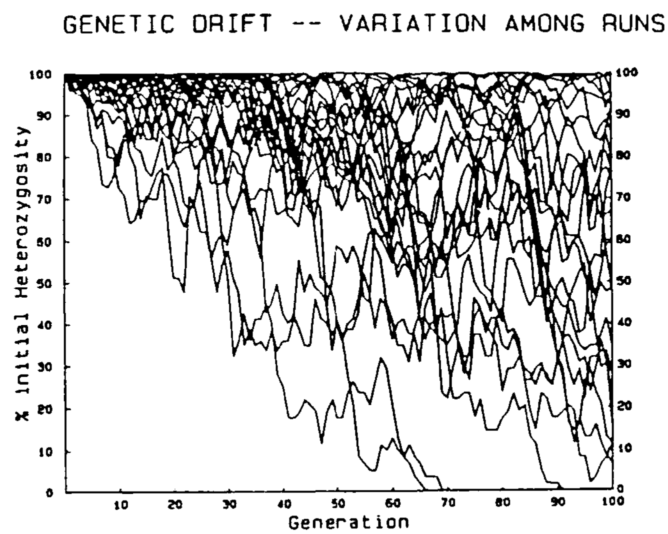

Figure 6. The losses of heterozygosity at a genetic locus in 25 populations of 120 randomly breeding individuals, simulated by computer. Figure from Lacy 1987a.

Most populations, whether natural, reintroduced, or captive, are founded by a small number of individuals, usually many fewer than the ultimate carrying capacity. Genetic drift can be especially rapid during this initial bottleneck (the "founder effect"), as it is whenever a population is at very low size. To minimize the genetic losses from the founder effect, managed populations should be started with 20 to 30 founders, and
the population should be expanded to carrying capacity as rapidly as possible (Foose et al. 1986, Lacy 1988, 1989). With twenty reproductive founders, the initial population

would contain approximately 97.5% of the genetic variance present in the source population from which the founders came. The rate of further loss would decline from 2.5% per generation as the population increased in numbers. Because of the rapid losses of variability during the founding bottleneck, the ultimate carrying capacity of a managed population may have to be set substantially higher than the 100 breeding individuals given above in order to keep the total genetic losses below 90% (or whatever goal is chosen).

The above equations, graphs, and calculations all assume that the population is breeding randomly. Yet breeding is random in few if any natural populations. The "effective population size" is defined as that size of a randomly breeding population (one in which gamete union is at random) which would lose genetic variation by drift at the same rate as does the population of concern. An unequal sex ratio of breeding animals, greater than random variance in lifetime reproduction, and fluctuating population sizes all cause more rapid loss of variation than would occur in a randomly breeding population, and thus depress the effective population size. If the appropriate variables can be measured, then the impact of each factor on N_e can be calculated from standard population genetic formulae (Crow and Kimura 1970, Lande and Barrowclough 1987). For many vertebrates, breeding is approximately at random among those animals that reach reproductive age and enter the breeding population. To a first approximation, therefore, the effective population size can be estimated as the number of breeders each generation. In managed captive populations (with relatively low mortality rates, and stable numbers), effective population sizes are often 1/4 to 1/2 the census population. In wild populations (in which many animals die before they reach reproductive age), Ne/N probably rarely exceeds this range and often is an order of magnitude less.

The population size required to minimize genetic losses in a medium sized animal, therefore, might be estimated to be on the order of $N_e = 100$, as described above, with $N = 200$ to 400. More precise estimates can and should be determined for any population of management concern from the life history characteristics of the population, the expected losses during the founding bottleneck, the genetic goals of the management plan, and the timescale of management.

Although the fate of any one small population is likely to be extinction within a moderate number of generations, populations are not necessarily completely isolated from conspecifics. Most species distributions can be described as "metapopulations", consisting of a number of partially isolated populations, within each of which mating is nearly random. Dispersal between populations can slow genetic losses due to drift, can augment numbers following population decline, and ultimately can recolonize habitat vacant after local extinction.

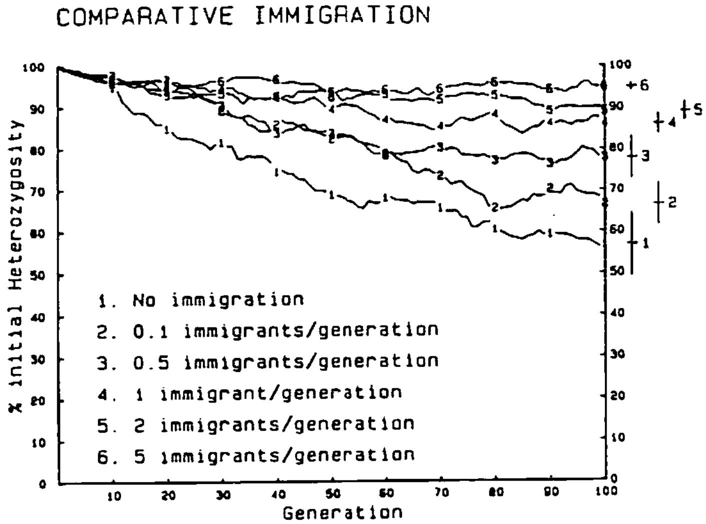

Figure 7. The effect of immigration from a large source population into a population of 120 breeding individuals. Each line represents the mean heterozygosity of 25 computer-simulated populations (or, equivalently, the mean heterozygosity across 25 non-linked genetic loci in a single population). Standard error bars for the final levels of heterozygosity are given at the right. Figure from Lacy 1987a.

If a very large population exists that can serve as a continued source of genetic material for a small isolate, even very occasional immigration (on the order of 1 per generation) can prevent the isolated subpopulation from losing substantial genetic variation (Figure 7). Often no source population exists of sufficient size to escape the effects of drift, but rather the metapopulation is divided into a number of small isolates with each subjected to considerable stochastic forces. Genetic variability is lost from within each subpopulation, but as different variants are lost by chance from different subpopulations the metapopulation can retain much of the initial genetic variability (Figure 8). Even a little genetic interchange between the subpopulations (on the order of 1 migrant per generation) will maintain variability within each subpopulation, by reintroducing genetic variants that are lost by drift (Figure 9). Because of the effectiveness of even low levels of migration at countering the effects of drift, the absolute isolation of a small population would have a very major impact on its genetic viability (and also, likely, its demographic stability). Population genetic theory makes it clear that no small, totally isolated population is likely to persist for long.

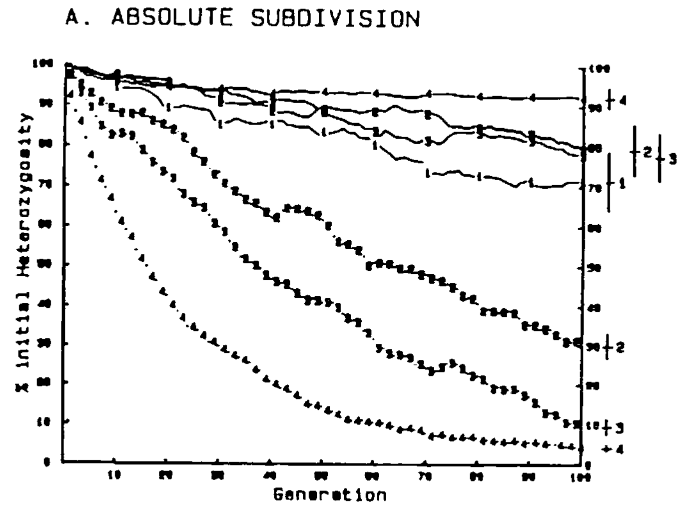

Figure 8. The effect of division of a population of 120 breeders into 1, 3, 5, or 10 isolated subpopulations. Dotted lines (numbers) indicate the mean within-subpopulation heterozygosities from 25 computer simulations. Lines represent the total gene diversity within the simulated metapopulation. Figure from Lacy 1987a.

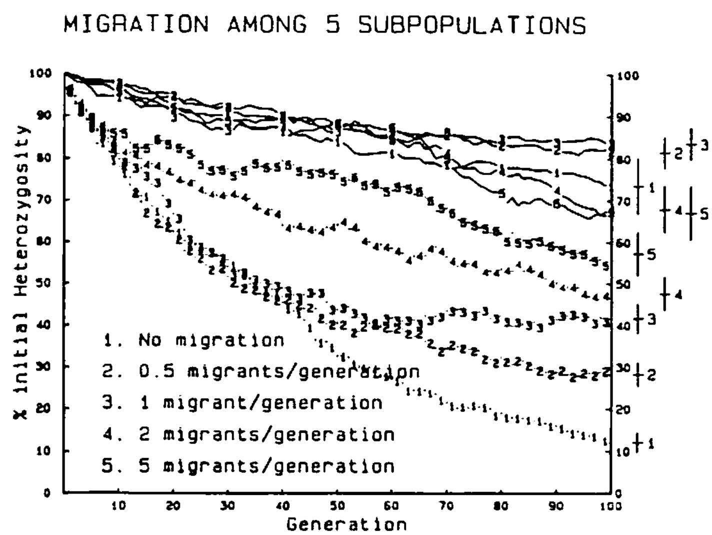

Figure 9. The effect of migration among 5 subpopulations of a population of 120 breeders. Dotted lines (numbers) indicate the mean within-subpopulation heterozygosities from 25 simulations. Lines represent the total gene diversity within the metapopulation. Figure from Lacy 1987a.

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KENYA BLACK RHINOCEROS

METAPOPULATION WORKSHOP

BRIEFING BOOK

SECTION 4
LONG TERM MANAGEMENT STRATEGIES

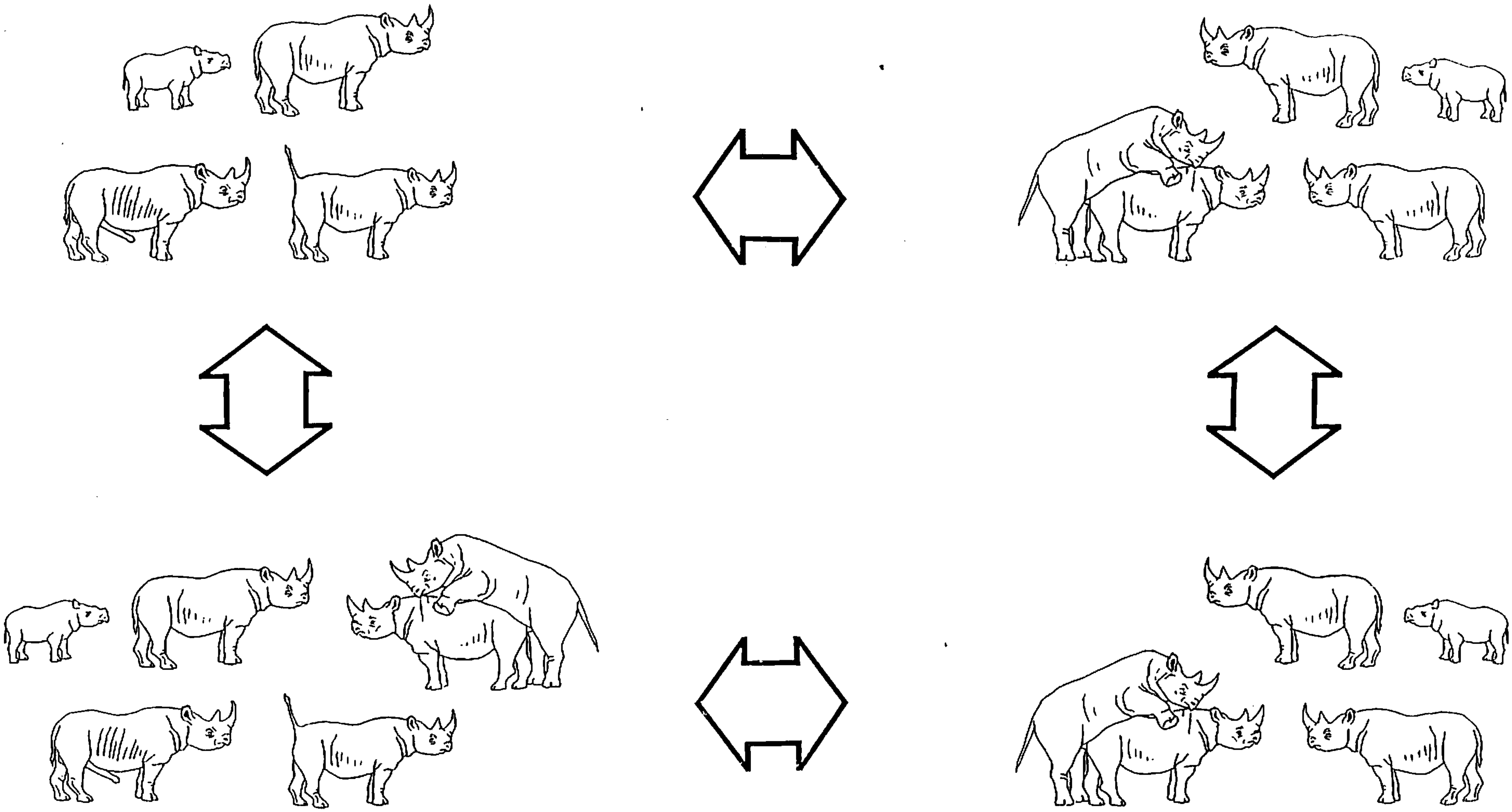
OPTIONS FOR RHINO CONSERVATION

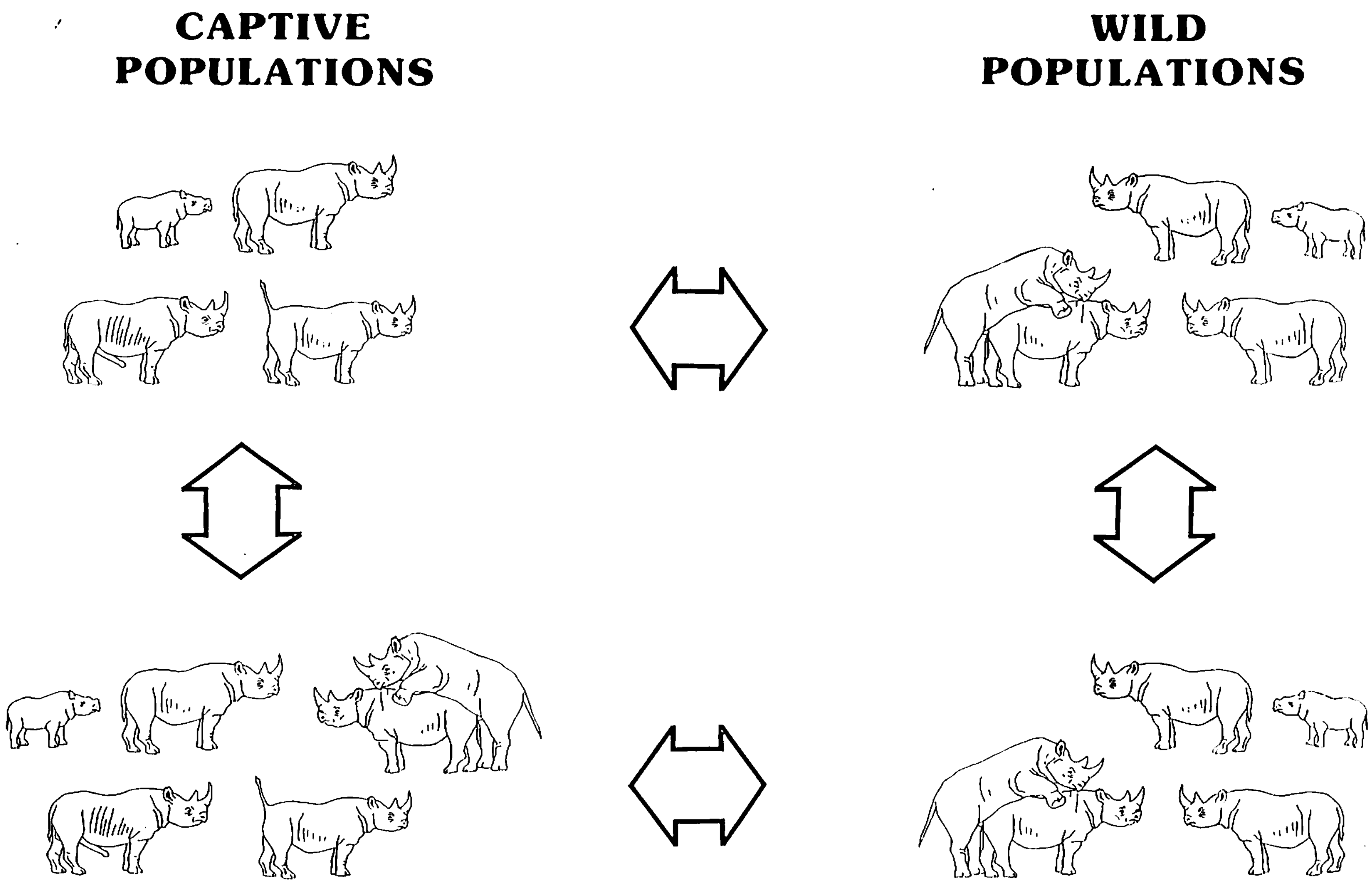
Genome Banks — Captivity Out Of Range — Sanctuary Out Of Range — Captivity In Range — Sanctuary In Range — WILD

EX-SITU	*IN-SITU*
Genome Banks; Captivity Out Of Range; Sanctuary Out Of Range	Captivity In Range; Sanctuary In Range; WILD

Modified from Mark Stanley-Price (1991)

