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 (Table 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 2) 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 protected areas 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 1) 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 (protected) area of the natural range of the species now. Instead, this guideline for subpopulation size represents a minimum number that the protected area 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 protected areas 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 protected areas for either captive propagation or for careful translocation into larger or securer areas.

Such animals have been designated "doomed" or more recently and less negatively "isolated". 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 or isolated 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 overmultiple "subpopulations" will actually increase the effective size of the total number maintained in terms of the capacity to tolerate the stochastic problems. (Figure 1). 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, protected areas 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 mostly 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 protected areas 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 37 viable populations and hence significant protected areas in 11 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 1). 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 1). Price (this volume) has elaborated on this rather simplistic scheme of captive and wild by describing a more detailed spectrum of *in situ* and *ex situ* options for rhino conservation.

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 2).

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 3). 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% of what has been observed for vigorous growth in 3 wild *Rhinoceros* populations (Dinerstein & Price 1991, Amman 1985); only about 45% of the 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 3). Genome banks thus become another component in the metapopulation.

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 International Black Rhino Foundation which has been 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. However, their modest financial support may be catalytic and critical. Moreover, 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. Further, 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 4. Particularly noteworthy is the parallelism between animal-by-animal recommendations in zoos and protected area-by-protected area 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 protected area size (Table 4). It also provides for explicit mechanisms to implement the plan (Figure 5)

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 developmentof 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 1).

Highest priority for field conservation efforts should be extended to the 37 most viable populations and protected areas in 11 countries worldwide (18 in 6 African nations; 19 in 5 Asian nations) (Table 5).

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 6 & 7). 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. Resources for conservation are limited but these figures are probably not unattainable, particularly if rhinos are indeed used as umbrella and flagship taxa.

It is perhaps tempting to compare these costs with the operating expenses for captive facilities. For example, 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. However, much if not most of the money in zoos that can be "exploited" to serve a conservation benefit through *ex situ* programs simply is not and will not be transferable to *in situ* conservation in lands far away. These monies are primarily available to provide recreational, educational, and cultural benefits to the local communities. These monies are exploited to serve conservation at the same time they fulfill these other functions. However, if not used for the local zoos and aquariums this money would be applied to the many other needs of these communities, e.g. supporting schools, repairing roads, reducing crime, etc. Some monies are available for conservation efforts beyond the local community. More will be obtainable through use of captive programs for development of public appreciation and support in addition to providing ultimate back-up nuclei through captive propagation.

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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TABLE 1

MACE/LANDE CATEGORIES AND CRITERIA OF THREAT

POPULATION TRAIT	CRITICAL	ENDANGERED	VULNERABLE
Probability of Extinction	50% within 5 years or 2 generations, whichever is longer	20% within 20 years or 10 generations whichever is longer	10% within 100 years
	Or	Or	Or
	Any 2 of following criteria	Any 2 of following criteria or any 1 CRITICAL criterion	Any 2 of following criteria or any 1 ENDANGERED criterion
Effective Population N_e	$N_e < 50$	$N_e < 500$	$N_e < 2,000$
Total Population N	N < 250	N < 2,500	N < 10,000
Subpopulations	$\leq$ 2 with $N_e > 25$, N > 125 with immigration < 1/gen.	$\leq$ 5 with $N_e > 100$, N > 500 or $\leq$ 2 with $N_e > 250$, N > 1,250 with immigration < 1/gen.	$\leq$ 5 with $N_e > 500$, N > 2,500 or $\leq$ 2 with $N_e > 1,000$, N > 5,000 with immigration < 1/gen.
Population Decline	> 20%/yr. for last 2 yrs or > 50% in last generation	> 5%/yr. for last 5 years or > 10%/gen. for last 2 gens.	> 1%/yr. for last 10 years
Catastrophe: Rate & Effect	> 50% decline per 5-10/yrs or 2-4 gens.; subpops. highly correlated	> 20% decline/5-10 yr, 2-4 gen > 50% decline/10-20 yrs, 5-10 gen. with subpops. correlated.	> 10% decline/5-10 yrs, > 20% decline/10-20 yrs, or > 50% decline/50yrs. with subpops. correlated.
Or			
Habitat Change	resulting in above pop. effects	resulting in above pop. effects	resulting in above pop. effects
Or			
Commercial Exploitation or Interaction/Introduced Taxa	resulting in above pop. effects	resulting in above pop. effects	resulting in above pop. effects

