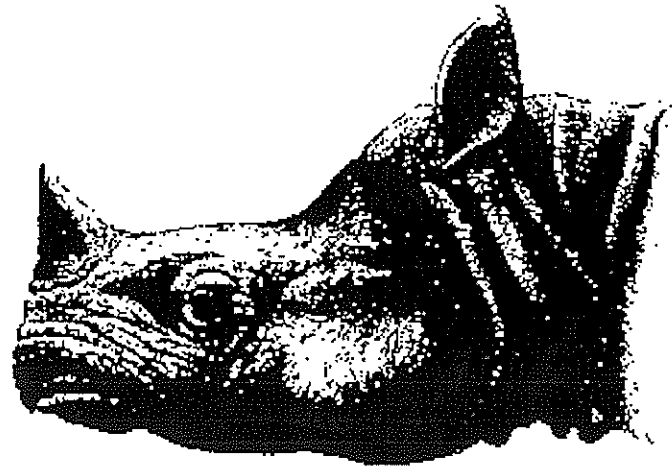
Javan Rhinoceros

Rhinoceros sondaicus



Population Viability Analysis

5-7 June, 1989

IUCN/SSC

Captive Breeding Specialist Group

CBSG

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16 August 1994

Captive Breeding Specialist Group

Species Survival Commission
International Union for the Conservation of Nature and Natural Resources

U. S. Seal, CBSG Chairman

Date: 12 January 1990

Subject: Javan Rhinoceros PVA Report

From: U. S. Seal, CBSG

To: Readers of the Report

1. Enclosed is a copy of the report on a Population Viability Analysis for Javan Rhino that was initiated at the Workshop on Indonesian Rhino Conservation sponsored by PHPA and IUCN in Bogor 5-7 June 1989.

2. This document contains the PVA analyses, documentation on the concepts guiding the analyses, and information on the analytical and simulation models used including their assumptions. Disk copies of the software used are available for MS-DOS machines (IBM PC compatibles). A hard disk is required and a mathematics coprocessor is desirable for some of the models.

3. The document also includes an appendix with a copy of the minutes of Bogor the meeting and a consensus report by the participants in the workshop. Various other protocols are also included.

4. Comparison of the Bogor workshop consensus report and the recommendations in the PVA report will reveal a number of differences. These differences reflect a substantial number of additional analyses that were done after completion of the workshop and that were not reviewed and discussed by all of the participants in the workshop. These recommendations and suggested scenarios therefore do not reflect a consensus by workshop participants. Instead they are based upon the results and options suggested by the additional analyses and our interpretation of these results.

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5. The basic observations of the workshop participants that are fundamental were:

   a. that the rhino population in Ujung Kulon may be near carrying capacity,
   b. that the Ujung Kulon rhinos constitute a single isolated population,
   c. that this population is gradually losing genetic diversity, and
   d. that this population is at risk of extinction from environmental events (with disease perhaps the most likely threat).

   These observations led to the consensus recommendation that a captive population (divided into 2 or 3 separate units) needs to be established, and that new reserves for additional wild populations need to established.

6. If it is decided to implement these basic recommendations, it will be desirable to discuss the various options and in depth in additional meetings. In particular it is very clear that establishment of a captive population and an additional reserve is of high priority. In our experience with other species which have been the subject of this approach the first decision to undertake a new program has been most difficult. It has always been necessary to discuss in depth the details and the methods for implementation of the program to assure the maximum benefit to the species at the least risk. The same approach will undoubtedly be desirable for the Javan Rhinoceros.

U. S. Seal

Captive Breeding Specialist Group

Species Survival Commission
International Union for the Conservation of Nature and Natural Resources

U. S. Seal, CBSG Chairman

JAVAN RHINOCEROS

Rhinoceros sondaicus

POPULATION VIABILITY ANALYSIS

and

RECOMMENDATIONS

Captive Breeding Specialist Group

and

Asian Rhinoceros Specialist Group

Species Survival Commission IUCN

Prepared by

U. S. Seal and T. J. Foose

with contributions from

J. D. Ballou, R. C. Lacy

24 July 1989

(Based upon a population viability analysis workshop
held 5 - 7 June 1989 at Bogor, Indonesia)

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JAVAN RHINOCEROS

POPULATION VIABILITY ANALYSIS

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PVA ANALYSIS

(3) Project the potential expansion or decline of rhinoceros population numbers under various management regimes.

(4) Outline metapopulation structure needed to establish viable populations of each species. Indicate management consequences of this approach.

(5) Formulate quantitatively and evaluate role of captive propagation as a component of the strategy for the Javan rhinoceros. In particular, consider how captive propagation can:

a) accelerate expansion of population,

b) enhance preservation of genetic diversity,

c) protect population gene pool against fluctuations due to environmental vicissitudes in wild, and

d) provide animals for reinforcement of wild populations and establishment of new populations.

(6) Develop goals for the captive populations to provide rhinos for release to the wild without compromising the genetic diversity and demographic stability of the captive population.

(7) Identify problems and issues that need continuing analysis and research.

(8) Recommend courses of action.

(9) Produce a document presenting the results of the workshop.

Captive Breeding Specialist Group

Species Survival Commission
International Union for the Conservation of Nature and Natural Resources

U. S. Seal, CBSG Chairman

JAVAN RHINOCEROS

Rhinoceros sondaicus

POPULATION VIABILITY ANALYSIS

RECOMMENDATIONS

1. Continue and intensify protection of the rhinoceros population at Ujung Kulon. The major threats are poaching and disease. Removal of 1 animal every 2 years is sufficient to prevent population growth and is a threat to survival of this small population. Disease threats to the wild population should be evaluated.

2. Establish a captive breeding program in 1990 with the objectives of collecting as full a genetic representation of the wild population as possible and expanding the total captive population to 150 animals as soon as possible.

   a. Establish 2 protected captive populations as soon as possible to protect against loss of the species and to assist expansion of numbers. One of these populations should be located near a site on Sumatra selected for eventual reintroduction into the wild. One population might be located on Java either in a zoo or a facility that can be expanded to hold 15-25 animals. It is essential that all captured animals be placed in groups in facilities designed for secure management and breeding. A captive population also should be located outside of Indonesia to provide maximum security for the species.

   b. Remove 18-26 animals from the population at Ujung Kulon to establish the captive populations. This should be done with continuing evaluation, according to the suggested guidelines, of the experiences with capture and postcapture management and mortality. The wild population appears to be at carrying capacity which is limiting further growth. It can recover from this removal within 10 years if growth rates increase to 3.5+% as occurred during 1971-1981.

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3. Expand the total captive population to a minimum of 80 - 100 animals with an annual growth rate of 3.5% before beginning a release program. This is necessary to protect the species gene pool and to have sufficient animals to supply a release program without jeopardizing the demographic security of the captive population and the species gene pool.

4. Plan to restore the Javan Rhinoceros to reserves throughout its historical range to a total population of at least 2000 animals and manage the individual populations as a single metapopulation.

5. Initiate a field research program, using radiotelemetry, with the Ujung Kulon rhino population to provide information on the population dynamics and ecology of the species in preparation for future reintroduction programs. This will also provide additional protection for the population.

6. Initiate molecular genetic studies on all of the animals, as captured, to evaluate remaining levels of heterozygosity and to assist in identifying pedigree relationships among the animals as a guide to the captive breeding program. These studies will also allow comparison with samples to be collected from the Vietnamese population to evaluate the relationships of the two populations.

7. Initiate serological and laboratory studies on the rhinos as a guide to their health status and disease history. Samples should also be collected from banteng as a baseline for any future disease outbreaks in the rhinos and banteng.

8. Initiate reproductive studies of the species, including cryopreservation of semen, to assist in captive breeding management, preservation of genetic material, and to determine if the wild population is having reproductive problems.

9. Establish a collaborative species recovery and management program to develop a genetic and demographic masterplan for the captive and wild populations and to develop the necessary resources to undertake these programs.

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, 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 minimum viable populations (MVP's), i.e. populations large enough to permit long-term persistence despite deterministic and stochastic 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 the early stages of evolution. 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

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

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

The *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 effective population size 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. For larger vertebrates, there is a point of diminishing genetic returns (Figure 1). Hence a common genetic objective is to obtain 20-30 effective founders to establish a population. If this objective can't 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.

The number of effective founders desirable for a recovery program for Javan rhinoceroses can be estimated at between 20 and 30, depending on whether every wild caught rhino reproduces and is accepted as the starting point for the population or whether kinships among the rhinoceroses are also considered.

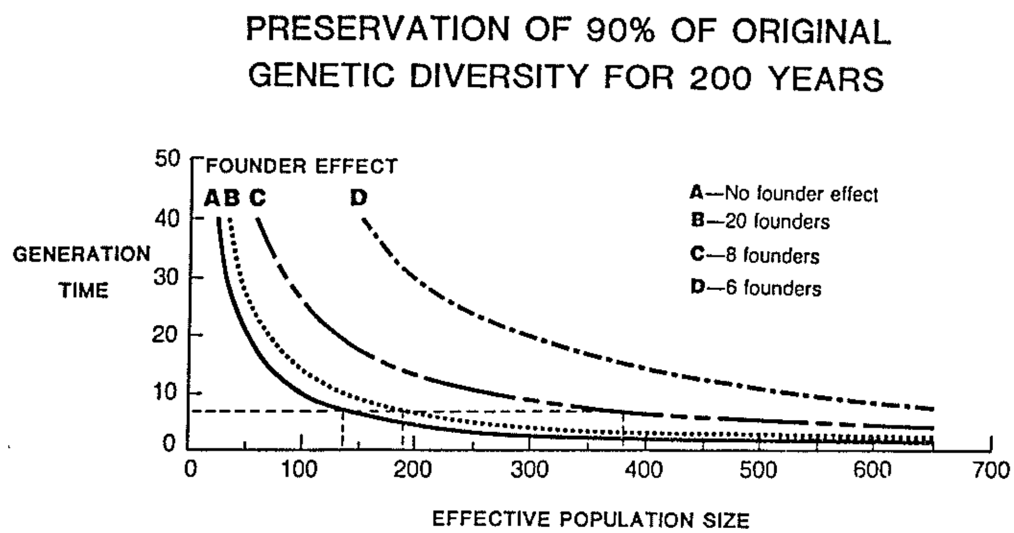


Figure 1. Interaction of number of founders, generation time of the species, and effective population size required for preserving 90% of the starting genetic diversity for 200 years.

Effective Population Size. Another very important consideration is the effective size of the population, designated N_e. N_e is not the same as 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 a set of genetic objectives; the census population size might have to be 2000.

Growth Rate. The higher the growth rate, the faster a population can recovery 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 already been applied more or less to about 30 species (Parker and Smith 1989; Seal 1989).

As mentioned earlier, PVA modelling currently must be performed separately with respect to genetic and demographic events. Recent models allow simultaneous consideration of environmental uncertainty and demography. 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.

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 50% of actual populations will become extinct before 70% of the average 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 of course imply minimum critical areas of natural habitat, that will be vast for large carnivores like the Florida panther. 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 so-called 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.

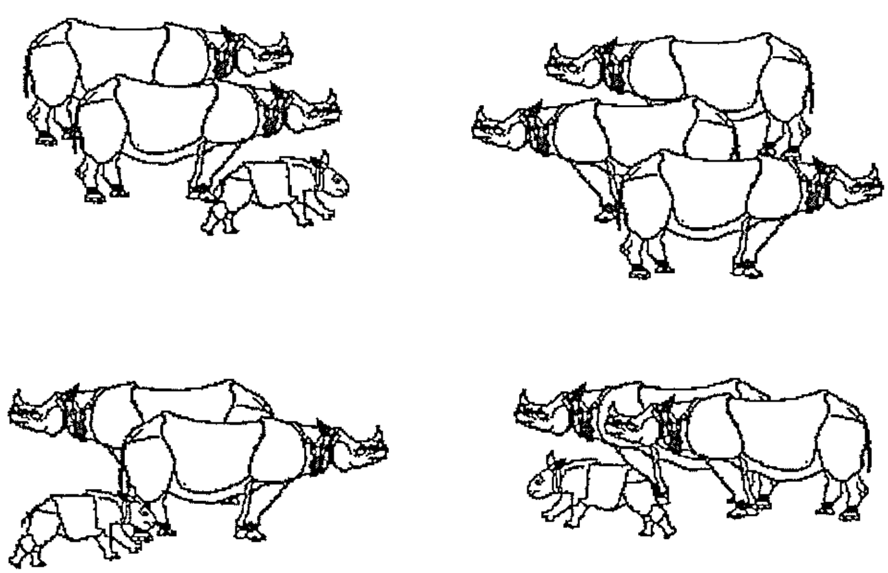


Figure 2. Multiple subpopulations as a basis for management of a metapopulation for survival of a species in the wild.

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

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. The desirable MVP would allow management by benign neglect. It is possible to reduce the MVP required for a set of objectives, or 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.

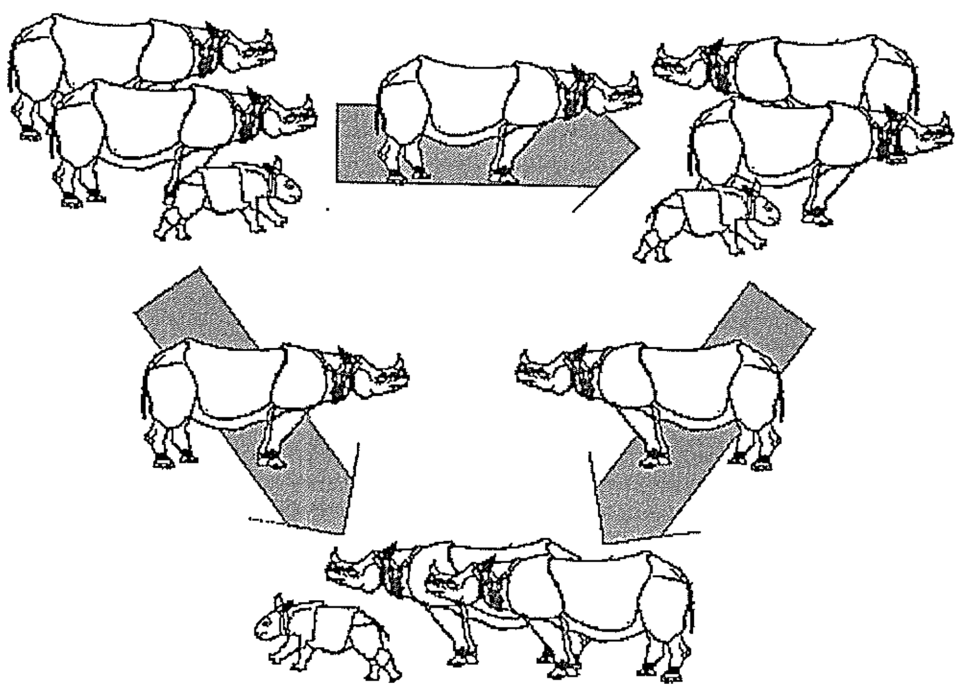


Figure 3. Managed migration among subpopulations to sustain gene flow in a metapopulation.

Management interventions that currently are being applied to the Javan rhinoceroses include monitoring, protection of habitat, and protection against poaching.

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.

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.

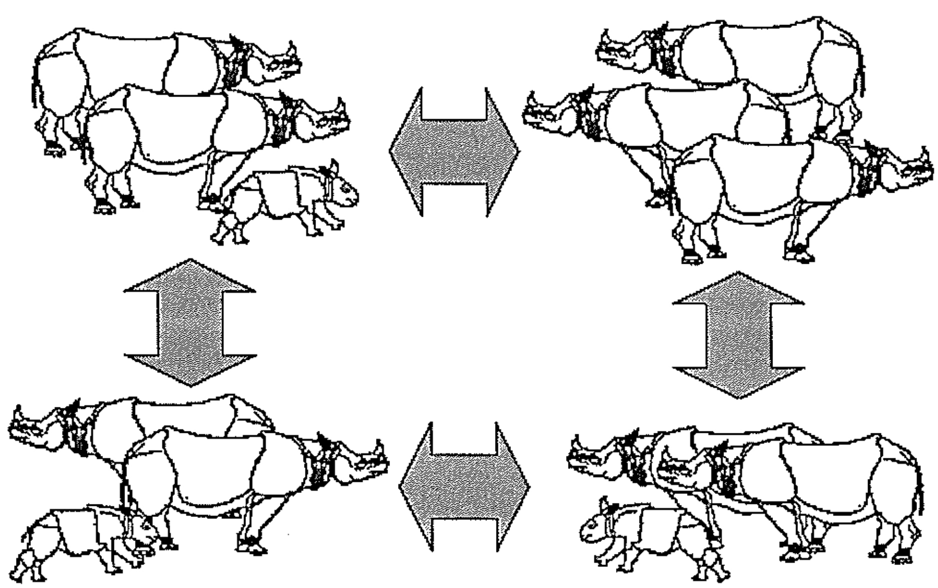


Figure 4. The use of captive populations as part of a metapopulation to expand and protect the gene pool of a species.

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 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.

Prime examples of such a captive/wild strategy are the red wolf, black-footed ferret, Puerto Rican parrot, and Puerto Rican crested toad programs. In fact, there is now a combined USFWS Recovery Plan/SSP Masterplan for the red wolf and others are being developed for the toad and parrot. Much of the captive propagation of red wolves has occurred at a special facility in Washington state. But there are 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 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 and the red wolf. Another option might 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 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 Javan Rhinoceros was formerly widespread on Java and from Malaysia to Vietnam and numbered perhaps a 50-100,000 rhinos. By 1937 the species was reduced to just 25 rhinos on Java in Ujung Kulon with none in captivity. Intensive efforts since 1967 accomplished a steady increase to about 45 rhinos in 1977 and to 52-60 rhinos in Ujung Kulon in June 1989. The wild population is still much too small to be assured of persistence over even short time spans.

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), and because we rarely examine feedback among the factors, 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, however, 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 down listed 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 1987). 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 Florida panthers (_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 Florida panthers. No deleterious trait in rhinoceroses has yet been clearly demonstrated to have a genetic basis, but poor breeding performance and a decline in disease resistance can result from, in part, genetic causes.

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. As the Ujung Kulon population of Javan rhinoceroses was 30 or less for about 60 years (3-4 generations), it is possible that many of the currently breeding rhinos are related and perhaps some pairs are full-siblings. 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), and a few wild populations. 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) 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 Javan rhinoceros (perhaps 15-20 years), the present bottleneck has existed for just 3 or 4 generations, and could be exited (successfully, we hope) before another generation passes and further genetic decay occurs. 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

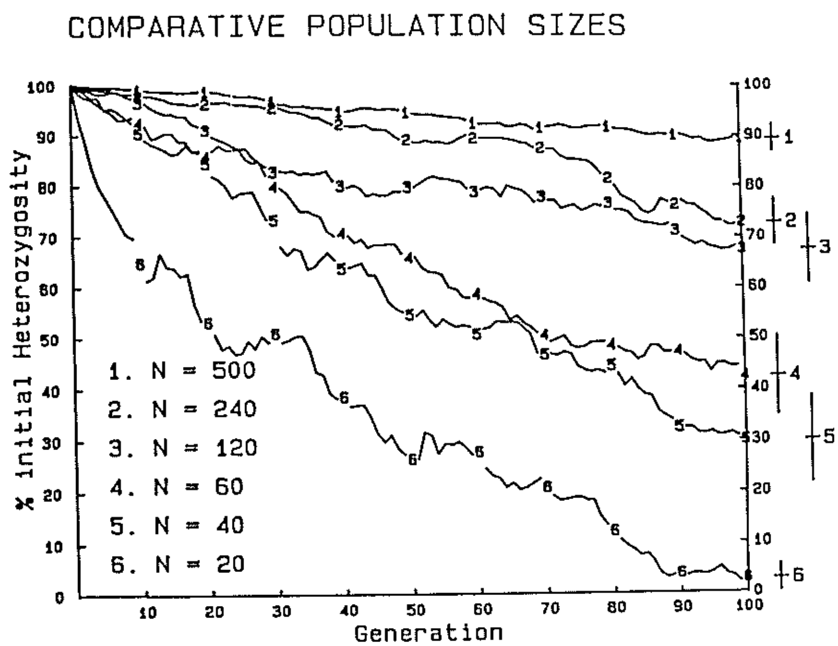


Figure 5. The average losses of genetic variation (measured by heterozygosity or additive genetic variation) due to genetic drift in 25 computer-simulated populations of 20, 50, 100, 250, and 500 randomly breeding individuals. Figure from Lacy 1987.

