KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKSHOP REPORT

1 May 1993

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Kenya Wildlife Service

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The International Black Rhino Foundation
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SECTION 1
SUMMARY AND RECOMMENDATIONS

KENYA BLACK RHINO METAPOPULATION WORKSHOP

SUMMARY AND RECOMMENDATIONS

INTRODUCTION:

This report presents the results of a Kenya Black Rhino Metapopulation Workshop that was conducted during November 1992 in Nairobi Kenya. The Workshop was a collaborative endeavor of the Kenya Wildlife Service (KWS) and the Captive Breeding Specialist Group (CBSG) of the Species Survival Commission (SSC) of the IUCN - The World Conservation Union. This report consists of various results from this Workshop as well as various reference material.

The purpose of the Workshop was to utilize available biological data and expert knowledge to assess the current situation and plans for the black rhinoceros in Kenya (*Diceros bicornis michaeli*). Participants in the Workshop included most of the persons who have been centrally involved with the black rhino program for KWS as well as rhino researchers and managers from other parts of Africa. A list of Workshop participants appears in Section 2.

Stochastic simulation computer models have been used for this assessment. Results of these analysis provide a basis for some recommendations for further development of the conservation strategy and recovery plan for the Kenya black rhino.

PROBLEMS OF SMALL POPULATIONS

Small and fragmented populations are at high risk of extinction. In addition to the processes of unsustainable exploitation and habitat degradation that are usually the causes for the reduction in numbers and fragmentation of distribution, small populations are also subject to a number of stochastic problems that can also imperil viability. These stochastic problems include environmental, demographic, and genetic problems. Environmentally, fluctuations in conditions can disrupt survivorship and reproduction of individuals in the population. Periodically, more drastic fluctuations, i.e. "catastrophes", can devastate populations by more severely increasing mortality or decreasing reproduction. Demographically, even in the absence of environmental fluctuations, there can be intrinsic variation in the birth and death processes that in larger populations "average out", but in smaller populations can be fatally disruptive. Genetically, small populations lose genetic variation or diversity that is essential for fitness (survival and reproduction) under existing environmental conditions) and adaptability when environments change. Generally, the smaller the population is, the greater these problems are.

MANAGEMENT AND PHVAs

Management can often moderate or remedy the problems of small populations to permit long-term survival or recovery, i.e. viability. When small populations are also fragmented into disjunct isolates, which are obviously even smaller, it is often useful to consider managing the separate demes or subpopulations interactively to some extent as a "metapopulation". Such management is likely to be more successful when as much as possible is known about the processes imperiling the population and the consequences of various possible management actions. A tool available for assessing population viability and management options is population and habitat viability analyses (PHVAs).

PHVAs use computer models which incorporate demographic and genetic characteristics of a population(s) and conditions in the environment to simulate probable fates of the population(s) under these described circumstances. The fate of the population is measured in terms of probability of extinction P(E) or survival P(S) and fraction of original genetic diversity (e.g., expected heterozygosity, (H) retained.

In terms of threatened populations, PHVAs:

(1) explore the extinction processes that operate on small and fragmented populations, and

(2) examine the probable consequences for the viability of the population of various management actions or inactions.

Thus, PHVA models can evaluate a range of scenarios for populations under a variety of management (or non-management regimes). As a result of the different scenarios explored, it is possible to recommend management actions that maximize the probability of survival or recovery of the population.

KENYA BLACK RHINO PHVA

The Kenya black rhino population (*Diceros bicornis michaeli*) seems particularly appropriate for a PHVA analysis. Throughout Africa, the number of black rhino has declined by more than 95% over the last 20 years due mostly to poaching for the horn. The latest estimates contend that fewer than 3000, and perhaps closer to only 2000, black rhino survive in natural habitat on the entire continent of Africa. About 200 black rhino (~ 160 of them *D.b. michaeli*) reside in captive facilities around the world, mostly in North America and Europe.

The decline of this species has been particularly severe in Eastern Africa, which is inhabited by populations taxonomically described as the *Diceros bicornis michaeli* subspecies, geographic variety or ecotype. Approximately, 500 *D.b. michaeli* survive in natural habitat: about 100 outside Kenya; about 400 inside Kenya. The Kenya population is fragmented with the majority of rhino (about 300) residing in 11 disjunct areas known as "sanctuaries" that are intensely protected and increasingly managed (**Table 1** and **Figure 1**). Indeed, 6 of these sanctuaries are already entirely enclosed by fence; 3 are partially enclosed; and 2 are still open. About 160 of the black rhino in captivity are of East African origin.

KENYA WILDLIFE SERVICE RHINO PLAN

At the time of the Workshop, the conservation strategy and recovery plan for this species provides for:

(1) protect and manage rhino in the system of 11 sanctuaries;

(2) manage the sanctuaries as a metapopulation by interchange of rhino where feasible and desirable to maintain genetic diversity and demographic integrity and productivity;

(3) expand sanctuary rhino from the current 285 to 500 by 1995 and then to ~700 by the Year 2000;

(4) use a sustainable harvest from the sanctuaries to recolonize other areas that can be secured in Kenya and perhaps eventually in Tanzania or other East Africa countries.

(5) restore the Kenya population to at least 2000 rhino.

SUBSPECIES AND ECOTYPES

The black rhino in Kenya are considered part of a described subspecies (*Diceros minor michaeli*) or at least a defined geographical variety the eastern populations in Kenya and northern Tanzania. The IUCN SSC African Rhino Specialist Group has recommended that these eastern or michaeli populations be treated as conservation units separate from other black rhino subspecies or regional populations: the southern central populations extending from Natal through Zimbabwe and Zambia into southern Tanzania (*D.b. minor*); the southwestern populations in Namibia (*D.b. bicornis*); and the northern-western populations extending from the Horn of Africa to the Central African Republic and Cameroon (*D.b. longipes*). (du Toit et al 1987)

Research continues on the molecular genetic differences among these conservation units. Preliminary results are not unequivocally conclusive. A decision process needs to be developed based on the data generated by these studies. Presumably, the recommendations of African Rhino Specialist Group will be recognized as the highest authority on subspecies/conservation-unit decisions by rhino managers.

However, at this time there seems to be no compelling reason to consider interbreeding of the Kenya rhino with animals from any of the other populations. This observation applies to rhino both in the Kenya Sanctuaries and in the captive population outside Kenya.

Beyond, the geographical varieties, concern has also been expressed at the Workshop and elsewhere (du Toit et al.) that there may be significant ecotypes (e.g. highland versus lowland; xeric versus mesic) that would or should not be readily intermixed, e.g. translocating rhino from the Kenya highlands to lowland areas such as Ngulia. Again, data does not seem to be available to unequivocally resolve this question. The Workshop encourages collection of data on this issue as rhino are translocated. It is also recommended that rhino translocated from highland to lowland or vice versa be closely monitored for indications of possible stress and consequent remedial intervention during acclimatization periods.

ROLE OF CAPTIVE POPULATIONS

Captive propagation is one component of a spectrum of management options that are available for threatened species such as the black rhino (**Figure 2**). Holistic strategies will incorporate both *in situ* and *ex situ* components. In general, captive population and programs can serve 3 major roles in holistic conservation strategies:

(1) living ambassadors that can educate the public at all levels and generate funds for *in situ* conservation.

(2) scientific resources that can provide information and technologies beneficial to protection and management of populations in the wild;

(3) genetic and demographic reservoirs that can be used if and when opportunity and need occurs to reinforce survival or recovery of populations in the wild either by revitalizing populations that are languishing in natural habitats or by re-establishing populations that have become extinct.

The third of these roles may often be a benefit for the longer term as return to the wild may not be a feasible or useful prospect for the immediate future. However, with a species like the black rhino that is declining so rapidly and much faster than its habitat is disappearing, captive refugia may be especially critical for survival and recovery of the species.

The demographic and genetic status of the captive population is summarized in Section 7. Globally, the captive population is just self-sustaining. Locally in the most intensively managed region (North America), the population has a positive rate of growth. The growth of the captive population has been restricted by a major medical syndrome characterized by hemolytic anemia and mucocutaneous ulceration. A summary of this syndrome and the intensive research in progress to investigate this problem is presented in Section 8. Recently, there have been results from this research that provide encouragement that remedy for the problem may soon be developed and growth of the captive population improved. Genetically, the captive population is extremely healthy with 98-99% of the genetic variation of the wild gene pool estimated to exist in captivity. An unequivocal conclusion from this summary is that there is no need at this time to move additional *D.b. michaeli* into captivity. In the future, it is possible that exchanges of rhino between the captive and wild population, as components of a global metapopulation for might be mutually beneficial.

CONCLUSIONS AND RECOMMENDATIONS

- The KWS conservation strategy and recovery plan for black rhino seems viable. The metapopulation of sanctuaries will survive with high levels of genetic diversity for the 200 year period, especially if management occurs to mitigate the effects of possible catastrophes and to perform artificial migration of rhino among subpopulations to correct genetic (inbreeding depression) and demographic (local extinction) problems.

- Stated expectations that the sanctuary population can grow from 300 to 500 by 1995 and 680 by the year 2000 seems overly optimistic. In the absence of recruiting large numbers of rhino from outside of existing sanctuary populations, the current rate of growth predicted by the model under the most optimistic conditions is about 4.5% per year. This rate would produce a sanctuary population of about 360 by 1995 and 450 by the year 2000.

- Two of the current sanctuaries (Lewa Downs and Ol Jogi) are too small to accommodate populations large enough to be demographically and genetically stable for the 200 year period. If possible they should be enlarged, i.e. their carrying capacities (K) increased. In general, sanctuaries on the order of 50-100 rhinos are indicated for acceptable stability of their rhino populations over the 200 year period.

- Two of the current sanctuaries (Amboseli and Ol Pejeta) lack enough rhinos to serve as adequate founders, genetically or demographically, to permit acceptable recovery of viable populations. Supplementing the founder base of the populations in these sanctuaries is indicated. In general, at least 10 and preferably 16-20 founders are advisable.

- In terms of genetic and demographic viability and stability, larger populations are always beneficial, especially for longer time periods. Hence, longer-range goals (i.e. > 200 years) would likely require more populations of larger size, e.g. 20 sanctuaries with K $\geq$ 100 rhino.

- Catastrophes, especially drought and poaching, severely reduce the probability of population survival and recovery. Management should attempt to reduce the frequency and severity of catastrophic episodes. Areas where such catastrophic episodes cannot be successfully managed cannot be considered secure "sanctuaries" for rhino. Ngulia, Laikipia, Mara, and Amboseli are in particular need of further careful evaluation and possible management of catastrophic factors if they are to serve as rhino sanctuaries.

- Migration, which will need to occur through managed translocation of rhino, does improve the viability of sanctuaries at significant risk, especially if catastrophes are also mitigated.

- Rhino translocated between different types of habitat (e.g. from highlands to lowlands) should be monitored for indications of stress and possible corrective interventions.

- Sustainable harvests are possible from several of the larger populations in more stable habitats (Solio and Nairobi) now and are expected from other sanctuaries (e.g., Nakuru, Ol Pejeta, Aberdare) in the future (**Table 12**).

- The PHVA modelling should be continued and extended as part of an adaptive management process for rhino. Preferably, KWS could develop further the capability to conduct the PHVA process itself. Alternatively, it would be possible for KWS to contract for these services to be performed.

- In a global sense, the systematics issues for black rhino should be investigated as vigorously as possible to clarify options and optima for conservation action. However, the continuing uncertainty and controversy seems to have no immediate indications for adjustments to the KWS rhino plans.

- The captive population should continue to be managed as well as possible to serve as an ultimate reservoir of genetic and demographic material if recovery efforts in the wild prove inadequate for this species. However, there is no need or justification to move any more East African black rhino into captive populations outside Kenya (or Tanzania) at this time.

REFERENCES

du Toit, R.F., T.J. Foose, D.H.M. Cumming. 1987. Proceedings of the African Rhino Workshop, Cincinnati, Ohio, October 1986. Pachyderm 9. IUCN, Gland, Switzerland.

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SECTION 2
PROBLEM STATEMENT, AGENDA, PARTICIPANTS

KENYA BLACK RHINOCEROS
Diceros bicornis michaeli

METAPOPULATION AND HABITAT VIABILITY ASSESSMENT AND CONSERVATION ACTION PLAN WORKSHOP

PROBLEM STATEMENT

The numbers of black rhino in Africa have declined 90% in the last 20 years. Only 3800 are estimated to survive on the entire continent. The major cause of the decline is poaching for the horn.

The decline of this species has been particularly severe in Eastern Africa which is inhabited by populations described as the *Diceros bicornis michaeli* subspecies or ecotype. Fewer than 100 *D.b. michaeli* are believed to survive outside Kenya; 370-400 are estimated inside Kenya.

The majority of the Kenya rhino (285) are located in 11 intensely protected areas designated "sanctuaries". Of these sanctuaries: 6 are entirely enclosed by fence; 3 are partially enclosed; and two are open. The range of population sizes in these sanctuaries is from 4 to 60. For the most part, these populations have been established with founders translocated from areas outside the sanctuaries. The range of estimated carrying capacities of these sanctuaries is 15 to 100. The total estimated ecological carrying capacity of the 11 sanctuaries is 680. The sanctuaries thus constitute a metapopulation of 11 small and fragmented subpopulations. As such, they are subject to risks of extinction from demographic, environmental, and genetic stochasticity.

The remainder of the Kenya rhino (85-100) occur outside the sanctuaries and most (50-70) are isolated and non-reproducing animals living in remote and largely unprotected areas. These animals are potential resources and candidates for translocation into the sanctuaries to reinforce the founder populations as needed and feasible.

There are about 150 *D.b. michaeli* in zoos worldwide. About 130 of these are in well organized captive propagation programs (SSP in North America; EEP in Europe; SSCJ in Japan).

The current conservation strategy and recovery plan for this species in Kenya is to expand the number of rhinos in the sanctuaries from an appropriate number and diversity of founders from the current 285 to 500 in 1995 and then to the sanctuary carrying capacity of 680 by 2000. The Kenya plan further aspires to manage the sanctuaries as a metapopulation by managed interchange of animals where feasible and desirable to maintain genetic diversity and demographic integrity and productivity. Thereafter, the plan is to use a sustainable harvest of surplus from the sanctuary populations to recolonize areas in the former range of the species in Kenya and perhaps neighboring Tanzania and Uganda. The ultimate goal of the Kenya plan is to restore a population of at least 2000 *D.b. michaeli* in Kenya and environs.

GOALS

(1) Conduct a Population and Habitat Viability Analysis for the Kenya metapopulation(s) of black rhino.

(2) Assess the current Kenya rhino conservation plan using models (VORTEX, perhaps GAPPS and RAMAS) for quantitative evaluation of genetic, demographic, and environmental risks.

(3) Using the simulation models in conjunction with other information on the biology of the rhino and its environment, delineate a metapopulation strategy for black rhino in Kenya that will provide for maintenance of genetic diversity and demographic security over the short term (10-50 years) and recovery of evolutionary potential over the longer-term. This strategy will recommend:
  - total metapopulation number
  - number and sizes of subpopulations
  - number and nature (sex, provenance, etc.) of founders for each subpopulation
  - rate of migration (managed) among subpopulations

(4) Prepare a report of the analyses and results of the workshop with recommendations for achieving the above goals.

OBJECTIVES

(1) Consolidate existing information on black rhino distribution, numbers, and habitat. As far as possible, this information will be assembled using maps of the various areas involved.