METAPOPULATION

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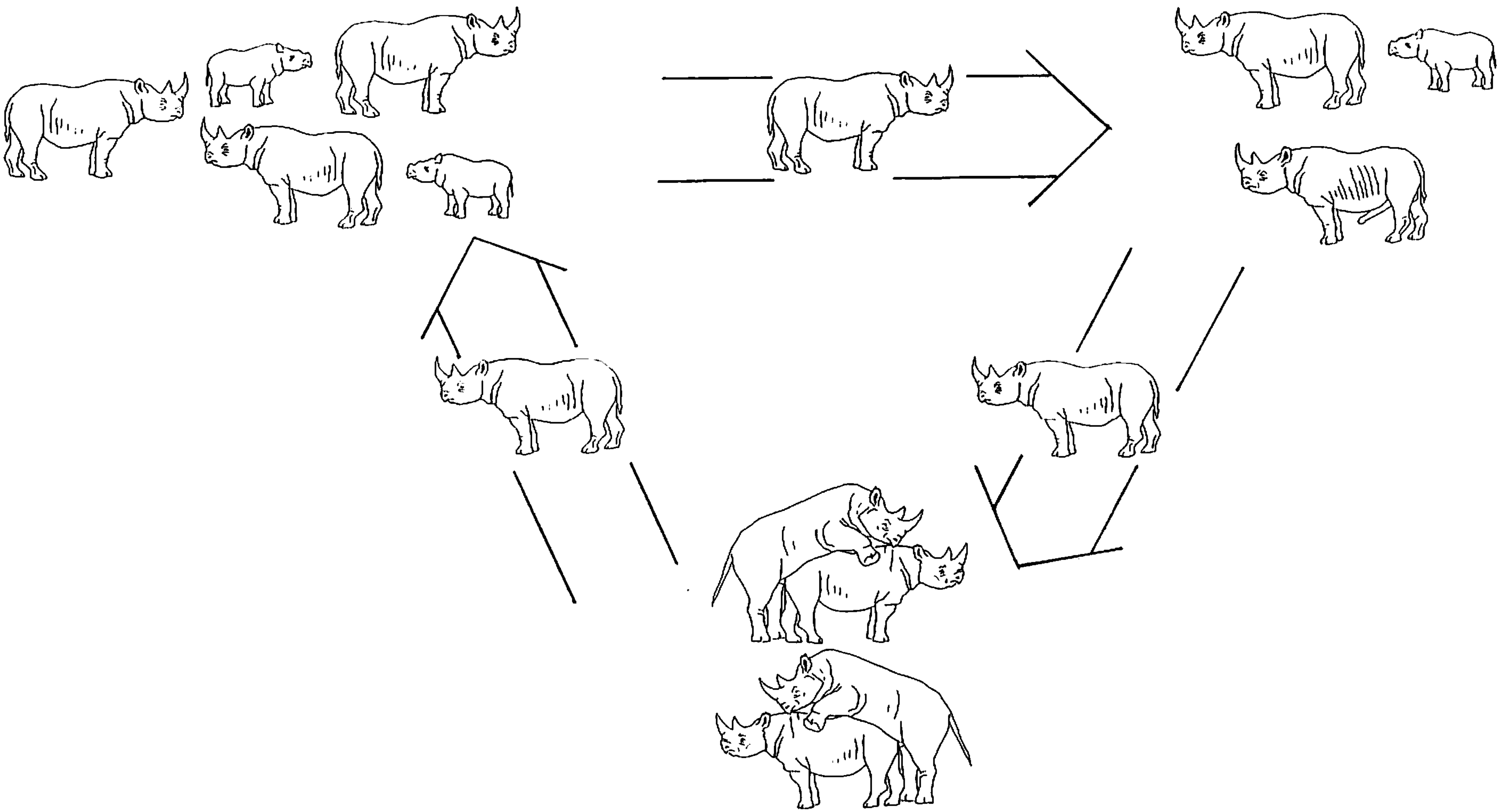
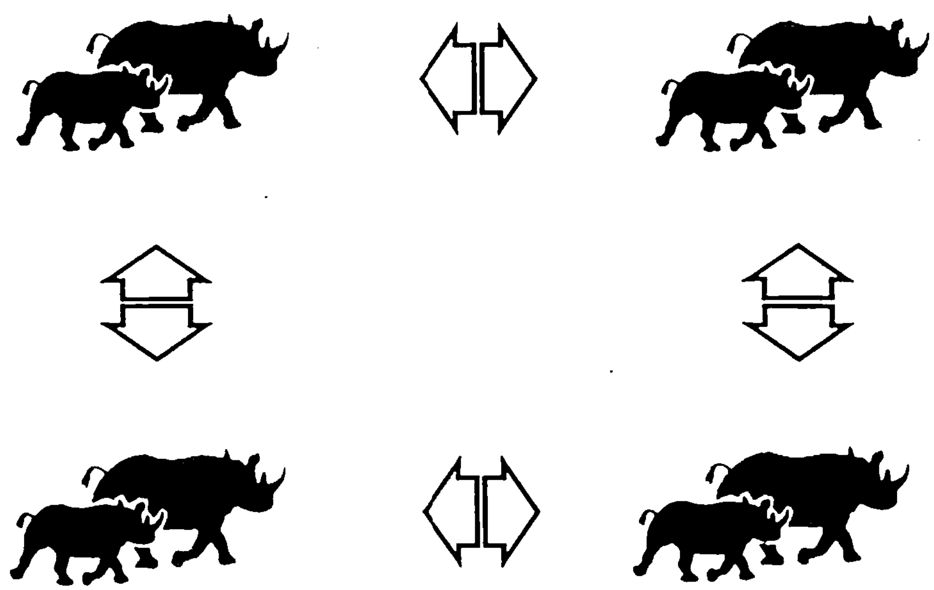


PACHYDERM

NEWSLETTER OF THE AFRICAN ELEPHANT AND RHINO SPECIALIST GROUP

CAPTIVITY **WILD**



SPECIAL ISSUE

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Edited by R.F. du Toit, T.J. Foose and D.H.M. Cumming

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Proceedings of African Rhino Workshop

INTRODUCTION

Rhinos in Africa are in a crisis situation. Numbers of black rhinos in Africa have been reduced, largely by poaching, from an estimated 60 000 in 1970 to less than 4 000 today. Moreover, many of the remaining animals are distributed in small and fragmented populations whose survival may be endangered by genetic and demographic problems even if they can be protected from poachers. About 150 black rhinos are maintained in the zoos of the world. Almost all of these animals are derived from the East African populations.

The northern subspecies of the white rhino has declined to even lower numbers, with a maximum of only 20 animals known to survive in the wild in Africa. About a dozen animals are maintained in captivity, 9 of them (including all of the females) at a single institution, the zoo at Dvur Kralove, Czechoslovakia.

In response to this crisis, an African Rhino Workshop convened at the Cincinnati Zoo, 25-28 October 1986. The Workshop was organized by Cincinnati Zoo, the King's Island Wild Animal Habitat, and the AAZPA Conservation Coordinator's Office in consultation with the IUCN/SSC African Elephant and Rhino Specialist Group (AERSG) and Captive Breeding Specialist Group (CBSG). The Workshop was supported by a number of zoological organisations and institutions in North America including the AAZPA Conservation Endowment Fund.

Approximately 100 persons participated in the Workshop, representing field conservationists, zoo professionals, academic researchers, and support organizers from Africa, North America and Europe. The chairmen and many members of the AERSG and CBSG were in attendance. Lists of participants and sponsors are appended.

The Workshop was organized to persue several objectives:

(i) to contribute to development of the global strategy to conserve African rhinos;

(ii) to integrate and coordinate field and captive programs to preserve African rhinos, and especially to delineate how zoos can assist more with attempts to preserve these species;

(iii) to apply the principles of conservation biology, especially genetic-demographic management and decision analysis, to conservation of African rhinos.

The Workshop participants discussed problems and potentials for these objectives for three days. As a result, a number of recommendations and resolutions were adopted.

RECOMMENDATIONS

GENERAL

1. The Workshop emphasizes that continued poaching for the illegal trade in rhino horn is the greatest threat to the ultimate objective of survival of African rhinos in the wild, both as species and as components of their ecosystems. Therefore, the Workshop strongly encourages continued and intensified anti-poaching measures. Further, the Workshop urges continued and intensified efforts to reduce and eventially eliminate the trade in rhino horn. In particular, the Workshop urges the Organization of African Unity (OAU) and its member nations to apply pressure on those African countries harboring culprits to implement all measures necessary to eliminate poaching and illegal trade in rhino horn and other products.

2. To facilitate the *ex situ* programs for African rhinos, the Workshop observes the great need for annual updates of the International Studbook for both black and white rhinos. Moreover, the Workshop suggests that there be consideration of using studbook techniques for intensive *in situ* management of rhinos in Africa. The zoo community is able and willing to help African nations technically and financially with this endeavour.

3. The Workshop believes there is a need to improve the clinical and pathological investigations of both black and white rhinos in captivity and where practical in the wild. In this regard, the Workshop recommends that there be consideration of formulating and implementing standard methods of recording information collected in these investigations. It is also desirable to preserve and inventory biological samples, including osteological material.

4. The Workshop recommends that research be conducted on enhancement of reproduction in rhinos to provide techniques for transfer of germ plasm or genetic material which can be used for genetic and demographic management of captive and wild populations to assist in their survival. These techniques could reduce the costs and risks of moving live animals for management purposes and could permit more rapid expansion of under-represented genetic bloodlines of rhinos.

This research would include oestrus detection and synchronization; the collection, analysis and cryopreservation of germ plasm; artificial insemination; and embryo transfer technology.

A researcher, working with an established reproductive research group, is needed to coordinate efforts currently underway and to conduct further specific projects. Such an effort will need to be funded for 3-5 years with direct costs of about $65 000 per year. The responsibility for organizing this effort has been accepted by the AAZPA SSP Species Coordinators for Black and White Rhinos.

5. The Workshop recognizes the usefulness of *Pachyderm,* the Newsletter of the AERSG, as a primary reference on rhino conservation, issues and priorities. Therefore, the Workshop urges wider distribution of *Pachyderm,* especially to *ex situ* facilities and fund-raising organizations. Further, the Workshop endorses the idea of including in *Pachyderm* issues a status update with the most recent reports and estimates of numbers of rhinos in Africa. Further, it would be useful if AERSG regularly produced a list of the prioritized rhino projects, along with their costs, as an aid to fund-raising efforts and coordination.

BLACK RHINOS

1. The Workshop endorses the draft continental strategy for black rhinos in Africa formulated by the AERSG.

2. The Workshop reaffirms that the three major components of the conservation strategy for black rhinos consist of:

(i) protection of the larger (more than 100 animals) populations in the wild;

(ii) intensive *in situ* management of smaller (less than 100 animals) populations in the wild;

(iii) *ex situ* programs, specifically captive propagation, to reinforce survival of wild populations.

3. As an interim strategy, until more is known about the genetic and ecological differences within the species, the Workshop recommends that the intensive *in situ* and the *ex situ* programs recognize four conservation units within the

black rhino range:

(i) the southwestern populations in Namibia;
(ii) the southern-central populations extending from Natal through Zimbabwe and Zambia into southern Tanzania;
(iii) the eastern populations in Kenya and northern Tanzania;
(iv) the north-western populations extending from the horn of Africa to Central African Republic and Cameroun.

Ex situ and intensive *in situ* programs should not mix animals from these four conservation units at this time.

4. Appropriate studies of evolutionarily significant differences, including both genetic diversity and ecological adaptations, are greatly needed for management decisions concerning both the wild and the captive populations. The Workshop recommends that such studies be conducted as soon as possible and be coordinated through the AERSG. Hence the Workshop recommends that necessary funds be recruited for these studies. Specifically, the Workshop urges that $10 000 be sought by the zoo community, through the AAZPA SSP Species Coordinator, for the genetic studies of black rhino being conducted by Dr. Don Melnick in liaison with the AERSG. This $10 000 would represent matching funds for the $10 000 already offered by the New York Zoological Society to cover the estimated $20 000 total cost of this project.

The Workshop also encourages both field and zoo programs to provide sample materials, as requested and where practical, to Dr. Melnick for these studies.

5. For the long-term conservation of the species, the Workshop urges continuation and extension of the analysis of demographic and genetic problems for the species in the wild through population modelling and decision analysis. The appropriate experts on both captive and wild communities should collaborate on these studies; African governments are encouraged to cooperate with these initiatives.

6. Considering principles of conservation biology, the Workshop acknowledges that a minimum, long-term objective for each of the recognized conservation units in the wild is a total population whose genetically effective size Ne = 500. Since the genetically effective size is usually much lower than the census number, minimum populations for each conservation unit larger than 500 will be required to achieve this objective. If it can be assumed (based on comparison with some other species that have been studied) that Ne/N ratios in the wild will be the order of 0.25, a minimum total population of 2 000 per conservation unit may be required to achieve the objective of Ne. = 500.

Since four conservation units are being recognized, these considerations suggest a minimum viable population of at least 8 000 rhinos in Africa as an optimal long-term objective. The Workshop also realizes that it is impossible that a contiguous population of 2 000 within any conservation unit will build up in the foreseeable future. However, by interactive management of the several disjunct populations that will likely characterize each conservation unit, the overall N and Ne objectives of some of these combined populations should be achieved.

The Workshop observes that the total estimated population of black rhinos in Africa is less than half the total recommended minimum number of 8 000 and that only the southern-central populations are near the 2 000 MVP recommended for each conservation unit. Finally, it must be emphasized that these recommendations are for minimum numbers. It is highly desirable that populations larger than the minimum be maintained.

7. Since the conservation units being recognized will extend across political boundaries, there will be a need for regional cooperation within Africa for the optimal integrated and interactive management of the populations.

8. Recognizing the value of captive propagation as a back-up to *in situ* conservation, the Workshop recommends that action should commence immediately to establish viable foundations in captivity of the three conservation units of black rhinos not presently represented well in zoos. Genetic analyses suggest that a foundation for the captive population of each conservation unit optimally be at least 20 rhinos from the wild that reproduce in captivity. Only the East African populations are represented by this number of founders in zoos. The southern-central populations are represented by four founders at most. There are no known representatives of the southwestern or the northern-western populations currently in zoos.

Although the most endangered of the conservation management units is the northern-western population, acquisition of founder animals for all three conservation units not well represented in captivity should be pursued immediately and in parallel.

It is recommended that any new founders should be incorporated in the captive populations under auspices of the AAZPA SSP or similar management programs and should be placed in facilities with a proven record in black rhino reproduction.

9. Considering the plight of the northern-western populations, the Workshop urges that a rapid survey be conducted of these populations to determine what intensive *in situ* or *ex situ* action is possible and appropriate. It is recommended that the Chairman of the AERSG coordinate recruitment of a person or persons to conduct such surveys within the next six months. It is further recommended that recruitment of the financial support for such a survey will be coordinated by the AAZPA SSP Species Coordinator.

10. The Workshop observes that it will be desirable for *ex situ* programs and technology to be applied to conservation of black rhinos both in the African countries where the species occurs as well as in the zoos elsewhere in the world. Therefore, the Workshop agrees that the zoo community outside Africa should provide as much assistance as possible to African nations in developing intensive *in situ* management technology and facilities.

NORTHERN WHITE RHINOS

1. The Workshop recognizes that there are two conservation management units of white rhinos: the described southern and the northern subspecies. At present, the southern white rhino seems secure in the wild. However, the situation for the northern white rhino is critical. Although genetic studies are still inconclusive about the differences between these two units, it is believed the northern population should be conserved because of:

(i) its probable ecological adaptations to the very different habitats it occupies compared to the southern populations;
(ii) its probable resistance to endemic diseases not present in the range of southern populations;
(iii) the possible genetic diversity the population contains for the species;

(iv) the resources that have already been expended on its conservation, and the interest and willingness of Zaire to conserve the species;
(v) the flagship nature of the species for conservation in this region of Africa.

2. The Workshop recommends integration of the conservation programs for the wild and captive populations. Ultimately, these programs are expected to entail exchange of genetic material between the wild and captive populations. Fewer than 15 founder animals are known to exist for both the small wild and captive populations. These founders are evenly divided between the wild and captive populations. However, over the short term it is recommended that no animals be exchanged between the wild and captive populations; at this time it is recommended that every effort be exerted to expand the wild and captive populations as rapidly as possible from their small founder bases.

3. The Workshop endorses continued support for the *in situ* conservation programs in Garamba National Park. In particular, the Workshop believes that, in addition to the activity currently occurring, funds should be provided for a field biologist who can be deployed continuously in the Park with the rhinos. Further, the Workshop also strongly recommends that there be an intensive effort to train Zairois biologists to continue with these conservation programs into the future.

4. With respect to expansion of the captive population, the Workshop acknowledges and commends the considerable efforts of Dvur Kralove, in collaboration with the IUCN/SSC CBSG, to enhance the captive breeding program, as reflected in the report and recommendations by CBSG chairman Dr. U.S. Seal and CBSG member Dr. D. Jones, issued after their visit to Dvur Kralove in February 1986. Many of these recommendations have been implemented, including some reproductive examination of females, the movement of a lone male rhino from London to Dvur Kralove, the initiation of a facility enlargement at Dvur Kralove, and collection of samples for genetic analysis.
However, further analysis and evaluation of both the captive and wild population emphasizes the urgent need to expand the captive nucleus as soon as possible. Concerns over the demographic risks of maintaining the entire captive nucleus in one facility have intensified.
Therefore, the Workshop recommends that Dvur Kralove consider movement of 1/2 adult animals to another facility with experience in breeding the southern white rhino. Further, the Workshop recommends that Dvur Kralove be requested to suggest a timetable by which, if further reproduction does not occur there, other relocations will be undertaken. The reasons for these recommendations relate to enhancement of reproduction and reduction of demographic risks, as will be explained more fully in a white paper to be prepared over the next few months by Dr. Jones and Dr. Seal.

5. The Workshop encourages the use of the southern white rhino for development of reproductive technology to help the northern white rhino.

6. The Workshop also encourages continued investigation of the genetic and ecological differences between the northern and southern forms. With respect to the genetic studies, both field and zoo programs are encouraged to provide sample materials as requested and where practical to Dr. O. Ryder and colleagues.