TABLE 2

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

TABLE 3

RHINOS IN CAPTIVITY

TAXON POPULATION	CURRENT POPULATION	TARGET
Northern Black	160	150
Southern Black	22	150
Northern White	10	150
Southern White	550	150
Indian/Nepali	114	200
Sumatran	24	200
Javan	0	200
TOTALS	880	1200

TABLE 4

PROTECTED AREA OBJECTIVES SUMATRAN RHINO

Country	Protected Area	Size (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

TABLE 5

PRIORITY PROTECTED AREAS FOR RHINO

CONTINENT	COUNTRY	PROTECTED AREA
Africa	Kenya	Aberdare
		Masai Mara
		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

TABLE 6

ANNUAL COSTS FOR CONSERVATION OF VIABLE POPULATIONS OF RHINO IN THE WILD

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

TABLE 7

ANNUAL COSTS FOR CONSERVATION OF VIABLE POPULATIONS OF RHINO IN THE WILD

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

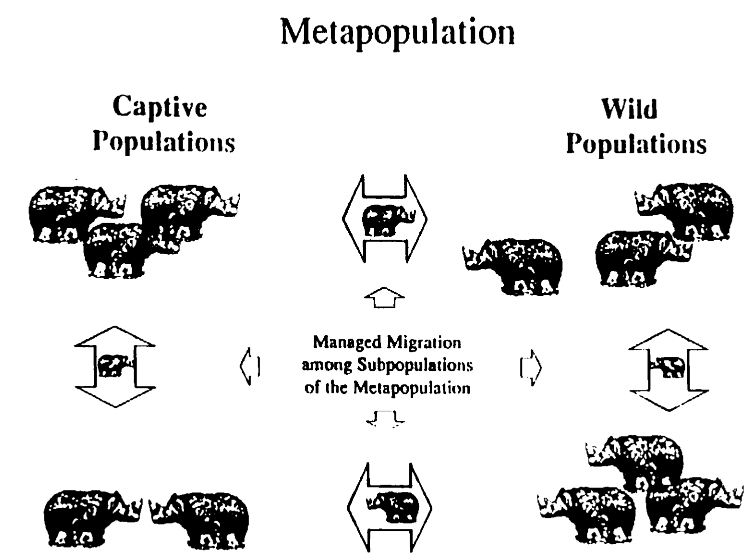

Figure 1

Figure 2

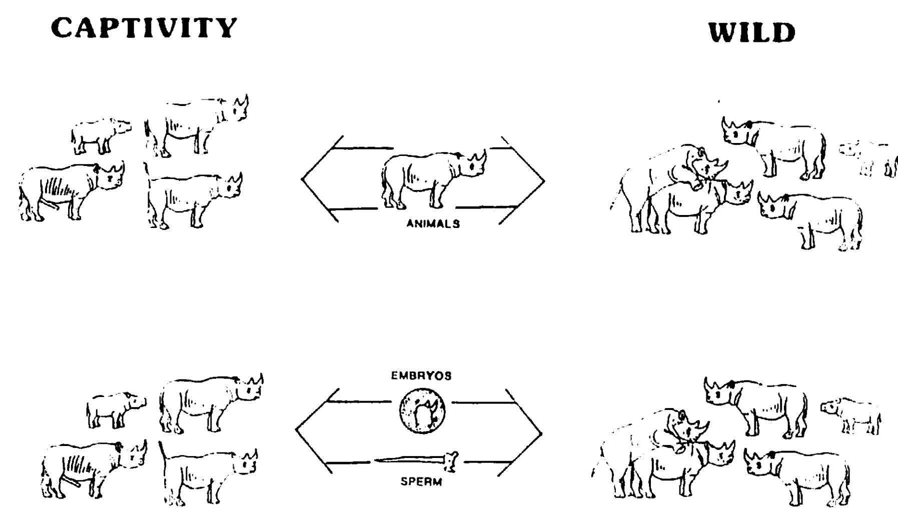

Figure 3

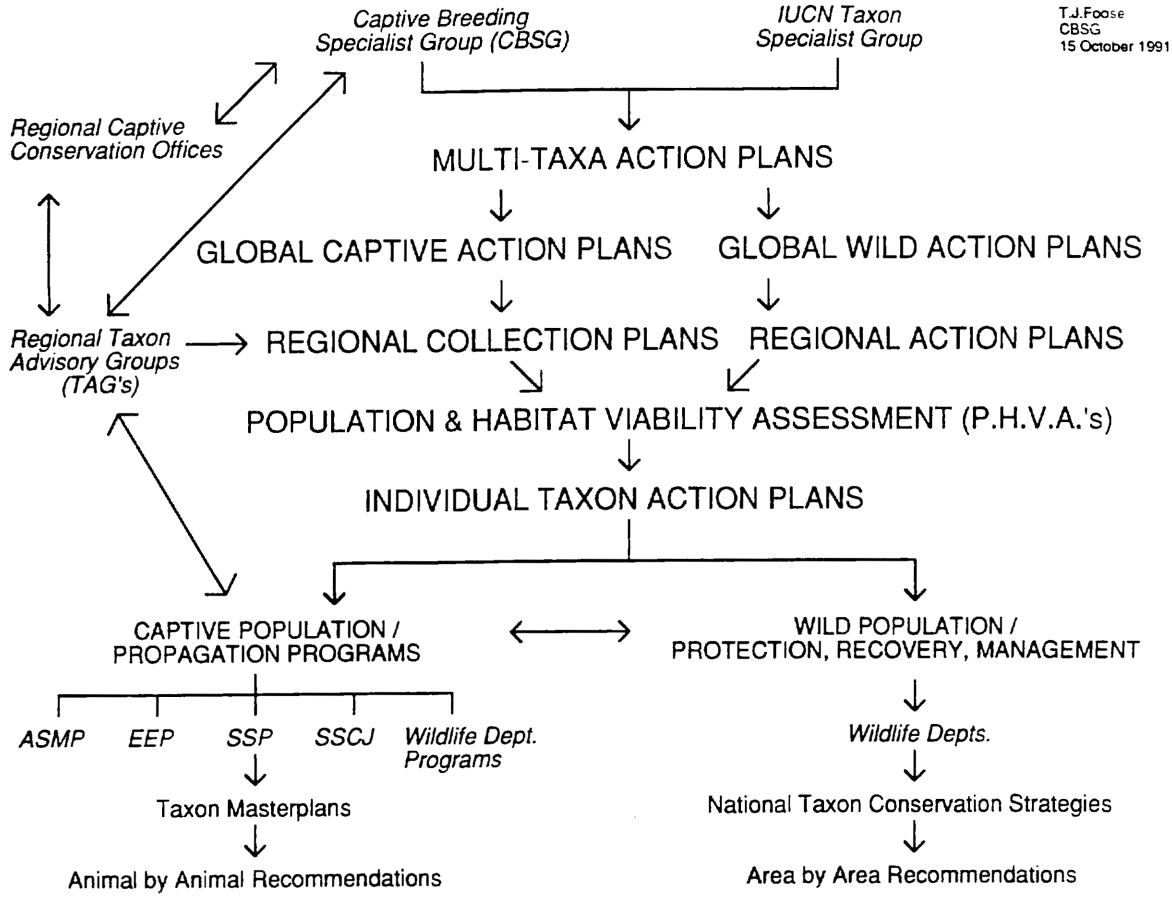

Figure 4

Tentative Organization of Indonesian Rhino Conservation Service

Figure 5