(1) Operationally review life history information of the species as needed for simulation models.

(3) Explicitly, and as far as possible quantitatively, identify and assess specific risks, deterministic and stochastic, to the black rhino and its habitat in various sanctuaries under existing and projected conditions.

(4) Assemble information to:
  (A) assess human population growth around each area;
  (B) identify current and planned land use patterns and their impact on protected reserves and rhino habitat;
  (C) explore full range of possible poaching scenarios over next 20 years.

(5) Delineate current, planned, and possible/desirable levels of protection and management of reserves.

(6) Project the potential expansion or decline of black rhino population numbers under various management regimes.

(7) Evaluate the need/benefit of retrieving additional outlier rhino as founders for the sanctuary populations.

(8) Employing simulation models, determine numbers of black rhino and subpopulations required for various probabilities of survival and preservation of genetic diversity for specified periods of time (i.e. 50, 100, 200 years) and for eventual recovery of evolutionary potential.

(9) Consider habitat and carrying capacity requirements needed to achieve objectives of establishing population sizes needed for a viable population.

(10) Explore metapopulation manipulations that could be used to establish or maintain viable populations: e.g. managed migration among subpopulations; pedigree management of sanctuary populations.

(11) Examine obstacles (e.g. behavioral, logistic, financial problems) to and consequences of this approach.

(12) Consider how possible interventions in the wild population and its habitat might increase its rate of growth, maximize retention of genetic diversity, and reduce risk of extinction.

(13) Evaluate possible role of captive propagation as a component of the metapopulation strategy. In particular, consider how captive propagation could: A) contribute to 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 or establishment of new wild populations.

(14) Consider other ways the global zoo community can strategically but realistically assist the conservation of black rhino in Kenya.

(15) Formulate and/or evaluate criteria developed for establishment of new black rhino populations.

(16) Develop quantitative scenarios for harvest of animals from sanctuary populations for translocation to new areas.

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

(18) Consider how social and rural development realities as well as educational and informational efforts can be effectively incorporated into action plans.

(19) Consider Kenya strategy in context of (A) plans for species elsewhere in Africa and (B) of subspecies issue.

(20) Produce a Conservation Strategy and Action Plan Document presenting the results and recommendations from the Workshop for various scenarios and courses of conservation action.

KENYA BLACK RHINO PHVA/CAP WORKSHOP OVERVIEW

A Metapopulation Conservation Strategy Document will be prepared in draft form during the workshop. It is a goal of the workshop that this document be reviewed and revised by all participants during the workshop to achieve agreement on its content before departure. This document will include specific recommendations and priorities for management and research of both captive and wild populations. The Conservation Strategy will be developed by detailed examination of the natural history, biogeography, life history characteristics, status in the wild and captivity and threats to the species continued existence.

Participants

The workshop will be conducted as a joint endeavor of the Kenya Wildlife Service and the Captive Breeding Specialist Group (CBSG). The list of invited participants includes the Chairman of the SSC African Rhino and Reintroduction Specialist Groups. Representatives of the African Rhino Specialist Group from several other African nations (Tanzania and Zimbabwe) have also been invited.

Briefing Book

A briefing book will be distributed to all participants at the workshop. The book will contain summary information on: population biology concepts as they relate to developing conservation strategies (species survival plan, recovery plan); selected papers on the Kenya black rhino situation and recovery plan; natural and life-history of the black rhino; status of the wild and captive populations; and preliminary results of computer models evaluating the extinction vulnerability of rhino species (to be revised and refined during the workshop).

Workshop Format

The duration of the workshop will be 3 full working days and then an additional day for a smaller group to complete preparation of the report. The workshop will be organized in an effort to combine available information on the biology and status of the species with analytical techniques that evaluate their conservation implications. Once the basic data are presented, analytical models will be prepared to simulate future population trends. These models will focus on estimating the probability of the species going extinct given various conditions and scenarios (Population Viability Analysis PVA). Conservation strategies for both captive and wild populations based on information obtained will be developed.

KENYA BLACK RHINO METAPOPULATION WORKSHOP

AGENDA

DAY 1: SATURDAY 2 NOVEMBER 1992

MORNING

9:00	Introductions, opening remarks and arrangements. (Leakey, Brett)
9:30	Goals, Problems, and Assignments for Workshop. (Brett, Seal, Foose)
10:30	Break
11:00	Basic Overview of Small Population Biology and Management (Foose, Lacy).

- Demographic, environmental, and catastrophic effects on persistence of small populations.
- Genetics and persistence of small populations.
- Species survival planning and collaborative management approaches for small populations.
- VORTEX, GAPPS and other models available for PHVA.

12:00	Overview of the Kenya Black rhino situation and current plan. (Brett, Wanjohi)
13:00	Lunch

AFTERNOON

14:00	Taxonomy, genetic analyses, population substructure (Ryder, Aman)
15:00	Review and assembly of population biology, life history and basic black rhino biology parameters for models. (Brett, Emslie, Hillman, et al.)
15:30	Break
16:00	Organize working groups.

EVENING

Initiate working groups and simulation runs for black rhino.

DAY 2: SUNDAY 3 NOVEMBER 1992

MORNING

9:00 Distribution and review of draft minutes from Day 1.

Present results from initial model simulations.

9:30 Consideration possible pedigree management of sanctuary populations. (Lacy).

10:30 Break

11:00 Consideration of reintroduction protocols and criteria (Price).

12:00 Consideration of possible role of captive propagation and other actions by global zoo community in recovery plan. (Foose)

13:00 Lunch

AFTERNOON

14:00 Continue working sessions and model runs.

EVENING

Working groups work on documents.

DAY 3: MONDAY 4 NOVEMBER 1992

MORNING

9:00 Distribution and review of draft minutes and reports from Day 2.

9:30 Discussion of Kenya populations and plans in relation other national strategies and continental action plan by AERSG. (Brett, DuToit, Emslie)

10:30 Break

11:00 Discussion of behavioral, logistic, financial, other impediments to metapopulation management. (Brett, DuToit)

12:00 Presentation of results from model simulations. Discussion of full range of scenarios, problems and potential solutions. Identification of conservation priorities.

Assemble first draft of final workshop document.

13:00 Lunch

AFTERNOON

14:00 Presentation and review of final documents.

Identification of items that are dependent upon further data and analysis to be completed after the Workshop. Organize mechanism to continue process developed at Workshop.

Achievement of consensus on the Summary and Recommendations of the Conservation Strategy Document.

EVENING

Working groups continue to refine and finalize documents.

DAY 4: TUESDAY 5 NOVEMBER 1992

MORNING

Further modeling analysis, if required.

AFTERNOON

?

KENYA BLACK RHINO METAPOPULATION WORKSHOP

PARTICIPANTS

KENYA

Richard Leakey	Kenya Wildlife Service (KWS)
Rob Brett	Kenya Wildlife Service
Jim Else	Kenya Wildlife Service
John Kagwi	Kenya Wildlife Service
Pius Mulwa	Kenya Wildlife Service
Sam Ngethe	Kenya Wildlife Service
Tim Oloo	Kenya Wildlife Service
Evelyn Wanjohi	Kenya Wildlife Service
Fred Waweru	Kenya Wildlife Service
Rashid Aman	National Museum of Kenya
Holly Dublin	World Wide Fund for Nature (WWF)
Rob Eley	Institute of Primate Research
Chris Gakahu	Wildlife Conservation International
Helen Gichohi	Wildlife Conservation International
Shirley Strum	Wildlife Conservation International
Esmond Bradley Martin	IUCN SSC/WWF
Steve Mihok	Tsetse Research Project ICIPE
Mark Stanley Price	African Wildlife Foundation
Alison Wilson	IUCN SSC Reintroduction Specialist Group
Kuki Gallmann	APRLS

OUTSIDE KENYA

Ulysses S. Seal	IUCN Captive Breeding Specialist Group
Thomas J. Foose	IUCN CBSG
Robert C. Lacy	IUCN CBSG/Chicago Zoological Society
Richard Emslie	Ecoscot Consultancy Services/Natal Parks
Richard Kock	Zoological Society of London (ZSL)/KWS
Oliver Ryder	San Diego Zoological Society
Klaus Schmitt	University of Bayreuth
Kes Hillman-Smith	Garamba National Park
Raoul du Toit	Zimbabwe Natl. Parks and Wild Life Mgmt.

APOLOGIES

Martin Brooks	IUCN African Rhino Specialist Group
Georgina Mace	Institute of Zoology (ZSL)
David Western	Wildlife Conservation International

KENYA BLACK RHINO METAPOPULATION WORKSHOP

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SECTION 3
POPULATION AND HABITAT VIABILITY ANALYSES

KENYA BLACK RHINO METAPOPULATION WORKSHOP

POPULATION AND HABITAT VIABILITY ANALYSES

INTRODUCTION

Population and habitat viability analyses (PHVAs) use computer models which incorporate demographic and genetic characteristics of the population(s) and conditions in the environment to simulate probable fates of the population(s) under these circumstances. Fate of the population is measured in terms of probability of extinction (P_E) or survival (P_S) and fraction of original genetic diversity (specifically expected heterozygosity, H) retained.

Simulations for this PHVA of the Kenya black rhino population(s) have been performed using VORTEX software. A brief description of this software is presented in Section 10 and is described in more detail in Lacy 1993. A User's Manual is also available (Lacy and Kreeger 1992)

Population characteristics and environmental conditions are entered into the VORTEX models as parameters. Values of these parameters are obtained from various sources, especially information provided by managers and researchers of the population who participate in the PHVA Workshops. Thus, the parameters for this Kenya Black Rhino PHVA were formulated by a Population Modelling Working Group at the Workshop consisting of: Rob Brett, Evelyn Wanjohi, Richard Emslie, Esmond Martin, Tom Foose, and Bob Lacy. Additional refinement was provided by other Workshop participants as well as some published information on black rhino populations in Kenya and elsewhere in Africa.

MODEL PARAMETERS

The major parameters of the VORTEX model and the values formulated by the Workshop are:

Size and Identity of Populations:

Two kinds of simulations have been performed:

- The first kind is of hypothetical small populations of various sizes to provide an overview of the general effect of population size on its fate (Tables 2 & 3; Figures 3-14);

- The other of specific populations that actually exist in Kenya and are considered part of the managed system of sanctuaries. Eleven specific populations (Tables 4-13; Figures 15-23) have been analyzed individually and collectively, as a metapopulation.

Time Period:

The period of immediate interest is the next 100 years. However, the simulations have been conducted for 200 years to provide better perspective on population trends and fates. Status of the population have been reported at intervals of:

- 10 years in the graphs
- 50 years in the tables.

For each kind of population, VORTEX requires both

- **Initial Size (N_0)**, which is the current estimated number and
- **Carrying Capacity Size (K)**, which is the ultimate size the population can attain in that area.

Values of N and K have been formulated:

- For the nonspecific populations, K's of 10, 20, 30, 40, 50, 60, and 100; in each case the initial size N = K.
- For the 11 actual sanctuaries, the best information on current population size (and age/sex structure) have been used for the N's and the best guesstimates of ultimate carrying capacity of each area have been used for the K's. These latter guesstimates were provided by a Habitat Evaluation Working Group comprising: Holly Dublin, Chris Gakahu, Sam Ngethe, Mark Stanley Price, Shirley Strum, Fred Waweru (Refer to Section 6).

Catastrophes:

A catastrophe is defined as an event or factor that causes changes in mortality (usually an increase) and/or fertility (usually a decrease) at levels outside the normal range of variation. In VORTEX, catastrophes are defined by:

- type: e.g., climatic calamity (drought, fire), disease epidemic, human decimation (poaching).
- frequency: how often the event or factor occurs; measured as percent (ranging from 0 to 100) representing expected rate of occurrence per 100 years, e.g. 10 indicates the event will on the average happen once every 10 years.
- severity: effect the catastrophe has on mortality (or conversely on survival) and fertility; measured as a number (usually a decimal) representing what fraction of normal survival or reproduction is achieved when the catastrophe occurs, e.g. 1 indicates the catastrophe has no effect; .5 indicates survival or fertility is 50% of normal; 0 indicating that the catastrophe completely eliminates reproduction or survival.

For the Kenya black rhino, 3 major kinds of catastrophes are identified:

- poaching,
- disease,
- drought.

Unfortunately, there are not good data to estimate the frequency or severity to be expected for any of these catastrophes. There was general agreement in the Habitat Working Group that the various catastrophes will probably affect the specific sanctuaries variably, i.e. not all sanctuaries are subject to all catastrophes. This variation is indicated in the tables and narrative of results of the simulation for the specific sanctuaries.

Where the catastrophes do occur, the best guess of the frequency and severity are:

TYPE	FREQUENCY (%)	SEVERITY REPRODCT	SURVIVAL
Poaching	5	1	.67
Disease	1	1	.6
Drought	10	0	.8

The Working Group have provided some additional comments about the various kinds of catastrophes:

Poaching: The Working Group believes populations will differ significantly in susceptibility against poaching catastrophe. They envision no scenarios that would eliminate all populations. Official records indicate 15 rhino deaths from 1986-1991 are due to poaching. However, poaching pressure throughout Africa remains high and is intensifying in southern parts of the range. As populations there decline, it may be expected that poaching pressure in Kenya may increase. Hence, the VORTEX modelers have also explore some "worse case" scenarios for the non-specific populations of various sizes to indicate the effect of two higher levels of poaching, given below.

TYPE	FREQUENCY	SEVERITY REPRODCT	SURVIVAL
Intensified Poaching 1	33	1	.95
		(losing 5% of population every 3 years)	
Intensified Poaching 2	33	1	.90
		(losing 10% of population every 3 years)	

Disease:	There is great difficulty in estimating the probability of this kind of catastrophe. No data are available on incidence of epidemic disease in rhinos in the wild. The Disease Working Group (Richard Kock, Steve Mihok, Richard Emslie, Raoul du Toit, Jim Else) formulated a guesstimate (above) which is applied to all sanctuary populations. Refer also to the Working Group Report on Disease in Section 6.
Drought:	The Habitat Working Group recommends applying this catastrophe selectively to sanctuaries as indicated in the Tables 5, 7, 9, 11.

Inbreeding:

There are no data on the effects of inbreeding on rhinos. Hence the Working Group has utilized estimates from other mammal species. Referring to the best study of inbreeding effects in mammals (Ralls et al. 1988), the Working Group has selected the value (3.12 recessive lethals) reported for zebra, which is the closest relative to the rhino among the species for which data have been published. This value also represents a level near the median (3.14 recessive lethals) for the 40 mammal species examined. This level is used for both the hypothetical and actual sanctuary populations. To consider a worse case scenario, a level twice as severe (6.24) has also been examined in the case of the non-specific populations.

Age at First Reproduction:

Female	7 Years
Male	10 Years

These estimates are derived from Hitchins & Anderson data for Natal which was based on data from over 300 animals. The group acknowledges that it would be useful to have better estimates of variance in age at first breeding.

Senescence:

37 Years for both sexes

Sex Ratio:

.5

Litter Size:

1

Female Reproduction:

Calculated rates for the sanctuaries produces an estimate of 24% of females breeding in any one year:

> In last 58 months, 101 births have been observed. There are approximately 91 adult females + 15 adults of unknown sex, so it is estimated there are roughly 99 females now. There were an estimated 87 adult females in 1988, the midpoint of the time interval under consideration for these calculations. So, 101 births from 87 females equals 1.6 births per female per 58 months or .24 births/female/year.