AFRICAN RHINO SYSTEMATICS
Session Chairman RAOUL DU TOIT

RATIONALE FOR INVESTIGATIONS OF AFRICAN RHINO SYSTEMATICS
Comments by David Western (New York Zoological Society)

To ensure that efforts to conserve rhinos in the wild as well as in captivity are maintaining the existing genetic diversity of the species, it is necessary to establish the "evolutionarily significant units" within the different species. In the case of the northern white rhino, there has been much debate over whether this "subspecies" is sufficiently different from the southern white rhino to merit the expense and effort required to maintain the last remaining population in the Garamba National Park, Zaire. Funds allocated to conservation of these northern white rhinos might be better spent on initiatives to conserve black rhinos, which have dwindled from about 15 000 at the time when this issue was first debated to a present level of under 4 000. The importance of subspecies designations thus requires critical review in order to assign priorities for rhino conservation action in Africa, but conservation initiatives need not be delayed while the necessary research is undertaken.
In debating the significance of genetic differences between allopatric groups of rhinos, it is necessary to consider not only the need to maintain the evolutionary potential of the species by preserving overall genetic diversity, but also the need to maintain genetic traits that constitute specific ecological adaptations, allowing some of the rhinos to thrive in habitats which may be unfavourable for other members of the species. Altitudinal zonation of habitats in East Africa may be one important factor influencing ecological adaptations of rhinos.
A further aspect to consider in strategies for conservation in Africa is the likelihood that the recognition of a certain group of a spectacular "flagship species" as being different to other groups of the same species elsewhere gives impetus to national and international efforts to save those animals and their habitats — the effort to protect the mountain gorilla in Rwanda has been a case of this "political" aspect of systematics.

THE EXISTING BASIS FOR SUBSPECIES CLASSIFICATION OF BLACK AND WHITE RHINOS
Summary of presentation by Raoul du Toit (IUCN African Elephant and Rhino Specialist Group)

The efforts of Hopwood (1939) and Zukowsky (1965) in revising black rhino systematics did not greatly improve the classification since these authorities erected subspecies on the basis of very small numbers of representative skulls, and in some instances the skulls representing their subspecies were those of immature animals (notably the subspecies *holmwoodi*). In view of these deficiencies, Groves (1967) produced a revision which identified 7 subspecies, but probabilities of extinction of *bicornis, minor*, and *michaeli* were used to show how the decision strategy might change. In the second example, sensitivity of the decision to the probabilities of outbreeding depression, of survival in the wild, and of successful establishment of separate captive populations can help identify the circumstances under which semicaptive management would be better than zoos.

A structured analysis shows where additional information about chance events could reduce uncertainty and lead to a better decision. Genetic analyses of rhino subspecies can help reduce uncertainty about outbreeding depression in mixed populations, guiding the sampling of geographic regions for founders of captive and semicaptive populations and the merging of these populations in the future.

Tradeoffs among conflicting criteria, particularly between financial and biological criteria, are typical of endangered species management decisions. The two examples presented here raise the difficult question of how the value of obtaining founder animals from the northern-western subspecies of black rhino should be weighed against the difficulty and expense of doing so.

In addition to the two questions addressed by these preliminary examples, many other rhino management decisions might benefit from formal analysis:

(i) Under what circumstances is wild, intensive *in situ*, or *ex situ* management best? Among the criteria to be used for this decision are: biological impacts, including disruption of behavioural adaptations or coadapted gene pools; political impacts on local and national support for conservation; socio-economic impacts on local economies; and likelihood of sub-species survival.

(ii) How many founders are required to justify maintaining a separate subspecies population? At what point should some subspecies populations be merged for semicaptive or captive management? Among the issues here are the genetic and demographic risks of few founders weighed against the irreversibility of merger.

(iii) What are the optimal strategies for translocating animals among semicaptive and/or captive popultions? Which sexes and ages should be moved, what size groups, how frequently? The concerns here are the relative genetic and demographic contributions of different sexes and ages, social disruption caused by moving animals, risks of mortality during and after translocation, financial cost, and hazards of inbreeding in isolated populations. Some of these issues are addressed in Maguire (1986) and in previous analyses of translocations to augment grizzly bear populations (Maguire, unpublished report to U.S. Forest Service).

(iv) What are the risks and benefits of ongoing exchanges of animals, or genetic material, among captive, semicaptive and wild populations? Social disruption, impact of removals, transmission of disease, risks of injury or death to individual animals, disruption of local adaptation, and loss of genetic variation from drift and inbreeding are among the considerations here.

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SMALL POPULATION MANAGEMENT OF BLACK RHINOS
Session Chairman DAVID CUMMING

STATUS OF BLACK RHINOS IN THE WILD

The black rhino has declined more rapidly over the past 20 years than any other large mammal. In 1970 there were about 65 000 black rhinos in Africa; the total is now under 4 000, a decline of 94%. The population sizes in the various African countries within this decade are roughly as shown in Table 3.

The remnants of a number of the populations are scattered as individuals or in very small groups over vast areas. For instance, the estimated 200 rhinos remaining in the Selous Game Reserve of Tanzania are dispersed over 55 000 km^2.

The recent decline of the species is due almost entirely to commercial poaching for rhino horn. The decline in South Africa, due to natural factors in the Umfolozi-Hluhluwe complex, appears to be the one exception (the 1984 figure was probably an overestimate). In the early 1980's about half of the horn put onto the world market went to North Yemen where it is used for making dagger handles, while the remaining half went to eastern Asia for the production of traditional medicines. Most of these rhino horn mixtures are produced because they are believed to lower fevers, not because of alleged aphrodisiac properties. North Yemen has recently strengthened some controls on the import and use of rhino horn, so there may be changes in the relative importance of the markets.

Prices for African rhino horn have risen from about $30 per kg wholesale in 1970 to about $900 per kg today. Asian rhino horn is believed to have more potent medicinal properties and therefore commands much higher prices in eastern Asia.

To halt and reverse the precipitous decline in the numbers of black rhinos will require concerted action by many individuals and organisations. International, national and local conservation efforts will be most effective and make the best use of scarce resources if they are part of a planned campaign. To achieve this coordination of effort, a broad framework of policies on rhino conservation (i.e. a continental rhino conservation strategy) must be agreed upon by the principal agencies involved, and plans of action — with clear priorities — must also be elaborated in line with these policies, and kept updated as the black rhino situation changes. The African Elephant and Rhino Specialist Group

Table 3. Status of black rhinos in Africa.

	1980	1984	1987	% of total 1987 rhino population
Tanzania	3 795	3 130	270	7%
C.A.R.	3 000	170	10?	0.2%
Zambia	2 750	1 650	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	

(AERSG) is currently developing a continental black rhino conservation 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

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

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.

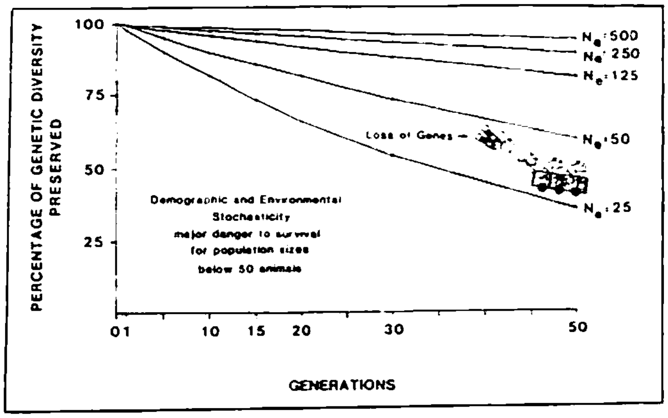
LONG-TERM MANAGEMENT OF SMALL RHINO POPULATIONS

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 vital to permit adaptation to continually changing environments. At the individual 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 popualtion sizes (Ne), possible for a total population (N) of 250.



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 adaptibility. 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 attemps at prescribing MVP's for both wild and captive black rhinos. These analyses were performed using microcomputer software developped 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
	10	—	—	—	—	—	—	—
EFFECTIVE	20	62	131	236	367	603	891	1 134
NUMBER	25	50	121	189	273	459	641	832
OF	30	50	103	170	241	393	551	712
FOUNDERS	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
	10	115	292	534	786	1 310	1 842	2 384
EFFECTIVE	20	50	115	187	261	414	568	727
NUMBER	25	50	106	170	235	369	505	642
OF	30	50	102	160	221	345	471	598
FOUNDERS	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	1 069	1 573	2 621	3 685	4 769
EFFECTIVE	20	101	231	374	522	829	1 136	1 451
NUMBER	25	100	212	339	470	737	1 010	1 284
OF	30	100	204	320	442	689	942	1 195
FOUNDERS	50	100	200	295	400	615	835	1 054
	75	100	200	295	386	589	794	1 001
	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 analyses were conducted using best-guess data available from a variety of sources; the data, the models used, and the analyses of the results can and should be improved.

Analysis of founder members for the captive populations

Captive populations often derive from so few wild-caught "founders" that they poorly represent the genetic (and morphological, ecological, physiological, and behavioural) diversity of the wild populations. To examine the founder stock from which the captive populations of African rhinos descend, I analyzed the international studbooks for black and white rhinos (updated computer versions provided just prior to the October 1986 workshop). Numbers of living wild-caught animals, numbers of founders, and numbers of "effective founders" were calculated.

Founders were defined as wild-caught animals (currently alive or not) that have living descendants in captivity. Thus, if a wild-caught animal left no living descendants, it is not a founder of the captive population. Even if a wild-caught animal is still alive, but has not left any progeny, it is still not a founder but rather is a *potential* founder, of potential genetic value but so far just an occupant of valuable space for breeders.

Effective founder number is a measure that I devised to account for unequal representation of founders in the gene pool of the present population. It is analogous to the concept of "effective number of alleles" at a genetic locus, and related to the concept of "effective population size". Algebraically, the effective number of founders is

$1/(P1^2 + P2^2 + \ldots + Pn^2)$,

in which Pi is the proportion of the captive (and non-wild-caught) gene pool that has descended from founder i. The Pis are the founder representations calculated from pedigree data and often discussed in studbook management. If the founder representations are all equal, then the effective number of founders will equal the actual number of founders. If founders have contributed unequally, the effective number will be less. For example, if three founders have contributed 50%, 25% and 25% to the living captive population, the effective number of founders would be 2.67. If one founder contributes 50% of the gene pool, and a very large number of founders each contributes a small fraction of the other 50%, then the effective number of founders approaches 4. The effective number of founders can be thought of as the number of ideal (equally contributing) founders that would be required to obtain a population with the genetic diversity represented in the actual population. Bottlenecks in the pedigree can alter this somewhat, because they make it more likely that the entire genetic contribution of a founder derives from only half its genes. In the case of rhinos, however, bottlenecks exist only in the lineages of poorly represented founders, and therefore affect the effective number of founders almost not at all.

The results of the analyses of studbook data are as follows.

BLACK RHINOS

World captive population:
87 males (38 wild-caught, 20 captive born)
103 females (55 wild, 48 captive born)
82 identifiable founders (12% of captive animals are of unknown parentage and source, thus more founders may exist)
49.6 effective founders.

North American population:
32 males (12 wild, 20 captive born)
41 females (19 wild, 22 captive born)
(17% are of unknown history)
35 identifiable founders
24.6 effective founders

WHITE RHINOS

World captive population:
309 males (195 wild, 114 captive born)
348 females (259 wild, 89 captive born)
(28% are of unknown parentage)
121 identifiable founders
17.6 effective founders
(Male No. 52 contributed 11% of current gene pool)

North American population:
86 males (53 wild, 33 captive born)
113 females (74 wild, 39 captive born)
(21% are of unknown history)
47 identifiable founders
16.1 effective founders
(Male No. 52 contributed 16% of gene pool)

The captive populations have enough effective founders to be sufficiently representative of the gene diversity in the wild. However, most founders have contributed very little, a few founders have left many descendants, and about a third of the black rhinos and about half of the while rhinos in captivity are wild-caught animals that have never bred. Thus, the captive population should be in reasonable shape genetically, but a large number of wild-caught animals have been wasted with respect to genetic and demographic goals of captive breeding.

Analysis of demographic stability of small populations of rhinos

Even if a population is growing, on average, random fluctuations in births and deaths can lead to chance extinction of a small population. Once a population has grown to large size, such chance extinction is unlikely. I used a population stimulation program written by James Grier of North Dakota State University to examine the likelihood of success (non-extinction) of rhino populations started from small numbers of founders. The intent was to provide some rough guidelines for the re-establishment of populations in reserves. The simulation model *very* optimistically assumes that births and deaths are random processes that occur with some constant probability in each year. Thus, fates of individuals are independent; good years and bad years are due to accidental concordance between reproduction and mortality within the population; no environmental fluctuations exist that would cause population-wide trends in reproduction and mortality. Because environmental fluctuations do exist in the wild and do affect populations as a whole, the results below should be thought of as upper limits on the likelihood of a small population persisting.

The demographic parameters input into the model were obtained from field data on East African black rhino populations, gleaned from AERSG reports, reports of Peter Jenkins to Kenyan authorities, and other published and unpublished sources. Rhinos were assumed to be capable of breeding at age 7, with each adult female producing offspring in 28% of the years (3.57 year average interbirth interval).

Juvenile (first year) mortality in the wild has been reported to be about 16%, with 5 to 10% annual mortality of adults. I explored the models with 13%, 15%, 16%, or 20% juvenile mortality, and 5%, 6%, or 6.808% adult mortality. This last value of adult mortality would lead to a stable, non-growing population when juvenile mortality was 16%. Higher values of adult mortality were not modelled (even though higher values have been recorded in the field), because they would lead to precipitous declines in the population and thus extinction of the population would be virtually certain. Either 10 or 20 animals were used to begin each simulated population, and populations were followed for 85 or 170 years (5 or 10 generations). Table 9 gives the expected reproductive rates (Ro, population growth per generation, determined from life table analysis, not from the simulation program), the percent of the simulated populations (out of 100 in each case) that did not go extinct in the time span considered, and the average population size at the end of the simulation of those populations that survived. Not all combinations of parameters were tested.

Over the time span considered, random fluctuations in births and deaths would lead to the extinction of relatively few populations of rhinos that have long-term average growth rates greater than one. However, the field estimates of birth and death rates, if accurate, mean that rhino populations have very low net reproductive rates (not a surprise), and that even slight increases in deaths or decreases in births will lead to long-term decline rather than population growth. Note that the claimed rates of population growth in some game reserves (e.g. those in South Africa) do not seem compatible with the reported birth and death rates that were used in this model.

To a considerable extent, the high rate of population survival in this model results from the short time span considered and the lack of any limit to population growth. Because rhinos are so long-lived, even a declining population has a reasonable chance of surviving 85 to 170 years. Because no upper limit was put on population growth, some simulation populations grew to more than 100 individuals and thus became fairly immune to random processes.

Adult mortality affects the growth rate and persistence of the populations more than does juvenile mortality; even slight increases in adult mortality have very large effects, while small increases in juvenile mortality have little effect.

Loss of genetic variability in black rhino reserves in Kenya

Soon, few black rhinos will exist outside of carefully managed and guarded parks and reserves. One consequence will be that formerly contiguous populations will be isolated and, unless animals are moved between reserves, inbreeding and loss of gene diversity within the populations could lead to their demise. (Because of the slow growth of rhino populations, even moderate inbreeding depression could cause populations to decline). I used a simulation program to examine the loss of genetic diversity from semi-isolated populations of black rhinos remaining on reserves in Kenya. The simulation program models the random transmission of genes through generations, given input parameters for population sizes, migration rates, population growth rates, limiting population sizes, and (though not shown here) mutation, and selection. Although the model assumes random mating within each population, population censuses can be (and were) adjusted to produce estimated genetically "effective population sizes", Ne (the size of a randomly mating population that would lose genetic variability at the same rate as does the real population).

Eight Kenyan populations that have a reasonable probability of receiving sufficient protection from poaching were considered. Estimated population sizes and carrying capacities were obtained from reports by Peter Jenkins and others. It was assumed that only those rhinos within areas proposed to be fenced would be protected from poaching. The ratio of effective population size to census population size was perhaps optimistically assumed to be 1:2.

Simulations were run assuming that each population started growing from its 1985 numbers, with growth rates of 25%, 50%, 129%, 216%, or 270% per generation (1.3%, 2.4%, 5%, 7%, or 8% per year). The first two growth rates match some of the more optimistic, but not unrealistic, growth rates obtained from demographic analyses. The latter three match estimates reported at the Cincinnati meeting for variability after populations reached carrying capacity, simulations were also run assuming that each population was begun at its carrying capacity. In all cases, random demographic fluctuations were incorporated into the population sizes, modelling the fluctuations that would be expected if births and deaths were independent (Poisson) processes.

Table 9. Results of simulation study of extinction in small populations of rhinos.

Juvenile mortality %	Adult mortality %	Number founders	R_0	85 years % surviving	85 years N	170 years % survivng	170 years N
13	5	10	1.35				
		20	1.35				
	6	10	1.12	90	34	82	168
		20	1.12	100	74	96	251
	7	10	0.94	68	16	48	50
		20	0.94	92	32	86	60
15	5	10	1.32	93	93		
		20	1.32	100	152		
	6	10	1.10	85	36	74	154
		20	1.10	98	61	96	259
16	5	10	1.30	95	86	94	711
		20	1.30	100	136		
	6	10	1.08	89	43	70	146
		20	1.08	98	62	95	215
	6.808	10	1.00	37	14	18	56
		20	1.00	72	19	52	41
		40	1.00	94	33	76	62
		80	1.00	100	64	98	97
20	5	10	1.24				
	6	10	1.03	87	34	67	100
	6	20	1.03	97	55	96	149

Table 10. Population estimates used in analysis of gene diversity.