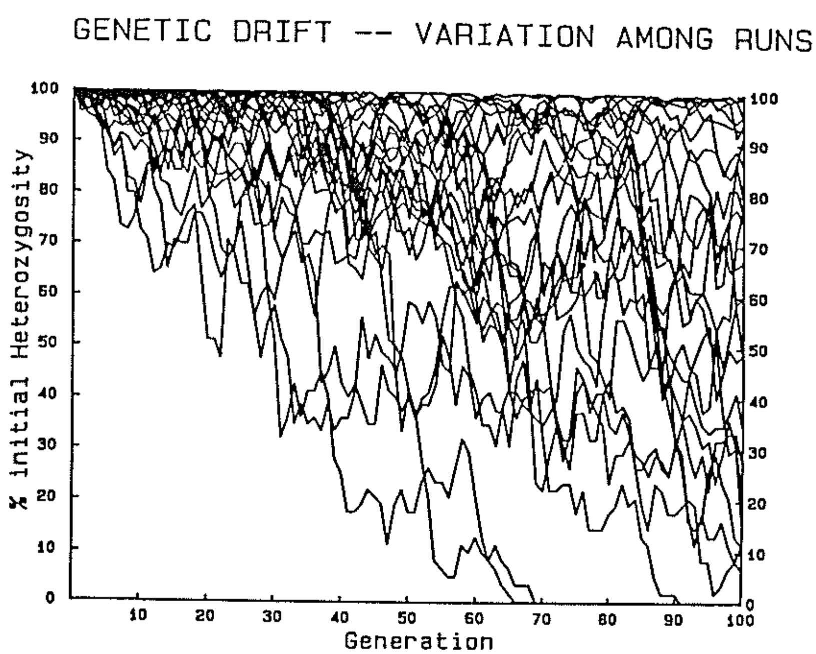


Figure 6. The losses of heterozygosity at a genetic locus in 25 populations of 120 randomly breeding individuals, simulated by computer. Figure from Lacy 1987.

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 time scale 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.

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 time scale of management.

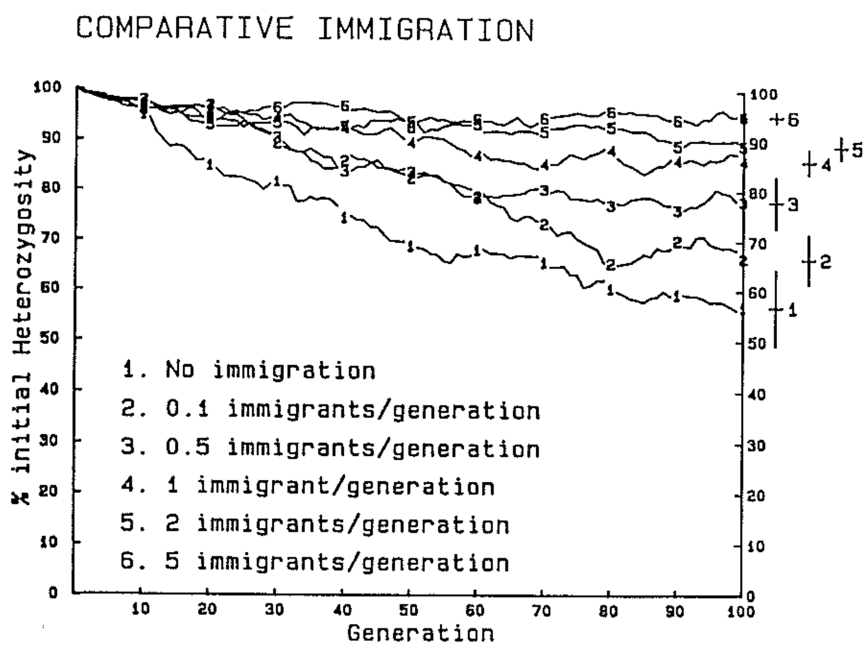


Figure 7. The effect of immigration from a large source population into a population of 120 breeding individuals. Each line represents the mean heterozygosity of 25 computer-simulated populations (or, alternatively, the mean heterozygosity across 25 genetic loci in a single population). Standard error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

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.

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.

<u>Genetic Considerations in Javan Rhinoceros Management</u> (U.S.Seal)

Effective Population Size:

The wild population of Javan rhinos may have had about 6-7 adult males and 9-13 adult females with at most 2-3 females and 1-3 males breeding each year during the six decades when it numbered 25-30 animals. The variance in family size is unknown. Annual fluctuations in the number of breeders and the sex ratio of breeders (less than 1:1 because Javan rhinoceroses are polygamous) will depress the effective size slightly. The effective population size may have been 10-14 during this time.

A. ABSOLUTE SUBDIVISION

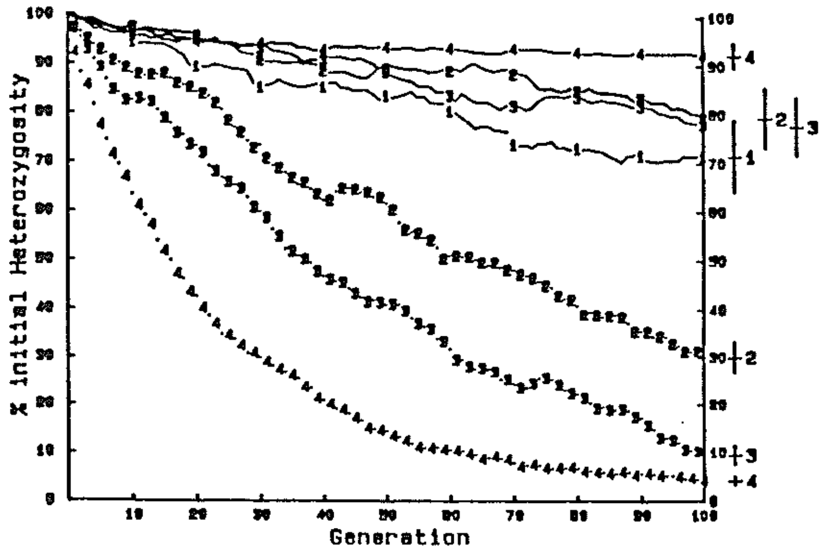


Figure 8. The effect of division of a population of 120 breeders into 1, 3, 5, or 10 isolated subpopulations. Dotted lines (numbers) indicate the mean within-subpopulation heterozygosities from 25 computer simulations. Lines represent the total gene diversity within the simulated metapopulation. Figure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

MIGRATION AMONG 5 SUBPOPULATIONS

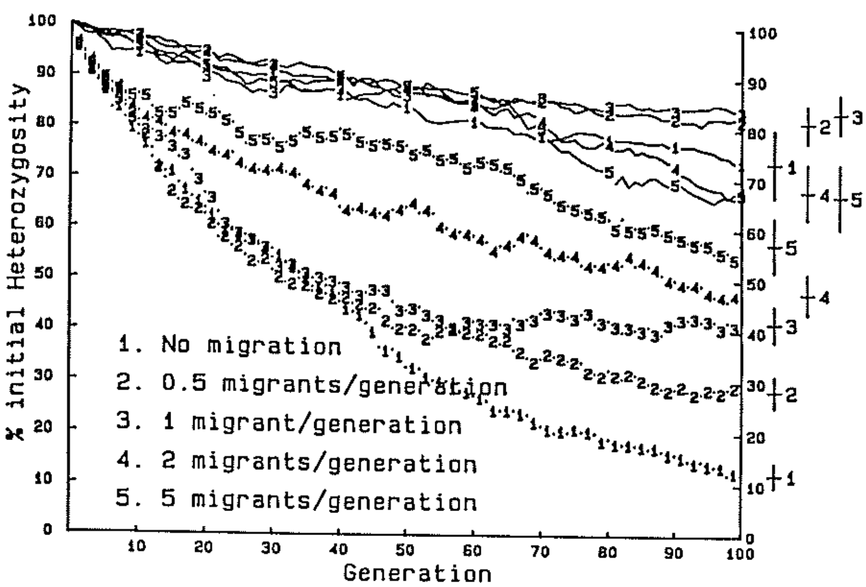


Figure 9. The effect of migration among 5 subpopulations of a population of 120 breeders. Dotted lines (numbers) indicate the mean within-subpopulation heterozygosities from 25 simulations. Lines represent the total gene diversity within the metapopulation. Figure from Lacy 1987.

This effective population size would result in a loss of genic diversity or heterozygosity of about 4 - 5% per generation (about 15-18 years). Thus perhaps 15-20% of genic diversity would have been lost during the 6 decades of small population numbers of Javan rhinoceroses. While this loss is not likely to cause immediate problems (nor is it sufficiently depressed to allow detection by molecular analysis of protein or DNA variation in small samples), the long-term genetic prognosis would not be good if the population were to remain at this low effective population size. Inbreeding is inevitable after three generations. (Even with maximal avoidance of inbreeding, each animal would have the same 10 great-grandparents in the third generation descendants, and the minimum inbreeding coefficient possible in fourth generation progeny would be F=.05.)

Enough wild-caught Javan rhinoceroses will need to be brought into captivity to provide a sufficient genetic base for a long-term propagation program. Twenty rhinos, if all breed equally, would capture 97.5% of the genic variation present in the wild. If needed, additional wild-caught Javan rhinos genetic representation could be achieved by collection of semen from wild males. Reproductive technology may also be used to assure that all captive animals contribute to the captive gene pool and to assist equal representation from all of the founder stick. The gene pool of the captive population could closely approximate that of the wild population.

Genetic Recommendations -- Javan Rhinoceros

Samples for molecular genetic analyses should be collected as soon as animals are taken into captivity. Also it is now possible to collect skin biopsies remotely with a dart device.

Allozyme data may permit inferences about the level of genetic variation or past inbreeding in the remnant population. It should be noted that the present population bottleneck (about 3 or 4 generations at effective population size of 10-14) is not narrow enough to cause a loss in diversity that could be measured with a few samples. Data on 25 to 35 allozymes should be obtainable, and comparisons to other rhinoceroses might allow assessment of possible past losses in diversity, continued monitoring of future losses of variation, and measurement of the genetic divergence of the Javan rhinoceros from the population recently located in Vietnam.

DNA fingerprinting can provide valuable insight into genetic relationships among the wild rhinos (though it is unlikely that relatives more distant than half-siblings could be identified by this or other techniques). Analysis of restriction fragment length polymorphisms of mitochondrial DNA could provide further evidence of relationships among the Javan rhinoceroses, and genetic divergence from the Indian rhinoceros.

As with any endangered species, each specimen is potentially a very valuable source of information. Whenever a rhinoceros dies in captivity or is found dead in the wild, tissues should be removed within hours, if at all possible. The tissues should be stored below -60 C for later genetic analysis. The best tissue for genetic analysis is generally liver.

The captive population should be expanded in numbers as rapidly as possible. Population growth rates of 5-6% per year can be achieved by removal of calves shortly after weaning (5-6 months) from the cows and rebreeding the female. Semen should be collected from all of the males and cryopreserved as soon as technically feasible. Avoidance of inbreeding in the captive population should be continued so long as it is possible and does not reduce the number of pairings that can be made. (Inbred offspring are better than no offspring: if only related rhinos are available for pairing they should not be kept separate.) Careful records should be kept to allow later comparison of mortality, fecundity, and growth of inbred vs. non-inbred rhinos. The genetic base of the captive population could be improved, and inbreeding in captivity therefore further postponed, if exchanges of captive and wild genetic material (semen, ova, embryos) can be made without risk to the rhinos in order to bring genes from unrepresented wild breeders into captivity.

Pairings should be planned to minimize the losses of genetic contributions from founder animals. Selective culling of rhinos with presumed genetic defects should be avoided unless the trait can be clearly demonstrated to have a genetic basis, and a demographic cost of allowing rhinos with the trait to breed can be shown (i.e., removing affected rhinos from breeding would allow enhancement of breeding by others). Even if some undesirable traits are in part genetically determined, the value of the limited genetic material in each of the remnant rhinoceroses is such that we would not recommend the selective removal of any rhinos (each of which almost certainly harbors both beneficial and deleterious genes). Causes of breeding failures should be vigorously investigated, not so much to demonstrate any genetic base (which would be interesting but of relatively little importance to management), but rather to allow correction of problems stemming from environmental causes.

DEMOGRAPHIC PROCESSES IN SMALL AND FRAGMENTED POPULATIONS

(J. Ballou)

Extinction rates (persistence times) of populations are determined by the population size, growth rate, susceptibility to demographic challenges (sometimes measured as variation in growth rate), and its spatial distribution. In turn, growth rate, and population's susceptibility to demographic challenges is determined by the population's life history characteristics, and such random factors as the severity of demographic, environmental, genetic, disease and catastrophic events affecting the population.

Preliminary models are available for estimating persistence times for specific populations providing data are available on the demographic characteristics of the population. These model have been most useful for developing conservation strategies for small populations.

While the mean (expected) persistence time can be roughly estimated, these models show that persistence time is distributed as an approximate exponential distribution. Hence there is a high probability that the population will go extinct well before its calculated mean time. Model results that indicate long mean persistence times are therefore misleading since more than 50% of the time populations will go extinct before the indicated mean time period.

To protect against this, very large populations or a number of different populations will be needed to assure high certainty of population survival for significant periods of time. Furthermore, management decisions need to specify both time frame for management and degree of certainty as specific management goals (e.g. 95% certainty of surviving for 100 years) in order to accurately evaluate available management options and develop Minimum Viable Population Size ranges for populations.

Goals

Goals of single-species conservation programs are, in general, specifically directed towards mitigating the risks of extinction for those species of interest. This is best accomplished by understanding, identifying and redressing those factors that increase the probability of the population going extinct.

Small populations, even if stable in the demographic sense, are particularly susceptible to a discouraging array of challenges that could potentially have a significant impact on their probability of survival (Soule, 1987). Among these challenges are Demographic Variation, Environmental Variation, Disease Epidemics, Catastrophes and Inbreeding Depression.

Challenges to Small Populations

Demographic Variation: This is the variation in the population's overall (average) birth and death rates caused by random differences among individuals in the population. The population can experience 'good' or 'bad' years in terms of population growth simply due to random (stochastic) variation at the individual level. This can have consequences for the population's survival. For example, one concern in captive propagation is the possibility that all individuals born into a small population during one generation are of one sex, resulting in the population going extinct. Figure 10 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. However, these risks are practically negligible in populations of much larger size. Similar consequences could result from the coincidental but random effects of high death rates or low birth rates.

In general, the effect of any one individual on the overall population's trend is significantly less in large populations than small populations. Thus intrinsic demographic variation is a minor demographic challenge in all but very small populations.

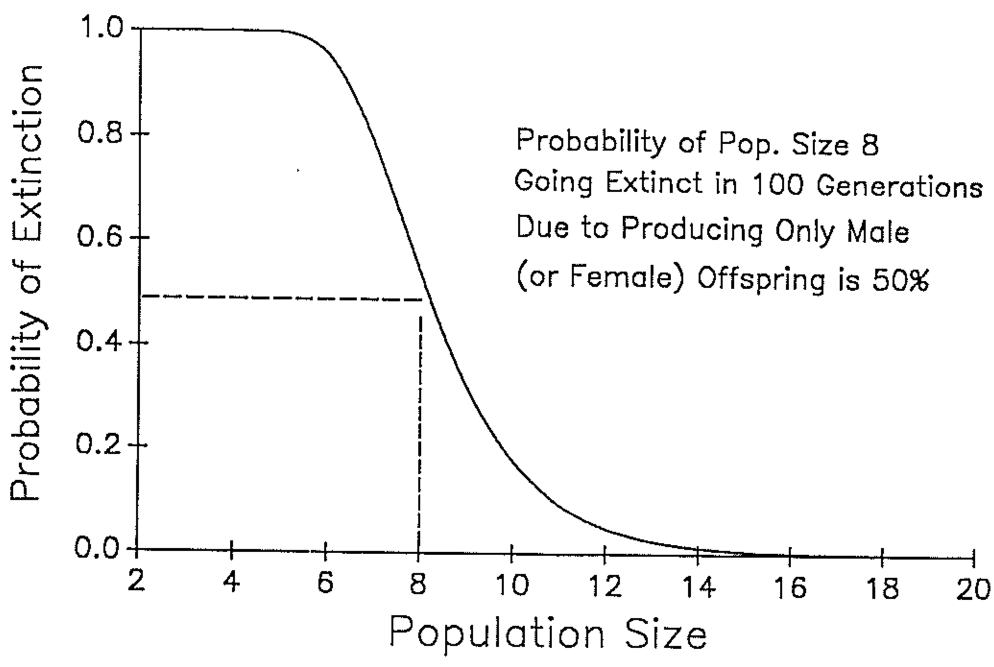


Figure 10. Example of Demographic Variation: Probability of extinction sometime during a 100 generation period due solely to producing only one sex of offspring.

Environmental Variation: Variations in environmental conditions clearly impact the ability of a population to reproduce and survive. As a result, populations susceptible to environmental variation vary 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 determines prey (snail) densities: nesting success rates decrease by 80% during years of low water levels. Snail kite populations, as a result, are extremely unstable (Beissinger, 1986).

Disease Epidemics: Disease epidemics and catastrophes are similar to other forms of environmental variation in the sense that they are external to the population. However, they are listed separately because we are just beginning to appreciate their role as recurrent and 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 which may act to decrease reproductive rates and increase mortality rates.

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 all of the 6 ferrets that had been brought into captivity (Thorne and Belitsky, 1989).

Catastrophes: From a demographic perspective, 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). 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).

Inbreeding Depression: In small closed populations, mate choice is soon limited to close relatives, resulting in increased rates of inbreeding. The deleterious effects of inbreeding are well documented in a large variety of taxa. Although inbreeding depression has a genetic mechanism, its effects are demographic. Most data on exotic species come from studies of inbreeding effects on juvenile mortality in captive populations (Ralls, Ballou and Templeton; 1983). These studies show an average effect of approximately 10% decrease in juvenile survival with every 10%

increase in inbreeding. Data on the effects of inbreeding on reproductive rates in free ranging wild species are limited (lions; Wildt et al, 1987); however, domestic animal scientists recognize that inbreeding effects on reproduction are likely to be more severe than effects on survival. Inbreeding also may reduce a population's disease resistance, and ability to adapt to rapidly changing environments (O'Brien et al, 1988).

Interacting Effects: Clearly, demographic challenges 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 (Figure 2). Over time the population becomes increasingly smaller and more susceptible to extinction (Gilpin, 1986).