Male Reproduction:

The Working Group estimates that, typically, 50% of the males reproduce in any year with the acknowledgement that better information is needed. But for Lewa Downs and Ol Jogi, they recommend a level of 30% because one or a few males could monopolize breeding in these very small populations.

Variance in Reproduction:

Variance ± 10%.

Mortality:

	Females	
Age	Qx	SD
0-1	10	3
1-2	4	2
2-3	6	2
3-4	3	1
4-5	1	.5
5-6	1	.5
6-7	1	.5
>7	1	.5

	Males	
Age	Qx	SD
0-1	10	3
1-2	4	2
2-3	6	2
3-4	3	1
4-5	1	.5
5-6	1	.5
6-7	1	.5
7-8	1	.5
8-9	1	.5
9-10	1	.5
>10	1	.5

These schedules of mortality were derived from some simple calculations using actual data on deaths in the sanctuaries:

> There are 61 calves (0-42 months of age) as of 10/91. The number of births over last 42 months (.24 X 3.5 Yrs. X 87 adult females) = 73. 61/73 = 83.56 % survival to date. But some additional are expected to die. So a guesstimate of mortality from 0-42 months is 20%, which has been distribute as 10%,4%,6%, 3% over first 4 years of life.
>
> 28 deaths were recorded in the population from 1/1/1986 to 11/1/91 (58 months, i.e. about 5.8 deaths/year). Of these, based on the above calculations, it is expected that about 12 calves died over last 48 months. Thus, it is further expected there would be 16.6 calf deaths over 58 months. Hence, it is concluded there are 11.4 deaths of animals above age 42 month over last 58 months. So, there would have been 11.4 deaths out of population of 248 non-calves (304-56)at end of 1990. Adjusted for the number 2 years earlier (mid-point of the 4 year interval being considered) and assuming a 5% realized growth rate, the calculations indicate 248 X .95 X .95 = 224 non-calves with 11.4/224 = .05 mortality over 58 months. This translates into a 1% mortality per year for non-calves. (In terms of survival: $.99^{58/12} = .95$)
>
> These mortality rates, with the above reproductive rate, produce an annual deterministic growth rate (lambda) of 1.047.

Correlation of Environmental Variation in Mortality and Reproduction:

The VORTEX model permits environmental variation in survival to be correlated or not correlated with the environmental variation in fertility. For the Kenya black rhino, it is assumed they are correlated because they would be jointly correlated with weather.

Density Dependence:

The Working Group believes it does occur but the extent is probably not great and the function relating reproduction to population density is unknown. It is also intended to remove rhino from the enclosed sanctuaries before any negative density-dependant effects would occur. No density dependence has been incorporated into these analyses.

Harvest and Supplementation:

Various levels of harvest and supplementation of specific sanctuaries have been investigated as indicated in the tables. These levels were specified by Rob Brett as the Rhino Coordinator for the Kenya Wildlife Service, with one minor modification. KWS has considered moving 9 rhinos out of Solio for translocation to other sanctuaries over the next two years. The VORTEX computer program does not allow different numbers of animals to be moved each year, so the analyses were completed assuming that 5 rhinos each year (10 total) would be removed from Solio.

The rhinos to be added to several sanctuaries (Lewa Downs, Ngulia, and Ol Pejeta), would be obtained from those sanctuaries with surplus rhinos (Solio and Nairobi) and also from an additional four or more rhinos to be captured from non-sanctuary areas (e.g., Tana River area). Except for Lewa, which is scheduled to receive an additional breeding male, it was assumed that for both removals and supplementations the rhinos chosen would be half subadults (age 4) and half adults (females age 7, males age 10).

Removals and supplementations tested were:

Solio -5 each year for two years
(2 sub-adult females, 2 sub-adult males, 1 adult male)

Nairobi -4 each year for three years
(1 sub-adult and 1 adult female, 1 sub-adult and 1 adult male)

Lewa Downs +1 adult male
also tested (see **Table 13**): +4 each year for two years
(1 sub-adult and 1 adult female, 1 sub-adult and 1 adult male)

Ngulia +4 each year for three years
(1 sub-adult and 1 adult female, 1 sub-adult and 1 adult male)

Ol Pejeta +4 each year for three years
(2 sub-adult females, 2 sub-adult males)

MODEL RESULTS

DEMOGRAPHIC PERFORMANCE - LIFE TABLE CALCULATIONS

Rates of Change (Growth or Decline):

Deterministic life table analysis of the birth and death rates estimated for the Kenyan black rhinos in sanctuaries produces a mean annual population growth of 4.7% (lambda = 1.047, r = .046), if catastrophes of disease, drought, and poaching are assumed never to occur. The growth rate observed from 1986 through 1990 in the sanctuaries was about 5% (data provided by R. Brett, KWS), closely in line with the life table projection. If possible catastrophes are incorporated into the life table (averaging the effects of episodic events over years), mean population growth rates are calculated as 4.3% (lambda = 1.043, r = .042) with disease epidemics, 2.6% (lambda = 1.026, r = .026) with disease and occasional poaching, 1.6% (lambda = 1.016, r = .016) with disease and droughts, and 0% (lambda = 1.00, r = .00) with disease, poaching, and droughts.

These deterministic calculations of population growth rates assume no annual fluctuations in birth and death rates, no inbreeding depression, a stable age distribution, and no random variation. Each of these factors could depress long-term population growth relative to the rate calculated from the life table.

Age Distributions:

The age distribution predicted from the life table, in the absence of catastrophes, yields about 24% calves (less than 4 years of age), 14% subadults (4-6 years), and 62% adults (7 years and older). The actual age distribution at the end of 1990 was 18% calves, 20% sub-adults, and 62% adults. The slight discrepancy between the predicted and actual percents in the younger age classes could easily be due to stochastic variation in the number of births each year.

SIMULATION RESULTS

The simulation results are presented in **Tables 2-13** and **Figures 3-23**. Each table presents the outcome for a number of scenarios or populations. Each case investigated is represented by a row in the tables. A case is defined by the conditions (representing varying input parameters) presented in several of the initial columns of the tables: the first three columns in **Tables 2 & 3**; the first five columns in **Tables 4-11** columns; the first four columns in **Table 12**; and the first four columns in **Table 13**.

The input parameters indicated in the tables are:

LOCATION OR SIZE
The black rhino sanctuary being modelled. In **Tables 2 & 3**, no specific populations are being modelled, rather the simulations explore the viability of hypothetical populations of various size.

INBR. DEPR.
In **Table 2**, two levels of inbreeding depression are examined as indicated: 3.12 lethal equivalents (**Table 2a**) and 6.24 lethal equivalents (**Table 2b**). (Refer to inbreeding section in "Population Biology Parameters" for further explanation.)
In **Tables 3-13**, the impact of inbreeding was set at 3.12 lethal equivalents.

N_0
The initial population sizes. In **Table 13**, the two levels of N listed for each population reflect initial sizes with and without an immediate translocation of additional founders to expand the number immediately to at least 20.

K
Carrying capacity, ultimate population sustainable, of the areas indicated.

CATS
Incorporation of catastrophes into the models:
Di = disease epidemic;
Dr = drought;
PW = poaching at the level projected by the Workshop.
PI1 = intensified poaching at level of 5% loss every 3 years
PI2 = intensified poaching at level of 10% loss every 3 years

+ or -
Initial addition of new founders or removal of surplus. Refer to text (above) for details on the time schedules and ages and sexes of animals proposed for translocation.

Other input parameters for the VORTEX model were constant in all scenarios examined at the values described in the section Model Parameters above.

The simulations for each case were repeated for:
- 500 replications in **Table 2 & 3**
- 250 replications in **Tables 4-11** and **13**.

All populations were simulated for 200 years, with results reported
- at 10 year intervals in graphical presentations;
- at 50 year intervals in tabular presentations.

The results of the population simulations are reported in terms of:

Pop. growth (r)
Population growth rate, prior to any carrying capacity truncation: positive values indicate population increase, negative values indicate population decrease. Both a mean, averaged across years and across replications and a standard deviation, **SD,** of variation across years and simulations are provided. Larger standard deviations, relative to the means, indicate greater instability for the population.

P(E)
Probability of extinction, i.e., the proportion of the simulated populations that became extinct.

N_T
The mean final size of those simulated populations that survive, presented as a mean and standard deviation **SD** across simulations.

H
The percent of the original gene diversity (expected heterozygosity) remaining in the surviving populations. For the metapopulation (last line of **Tables 3-11), H** gives the total gene diversity, both within and between subpopulations.

Median Time to Extinc.
The year in which the median (125th of 250 or 250th of 500) simulated population went extinct, reported only in those cases in which at least 50% of the simulated populations did not survive.

Figures 3-22 present the simulation results graphically, with the probabilities of each population remaining extant (not yet extinct) displayed in part **a** of each figure, and the remaining proportion of the original heterozygosity shown in part **b** of each. Standard error bars are given with the means on the figures displaying heterozygosities.

A. HYPOTHETICAL SMALL ISOLATED POPULATIONS:

Tables 2 & 3 present the results of scenarios examined with hypothetical small isolated populations varying in size from 10 to 100 rhinos. These hypothetical populations could represent unmanaged populations inside or outside sanctuaries. If the effects of inbreeding on juvenile survival are as estimated for a zebra (3.12 lethal equivalents), if inbreeding has no further impact on adult survival or reproduction, and if poaching, disease, and drought catastrophes never occur (top section of **Table 2a**, and **Figure 3a**), then even very small populations of rhinos may be viable. Populations of 30 or more always survived through the 200-year simulations, and populations as small as 10 had a median time to extinction of 161 years. Mean growth rates (calculated from the annual increments before carrying capacity truncation) were depressed in the smallest populations, presumably because of inbreeding depression and an occasional lack of mates (demographic stochasticity). The mean growth rates projected in the simulations of the larger populations are only slightly less than that predicted from deterministic life table calculations, evidence that stochastic factors would be relatively minor for rhino populations of 100 or more animals.

The possible viability of very small rhino populations is in accord with observations that several very small populations have remained relatively stable or grown, once they were very carefully and diligently protected from poaching and other catastrophes. The biology of rhinos may afford greater buffering from stochastic processes that would be the case for almost any other species of animal.

The standard deviations in population growth rates among years and iterations of the simulations give an indication of the demographic stability of small rhino populations. Fluctuations in growth rates were greater in the smallest populations, with the standard deviation of the growth rate greatly exceeding the mean growth rate. Even in populations of 100, however, the standard deviation exceeded the mean growth rate, indicating that these populations would decline, for stochastic reasons, in at least one year in six. This demonstrates that long term stability does not necessarily require or indicate near constant population growth from year to year. Although close monitoring of populations may be essential to prevent imminent catastrophes, such as epidemic disease or poaching, modest fluctuations in numbers without apparent cause can be expected in even the healthiest of populations.

Genetic variation, assessed by percent of initial heterozygosity, was steadily eroded in the smaller simulated populations (**H** columns in **Table 2a**, and **Figure 3b**). A loss of 25% heterozygosity represents the same cumulative genetic loss that would be expected from matings between full siblings or parents with offspring. This rather severe inbreeding was reached within 50 years in populations of 10, about 100 years in populations of 20, and about 200 years in populations of about 30 to 40. Soulé et al. (1986) recommended that conservation programs strive to keep genetic variation above 90% of its initial value, in order to minimize inbreeding effects and to allow for continued adaptive evolution. That goal could be achieved for 50 years with a population of 30 rhinos, for 100 years with a population of 50, and for 200 years with a population of 100.

Workshop participants were not aware of any published reports on the effects of inbreeding on any rhino species. Therefore, considerable uncertainty remains concerning the likely impact of inbreeding. Simulation models were tested also (**Table 2b**, **Figures 7-10**) with double the number of lethal equivalents observed in the zebra, a value that is still within the lower three quartiles reported by Ralls et al. (1988) for 40 mammal species. The greater effects of inbreeding reduced mean population growth, while increasing variance in population growth, among the smaller populations. The higher impact of inbreeding also accelerated extinction of the smallest populations, although the effects were not apparent until after 50 years (compare **Tables 2a** and **2b**).

Catastrophes (drought, epidemic disease, and poaching), occurring with the frequency and impacts estimated by workshop participants, could have disastrous effects on the viability of small populations of black rhinos (**Table 2**, **Figures 4-6**). Long-term population trends were negative, numbers fluctuated to a much greater extent, and none of the population sizes tested were adequate to assure population survival for even 50 years (**Figure 6a**). The additional effect of higher inbreeding impacts were minimal, as demographic instability dominated population dynamics when catastrophes were considered (**Table 2b**, **Figures 8-10**). These results highlight the vulnerability of long-lived, slowly reproducing (K-selected) species to catastrophic losses, even if they occur with relatively low frequency and have seemingly modest impact. Protection of the rhino populations from such catastrophes should be the highest priority, something that has been well recognized and demonstrated by recent history in east Africa.

Because the fates of small populations of rhino are sensitive to catastrophes, and because poaching of rhino has recently intensified in southern Africa, the effects of several levels of poaching were examined, in addition to the level identified at the Workshop. **Table 3** and **Figures 11-14** show the impact of either a 5% loss every three years (Poaching Intensity 1) or a 10% loss every three years (Poaching Intensity 2). The lower level of poaching is unsustainable if imposed on top of occasional drought and disease catastrophes (second section of **Table 3**, and **Figure 12**), and increases instability of the smallest populations in the absence of other catastrophes (top of **Table 3** and **Figure 11**). The higher level of poaching is unsustainable (bottom half of **Table 3**, and **Figures 13 & 14**), except perhaps for short periods of time in the larger populations.

B. VIABILITY OF THE RHINO SANCTUARIES:

Tables 4-11 and **Figures 15-23** give the results of 250 simulations each of 8 scenarios for the 11 rhino sanctuaries in Kenya. In the absence of catastrophes, with no managed movement of animals among sanctuaries initially, and with no later migration among sanctuaries (**Table 4**, **Figure 15**), the metapopulation is projected to be quite stable, with a mean annual population growth of about 4%, and with minimal overall losses of genetic variation through 200 years.

The subpopulations in four of the sanctuaries, however, are individually at risk. The small populations that can be sustained at Lewa Downs and at Ol Jogi are not sufficiently large to be demographically or genetically stable. Both populations undergo large fluctuations in numbers (relative to the population size), lose genetic variation rapidly, and have moderate to high chances of extinction. In addition, the populations at Amboseli and, to a much lesser extent, Ol Pejeta, are in large areas of habitat but have so few animals at present to serve as founders that they are at risk of quick extinction. They will also lose considerable genetic variation before numbers could build up (if they are lucky enough not to go extinct). If they survive the next few decades and do expand to fill the habitat, further genetic losses will be relatively small and delayed extinction is not as likely.

Although many of the sanctuary populations may be viable as isolated units, most would lose more genetic variation than might be desirable, although not until the second century. The subpopulations are each expected to undergo at least moderate fluctuations in numbers, with population declines occurring in some years due solely to chance (stochastic) phenomena.

