

CONSERVATION BIOLOGY OF BLACK RHINO

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The precipitous decline of black rhino populations over most of the range of the species in Africa necessitates emergency measures to ensure that at least some viable breeding groups are protected in African sanctuaries and in overseas zoos. The urgency of the situation places a responsibility on scientists to come up with quick answers to a number of questions. Upon which rhino populations should conservation efforts be concentrated in order to maintain the existing genetic variability within the species? What is the minimum number of animals required in a particular population to give a margin of safety against foreseeable factors that could depress the breeding? What degree of inbreeding is likely to occur in populations of certain sizes, and what recommendations can be made for transfer of animals or genetic material between populations to prevent excessive inbreeding? What are the major health problems that have to be considered when moving rhino and keeping them in zoos or small sanctuaries? This article elaborates on these issues and outlines progress in providing some guidelines.

Black Rhino systematics

It may appear strange to many people concerned about the survival of black rhino that some of the organizations which are centrally involved in the international rhino conservation effort (notably the African Elephant and Rhino Specialist Group and the American Association of Zoological Parks and Aquaria) are currently laying considerable emphasis on the seemingly academic issue of subspecies designations. This emphasis stems from the need to get a better idea of the genetic variability within the remaining black rhino. The available resources of money and expertise are too scanty to provide all rhino in Africa with the level of protection that is necessary to stave off commercial poaching. So which rhino should we try to save?

Decisions on this rather cold question are often determined by very practical considerations; international support will best be directed to areas where the prevailing social, political and economic influences are most conducive to rhino conservation – if a country's administrative and legislative framework is insufficiently developed to counter illegal depredations, it would be wasteful to throw in funds to finance some sort of cosmetic attempt at conservation, regardless of how unique the rhino in such a country may be. Conversely, if local initiatives are being made to save rhino, then the international conservation community has a considerable obligation to provide material support for these initiatives, even if they concern a race of rhino that is already relatively well-conserved elsewhere.

In some important cases, meaningful priorities can be set for rhino conservation initiatives that do take genetic factors into account. At present, American zoos are following a co-ordinated plan to provide more space for black rhino, in order to increase the captive breeding population as quickly as possible, thus insuring against failure of the various projects to save the animals in good

breeding situations within Africa. All but five of the seventy-odd black rhino in zoos in the United States are of East African origin, and therefore the zoo breeding programme must be expanded to include representatives of other black rhino "subspecies", in order to maintain the overall genetic diversity of the species at the highest level possible.

Past work on black rhino taxonomy has been scanty and provides an inadequate basis for deciding how to distinguish populations for a conservation strategy. As with many other species, the taxonomic work has consisted almost entirely of the measurement and comparison of the dimensions of skulls collected from different parts of Africa by museums. The last revision of the black rhino subspecies (Groves, 1967) cut down the number of designated subspecies to seven, but since only two of these were based on measurements of more than ten skulls, there has been considerable suspicion that there could be greater variability within the populations, thus making the taxonomic divisions less certain.

Confusion has also arisen over which of the supposed subspecies are still surviving. Rookmaker and Groves (1978) decided that the subspecies with the largest skull, *Diceros bicornis bicornis*, had occupied parts of Namibia and the Cape Province of South Africa until it was exterminated in about 1850. However, other zoologists (e.g. Smithers, 1983) still apply the name to extinct rhino in Southern Africa. The question of whether or not there are two subspecies in the subcontinent illustrates the central issues involved in the taxonomic debate. There are about 70 black rhino living in near-desert conditions in northern Namibia, and another 350 or so in the arid Etosha National Park. Are these populations significantly different to the rhino in Zululand and Zimbabwe? Is it worth making a special effort to get some of these animals into captive breeding facilities, in view of the political instability of Namibia?