Park	1985 *Census*	1985 *Ne*	Carrying Capacity *Total*	Carrying Capacity *Fenced*	*Ne*
Aberdare	60	30	600	100	50
Amboseli	15	7.5	150	50	25
Laikipia	60	30	50	50	25
Masai Mara	12	6	180	50	25
Meru	5	2.5	300	20	10
Nairobi	28	14	50	50	25
Nakuru	2(10)	5	80	80	40
Solio	71	35.5	50	50	25

Notes: Although Nakuru had only 2 rhinos in 1985, it was assumed that more would be brought in, bringing the number used to start that population to perhaps 10. Based on reports of habitat degradation, it was assumed that the Solio population was currently above its long-term carrying capacity.

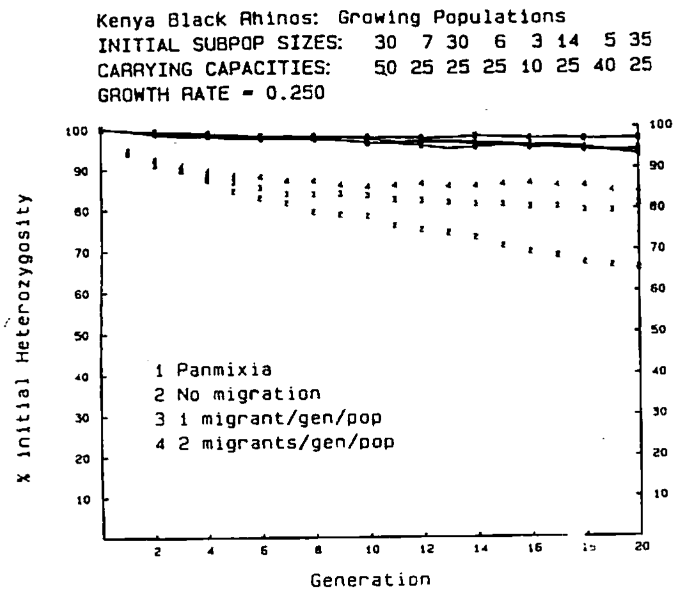
The genetic fates of the populations were monitored by the percent of the initial heterozygosity that would be expected to remain in each population, and by the overall gene diversity (the sum of within-population variability and between-population genetic variability), encompassed by the eight populations. The overall gene diversity can be thought of as the heterozygosity that would be present if all eight populations freely interbred. Populations were followed through 20 simulated generations (about 340 years).

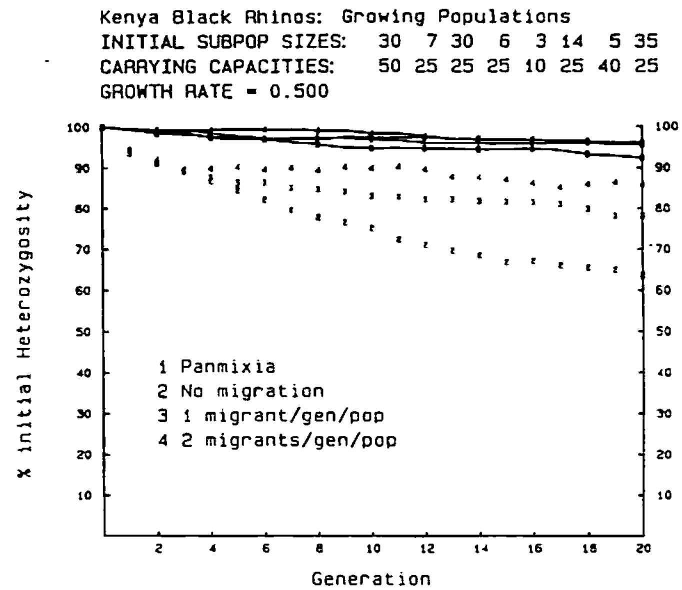
The fate of gene diversity over the twenty simulated generations is shown on the four accompanying figures, for either 25% or 50% population growth per generation, and either growth from 1985 levels to carrying capacities ("growing populations") or populations begun at carrying capacities ("stable populations"). In each case 25 simulations were run with no movement of animals between populations, the movement of one animal per generation per population, the movement of two animals per generation, and the movement of so many animals that the populations were essentially panmictic. Data points connected by lines display average (across 25 runs) of the total gene diversity present across all 8 populations at each generation; data points not connected by lines are the average within-population heterozygosities.

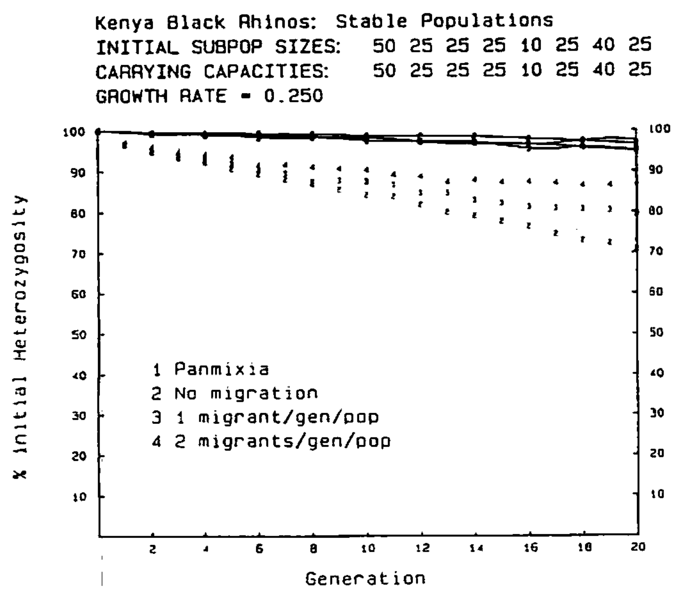
Table 11 summarizes the simulation results for the cases shown in the figures, and also simulated populations with higher rates of population increase (average of 25 simulations in each case).

Over just 20 generations, more than 95% of the gene diversity would be expected to remain somewhere in the 8 rhino populations, assuming of course that all grow at the rates modelled and then hover around the assumed carrying capacities. Total gene diversity is preserved somewhat better if the 8 populations are kept fully isolated ("no migration" case), because different genetic variants can become "fixed"

Figures 4-7. Results of simulation study of decline of heterozygosity in small populations of Kenya rhinos. These graphs correspond to data in Table 11. Data points connected by lines represent average (of 25 runs) of the total gene diversity across all 8 populations of each generation. Data points not connected by lines are the average within-population heterozygosities. The graphs differ in the growth rate of the population per generation (25% or 50%) and whether the populations commence at 1985 levels (growing populations) or at the ultimate carrying capacity estimated for the reserve (stable populations).







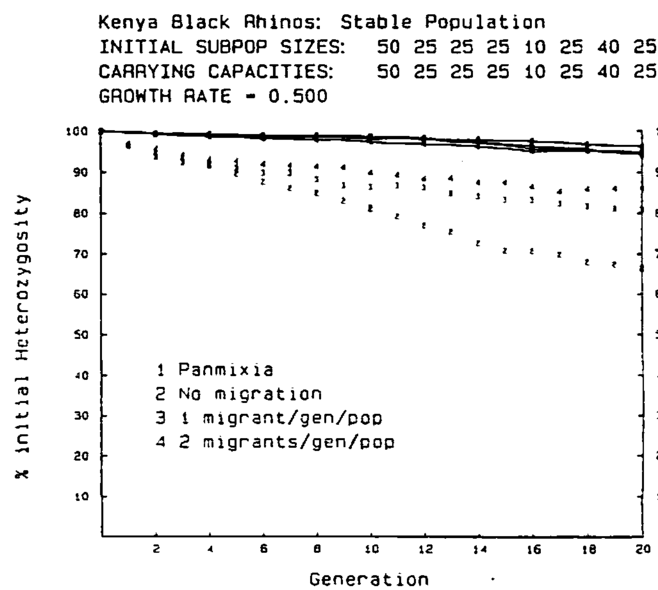


Table 11. Heterozygosity remaining at generation 200 as % of initial heterozygosity.

Annual growth	Generation growth	No migration	1 migrant	2 migrants	Panmixia
1.3%	25%	97	95	93	94
		66	81	84	94
2.4%	50%	96	92	95	96
		64	78	86	96
5.0%	129%	93	95	95	97
		63	81	87	97
7.0%	216%	95	94	95	96
		69	80	87	96
8.0%	270%	97	98	92	96
		64	80	84	96

Top values of each pair are average total gene diversity, bottom values are average within-population heterozygosities. Differences of less than 5% are probably not significant.

in each population, but the difference (in gene diversity preserved) between isolated populations, populations exchanging some migrants, and even a panmictic population is trivial for the rhinos.

Although total gene diversity is well maintained under all of the assumed population structures, heterozygosity is lost from within populations (i.e. some "inbreeding" occurs within each population). In the worst case (no migration), up to 35% of the heterozygosity would be lost, on average, from each isolated population. The average results from a much greater loss in the smaller populations (the Meru population would be expected to lose 64% of its heterozygosity in 20 generations, even if it were begun at its carrying capacity of 20) countered by lesser losses in the larger populations (Aberdare would lose about 18% of its heterozygosity in 20 generations). As very rough rules-of-thumb, the effect ("inbreeding depression") of a loss of less than 5% heterozygosity in any one generation is generally hard to detect, and animal breeders notice little or no effect of the loss of 1% heterozygosity per generation continued over many generations. Thus, the small rhino reserves are probably too small to sustain populations for many generations, in the absence of occasional inter-reserve movements of animals, free from genetic problems. Relatively low rates of migration, 1 or 2 migrants per generation per population, would probably be sufficient to prevent genetic problems. (This assumes migrants are as successful as are residents at breeding).

Neither starting the populations at carrying capacity (rather than 1985 levels) nor varying the population growth rate had much effect on the genetic results. This is because only rapidly growing populations were considered. At even the lowest population growth, 25% per generation, most of the populations would reach carrying capacities in just a few generations. The genetic fates of these populations are much more determined by their limited sizes than by the number of founders.

General comments

Rhinos, both in the wild and in captivity, are probably not in immediate danger of genetic problems arising from loss of diversity. Given the long generation time, all except the very smallest captive and wild stocks would experience minimal inbreeding in the next century or so. (For example, a population of 64 could be propagated for 6 generations with no matings between even distantly related animals). This optimistic genetic picture assumes, however, that protected rhino populations are currently at minima (i.e. they are at the worst phase of the population bottlenecks) and that they grow at reasonable rates over the next century.

Demographically, both wild and captive populations may be in serious trouble. The captive record is not good: as many as half of the animals have never reproduced, and birth rates approximately equal death rates. The large, and seemingly stable, captive population results in large part from the many wild-caught animals, not from a good record of captive breeding. As discussed in Cincinnati, there is reason to hope that this picture is changing, but the zoo community cannot yet claim to be able to sustain continuously growing stocks of black and white rhinos.

The small rhino reserves that are likely to receive adequate protection from poaching may not be large enough to prevent extinction due to random fluctuations in births and deaths, even under the most optimistic scenarios of environmental and demographic constancy. The primary cause for hope for the African rhinos lies in the very long generation times and low adult mortality (in the absence of poaching): traits that make population decline a very slow process, but also make rapid recovery difficult (witness the condor).

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DEVELOPING STRATEGIES FOR NORTHERN WHITE RHINOS

Session Chairman DAVID JONES

NORTHERN WHITE RHINOS IN GARAMBA NATIONAL PARK

Summary of presentation by Kes Hillman-Smith

Background

Garamba National Park in northern Zaire is now the last known place where the northern sub-species of white rhinoceros *(Ceratotherium simum cottoni)* exists in the wild with any chance of survival. At the turn of the century, the sub-species occurred from southern Chad, through South Sudan as far east as the Nile, and through the northern edge of Zaire to West Nile Province in Uganda (Hillman—Smith *et al.*, 1986).

When the Park was established in 1938 there were probably not more than 100 white rhinos there (Curry-Lindahl, 1972). Black rhinos *(Diceros bicornis)* have never occurred in this part of Zaire. The rhino numbers increased, until by 1963 there was estimated to be between 1 000 and 1 300 rhinos (Park reports in Curry-Lindahl, 1972). Then, during the "Simba" rebellion, the Park was occupied by guerillas and poaching from Sudan was rife. Curry-Lindahl states that approximately

Suggested Procedure for Priority Ranking of Black Rhino Populations

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Preamble

Systems for establishing priorities for action to conserve remaining black rhino populations have been developed at the Hwange (1981) and Nyeri (1987) meetings of AERSG. These systems are worthwile in that they lead those who are assessing priorities through a systematic process in which due consideration is paid to a full range of relevant factors. In order to produce final rankings, each area is given scores for the various factors that are considered relevant (e.g population size, genetic rarity, ecosystem diversity) and the scores for an area are then added to produce a total score to represent that area's priority in continental black rhino conservation initiatives.

A central problem with these systems is that weightings for the factors have arisen in an arbitrary way. Rigorous methodology for establishing the weighting (importance) of one factor relative to another, for the whole range of conservation situations within the species' range, has not been developed. In view of this, an alternative procedure for establishing rhino conservation priorities — with more flexibility in incorporating subjective value judgements — is proposed.

The information on rhino populations is derived from that presented at the 1987 AERSG meeting, at Nyeri, Kenya (the proceedings of the meeting are currently being published by IUCN).

Reasons for ranking

The design of a system for establishing the priority areas for rhino conservation is obviously dependent upon the objectives of the desired conservation action. These objectives are seen as:

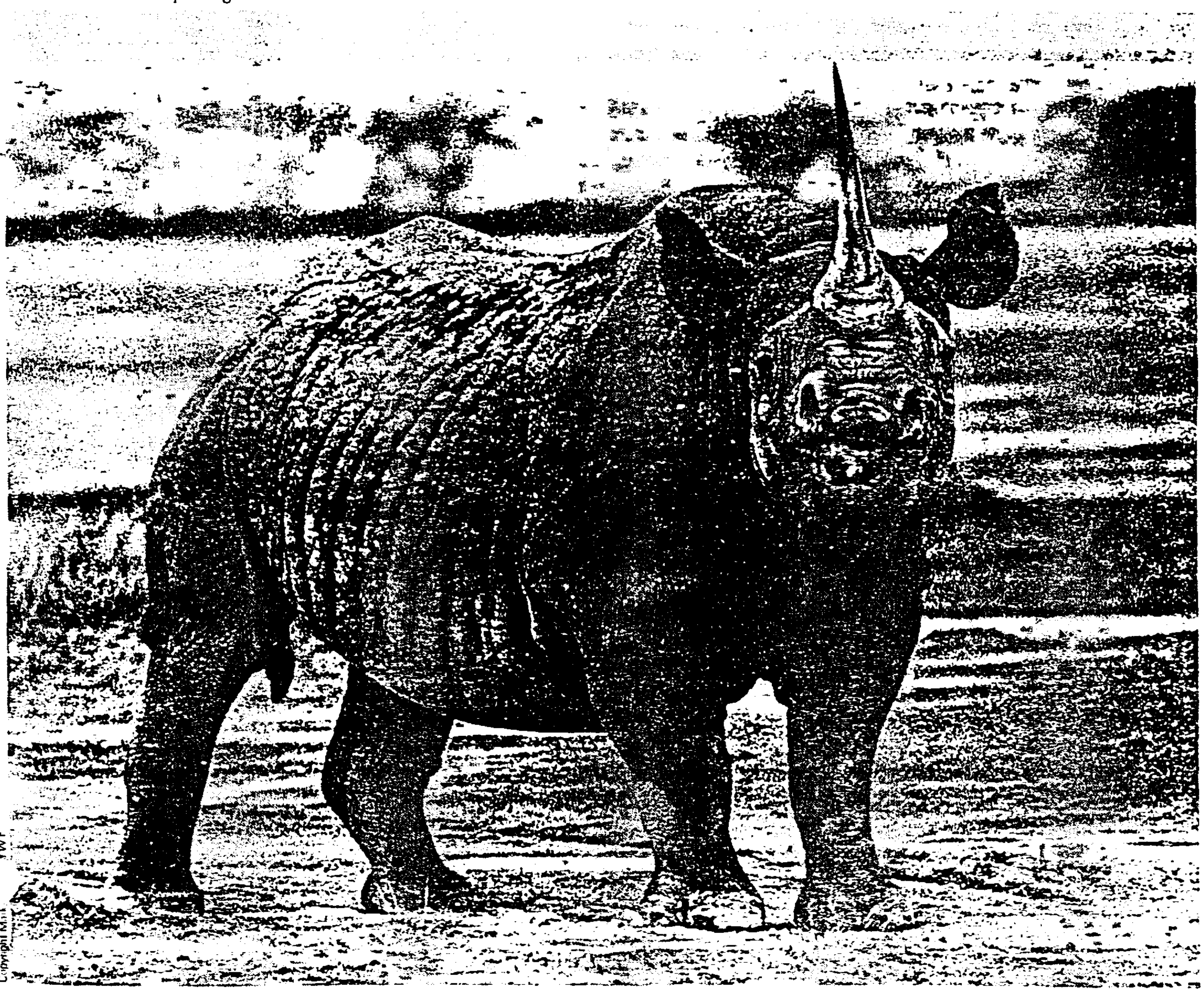
- To build up numbers of black rhinos in Africa as quickly as possible;
- To maintain the existing genetic variability within and between the remaining black rhino populations in the wild.

If these objectives are accepted by international conservation agencies that are able to allocate funds, expertise and other assistance to support rhino conservation efforts in Africa, then a role of AERSG is to indicate, to these agencies, which rhino populations should be the first ones to receive attention in order to meet the objectives.

Main factors to consider in the ranking system

The most important feature of each population (with regard to both objectives outlined above) is simply its size. The current population should be considered together with the likely population that will be present in that area in several years' time, following additions due to natural increase and reductions due to poaching. A five-year time horizon seems reasonable when considering rhino conservation initiatives for particular areas, given the uncertainties associated with poaching activity, government action and land-use changes within Africa. Where rhino populations are

Black rhino contemplating the camera man.



expanding in small areas, consideration must be given to carrying capacity; but if it is expected that carrying capacity will be exceeded within five years this need not be regarded as a negative feature since the excess rhinos can be translocated, to restock other areas.