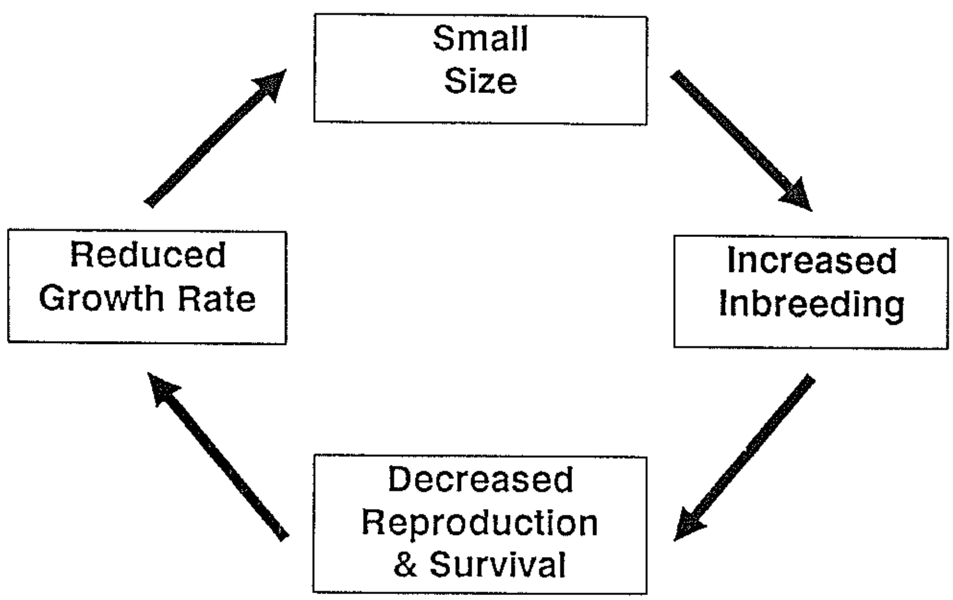


Figure 11. Negative feedback effects of inbreeding on small populations.

Susceptibility to Demographic Challenges

Populations differ in their susceptibility to demographic challenges. As mentioned above, population size clearly effects vulnerability. Large populations are relatively unaffected by demographic variation and are less apt to be totally devastated by environmental variation than small populations.

The severity of the demographic challenge is also important. A population in a fairly stable environment is less likely to go extinct than a population in a highly variable environment or an environment vulnerable to catastrophes.

A third important factor is a population's potential for recovering from these demographic challenges, in other words, the population's growth rate. A population at carrying capacity experiences normal fluctuation in population size; the degree of fluctuation depending on the severity of demographic challenge. Populations with low growth rates remain small longer than populations with rapid growth potential and therefore are more vulnerable to future size fluctuations.

A fourth important consideration is the population's spatial distribution. A population that is dispersed across several 'metapopulations,' or patches, is significantly less vulnerable to catastrophic extinctions than a same-sized population localized in a single patch. Extinction of one patch among many does not extinguish the entire population and colonization between patches could reconstitute extinct patches (Gilpin, 1987).

Populations dispersed over a wide geographic range are also unlikely to experience the same environment over the entire range. While part of a population's range may suffer from extreme environmental stress (or catastrophes), other areas may act as a buffer against such effects.

Estimating Susceptibility with Persistence Time Models

A population's susceptibility to demographic challenges can be measured in terms of the amount of time it takes a population to go extinct. This is often referred to as the persistence time of the population. Ideally, persistence time should be estimated from data on all the variables discussed above. Persistence times are usually estimated from mathematical models that either simulate the population over a period of time (stochastic models) or estimate the population's expected (mean) persistence time (deterministic models).

Unfortunately, methods are not (yet) available to simultaneously consider the effect of all the above variables on persistence time. Usually, persistence times are estimated by considering the effects of only one or two variables. The effects of spatial distribution are the most important; however, they are also the most difficult and consequently are not considered (or only rudimentarily considered) in most persistence time models. These models assume a single, geographically localized population.

Goodman(1987) presents an example of a deterministic persistence time model. This model estimates the mean persistence time of a population given its size, growth rate and its susceptibility to environmental and demographic challenges.

In Goodman's model, susceptibility to demographic challenges is represented by the variance in the population's growth rate. A population that is very susceptible to environmental perturbations will vary drastically in size from year to year, which, in turn, will be reflected as a high variance in the population's growth rate. Goodman's model is:

$$\text{Mean Extinction Time} = \sum_{x=1}^{N} \sum_{y=x}^{N} \frac{2}{y(yV - r)} \sum_{z=x}^{Y-1} \frac{zV + r}{zV - r}$$

where: r = exponential annual growth of the population
V = variance in r
N = Maximum (ceiling) population size

The mean persistence times for populations of size 30 and 50 (historical and recent estimates for the Javan rhinoceros population) with low growth potentials (.5% and 2% per year) are shown in Figure 12. These graphs are provided simply to introduce the concept of persistence time models and are not suggested as realistic models of the rhinoceros population. More realistic models, based on life history data collected from the field, are provided below.

The mean time to extinction is inversely related to the variation in the growth rate: if variance is extremely high, regardless of the population sizes or potential growth rates, the mean persistence time (time to extinction) is approximately 10 years. However, with variances of .2, mean persistence time varies from 42 to 57 years.

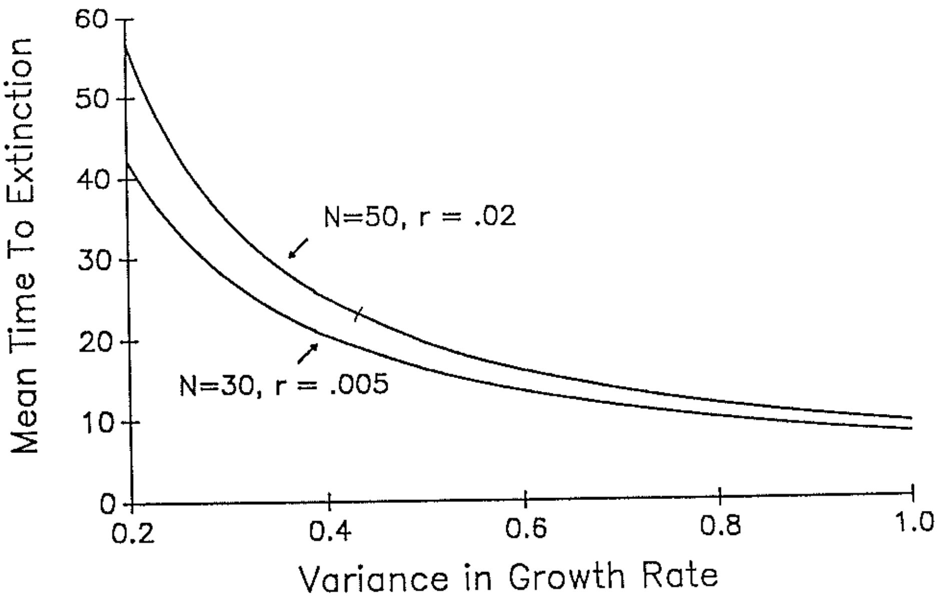


Figure 12. Mean time to extinction (persistence time) for a population of 50 animals with exponential growth rate of .02 (approx. 2% per year) and population of 30 animals with exponential growth rate of .005 (approx. 0.5% per year) under different levels of variation on growth rate. Variation in growth rate is a measure of the population's susceptibility to demographic challenges.

To provide perspective on the meaning of variance in r, if the growth rate is distributed as a normal random variable, a variance of .2 would mean that 75% of the growth rates experienced by the population would fall within the range of 50% increase per year and 50% population decline per year.

Persistence Time is Exponentially Distributed

An important characteristic of persistence time is that it has an approximately exponential distribution. The models provide the mean, or expected time to extinction; however, there is significant variation around this mean. Many population go extinct well before the mean time; a few go extinct long after.

The exponential distribution of persistence time for a population of 50 individuals with a growth potential of 2% and growth variance of .2 is shown in Figure 13. The mean persistence time is 57 years. However, since the distribution is exponential, there is a high probability that the time to extinction will occur before 57 years. In fact, there is a 33% chance that the time of extinction will be before 25 years.

Given that persistence times are approximately exponentially distributed, times to extinction can be estimated with various degrees of certainty. Again for the same population described in Figure 12, we can estimate the probability of extinction at different time periods (Figure 14). With growth rate variation at .2, mean time to extinction is 57 years; however, there is a 50% chance that the population will survive only to 40 years, only a 75% chance that the population will survive at least to 15 years, and a 95% chance that the population will survive at least to 4 years. In other words, there is a 5% chance that the population will go extinct in 4 years.

The Minimum Viable Population (MVP) Size concept is based on the premise that persistence times can only be defined with reference to degrees of certainty. Ideally, given a population's life history characteristics and management goal (a desired persistence time under a specified degree of certainty, e.g. 95% chance of surviving for 200 years), we could estimate the population size required to achieve the goal. This would be a Minimum Viable Population Size (MVP size) for the program (Shaffer, 1981). However, since MVP size is a function of the specific management goals of the population, there is no one "magical" MVP size for any given population in any given circumstance.

Management Implications

The implication of exponentially distributed persistence time is that management strategies can not be based on the mean persistence time if a high degree of certainty is desirable. Although the mean persistence time of the modeled population is 57 years, management strategies should recognize that to be 95% certain that the population survives even 50 years would require a population size whose mean persistence time is 975 years. This would require well over 1000 individuals.

A second implication is that management strategies can only be fully evaluated if both degree of certainty and time frame for management are specified. For example, programs may be evaluated in terms of their potential for assuring a 95% chance of the managed population surviving for 200 years. It is critical that the management decision making process recognize that the process of extinction is a matter of probabilities, as are all its components (environmental and demographic variation, probability of catastrophe, etc.; Shaffer, 1987).

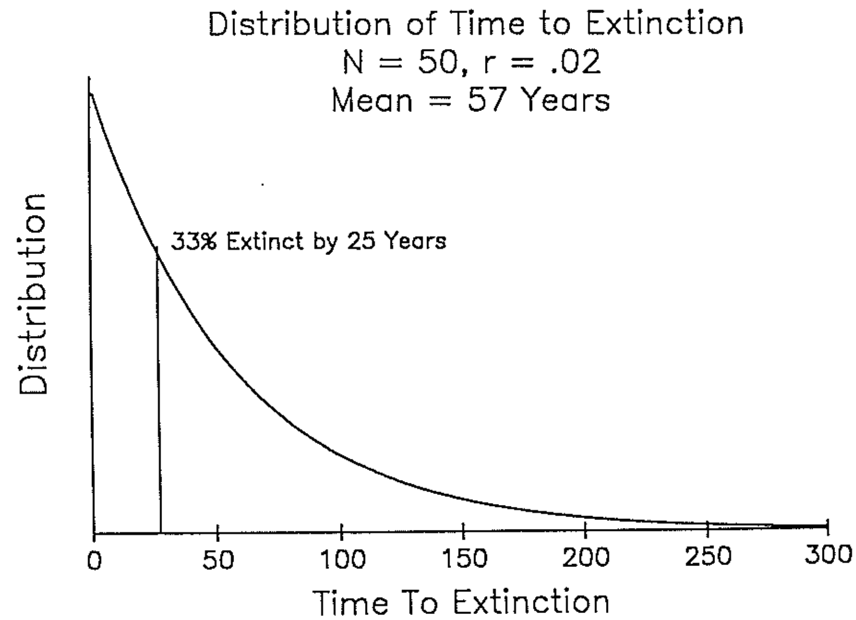


Figure 13. Exponentially distributed persistence time for a population of 50 animals growing at an exponential rate of .02 with a variation in growth rate of 0.2. While the mean (expected) persistence time is 57 years, the exponential characteristic of the distribution shows that there is a high probability of extinction before this period (33% chance by 25 years).

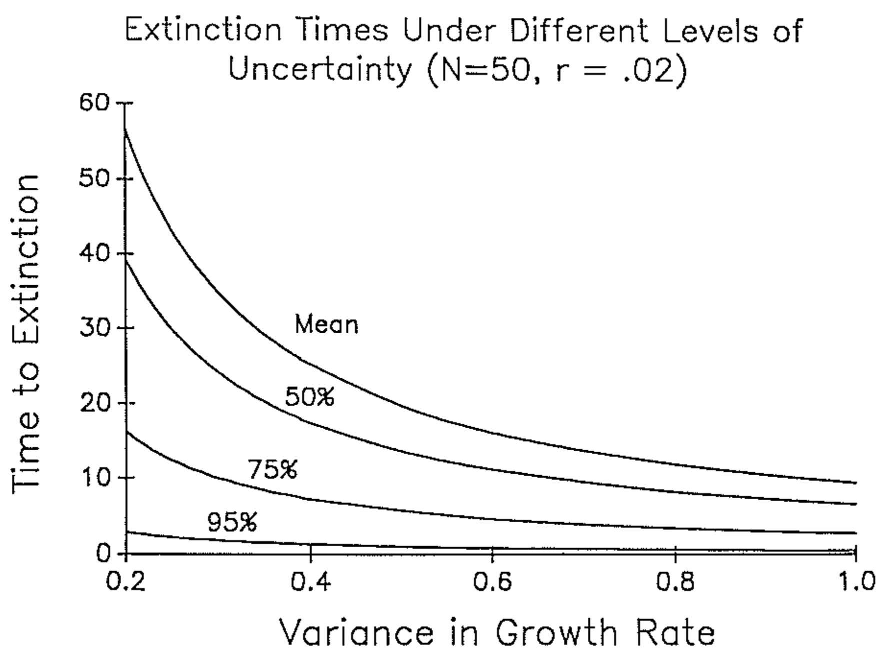


Figure 14. Extinction times under different levels of uncertainty. See text.

<u>Stochastic simulation of population extinction</u>
(R. C. Lacy)

Life table analyses yield average long-term projections of population growth (or decline), but do not reveal the fluctuations in population size that would result from the variability in demographic processes. To begin an examination of the probabilities of population persistence under various scenarios, we used a modified version of the SPGPC computer model, developed by James Grier of North Dakota State University (Grier 1980a, 1980b, Grier and Barclay 1988), to simulate the Javan rhinoceros population. The computer model simulates the birth and death processes of a population by generating random numbers to determine whether each animal lives or dies, and whether each female reproduces litters of size 0 or 1 during each year. Mortality and reproduction probabilities are the same for each sex, and fecundity is assumed to be independent of age (after an animal reaches reproductive age). Mortality rates are specified for each pre-reproductive age class and for reproductive-age animals. Each simulation is started with a specified number of males and females of each pre-reproductive age class, and a specified number of male and females of breeding age. The computer program simulates and tracks the fate of each population, and outputs summary statistics on the probability of population extinction over a specified time span and the mean time to extinction of those simulated populations that went extinct. By using constant probabilities of birth and death processes, the basic Grier model simulates demographic (individual) stochasticity, but does not allow for environmental variation that imposes greater or lesser birth and death probabilities across the population in subsequent years, nor does it allow for catastrophic impacts (e.g., severe storms, disease epidemics) on reproduction and mortality. (Grier is developing further his program to accommodate some of these factors.)

Modifications by R. Lacy of the basic Grier program include a translation of the program language from interpreted BASIC to compiled C, calculation of mean (deterministic) population growth rates and the stable age distribution, and the addition to the simulation of population carrying capacities, environmental variation in reproduction, mortality, and the carrying capacity, and catastrophes. A population carrying capacity is imposed by truncation of each age class (after breeding) if the population size exceeds the specified carrying capacity. The carrying capacity is not taken to be a fixed number, rather the carrying capacity each generation is drawn from a Poisson distribution with mean (and variance) equal to the specified limit. Each year in the simulation (during which age-specific probabilities of birth and death are constant), the number of animals surviving, as well as the number reproducing, would be expected to follow binomial distributions with means equal to the specified probabilities. Environmental variation in reproduction, survival, and the carrying capacity is incorporated into the model by increasing the binomial or Poisson variances in these parameters by an amount specified by the user. The frequency and severity of breeding and survival catastrophes are also specified by the user. A catastrophe is determined to occur if a randomly generated number between 0 and 1 is less than the probability of occurrence (i.e., a binomial process is simulated). If a breeding catastrophe occurs, the probability of breeding is multiplied by a severity factor that is drawn from a binomial distribution with mean equal to the severity specified by the user. Similarly, if a survival catastrophe occurs, the probability of surviving each age class is multiplied by a severity factor that is drawn from a binomial distribution with mean equal to the severity specified by the user. Thus, not all catastrophes are of equal magnitude, rather they are distributed around a mean specified by the user. Catastrophes impacting mortality and breeding are independent, and the severity of a catastrophe varies around the mean value specified.

Overall, the computer program simulates many of the complex levels of stochasticity that can impact a population. Some of its artificial characteristics are the absence of trends across years (e.g., no long-term changes in the environment, no multi-year environmental perturbations or catastrophes), the independence of environmental fluctuation in birth and death rates, and the lack of density dependence of birth and death rates except when the population exceeds the carrying capacity. The first two of these simplifications will likely lead to underestimates of extinction rates, while the third may cause overestimation of extinction. A sample output from the program (for the "basic scenario" below) is given as Table 1.

COMPUTER SIMULATION OF THE WILD JAVAN RHINOCEROS POPULATION (U. S. Seal)

The parameters used in development of the "baseline" scenario were chosen to represent, as best as could be determined, the current state of the wild population of Javan rhinos. Life history data (pp 38-41) and Table 1 are from information on the Indian rhino and from field studies of the Javan rhino - none of which have involved direct observation of the animals. Population structure on the wild population are from 1978-1989, the years that the population has been at its present size and when estimates were made of sex and age ratios. About 1 animal has been removed every two years by poaching during this time. At least 5 animals died in one area at the same time, perhaps of disease, in 1982. The observed population growth rate has been near zero during the past decade.

For the purposes of the demographic simulations, the start of life for a rhino can be considered to be its birth as a calf (alive or dead) so long as both the fecundity measurements and the first year mortality used in the model are based on the same starting point.

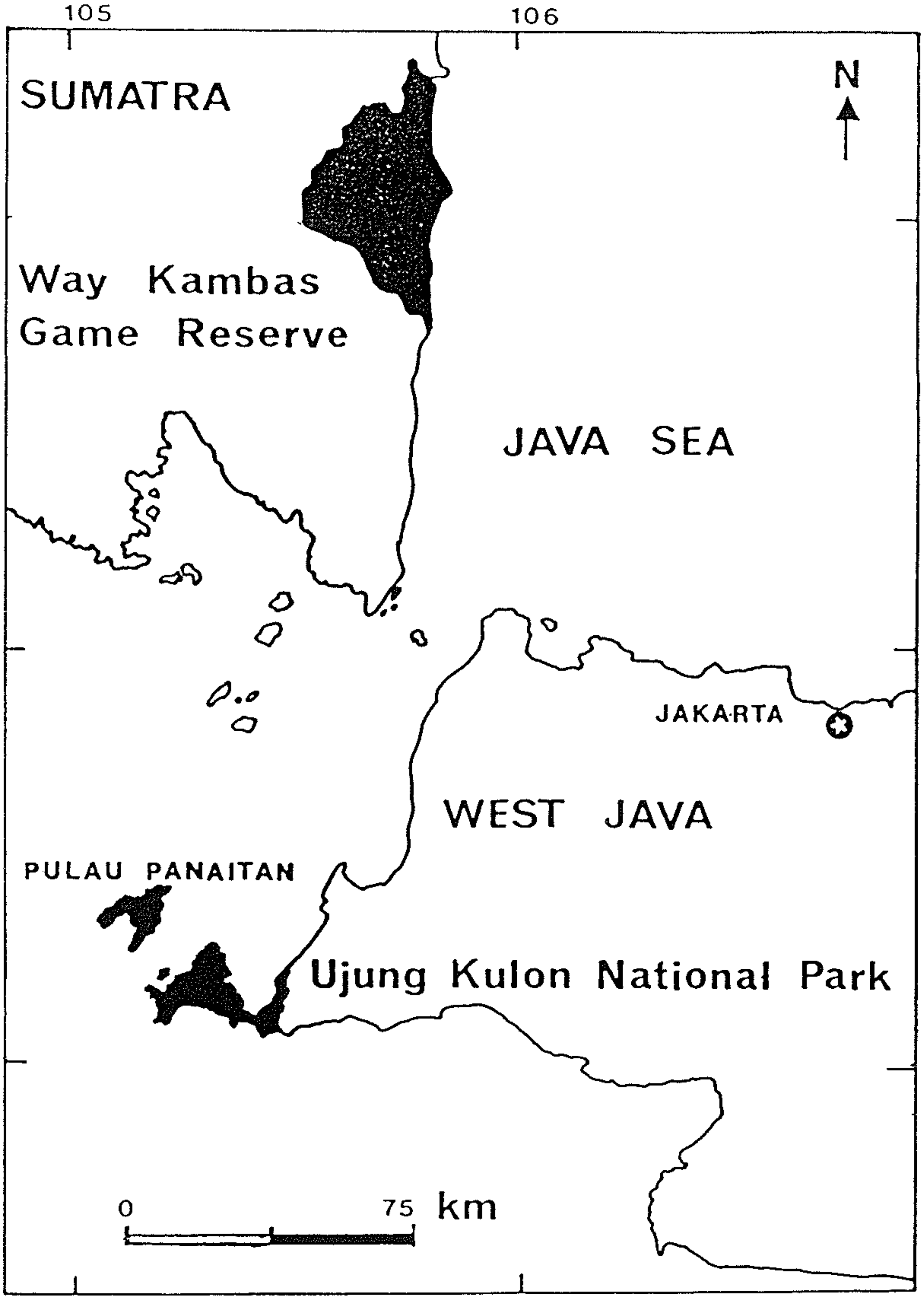
Table 1. Probable basic reproductive life history characteristics of the Javan rhinoceros.