Arguments for believing that the "Cape" subspecies, *D.b. bicornis*, is in fact not extinct but is the type still found in Namibia have been put forward by Hall-Martin (1985). In summary, the reasons given for this contention are:

1. that in common with the rhino that lived in the Cape, those now surviving in Namibia have larger skulls than members of the more common subspecies *D.b. minor*, which is said to occur from Zululand up to southern Kenya (Groves, 1967);
2. that rhino translocated to Etosha were caught in areas which were very close to the localities at which the specimens of *D.b. bicornis* were collected, and in view of the greater distance separating the Namibian from the Zululand rhino it is more likely that the Namibian and "Cape" rhino constituted a single gene pool;
3. the environmental conditions of Namibia are much the same as those of the Cape areas in which the rhino used to occur, and dissimilar to those of Zululand and other sections of the *D.b. minor* range.

The consideration of environmental conditions and their relationship to genetic diversity is a particularly important factor – one which gives much of the rationale for the attempt to sort out subspecies. In fact, the term "subspecies" is not the most appropriate to use since this term is applied somewhat arbitrarily (populations are generally described as subspecies if they occupy naturally separated ranges, or if 90% of individuals of one population differ from 90% of the individuals of the other population in the character used to discriminate – but the importance of the character being used, e.g. a skull dimension, is open to question).

Thus, the tendency of conservation biologists is rather to talk of "evolutionarily significant units", which is also a somewhat nebulous term but places a fundamental emphasis on the need to look out for features which make an animal specifically adapted to a particular environment. These features need not be obvious morphological differences but may be hidden physiological or even behavioural adaptations. Where a group of animals is living in environmental conditions which are considerably harsher than those experienced by other members of the species, it is sensible to regard this as an evolutionary significant unit that is worthy of special conservation effort; it is unlikely that representatives of the species from elsewhere could be successfully introduced into the marginal habitat if the original inhabitants died out.

So, since the Namibian rhino are desert animals which range over far greater areas than those normally occupied by rhino, and are somehow able to satisfy their requirements for water and browse, they can be regarded as a specially evolved genetic unit. As for the rest of the rhino in Africa, the habitat variability is less evident but there may well be environmental influences, such as varieties of blood parasites, to which the animals have become specifically adapted in different areas. Investigations of the genetic variability of black rhino are

currently being carried out at two levels. The first is the rather crude, traditional approach of measuring rhino skulls, but in far greater numbers than has been done before. This should give a rough indication of variability within the species. The second approach is a vastly more sophisticated one of biochemical taxonomy, in which the genetic molecules of different populations are compared.

Progress has been made with both these endeavours. A large number of rhino skulls (mostly the result of poaching) have been measured in Zimbabwe and Zambia, and smaller sets of data are available from Central, East and South Africa – these will be expanded in the near future. It is apparent from this research that there is a degree of sexual dimorphism in the rhino skulls and that this factor, which was ignored in the previous taxonomic studies, does have to be taken into account when comparing one sample with another. A tentative conclusion is that the variation in skull dimensions in the black rhino reflects a straightforward clinal situation, with the largest skulls in the southern extremity of the species' range and the smallest in the north. However, more work in Kenya and Tanzania may reveal a pocket of animals (maybe occupying a particular altitudinal zone) which differ markedly in their skull shapes from animals to the north and south of them.

If this is the case, it would indicate the need for more detailed analysis, using biochemical methods, of the genetic distinctions. The immediate objective of the biochemical research is to compare the genomes of the Zimbabwean and Kenyan populations through mitochondrial DNA sequencing. In mid-year, 1986, the opportunity was taken during a translocation of rhino from the Zambezi Valley to collect blood from 30 animals, to separate each sample into different fractions through centrifugation and to freeze the various cells and plasma in liquid nitrogen. Sophisticated laboratory work will now entail the extraction of mitochondrial DNA, its cleavage with restriction enzymes, and electrophoresis of the DNA fragments. During early 1987, blood will also be taken from rhino that are due to be translocated in Kenya, and the mitochondrial DNA of these animals can then be compared with the Zambezi samples.