The contentious issue of the likely effectiveness of aid provided by external agencies is best tackled by letting the record speak for itself, i.e. if local rhino conservation efforts have been inadequate (for whatever reason) and therefore do not give grounds for optimism that putting more money in will achieve much, then this will be reflected in the rhino population trends. Since it is one of AERSG's functions to monitor population trends, we can present reasonable estimates of the decline due to poaching in each area over the last five years, and extrapolate with this trend and with the estimated current population to indicate what the population may fall to in five years' time if no additional conservation effort is made.

The assumption that poaching in a large wildlife reserve will continue at the present rate is possibly questionable. For one thing, as the density of rhinos decreases, the ease with which the remaining animals can be found by poachers may diminish. However, as the rhino density decreases, it also becomes more difficult for the animals to maintain breeding contact, and so the natural rate of increase will also diminish — thus one effect offsets the other. Even if the estimates of future poached rhino populations are unreliable, this is not a crucial deficiency because the object of the exercise is primarily to present a reflection of the prevailing social/political/economic climate for conservation in each area.

Genetic rarity is obviously an important factor to consider. The difficulty of assigning weightings to the postulated races/subspecies of black rhinos may best be circumvented by allowing the judgement of the genetic rarity value of one rhino group versus another to remain an intuitive process — including the opinions of all AERSG members – so that a group consensus emerges without need for questionable numerical manipulations.

A major weighting factor in the previous ranking systems has been the "conservation importance", or "ecosystem diversity", of each area. This is obviously an important consideration for conservation funding agencies, since they are concerned with the protection of complete ecosystems containing key species in addition to the black rhino. However, it is perhaps best not to confuse too many issues; if AERSG can present a priority ranking simply for black rhinos, other groups in SSC/IUCN, WWF or other agencies can then attempt to mesh this list with the priorities for other organisms. There may well be a degree of "double-counting" if the AERSG rhino priorities include some consideration of ecosystem diversity, other rare organisms, etc., and these factors are again automatically considered at a later stage when the list of top rhino areas is compared with the lists of areas that are important for other African species, as is presumably done when funding bodies decide where to put their money.

To give initial consideration to the ecosystem diversity aspect, it is suggested that the classification that emerged in the IUCN survey of phytochoria in the Afro-tropical realm is simply shown for each area (where possible) once the final priority ranking has been derived.

The importance of establishing closely-managed rhino sanctuaries in several areas, as a safeguard against the loss of further large wild populations, is becoming increasingly evident. The strategic value of these sanctuaries must be weighed against their high costs and management problems (including the need to avoid future genetic problems); some conservationists may believe that an established or proposed sanctuary has higher priority for support than some efforts to conserve larger populations in poorly-protected areas. Allowance should be made for the incorporation of such views within the ranking system.

The suggested procedure

1. List all the areas in Africa which have 5 or more black rhinos (Table 1, column 1). For each, establish the areal extent (col. 2), the current rhino population (col. 3), and the population 5 years ago (col. 5). Indicate the reliablity of this information (col. 4 and 6), using the following codes:

1 count of known individuals;
2 estimate from rhino survey carried out within the previous 2 years;
3 estimate based on non-specific survey, or rhino survey carried out over 2 years previously;
4 informed guess.

2. From the estimate of the current population and that of the population 5 years ago, calculate the percentage decline in the population due to poaching over this period (col. 7). There may be a few exceptional cases in which a population has declined due to reasons other than poaching – e.g. Hluhluwe/Umfolozi – and these may require explanation in footnotes to the table.

3. Apply the rates of poaching to the current population estimates to obtain estimates of the population levels in 5 years, if poaching continues at present levels (col. 8).

4. For each population, obtain an estimate of the rate of natural increase, r (col. 9). This will vary according to habitat quality, and especially according to rhino density, being low at very low and probably very high densities, and at its highest when populations have not yet reached the carrying capacity of the areas within which they are confined. (If the rate of increase is 5% per year, r=0.05).

5. Calculate the population of 5 years hence (col. 11), presuming that

Table 1: Basic demographic data (as known in 1987)

1 Population	2 Area km2	3 1987 Pop.	4 Rel.	5 1982 Pop.	6 Rel.	7 Poaching crease 5yrs	8 Poached Loss	9 Natural In- 5yrs	10 Carrying Capacity r	11 Natural Pop. in 5yrs
Zambezi	13000	750	3	1000	4	25%	560	0.07		1050
Sebungwe	10000	650	3			5%	618	0.07		912
Etosha	22270	350	3	275	3	0	(447)	0.05		447
Hwange/Mat	18400	300	3			0	(401)	0.06		401
Umf./Hluh.	900	220	2			0	(220?)	0	300	220?
Selous	55000	200	4	2000	4	90%	20	0.03		232
Tsavo	20200	150	4	300	4	50%	75	0.03		174
Kruger	19485	140	2			0	(205)	0.08		205
Kaokoveld	70000	90	2	50	4	?	(115)	0.05		115
Solio	62	75	1			0	(110)	0.08	40	110
GonareZhou	5000	75	3	100	3	25%	56	0.06		100
Luangwa	16600	75	4			70%	23	0.04		91
Mkuzi	251	70	2			0	(94)	0.06	70	94
Aberdares	700	60	4	132	3	55%	27	0.05		77
Laikipia	350	47	1			0	(63)	0.06		63
Ndumu	100	42	2			0	(56)	0.06	40	56
Nairobi	120	40	3	20+	3	?	(56)	0.08	40	56
Mnt. Kenya	700	40	4	40?	4	?	(46)	0.03		46
Itala	297	35	2			0	(47)	0.06	60	47
Cameroon/Ch.	5000	30	4	100	4	70%	9	0.02		33
Pilanesburg	500	27	2			0	(38)	0.07	120	38
Ngorongoro		25	4	50	4	50%	12	0.05		32
Rubondo	460	25	4			?	(32)	0.05		32
Nakuru	140	20	1				(27)	0.06	40	27
Kasungu	2300	20	4	30	4	33%	13	0.03		23
Kafue	22400	20	4			70%	6	0.02		22
Masai Mara		19	1	30	3	37%	12	0.03		22
Ngeng Valley	500?	18	2			50%	9	0.04		22
Addo	80	17	1			0	(25)	0.08	30	25
Akagera	2500	15	4			?	(18)	0.04		18
Lewa Downs	20	11	1			0	(15)	0.06	15	15
Amboseli	400	11	1	17	1	33%	6	0.05		14
East Shores	800	10	1			0	(14)	0.07	40	14
Iwaba	98	8	1				(11)	0.07	30	11
Ol Jogi		7	1			0	(9)	0.06		9
Weenen	49	6	1			0	(8)	0.07		8
Aughrabies	650	5	1				(7)	0.07	30	7
Meru	870	5	4	30	4	80%	0	0.04		6
Manyara	320	5	4	10	4	50%	0	0.04		6
Mwabvi		?								
Angola		?								
Mocambique		?								
Ethiopia/Sudan/										
Somalia		?								
TOTALS		3713					+/-3500			+/-4880

Information on 1987 populations from AERSG meeting, Nyeri, May 1987.

poaching ceased immediately and the population expands at the natural rate. The equation is:

$$N5 = No\,(1+r)^5$$

where N5 is population in 5 years
No is current population
r is rate of natural increase.

6. For each area, establish what the ranking is for its current population, for its future population with unabated poaching, and for its future population with natural increase (Table 2). Add the three ranks together. Rerank the areas according to the sum of the three subsidiary ranks (ranking areas from lowest to highest totals). This effectively ranks the areas on the basis of their current populations with moderation according to possible natural increases and current poaching pressures.

Table 2: Ranking of areas for population importance

Population	Rank for current population	Rank for 5yr Poached population	Rank for 5yr Natural population	Sum	Overall rank
Zambezi	1	2	1	4	1
Sebungwe	2	1	2	5	2
Etosha	3	3	3	9	3
Hwange/Matetsi	4	4	4	12	4
Umfolozi/Hluh.	5	5	6	16	5
Selous	6	20	5	31	9
Tsavo	7	10	8	25	7
Kruger	8	6	7	21	6
Kaokoveld	9	7	9	25	7
Solio	10	8	10	28	8
Gona-re-Zhou	10	12	11	33	11
Luangwa	10	19	13	42	13
Mkuzi	11	9	12	32	10
Aberdares	12	17	14	43	14
Laikipia	13	11	15	39	12
Ndumu	14	12	16	42	13
Nairobi	15	12	16	43	14
Mount Kenya	15	14	18	47	16
Itala	16	13	17	46	15
Cameroon/Chad	17	27	20	64	20
Pilanesburg	18	15	19	52	17
Ngorongoro	19	25	21	65	21
Rubondo	19	16	21	56	18
Nakuru	20	17	22	59	19
Kasungu	20	24	24	68	22
Kafue	20	30	25	75	25
Masai Mara	21	25	25	71	23
Ngeng Valley	22	27	25	74	24
Addo	23	18	23	64	20
Akagera	24	21	26	71	23
Lewa Downs	25	22	27	74	24
Amboseli	25	30	28	83	28
Eastern Shores	26	23	28	77	26
Iwaba	27	26	29	82	27
Ol Jogi	28	27	30	85	27
Weenen	29	28	31	88	30
Aughrabies	30	29	32	91	31
Meru	30	31	33	94	32
Manyara	30	31	33	94	32

7. In plenary session, classify the areas, in their order of importance, into three categories according to their need for external assistance: urgent, moderate and low (Table 3). If any participant disagrees strongly with the classification for a particular area, the general opinion should prevail as the individual will get an opportunity for his/her viewpoint to be taken into account at a later stage.

8. Produce a simple analysis of the current classification system that has been adopted by AERSG to separate the various populations into "subspecies"/races/ecotypes/evolutionarily significant units (or whatever terminology is thought appropriate to describe interpopulation genetic variability), indicating the current numbers, and possible future numbers in 5 years, of rhinos belonging to each conservation unit (Table 4).

9. Give each participant a copy of Tables 1, 3 and 4. He/she is then asked to list the areas in order of importance, taking into account either the group's or his/her own viewpoint on each area's actual requirement for assistance, the need to maintain interpopulation genetic variability, and the need to develop sanctuaries rather than placing continuing emphasis on populations in large "protected" areas. If the participant disagrees with any of the figures in Table 1, or any of the procedures, then this stage gives him/her an opportunity to produce an independent ranking.

In other words, the analysis so far serves as a guide to the individual's decision-making, and need not be regarded as the final statement. If the participant is in fact satisfied that population size is the most important aspect, that the figures in Table 1 are reasonable, that consideration of poaching pressure has effectively side-stepped the thorny question of deciding whether it is worth putting money into an area (with current levels of anti-poaching performance), and that the assessment of requirements for external assistance is acceptable, then all he/she needs to do is to moderate Table 3 according to considerations of genetic rarity.

10. Once each person has produced a listing, all the ranks given to each area can be added and the areas reranked according to their total scores (as in stage 6).

11. This new listing can then be circulated for participants to once more review the ranking that has emerged from the group as a whole and change the order if they feel it is appropriate to do so.

12. The ranks can then again be added and a final listing produced, which represents the overall opinion of the group as to where international conservation agencies should direct their money, etc. for rhino conservation. The IUCN phytochorial classification can be shown for those areas to which it has been applied. For each area, existing or planned national or externally-supported rhino conservation intitiatives (or other projects that would help the rhinos) should be outlined, so AERSG can specify the kinds of activities and level of funding that are still required.

Notes

1. The procedure in stages 9-12 is an application of the Delphi process used in business decision-making. This process of iterative review has been found to be extremely successful in reaching a group consensus on issues where value-judgements are involved, and where one or two vociferous or authoritative individuals would otherwise tend to dominate the development of a group's viewpoint. It provides a means of blending the group's reasonably factual knowledge on the status and trends of rhino populations, and potentials for population expansion, with the subjective aspects (requirements for funding and considerations of genetic rarity).
2. While this may seem a lengthy process, the time taken in plenary session is relatively short: the generation of the raw data in Table 1 (although ideally this would be simply a review of data obtained from recent questionnaire returns, and collated prior to the meeting), the classification of areas according to their requirements for external assistance, and the final review of the ranking. The ranking of areas by individuals (stages 9–11) can be carried out during breaks in the meeting. If time is short, these stages could be side-stepped by the Chairman simply producing a priority list (stage 9) and presenting this to the group for endorsement or modification. To carry out the exercise entirely by correspondence would be a feasible, if somewhat protracted process.
3. The system can be refined if more information becomes available on the relationship between poaching offtake and density of rhinos, under different levels of protection (thus enabling a more accurate assessment of likely rates of poaching over the next 5 years). Also, if we know what range is occupied by rhino in each conservation area, what the existing

Table 3: Requirements for assistance from external agencies

Pop rank	Urgent	Moderate	Low
1	Zambezi		
2		Sebungwe	
3			Etosha
4			Hwange/Matetsi
5			Umfolozi/Hluhluwe
6			Kruger
7	Tsavo		
7		Kaokoveld	
8			Solio
9	Selous		
10			Mkuzi
11	Gona-re-Zhou		
12		Laikipia	
13			Ndumu
13	Luangwa		
14			Nairobi *
14		Aberdares	
15			Itala
16		Mount Kenya	
17			Pilanesburg
18	Rubondo		
19			Nakuru *
20	Cameroon/Chad		
20			Addo
21	Ngorongoro		
22		Kasungu	
23		Masai Mara	
23	Akagera		
24	Ngeng Valley		
24		Lewa Downs	
25	Kafue		
26			Eastern Shores
27			Iwaba
28			Amboseli *
29			Ol Jogi
30			Weenen
31			Aughrabies
32	Meru		
32	Manyara		

* Takes into account high levels of external assistance already being provided and/or high tourism development which should generate sufficient revenue to protect spectacular animals.

levels of anti-poaching effort are (in monetary terms: expenditure per square kilometre) and what the level of tourism development is, we can start to put significant brakes on the poaching declines anticipated in the problem areas.

4. Funding agencies can easily review the requirements for assistance (Table 3); if they disagree with the AERSG assessment, they can modify rankings accordingly.

5. By requiring estimates to be made of specific rates of reproduction and poaching rates, AERSG can improve its understanding of these aspects, when projected populations are compared with actual populations in years to come.

6. The assessment of likely population levels, taking natural increases and poaching attrition into account, assists in setting realistic population targets for the continental rhino conservation effort. Targets that might be set for the next 5-year period are population increases to the following levels:

Western Central Africa – 50 (this would require translocations and intensive management).
South Western Africa – 550
South Central Africa – 3,000
Eastern Africa – 650

TOTAL – 4,250 in 1992.

Table 4: Provisional genetic grouping of black rhino
(Following recommendations of Cincinnatti Rhino Workshop, 1986)

Conservation Unit	Current Population	Natural Pop. in 5 yrs	Poached Pop. in 5 yrs
West-Central Africa			
Cameroon/Chad	30	33	9
South-Western Africa			
Etosha	350		
Kaokoveld	90		
Aughrabies	5		
	445	569	500?
South-Central Africa			
Zululand to Southern Tanzania	2648	3524	2390
Eastern Africa			
Northern Tanzania – Kenya	590	754	542

Note: Where possible, viable rhino populations should be conserved in the different major ecological zones within the above broad conservation units, in order to maintain adaptations to local conditions; e.g. it is desirable to maintain the Tsavo population as a separate subunit in the Eastern Africa unit – provided there are sufficient founders to prevent inbreeding – rather than immediately mixing them with the other Kenyan populations (which are probably not large enough to be managed without genetic mixing, or have already been mixed).

Acknowledgements

David Cumming and Michael Soule commented on earlier drafts of this paper.

l'Union mondiale pour la nature
The World Conservation Union

Secrétariat de l'UICN
IUCN Headquarters

SEP 1991

Dr Thomas J. Foose
Executive Officer
Captive Breeding Specialist Group
12101 Johnny Cake Ridge Road
Apple Valley, MN 55124
UNITED STATES

Gland, 12 September 1991 SSG/M24/M

Dear Tom,

I am pleased to enclose the report of the IUCN/SSC African Elephant and Rhino Specialist Group meeting, held in Gaborone, Botswana, on 2-5 July 1991. I hope you find this useful.

With best wishes,

Yours sincerely,

Simon N. Stuart
Head
Species Survival Programme

Encl. as mentioned

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IUCN - THE WORLD CONSERVATION UNION
SPECIES SURVIVAL COMMISSION

AFRICAN ELEPHANT AND RHINO SPECIALIST GROUP

2-5 July 1991
Gaborone, Botswana

SUMMARY OF DECISIONS TAKEN

1. The AERSG will be split into two Groups: the African Elephant Specialist Group (AESG) and the African Rhino Specialist Group (ARSG). Dr Martin Brooks has been appointed Chair of the ARSG. The leadership of the AESG will be appointed shortly.

2. Terms of reference were agreed for the new Specialist Groups, and these are attached as Annex 1. These terms of reference uphold the role of the Groups as technical advisory bodies, and as promoters of conservation action. The Groups will not attempt to develop major policy, especially on controversial issues.

3. The AESG and ARSG will liaise closely with each other on many issues, including meetings and Pachyderm.

4. The following decisions were taken concerning Pachyderm:

   (a) In future, articles should be accepted in both English and French. Each article should have a summary in the "opposing" language.

   (b) The editor was asked to present a summary of the financial picture, as regards printing and distribution. This is attached as Annex 2.

   (c) Pachyderm should be circulated as widely as possible, especially to all relevant government agencies and non-governmental organizations in Africa. No subscription should be charged. Funds should be sought to cover the extra costs of wider free distribution.

   (d) Pachyderm should continue to receive both scientific papers and feature articles.

   (e) There should be regular liaison with the Asian Elephant and Asian Rhino Specialist Groups to include news of their activities in Pachyderm.