If catastrophes are added to the models, as estimated by the habitat working group at the workshop, the populations in many more of the sanctuaries would be vulnerable to extinction **(Table 5, Figure 16)**. Only the sanctuaries considered free of risk of drought and poaching are projected to have high probabilities of persistence. Although the rhino populations in the sanctuaries subjected to drought and poaching would be expected to grow at about 3 to 4% per year in the absence of such catastrophes, the long-term prognosis is that these sanctuaries may be demographic "sinks" (mean $r < 0$) if occasional catastrophes do occur. Population growth would not be sufficient to replenish the populations between the expected episodes of drought and poaching, so restocking of these habitats may be necessary to speed recovery after such events. These results re-emphasize the conclusion that the top management priority should be to minimize the frequencies and severities of catastrophic episodes. Populations that cannot be kept almost free of such risks for at least decades cannot be considered to be secure "sanctuaries" for rhinos, e.g. Amboseli National Park.

The Kenya Wildlife Service has recognized that several of the sanctuaries (e.g., Ngulia and Ol Pejeta) have very few rhinos at present, even though they do have habitat sufficient to support viable populations. Moreover, several other sanctuaries (Solio and Nairobi) are presently at or above the carrying capacity of the habitat. The effects of the movement of some rhinos into the currently underpopulated habitats are shown on **Tables 6 & 7** and **Figures 17 & 18**. In the absence of catastrophes **(Table 6, Figure 17)**, the proposed moves reduce the genetic losses from Ngulia and Ol Pejeta, and do remove the low possibility that the population at Ol Pejeta will go extinct before it grows to a more stable size. These beneficial effects are small, however, especially so in the case of Ngulia. The addition of a single (male) rhino to Lewa Downs decreases the probability of extinction during the next few decades, because the population has only a single male at present. The small Lewa Downs population has a high probability of extinction in later years, however, whether or not the current unbalanced sex ratio is rectified. (See below, under **Effect of Protection of Larger Areas of Habitat**, for discussion of alternative management strategies for Lewa Downs and Ngulia.) The removals of some animals from Nairobi and Solio are not projected to have any impact on the viability of those populations.

In the presence of occasional catastrophes (**Table 7, Figure 18**), the benefits of additional rhinos being added to Ngulia are more pronounced, but still do not afford adequate protection from the destabilizing effects of catastrophes.

C. EFFECTS OF PERIODIC MIGRATION:

Migration among sanctuaries, even at the low rate of 1%, prevents substantial loss of genetic variation from the populations, and provides animals for augmenting and re-colonizing the smallest populations (**Table 8, Figure 19**). Because the model was analyzed with symmetrical probabilities of migration among each pair of populations, the smallest populations receive more migrants than they disperse, and they benefit most from the migration. For Ol Jogi and Lewa Downs, most of the recruitment and stability in the populations results from immigration, rather than births.

For a population growing from about 300 to about 500, a 1% rate of migration would require the movement of 3 to 5 rhinos per year. The model assumes that the migrations are random among populations, while managed migration would be tailored to the needs of each sanctuary and may have even more beneficial effects than indicated in the Tables.

Regular migration can stabilize the rhino populations even in the presence of occasional catastrophes in some sanctuaries (**Table 9, Figure 20**). It is worth remembering, however, that the sanctuaries subjected to catastrophes are demographic sinks (**Table 5**). Migration results in the continual restocking of these sanctuaries with animals from those populations not subjected to catastrophes. The metapopulation growth rate ($r = .027$) is depressed relative to that observed for the metapopulation in the absence of catastrophes ($r = .046$) because of the metapopulation dynamics between source and sink populations.

The simulations of the sanctuaries with 1% continual migration are affected almost not at all by the additional assumption of some managed adjustments of founder numbers (compare **Table 8** with **Table 10**, and **Table 9** with **Table 11**).

D. AVAILABILITY OF RHINOS FOR TRANSLOCATION:

The analyses indicate little impact on the two largest populations, at Solio and Nairobi, if the suggested removals occur over the next three years (**Tables 6, 7, 10, 11; Figures 17, 18, 21, 22**). To examine the likely availability of rhinos from these and other sanctuaries from translocation to newly protected sites, the times until the capacity of each sanctuary would be reached and the expected annual surpluses available for translocation were calculated. The mean population growth rate of each sanctuary was projected to be the same as either the mean growth rates reported in **Table 6**, in which it was assumed that all sanctuaries would be fully protected from catastrophes and rhinos would be added to three populations over the next few years, or the mean growth rates reported in **Table 7**, in which it was assumed that vulnerability to catastrophes and initial adjustment of founder numbers would be as estimated at the Workshop. **Table 12** shows the growth rates, years at which capacity would be reached under these growth rates, and annual surplus. **Figure 23** illustrates these projections under the assumption that catastrophes would be as estimated by the Habitat Working Group.

The projections yield an estimated combined surplus of 20.4 rhinos per year (22.6 if Lewa is expanded to hold 60 rhinos) if no catastrophes occur, but many of those numbers will not be available for another decade or two. If catastrophes do occur periodically, 9.8 rhinos are projected to become available annually from the sanctuaries, but 5.5 of these would be needed to continually restock those populations that are subjected to unsustainable catastrophic losses.

E. EFFECT OF PROTECTION OF LARGER AREAS OF HABITAT:

It is hoped that the large areas of habitat adjacent to the present Aberdare, Ngulia, and Lewa Downs populations can be adequately protected to allow recolonization by black rhinos. If habitat for hundreds of rhino could again be made safe for rhinos in the Aberdares, a large, demographically stable population could be maintained (**Table 13**). The population would be expected to exhibit greater average growth (due to less inbreeding depression) and more stable growth (less demographic stochasticity), and would lose minimal genetic variation over 200 years. (Although not modelled here, the amount of variation lost would likely be wholly offset by new variation introduced by rare mutations.)

At Ngulia, re-expansion of the rhino population into the surrounding habitats of Tsavo would have a similarly beneficial effect only if catastrophes could be prevented (middle section of **Table 13**). If occasional poaching recurs, the Ngulia population would not have the opportunity to expand into available habitat. The addition of 12 more founders to the Ngulia population would accelerate growth into newly protected habitat, but would have a lasting effect only if poaching were wholly prevented.

At Lewa Downs, a proposed increase of the protected area to accommodate 60 rhinos could substantially decrease the probability of local extinction, but would not assure persistence unless disease and drought catastrophes were prevented and at least one additional male breeder were added to the population (as planned) (see bottom section of **Table 13**). A recently proposed supplementation with 8 rhinos (rather than just one) would further speed growth to a stable size, and would reduce the loss of genetic variation during that growth phase.

SUMMARY

Black rhinoceros breed and die so slowly that the populations can probably be maintained at smaller sizes than the "minimum viable population sizes" that have commonly been suggested in the literature for many other mammals (e.g., Belovsky 1987). Recovery from small numbers (as occurred in the greater one-horned rhino (*Rhinoceros unicornis*) in Asia and the Southern white rhino (*Ceratotherium simum*) in Africa) and relative stability of population size in habitat fragments that can sustain only small numbers should be possible for time periods on the order of 50-100 years.

Because of their life history, however, even rare episodes (once in a decade) of severe poaching, drought, or other catastrophes can destabilize the populations, as they would be unable to recover before subsequent catastrophes occurred.

Low levels of migration among isolated subpopulations can prevent inbreeding and concomitant losses of genetic variation from the subpopulations, and can help to stabilize the smaller isolates. A conclusion of these results is that viability of small and fragmented populations will require some interventive management to achieve viability.

The PVA modelling presented above only begins to explore the range of possibilities that were discussed at the workshop and which might be of interest and value in conservation and management. Other numbers of animals moved, and other levels of continued migration, could be examined. Varying levels of vulnerability to disease, drought, and poaching might also be usefully explored. As data are collected on the effects of inbreeding, or further data are collected on birth and death rates and on the capacity of habitats to support rhinos, more refined modelling should be possible.

The models presented above do provide a broad assessment of the viability of black rhino populations within the sanctuaries in Kenya under a variety of plausible scenarios. Projected growth rates, fluctuations in growth rates, and rates of loss of genetic variation can be compared to actual population performance in the coming years to help identify gaps in our understanding of the dynamics of small populations of rhinos as they are recovering from the decimation that occurred in the last few decades.

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KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKSHOP REPORT

1 May 1993

SECTION 4
TABLES

KENYA BLACK RHINO METAPOPULATION WORKSHOP

TABLES

Table 1.

Rhino Area:	----Males-----				----Females---				--Unknown Sex--					-----Management------					---Breeding---			1986-90		1990		Trans-90		
Type & Name	AD	SA	CF	ST	AD	SA	CF	ST	AD	SA	CF	ST	TOT	A	D	CC	ML	S	SR	%CC	%C	+	-	+	-	In	Out	CR
RING-FENCED:																												
Nakuru NP	11	2	1	14	8	2	2	12			2	2	28	142	0.20	71	53		1.17	63	17.8	6		4		4		1
Ngulia RS	1	1	1	3	4	3		7			1	1	11	73	0.15	73	55		0.43	14	9.0	3	2	1		1		1
Solio R GR	14	4	6	24	21	2	4	27			5	5	56	56	1.00	56	42	14	0.89	71	26.8	23	6	6	1		6	1
Lewa Downs R RS	2	2		4	5	2	3	10					14	40	0.35	26	20		0.28	43	21.4	4	1		1	2		1
Ol Jogi R GR	2	2	1	5	3	1	1	5			1	1	11	73	0.15	20	15		1.00	100	27.2	4	1	1				1
Ol Pejeta R GR	2	2		4	1	3		4					8	93	0.09	93	70		1.00	0	0.0					5		1
Total	32	13	9	54	42	13	10	65	0	0	9	9	128	477	0.27	339	255	14	0.83	67	21.9	40	10	12	2	12	6	
PART-FENCED:																												
Nairobi NP	18	4	7	29	18	9	4	31			1	1	61	117	0.52	60	45	16	0.94	67	19.7	18	2	6			5	1
Aberdare NP	8	1	1	10	10	3	2	15	12		3	15	40	70	0.57	100	(100)		0.67	56	28.0	8		3				2
Laikipia R	18	5		23	10	4	1	15	3	1	2	6	44	397	0.11	100	(100)		1.53	30	6.8	6	1	1				1
Total	44	10	8	62	38	16	7	61	15	1	6	22	145	584	0.25	260	245	16	1.02	55	14.5	32	3	10	0	0	5	
UNFENCED:																												
Masai Mara NR	4	4	4	12	9	1	2	12					24	1690	0.01	50	(50)		1.00	67	37.5	11	2	4	2			1
Amboseli NP	2	1		3	2	1	1	4					7	390	0.02	50	(50)		0.75	50	14.3	3	3	1	1			1
Total	6	5	4	15	11	2	3	16	0	0	0	0	31	2080	0.01	100	100		0.94	47	22.6	14	5	5	3	0	0	
TOTALS	82	28	21	131	91	31	20	142	15	1	15	31	304	3141	0.10	699	600	30	0.92	62	18.4	86	18	27	5	12	11	

Key:
AD=Adults (>6 y.o.)
SA=Subadults (4-6 y.o.)
CF=Calves (<4 y.o.)
ST=Subtotal (Sex)
TOT=Population total
A=Area of rhino reserve (sq km)
D=Density of rhino (per sq km)
CC=Carrying Capacity (Brett (1989) estimate)
ML=Management Level
S=Existing Surplus of Rhino (number of rhino exceeding ML (TOT-ML), available for translocation
SR=Known Sex Ratio (No.Males/No.Females)
%CC=Percentage of Adult Female (Cow) Rhinos with Calves
%C=Percentage of Calves in population
'+'=Total No. of Births for stated period
'-'=Total No. of Deaths for stated period
Trans-90=Total No. of translocations In and Out of sanctuary in 1990
CR=Census Rating (Du Toit 1989)
NP=National Park
NR=National Reserve
GR=Game Reserve
R=Private Ranch

Table 1 - Population Statistics for the black rhino in Kenya sanctuaries (at the end of 1990), and overall breeding performance from 1986 to 1990

2a. SMALL POPULATIONS OF RHINOCEROS

Inbr. depr.	Catas.	K	Pop. growth (r)		50 yr results				100 yr results				200 yr results				Median Time to extinc.
			mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
3.12	None	10	.014	.105	.06	9	2	73	.22	8	2	58	.70	6	2	33	161
		20	.025	.073	0	19	2	86	.01	18	2	77	.06	17	4	60	
		30	.032	.061	0	29	2	90	0	29	2	84	0	28	3	72	
		40	.036	.056	0	39	2	93	0	39	2	87	0	39	3	77	
		50	.038	.052	0	49	2	94	0	49	2	90	0	49	2	82	
		60	.039	.050	0	59	2	95	0	59	2	91	0	59	2	84	
		100	.042	.045	0	99	3	97	0	99	3	95	0	99	3	90	
3.12	Dr,Di	10	-.011	.177	.46	7	3	70	.85	5	2	52	1.00	10	0	50	53
		20	-.007	.151	.14	14	5	82	.40	12	5	68	.92	8	5	49	114
		30	-.004	.140	.03	21	7	87	.21	18	8	76	.69	13	9	59	165
		40	-.002	133	.03	28	10	90	.12	24	11	81	.47	17	11	64	
		50	.001	.128	.01	36	13	92	.07	32	14	85	.34	25	15	70	
		60	.002	.126	.01	44	15	93	.05	39	17	87	.27	29	18	74	
		100	.005	.119	0	76	24	96	.01	67	28	92	.13	59	30	84	
3.12	PW	10	-.000	.160	.35	7	2	71	.73	6	2	55	.98	6	2	36	68
		20	.004	.138	.06	15	5	83	.22	13	6	70	.68	11	6	51	155
		30	.008	.123	.01	24	7	88	.08	22	8	79	.35	18	9	62	
		40	.012	.115	.01	33	9	91	.02	31	10	84	.15	26	12	71	
		50	.015	.112	0	42	10	93	.01	40	12	87	.11	35	15	76	
		60	.017	.106	0	51	12	94	0	49	14	89	.04	44	16	79	
		100	.021	.101	0	86	19	96	0	85	20	94	0	81	22	88	
3.12	Dr,Di,PW	10	-.032	.220	.76	6	2	66	.98	4	2	44	1.00	--	--	--	30
		20	-.027	.196	.43	10	5	78	.87	8	5	63	1.00	--	--	--	56
		30	-.025	.185	.24	14	8	83	.67	12	8	69	.98	9	7	55	78
		40	-.022	.179	.13	19	11	86	.52	15	11	73	.96	9	7	60	98
		50	-.022	.175	.09	24	15	88	.46	18	14	78	.92	15	12	63	105
		60	-.021	.171	.06	29	17	90	.36	21	16	79	.90	12	9	65	119
		100	-.017	.164	.02	50	29	93	.22	39	29	87	.70	23	23	72	155

Note: deterministic r (from life table) = .046 without catastrophes or poaching; r = .016 with catastrophes; r = .030 with poaching; r = .000 with catastrophes and poaching.