Polygamous
Age of first reproduction = 7 years
Single calf
16 month gestation
3 year minimum interbirth interval (18-20 months if a calf is lost early).
25+ year life span
Equal sex ratio at birth

To explore other demographic parameters that may represent either the present conditions or future conditions, we examined a number of alternative scenarios with varied population sizes, carrying capacities, fecundity rates, mortality rates (infant, juvenile, adult), degrees of environmental fluctuations, and frequency and severity of catastrophes.

Population Biology Parameters: Javan Rhinoceros

Estimates of population parameters are needed for population viability assessment. The analyses presented here proceed directly from the body of data collected by biologists working with the Javan rhinoceros and made available in several monographs as well as by direct communications during the workshop from researchers working with the project.


105
106
SUMATRA
N
5
Way Kambas
Game Reserve
JAVA SEA
6
JAKARTA
WEST JAVA
PULAU PANAITAN
Ujung Kulon National Park
7
0
75
km

Captive Breeding Specialist Group

Species Survival Commission
International Union for the Conservation of Nature and Natural Resources

U. S. Seal, CBSG Chairman

POPULATION VIABILITY ANALYSIS DATA FORM - MAMMALS

Species: Rhinoceros sondaicus (Desmarest). Javan Rhinoceros.

Species distribution: *Ujung Kulon National Park (Java); Vietnam* - 1989; *Cambodia, Malaya, Burma? Historically in Malaya, Burma, Thailand, Indochina, Java, Sumatra, parts of northern India. Most unconfirmed until sightings in Vietnam.*
Study taxon (subspecies): *R. s. sondaicus*
R. s. annamiticus in Vietnam, Cambodia, Laos. R. s. inermis in Assam.
Study population location: *Ujung Kulon National Park. 30,000 hectares = 300 km^2.*
Metapopulation - are there other separate populations? Are maps available?: (Separation by distance, geographic barriers?)
Only one population known in Indonesia.

Specialized requirements (Trophic, ecological):
Browser. Prefers coastal forest zones and swamps in the park. 190 plants (179 dicots) with 4 comprising 44% of diet (Spondia pinnata, Amomum sp, Leea sambucina, & Dillenia excelsa).

Age of first reproduction for each sex (proportion breeding):

a)Earliest: *Female - 7 yrs; Male - 7;*
55 M in captivity. (Both Indian)
b)Mean: *Females 8 yrs in captivity (up to 20 yrs)*
Males 10 yrs

Gestation period (days or weeks): *16 months*

Litter size (N, mean, SD, range)(at birth?, weaning?): *1*

Birth Season: *Unlikely. None for Indians.*

Birth frequency (interbirth interval): *4-9 years for Javan.*
8 - 9 years suggested by Amman. Very long. 3-4 years for Indian with one at 18 months following loss of calf at a few days.
Reproductive life-span (Male & Female, Range):
30 yrs? G = 16 yr (F); = 19 yr (M) (Indians in captivity).
(G = generation time)
Life time reproduction (Mean, Male & Female): *4 - 8.*

Adult sex ratio: *.64 : 1 based upon 17 sexed animals (6:11).*

Adult body weight of males and females: *1500 kg.*

Social structure in terms of breeding (random, pair-bonded, polygyny, polyandry, etc; breeding male and female turnover each year?):

Solitary, females with young to about 3 years. No pair bonding. Male territory may overlap several females.

Proportion of adult males and females breeding each year:
? .113 of adult females (4 calves per year; assuming 70 animals, 83% adults and sex ratio 0.64:1.0. Estimated from footprints - difficult and little validation. If this age structure is correct, this is a dying population.

Dispersal distance (mean, sexes): *May move 15-20 km in a day.*

Migrations (months): *Move between feeding areas. Area with 5 deaths reoccupied by a male and female.*

Territoriality (home range, season): *Said to not have a stable home range. Female territory said to be 2.6-13.4 km2 and males 12.5 to 21 km2.*

Birth sex ratio: *1:1*

Birth weights (male and female):

Ovulation - induced or spontaneous: *Probably spontaneous.*

Implantation - immediate or delayed (duration): *Probably immediate. (About 3 weeks).*

Estrous cycles (seasonal, multiple or single, post partum):
Probably multiple and non-seasonal. Post partum possible but inhibited by lactation.

Duration of lactation: *About 12-18 months (Indian).*

Post-lactational estrus: *Probably at about 18 months postpartum.*

Age of dispersal: *Males 39.4 ± 4.8 months; Females 34.1 (Indian). This would be shortly before birth of next calf.*

Maximum longevity: *35 - 40 years.*

Population census - most recent. Date of last census. Reliability estimate.: *About 50 (census)-70 (extrapolation) in Ujung Kulon. April 1984. 10-15%?* See attached tables. Census and extrapolation methods.

1989: 57 (52 - 62) with no young detected. (Santiapillai, Widodo, & Bambang).

Projected population (5, 10, 50 years).: *Population has been stable for about 10 years.* Would be difficult to detect a change of 10% in any one year (± 5 animals). No calves were detected this year.

Past population census (5, 10, 20 years - dates, reliability estimates):

1955 30-35 (Hoogerwerf, 1970). 13 killed 1955-65.
1967 21-28 (Schenkel)
1980 54-70 (PHPA; Ammann). 1984 50-54 (Sadjudin).

Population sex and age structure (young, juvenile, & adults) - time of year.:

Alternate scenarios:				
	0 - 1 =	2.2	0.0	1.1 (2.2)
	1 - 6 =	6.10	6.6	6.6
	Adult =	12.16	18.26	18.26

Fecundity rates (by sex and age class):
Adult females - 0.11 calf per year. This implies greatly reduced reproductive rates (about 1 calf per 8 years) as compared to the Indian and other rhinos protected and in good habitat. Capable of 1 calf every 3 years. An alternative scenario is 1 calf per 4 years but a high infant mortality rate.

Mortality rates and distribution (by sex and age) (neonatal, juvenile, adult);

Uncertain but:		
	Infant =	5 - 20%
	Juvenile =	2 - 4 %
	Adult =	8 - 9%

Population density estimate. Area of population. Attach marked map.:
50 animals in 30,000 hectare (300 km²) Ujung Kulon Park. 1 per 600 hectare. However perhaps only 1/3 of habitat is suitable.

Sources of mortality-% (natural, poaching, harvest, accidental, seasonal?).:
Disease.
Poaching. 1 in 1985 and 1 in 1987.

Habitat capacity estimate (Has capacity changed in past 20, 50 years?).:
Banteng (Bos javanicus) population increasing.
Vegetation changes occurring.

Present habitat protection status.:
National Park.

Projected habitat protection status (5, 10, 50 years).:
Park to remain protected?

Environmental variance affecting reproduction and mortality (rainfall, prey, predators, disease, snow cover ?).:
5 bodies (4 adults and 1 calf) found in 1982. Diagnosis uncertain. Data on sex and ages?
Volcano activity. Poaching. Disease. Rainfall?

Is pedigree information available?:
NO

Attach Life Table if available. *See attached tables.*

Date form completed: June 6, 1989

Correspondent/Investigator:

Name: U. S. Seal

Address: CBSG c/o Minnesota Zoo
12101 Johnny Cake Road
Apple Valley, Minnesota 55124
USA

Telephone: 612-431-9325

Fax: 612-432-2757

References:

Nardelli, F., W.S. Ramono, & T. Foose. 1987. Project to conserve the Javan rhinoceros - Rhinceros sondaicus Desm.
Sadjudin, . 1987.

Schnekel, R. and H. Schnekel. 1969.

Amman, Hartman. 1985.

Laurie, A. 1982.

Indian Rhino SSP Analyses. Rockwell, R. 1989.

C. Santiapillai, S. R. Widodo, and P. D. Bambang. 1989.

Comments:

10 animals recorded in captivity during past 150 years (Reynolds, 1961). None now or in recent past. One lived 21 years.

Protected since the turn of the century in Ujung Kulon. Poachers and hunters took 16 in 1935-36, perhaps 20-25 in 1937. Estimated that 42 animals taken between 1930 and 1970, i. e. about 1 per year.

Population appears to have been stable in numbers for past 10 years. Interbirth interval is suggested to be about 8 years (would be 3 years in growing pop.),. Growth rate perhaps 4% now but was 10% from 1967 to 1974. Deaths in 1981-82 were in one area suggesting disease. These observations suggest that the population may be at carrying capacity of about 60 animals.

Current population size:

The demographic simulation begins just before breeding, i.e., breeding occurs prior to any mortality. In the basic simulations, we started the population with 56 animals distributed as 2 less than one-year calves, 10 juveniles equally distributed through the 2-6 year age classes, and 44 breeding age (7+ year) rhinos. This age and sex structure distribution is based upon those reported by Amman from footprint measurements and associations of footprints observed. In each age class, except the adults (18M and 26F) an equal sex ratio was assumed. This number (56) matches the estimate of the number of rhinos during the June 1989 census, Figure 15.

Table 2. Suggested sex and age structures of the Ujung Kulon population.

	Scenario 1		Scenario 2	
Age	Males	Females	Males	Females
1	1	1	2	2
2	1	1	2	2
3	1	1	1	2
4	1	1	1	2
5	1	1	1	2
6	1	1	1	2
Adults	18	26	12	18
Totals	24	32	20	30

The reported age distribution differs from the approximate stable age distributions obtained from life history table analysis. It is deficient in younger animals relative to reasonable combinations of fertility and mortality values reported for rhinos. This apparent discrepancy may reflect census difficulties for the youngest age class or reproduction may be declining and the population ageing. Further information on this population will require radiotelemetry studies. An alternative scenario (2) with a higher proportion of young animals was also included in the simulations.

To examine the viability of different starting populations and the effects of removals, we used 60, 45, and 30 rhinos in alternative scenarios reflecting removals of 15 and 30 animals or the population size at different times in its history.

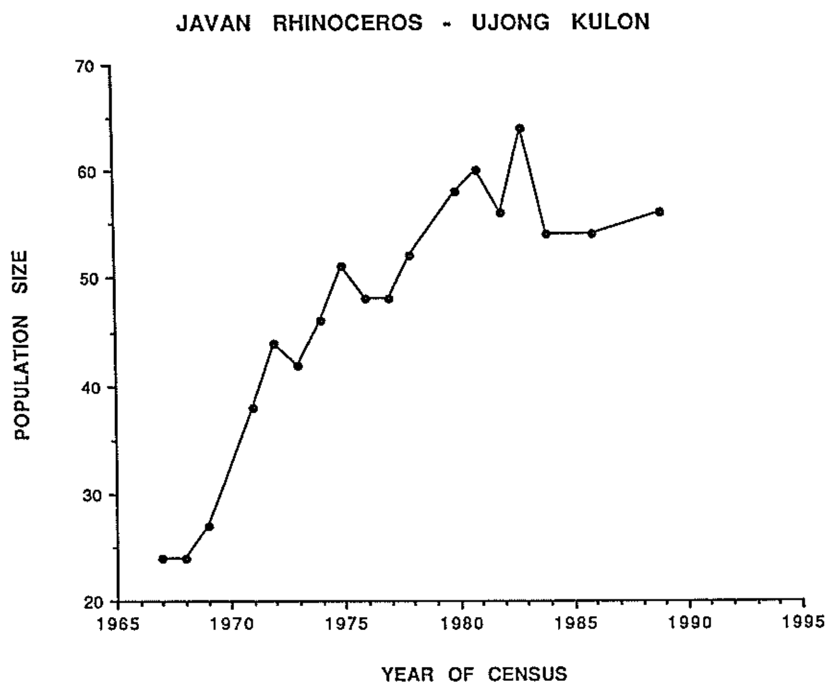


Figure 15. Census estimates for the Javan rhino population at Ujung Kulon for the years 1967 - 1989.

Carrying Capacity:

We do not know how many rhinoceroses could live in Ujung Kulon. Population numbers up to 100 have been suggested. It is also possible that the rhinoceroses are limited by the amount of preferred habitat and the expansion of banteng numbers. The present numbers of 60 rhinos may be close to the limits. We modelled carrying capacities of 70 and 100.

The approach to carrying capacity is not a simple linear function of recruitment and mortality (Figure 16). Recruitment is usually density dependent with faster rates at lower population numbers rising to a maximum and then declining (a parabolic function) to cross the death rate curve. The intersection of the two curves may be defined as the carrying capacity - K. The rising rate of recruitment at lower population sizes would reflect better nutrition and health of the females with better survival of calves and perhaps a shorter interbirth interval. This response has been observed in southern white rhinos and Indian rhinos in protected populations that had been severely depleted by harvesting activities. The declining recruitment and increasing death rate in populations near capacity can be attributed to declining nutrition and competition for limited resources.

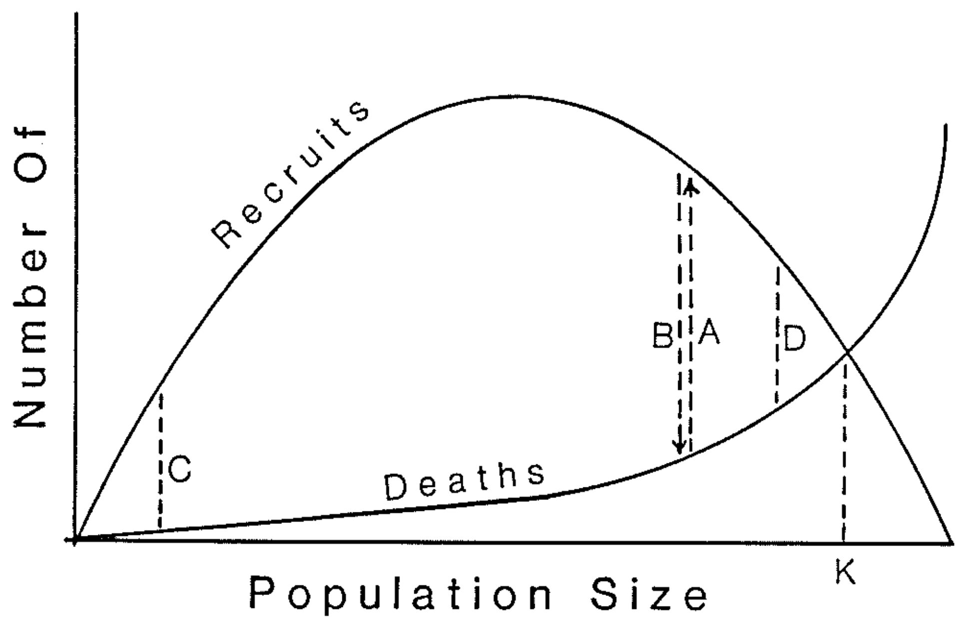


Figure 16. Simple density dependent model of population growth showing recruitment and mortality rates for a population of a species that is K-selected. (Taken from McCullough in Seal (ed.) Fertility Control of Wildlife).

The census data for the Javan rhino population at Ujung Kulon, Figure 15, indicate an increase from about 30 animals in 1970 to perhaps 55 in 1980. This amounts to a doubling time of about 12 years or an annual growth rate of 5+%. This is as high as has been reported for any rhinoceros species in the wild and captivity. There are uncertainties about the confidence limits of the census data for any given year, but the trend has been confirmed by 3 groups of investigators as has the relatively stable level of the past 10 years.

The interpretation of the Javan rhinoceros population data as indicating a population now near or at carrying capacity suggests that the growth rate is density dependent and that careful removal of animals for a captive propagation program may result in a return to the higher growth rates observed from 1970 to 1980. This would result in a return to present population numbers within 10-12 years if half of the population is removed. For this reason we modelled growth rates, after removal of animals for the captive populations, as the a low estimate (3.5%) of the rate during the period 1970-1980 and the near 0% value of the current population.

Fecundity:

Fecundity was measured as the number of wild pairs producing 0 or 1 calves each year, obtained from the census data reported over the past 10 years in Amman and in Santiapillai et al. The number of non-breeding adult rhinoceros has never been known precisely, but it has been estimated that approximately one of 8 of the adult females in the population produces a calf each year (0.12 calf per female per year). This implies an interbirth interval 8 years. This estimate was used as a lower bound for the number of breeding-age rhinos producing young each year. From these data, on average 87.5% of adults would produce no young and 12.5% would produce one calf each year. In alternative scenarios, we used fecundities of: 83.3% no calf and 16.7% one, 75% no calf and 25% one, and 67% no calf and 33% one calf. These represent interbirth intervals of 8, 6, 4, and 3 years respectively, Table 3.

Table 3. Fertilities Simulated

Birth Interval	Births 0	Births 1
8	87.5	12.5
6	83.7	16.3
4	75	25
3	67	33

It is important to remember that the calving rate is inferred from the number of young with mothers counted in the census which is based upon footprints. At low population numbers this estimate can have a significant variance. There is also a possibility of bias if the young do not move around with the female. It is also possible that young are being produced and have a high early mortality and thus are not counted. There are no direct observations of pregnant animals. Such information can be obtained (blood hormone assays and by observation) if animals are captured for removal or for radiotelemetry studies. This information is key to any analysis of possible reasons for the lack of growth in the population during the past 10 years.

Mortality:

Dead animals are rarely found except under the unusual circumstances of a mass mortality as discovered in 1982. Individual animals have not been identified and monitored over time so age and life expectancy estimates are based primarily upon footprint diameters. The only mortality data available, based on the age structure for the years 1978-1989, yield estimates of 15-30% first-year mortality, 2-6% annual mortality of subadult age classes, and 6-9% mortality of adults. We assumed that mortality of non-breeding adults is the same as that of breeding adults. Mortality of Indian rhinos is in this range, but the paucity of data and changing management make accurate estimation difficult. There are no captive data for the Javan rhino and there are too few data for captive Indian rhinos to be of much help. We simulated various combinations of the mortalities over the ranges listed, Table 4.