5. Elephant population estimates were reviewed for the African continent, and agreed figures are given in Annex 3. The meeting also made the following decisions:

   (a) Data were too poor from some countries to allow any population estimate to be made. These countries are: Angola, Ghana, Guinea, Mozambique, Nigeria, Sierra Leone, Somalia, Sudan and Zambia. As a result, no continental total for elephants can be estimated at present, and the addition of the country totals in Annex 3 will give a population estimate considerably less than the true continental total.

(b) It was agreed that very high priority should be given to filling the current gaps in knowledge on elephant distribution and numbers.

(c) It was noted that elephants have now been extirpated in Mauritania. It was agreed that once elephants have been extirpated in a country, that country should no longer be considered an elephant range state, unless a serious re-introduction programme is initiated.

6. The following decisions were taken concerning the African Elephant Database:

(a) The AESG should take full responsibility for what should be known as the "AESG African Elephant Database".

(b) Funds should be sought, possibly from the EEC, to enable the database to be continued after the present funding runs out in March 1992.

(c) It was agreed that discussions should be held with the World Conservation Monitoring Centre concerning the possibility of providing them with a copy of the database in return for other datasets being made available to the members of the AESG. Some concerns were expressed, in particular regarding WCMC's policy of selling data. The meeting considered that the data should be freely available to all users. There should be a report back to the next meeting of the AESG on all the aspects of an AESG-WCMC agreement on the database before any final decision and commitment could be made.

(d) It was emphasised that continued updating of the database should take place in Africa.

(e) It was agreed that a "user-friendly" guide to the possibilities of the database should be made available to AESG members, perhaps through the medium of Pachyderm.

7. It was agreed that the Specialist Groups should continue to prepare and update Action Plans which should assess the biological priorities on a continental basis. However, information was not available to allow this process to take place during the current meeting, but it would be pursued in future meetings. For the same reasons, the meeting felt unable to update the AECCG Action Plan as had been requested; however, it was recommended that the AECCG should prepare an overview document for the range states meeting in Nairobi, which would review priorities from the individual country action plans.

8. The francophone elephant subgroup produced a report on their deliberations, which is included in Annex 4.

9. The ARSG reviewed rhino numbers throughout Africa, and their report is included as Annex 5.

10. Other conclusions relating to the ARSG are included as Annex 6.

ANNEX 1

IUCN SPECIES SURVIVAL COMMISSION
African Elephant Specialist Group
African Rhino Specialist Group

Terms of Reference

Mission: To promote the long-term conservation of Africa's elephants and rhinos, and, where necessary, the recovery of their populations to viable levels.

Objectives:

1. To provide and improve technical information and advice on the conservation of Africa's elephants and rhinos to the following clients:

   a) government range state management agencies.
   b) non-governmental conservation organizations, including both international and African-based organizations.
   c) inter-governmental organizations
   d) non-range state governments.

   Special effort will be made to target outputs in a manner that meets the needs of the different clients.

2. To promote and catalyse conservation activities on behalf of Africa's elephants and rhinos, to be carried out by the clients listed above.

Activities:

1. To review, ideally on an annual basis, the status and trends of elephant and rhino populations in Africa.

2. To assess the impact of utilization and other human activities on these populations.

3. To undertake analyses of these data to assess conservation priorities, and to use these as the basis for regularly updated Action Plans. The Elephant Action Plan should appear in both English and French.

4. To assess the options for conservation action through interaction with governments on both national and regional bases, thereby providing technical support for the development of conservation strategies, and for promoting their implementation.

5. To facilitate coordination and cooperation in conservation-related research on these species to ensure that lessons learned can be disseminated and applied as widely as possible.

6. To evaluate the effectiveness of different forms of conservation action, thereby advising the different clients on the implications of various policy options.

7. To produce a joint newsletter and journal of the two Specialist Groups, Pachyderm, accepting articles in both English and French, with summaries of each article in both languages.

8. To liaise as closely as possible with the IUCN/SSC Asian Elephant and Asian Rhino Specialist Groups on all technical aspects.

Organization

1. Both the African Elephant and African Rhino Specialist Groups will each have a Chairman, who will maintain close contact with each other on the activities of their two Groups.

2. Funds will be sought to enable a full-time Executive Officer to take up office to serve the African Elephant Specialist Group. The anticipated start date for this position would be 1 January 1992. Funds will also be sought for support of the African Rhino Specialist Group, the exact nature of this support to be determined.

3. The internal structure of the two Groups should be kept flexible, allowing for the convening of regular ad hoc consultations on regional or national bases, or to deal with specific conservation issues or techniques.

4. The Groups should be composed of specialists selected in their own right, as well as scientists or managers nominated by government management agencies as their representatives. The means of achieving the balance between specialists and government representatives will need to be worked out by each Specialist Group.

5. Every effort should be made to facilitate and improve communication within the Specialist Groups between government representatives and the rest of the members. The Groups should aim to develop close and constructive relationships with governments with a view to ensuring that inputs from the Specialist Groups are not seen as outside interference, but rather part of an ongoing, mutually positive working relationship.

6. Both Groups should aim to meet once a year, preferably in the same location, starting with a meeting of one of the Specialist Groups, followed by a period devoted to issues of common concern, and concluding with a meeting of the other Specialist Group.

POPULATION ESTIMATES FOR BLACK RHINOCEROS *Diceros bicornis* AND WHITE RHINOCEROS *Ceratotherium simum* IN AFRICA IN 1991, AND TRENDS SINCE 1987

Country	Black rhino			White rhino			Source
	Pop'n size & reliability	No of pop'ns	Pop'n trend	Pop'n size & reliability	No of pop'ns	Pop'n trend	
ANGOLA	± 50 (4)	S	?	0			Hall-Martin
BOTSWANA	10+ (4)	S	?	56 (3)	S	?	Gavor
CAMEROON	± 50 (4)	4	Down	0			Alers
CAR	± 5 (4)	S	Down	0			Doungoube
CHAD	0?		Down	0			Daboulaye
ETHIOPA	0?	S	Down	0			Allen-Rowlandson
KENYA	398 (1/2)	19	Up	57 (1)	5	Up	Wanjohi
MALAWI	5 (3)	1	Stable	0			Hall-Martin
MOZAMBIQUE	50+ (4)	S	Down	0?			Hall-Martin
NAMIBIA	481 (2)	4	Up	80 (2)	5	Up	Joubert
RWANDA	•			0			Gakahu
SOMALIA	•			0			Gakahu
SOUTH AFRICA	798 (2)	14	Up	4700 (2)	171	Up	Hall-Martin
SUDAN	•			0			E Martin
SWAZILAND	6 (1)	1	Stable	60 (2)	3	Stable	Hall-Martin
TANZANIA	185? (4)	S	?	0			Gakahu, Leader-Williams
UGANDA	3 (2)	?	Stable	0			Edroma
ZAIRE	0			28# (1)	1	Up	E Martin
ZAMBIA	40? (4)	1+	Down	0		Down	Mvima
ZIMBABWE	1400 (3/4)	±20	Down	250 (3)	10	?	du Toit
Totals	3481		Down	5231+		Up	

Key:
S : populations scattered
• : population size unknown, but very small
: population of northern sub-species *C.s.cottoni*

Reliability of census:
(1) Total count
(2) Estimate based on rhino survey within last 2 years
(3) Estimate based on rhino survey more than 2 years ago, or recent non-specific survey
(4) Guess

PMB/lh
ARSG/91.08.08

ANNEXURE 6

AFRICAN RHINO SPECIALIST GROUP

Working Group Sessions
2-4 July 1991. Gaborone, Botswana

SUMMARY OF DISCUSSIONS AND DECISIONS

ACTION

1. **Composition and modus operandi of ARSG.**

(i) Government representatives, ideally decision-makers involved in national rhino strategies, should be invited from at least 11 African countries. Specialists from a number of disciplines (e.g. biological, management, trade) would complete the Group. Certain organisations would be invited to attend meetings.

(ii) Emphasis should be placed on the provision of advice and strategy development, and increased efforts would be made to integrate these into management programmes in Range States. Increased participation of government representatives would be sought, and local rhino co-ordinating groups, and both national and regional plans, would be promoted.

(iii) Meetings should concentrate on debate and discussion on generic problems and approaches, with the development of detailed strategies being handled externally through other meetings and workshops.

(iv) A contingency fund of about US$ 10 000 would be required for 1991 for clerical/administrative support and minor consultancies, and this should be motivated for through the Head Species Survival Programme. The possibilities for future funding would be investigated with AWF by Dr Leader-Williams, WWF by Dr Thomsen and SANF (Chairman). It is IUCN/SSC's goal to cover meeting expenses, including travel, while the IUCN office in Harare could be considered for second pillar IUCN support, especially for organising meetings in Harare.

Chairman

Leader-Williams
Thomsen

2. **Rhino population estimates**

The population estimates for both black and white rhinos for 1991 were tabulated by country, and population trends since 1987 recorded. The black rhino estimate of 3 481 was slightly below the 1987 figure of 3 832; while white rhino numbers had increased from 4 634 to over 5 230 over the same period, which represents a growth rate of about 3% p.a.

3. Trade in rhino horn

(i) Mr J Berney (CITES) requested a report on the trade in rhino horn for use at the forthcoming CITES Conference of Parties. — E Martin (early Oct. '91)

(ii) Dr J Thomsen (TRAFFIC) summarised the results of recent trade investigations which had revealed extensive stocks of rhino horn in Taiwan. Surveys in China, Thailand and S. Korea were planned. Stockpiles in Asia and Africa could be significant, and further information is required on which to base objective decisions regarding the continuation of trade, particularly the rate of consumption in Asia and the extent of African stocks. Dr Thomsen to draw up a project proposal (assisted by Drs Leader-Williams and Cumming) outlining the need to investigate supply and demand, including the estimation of the realistic MSY of horn (and other products) from Africa and economic aspects of marketing; and to ensure the study is conducted. A special working group may be required to evaluate the results and to translate into the implications for decisions on trade. — Thomsen

4. Pachyderm

The group strongly recommended that African subscriptions be dropped, and that inputs from the Asian Group should be considered. These issues were subsequently discussed in plenary session with the AESG (see Summary of Decisions). — E. Martin

5. SADCC initiative

Mr Huxley briefly described the Rhino Conservation Programme being formulated by the Southern African Development Co-ordinating Conference. Zimbabwe was currently re-designing the project. Ideas on initiatives to include were requested from the Group, and after discussion the following were suggested:

- Strong, regional rhino conservation strategy on which to base national strategies and to provide the focus for funding.

- Increased regional interaction and co-operation on security issues.

- Intelligence Units in each country with long-term aim of closing down cross-border activities.

- Game scout training.
- Increased use of experts from other countries.

ARSG could offer advice to SADCC on rhino conservation matters, and Dr Joubert Agreed to offer the Group's services at the next SADCC meeting; and to keep the Group informed on the SADCC initiative. Joubert

Further, the Group would consider if any priority projects could be passed to SADCC for consideration for implementation. Members

6. **Priority listing of rhino populations**

It was agreed that it was impractical, and of little applied value, to attempt to list rhino populations in Africa in priority order.

(i) It was agreed that it would be valuable to review the factors affecting the conservation of each population, thereby identifying common problems. By developing a suitable matrix, with the individual reserves and the key management/conservation concerns (e.g. security, inbreeding, neighbour programmes) as the two axes, it would be possible to highlight key issues and facilitate selection by the funding agencies of those particular criteria that suit their purposes. Such a super-matrix, while not providing a ranking of reserves, would allow the Group to determine priorities for given agencies against a specific set of conditions or selection criteria provided by them.

Mr du Toit agreed to draft an appropriate questionnaire, which the Chairman will send to the ARSG's government representatives for return and collation before the next meeting. du Toit Chairman

7. **Action plan**

It was agreed that the priority issues for rhino conservation on the continent needed to be established. Mr du Toit would draw up a framework document giving the rationale (use by interested groups), the aims of the exercise and the suggested approach and mechanism for determining the priorities, and submit to the Chairman for consideration. du Toit (end Sept. '91)

Once conservation priorities have been identified and the issues attached to these recognised, it may be possible to develop technical guidelines for key programmes.

8. **Additional agenda items**

The following agenda items were identified but not discussed:

- Genetic developments (du Toit)
- Repeat of law enforcement survey (Leader-Williams)
- Improvement to database on numbers and trends (Cumming)
- Resource economics, especially w r t local people (Taylor)
- Pros and cons of licensed sport-hunting (E Martin)
- Research needs, and co-ordination of research (Leader-Williams).

9. **Contributions to working sessions**

The following recorded their presence at, and contributed to, various working sessions :

J Berney, M Brooks, D Cumming, R du Toit, S Gartlan, L Gavor, A Hall-Martin, E Joubert, N Leader-Williams, B Loutit, E Martin, N Owen-Smith, S Stuart, A Steiner, R Taylor, J Thomsen, E Wanjohi.

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91.08.08/ARSG

GLOBAL MANAGEMENT OF RHINOS

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INTRODUCTION

The 5 extant species of rhinoceros provide spectacular examples of the rapid and accelerating disappearance of wildlife on this planet. The immediate causes of this endangerment and extinction of wildlife are habitat destruction and unsustainable exploitation. In the case of the rhinos, the second cause, in the form of decimation by poachers, is the primary problem. Rhinos, like so many of the megavertebrates, are species that actually vanish well before their habitat disappears. To preserve the species of rhino, it is obviously necessary to protect them from poacher activity and habitat destruction.

However, while such protection is necessary, it is not sufficient. It is no longer enough to protect rhinos and their habitat in situ. Surviving rhino populations must also be managed if they are to survive over the long-term, i.e. at least the next several centuries.

Indeed, there is to a great extent no longer any wild, at least for the larger vertebrates. For them and for many other species what survives on the planet is a spectrum of situations and scenarios that vary only in the level of human exploitation and management applied to them. It will still be convenient to refer to populations more or less free ranging in natural habitats as being in the wild, but with the realization that species are not in unexploited or unmanaged situations.

PROBLEMS OF SMALL POPULATIONS

The reason management is necessary is that the populations that can be maintained of under the pressures of unsustainable exploitation and habitat degradation are small, i.e. a few tens to a few hundreds, or at best a few thousands depending on the species. Small populations are vulnerable to stochastic problems that can imperil survival just as much as the more deterministic threats of habitat degradation and unsustainable exploitation. These problems are random or stochastic in nature. Hence, they are difficult to predict. However, there are remedial measures possible through management. The problems of small populations apply to species in both the wild and in captivity, although much of the management methodology is being developed in zoos.

Stochastic problems can be environmental, demographic, or genetic in nature. Environmentally, small populations can be devastated by catastrophes or decimated by less drastic fluctuations in environmental conditions that can impair survival and fertility of individuals. Catastrophes (e.g., droughts, floods, epidemics) are increasingly recognized as severe threats to small populations (Thorne 1991). Demographically, even in the absence of deleterious fluctuations in the environment, small populations may develop intrinsic demographic problems (e.g., biased sex ratios, unstable age distributions, or random failures in survival and fertility) that can fatally disrupt propagation and persistence. Genetically, small populations also can rapidly lose heritable diversity that is necessary for fitness under existing environmental conditions and adaptation to changed environments in the future. The smaller the population and the more limited it is in distribution, i.e. the more fragmented it is, the greater these stochastic risks will be.

For the shorter term, environmental and demographic problems are likely to be more serious for small populations of rhino (Lacy 1987 b). Over the longer term, the genetic problems will become significant if rhino populations remain small.

VIABLE POPULATION STRATEGIES

Because of these problems, conservation strategies for species which are reduced in number, and which most probably will remain that way for a long time, must be based on maintaining certain viable populations, i.e. populations sufficiently large and well distributed to survive the stochastic as well as the deterministic threats. An critical characteristic of a viable population strategy is that it provides explicit and quantitative objectives, e.g.

- 99% probability of survival and 95% preservation of diversity for next 100 years
- 99% probability of survival and achieve recovery of evolutionary potential by end of next 100 years
- Consequently, populations of quantitatively specified size and distribution to achieve these objectives.

There are at least two major reasons to be as numerate or as quantitative as possible. Action plans (captive and wild) ultimately must establish numerical objectives for population sizes and distribution as countermeasures to the stochastic problems if populations are to be viable. Numbers also provide for more objectivity, less ambiguity, more comparability, better communication and hence cooperation.

There is no single magic number that represents a viable population size for all taxa. Indeed there is no single number that represents a minimum viable population for any one taxon all the time. Rather viable population size depends on several sets of factors:

(1) Genetic and demographic objectives of the conservation program;
  - (a) The probability of survival of the population;
  - (b) The kinds and amounts of genetic diversity to be preserved;
  - (c) The period of time over which this genetic diversity and survival probability are to be maintained.

(2) Biological characteristics of the population;
  - (a) The generation time (average age at which animals produce their offspring) in the population;
  - (b) Growth rate of the population;
  - (c) Number of founders;
  - (d) Ratio of genetically effective size N_e to the total size N.
  - (e) The degree of subdivision or fragmentation.

(3) The kinds and levels of stochasticity operating.

While the exact sizes for population viability will vary depending on these factors, it may be possible to provide some useful generalizations and guidelines. Mace and Lande (1991) have recently proposed such a general scheme of guidelines as a basis for reformulating the IUCN Red Data Categories in a more quantitative way to reflect small population problems (Figure 1). The Mace-Lande scheme provides quantitative criteria in terms of population sizes, distribution, trends, stochasticity.

These criteria are formulated in terms of both effective (N_e) and total population sizes (N). Effective size is critical with respect to the stochastic problems, in particular the loss of genetic diversity. The effective size of a population is not the same as the actual number of animals. Instead, the (genetically) effective size is a measure of how the members of the population reproduce with one another to transmit their genes to future generations. Normally, the effective population size, denoted by N_e, is much smaller than the total number of animals. Such normal occurrences as failure of some/many animals to reproduce, disparities in lifetime production of offspring (lifetime family sizes) or biases in the sex ratio of breeding animals will depress N_e well below the census number. For example, N_e may be as low as 10 to 25% of the total population number. Mace and Lande use a general N_e/N ratio of .2 which may be low for some taxa. But conservatism is prudent. Thus, a recommended N_e of 500 to provide genetic and demographic viability for each distinct kind of rhino may require that, using the Mace-Lande guidelines, a population of at least 2500, or better more, actually be maintained. It is important to realize the minimum that is scientifically recommended as necessary for long-term survival under the best information available is just that, a minimum. More is always better and safer.