2b. SMALL POPULATIONS OF RHINOCEROS -- MORE SEVERE INBREEDING EFFECTS

Inbr. depr.	Catas.	K	Pop. growth (r)		50 yr results				100 yr results				200 yr results				Median Time to extinc.
			mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
6.24	None	10	.006	.204	.10	8	2	74	.40	6	2	58	.97	3	2	44	113
		20	.015	.077	0	19	2	87	.01	18	3	78	.22	12	5	60	
		30	.024	.061	0	29	2	91	0	29	3	85	.01	25	6	73	
		40	.029	.055	0	39	2	93	0	39	2	88	0	37	4	79	
		50	.032	.051	0	49	2	94	0	49	2	90	0	48	3	83	
		60	.034	.049	0	59	2	95	0	59	2	92	0	58	3	85	
		100	.039	.044	0	99	3	97	0	99	3	95	0	99	3	90	
6.24	Dr,Di	10	-.017	.178	.46	6	2	70	.92	6	2	55	1.00	--	--	--	51
		20	-.014	.155	.14	13	5	81	.61	10	5	67	1.00	--	--	--	88
		30	-.013	.146	.05	20	8	87	.26	14	8	76	.91	8	6	61	132
		40	-.009	.137	.03	28	10	90	.17	21	12	81	.75	12	8	64	160
		50	-.007	.133	.01	35	12	92	.08	28	15	84	.60	15	11	70	183
		60	-.005	.130	.01	43	16	93	.07	35	17	86	.52	21	17	73	195
		100	.001	.119	0	74	25	96	.01	65	28	92	.17	46	30	83	
6.24	PW	10	-.006	.163	.34	7	2	72	.86	5	2	57	1.00	--	--	--	66
		20	-.004	.141	.05	15	5	83	.32	12	5	73	.92	7	4	53	128
		30	-.000	.127	.02	24	7	89	.10	20	9	79	.64	12	8	64	179
		40	.004	.119	0	32	9	91	.04	29	10	84	.36	19	11	69	
		50	.008	.114	0	42	10	93	.01	37	13	87	.23	26	16	75	
		60	.010	.110	0	50	13	94	.02	46	15	89	.15	36	18	79	
		100	.016	.103	0	86	19	97	0	82	22	94	.02	72	28	87	
6.24	Dr,Di,PW	10	-.031	.212	.77	5	2	67	.99	4	2	50	1.00	--	--	--	33
		20	-.030	.193	.40	9	5	78	.89	7	5	62	1.00	--	--	--	58
		30	-.027	.182	.24	13	8	82	.75	9	6	70	1.00	--	--	--	72
		40	-.027	.180	.15	19	11	86	.64	13	9	75	.99	6	3	56	86
		50	-.026	.173	.09	22	14	88	.52	14	11	77	.99	4	2	68	98
		60	-.025	.174	.07	30	17	90	.45	20	16	79	.98	16	15	68	108
		100	-.023	.169	.03	45	28	93	.27	29	25	86	.84	15	15	74	131

Note: deterministic r (from life table) = .046 without catastrophes or poaching; r = .016 with catastrophes; r = .030 with poaching; r = .000 with catastrophes and poaching.

3. SMALL POPULATIONS OF RHINOCEROS -- INCREASED INTENSITY OF POACHING

Poaching Intensity Freq/Svrt	Catas.	K	Pop. growth (r)		50 yr results				100 yr results				200 yr results				Median Time to extinc.
			mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
33.3/.05	None	10	.000	.131	.20	7	2	72	.60	6	2	53	.97	5	2	29	86
		20	.007	.095	.01	17	3	85	.06	16	4	73	.43	12	5	53	
		30	.014	.075	0	28	3	90	0	26	5	82	.05	22	7	68	
		40	.018	.067	0	37	4	93	0	37	4	87	.01	33	8	75	
		50	.020	.062	0	48	4	94	0	47	4	89	0	45	8	80	
		60	.022	.059	0	58	4	95	0	57	5	91	0	55	6	84	
		100	.025	.053	0	97	4	97	0	97	5	94	0	96	5	90	
33.3/.05	Dr,Di	10	-.025	.188	.66	6	2	68	.96	5	2	47	1.00	--	--	--	39
		20	-.023	.171	.28	10	5	78	.76	8	5	62	.99	6	6	47	69
		30	-.022	.159	.15	16	8	84	.56	12	8	70	.98	6	4	53	94
		40	-.020	.153	.08	21	11	87	.40	16	10	75	.94	9	5	56	111
		50	-.020	.151	.05	26	14	89	.33	18	13	78	.90	13	11	66	121
		60	-.018	.146	.03	32	17	91	.26	24	17	80	.81	16	15	68	136
		100	-.015	.135	.02	56	28	95	.11	40	28	87	.57	26	24	75	186
33.3/.10	None	10	-.013	.158	.44	6	2	68	.86	5	2	49	1.00	--	--	--	56
		20	-.011	.128	.05	14	5	82	.41	11	5	68	.94	7	4	48	117
		30	-.007	.113	.03	22	7	88	.13	18	8	76	.67	11	7	58	170
		40	-.004	.101	0	31	8	91	.05	26	10	83	.43	16	10	65	
		50	-.002	.092	0	39	10	93	.03	34	13	86	.26	23	14	71	
		60	-.000	.087	0	49	11	94	.01	42	15	88	.17	30	17	76	
		100	.005	.074	0	84	15	97	0	79	21	93	.02	65	26	86	
33.3/.10	Dr,Di	10	-.045	.209	.87	4	2	62	1.00	--	--	--	1.00	--	--	--	26
		20	-.038	.185	.55	8	5	74	.95	6	3	63	1.00	--	--	--	48
		30	-.037	.180	.33	11	7	80	.85	7	5	62	1.00	--	--	--	63
		40	-.038	.175	.22	14	10	83	.83	8	5	70	1.00	--	--	--	70
		50	-.037	.170	.19	17	12	86	.72	11	10	71	1.00	11	10	57	77
		60	-.035	.167	.12	20	13	87	.64	13	11	76	.99	6	6	51	86
		100	-.034	.160	.05	35	24	92	.47	18	16	80	.98	9	7	69	103

Note: deterministic r (from life table) = .029 no catastrophes, PI1; r = -.001 Dr, Di, PI1; r = .012 no catastrophes, PI2; r = -.018 Dr, Di, PI2.

4. RHINO SANCTUARIES, NO CATASTROPHES, NO ADJUSTMENT OF FOUNDERS, NO MIGRATION

LOCATION	N_0	K	CATS	+ OR -	Pop growth (r)		50 yr results				100 yr results				200 yr results				Median Time to Extinc.
					mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
NAKURU	29	52			.038	.052	0	51	2	94	0	51	2	90	0	51	2	82	
SOLIO	59	56			.039	.051	0	55	2	95	0	55	2	91	0	55	3	83	
NAIROBI	63	63			.038	.049	0	62	2	95	0	62	3	92	0	62	2	85	
MARA	26	50			.039	.053	0	49	2	94	0	49	2	89	0	49	2	81	
OL JOGI	11	18			.024	.077	.01	17	2	84	.02	16	3	73	.10	15	3	55	
LEWA	11	10			.015	.108	.21	9	1	71	.36	8	2	55	.78	6	2	32	131
NGULIA	12	55			.036	.054	0	53	6	91	0	54	2	87	0	54	3	81	
OL PEJETA	8	70			.036	.053	.01	61	13	88	.01	69	5	85	.01	69	4	80	
LAIKIPIA	38	100			.040	.045	0	99	3	96	0	99	3	94	0	99	3	89	
ABERDARE	33	43			.037	.055	0	42	2	93	0	42	2	88	0	42	3	79	
AMBOSELI	3	50			.013	.095	.41	15	10	66	.50	31	17	59	.58	40	15	53	105
META-POP	293	567			.038	.018	0	506	21	99	0	518	21	99	0	512	25	98	

Note: deterministic r (from life table) = .046

5. RHINO SANCTUARIES, CATASTROPHES, NO ADJUSTMENT OF FOUNDERS, NO MIGRATION

LOCATION	N_0	K	CATS	+ OR -	Pop growth: r		50 yr results				100 yr results				200 yr results				Median Time to Extinc.
					mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
NAKURU	29	52	Di		.032	.075	0	49	6	94	0	49	6	89	0	48	7	81	
SOLIO	59	56	Di		.033	.074	0	54	5	94	0	53	6	90	0	52	8	82	
NAIROBI	63	63	Di		.033	.072	0	60	7	95	0	61	6	91	0	59	7	84	
MARA	26	50	Di,P		.009	.127	0	37	12	91	.04	35	13	84	.22	28	15	71	
OL JOGI	11	18	Di,Dr		-.008	.157	.19	12	5	78	.57	10	5	63	.94	8	4	50	91
LEWA	11	10	Di,Dr		-.008	.177	.55	6	3	66	.90	5	2	44	1.00	--	--	--	43
NGULIA	12	55	Di,Dr,P		-.026	.195	.42	14	11	78	.80	10	9	66	1.00	6	0	28	58
OL PEJETA	8	70	Di		.028	.080	.02	55	19	87	.03	63	14	83	.06	64	11	78	
LAIKIPIA	38	100	Di,Dr,P		-.023	.173	.15	34	27	89	.42	27	23	79	.87	17	21	73	111
ABERDARE	33	43	Di		.032	.078	0	41	5	93	0	40	6	87	.01	39	7	78	
AMBOSELI	3	50	Di,Dr,P		-.039	.244	.97	5	3	61	1.00	--	--	--	1.00	--	--	--	14
META-POP	293	567	Above		.028	.030	0	346	45	99	0	320	34	98	0	283	30	96	

Note: deterministic r (from life table) = .042 with Disease, .026 with Di and Poaching, .016 with Di and Drought, and .000 with Di, Dr, and P

6. RHINO SANCTUARIES, NO CATASTROPHES, MANAGED FOUNDER NUMBERS, NO MIGRATION

LOCATION	N_0	K	CATS	+ OR -	Pop growth (r)		50 yr results				100 yr results				200 yr results				Median Time to Extinc.
					mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
NAKURU	29	52			.038	.052	0	51	2	95	0	51	2	90	0	51	2	82	
SOLIO	59	56		-10	.039	.051	0	55	2	95	0	55	2	91	0	55	2	83	
NAIROBI	63	63		- 8	.038	.049	0	62	2	95	0	62	2	92	0	62	3	85	
MARA	26	50			.038	.053	0	49	2	94	0	49	2	89	0	49	2	81	
OL JOGI	11	18			.024	.076	0	17	2	84	.01	17	2	74	.08	15	4	56	
LEWA	11	10		+ 1	.015	.108	.18	8	2	71	.37	8	2	55	.76	7	2	39	129
NGULIA	12	55		+12	.038	.051	0	55	2	94	0	54	2	90	0	54	2	82	
OL PEJETA	8	70		+ 8	.040	.049	0	70	2	94	0	69	3	91	0	69	2	85	
LAIKIPIA	38	100			.040	.045	0	99	3	96	0	99	3	94	0	99	3	89	
ABERDARE	33	43			.037	.055	0	42	2	93	0	42	2	88	0	42	2	79	
AMBOSELI	3	50			.014	.094	.44	15	11	65	.50	32	16	60	.56	41	13	55	99
META-POP	293	567			.039	.018	0	516	13	99	0	519	21	99	0	515	24	98	

Note: deterministic r (from life table) = .046

7. RHINO SANCTUARIES, CATASTROPHES, MANAGED FOUNDER NUMBERS, NO MIGRATION

LOCATION	N_0	K	CATS	+ OR -	Pop growth (r)		50 yr results				100 yr results				200 yr results				Median Time to Extinc.
					mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
NAKURU	29	52	Di		.032	.075	0	50	6	94	0	49	6	89	0	48	7	82	
SOLIO	59	56	Di	-10	.034	.074	0	53	7	94	0	53	7	90	0	52	8	83	
NAIROBI	63	63	Di	- 8	.033	.070	0	61	6	95	0	60	7	91	0	60	7	84	
MARA	26	50	Di,P		.010	.127	.01	38	13	91	.03	33	15	84	.23	30	15	73	
OL JOGI	11	18	Di,Dr		-.007	.156	.20	12	5	79	.51	9	5	66	.94	9	5	47	100
LEWA	11	10	Di,Dr	+ 1	-.008	.174	.48	7	2	69	.87	5	3	51	1.00	--	--	--	52
NGULIA	12	55	Di,Dr,P	+12	-.022	.179	.18	24	16	87	.48	19	16	76	.93	13	15	65	104
OL PEJETA	8	70	Di	+ 8	.035	.071	0	67	7	94	0	66	8	90	0	66	8	84	
LAIKIPIA	38	100	Di,Dr,P		-.024	.175	.13	33	26	88	.45	28	24	81	.89	16	15	68	109
ABERDARE	33	43	Di		.032	.078	0	40	5	93	0	40	6	87	0	39	7	77	
AMBOSELI	3	50	Di,Dr,P		-.033	.234	.93	6	5	60	.99	4	1	33	1.00	--	--	--	15
META-POP	293	567	Above		.029	.029	0	370	38	99	0	332	34	98	0	290	28	97	

Note: deterministic r (from life table) = .042 with Disease, .026 with Di and Poaching, .016 with Di and Drought, and .000 with Di, Dr, and P

8. RHINO SANCTUARIES, NO CATASTROPHES, NO ADJUSTMENT OF FOUNDERS, MIGRATION

LOCATION	N_0	K	CATS	+ OR -	Pop growth (r)		50 yr results				100 yr results				200 yr results				Median Time to Extinc.
					mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
NAKURU	29	52			.037	.079	0	50	3	98	0	50	3	98	0	50	3	97	
SOLIO	59	56			.028	.076	0	54	3	98	0	54	4	98	0	54	3	97	
NAIROBI	63	63			.019	.073	0	59	5	98	0	59	4	98	0	59	5	97	
MARA	26	50			.041	.080	0	48	3	98	0	48	3	98	0	48	3	97	
OL JOGI	11	18			.201	.139	0	18	2	96	0	18	2	96	0	18	2	95	
LEWA	11	10			.375	.203	0	10	2	94	0	10	2	93	.01	10	2	93	148*
NGULIA	12	55			.036	.081	0	52	4	98	0	53	4	98	0	52	4	97	
OL PEJETA	8	70			.023	.082	0	64	6	98	0	65	6	98	0	64	6	97	
LAIKIPIA	38	100			.004	.068	0	75	13	98	0	78	12	98	0	76	12	97	
ABERDARE	33	43			.054	.085	0	42	3	98	0	42	3	97	0	42	2	96	
AMBOSELI	3	50			.050	.104	0	48	3	98	0	49	3	98	0	48	4	96	
META-POP	293	567			.046	.018	0	518	18	99	0	525	17	99	0	522	17	98	

Note: deterministic r (from life table) = .046; * Median time to first extinction, population usually recolonized.

9. RHINO SANCTUARIES, CATASTROPHES, NO ADJUSTMENT OF FOUNDERS, MIGRATION

LOCATION	N_0	K	CATS	+ OR -	Pop growth: r		50 yr results				100 yr results				200 yr results				Median Time to Extinc.
					mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
NAKURU	29	52	Di		.018	.095	0	47	6	98	0	47	6	97	0	48	6	96	
SOLIO	59	56	Di		.012	.093	0	49	7	98	0	49	7	97	0	49	7	96	
NAIROBI	63	63	Di		.006	.090	0	53	9	98	0	54	8	97	0	53	9	96	
MARA	26	50	Di,P		.015	.131	0	41	9	98	0	42	8	97	0	42	8	96	
OL JOGI	11	18	Di,Dr		.133	.165	0	17	2	96	0	17	2	95	0	17	2	94	
LEWA	11	10	Di,Dr		.280	.218	0	10	2	94	.02	10	2	93	.01	10	2	92	128*
NGULIA	12	55	Di,Dr,P		.009	.163	0	38	11	97	0	38	10	97	0	38	11	96	
OL PEJETA	8	70	Di		.013	.099	0	54	11	98	0	56	9	97	0	57	10	96	
LAIKIPIA	38	100	Di,Dr,P		.000	.160	0	39	13	97	0	40	13	97	0	40	13	96	
ABERDARE	33	43	Di		.031	.100	0	40	5	98	0	40	5	97	0	40	4	96	
AMBOSELI	3	50	Di,Dr,P		.018	.176	0	36	9	97	0	36	10	97	0	36	10	96	
META-POP	293	567	Above		.027	.030	0	424	35	99	0	430	35	99	0	429	34	97	

Note: deterministic r (from life table) = .042 with Disease, .026 with Di and Poaching, .016 with Di and Drought, and .000 with Di, Dr, and P;

* Median time to first extinction, population always recolonized.