A further insight into the degree of genetic divergence that has occurred between populations within the formerly continuous black rhino range may be obtained through the assessment of similar genetic studies that are likely to be carried out on the Zululand rhino. This biochemical research, in conjunction with the morphometric studies and consideration of environmental adaptations, should therefore get us a long way towards the objective of establishing the evolutionary significant units of black rhino.

Genetic Management

Once small populations of rhino come under close management, either as a result of intensive protection being afforded to remnant groups in parts of their former range, or as a result of the translocation of animals (hopefully

selected for their genetic importance) to *ex situ* captive breeding facilities, the managers have to follow some plan to minimize loss of genetic variability.

As suggested by common sense, each plan will depend primarily on the size of the founder population. The fundamental requirement in the business of genetic management is to identify the size of a population that has to be maintained as an interbreeding unit in order to prevent extinction, i.e. to establish the Minimum Viable Population (MVP). Soule and Simberloff (1986) provide a useful metaphor to illustrate the questions and responsibilities facing conservation biologists attempting to conserve a particular endangered species. They liken the conservation effort to a kind of journey, but one through time rather than space – one of millenia. We humans are the travel agents, trying to anticipate the crises that may threaten our charges, and to prepare them for such eventualities. The crucial things to pack to ensure that the journey ends in survival rather than extinction are alleles (not jeans!). Unlike Noah, we need more than two founders for each species in order to ensure that the species has enough genetic variability to last the journey.

Soule and Simberloff (1986) also classify the forces that drive species into extinction. These fall into two categories: extrinsic and intrinsic. Extrinsic forces include deleterious interactions with other species (increases in predation, competition, parasitism, disease or decreases in mutualistic interactions) and deleterious events or changes in habitat or the physical environment. Intrinsic factors involve random variation in genetically-based traits of the species and interactions of these traits with the environment. The most important of these factors for rhino are probably 1.) demographic stochasticity (random variation in sex ratio, and in birth and death rates), and 2.) genetic deterioration brought on by inbreeding, genetic drift and other factors.

Demographic stochasticity is obviously a far greater threat to small than to large populations; for instance, the probability that all offspring of one generation will be of a single sex and therefore unable to reproduce will be higher the smaller the population. The effects of demographic stochasticity are not likely to have serious effects in themselves on black rhino populations of over 20 or so individuals, but may operate in conjunction with environmental catastrophes such as droughts or disease epidemics to cause the demise of a population of even 100 or more. These compounding problems may have a lot to do with the decline of black rhino in Hluhluwe Game Reserve (Zululand) by about two-thirds over the last 13 years to a current level of only about 70, with no evidence of significant poaching.

Genetic deterioration involves a set of rather complex issues and some of the concerns are based more on theoretical considerations than on direct observations, because of the time-scales involved. However, there is abundant evidence that inbreeding among normally outbreeding organisms generally results in a sharp decrease

in fitness; genetic defects have significantly depressed survival rates of a number of inbred populations in zoos (Ralls and Ballou, 1983). The minimum population size required to prevent inbreeding will vary from species to species since there are of course many different ways in which animals go about their breeding.

A rough rule of thumb in conservation genetics relating to vertebrate species is that for short-term maintenance of a safe level of genetic variability the maximum rate of inbreeding should be no more than 1% per generation; this corresponds to an effective population size of about 50. "Effective population size" is a number based on the extent to which each member of a population is involved in passing on alleles to the next generation; this number is usually in the order of one-third to one-fourth of the actual population size. Thus, to have an effective population size of 50, the minimum actual size of a breeding group must be 150 to 200 individuals.