Table 4. Mortalities Simulated

Infant	5 - 50%
Juvenile	2 - 8%
Adult	4 - 10%

Environmental Variation:

Confirming the lack of significant annual variation in demographic parameters (over the past ten years) is the similarity observed between the variance in population numbers over the first ten years in the simulated populations when environmental variances were set to zero (V = 24) for simulations starting with 50 rhinos) and the annual variation observed in the size of the wild population over the past 10 years (V = 25). It is unlikely that birth and death rates are absolutely constant over time (even though we have no evidence that they have fluctuated over the past ten years), and for our base simulation we assumed that environmental variations in the birth rate, in death rates, and in the population carrying capacity are equal to the expected (binomial or Poisson) demographic variation. In alternative scenarios, we examined cases with no annual variation in fecundity, mortality, and carrying capacity and scenarios with environmentally imposed variation in birth and death rates and carrying capacity equal to 2, 3 and 10 times the expected demographic variation.

Catastrophes:

Biologists managing the remnant population of rhinos recognize that the risk of a catastrophe largely or wholly eliminating the species is not trivial (nor, hopefully, unavoidable). Habitat encroachment and poaching earlier in this century are believed to have reduced the rhinoceros populations. The probability and effect of a major disease epidemic is more difficult to predict, although possibly is no less likely to cause the demise of the rhinos than poaching. The recent history of the black-footed ferret makes clear the potential for disease to eliminate a small, remnant population. This small wild population of rhinos is vulnerable to a single environmental event, and the restricted habitat and increasing presence of banteng may make them more vulnerable to epidemics as well. A dispersed captive population could probably be protected from a severe storm or fluctuations in food supply, but may be vulnerable to a disease outbreak.

For the basic PVA, we assumed that the probability of a disease event, poaching or other catastrophe of similar effect is 10% annually and that such events would kill about 10% of the subadult and adult animals and would have no effect on reproduction. We also modelled scenarios with (a) no catastrophic impacts, (b) with 20% probabilities of occurrence (with the above effects), (c) with 10% probability of occurrence and 20% mortality, (d) the same as (c) with a 50% reduction in reproduction and (e) with removals of animals treated as effective one time events both in the presence and absence of unplanned losses due to disease or poaching. Also if the population is at or near carrying capacity, then removal of animals might result in an increase in recruitment rate and a return to a positive growth rate. This was modelled with shorter interbirth intervals and lower infant mortality rates.

Table 5. Sample input for the demographic simulation program for the best guess demographic parameters (the "basic scenario") with addition of two types of catastrophic variance for the wild population of Javan rhinoceros.

SIMPOP4
Welcome to SIMPOP.
Written by R.C. Lacy, Chicago Zoological Park
Version 4.0, 1 August 1989

Input file name? (CR for keyboard)

Output file name (S for screen)
JAVABAS3.USS

How many times do you want the simulation repeated? *1000*

Do you want the full table printed (first 4 runs only)? N

Monogamous (=M) or polygamous (=P)? P

At what age do the animals normally begin breeding? 7

What is the maximum number of young per litter? 1

What percent of adult females produce 0 young? 75
What percent of adult females produce 1 young? 25

What is the percent mortality between ages 0 to 1? 25
What is the percent mortality between ages 1 to 2? 2
What is the percent mortality between ages 2 to 3? 2
What is the percent mortality between ages 3 to 4? 2
What is the percent mortality between ages 4 to 5? 2
What is the percent mortality between ages 5 to 6? 2
What is the percent mortality between ages 6 to 7? 2
What is the percent mortality of adults (age > 7)? 8

What is the population carrying capacity? 75

Enter levels of environmental stochasticity as factors
to be applied to the indicated variances.

Reproductive rates: Binomial variance for breeding success x ? 1

Mortality rates: Binomial variance x ? 1

Carrying capacity: Poisson variance x ? 1

Table 5 continued.

Enter the probability of catastrophe type I (as a percent): 10

Enter the severity of type I catastrophes as a mean multiplicative effect
(to which will be applied a binomial variance).
Note: 0 = total catastrophe, 1 = no effect.

Severity with respect to reproduction? 1

Severity with respect to survival? .90

Enter the probability of catastrophe type II (as a percent): 50

Enter the severity of type II catastrophes as a mean multiplicative effect
(to which will be applied a binomial variance).
Note: 0 = total catastrophe, 1 = no effect.

Severity with respect to reproduction? 1

Severity with respect to survival? .98

How many years do you want the simulation to run? 100

At what time interval do you want extinction reports? 10

How many males, females of age 1 are in the initial population? 1,1
How many males, females of age 2 are in the initial population? 1,1
How many males, females of age 3 are in the initial population? 1,1
How many males, females of age 4 are in the initial population? 1,1
How many males, females of age 5 are in the initial population? 1,1
How many males, females of age 6 are in the initial population? 1,1
How many male, female adults (age > 7) in the initial population? 18,26

For how many years do you want to harvest/supplement the population? 0

Results of demographic simulations

Each scenario for the Javan rhinoceros at Ujung Kulon under various assumptions about the demography and sources of variation and risk was run through 1000 computer simulations. For each set of input parameters, the mean annual population growth (lambda) and generation time calculated from the life table of birth and death rates, the proportion of simulated populations that survived 100 years, and the mean size at 100 years of those populations that persisted were calculated. Populations declining in size at 100 years would usually become extinct by 200 years. The long life span of the rhinoceros and the relatively low contributions of catastrophes and environmental variance to mortality rates resulted in the survival of some animals at 100 years even in the face of negative growth rates.

The interactions of infant, juvenile, and adult mortality were examined with the interbirth interval set to 4 years, Table 6, and no catastrophic events affecting the population. Zero growth was obtained with infant mortality at 20-25%, adult mortality at 6-8%, and juvenile mortality at 2-8%. The probability of population survival for 100 years ranged from 84 to 100%. Final population sizes ranged from 17 to 94 indicating that many of these populations would become extinct over a longer time interval. The set of simulation conditions that provided the closest correspondence of population structure to the information from Ujung Kulon was an infant mortality of 25% (range of 20-25%), juvenile mortality of 2% (range of 2-4%), and adult mortality of 8% (range of 6-8%).

This set of values was selected as the "basic scenario" for comparisons with other conditions. These conditions provided a population of 52 $\pm$ 23 individuals, a growth rate of less than 1%, and a probability near 1.00 for population survival for 100 years with the population near present levels. Addition of a 10% frequency (about once per 10 years) of a catastrophic event that killed 10% of the animals (disease or poaching or something else resulting in mortality but with no effect on reproduction) significantly reduced the growth rate and expected size of the population, Table 7. This set of analyses did not include any density dependent effects on reproduction.

Given the calculated birth and death rates, a year-to-year environmental variation in birth and death rates that is comparable to the (binomial) variation between individuals, and the predicted frequency and severity of poaching and disease events, the simulations suggest that the present wild population has about a 80-90% chance of surviving 100 years but with a declining population and only a 50% chance of a few animals persisting 200 years.

Table 6. Javan Rhino Population simulations results. The variables were first year mortality, juvenile mortality, and adult mortality. The remaining conditions were: polygamous, 7 year age first reproduction, 75% no calf, 25% one calf per year, environmental variances set at 1, no catastrophic variance, population structure (2,2; 2,2; 1,2; 1,2; 1,2; 12,16). Carrying capacity of 100. 500 runs for 100 years.

Adult Mortality%		Infant Mortality % 10	15	20	25
Juvenile mortality = 2%					
4	Lambda	1.029	1.028	1.026	1.024
	Surv	1.00	1.00	1.00	1.00
	N	94 ± 8.5	93 ± 8.9	92 ± 9.0	92 ± 8.6
6		1.022	1.020	1.017	1.014
		1.00	1.00	1.00	1.00
		90 ± 9	88 ± 10	87 ± 10	84±15
8		1.012	1.009	1.005	1.002
		.997	.997	.993	.987
		77 ± 19	74 ± 20	62 ± 23	52±23
10		1.000	.996	.993	.989
		.977	.957	.850	.753
		46 ± 24	35 ± 22	26 ± 18	21±16
Juvenile mortality = 4%					
4	Lambda	1.025	1.024	1.022	1.020
	Surv	1.00	1.00	1.00	1.00
	N	92 ± 7.8	92 ± 8.7	90 ± 8.7	90 ± 8.9
6		1.017	1.014	1.012	1.009
		1.00	1.00	1.00	.997
		86 ± 11.3	83 ± 14	81 ± 16	75 ± 19
8		1.005	1.002	.999	.995
		.990	.983	.970	.933
		63 ± 24	54 ± 23	43 ± 24	33 ± 20
10		.992	.989	.985	.981
		.853	.817	.647	.620
		26 ± 18	21 ± 16	16 ± 12	14 ± 10

Table 6. Continued.

Adult Mortality%		Infant Mortality % 10	15	20	25
Juvenile mortality = 6%					
4	r	1.021	1.020	1.018	1.016
	Surv	1.00	1.00	1.00	1.00
	N	90 ± 9.1	90 ± 8.2	89 ± 8.8	88 ± 9.7
6		1.011	1.009	1.006	1.003
		1.00	1.00	1.00	.990
		80 ± 15	74 ± 19	66 ± 23	57 ± 23
8		.998	.995	.992	.989
		.977	.910	.903	.843
		42 ± 23	35 ± 23	26 ± 17	21 ± 13
10		.984	.981	.977	.973
		.677	.627	.437	.390
		17 ± 12	13 ± 8.9	12 ± 8.8	9 ± 5
Juvenile mortality = 8%					
4	r	1.017	1.015	1.013	1.011
	Surv	1.00	1.00	1.00	1.00
	N	89	89	87	83
6		1.006	1.003	1.000	.998
		.997	.997	.993	.963
		64	57	50	38
8		.991	.988	.985	.982
		.863	.847	.773	.683
		27	22	16	14
10		.976	.973	.969	.965
		.477	.450	.310	.200
		10	9	9	7

Table 7. Javan Rhino Population simulations results. The variables were first year mortality, juvenile mortality, and adult mortality. The remaining conditions were: polygamous, 7 year age first reproduction, 75% no calf, 25% one calf per year, environmental variances set at 1, catastrophic variance 0.1, 0.9 (10 events per century with 10% mortality), population structure (2,2; 2,2; 1,2; 1,2; 1,2; 12,16). Carrying capacity of 100. 500 runs for 100 years.

Adult Mortality%		Infant Mortality % 10	15	20	25
Juvenile mortality = 2%					
4	Lambda	1.024	1.022	1.020	1.017
	Surv	1.00	1.00	1.00	1.00
	N	89	90	88	86
6		1.014	1.011	1.008	1.005
		1.00	1.00	.997	.987
		82	73	68	59
8		1.002	.999	.996	.992
		.967	.973	.903	.847
		49	42	35	26
10		.990	.986	.983	.979
		.830	.650	.613	.467
		22	16	17	12
Juvenile mortality = 4%					
4	Lambda	1.019	1.017	1.015	1.012
	Surv	1.00	1.00	1.00	1.00
	N	87	85	83	78
6		1.008	1.005	1.002	.999
		.993	.987	.987	.967
		65	59	52	44
8		.995	.992	.989	.985
		.890	.870	.757	.683
		33	27	21	18
10		.982	.979	.975	.971
		.573	.480	.373	.287
		14	13	10	9

Interbirth intervals were examined over the range of 3 to 8 years, Table 8, with mortalities varied to identify a set of conditions that would yield a lambda near 1.000. Increase in infant mortality effectively counteracted the growth rate increase that would be provided by more frequent reproduction. However even reduction of infant mortality to 5% was not sufficient to provide a positive growth rate at the 8 year interbirth interval. Inclusion of additional mortality from catastrophic events with 10% frequency and a 10% mortality resulted in declining populations. It is probable as the population declines in size that a density dependent increase in recruitment might occur. However a continuing decline in genic diversity by drift would occur at these small population sizes with a reduction in fitness and greater risk of entering an extinction vortex. This population size is too small to be viable over the long term.

Table 8. Interbirth Interval and Population Growth

Interval(Years)	Infant	P [Surv]	Lambda	N
I = 4 (Basic)	25	1.000	1.008	91 ± 9
I = 8 (87.5,12.5)	5	1.000	.986	80 ± 15
+ Catas		.924	.975	29 ± 21
I = 6 (81.3,18.7)	15	1.000	1.000	92 ± 9
+ Catas		.966	.990	44 ± 24
I = 3 (67, 33)	50	1.000	1.002	74 ± 29
+ Catas		.950	.992	38 ± 23

100 year projections. 1000 simulations. K = 100. Numbers in parentheses refer to proportion of females with no calf or one calf each year. The catastrophe event was set at 0.1 frequency and 0.9 survival.

Table 9. Interbirth Interval and Stable Age Distribution

	Interval - Years			
Age Class	3	4	6	8
0 - 1 (%)	10.4	7.7	6.2	4.5
1 - 7	29.3	32.2	30.2	25.9
Adult	60.3	60.1	63.6	69.6

The proportion of the young in the population declined with the increased interbirth interval, Table 9, and the 4.5% in the 0-1 age class at the 8 year interval is close to the value reported for the Ujung Kulon population over the past 10 years. However the uncertainty in these census values is too great to use them to discriminate among these intervals. They do suggest that the population may be aging which could further reduce its reproductive potential. A skewed age distribution has important implications for any strategy to remove animals for another breeding population. Removals to a captive population should probably favor the older animals and leave the young animals as the most viable breeding nucleus for the Ujung Kulon population.

Table 10. Effect of changes in adult mortality on population persistence at 8 year interbirth interval.

Adult Mortality	P [Surv]	Lambda	N
8	.332	.967	7
7	.560	.975	10
No catas.	1.000	.986	80
6	.894	.983	24
No catas.	1.000	.994	76
5	1.000	.992	
No catas.	1.000	1.000	78

100 years. 500 runs. K=100. Mortality: Juvenile = 2%, Infant =5%.

Reduction of adult mortality to 5%, at an interbirth interval of 8 years and an infant mortality of 5%, was necessary to achieve a growth rate of 1.000. However the inclusion of catastrophic events produced a negative rate and a slowly declining population with an increased risk of extinction. The rate of decline and risk of extinction increased with increasing adult mortality. A population with these demographic characteristics has reduced viability and the age distribution will continue to become even further skewed to old animals.

A basic scenario with K set at 100, Table 11, constructed from the simulations and the available information was used to evaluate the effects of variation in carrying capacity, environmental variation, and catastrophic events acting upon fertility, mortality, and carrying capacity on the probability of extinction and population growth rates. This model reflects the demographic characteristics of the population near carrying capacity and will need to compared with the probably different demographic characteristics of the population when it is reduced in size by removals or losses.

Table 11. Javan rhinoceros - a basic scenario for the available demographic data on the Ujung Kulon population.

K = 100	T = 100 yrs	
EV = 1, 1, 1	No catastrophes	
Fertility:	75%=0	25%=1
Mortality: Inf = 25%, Juv = 2%, Ad = 7%		
P Surv = 1.000	Lambda = 1.008	
GT = 20.5	N = 91 ± 9	

Effects of Catastrophes and Removals:

A more realistic set of scenarios needs to include estimates of the probability of unpredicted removals, losses, and decreased reproduction, Table 12. We also need to consider the impact of the removal of animals for establishment of captive populations and new wild populations upon the probability of extinction and upon the demographic characteristics of the population, Figure 16. The effects of removal of about 1 animal every two years by poaching and the loss of 10% of the animals every 10 years from disease were evaluated as modest catastrophic events. The effects are additive and result in a declining population with an increased risk of extinction during the next 100 years. This effect is intensified if the carrying capacity is reduced to 75 animals which fits more closely with the level of the population during the past 10 years.

Table 12. Effects of catastrophes and removals on the population.

Scenario	P [Surv]	Lambda	N
Basic (75, 25)	1.000	1.008	91 ± 9
Catastrophe(.1,.9)	.996	.999	61 ± 23
Catastrophe(.2,.9)	.88	.988	22 ± 15
Removal (All adults)	.946	1.008	62 ± 27
+ Catas	.770	.999	46 ± 28
Removal (1/2 Ad & J)	.992	1.008	77 ± 22
+ Catas	.852	.999	40 ± 26

Two scenarios for removing animals from the population were simulated using the basic scenario developed for the population at carrying capacity and the growth scenario developed for the population based upon its growth characteristics during 1971-1980, Table 13. The effects of environmental and catastrophic variation were also examined. We evaluated the effects of removal of all adults or the removal of one-half of all age classes on projected population numbers and the probability of persistence of the population.

The populations, with carrying capacity demographic characteristics, recovered slowly in both removal scenarios and the risk of extinction was increased for the remaining wild population. However the population which suffered removal of half of all age classes had a better probability of survival and reached higher numbers by 100 years. It also was less vulnerable to the effects of catastrophe.

Table 13. Population projections: response to removals and catastrophes in a population that increases its growth rate.

				Years			P
Scenario (N)	0	20	40	60	80	100	[Surv]
Basic	50	88	91	92	91	91±9	1.000
EV 10,10,10	50	49	43	39	39	37±20	.842
CV .1, .9	50	62	65	64	63	61±23	.996
CV .2, .9	50	55	54	45	42	39±23	.938
Rem All Adults	20	27	36	46	55	62±27	.946
CV .1,.9	20	23	27	29	31	35±24	.770
Rem 1/2 A & Y	26	40	55	65	72	77±22	.992
CV .1,.9	26	30	33	35	38	40±26	.852

500 RUNS. K=100. Mortality: I=25%, J=2%, A=7%.

The populations with the demographic characteristics of a growing population, Table 13, responded more vigorously and rapidly. In order to achieve a 3.5% growth rate, the interbirth interval was set 3 years, the infant mortality at 10%, and the adult mortality at 6% with K = 75. This resulted in a rapid return within 15 years to levels near the carrying capacity, Table 13. The annual growth rate achieved was dependent upon the levels of environmental variance included and ranged from 3.3% to 1.8% over a 3-fold range in this variance. The projected final population size ranged from 67 to 46 at 100 years and the probability of extinction was near zero. These simulations suggest that if the population can be protected and if it responds as a density dependent population to a decrease in size with an increase in growth rate then it can replace the removal of half the population in less than 15 years. This corresponds to its behavior from 1971 to 1981.

Table 14. Output data for a simulation of a population responding to removal of half the population with an increase in growth rate.

```
  Polygamous breeding    First age of reproduction: 7
   67.00 percent females produce litters of size 0
   33.00 percent females produce litters of size 1
   10.00 percent mortality between ages 0 and 1
    2.00 percent mortality between ages 1 and 7
    6.00 percent annual mortality of adults (age > 7)
  Carrying capacity of 75
  Environmental stochasticity:
    Reproductive success binomial variance x  1.000
    Mortality binomial variance x  1.000
    Carrying capacity poisson variance x  1.000
  Frequency of type I catastrophes: 10.000 percent
    with  1.000 mean multiplicative effect on reproduction
     and  0.900 mean multiplicative effect on survival
  Population simulated for 100 years, 100 runs
  Initial population size:
    1 males, 1 females 1 years old
    1 males, 1 females 2 years old
    1 males, 1 females 3 years old
    1 males, 1 females 4 years old
    1 males, 1 females 5 years old
    1 males, 1 females 6 years old
    18 male, 26 female adults (age > 7)
  Population managed with supplementation/harvest through year 1 of:
    -1 males, 0 females 1 years old
    0 males, -1 females 2 years old
    -1 males, 0 females 3 years old
    0 males, -1 females 4 years old
    -1 males, 0 females 5 years old
    0 males, -1 females 6 years old
    -9 male, -13 female adults (age > 7)

Deterministic population growth rate:
     r =       0.028
     lambda =  1.028
     R0 =      1.767
     Generation time =  20.60
In 100 simulations of 100 years:
1.    0 populations went extinct and 100 survived.
This gives a probability of extinction of      0,
  or a probability of success of 1.0000.
2.    Mean final population for successful cases was   66.20,
  with a standard deviation of    9.99.
3.    During 1 years of harvest/supplementation
  mean lambda was 0.5784, with standard deviation  0.0617 .
4.    Without harvest/supplementation, prior to carrying capacity truncation,
  mean lambda was 1.0304, with standard deviation  0.0596 .
```

Table 15. Javan rhinoceros - a growth scenario for the Ujung Kulon population reduced below carrying capacity.