10. RHINO SANCTUARIES, NO CATASTROPHES, MANAGED FOUNDER NUMBERS, MIGRATION

LOCATION	N_0	K	CATS	+ OR -	Pop growth (r)		50 yr results				100 yr results				200 yr results				Median Time to Extinc.
					mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
NAKURU	29	52			.037	.079	0	50	3	98	0	50	3	98	0	50	3	97	
SOLIO	59	56		-10	.029	.076	0	53	4	98	0	54	4	98	0	54	4	97	
NAIROBI	63	63		- 8	.020	.073	0	59	5	98	0	59	5	98	0	59	5	97	
MARA	26	50			.041	.080	0	48	3	98	0	48	3	98	0	48	3	97	
OL JOGI	11	18			.203	.139	0	18	2	96	0	18	2	96	0	18	2	95	
LEWA	11	10		+ 1	.377	.200	0	10	2	94	0	10	2	94	0	10	2	93	171*
NGULIA	12	55		+12	.033	.077	0	53	4	98	0	53	4	98	0	53	3	97	
OL PEJETA	8	70		+ 8	.017	.073	0	65	6	98	0	64	6	98	0	65	6	97	
LAIKIPIA	38	100			.005	.067	0	77	13	98	0	78	12	98	0	77	12	97	
ABERDARE	33	43			.055	.085	0	42	3	98	0	42	2	97	0	42	3	96	
AMBOSELI	3	50			.051	.105	0	49	3	98	0	48	3	98	0	48	3	97	
META-POP	293	567			.045	.017	0	523	17	99	0	524	17	99	0	524	17	98	

Note: deterministic r (from life table) = .046; * Median time to first extinction, population always recolonized.

11. RHINO SANCTUARIES, CATASTROPHES, MANAGED FOUNDER NUMBERS, MIGRATION

LOCATION	N_0	K	CATS	+ OR -	Pop growth (r)		50 yr results				100 yr results				200 yr results				Median Time to Extinc.
					mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
NAKURU	29	52	Di		.019	.095	0	47	6	98	0	47	6	97	0	47	6	96	
SOLIO	59	56	Di	-10	.013	.093	0	50	7	98	0	48	7	97	0	50	7	96	
NAIROBI	63	63	Di	- 8	.008	.091	0	54	9	98	0	54	8	97	0	54	8	96	
MARA	26	50	Di,P		.015	.131	0	41	8	98	0	41	8	97	0	42	8	96	
OL JOGI	11	18	Di,Dr		.134	.166	0	17	2	96	0	17	2	95	0	17	2	94	
LEWA	11	10	Di,Dr	+ 1	.283	.215	0	10	2	94	0	10	2	93	0	10	2	92	154*
NGULIA	12	55	Di,Dr,P	+12	.005	.161	0	38	10	97	0	37	11	97	0	37	11	96	
OL PEJETA	8	70	Di	+ 8	.008	.092	0	56	11	98	0	56	11	97	0	56	11	96	
LAIKIPIA	38	100	Di,Dr,P		.000	.160	0	39	12	97	0	41	13	97	0	40	13	96	
ABERDARE	33	43	Di		.033	.099	0	41	4	98	0	41	4	97	0	40	5	96	
AMBOSELI	3	50	Di,Dr,P		.019	.173	0	37	9	97	0	37	10	97	0	36	9	96	
META-POP	293	567	Above		.027	.030	0	430	33	99	0	430	35	99	0	429	36	97	

Note: deterministic r (from life table) = .042 with Disease, .026 with Di and Poaching, .016 with Di and Drought, and .000 with Di, Dr, and P;

* Median time to first extinction, population always recolonized.

12. PREDICTED SURPLUS AVAILABLE FOR TRANSLOCATION

Location	$N_0 \pm$ Founder adjustment	K	Catastrophes	Pop growth: r	Year at K	Mean available for harv.
NAKURU	29	52		.038	2007	2.0
	29	52	Di	.032	2010	1.7
SOLIO	59 - 10	56		.039	1995	2.2
	59 - 10	56	Di	.034	1996	1.8
NAIROBI	63 - 12	63		.038	1997	2.4
	63 - 12	63	Di	.033	1998	2.1
MARA	26	50		.038	2009	1.9
	26	50	Di,P	.010	2079	0.4
OL JOGI	11	18		.024	2013	0.4
	11	18	Di,Dr	-.007	----	-0.1
LEWA	11 + 1	10 60		.015 .037	1992 2035	0.1 2.3
	11 + 1	10 60	Di,Dr	-.008 -.002	1992 ----	-0.1 -0.1
NGULIA	12 + 12	55		.038	2014	2.1
	12 + 12	55	Di,Dr,P	-.022	----	-1.2
OL PEJETA	8 + 12	70		.040	2023	2.9
	8 + 12	70	Di	.035	2028	2.5
LAIKIPIA	38	100		.040	2016	4.1
	38	100	Di,Dr,P	-.024	----	-2.4
ABERDARE	33	43		.037	1999	1.6
	33	43	Di	.032	2000	1.3
AMBOSELI	3	50		.014	2193	0.7
	3	50	Di,Dr,P	-.033	----	-1.7

13. LARGE SANCTUARIES AT ABERDARE, NGULIA, AND LEWA

LOCATION	N_0	K	CATS	Pop. growth: r		50 yr results				100 yr results				200 yr results				Median Time to Extinc.
				mean	SD	P(E)	N_t	SD	H	P(E)	N_t	SD	H	P(E)	N_t	SD	H	
ABERDARE	33	43		.037	.055	0	42	2	93	0	42	2	88	0	42	3	79	
	33	43	Di	.032	.078	0	41	5	93	0	40	6	87	.01	39	7	78	
	33	500		.045	.041	0	392	86	97	0	500	6	97	0	498	7	96	
	33	500	Di	.039	.065	0	316	120	97	0	481	58	96	0	488	39	95	
NGULIA	12	55		.036	.054	0	53	6	91	0	54	2	87	0	54	3	81	
	12	55	Di,Dr	-.005	.143	.13	25	16	83	.31	26	17	75	.66	21	15	64	143
	12	55	Di,Dr,P	-.026	.195	.42	14	11	78	.80	10	9	66	1.00	6	0	28	58
	24	55		.038	.051	0	55	2	94	0	54	2	90	0	54	2	82	
	24	55	Di,Dr	.000	.131	.02	38	15	91	.09	33	16	84	.37	25	16	71	
	24	55	Di,Dr,P	-.022	.179	.18	24	16	87	.48	19	16	76	.93	13	15	65	104
	12	500		.040	.045	0	122	52	92	0	462	84	91	0	498	6	90	
	12	500	Di,Dr	-.003	.139	.14	32	26	84	.33	56	70	78	.59	106	136	73	165
	12	500	Di,Dr,P	-.022	.186	.38	18	18	79	.74	24	26	73	.96	18	14	73	66
	24	500		.043	.041	0	257	87	96	0	499	7	96	0	499	6	95	
	24	500	Di,Dr	.003	.124	.01	69	51	92	.07	120	125	87	.26	194	166	85	
	24	500	Di,Dr,P	-.020	.171	.13	31	30	87	.44	33	45	78	.84	17	17	66	112
LEWA	11	10		.015	.108	.21	9	1	71	.36	8	2	55	.78	6	2	32	131
	11	10	Di,Dr	-.008	.177	.55	6	3	66	.90	5	2	44	1.00	--	--	--	43
	12	10		.015	.108	.18	8	2	71	.37	8	2	55	.76	7	2	39	129
	12	10	Di,Dr	-.008	.174	.48	7	2	69	.87	5	3	51	1.00	--	--	--	52
	11	60		.035	.053	.02	59	4	85	.02	59	2	82	.02	59	3	77	
	11	60	Di,Dr	-.003	.138	.15	31	17	80	.28	29	18	73	.65	22	17	63	154
	12	60		.037	.053	0	59	3	89	0	59	2	86	0	59	3	80	
	12	60	Di,Dr	-.002	.136	.10	31	18	83	.23	30	18	76	.58	24	18	64	172
	19	60		.039	.052	0	59	3	93	0	59	2	89	0	59	2	82	
	19	60	Di,Dr	.001	.133	.05	39	18	88	.13	33	18	81	.40	27	17	69	

Note: deterministic r (from life table) = .046 without catastrophes, .042 with Di, .016 with Di and Dr, and .000 with Di, Dr, and Poaching.

KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKSHOP REPORT

1 May 1993

SECTION 5
FIGURES

KENYA BLACK RHINO METAPOPULATION WORKSHOP

FIGURES

9. Simulation of hypothetical small populations: no catastrophes, no poaching, 6.24 lethals
   a. Proportion of simulated populations extant (survive)
   b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

10. Simulation of hypothetical small populations: no catastrophes, no poaching, 6.24 lethals
   a. Proportion of simulated populations extant (survive)
   b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

Data in Figures 11-14 same as in Table 3.

11. Simulation of hypothetical small populations: no catastrophes, poaching at increased level 1, 3.12 lethals
   a. Proportion of simulated populations extant (survive)
   b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

12. Simulation of hypothetical small populations: catastrophes, poaching at increased level 1, 3.12 lethals
   a. Proportion of simulated populations extant (survive)
   b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

13. Simulation of hypothetical small populations: no catastrophes, poaching at increased level 2, 3.12 lethals
   a. Proportion of simulated populations extant (survive)
   b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

14. Simulation of hypothetical small populations: catastrophes, poaching at increased level 2, 3.12 lethals
   a. Proportion of simulated populations extant (survive)
   b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

In Figures 15-22, individual populations and the metapopulation are labelled when the lines are sufficiently distinguishable.

Data in Figure 15 same as in Table 4.

15. Simulations of sanctuary populations: no catastrophes, no founder adjustment, no migration, 3.12
   a. Proportion of simulated populations extant (survive)
   b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

Data in Figure 16 same as in Table 5.

16. Simulations of sanctuary populations: catastrophes, no founder adjustment, no migration, 3.12
    a. Proportion of simulated populations extant (survive)
    b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

Data in Figure 17 same as in Table 6.

17. Simulations of sanctuary populations: no catastrophes, founder adjustment, no migration, 3.12
    a. Proportion of simulated populations extant (survive)
    b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

Data in Figure 18 same as in Table 7.

18. Simulations of sanctuary populations: catastrophes, founder adjustment, no migration, 3.12
    a. Proportion of simulated populations extant (survive)
    b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

Data in Figure 19 same as in Table 8.

19. Simulations of sanctuary populations: no catastrophes, no founder adjustment, migration, 3.12
    a. Proportion of simulated populations extant (survive)
    b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

Data in Figure 20 same as in Table 9.

20. Simulations of sanctuary populations: catastrophes, no founder adjustment, migration, 3.12
    a. Proportion of simulated populations extant (survive)
    b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

Data in Figure 21 same as in Table 10.

21. Simulations of sanctuary populations: no catastrophes, founder adjustment, migration, 3.12
    a. Proportion of simulated populations extant (survive)
    b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

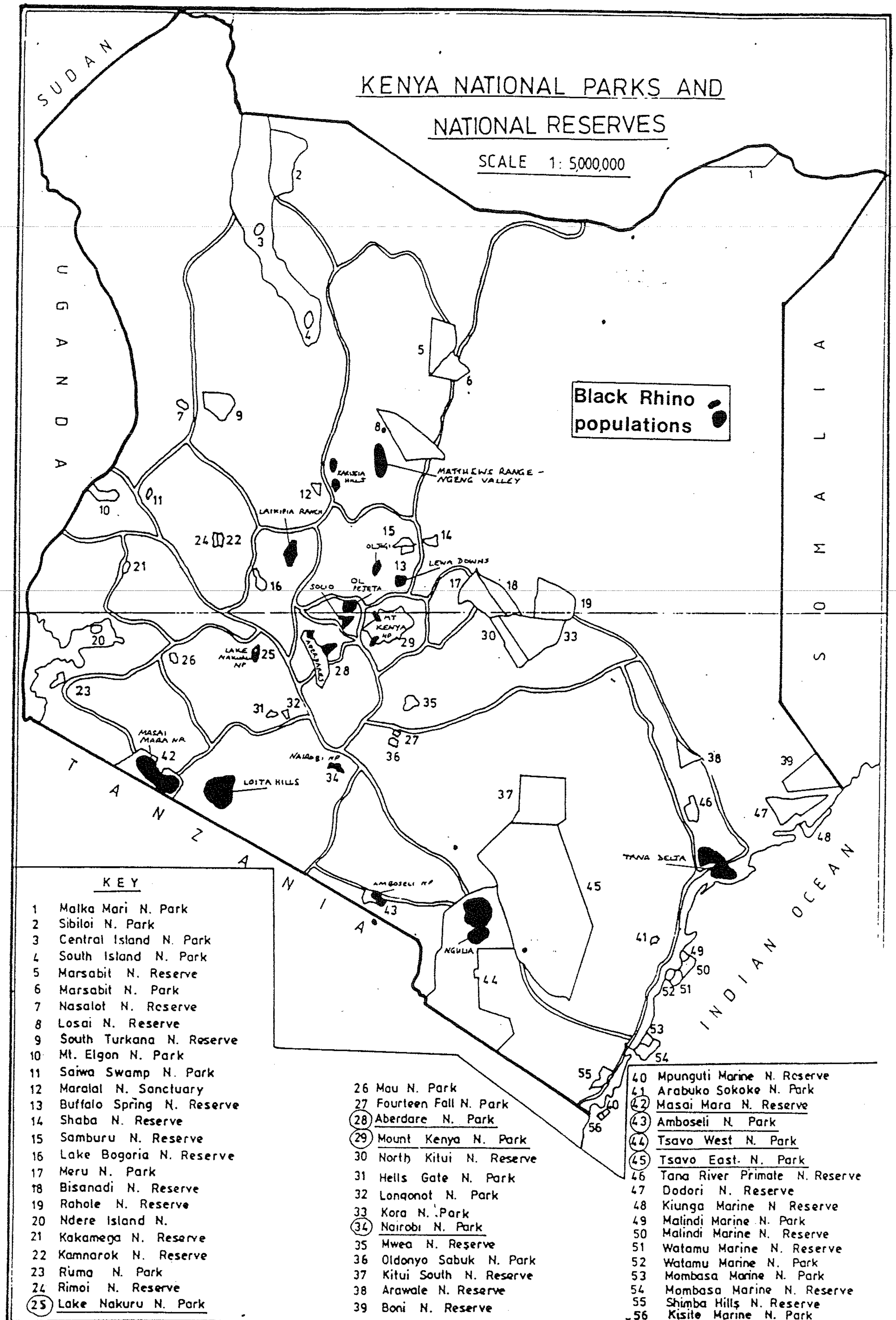
Data in Figure 22 same as in Table 11.