Zookeepers have developed species-specific management techniques that have enabled them to increase the effective population sizes of many species in captivity, but not to a marked extent in the case of rhino. Of the 558 southern white rhino in zoos at the end of 1980, only 20 males and 65 females were reproducing (Foose, 1983). The problem of maintaining a sufficiently large population to satisfy basic genetic requirements becomes even more daunting when one considers the effective population size required to prevent long-term loss of variability through genetic drift (random changes in allele frequencies). Franklin (1980) has suggested, on the basis of the rather rough equations that are currently available to geneticists, that for long-term conservation the minimum effective size should be 500. Below this value, it is likely that genetic variance for complex traits will be lost at a significantly faster rate than it is renewed by mutation, and the species will be unable to evolve to suit changing environmental conditions.

To have an effective population size of 500, the total population has to be 1 500 or more. Since the population of black rhino in the Zambezi Valley below Kariba is now the largest remaining contiguous population and yet is probably under 1 000 individuals, the long-term future of the rhino as a naturally-evolving species looks bleak. However, provided Zambian poachers can be prevented from doing much more to destroy the future of the species, there is the possibility of managing the entire Zimbabwean population (1 500+) as a single breeding unit, through periodic transfers of animals from one naturally interbreeding group to another. The rate of transfer need not be very high; it would seem from information presented by geneticists at a workshop on African rhino management in Cincinnati in October, 1986, that the movement of one genetically effective animal per generation (every 17 years or so) into each small population (of about 50 individuals) would be sufficient to prevent excessive inbreeding.

In fact, it is necessary to avoid too much exchange of

genetic material between small populations because this could ultimately result in a high degree of relatedness among all individuals in all populations – hence excessive outbreeding can promote a future inbreeding problem. Genetic transfer between populations is a double-edged sword because on the one hand it can help reduce inbreeding depression, but on the other hand tends to prevent further evolution of the different populations. The development of a genetic trait within a population as an adaptation to some change in the environment within which that particular population lives (e.g. the Zambezi Valley) will be retarded if the gene pool is also made up of populations which are not exposed to the same selective pressure (e.g. Namibian or Kenyan rhino).

Since we have already got to the stage where we have to worry about these genetic considerations as they apply to wild as well as captive populations, we need to get a better idea of demographic parameters, breeding behaviour and genetic variability within the wild populations. While mitochondrial DNA sequencing is thought to be the appropriate technique for investigating genetic variation between the different rhino populations, the investigation of genetic variability within a particular population is generally tackled through electrophoresis of serum proteins. This technique has severe limitations; it can only detect variability in a small fraction of a percentage of the genome. Thus the finding that there are differences in serum proteins between individuals in a population will enable one to say that the population is genetically diverse, but the lack of any apparent differences will not allow one to say that the population is genetically uniform. There may be significant differences elsewhere, in all the rest of the genome which is not involved in coding for serum proteins. Nonetheless, protein electrophoresis is the first step to take in investigating within-population variability, and therefore serum samples were collected from Zambezi rhino during the 1986 translocations to be analysed in this way.

A final topic that must be touched upon in this very brief overview of some of the genetic considerations of rhino conservation is that of artificially-enhanced breeding. An effective population size can be made as much as twice the actual population size (Foose, 1983), largely through techniques such as artificial insemination and embryo transfers. Semen has been collected from black rhino, and work has been done in zoos on oestrus determination through observation of physical and behavioural signs and through hormone assays of urine, but no successful artificial insemination has yet been reported for the species.

White rhino cows – which are relatively numerous in zoos – may well be used as surrogate mothers for black rhino, through embryo transplants (just as eland have served as surrogate mothers for bongo). An obvious benefit that may be realized if methods for cryopreservation and use of rhino semen can be improved is that it would then be less necessary to move live animals around in order to maintain gene flow, and thus expenses and risks would be vastly reduced. The American Association of Zoological Parks and Aquaria is currently initiating an intensive

programme of research on artificial enhancement of rhino breeding.