In terms of these Mace-Lande criteria, all extant taxa of rhino (Table 1) are in a category of threat or concern, most of them are critical or endangered. Rhino populations would need to be expanded to the 5,000 to 10,000 range for reasonable viability and security.

Naturally, the number of evolutionarily significant units or subspecies of rhino recognized as separate entities to be conserved is critical for conservation efforts. For the short term, splitting is better than lumping. Units initially accepted can be merged or eliminated later if necessary for viability. Whatever the decisions about what constitutes an evolutionarily significant unit and therefore conservation units, each "taxon" should be managed as a viable population.

It will be difficult or impossible to maintain single, contiguous populations in the hundreds or thousands required for viability. However, it is possible for smaller populations and sanctuaries to be viable if they are managed as a single larger population (a so-called metapopulation). Hence viable population strategies for megavertebrates like the rhino will require development of metapopulations (Figure 2) to achieve populations that are large and widely distributed enough to have an acceptable probability of surviving the stochastic risks. Metapopulation strategies will entail interactively managing the subpopulations to maximize the probability of survival of the species.

A metapopulation strategy (or survival plan) must recommend the number, sizes, and distribution of the subpopulations and the level of interchange among them to achieve the goals of the conservation program. Population viability assessments can provide recommendations on the number, size, and interaction of the separate subpopulations that are being managed collectively and interactively to constitute the metapopulation. Preliminary analyses suggest that a viable number for each separate subpopulation of rhino should perhaps be at least 100 animals (Foose 1987; Foose and Seal 1989; Khan 1989). However, this recommendation does not necessarily refer to the actual number of rhinos existing in some defined area, e.g. a sanctuary, of the natural range of the species now. Instead, this guideline for subpopulation size represents a minimum number that the area or sanctuary must be able to sustain if the rhinos can be protected and hence permitted to grow to the carrying capacity of the habitat.

As an example of application of this kind of strategy, the IUCN SSC Asian Rhino Action Plan for each of the 3 species of Asian rhinos recommends (Khan 1989):

Effective Population Size (N_e) $\geq$ 500
Total Population Size $\geq$ 2500
Number of Subpopulations $\geq$ 10
Size of Each Subpopulation $\geq$ 100

These population biology considerations in conjunction with the acuteness of the crisis for rhinoceros species suggests a conservation strategy for rhinos that consists of 2 major components.

(1) One component is to concentrate field efforts and available resources on protection and management of those wild populations and their sanctuaries that are large and/or protectable enough to be viable for the long-term.

It will be lethal to continue to diffuse limited resources trying to save inviable remnants (Leader-Williams and Albon 1988).

(2) The other is to employ animals that are located outside the viable populations and sanctuaries for either captive propagation or for careful translocation into larger or securer areas.

Such animals have been designated "doomed". A rhino is doomed if it cannot contribute to the long-term survival of the species because
(A) It cannot be protected from poacher activity or habitat degradation with feasible resources and/or
(B) It is not part of a population large enough to be viable genetically or demographically.
Employing doomed rhino for either captivity or translocation can reinforce the viable populations.

RHINO ACTION PLANS

To be more explicit, action plans to achieve these viable population strategies should therefore entail:

(1) Protection of Larger (> 100) Populations in Wild

Based on the discussion in the previous section, this goal would translate into trying to secure enough subpopulations, normally of at least 100 rhinos each, to produce a metapopulation at least equivalent to the MVP recommended for the species.

(2) Intensive *In Situ* Management of Smaller (< 100) Populations in Wild

Metapopulation management will entail moving animals around to correct genetic and demographic problems. Actually, distributing animals over multiple "subpopulations" will actually increase the effective size of the total number maintained in terms of the capacity to tolerate the stochastic problems. (Figure 2). Any one subpopulation may become extinct or nearly so due to these causes; but through recolonization or reinforcement from other subpopulations, the metapopulation will survive.

As new populations are established or reestablished a very important consideration is the number of founders. A founder is an animal from a source population that establishes a derived population. There must be care to insure that the founders represent a viable sample genetically from the source population. Again preliminary analyses suggest that at least 20-30 effective founders should be employed to establish new populations (Foose 1987; Lacy 1989).

This type of managed migration is one example of the kinds of intensive management and protection of viable populations in the wild. More intensive management may also be possible and needed within small wild populations (Foose 1989). It will be necessary to intervene in small "wild" populations to apply corrective measures if and when stochastic problems are detected. Some examples might be to: accelerate turnover in dominant males that might be monopolizing breeding of multiple females and thereby causing distortion of sex ratios and depression of N_e; translocation of otherwise doomed dispersing young animals to available habitat to which they could not migrate naturally; relocation of animals to prevent reproduction by close relatives; action to improve juvenile survival. As traditional zoos become larger and more naturalistic, sanctuaries in the wild are becoming smaller and more artificial. In essence they are becoming megazoos. The same kinds of intensive management in genetic and demographic terms will need to be applied to both zoos and wild. In Kenya, the 500 or so rhino that survive are most in sanctuaries that are now completely enclosed with fences and are further protected by frequent guard patrols. Intensive management will require much sophisticated genetic and demographic analysis of populations and will require more detailed data compilation on wild populations including the possibility of "studbooks". Studbooks are already being compiled and applied to these megazoo situations (Brett 1990).

(3) *Ex Situ* Programs To Reinforce Wild Populations

This kind of strategy has been adopted for conservation of the Sumatran rhino by the IUCN Asian Rhino Specialist Group (Khan), especially for the Sumatran rhino. Although, the estimated 900 Sumatran rhinos are widely distributed over much of Southeast Asia, 7-9 main sanctuaries and populations, each capable of accommodating 100 or more rhino for a total of at least 2500, have been recognized as viable in terms of priorities for allocation of resources and effort on the species in the wild.

The African Elephant and Rhino Specialist Group (Cumming et al. 1990) has also developed priorities for conservation efforts based in large part on population viability considerations. Population viability considerations also emphasize the importance of national, or better regional and continental, strategies and programs for rhino conservation. Again, both the Asian and African Rhino Specialist Groups have proposed and delineated such strategies. Such strategies have been proposed for black rhino (*Diceros bicornis*) in particular nations of Africa (Leader Williams & Albon 1988; Martin, this volume) and for the rhino in Indonesia (Widodo, this volume).

Based on a viable population strategy, there currently are collectively for all rhino perhaps 35 viable populations and hence significant sanctuaries in 10 countries that should receive priority for conservation action and resources.

ROLE OF CAPTIVE PROGRAMS

Applying the second component of a viable population strategy and action plan, metapopulations of rhino will often, perhaps usually, contain captive as well as wild populations, i.e. real zoos, at least for some period of time (Figure 2). The IUCN (IUCN 1987) recommends that captive propagation be invoked for any taxon whose wild population declines below 1000 individuals, an admittedly simplistic and arbitrary number but one that at least provides a point of departure. The new Mace-Lande categories suggests that this threshold should in general perhaps be 2500.

When numbers decline to very low levels, as in the case of the Javan rhino (*Rhinoceros sondaicus*), how to manage the population becomes a very real dilemma (Seal & Foose 1989; Widodo et al., this volume). It is far better to initiate captive programs when populations are larger as in the case of the Sumatran rhino.

Captive propagation can and must contribute to the conservation strategies for rhinos. There are a number of advantages to captivity: animals can be protected from poachers; environmental variance can be moderated; there can be more genetic management, specifically the N_e of any given number of animals can be maximized; numbers can be securely expanded, ultimately to provide rhino for return to natural habitats.

The purpose of captive propagation is to reinforce survival of wild populations of rhino, i.e. populations of rhinos surviving in natural habitats within their historic range. In other words, zoos must serve as reservoirs of both genetic and demographic material that can periodically be transfused into natural habitats to re-establish rhino populations that have been extirpated or to revitalize populations that have been debilitated by genetic, demographic, or environmental problems. Indeed, what appears optimal and inevitable are conservation strategies for the rhino species incorporating both captive and wild populations that are interactively managed for mutual support and survival (Figure 2).

It will be important to retain or to restore some populations to the wild as soon as possible with the goal of allowing natural selection to operate. The goal of enabling natural selection to occur will impose minimum size constraints on the wild populations reintroduced. Simulation models can suggest what these minimum size constraints will be under any particular set of conditions. Based on one such model, Lacy (1987b) demonstrates that under the assumptions of his simulations, populations normally must be greater than 100 breeding individuals for natural selection to predominate over random genetic drift.

The formal programs operate through masterplans that perform sophisticated genetic and demographic analyses to formulate animal-by-animal recommendations for the entire managed captive population (Foose & Ballou 1988; Dee 1989; Ballou & Foose 1992). The objectives of formally organized captive propagation programs for rhino are to propagate and manage ex situ populations of highly endangered taxa with prescribed levels of demographic stability and genetic diversity for defined periods of time to prevent extinction of the taxa and to fulfill the goal of establishing or restoring viable populations in the wild. Captive propagation programs all attempt to minimize the amount of genetic change that may occur in a taxa during its time in captivity. The challenge is to insure that the animals emerge from the ark in some semblance of how they entered. A very important element in every masterplan is to establish target population sizes that are large enough to achieve the genetic and demographic objectives.

Such propagation and management programs for 4 of the 5 species of rhino have been formally organized in many parts of the zoo world: the Species Survival Plan (SSP) in North America, the Europaiesches Erhaltungszucht Program (EEP) in Europe, the Australasian Species Management Program (ASMP) in Australia/New Zealand; the Species Survival Committees of Japan (SSCJ) (Foose, 1988; Reece, this volume). The importance accorded to rhino conservation by the zoo world is reflected in the logo that has been adopted by 3, and it is hoped eventually all, of the organized regions to designate their programs (Figure 3).

These regional programs are integrating into global efforts through a Global Captive Action Plan for Rhino being developed by the CBSG. A Global Captive Action Plan provides a strategic framework for effective and efficient application and allocation of captive resources to conservation of the broad group of taxa of concern, in this case the rhino. In North America, a Rhino Taxon Advisory Group (TAG) has also been formed for more strategic and coordinated program development and resource allocation collectively for rhino taxa. The CBSG Action Plan will encourage formation of more regional multi-taxa coordination groups in other regions. The Global Captive Action Plan will also recommend how responsibility for the captive programs for each rhino taxon might optimally be distributed over the various organized regions of the global captive community. Finally, the Global Captive Action Plan will also consider how genome banks and reproductive technology might be incorporated into the conservation strategy for various taxa

Currently, there are about 900 of 4 species in zoos worldwide (Table 2). In most cases, these numbers are considerably below satisfactory target population objectives for captive programs that have been established through appropriate population viability analyses (Foose 1987). More space and resources, i.e. money, are required if zoo programs are going to be able to fulfill their function in rhino conservation strategies. Existing space and resources must be utilized as effectively and efficiently as possible.

Formally organized and scientifically managed programs for population management and propagation have only been in progress for last 5-10 years. Already these intensified efforts are producing results. Nevertheless, rhino populations in captivity need to be managed better for propagation (Reece, this volume). The highest rate of increase yet demonstrated for a rhino taxon in captivity is for the North American population of *Rhinoceros unicornis* which has grown at a rate of about 4.5% over the last 15 years (Dee 1989). This rate of increase is equivalent to the Nepal *Rhinoceros unicornis* population (Dinerstein & Price 1991) but is only about 60% what has been observed for vigorous growth in 3 wild *Rhinoceros* populations (Dinerstein & Price 1991, Amman 1985); only about 45% of most rapid rates of stable growth observed and biologically possible (Owen-Smith 1981; Martin, this volume; Foose, in prep); and about 33% of what can be achieved for short periods in favorably unstable wild populations (Brett 1990, this volume). achieved. However, reproduction is good in all 3 species of rhino for which adequate of numbers of both sexes have been available. Captivity may not be the most conducive environment in which to reproduce rhino. However, it may be the most secure for the near future. It contributes to a strategy of maximizing options and minimizing regrets for the future.

Even maximal participation and coordination of the world's zoos, may not provide enough captive habitat and resources to assist all the rhino taxa in need. Captive propagation programs must be not merely internationalized but also globalized in the sense that governmental wildlife departments and other non-zoo organizations must also apply these techniques. Captive propagation need not occur only in traditional zoos. There is great merit in wildlife departments developing captive propagation programs, often in collaboration with traditional zoos, especially within or near natural habitat of taxon. A major problem is that such endeavors will divert resources that might otherwise be applied to freer ranging populations. Quantitative cost benefit analyses must be conducted to resolve the conflicts. Captive propagation programs operated by wildlife departments are in progress for the Sumatran rhino in Peninsular Malaysia and Sabah and are under development for black rhino in Zimbabwe.

Another area where zoos can contribute is in research applicable to conservation for rhino in both captive situations and in more natural habitats. Some research of note includes: nutrition, where vitamin E deficiencies are being elucidated; disease, where a strange hemolytic anemia syndrome afflicting wild as well as captive black rhino is being investigated; taxonomic clarification.

Particularly notable is reproductive technology, where development of artificial insemination and embryo transfer techniques could greatly facilitate management of rhino in the wild as well as captivity and especially in interactions between the two (Figure 4). Reproductive technology may also greatly facilitate the "readaptation" process from captivity to the wild. There may be significant difficulties for captive-bred animals to readapt to wild conditions. However, where remnant natural populations survive, it may be possible to infuse "new blood" from the genetic reservoirs in captivity into individuals in the wild which still retain survival skills that are acquired by experience rather than inheritance. Thus, the reproductive technology may permit conservation management to achieve the best of both worlds. Unfortunately, progress on reproductive technology has been slow.

In North America, the SSP has recently organized a comprehensive and coordinated program of research in these areas on rhino. However, this kind of activity is expensive and often difficult or impossible for zoos to support out of their own budgets. Exacerbating the problem is the difficulty of securing research support from funding agencies, such as the National Science Foundation in the United States, for projects that are primarily conservation.

Yet another way zoos can contribute to conservation of rhinos is by transfer intensive-management, i.e. captive-type, technology to wildlife managers in Africa and Asia. The same kinds of intensive management in genetic and demographic terms will need to be applied to both kinds of places where rhinos are being preserved. A start in this direction was generated out of the African Rhino Workshop conducted in Cincinnati in 1986. Attempts are now in progress to organize small population biology workshops in Africa, and the semblance of one has actually occurred in Malaysia. The traditional zoos can help substantially with this need of the new megazoos.

Zoos can contribute to *in situ* conservation of rhino in other ways. One is to provide limited financial support for actual protection in the wild. An eminent example is the Minnesota Zoo's program to provide assistance for protection and management of Ujung Kulon. Included is support for equipment and education. Adopt-a-park programs are a trend for the future (Tilson 1991). Another is the proposed International Black Rhino Foundation which is being established to develop a cooperative program between Zimbabwe and the captive community in North America and Australia and eventually other parts of the world. The program has both *in situ* and *ex situ* components. *Ex situ*, As recommended by the Zimbabwe National Conservation Strategy (Martin, this volume), it will translocate 40 more black rhino into the captive program outside Zimbabwe. It will also assist Zimbabwe to initiate its own captive propagation programs for this species. *In situ*, it will provide support for acquisition, maintenance, and operation of helicopters for anti-poaching activities for a period of at least 7 years. Yet a third example is the Rhino Walk being co-sponsored by the AAZPA and its member institutions in collaboration with many field conservation organizations.

All these programs are examples of an emerging partnership between zoos and field conservation. Unfortunately, zoos are not likely to become a major funding agency for field conservation although their modest financial support may be catalytic and critical. There is certainly need and intention by the captive community to develop a more strategic approach in allocation of the limited funds that are available for support of *in situ* protected areas. Moreover, zoos can be a major force in conservation education that will generate more public support, morale and material, for protection and management of wild places and populations.

In summary, each rhino taxa should be managed as a global metapopulation incorporating the animals both in the wild and in captivity. A preliminary chart of evolving relationships among various levels and kinds of action plans, PVA's, and captive and wild programs is provided in Figure 5. Particularly noteworthy is the parallelism between animal-by-animal recommendations in zoos and sanctuary-by-sanctuary recommendations in wild.

FLAGSHIPS, UMBRELLAS, AND HERITAGE SPECIES

Conservation strategies and programs for rhino have significance beyond survival of these magnificent creatures. Megavertebrates like the rhino are both flagship and umbrella species for conservation of many other kinds of wildlife. They are flagships because they have the charisma to secure support for conservation. They are umbrella species because the habitat required to sustain their viable populations is sufficiently large to encompass appreciable parts of natural ecosystems. This function as umbrella species can ameliorate, in part, the concern that investing so much money for the preservation of a few megavertebrates like the rhinos is unjustified while the greater number, and perhaps more important but less charismatic, species may be neglected.

Such flagship and umbrella species are the inspiration for the developing Global Heritage Species Programme of the IUCN Species Survival Commission. The GHSP concept of a Global Heritage Species Program (GHSP) is to carefully select a group of ecologically significant, culturally important, and publicly charismatic species that can be used as flagship and umbrella taxa to attract support for conservation not only of the species themselves but also their ecosystems.

The GHSP has recommended that a conservation action plan based on population viability assessment and conservation biology principles must be developed for each heritage species. These plans can formulate explicit and preferably quantitative goals and objectives can be formulated which will also facilitate evaluation of performance toward achieving its ends. Further to this end, the plans should also be organized with modularized components and budgets, to facilitate implementation, funding, and evaluation. Finally, the GHSP has recognized that there will be benefits of selecting taxa whose survival definitely depends on both *in situ* protection/management and captive propagation so that both the field and zoo communities can be actively involved.