22. Simulations of sanctuary populations: catastrophes, founder adjustment, migration, 3.12
    a. Proportion of simulated populations extant (survive)
    b. Proportion of initial heterozygosity remaining in surviving populations (with standard error bars).

Data in Figure 23 is same as in Table 13.

23. Bar graph of sanctuaries with carrying capacity (K) and harvest as the bars. Founder adjustments and catastrophes, but no migration (i.e., same as in Table 7 and Figure 18). Each bar indicates the population size in 1992 (N-1992), the expected capacity (K), and the mean annual surplus expected after K is attained, and the year in which K is projected to be achieved. **** indicates that the population is expected to decline and hence never attain K.

Figure 1.

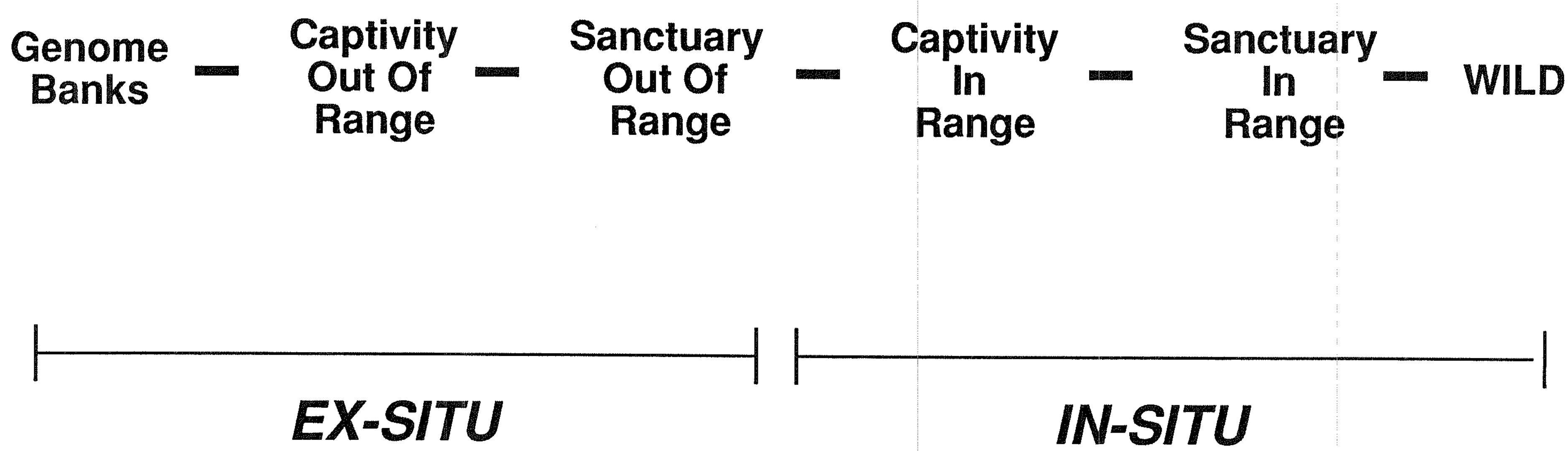


KWS—WPU—1990

Compiled and Drawn By F.N. Muchiri

Figure 2.

OPTIONS FOR RHINO CONSERVATION



Modified from Mark Stanley-Price (1991)

Figure 3a.

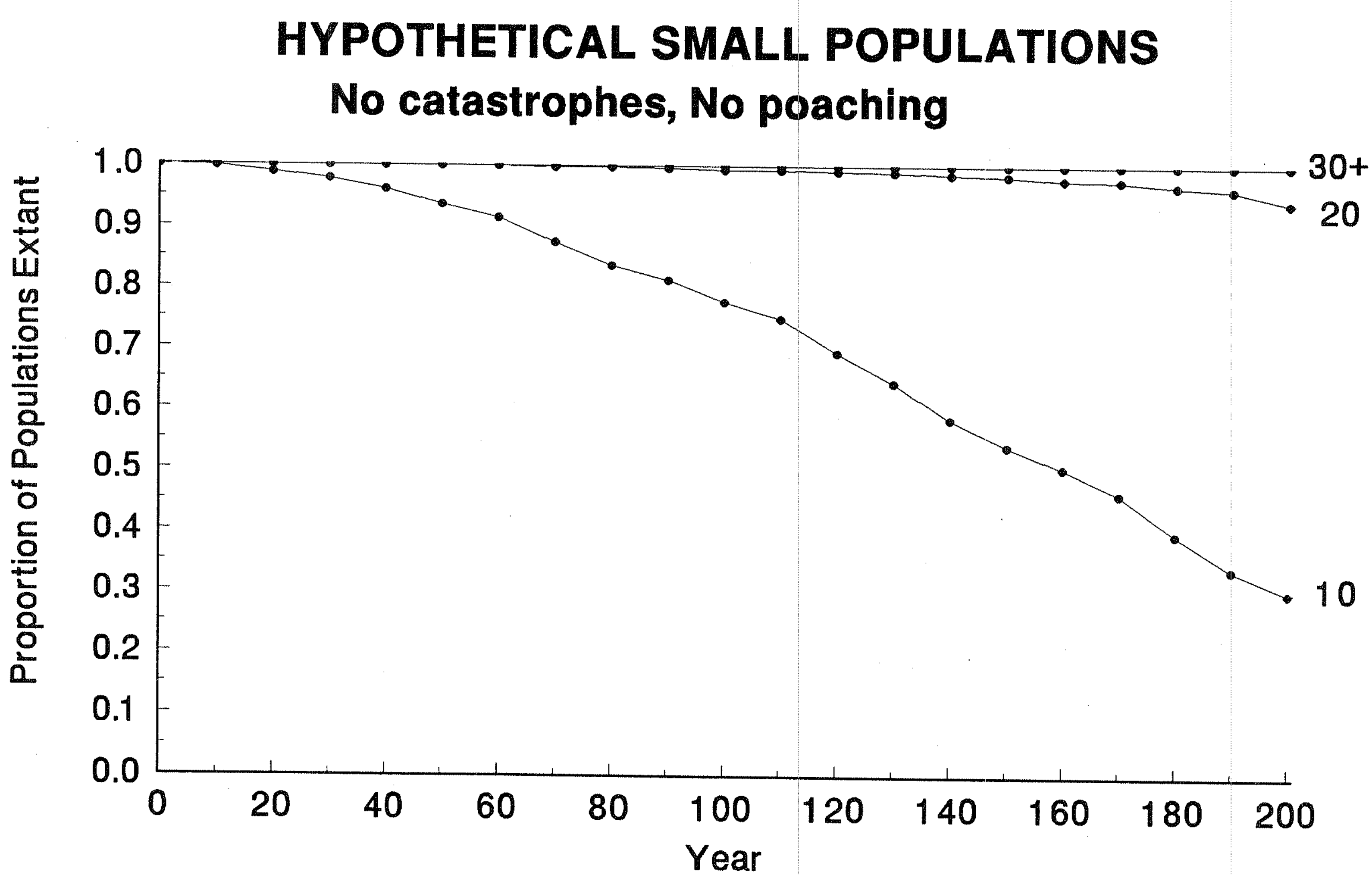

HYPOTHETICAL SMALL POPULATIONS
No catastrophes, No poaching
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
30+
20
10

Figure 3b.

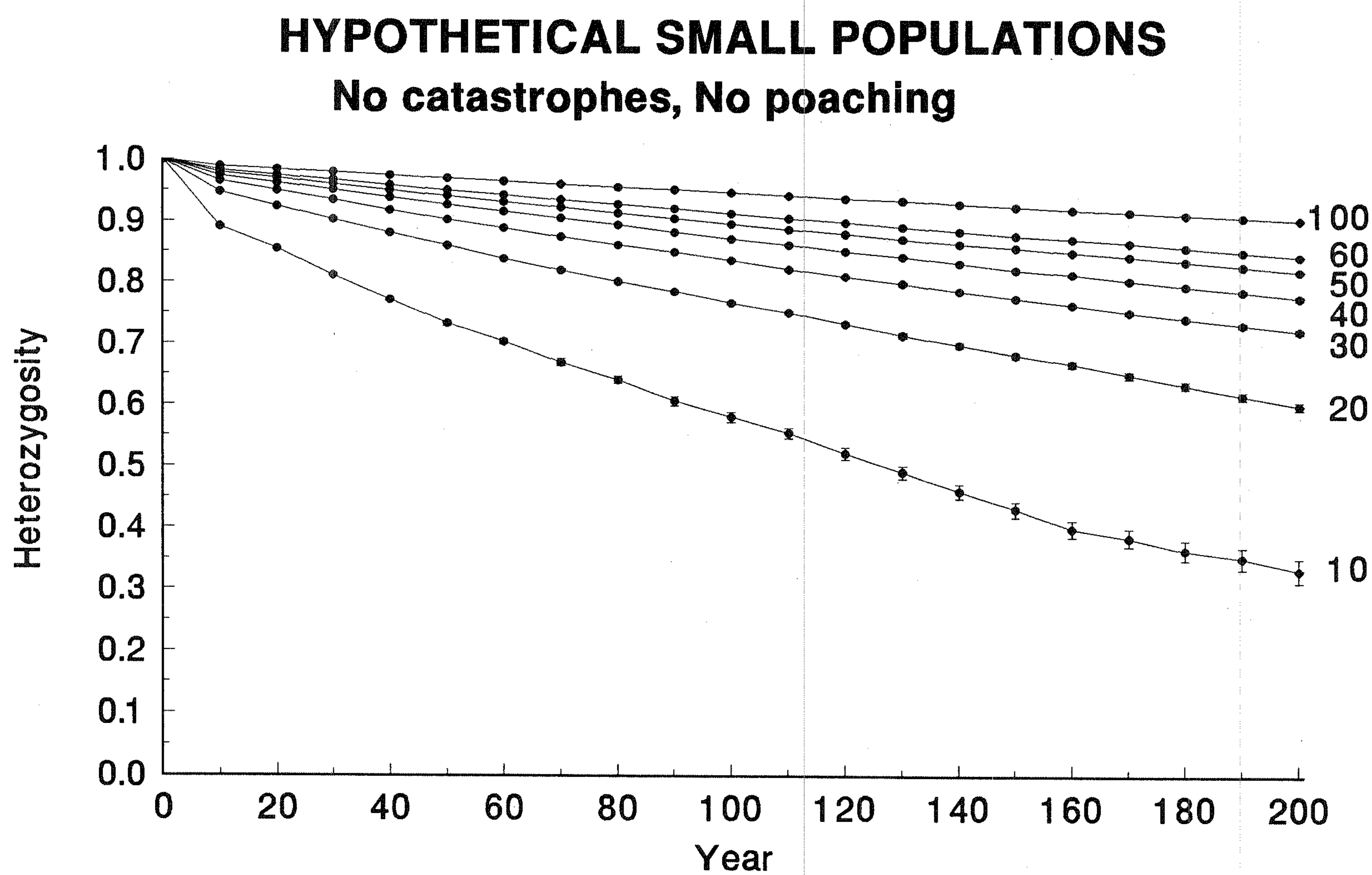
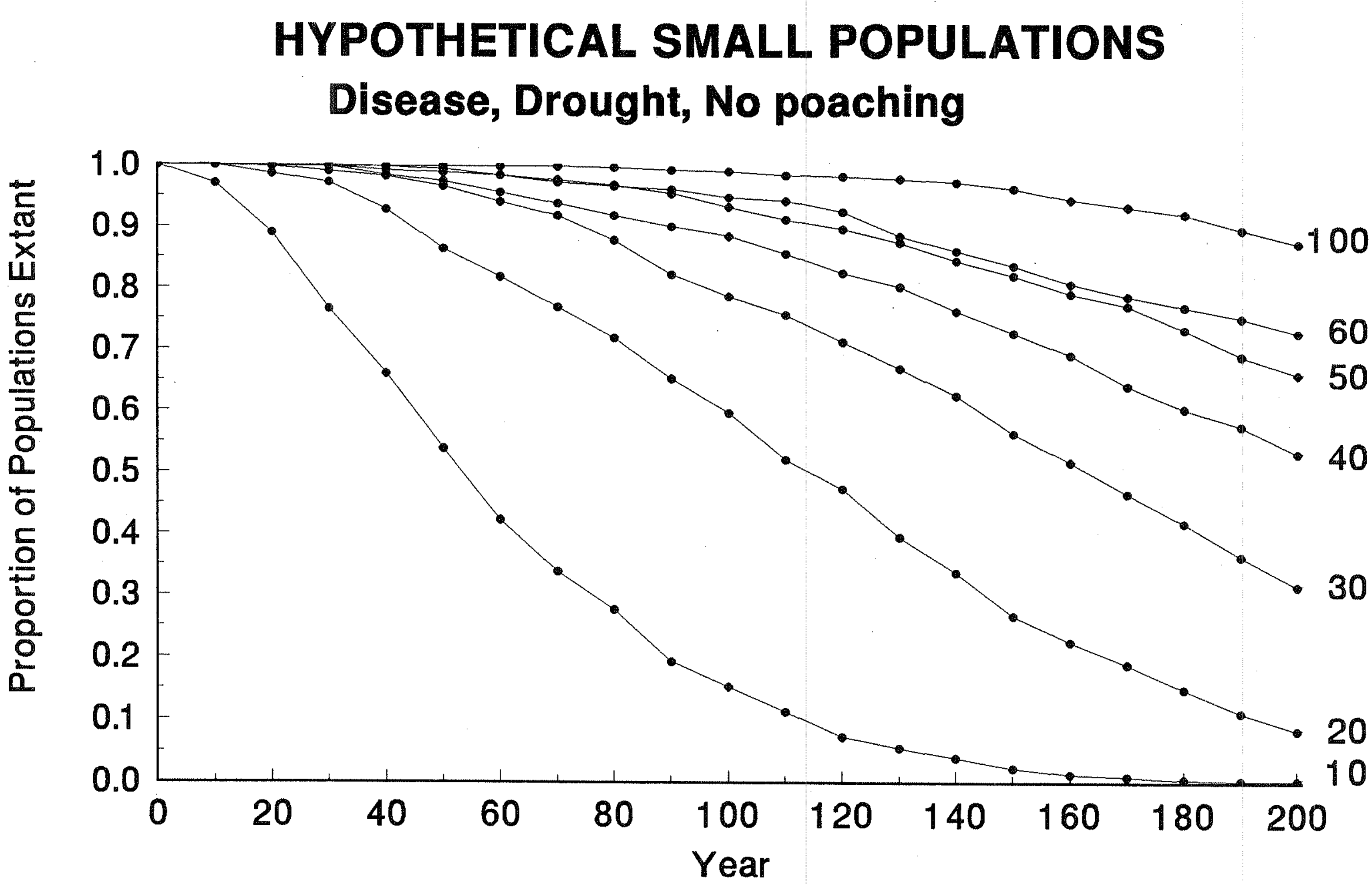

HYPOTHETICAL SMALL POPULATIONS
No catastrophes, No poaching
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 4a.



HYPOTHETICAL SMALL POPULATIONS
Disease, Drought, No poaching
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 4b.