If artificial insemination is to be used in wild populations, where considerations of translocation costs are especially crucial, then some work on oestrus determination through chemical analyses of rhino dung would be very worthwhile. Black rhino create a communications system within their ranges by kicking up their dung so that scent is left by their feet as the animals go about their generally solitary daily business, and these scent trails are known to be important in demarcating ranges and in getting breeding pairs together. Thus there are likely to be some volatile hormone residues in the dung that could be detected through gas chromatography, thereby avoiding the almost insurmountable problem of collecting urine samples for hormone assays.

Diseases of Rhino

Underpinning the success of all the elaborate breeding programmes that may be carried out is the well-being of the individual rhino. There are of course numerous disease problems that afflict black rhino (see Jones, 1979, and Silberman and Fulton, 1979, for reviews) and discussion in this paper will be restricted to a couple of interlinked problems that are now causing particular concern.

A recent survey in zoos has shown that 40% of deaths of adult black rhino are associated with haemolytic anaemia (Chaplin et al., 1986). The underlying reasons for the intravascular destruction of red cells have not been established despite a range of haematologic and immunohaematologic studies carried out with small samples in the United States (see Chaplin et al., 1986). In view of the seriousness of this problem (which is aggravated by a lack of data on the normal blood parameters of wild rhino), a full range of blood analyses were carried out on samples taken during the 1986 Zambezi translocation, and particular attention was paid to studies of red cell fragility and haemoglobin stability. This work has shown that black rhino have an unstable haemoglobin, thus making them inherently prone to haemolytic anaemia triggered by a variety of stress factors.

The question that is now raised is what kind of adaptive advantage can unstable haemoglobin (and other abnormalities of the red cell) confer to black rhino. Perhaps this is an adaptation to blood parasites. The classic case of a normally debilitating blood condition being advantageous in a situation of parasite challenge is that of sickle cell anaemia and the resistance it affords humans against malaria. There are also strong indications that a deficiency of the red-cell enzyme glucose-6-phosphate dehydrogenase, while the cause of lethal favism, is advantageous to people in areas with falciparum malaria because it makes red cells prone to destruction under the oxidant stress of parasitaemia and thus prevents the parasite from completing its life-cycle within the body (Golenser et al., 1983).

In Kenya, it has been found that, without prophylactic treatment, black rhino often die due to trypanosomiasis or piroplasmiasis after being captured, because physiological stresses of capture, and possibly inadequate nutrition in holding pens, reduce the animals' resistance to blood parasites (Clausen, 1981; McCulloch and Archard, 1969). This shows that the animals generally maintain a fairly delicate balance with their blood parasites. There have been a number of die-offs of rhino in the wild which have not been satisfactorily explained but which may well be due to a reduced resistance to parasitaemia as a consequence of nutritional stress, and/or to forms of excessive oxidant stress on the red cells, promoting haemolytic anaemia.

For instance, about 300 black rhino died in Tsavo National Park in the early 1960's. The animals were short of food due to habitat destruction by elephant and a prevailing drought, but the cause of death was not thought to be simple starvation and was tentatively ascribed to "nutritional anaemia". There have also been puzzling deaths of 46 rhino in north-eastern Hluhluwe in 1961, and about 40 in the Zambezi Valley in 1983-84, added to which are some recent losses after translocation of rhino from the Valley.

Further research on these disease problems is intended since they have such drastic implications for the small breeding groups that will be the only hope for the survival of rhino occurring north of the Zambezi. Within Zimbabwe, South Africa and Namibia, translocations of rhino to build up populations in as many areas as possible will be a major component of the national rhino conservation strategies, and guidelines on parasite control, and other health problems, are clearly required.

Conclusion

This paper has touched on a limited set of facets of the conservation biology of black rhino; the range of research that is required is considerable, and will be costly. However, unless this work is supported, many of the efforts to save the species will be no more than panic measures of very transient benefit. To avoid directing rhino conservation up blind alleys, we must adopt a very broad and long-term perspective on what our charges require for their journey into the future.

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