K = 75	T = 100 yrs	
EV = 1, 1, 1	Catastrophes = 0.1,0.9	
Fertility:	67%=0	33%=1
Mortality:	Inf = 10%, Juv = 2%, Ad = 6%	
P Surv = 1.000	Lambda = 1.033	
GT = 20.6	N = 67 ± 7	

Table 16. Population projections with removals and catastrophes in a population that responds with an increase in growth rate.

Scenario (N)	Years 0	20	40	60	80	100	P [Surv]
Basic	56	70	72	71	70	69± 6	1.000
EV 10,10,10	56	39	38	38	32	38±17	.550
EV 3, 3, 3	56	61	62	61	60	62±10	1.000
CV .1, .9	56	62	65	64	63	67± 7	1.000
CV .1, .9 & .5, .98	56	64	66	65	66	66± 9	1.000
CV .1,.9 & .5,.98 & EV = 3,3,3	56	46	41	38	36	35±18	.901
Rem 1/2 A & Y	26	61	64	66	66	66±10	1.000
CV .1,.9	26	52	55	55	55	57±14	1.000
Rem over 2 years CV .1,.9, .5,.98	30	54	60	62	62	62±12	.998

500 RUNS. K=75. Mortality: I=10%, J=2%, A=6%.

The standard errors of survival probabilities (given by P x [1 - P] / sqrt[# runs]) are typically about .005, and standard errors around the number of rhinos in surviving populations ranged from about 1 to 5. In all cases examined the asymptotic stable age distribution just prior to each breeding season was 6-10% 1-year old rhinos: 28% sub-adults between 1 and 7: 60% breeding-age rhinos. This distribution differs from that observed at Ujung Kulon (e.g., calves comprised about 4-5% of the census in the past 5 years).

Modest annual environmental variation at Ujung Kulon does not have much impact on the probability that the population will survive 100 years (though it does affect the sizes of the persisting populations). With the observed zero to small positive mean growth rate, moderate environmental variation would not be sufficient to cause extinction. However if the character of the environment changes over time with expansion of bantang populations or removal of timber the impact of environmental variation upon the rhinoceroses may also change. More information on the ecological requirements of the species will be of value to assess these possibilities.

The predominant demographic factor controlling extinction rates is the frequency of modest catastrophic mortality as might be caused by poaching or a localized disease epidemic or a short term reduction in food supply. The modest growth rate of the Ujung Kulon population is likely to be insufficient to assure that the population will recover from one catastrophe before the next one occurs. The mean time to extinction (of those simulated populations that go extinct within 100 years) for almost all scenarios was approximately 85 years, with extinctions accumulating over the 100 years. It appears that simulated populations regularly declined and increasingly many went extinct as years progressed and indeed if many of the simulations were extended to 200 years many more populations would go to extinction.

The effects of poaching and catastrophes such as disease outbreaks on the probability of survival depend significantly on the carrying capacity and growth rate of the population at the low population levels at Ujung Kulon. The existence of other independent populations would reduce the probability of extinction as a product of the individual population probability estimates. If catastrophes are as frequent as has been estimated and become more severe, then a population often will not reach the carrying capacity before being reduced again. The effect of catastrophes on population survival is highly dependent upon the growth rate of the population, with more slowly growing populations being especially vulnerable (presumably because they rarely recover from a catastrophe before another strikes the population).

If several populations of Javan rhinos existed at a sufficient distance from one another to minimize the chance that a single catastrophe would decimate both, the probability that all would perish within 100 years would be equal to the product of the probabilities that each would go extinct, if no recolonization from extant populations followed local extinctions. Thus if the populations are independently vulnerable and each has a probability of extinction of 0.2 then the joint probability of simultaneous extinction is (0.2 x 0.2) = 0.04. The likelihood of extinction is dramatically reduced with active management plans that include recolonization of areas depleted of rhinos from other populations whether wild or captive.

Demographic Recommendations

Additional sites:

The primary risk to the Javan rhinoceros at this time seems to be the chance that modest catastrophes will continue to strike the population and that it will continue to lose genic diversity because of its small and varying effective population size. The wild population seems sufficiently large so that, in the absence of a sudden population decimation, the modest growth rate as experienced over the past ten years will prevent random fluctuations in birth and death rates (demographic and environmental variability) from driving the population to extinction. The probability that a disease outbreak or some other natural catastrophe will decimate the population is very difficult to estimate. The perhaps conservative guesses about the frequency and effect of disease and poaching made by participants in the PVA workshop were found to lead to extinction probabilities that we find unacceptably high. The simulation results support the view expressed in the points of agreement that a primary and urgent goal of the program should be to establish captive and additional wild populations of the Javan rhinoceros as soon as possible.

Given that no one wild population of rhinos is likely to provide sufficient security for the survival of the species and that no single wild population is likely to be larger than 100 animals we would recommend that long term plans be made (this need has been addressed in the Asian Rhino Specialist Group Action Plan) to secure 20 wild sanctuaries with a total capacity of at least 2000 animals for this species throughout its historic range.

Given that the most urgent need for protection and conservation of the Javan rhinoceros is to expand its numbers as rapidly as possible we recommend that up to one-half the animals be removed from the wild population at Ujung Kulon to establish 3 captive populations. This would provide up to 26 founder animals for the captive population.

The total captive population should be expanded to 150 - 200 animals as rapidly as possible. This action will protect against continuing lose of genic diversity and afford protection against demographic loss of the species. The growth potential of the current wild population appears to be constrained by its carrying capacity. It is likely that with removal of these animals from the wild population and continuing protection that the population will replace these animals within 10 - 15 years as occurred during the growth period 1971 - 1981.

The new sites for rhinoceroses should be off the island of Java, so that they are outside of the likely path of severe destruction of any storm that may hit the island or a disease epidemic. One of these sites would best be located near or within the first large planned release or reintroduction site. This site will require construction of facilities that are adequate for holding and managing about 25 - 30 animals. The development of captive rhino management expertise and a rhino team for capture of the animals and later for conducting and monitoring a release program are essential. There will be a need at Ujung Kulon to undertake radiotelemetry studies of animals that are captured and released as a part of a systematic program to learn more about the population dynamics of this population and the ecology of the species. Such information can provide important guidance for the reintroduction program.

Efforts should begin immediately to identify a captive breeding facility in Indonesia that has experience and success in breeding rhinoceros, that has good quarantine facilities, and that can give them intensive management.

The timetable for moving rhinos to the chosen sites is constrained by site selection, by construction schedules, the need to assemble an experienced capture team, the need for holding facility, and costs. The schedule for capture and moving rhinos must be a compromise between the urgent need for establishing populations that are isolated from Ujung Kulon and the need to avoid placing a substantial number of rhinos in tested facilities that may harbor unknown disease vectors or have other unforeseen management problems. There are significant risks associated with a capture, holding and transport operation as has been found with the Sumatran rhinoceros operations in Indonesia, Malaysia, and Sabah.

While the captive populations will provide back-up in case of catastrophe (and allow more opportunity for experimentation with varied management approaches), longer-range recovery plans should address the need for at least 10 reasonably independent populations of rhinoceroses in Indonesia and other countries in the historical range of the species. Only after Javan rhinoceroses are well-established in multiple sites (5 or more) could the risk of extinction be considered low enough to permit easing of recovery efforts (the ultimate goal of any recovery planning).

Interactive demographic management of the wild and captive populations:

The wild population of Javan rhinoceroses in Ujung Kulon and those populations to be established in the next 25 - 50 years are likely to be at such low numbers that extinction of individual populations will be a continuing threat. As the computer modelling demonstrates, the chance that a disease or other catastrophe will eliminate a rhinoceros population is critically dependent on the rate of growth of that population and is strongly dependent on the initial size of the population.

Because of this continuing risk and uncertainty we would recommend that high priority be given to maintenance of a dispersed thriving captive population. Wild populations of many species, endangered and otherwise, are subject to so many risks that any one has a relatively short expected duration. Black-footed ferrets, California condors, and whooping cranes are just a few of the better known examples of wild populations being decimated very quickly. Captive populations do not always thrive, but they also rarely are exterminated quickly, especially if divided among multiple locations. Mortality is generally very low in captive facilities with experience in propagating a species (as is the case for now for the Indian rhinoceros). This low mortality can "buy time" while husbandry methods for enhancing reproduction are developed (hence the lower probability of sudden extinction). Improvements in the management of the wild population may also assist that population, but dramatic increases are unlikely.

Given that highest priority should go toward increasing numbers of rhinoceroses by whatever means are available, we favor retaining most or all of captive-produced rhinos in the captive breeding program until the population goals of the captive program are met. If captive production is faster than production in the wild, the quickest route to a secure wild and captive population is to use the captive population as a short-term, high-investment production facility. Slowing growth of the captive populations will likely lead to costly delays in progress toward full recovery of the species.

Our recommendation to retain rhinos in captivity until the captive population is large and secure has a qualifier. In the event of disastrous events in the wild, the wild population should not be allowed to perish if that can be prevented without also sacrificing the captive population. Unlike the case with the Arabian oryx, Przewalski's horse, California condor, red wolf, and black footed ferrets, the rhinoceros recovery program has the very important advantage of having a wild population of experienced animals.

If no catastrophe strikes, the wild population is likely to recover from the removals even if there is no input from the captive population. If a natural disaster or disease does decimate the wild population of rhinoceroses, a large captive population as a source for replenishment or reestablishment will likely be far more important to the recovery of the wild population than will additional animals in the pre-catastrophe wild population.

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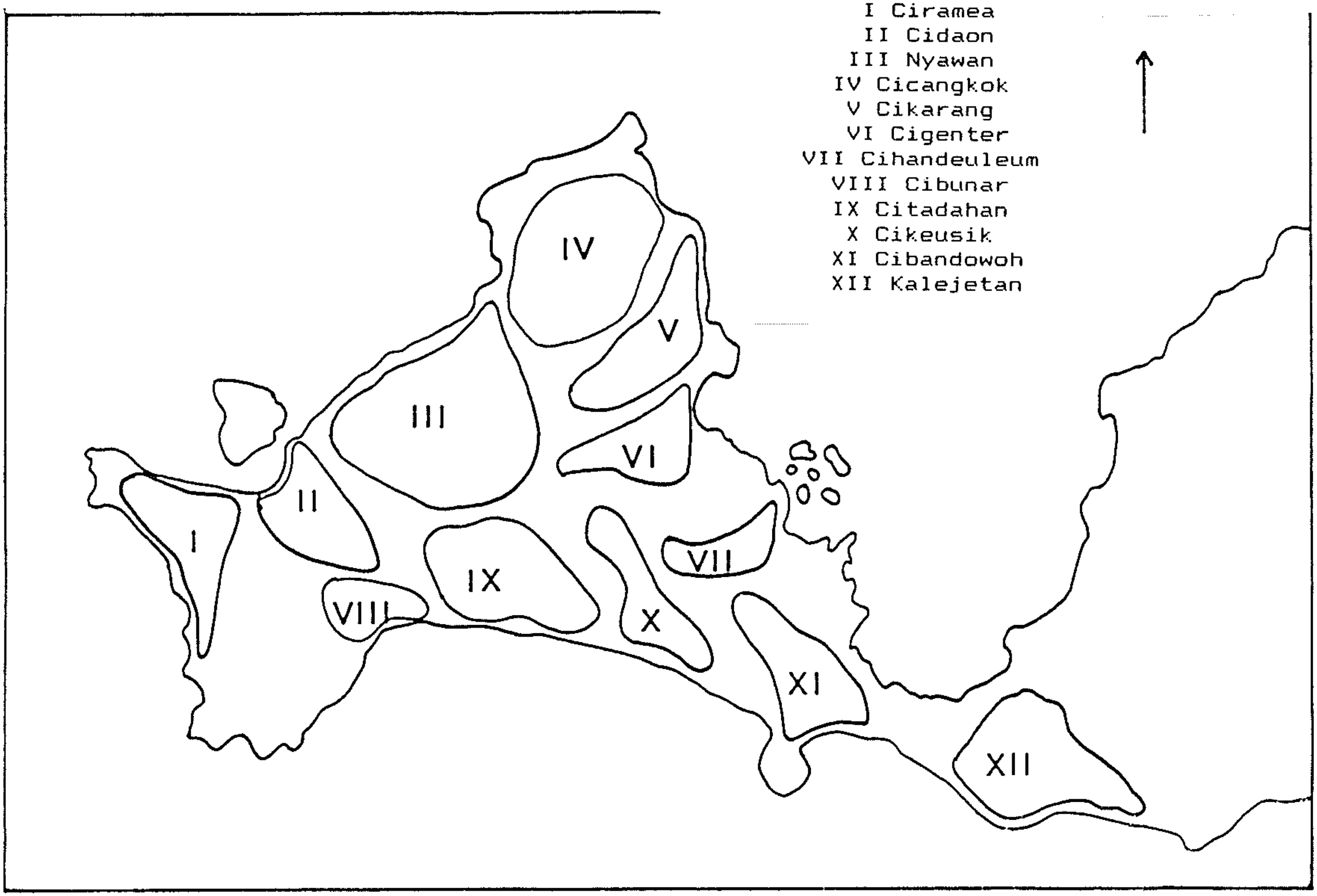

INDONESIAN RHINO INTER-ORGANIZATIONAL MEETING
BOGOR - 5-7 JUNE 1989

MONDAY - 5 JUNE - AM

Attendance: Sutisna, Betts, Rabb, Effendi, Van Strien, Clark, Thomas, Nardelli, Foose, Schenkel, U. Seal, M.Seal, Rubini, Syafi, Khan, Stuart, Santiapillai, Widodo, Tilson, Harudin, Parkinson, PHPA staff, students, Dinerstein, Fujita, Dr. Linda, Sukianto

Stuart: Indonesia the only nation with two extant species of Asian rhino.

Effendi: Very brief but advocates/invites action plan.

Schenkel: Chronicle of last 25 years on Javan rhino.

1967: Facilities and staff conditions very bad. Poaching occurred. Lindberg instrumental in arranging for U.S. WWF money for project. Widodo first Schenkels' assistant, then director of Ujung Kulon.

Is possible to protect rhino in ujung kulon effectively. Govt. must decide to save rhino from extinction; must provide full support to project. Should appoint competent and committed field man to lead the project. Must be effective manager of field team. Exhorts Govt. to appoint person of integrity as well as competence. Criticizes IUCN/WWF for not actively promoting an Asian rhino campaign.

1989: Conditions still not satisfactory. WWF disengaged in 1978-79. Govt. wanted to assume control of project. No plan or implementation thereof. Equipment and support for guards inadequate. Director is administrator; needs to be a field man. War leader. Must consider practical plan for protection in addition to analyses of population viability. Advocates protection of Ujung Kulon population can contribute so rhino can recover to 'optimal' level; then other alternatives can be considered.

Widodo: Results of recent survey. Survey team of 12. U.K. and immediately east thereof. Tracks of 24-36 cm. Should be 14-40? Estimate 52-62 animals. Contends represents slight increase over last survey. Rhinos reoccupying areas again from which absent since 1982, esp. in east, on isthmus, and around lighthouse. Distribution now over most of U.K. Recommend another survey in Oct./Nov.

Thomas: Delivers report on status of captive propagation projects. Two females recently moved to North America adjusted very well.

Table 1. Sumatran rhino capture statistics.

	Captured	Died	Born	Surviving
Indonesia	4/6	0/1		2/2
W. Malaysia	2/9	2/1	0/1	1/7
Sabah	3/1	2/0		1/1
United States				0/2
United Kingdom		0/1		1/1
Thailand		0/1		
Total	9/16	4/4	0/1	5/13

Table 2. Current Locations

Facility	Number
Indonesia:	
Jakarta	1/1
Surabya	1/0
Bogor Safari Park	0/1
West Malaysia:	
Malacca Zoo	1/7
Sabah:	
Sepilok	1/1
North America:	
Cincinnati	0/1
Los Angeles	0/1
United Kingdom:	
Port Lympne	1/1
Total	5/13

Santiappil. Inquires if female from Bogor and male from Surabya be placed together?

Thomas: Yes.

Khan: Can accommodate 8 at Malacca; 12 at Sungei Dusun. Haven't captured any for 1 year but will resume again soon. Clarifies other points about program in Malaysia.

Schenkel: Discusses behavioral aspects of managing Indian rhinos for reproduction. Emphasizes aggression that occurs if animals kept together for prolonged periods. Also inquires if any signs of estrus or sexual behavior.

Thomas: Hormonal studies indicate cycles, but no behavioral sings. Affirms zoos aware of management problems.

Khan: Comments on some aggression among females kept together.

Santiap: Acknowledges there are 3 viable populations. May be animals in Benkulu, but habitat destruction occurring rapidly. Even protected areas will be under pressure. Emphasizes importance of Kerinci. Govt. doesn't have resources to protect effectively. Funds needed from outside. However, the $1.2 million in field `conservation over last 20 years, but 85% to ex patriate salaries. Cites Malaysia as model. Encourages international funding agencies consider this problem. Also laments lack of training that has occurred in conjunction with captive propagation project. Recommends reorienting to provide such training. Already have enough ecological information; now need actual management.

Khan: Acknowledges the Schenkels as progenitors of action plan. Presents highlights of Action Plan. Mentions Javan Rhino in Vietnam and advocates possibility of captive breeding. For Sumatran Rhino in Sumatra, verbalizes inability to protect smaller fragmented groups. Losses may be 10% in Sumatra. Poaching heavy in Sabah.

Indian Rhino: About 1700. Goal is 2000 rhinos in at least 5 areas. Establish and expand areas. Captive propagation.

Javan Rhino: Rarest large mammal in world. < 100 in world; most in Java; a few in Vietnam. Cites recommendation for captive propagation and also establishment of new wild populations.

Sumatran Rhino: Not as critically endangered as Javan but is probably experiencing the most serious poaching and habitat destruction problems. Cites high mortality of animals moved abroad.

MONDAY - 5 JUNE - PM

Attendance: Rabb, Effendi, Van Strien, Clark, Thomas, Foose, Nardelli, Schenkel, U. Seal, M.Seal, Syafi, Khan, Stuart, Santiapillai, Widodo, Tilson, Harudin, Parkinson, PHPA staff, students, Dinerstein, Fujita, Dr. Linda, Sukianto

Seal: To perform PVA, must agree on some goals and objectives
Seal advises everyone that everyone can express their opinions and thoughts. If don't, can't complain. Also if want contributions accurately documented in record, submit in writing to Seal.

JAVAN RHINO

1. Ultimate goal is species survival

2. How do we desire it to survive:

   a. As an evolving species - population large enough for natural selection and mutation to counteract drift. May need 2000.

   b. As a holding action, e.g. 90% for 200 years. May need 200.

   Much discussion from Schenkel about need to preserve rhino as component of co-evolved ecosystem. Clark contends that 2a is end; 2b a means.

3. Current resource:

   a. Ujung Kulon population 50-70.

   b. Vietnam population

   Widodo inquires about genetic diversity.

1900	10^3
1937	25
1967	25
1977	45
1987	55

Best case scenario is that there have been 3 generations (20 years) since 1930's. If N_e = 20, loss of diversity about 2.5% per generation or about 7.5% total. If N_e = 10, then loss would be 5% per generation or about 15% for the 60 year period. Dinerstein notes estimate of N_e/N ratio for Indian rhino is about .4.