In April 1990, the Captive Breeding Specialist Group (CBSG) was invited by the Chairman of the IUCN Species Survival Commission (SSC) to lead preparation of one or two proposals for conservation action plans that could be used as prototypes for GHSP.

CBSG immediately proposed the Sumatran rhino (*Dicerorhinus sumatrensis*) as a species which eminently qualified as a candidate under GHSP criteria. A first draft of a GHSP conservation action plan prototype employing Sumatran rhino was prepared in October 1991 by the CBSG in collaboration with scientists and managers in Indonesia and Malaysia. This draft plan was based closely on the Asian Rhino Specialist Group Action Plan (Khan 1989). The prototype plan provides for quantitative objectives for population and sanctuary size (Table 3). It also provides for explicit mechanisms to implement the plan (Figure 6)

The first draft of this prototype action plan was presented at the IUCN SSC meetings in Perth, Australia 24-27 November 1991 by representatives of CBSG, the Asian Rhino Specialist Group, the Department of Forest Protection and Nature Conservation of Indonesia (PHPA), and the Department of Wildlife and National Parks (DWNP) of Malaysia. At Perth, the Steering Committee of the SSC encouraged further development of the prototype, especially at and through the Indonesian Rhino Conservation Workshop now proposed for Bogor, Indonesia 3-5 October 1991. A second draft of this prototype plan has just been completed and will serve to continue the development process. The objective is a full proposal for a prototype action plan for presentation to SSC Steering Committee. All rhino taxa would be good candidates for the GHSP.

CONCLUSIONS

In conclusion, rhino conservation needs to be developed in a more strategic and global manner than has occurred to date. Each rhino taxa should be managed as a global metapopulation incorporating the animals both in the wild and in captivity (Figure 2).

Highest priority for field conservation efforts should be extended to the 37 most viable populations and sanctuaries in about 11 countries worldwide (16 in 5 Asian nations; 21 in 6 African nations). Eventually, priority status should probably be expanded to another about 15 sanctuaries and 5 countries to improve further the viability of rhino (Table 4).

Captive programs need to be expanded and improved. More coordination and integration of regional efforts into global programs will be most beneficial.

Very generally, numbers of rhino in the wild and in captivity need to be increased at least twofold and probably fourfold for long-term viability and security.

In developing global strategies and programs, political vicissitudes must be accepted as an important source of stochastic risk for rhino or any threatened taxa. Hence, one important guideline for conservation strategies is that no taxa of rhino should be dependant on a single political authority for its survival.

Are such global strategies feasible biologically, logistically, financially, politically? Biologically, the science, although still evolving, is probably adequate to the task. Logistically, the program is feasible if the funds are available.

Financially, some very crude, general, and preliminary estimates for conserving viable populations of rhino in the wild (Tables 5 & 6). These estimates are based on some estimates and assumptions about viable population objectives, rhino carrying capacities, and operation costs per unit area (Cumming et al 1990; Leader-Williams and Albon 1988; Martin, this volume; PHPA). While in no sense precise, these estimates probably provide fairly good approximations of the overall costs. These estimates suggest that about U.S.$ 20,000,000/ year will be needed to protect and manage viable populations of 2500 rhino/taxon for the 9 taxa being recognized or a total of 22,500 rhino (about double the current number) on the planet. If a higher goal of 5000 for viable population size for each taxon is adopted, the annual cost is about U.S. $40,000,000. To this can be added $14,000,000/year, the annual costs for maintaining 1200 rhino recommended for viable captive populations (Conway 1986). In other words, about $35,000,000-65,000,000/year may be needed to conserve rhinos globally. For perspective the annual operating budget of the San Diego Zoo is about $34,000,000 and for the Zoo and the Wild Animal Park combined about $50,000,000. Resources for conservation are limited but these figures are probably not unattainable, particularly if rhinos are indeed used as umbrella and flagship taxa.

The most difficult problems for rhino conservation, as is almost always the case with threatened species, will be political. The problems are all those personality conflicts, competing agendas, power struggles, and ego sensitivities that characterize all human endeavors and which seem to intensify in inverse proportion as the numbers of an endangered species decline. This Conference is testimony to the fact that there are many organizations, agencies, institutions, and individuals interested in rhino conservation. Moreover, the crisis for rhino survival is intensifying. It is time for the most effective and efficient action possible. The kind of global strategy delineated above is intended to respond to this need but will need great cooperation and coordination to succeed.

What is needed are greater coalitions interested and involved in rhino conservation so they could at least communicate and optimally coordinate to implement the global management strategies. There would be significant benefit from global management committees for each of the taxa of rhino. These committees should consist of the representatives of each of the range states for the wild populations as well as the captive community involved in *ex situ* programs and other experts. The Specialist Groups of the IUCN SSC are a start in this direction but more is needed.

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ANNUAL COSTS FOR CONSERVATION OF VIABLE POPULATIONS OF RHINO

TAXON	TARGET POPULATION	DENSITY (km/rhino)	AREA (km^2) REQUIRED	COST per km^2	ANNUAL COST
N. Black	2,500	3	7,500	$400	$3,000,000
S. Black	2.500	3	7,500	$400	$3.000.000
S.W. Black	2,500	3	7,500	$400	$3,000,000
N. White	2,500	1.5	3,750	$400	$1,500,000
S. White	2,500	1.5	3,750	$400	$1,500.000
Indian/Nepali	2.500	0.5	1,250	$250	$300.000
Sumatran (2 subspecies)	5,000	10	50,000	$100	$5.000,000
Javan	2,500	5	12,500	$200	$2,500,000
TOTALS	22,500		93,750		$19,800,000

RHINOS IN THE WILD

TAXON	CURRENT POPULATION
Northern Black	600
Southern Black	2,300
South Western Black	400
Northern White	28
Southern White	4,700
Indian/Nepali	1,700
Sumatran	700
Javan	75
TOTALS	10,628

RHINOS IN CAPTIVITY

TAXON POPULATION	CURRENT POPULATION	TARGET
Northern Black	160	150
Southern Black	22	150
Northern White	10	150
Southern White	0	150
Indian/Nepali	114	200
Sumatran	24	200
Javan	0	200
TOTALS	880	1200

ANNUAL COSTS FOR CONSERVATION OF VIABLE POPULATIONS OF RHINO

TARGET POPULATION PER TAXON	TOTAL RHINOS	AREA REQUIRED (km^2)	ANNUAL COST
2,500	22,500	94,000	$20,000,000
5,000	45,000	188,000	$40,000,000

SUMATRAN RHINO

MORTALITY SUMMARY

	CAPTURED	DIED	% MORTALITY	LAST DEATH
Indonesia	14	3	21	1987
P. Malaysia	11	4	36	1989
Sabah	4	2	50	1988
TOTAL	29	9	31	

T.J. Foose
7 May 1991

SANCTUARY OBJECTIVES FOR SUMATRAN RHINO

Country	Sanctuary	Area (km^2)	Current Population	Target Population
Indonesia	Gunung Leuser	8,000	130-200	400
	Kerinci Seblat	10,000	250-500	500
	Barisan Selatan	3,600	25-60	100
	Kayan Mentarang	16,000	Some	500
Malaysia				
Peninsula	Endau Rompin	1,600	10-25	100
	Taman Negara	4,400	22-36	200
Sabah	Tabin	1,200	20+	100
	Danum Valley	2,000	10	100
Sarawak	Ulu Limbang	1,000 *	5-15	100

* Will require enlargement of protected area from current 600 km^2

PRIORITY SANCTUARIES FOR RHINO

CONTINENT	COUNTRY	SANCTUARY
Africa	Kenya	Aberdare
		Nairobi
		Nakuru
		Tsavo
		Solio
		Laikipia
	Namibia	Etosha
		Kaokoland
	South Africa	Hluhluwe/Umfolozi
		Kruger
		Mkuzi
	Tanzania	Selous
	Zaire	Garamba
	Zimbabwe	Hwange/Matetsi
		Sebungwe
		Zambezi
		Central Highlands
Asia	Indonesia	Kerinci Seblat
		Gunung Leuser
		Barisan Selatan
		Kayan Mantarang
		Ujung Kulon
		Way Kambas
	Peninsular Malaysia	Taman Negara
		Endau Rompin
	Sabah	Tabin
		Danum Valley
	Sarawak	Ulu Limbang
	Vietnam	Nam Cat Tien
		Bugiamap
	India	Dudhwa
		Kaziranga
		Manas
		Orang
	Nepal	Chitawan
		Bardia

Plenary VI - Summary
Biology and Conservation of Sumatran and Javan Rhinos

Mohd. Khan, chair: *Conservation planning for the Sumatran rhinoceros*
C. Santiapillai *Conservation and management of Javan rhino (Rhinoceros sondaicus) in Vietnam*
K. MacKinnon: *Conservation and management of Sumatran Rhino (Dicerorhinus sumatrensis) in Indonesia*
Sukianto Lusli: *The status of Sumatran Rhino Rescue Programme in Indonesia*
Widodo Ramono: *Conservation and management of Javan rhino (Rhinoceros sondaicus) in Indonesia*
Linda Prasetyo: *Sumatran rhino (Dicerorhinus sumatrensis) captive propagation in relation to its conservation*

(Plenary session summary not available at this time)

Indonesian Rhino Conservation Informal Meeting

An informal meeting was conducted to exchange information and ideas relative to rhino conservation in Indonesia.

In particular, the group discussed plans and preparations for the Indonesia Rhino Conservation Workshop that had been postponed last January and is now to occur 3-5 October 1991 in Bogor, Indonesia. The draft agenda for this Workshop was reviewed and revised. Major items on the agenda include a review of the PVA process for Javan rhino, the Global Heritage Species Programme proposal for Sumatran Rhino, and the Indonesian Rhino Conservation Action Plan. Also reviewed was the Briefing Book being prepared for this Workshop. Numerous recommendations and materials were submitted for addition.

Also distributed and discussed were:

The latest draft Studbook for Sumatran Rhino including more refined analyses of the mortality that has occurred during the program.

The second draft of the Prototype Action Plan for Sumatran Rhino as a Global Heritage Species Programme.

Further PVA Analyses using VORTEX software from R. Lacy as well as an alternative approach developed by H. Prins. Directions for additional analyses before the October Workshop were explored.

The meeting concluded with an agreement by those attending to continue dialogue in preparation for the October Workshop to maximize the productivity of that meeting.

Summary of Global Propagation Group Meeting - Sumatran Rhino

The first meeting of the Global Propagation Group for the Sumatran Rhino was convened in conjunction with the International Rhino Conference in San Diego. In attendance were representatives of the 4 countries and 8 of 11 facilities maintaining captive specimens.

The purpose of the session was to review and advance the captive propagation program as part of the conservation strategy and action plan for this species. Studbook Keeper Foose presented a summary of the program since 1984.

31 (12/19) rhino have been captured in the 3 regions where rescue operations are being conducted: Indonesia 15 (6/9); Peninsular Malaysia 11 (2/9); Sabah 5 (4/1).

9 (4/5) rhino have died from a variety of causes which were reviewed; mortality has been differential in the various regions and facilities; death rates have declined over history of the program; last death occurred in 1989.

One animal has been born in captivity although conceived in the wild.

23 (8/15) rhino are alive in captivity today in 5 countries and 11 facilities: Indonesia 7 (3/4) rhino at 4 sites; Peninsular Malaysia 7 rhino (1/6) at 2 sites; Sabah 3 (2/1) rhino at 1 site; U.K. 2 rhino (1/1) at 1 sites.

Reproduction has been impeded by dearth of mature males.

An institution and animal by animal review of the captive population was conducted. Representatives of the 3 regions described their plans to optimize reproductive opportunities for rhino. Breeding activity was described in the U.K. and Jakarta where apparently full copulations have been observed. Plans were discussed to place male with females on regular basis in new Sungai Dusun Rhino facility in Peninsular Malaysia which will also now resume attempts to capture additional rhino especially males. U.S. representatives discussed plans to place all 3 females with the available male over next year.

Parties agreed to intensify efforts to investigate subspecies distinctions among rhino from different regions to guide reproductive programs. Amato offered his laboratory without qualifcation for this effort. A research working group was also organized to facilitate and improve cooperation and coordination among scientists in the several countries.

Finally, a prototype proposal to employ the species as an umbrella and perhaps Heritage Species was presented.

Parties agreed to continue dialogue and collaborations at October Rhino Workshop in Indonesia.

Plenary VII - Summary
Strategic Planning for Rhinoceros Conservation

R. Martin, chair: *Development of the Zimbabwe national conservation strategy for black rhinocerso*
T.J. Foose: *Global management of rhinos*
N. Leader-Williams: *Theory and pragmatism in the conservation of rhinos*

All these papers recognized a average minimum recurrent cost of US $200/sq. km. to conserve wild rhinos *in situ*. Martin showed data which indicated that this could rise to $400/sq km under conditions pertaining in Zimbabwe. Foose used these figures to estimate *in situ* conservation costs for viable populations of all taxa of rhino at $20-40 million per year.

All three speakers agreed that it was necessary to meet threshold funding (and manpower) levels to prevent failure of *in situ* conservation efforts. With current funds available for conservation this inevitably implies a departure from attempts to conserve rhinos in very large areas and an emphasis on smaller units dictated by budgets. Programs in Zimbabwe and other countries have incorporated this feature by focussing additional manpower in designated zones to protect large wild populations.

Thereafter there was some divergence of opinion among the speakers on the most effective approach for conservation action. In his presentation of a global strategy, Foose placed emphasis on the conservation biology aspects of rhino populations which were

Metabolic consequences of anesthesia and the stresses associated with capture and the sequelae of both should be assessed.

Studies to address the immunocompetency of wild and captive black rhinoceroses and the role that immunology may play in several of their diseases, eg, fungal pneumonia of black rhinoceroses.

Nutritional research should include general review of the feeding practices used in all species in captivity with particular attention to minimal requirements. Basic nutritional evaluations should focus attention on both the nutrition of wild and captive populations. Research to establish effective dietary supplementation with α-tocopherol should be encouraged.

In black rhinoceroses further research should be designed to evaluate the following diseases and syndromes:

Hemolytic anemia - Current recommenda-tions for the prevention of acute hemolytic anemia include vaccination of captive animals with a bacterin containing 5 leptospiral serovars. Research to an underlying cause for the hemolysis should continue.

Oral/skin ulcers

Further evaluation of iron metabolism due to the accumulation of hepatic iron in captive and newly captured black rhinoceroses.

Fungal pneumonia

Encephalomalacia.

2. In conjunction with the above proposals, identification of additional funding resources to support health research in rhinoceroses is vital.

3. Continued maintenance and enhanced participation in regional biomaterial banks (tissue, sera, urine, etc) with materials from both captive and wild rhinoceroses of all available species is vital to future comparative studies.

4. Continued and enhanced collection of genetic samples from anesthetized animals whenever possible.

5. Continued and improved communication between veterinarians working with both wild and captive rhinoceroses should be enhanced through future meetings. Special effort should be applied to the maintenance of continuous medical histories for rhinoceroses translocated from the wild to captivity.

In summary, there should be veterinary participation in the management of captive and wild rhinoceros populations. This participation should be an integral part of a multidisciplinary approach to their care, and is particularly relevant to their capture and translocation. Such efforts will contribute to the long term survival of both *in situ* and *ex situ* rhinoceros populations.

Planning for Rhinoceros Conservation

Proposed consensus items and/or issues for discussion and clarification:

1) There should be a greater flow of funds from international development agencies to projects that conserve biological diversity.

2) There is a need for increased flow of information concerning the costs of *ex situ* and *in situ* conservation.

3) There is a need for more accurate and timely reporting of data concerning population abundance, especially for *in situ* populations of black, Sumatran and Javan rhino.

4) Civil and military conflicts within and between nations pose a proximate threat to rhino populations.Demographic vulnerability due to small population size poses the most immediate threat to wild populations of rhinos where poaching activities are under control and where negative civil and military impacts on rhino populations are precluded.

5) A closer examination of husbandry regimes for rhinos in zoological parks is warranted in order to gain insights into their apparently less-than-maximal reproduction rates.

6) Non-invasive reproductive monitoring of rhinos in zoological parks should be expanded and, as possible, compared with data obtained from *in situ* sanctuary and *ex situ* sanctuary populations of rhinos.

7) The development of a simple pregnancy test, especially one that could be employed under field conditions would be of use in both *in situ* and *ex situ* management of rhinos.

8) It is worthwhile at this time to conduct experiments in the introduction of black rhinos into existing populations. The existing populations should be derived from demographically and genetically secure sources so that their reproduction is not considered essential for meeting gene pool conservation goals in the region. The introduced rhinos could include individuals of either sex and be derived from zoological parks or *in situ* populations. (i.e., it is valuable now to begin to develop successful approaches for the creation of metapopulations).

9) A Second International Conference on Rhinoceros Biology and Conservation is warranted as in three years' time new information on disease, reproduction and the development of sanctuary programs is anticipated.

Working Group Report Conservation of the Northern white rhinoceros

Ceratotherium simum cottoni

At the International Conference on Rhinoceros Biology and Conservation the most recent information available was exchanged. A Northern white rhinoceros working group met and presented their report at a conference plenary session.

Recommendations are made in three areas: conservation of the *in situ* population, conservation of the *ex situ* population, and coordination of these efforts.

In situ population

The success of the conservation efforts for the Northern white rhinoceros in Garamba National Park taken by the government of Zaire is recognized and those responsible are to be commended for their actions.

Continuation or increase in the levels of international funding for the Garamba ecosystem and an increase in the level of research efforts in support of the Northern white rhinoceros is recommended.

External assistance is recommended for the further training of park staff in techniques of wildlife protection.

Further research should be undertaken on nutrition and feeding ecology. Research should also be undertaken on the genetic status of the Garamba population. Collection of samples for genetic analyses, including examination of the levels of genetic diversity and in methods of parentage determination, should be encouraged. Research should be initiated on the role of infrasonic vocalizations in communication between and among individual rhinos in the park.