Seal moves through handout sheets. Polygamous. First reproduction: females at about 7; males at about 15 years. Discussion of inter-birth interval, hence age-specific fertility of rhinos. Schenkel suggests Amman's data might not be valid because of likelihood of not detecting young calves. Agree that estimates of mortality plausible. Carrying capacity: U.K. = 300 km^2; but is suggestion that rhino habitat only 100 km^2; density = 1/5-10 km^2. Carrying capacity = 70-100 (Schenkel, etc.) Observation: population seems to have stabilized at about 50-60 animals for last decade. Explains 2 population models. Then discusses consequences of removing 3.6 adults.

Foose: Demography primer interlude.

Seal: Possible goal is to restore to historic range, perhaps/obviously not in original numbers.

Santiap: How long would it require for Javan rhinos in zoos to increase from 20 to 1000 as Indian rhino has in Kaziranga.

Foose: Rate of increase in Kaziranga about 5% per year. This rate would be required in captivity or wild. Annual rate of increase of Indian rhino in captivity over the last 15 years has been about 4.5%

Dinerstein: About same rate of increase under optimal conditions in wild in Nepal.

Schenkel: Discusses relative risks and problems of translocation versus captivity.

Effendi: Proposes combination of captive propagation and translocation. Also Javan rhino belongs to world not just Indonesia. Proposes gen pool concept for "Ujung Kulon".

Thomas: Very encouraged by words. Need to consider all options. Protection of Ujung Kulon and exploration of translocation sites. Also interested in statements about captive propagation. Suggests that if are going to remove animals from Ujung Kulon for captivity or translocation, must consider number, sex, age of animals to be removed and over what period of time.

Seal: Short-term objective is to establish 2 more populations immediately.

Clark: Proposes applicability of decision analysis to this question. Recommends invite Lynn Maguire to contribute paper to proceedings of workshop.

Rabb:	Can we assemble data pertinent to good decision analysis, e.g. poaching intensity?
Schenkel/ Santiap:	Can't really estimate rate of poaching from field data.
Seal:	Data indicates losing about 5 adults total per year.
Stuart:	What are consequences of various levels of poaching.
Seal:	Will calculate more; but indications now are that loss of 3 more adults per year will be intolerable.
Foose:	Long-term optimism versus short-term pessimism. Can only expect poaching pressure to intensify over short-term as populations of other rhinos disappear elsewhere.
Syafi:	From discussion, pessimistic about prospects of translocating rhinos. Habitat may not be available. Advocates captive propagation better alternative.
Stuart	For both species, need to identify present and potential viable populations. Also need estimate of resources required to reduce poaching.
Dinerstein	Nepal does demonstrate populations if protected will expand, assuming habitat not at carrying capacity. Value of presence of research activity in reducing poaching.
Widodo	Can improve protection.
Schenkel	Nature self-regulating.
Fujita	Would captivity preserve genetic diversity better than translocation.
Seal	Also high-tech possibilities.

TUESDAY - 6 JUNE - AM

Attendance: Rabb, Effendi, Van Strien, Clark, Thomas, Foose, Schenkel, U. Seal, M. Seal, Rubini, Khan, Stuart, Santiapillai, Widodo, Tilson, Harudin, Parkinson, PHPA staff, students, Sukianto, Fujita, Dr. Linus

Schenkel: Agree should protect Ujung Kulon. Also agree should establish second population, ideally in forested area large enough to accommodate viable number of animals.

Presentation on protection of Ujung Kulon.

Seal: Continues Javan Rhino PVA

Points/Objectives of Agreement

- Long-term:
    - Total (meta)population of 2000 animals distributed over 10-20 subpopulaions distributed over historic range of species.
- Short-term:
    - Protect Ujung Kulon
        - Interlude on drift versus selection. In populations < 100, drift will predominate over selection unless selection very (abnormally) intense. In Ujung Kulon, estimates of loss due to drift over last 60 years are 10-15%.
        - Rabb: Even if protected, Ujung Kulon population is so small (< 100), that is already on way to extinction.
        - Schenkel contends that selection will have produced fittest animals
        - Tilson and Fujita emphasize that dominance and fitness not well correlated
        - Foose presents simple 2-locus example.
    - Need to establish 2 more populations as soon as possible:

- Translocated populations
- Captive populations
  - Captive population will permit approximately twice retention of diversity as randomly breeding translocated population.
  - Ultimate goal is to return animals from captivity to wild as soon as possible (ideally 2 or 3 generations at most).
  - Can expand population more rapidly because:
    - Reduction of inter-birth interval
    - Decrease in mortality (protection from poachers, disease, etc.)
- Need to decide what combination of captive and translocated populations are optimal.
  - Discussion of semi-reserves as compromise.

Seal describes new sets of analyses performed. (Refer to attached sheets)

TUESDAY - 6 JUNE - PM

Attendance: Rabb, Effendi, Van Strien, Clark, Thomas, Foose, Schenkel, U. Seal, M. Seal, Rubini, Khan, Stuart, Santiapillai, Widodo, Tilson, Harudin, Parkinson, PHPA staff, students, Sukianto, Fujita, Dr. Linus, Syafi, Harudin, Nardelli

Seal — Consider general characteristics of captive situation and translocation site:

Analyses suggest Ujung Kulon population could tolerate a 1 time loss of half (about 10) of animals under 7 years and 3.6 animals over 7 years. Must distinguish this kind of removal from a continuing reduction, e.g. due to poaching, which population will not be able to sustain.

Schenkel — Concern about age of animals to be removed, in terms of their dependance on mothers and their adaptability to new sites.

Khan/Thomas — Discussion of selection criteria for animals.

Thomas — Proposes capture protocol

Try for the 3.6 adults

No aged animals;

No calves with mothers unless keep parent

No lactating females

Retain any animals under 7 acquire as are accumulating adults

Et alia — Discussion of stochasticity (unpredictability) of age and sex structure of captured animals.

Foose — Need more flexible guidelines in terms of various combinations of adults and subadults that could be removed. Inquires if analyses don't indicate that population can sustain removal of 6.12 regardless of age. Also `need to consider minima in terms of founder base for new populations.

Seal — Need to better define boundaries, i.e. maxima and minima, for numbers to be captured.

Clark — Should collect as much data from all animals.

Van Strien — Should also suggest sex ratio of subadults. Also must consider time span of captures

Seal — Yes. Based on what know about sex ratios, proposes 3-4 males and 6-7 females. In terms of time span, removal of all animals over short period of time the worst case scenario.

Khan — Recommends that capture occur in all parts of reserve so that sample is representative.

Dinerstein — Comments that operationally may be impossible to distinguish ages of animals.

Widodo — Recommends that intensive monitoring.

Foose: — Inquires if animals that might be captured and then released back into Ujung Kulon should be followed by radiotelemetry.

Schenkel: — Must be preparations and plan for release.

Seal: — Are there suggestions of guidelines for timetable for capture.

Parkinson — Should not have more than 2 traps activated at a time. Would expect that could capture an animal every 5 or 6 weeks.

Seal — Minima

Foose — Suggests 20 as minima if there are two new populations established. 10 if only one population. 10 founders will be expected to represent 95% of the average heterozygosity.

Clark — Suggests that demography more important than genetics for establishing minima.

Seal — Suggests 10 as a minima.

Seal — Now consider translocation site or captivity situation.

- Translocation and Translocation Sites:
  - Appropriate habitat
  - Sufficient area
    - 100 or more as population size
    - Hence 600-1000 km^2
  - Adequate protection
  - Natural boundaries
  - Within Historic Range of Species
  - Geographic separation from Ujung Kulon
  - Distance from human activity
  - Predator free
  - Competition free
  - Political approval
  - Site preparation

Widodo — Suggest Way Kambas and Barisan Selatan as candidates.

Seal — List of potential sites:

Way Kambas

Barisan Selatan

Pulau Panaitan

Newly created reserve

Kalimantan

Stuart — Some assignments for components of workshop document:

Will be a short, general statement of recommendations

Protection: Schenkel, Widodo, and Van Strien

Protocols for Removal of Animals: Thomas and Parkinson

Captive Management: Khan & Foose

Reintroduction: Dinerstein

Priority Areas for Species: Effendi

Surveys, Monitoring, Research: Rubini and Fujita

PVA: Seal, Foose

Training: Santiapillai

Seal: — Captive situations

- Adequate facilities (to accommodate and manage original animals and expansion)
  - 6-12 animals optimal
- Experienced Staff (with rhinos)
  - Curatorial
  - Veterinary
  - Nutritional

- Multiple sites (Far enough for stochastic security but close enough for ready exchange of animals)
- Coordinated Plan (SSP)
- General Accessibility
- Security
- Funding
- Official Approval
- Cooperation, Technology Transfer, Training
- Proximity to Human Centers of Activity so can serve educational purposes
- Research Capabilities

Candidate sites

- New site near Ujung Kulon
- New site close to Bogor
- Zoos with Sumatran rhinos
- Other zoos
- New site near Way Kambas
- Sungei Dusun
- New Site near proposed translocation sites.

Seal Evaluation of translocation sites

Way Kambas:

estimated carrying capacity 100-200
habitat similar to Ujung Kulon
distant from Ujung Kulon
protectability: intermediate
easily accessible
tigers & clouded leopards
near people

Barisan Selatan:

estimated carrying capacity 100-120
distant from Ujung Kulon
similar to Ujung Kulon
protectability: logistically most difficult
difficult access
tigers & clouded leopards

Pulau Panaitan:

estimated carrying capacity is no more than 30 animals

and is not sufficiently separated from Ujung Kulon

20 km of sea

protectability: least difficult (Widodo) but poorly protected at moment (Schenkel)

no fresh water

intermediate access

no predators

Relegate next two to later consideration when trying to locate the 10-20 sites.

Newly created reserve
protected site away from people in central Sumatra

Kalimantan
not within historic range

specific site not identified

distant from Ujung Kulon

WEDNESDAY - 7 JUNE - AM

Attendance: U. Seal, M. Seal, Rabb, Foose, Tilson, Fujita, Rubini, Schenkel, Syafi, Clark, Betts, Santiapillai, Widodo, Effendi, Van Strien, Khan, Thomas, Stuart, Nardelli, Dinerstein, Harudin

Seal — More on captive propagation option.

Point: Are wild caught animals for captive propagation be retained within Indonesia or can foreign facilities be considered.

Thomas — First step is to consider if animals out of wild must be retained within Indonesia

If they must, can/should progeny from wild-caught animals be moved abroad

Indonesians must decide.

Rubini — Should commence in Indonesia, then progeny can move abroad.

Effendi — Realize that rhinos doesn't just belong to Indonesia. However, protection of rhino must be first priority. Captive propagation should be commenced in Indonesia. Later can decide if progeny can move abroad. With Sumatran rhino, why not consolidate existing animals, then can determine if additional animals are needed.

Schenkel — Discusses captive sites

Options on captive sites:

1. Near translocation sites
   - A. Way Kambas
   - B Barisan Selatan
   - C. Pulau Panaitan
2. Bogor
3. Elsewhere

Thomas — Is it possible to insure protection of another in situ site.

Santiap — If establish captive facility at Way Kambas, would it not be possible/advisable to have ex patriot experts.

Thomas — Don't need to have captive facility at release site. Need to have captive facility where best support resources are.

Schenkel — Captive facility at Way Kambas would facilitate and motivate better protection at Way Kambas.

Rabb — Agrees in part with Schenkel, but primary objective of captive propagation should be to maximize production of animals and preservation of gene pool. To achieve these objectives, captive propagation needs to be where existing expertise, resources, and facilities are.

Tilson — Not good idea to have captive facility where wild is because of the stochastic problems.

Foose — Agree with and will extend Tilson's comments. For this reason, Effendi's suggestion that consolidate all Sumatran rhinos in captivity at single site would not be advisable. Moreover, don't yet have enough Sumatran rhinos in captivity to constitute a genetically viable foundation. Likewise, should be multiple captive sites.

Schenkel — Will try to synthesize. Would prefer translocation to Way Kambas. But realizes that perhaps need to commence with captive propagation. But would it not be possible to commence with 2 captive propagation sites: 1 in Way Kambas and 1 elsewhere.

Widodo — If establish 1 captive facility, should have ex patriot expertise.

Rabb — What about Bogor as second facility.

Thomas — Should not return animals to the wild until captive population is secure and self-sustaining so can produce sustainable harvest. Suggests California condor as model.

Schenkel — Why not utilize Safari Park in Bogor as one site and Way Kambas as the other site.

Rabb — Tries to reconcile the Schenkel and Thomas/Rabb positions.

Thomas — Concern about Safari Park is the high traffic of animals in and out because of disease dangers.

Stuart — Perceives a consensus emerging, i.e. for 2 captive populations with translocation deferred until later. But must remember that there are other considerations beyond just the biology. Must preserve the natural habitat. Might even consider consolidating

Effendi — Provide assurance that Govt will protect Way Kambas. Has just been declared a national park. Thinks idea of locating a captive facility at Way Kambas is good. Is already an elephant training facility there. Also approves of Bogor.

Seal Inquires about possibility of a rhino specialist team?

Effendi Yes, moving in that direction. Widodo now species conservation officer for PHPA. Using this office as a base, will try to establish a rhino specialist unit.

Rabb Would this rhino unit have management authority with respect to rhino reserves.

Effendi PHPA is organized into functional (advisory) units and management units.

Seal After much discussion (Refer to Maryalice's notes), consensus seem to be that Way Kambas best translocation sites. (Refer to evaluation matrices).

Thomas (Accepted as part of consensus by Seal). Do captive propagation first a 2 sites before attempt translocation.

Seal Two sites recommended are Way Kambas and Bogor.

THE CONSERVATION OF RHINOS IN INDONESIA

IUCN/PHPA

Points of Agreement

GENERAL POINTS

1. The recovery of the populations of the Javan and Sumatran rhinoceroses to levels that would ensure their long-term survival is among the highest conservation priorities in Indonesia.

2. The responsibility for saving these species and their natural environments rests with the authorities and people of Indonesia.
However, the survival of these species are of importance and interest to the whole world and hence the international community should also contribute to the conservation of these species and their habitats.

JAVAN RHINOCEROS

3. The long-term goal is to save the Javan rhino in its former and present natural habitat. This will entail the establishment of a total population of at least 2000 rhinos distributed over 10 to 20 viable populations (i.e., populations of 100 animals or more) in secure areas throughout the former range of the species (including in countries outside Indonesia). This means identifying and adequately protecting natural forests in advance of reintroductions or translocations.

4. To achieve this goal, the first priority is to provide strict protection for the surviving population in Ujung Kulon National Park, ensuring that the level of poaching is zero. Methods for bringing this about are given in Appendix X.

5. Another priority is to identify and protect potential forest sites for re-establishment of rhino populations in the future.

6. However, the population of rhinos in Ujung Kulon is not, and never can be, of sufficient size to secure the species for the long-term. It is too small for long term viability in ecological, demographic, and genetic terms. Plainly, it is vulnerable to catastrophic events or circumstances. In short, the Javan rhino is now in the process of becoming extinct and will be extinct unless we take action now.

7. It is likely that the population in Ujung Kulon is at, or is approaching, carrying capacity of the environment, and cannot be expected to increase much further.

8. The response to this dilemma by removal of animals from Ujung Kulon to establish other populations can be supported by decision analysis, and population viability analysis indicates the level of removal that can be sustained without impairing the survival of the Ujung Kulon population. As a matter of high priority, it is therefore recommended that two additional

populations be set up as soon as feasible by removing animals from Ujung Kulon. The biological and management arguments and the capture protocol are given below.

9. The greatest concern for the genetic and demographic survival of the species is to rapidly increase its numbers and to establish populations in other locations. This means a closely managed situation is preferable initially, and therefore a captive breeding program is indicated. One of the initial captive propagation sites could be situated in or adjacent to a prime translocation or reintroduction site in Sumatra. The other captive propagation site should be located near Bogor based upon a detailed site analysis.

10. Before removals from Ujong Kulon can take place, it is essential that the receiving sites be adequately prepared, including all the necessary aspects of protection.

11. Identification, preparation, and protection of additional proposed relocation and reintroduction sites should be started as soon as possible, unless such sites be lost, thereby jeopardizing the long-term goals of the recovery programme.

12. Based on a risk analysis of advantages and disadvantages of potential sites, the first removals and transfers to the receiving sites should take place in 1990. Removals and transfers should continue in 1990 and 1991 until the required numbers of animals are obtained. Procedures for capture and captive management are given below.

13. Additional captive breeding facilities should be considered in relation to the conservation needs of the species as the captive bred population expands.

14. All aspects of the conservation work on the Javan rhino should be accompanied by appropriate monitoring and research, including monitoring of the Ujung Kulon, captive, translocated, and reintroduced populations. Guidelines for research are given below.

15. Similarly, all conservation projects on the Javan rhino should include a training component, including captive breeding projects. Guidelines for training are given below.

SUMATRAN RHINOCEROS

16. The long-term goal for the species in Indonesia is to secure viable populations in the wild amounting to at least 1000 animals in Sumatra and 300-500 animals in Kalimantan.

17. The top priority is to enforce strict protection and anti-poaching measures in Kerinci-Seblat, Gunung Leuser and Barisan-Selatan National Parks. The guidelines given below apply to the Sumatran rhino as well, except that specific anti-poaching units are needed in addition to normal reserve guards.

18. Surveys are needed to locate additional viable populations for protection in Sumatra (perhaps in northern Aceh and Gunung Patah), and in Kalimantan (perhaps along the border with Sarawak).

19. The existing capture programme for doomed animals for captive breeding should be continued until such time as sufficient founder animals are available for zoos, both in Indonesia and in the United States and the U.K.

20. The captive breeding programmes should not only secure the total population adequately for long term survival, but also to provide animals for selective reintroductions, and a programme for such reintroductions should be developed as appropriate.

21. The Sumatran Rhinoceros conservation programme has similar training, monitoring, and research needs to the Javan Rhinoceros Programme. Training, in particular, should be an integral part of each project.

22. If no viable population can be found in Kalimantan, a long-term activity would be to enter into an agreement with Malaysia to seek animals from the Sabah captive breeding programme.

CLOSING POINTS

23. A Rhinoceros Conservation Unit should be established within the PHPA to have responsibility for all operational aspects of rhino management in Indonesia.

24. The effectiveness of protection measures for important rhinoceros populations is closely related to the attitude of the local people to the local people in the protected areas. Similarly, education and awareness programmes are needed in all parts of Indonesia, emphasizing the country's importance and responsibility for both species of rhino.

25. Appropriate rural development projects in the buffer zones around the reserves is an important means of avoiding and resolving conflicts over resource use.

26. Continued vigilance is needed to eliminate the illegal trade in rhinoceros products, and to bring offenders to justice. Increases of penalties and other appropriate actions are recommended to enhance the enforcement of the laws dealing with these crimes.

27. International cooperation on rhinoceros conservation with other Asian countries should be pursued, with a view to sharing information and uncovering illegal trading routes.

28. An international awareness and fund-raising programme on the conservation needs of Indonesia's rhinos should be launched as soon as possible.

MONITORING AND RESEARCH PRIORITIES: JAVAN RHINOS

I. Stock Population At Ujung Kulon

All research and monitoring activities are assigned priorities with respect to applied importance for translocated populations.

1) Describe the status and demographic profile of the present population; refine and improve current census techniques.
   - -use trip cameras to identify individuals (build up photo register)
   - -establish a grid system of trails for censuses
   - -assess variation among sampling periods and sampling effort
   - -information needed: number, sex, age

2) Compare availability of preferred browse plant species (e.g. study by Hartmann) with relative abundance of rhinos in the twelve areas within Ujong Kulon.
   - -identify browse plant species diversity within the areas
   - -describe phenological patterns of browse species within the areas
   - -collect rhino scats in areas for fecal analysis to determine percent of browse vs. graminoids in diet (and consider more refined methods to determine nutrition obtained from food sources [e.g.bomb calorimetric studies] and nutritional studies of browse species)

3) As the capture program proceeds:
   - - radio collar individual animals that are to be released to obtain information on ranging patterns and habitat use, wallowing behavior, activity budgets, feeding ecology, social organization, etc.
   - -develop immobilization procedures using other rhino species, and ensure that the immobilization of Javan rhinos is conducted by only very well-trained and experienced personnel
   - -on all captured animals, obtain age correlates, blood samples for genetic analysis, screen for diseases, collect ectoparasites, weights, morphometric data, establish criteria for aging animals by dentition, (if female) collect saliva for reproductive endocrinological studies, individually mark hoofs for track surveys

As more accurate census data becomes available provide this for refinement/adjustments of PVA.

II. Translocated Population (n= 8 to 10 animals)

This section assumes site preparation has already been performed and that translocated animals have been handled as little as possible so as to retain their wild state (i.e. no excessive exposure to humans, minimal stress and holding time).

The appropriate agencies/institutions that will carry out the monitoring and research activities described below should be identified as soon as possible.

It is also strongly suggested that a Javan Rhino translocation team be established within PHPA with assistance from appropriate organizations, both national and international, to carry out the monitoring/research program.

In general, research priority should be to establish how well translocated animals have adapted to their new habitat. A review of the existing literature on Javan rhinos should be conducted prior to initiation of research in order to decrease any redundancy of efforts.

Research and monitoring priorities for reintroduction biology were not specifically considered here (e.g. studies on rehabilitation and behavioral changes upon release), but are an important component of the long-term goals of the Javan rhino conservation program.

All animals should be radio-collared to permit the following research [Note: collars for subadults should be expandable to allow for growth of animal]:

1) Develop protocol for data collection, storage and analysis

2) Characterize vegetation of translocated area prior to animal reintroduction (along similar lines of Unjung Kulon study for comparative purposes)

3) The key research objectives of the monitoring/research program for the translocated population are:

- -establish how animals locate and harvest food
- -establish how animals recognize and avoid predators
- -establish how animals move and orient in space (home range)
    - -determine dispersal distance from initial site of release
    - -determine whether correlates exist in movement patterns in relation to human settlements
- -determine how animals interact with conspecifics and other herbivores
- -determine thermoregulation behavior
- -conduct post-release evaluation to secure data on mortality, reproductive success, disease susceptibility and demographic structure

4) Identify and conduct surveys of other areas to examine the suitability of these areas as future reintroduction sites (especially with regard to the Sumatran rhino)

PROTECTION OF UJUNG KULON: PRIORITY ASPECTS

OUTLINE

1) Housing, equipment (and maintenance)

2) Functioning at the protection front, leadership and management

3) Relationship with human communities adjacent to Ujong Kulon

4) Support by PHPA as the link to the top levels of the Government

5) Support by the top level of the Indonesian Government

6) Assistance by international organizations (IUCN/WWF)
   - financial assistance
   - other assistance

7) Creating public awareness
   - in Indonesia
   - on an international level

8) Care of tourism

1. HOUSING, EQUIPMENT, MAINTENANCE

Housing: guardposts, shelters, guard center

Equipment of buildings: lamps, tools (axe, saw, etc.), kitchen equipment, office equipment, etc.

Firearms: ammunition, compass, map, rucksacks, etc.

Personal equipment: uniforms, shoes, torch, golog, etc.

Vehicles for patrolling: motorboats (Haudenleum, Peucang), dugouts, motorcycles

Vehicles for logistics: car (Bogor/Jakarta/Tamanjaya), motorboat (Badak)

Telecommunications:

Maintenance: regular inspection, regular service, repair, tools for specialist

2. FUNCTIONS AT PROTECTION FRONT (leadership and management)

"Front leader":

-education/training of field staff, emphasis on practical in Ujong Kulon

-preparing and instructing working program for field staff: patrolling, surveying, reporting

-inspection of guard work in the field, status of housing and equipment

-taking care of recruitment and promotion on the basis of the character (reliability, collaboration, motivation)

-dismissal of unfit people within field and office staff

-employment and supervision of specialist(s) for maintenance, servicing, repair of technical equipment

In coordination with "assisting manager":

-organization of logistic service, transport of people (care of sickness)

-taking care of economic situation of the staff; applications to superiors...WWF

-financial administration

3. TO CREATE GOODWILL IN HUMAN POPULATION TOWARDS NATIONAL PARK

Establish contacts with local authorities

Explain aims and meaning of nature conservation, its benefits to mankind

Practical aspects: interest of water household, employment of local people as guards for additional work in the context of tourism

Information of village people on Ujong Kulon, its natural values, its rhinos, aims of nature conservation

PROTOCOL ON REMOVAL OF ANIMALS FROM SOURCE POPULATION

Using the agreed number and sex ratio of animals to be removed from the parent population of 3 male and 6 female adults and one half of the young under 7 years of age, we would suggest that the plan of action should be to make every effort to catch the targeted number and ratio of adults. Those young of the agreed age range and sex ratio caught in the process would be kept until the adult quota is achieved. That accomplished, would constitute the group to be removed. To continue on past this point would be economically unsound and not really necessary!

Obviously, aged animals caught should be rejected as well as lactating females unless the existing baby can be caught as well. Because of the expenditures of money and time, we feel that the catching operation should be done all at one time. We caution that only very experienced personnel should be used.

CAPTIVE MANAGEMENT

1. Protocol for removal of rhino from trap and transport to captive facility.

2. Captive facility:

   A. Should be constructed on a sound design.

   B. The facility at the Malacca Zoo and the new one being constructed at Sungei Dusun could serve as models. (Plans to be attached).

   C. Facility should include individual outside paddocks and inside stalls for each animal; there should also be several other unoccupied stalls that can be used for shunting animals for cleaning and other routine husbandry.

   D. Each inside stall should have troughs/dispensers for food and water.

   E. There should be gates interconnecting all inside stalls and outside paddocks

   F. The outside paddocks should be relatively large (.25 - .5 hectare?); there should be a two tiers of outside paddocks: the smaller one just described connecting with larger ones (1 hectare or more).

   G. All enclosures inside and outside should have good drainage.

   H. Floors should be tile to minimize foot abrasion

I. The outside paddocks should contain trees to provide shade.

J. The outside paddocks must have wallows covered by shade.

K. Physical restraint facilities (squeeze chutes) should be constructed into each facility.

L. Inside stalls should have vertical grills far enough apart to provide good visibility of animals.

M. There should be space for storage of food, medicines, and other supplies.

N. The facility must have good running water and electricity.

3. Routine animal husbandry

A. Animals should be moved into individual stalls at night.

B. Nutrition/Diets

a. If natural vegetation is to be used, selection should be based on best available information about diets in the wild.

b. If animals are to be converted to more conventional zoo diets, there must be an adequate acclimatization/adjustment process and period.

C. Good hygiene is critical to prevent disease; enclosures must be well cleaned each day.

4. Staff

A. Good keepers must be available to care for the animals.

B. Keepers should be knowledgeable about animals, interested in rhinos, and should receive basic training in captive husbandry of rhinos (e.g. at zoos with rhinos or through training provided on site by visiting or resident zoo professionals).

C. In Indonesia, PHPA rangers that are trained in fundamentals of captive husbandry would be good candidates. (this source has been used successfully in Malaysia).

D. The number of keepers will depend on the number of animals. However, considering the need for shifts and absences, a good guide might be 1 keeper per every 2 animals.

E. A good on-site supervisor/curator should be responsible for the operation.

F. Clear and specific instructions and protocols (written) must be provided to guide the keepers.

G. Keepers must be adequately paid.

5. Veterinary Care:

A. A veterinarian with rhino experience must be permanently assigned to the facility and project.

B. Regular parasite control programs must be implemented.

C. Other disease prophylaxis programs should also be applied.

6. Data collection:

7. Behavioral Management

8. Propagation Management

A. Placement of animals together for reproduction should be guided by a coordinated population management plan based on genetic and demographic analyses and objectives.

B. A studbook must be maintained for the species.

TRANSLOCATION PROGRAM FOR JAVAN RHINOCEROS

The design and implementation of reintroduction programs are critical for the long-term viability of endangered species. The Javan rhino is among the most rare of free-ranging large mammals, and it is agreed that translocation to another reserve in Sumatra is highly desireable in the near future. However, no such translocation program has been attempted to date in Indonesia involving rare species. Fortunately, translocation programs already underway in Nepal and India concerning the closely related Greater One-horned rhinoceros provide some valuable guidelines and field experience in shaping the reintroduction program in Indonesia.

The most important initial step is for the responsible agency to appoint a Javan rhino translocation team (JRTT). The Nepal and India experiences clearly illustrated that translocation requires detailed planning, site surveys, dry-runs, and political cooperation and cooperation of law enforcement officers between districts before any translocation can take place. The leader of the team must be a high-ranking official to assure access to decision-makers and sound planning.

Under the leadership of the JRTT, a research unit should be appointed to carry out the field surveys in Way Kambas to determine the optimal release sites, establish a grid of trails for monitoring the movements of translocated, radio-collared animals, and to become familiar with telemetry and field monitoring techniques. Assuming that additional Greater one-horned rhinoceros will be moved from Royal Chitwan National Park to the Royal Bardia Wildlife Reserve in 1990, the Javan rhino research team should be invited to observe the translocation effort in Chitwan and the follow-up monitoring program in Bardia.

In practice, translocation can be expensive, time-consuming, labor-intensive, and requires dedication by a highly motivated team. The JRTT should develop a realistic timetable and budget as soon as the team is developed. This plan could be developed with technical support from individuals associated with translocations of rhinos in Asia. The Nepal experience, documented in a report to the King Mahendra Trust for Nature Conservation, revealed that Greater one-horned rhinoceros could be relocated for about US$2,000/animal. Funding sources would need to be identified early on in the project and commitments made to the translocation effort to insure swift development of the translocation program. At the same time, the in-kind contributions of the Indonesian government should be made clear. The JRTT should review available documents published by the Government of India and Nepal and adapt these programs to the local situation.

A major question remains regarding the release. How long should the translocated animals be held in Way Kambas or a different site prior to release? The decision will rest with the JRTT and may vary on the temperament and condition of the individual which has been translocated.
For research protocol on translocated animals see section 6: Surveys, monitoring and research.

The key point is that translocation cannot be considered a success until animals raise offspring in new locations. Given the low reproductive rates of rhinoceros, this will require a long-term commitment on the part of the JRTT and outside donors of a minimum of 5-6 yr.

JAVAN RHINOCEROS - SITES FOR REMOVED ANIMALS

I. TRANSLOCATION SITE CRITERIA:

- Translocation and Translocation Sites:
  - Appropriate habitat
  - Sufficient area
    - 100 or more as population size
    - Hence 600-1000 km^2
  - Adequate protection
  - Natural boundaries
  - Within Historic Range of Species
  - Geographic separation from Ujung Kulon

- Distance from human activity
- Predator free
- Competition free
- Political approval
- Site preparation

List of potential sites:
- Way Kambas
- Barisan Selatan
- Pulau Panaitan
- Newly created reserve
- Kalimantan

II. EVALUATION OF PROPOSED TRANSLOCATION SITES

Way Kambas:
- estimated carrying capacity 100-200
- habitat similar to Ujung Kulon
- distant from Ujung Kulon
- protectability: intermediate
- easily accessible
- tigers & clouded leopards
- near people

Barisan Selatan:
- estimated carrying capacity 100-120
- distant from Ujung Kulon
- similar to Ujung Kulon
- protectability: logistically most difficult
- difficult access
- tigers & clouded leopards

Pulau Panaitan:
- estimated carrying capacity is no more than 30 animals and is not sufficiently separated from Ujung Kulon 20 km of sea
- protectability: least difficult (Widodo) but poorly protected at moment (Schenkel)
- no fresh water
- intermediate access
- no predators

III. CAPTIVE SITES CRITERIA

Criteria:
- Adequate facilities (to accommodate and manage original animals and expansion)
- 6-12 animals optimal
- Experienced Staff (with rhinos)

Curatorial
Veterinary
Nutritional
Multiple sites (Far enough for stochastic security but close enough for ready exchange of animals)
Coordinated Plan (SSP)
General Accessibility
Security
Funding
Official Approval
Cooperation, Technology Transfer, Training
Proximity to Human Centers of Activity so can serve educational purposes
Research Capabilities

Candidate sites:

New site near Ujung Kulon

New site close to Bogor

Zoos with Sumatran rhinos

Other zoos

New site near Way Kambas

Sungei Dusun

New Site near proposed translocation sites.

IV. EVALUATION OF PROPOSED CAPTIVE PROPAGATION SITES

Candidate sites:

New Site near proposed translocation sites.
- New site near Ujung Kulon
- New site close to Bogor
- New site near Way Kambas

Zoos with Sumatran rhinos

Other zoos

Sungei Dusun

Table 1. Sumatran Rhino - Capture Statistics

	Captured	Died	Born	Surviving
Indonesia	4/6	0/1		2/2
W. Malaysia	2/9	2/1	0/1	1/7
Sabah	3/1	2/0		1/1
United States				0/2
United Kingdom		0/1		1/1
Thailand		0/1		
Total	9/16	4/4	0/1	5/13

Table 2. Sumatran rhinos - current locations.

Facility	Number
Indonesia:	
Jakarta	1/1
Surabya	1/0
Bogor Safari Park	0/1
West Malaysia:	
Malacca Zoo	1/7
Sabah:	
Sepilok	1/1
North America:	
Cincinnati	0/1
Los Angeles	0/1
United Kingdom:	
Port Lympne	1/1
Total	5/13

List of Participants

A. From the ministry of Forestry/PHPA

Ir Sutisna Wartaputra (Director-General of PHPA)
Ir Sujadi Hartono (Secretary-General of PHPA)
Dr. Effendy A. Sumardja (Director of Nature Conservation)
Ir Toga Siallgan (Director of National Parks)
Mr. Widodo Sukohadi Ramono (Chief, Species Conservation)
Prof. Rubini Atmawidjaja (President, Indonesian Wildlife Fund)
Ir Muladi Widjaja (PHPA)
Ir Bambang Darmadji (Ujung Kulon NP)
Ir Mohammed Haryono (Ujung Kulon NP)

B. From IUC/SSC

Dr. George Rabb (Deputy Chm, IUCN Species Survival Commission)
Dr. Simon Stuart (Species Programme Officer, SSC Executive Office)
Mr. Mohd. Khan bin Momin Khan (Chm, IUCN/SSC Asian Rhino Specialist Group)
Ir Syaffii Manan (Deputy Chm, IUCN/SSC ARSG)
Prof. Ruedi Schenkel (Former Chm, IUCN/SSC ASRG)
Dr. Ulysses S. Seal (Chm., IUCN/SSC Captive Breeding Specialist Group)

C. From International Zoo Community

Dr. Thomas Foose (Conservation Director, AAZPA)
Dr. Warren Thomas (Director, Los Angeles Zoo; Coordinator SRT)
Mr. Francisco Nardelli (Sumatran Rhino Trust [SRT])
Dr. Tim Clark (Brookfield Zoo)
Dr. Ronald Tilson (Minnesota Zoo)
Mr. Tony Parkinson (Sumatran Rhino Trust)

D. Others
Dr. Nico van Strien
Dr. Charles Santiapillai (WWF-I)
Dr. Eric Dinerstein (WWF-US)
Dr. Marty Fujita (Smithsonian Institution)
Dr. Linda Buntaran (IPB)
Dr. Hadi Ali Korda (IPB)
Dr. Machmud Thohari (BIOTROP)
Mr. Suhianto Lusli
Mrs Marialice Seal
Mr. Haerudin Sadjuddin (UNAS)
Director of Surabaya Zoo
Dr. Linus Sumanjunta (Director, Ragunan Zoo)
Director of African Safari Park (Cisarua)
Group of 10 Students

Regrets: Hon'ble Minister of Forestry, Ir Hasjrul Harap

THE CONSERVATION OF RHINOS IN INDONESIA

An inter-organizational meeting convened by

IUCN - The World Conservation Union

and the

Directorate General of Forest Protection and Nature Conservation

held at the BIOTROP Institute, Bogor, 5-7 June 1989

Report of the Meeting

The impetus for this meeting was the finalization of the Action Plan for the Conservation of Asian Rhinos, which was prepared on behalf of IUCN and its members by the IUCN/SSC Asian Rhino Specialist Group. The Action Plan identifies conservation action on behalf of the Javan and Sumatran rhinos in Indonesia as being a particularly high priority. The purpose of the meeting was to explore how the recommendations of the Action PLan can be put into effect within Indonesia. The meeting concentrated mainly on the Javan rhino, since many of the more difficult issues surrounding the Sumatran rhino had been addressed in earlier meetings. However, the points of agreement by the meeting, and the rhino conservation programme that is now recommended, cover both species. For this programme to move ahead, and for donor participation to be sought, the conclusions of the meeting now await formal endorsement by the Government of Indonesia.

The consensus reached during the meeting is summarised in the "Points of Agreement". Further details are provided in the relevant Annexes. The biological basis for the recommendations made is provided in the population viability analysis in Annex 2.

It was the unanimous conclusion of the meeting that the current opportunity to save the Javan and Sumatran rhinos, and to restore them to healthy population levels, should not be lost. The recommendations made by the meeting provide the most effective means to convert this desire into reality.

Message from the Hon'ble Minister of Forestry

Distinguished guests,

I am pleased to welcome you to this meeting convened by the INternational Union for Conservation of Nature and Natural Resources (IUCN) and the Directorate General of Forest Protection and Nature Conservation (PHPA) on Asian rhinos. This meeting has been specifically organized to implement the action plan prepared by IUCN to conserve the rhinos in Asia. Given that two of the three species of Asian rhinos occur in Indonesia, it ia also a meeting where our participation becomes all the more important and invaluable. International concern has always been focused on the plight of the Asian rhinos, especially the two species that occur in Indonesia - the Javan rhino and the smaller Sumatran or wooly rhino - ever since poaching and habitat loss led to a drastic reduction in their numbers. At present a viable population of the Javan rhino is to be found in just one locality in Indonesia, i.e. the Ujung Kulon National Park in West Java. The Sumatran rhino on the other hand, enjoys a wider distribution in Sumatra. It is also, in comparison to the Javan rhino, more numerous. But there is no room for complacency. Both species are endangered in Indonesia and the prospect for their long-term survival appears to be grim but not entirely hopeless.

Increasing human population and increasing agricultural land use have considerably reduced the land available to the wildlife in Indonesia since the turn of the century. The animals that are most affected by the continued contraction of their range are the large mammals such as the elephant, rhino, and tiger which need relatively large areas to survive. For this reason alone, it is necessary that action be taken at the highest level to decide upon policies to ensure the long-term survival of viable populations of the two species of rhino in Indonesia.

Purely from a commercial point of view, a rhino is more valuable dead than alive when its horn, hide, and even blood are sold to wholesalers in south-east Asia. There has been a continuous whittling away of rhino populations in Indonesia to provide rhino products in Chinese medicine. Poaching has been identified as the one agency that represents an over-riding threat to the Javan rhino.

The long-term survival of rhinos in Asia depends on man and his willingness to share with them the resources of the land. We need to formulate conservation policies in the light of the prevailing socio-economic conditions and their development plans. But since conservation is of world-wide importance, as well as of National benefit, the International Community too has a responsibility to provide assistance, which may in the form of funds, equipment, or technical collaboration, as well as cooperating in controlling international trade in rhino products.

This meeting itself is proof that international organizations are seriously concerned about the plight of the Asian rhinos and are prepared to extend their help to where the rhinos occur to enhance the long-term survival of the species in their natural habitat.

We look forward to a fruitful collaboration on our joint efforts to safeguard the species from becoming extinct in Asia. May I wish you all every success at your deliberations.