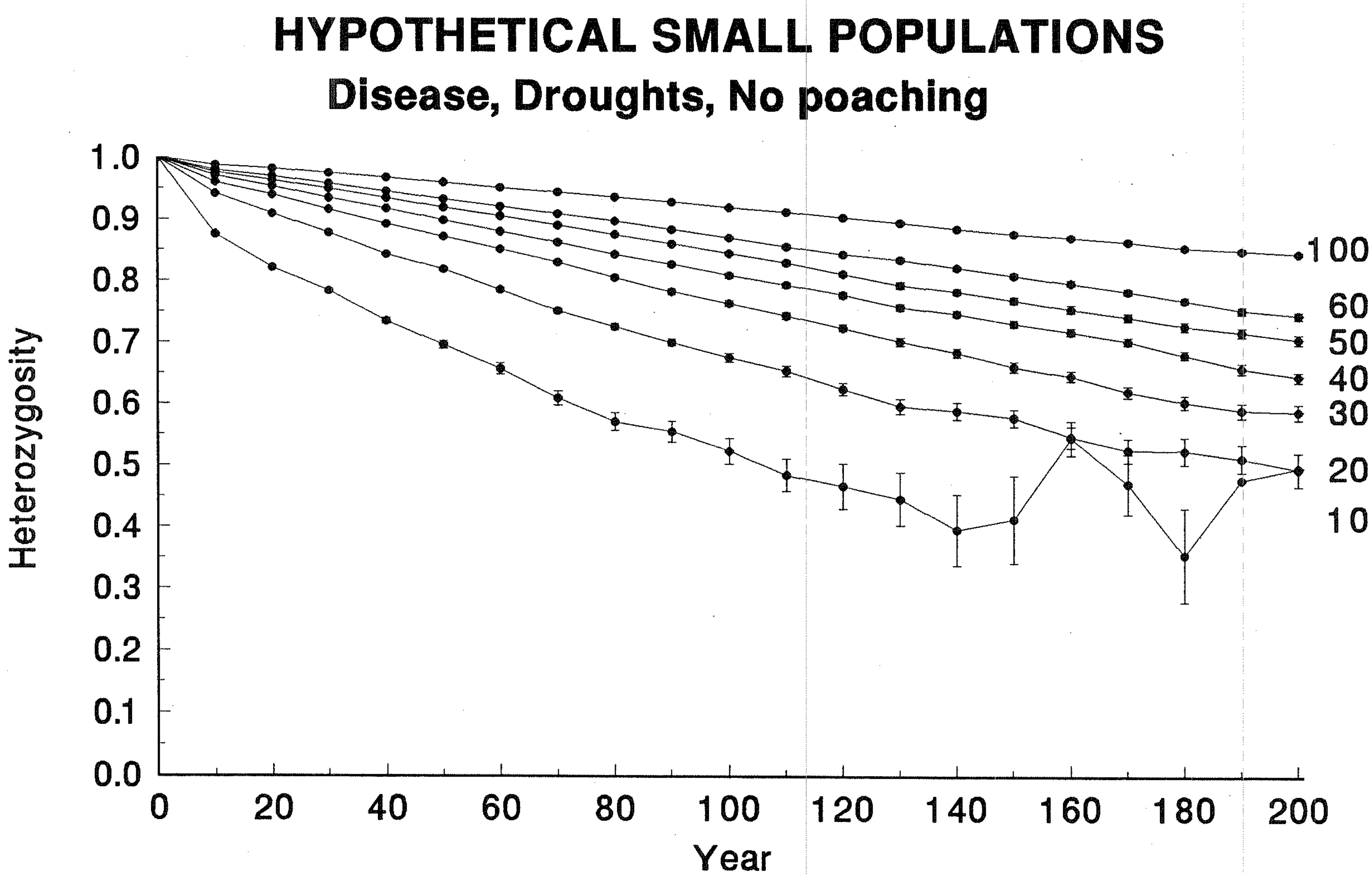

HYPOTHETICAL SMALL POPULATIONS
Disease, Droughts, No poaching
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 5a.

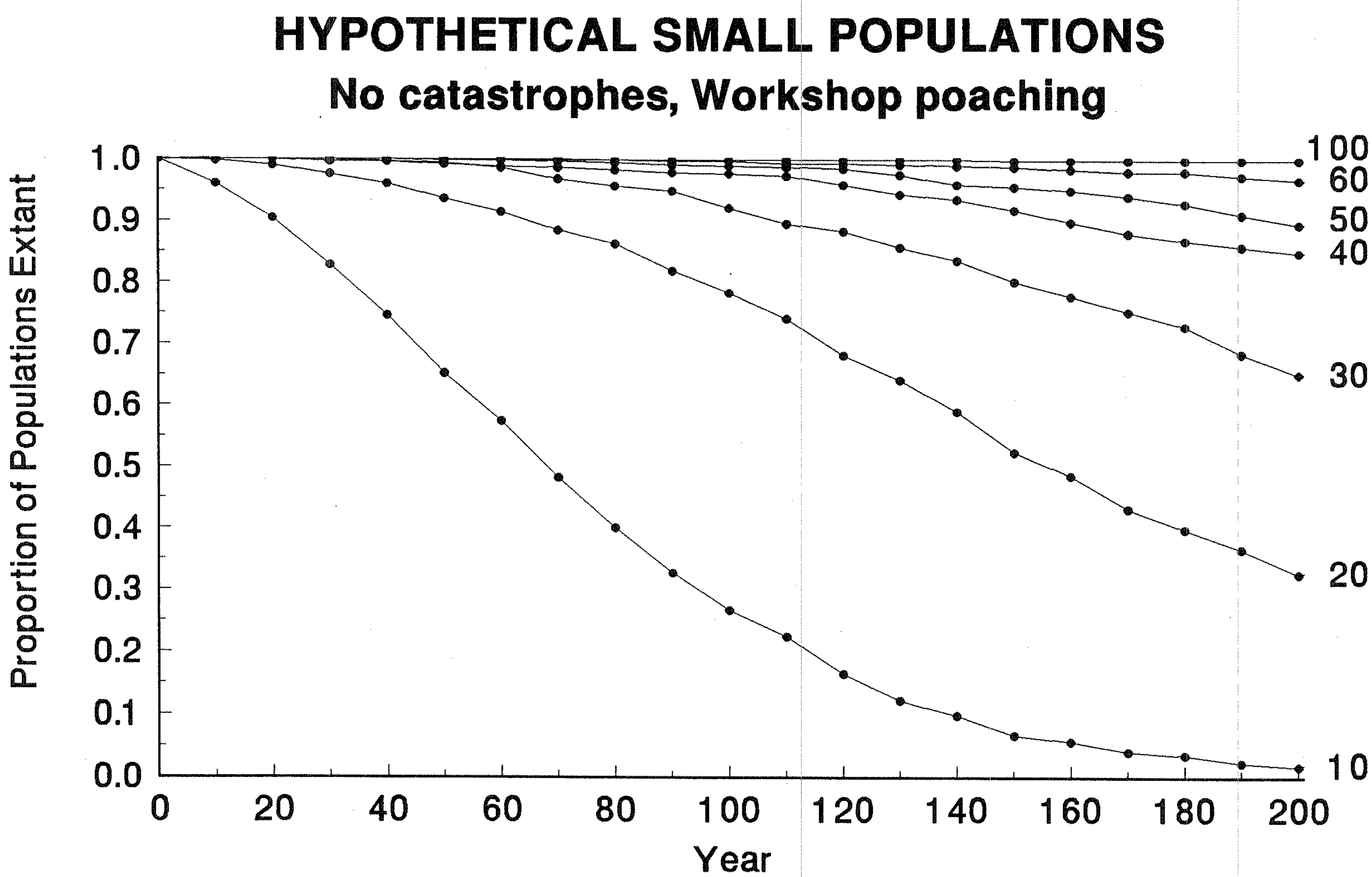
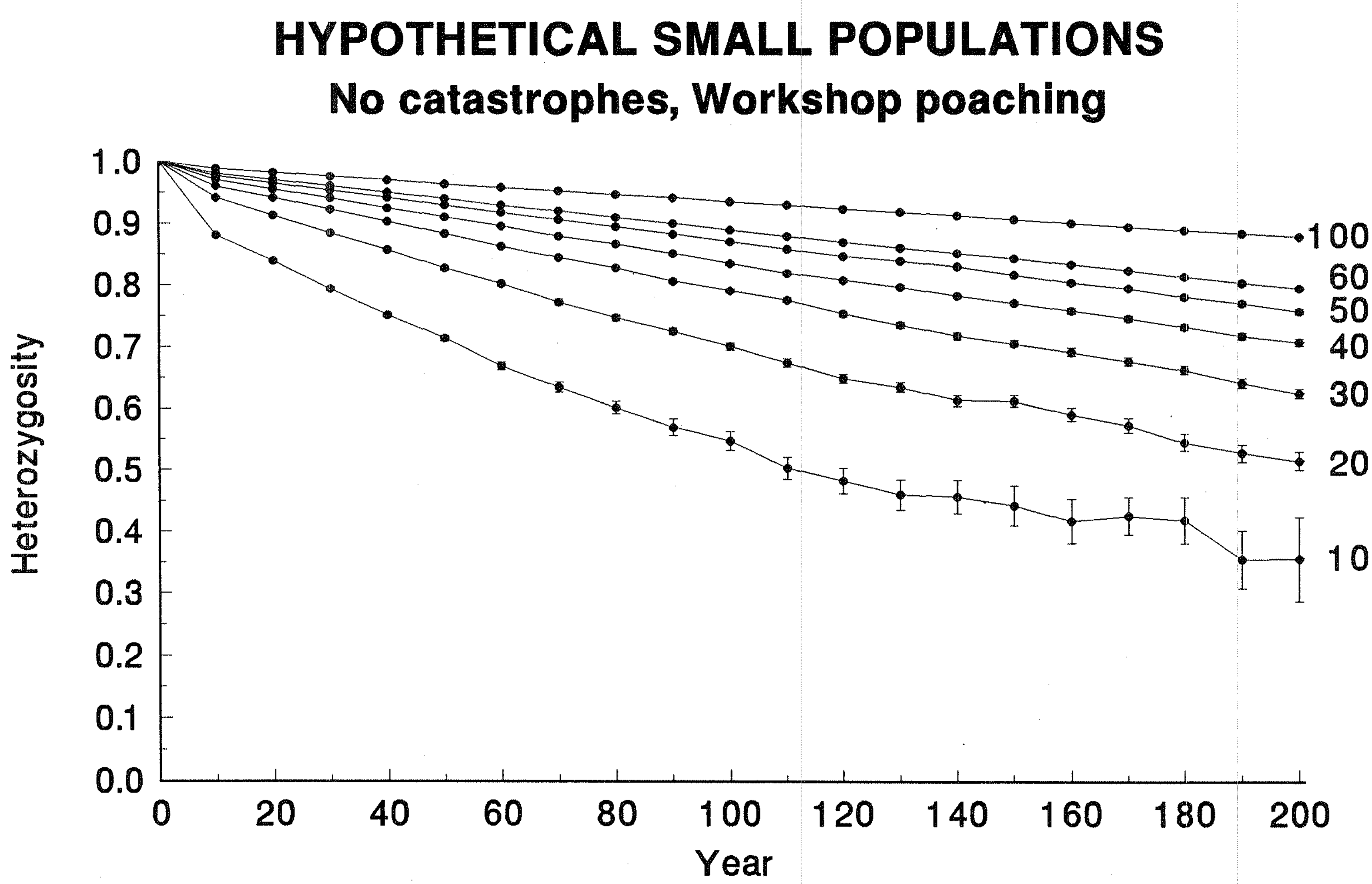

HYPOTHETICAL SMALL POPULATIONS
No catastrophes, Workshop poaching
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 5b.



HYPOTHETICAL SMALL POPULATIONS
No catastrophes, Workshop poaching
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 6a.

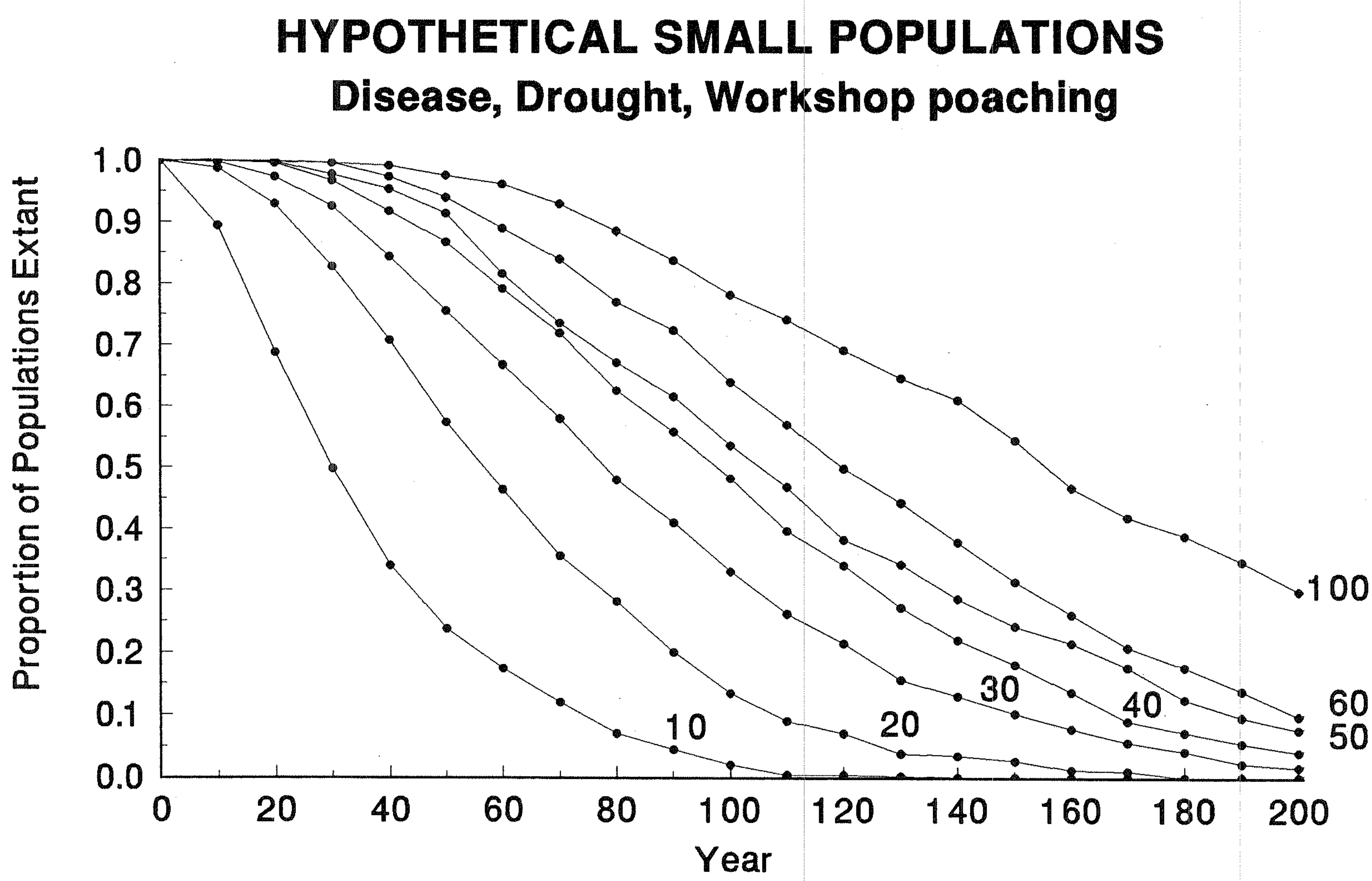
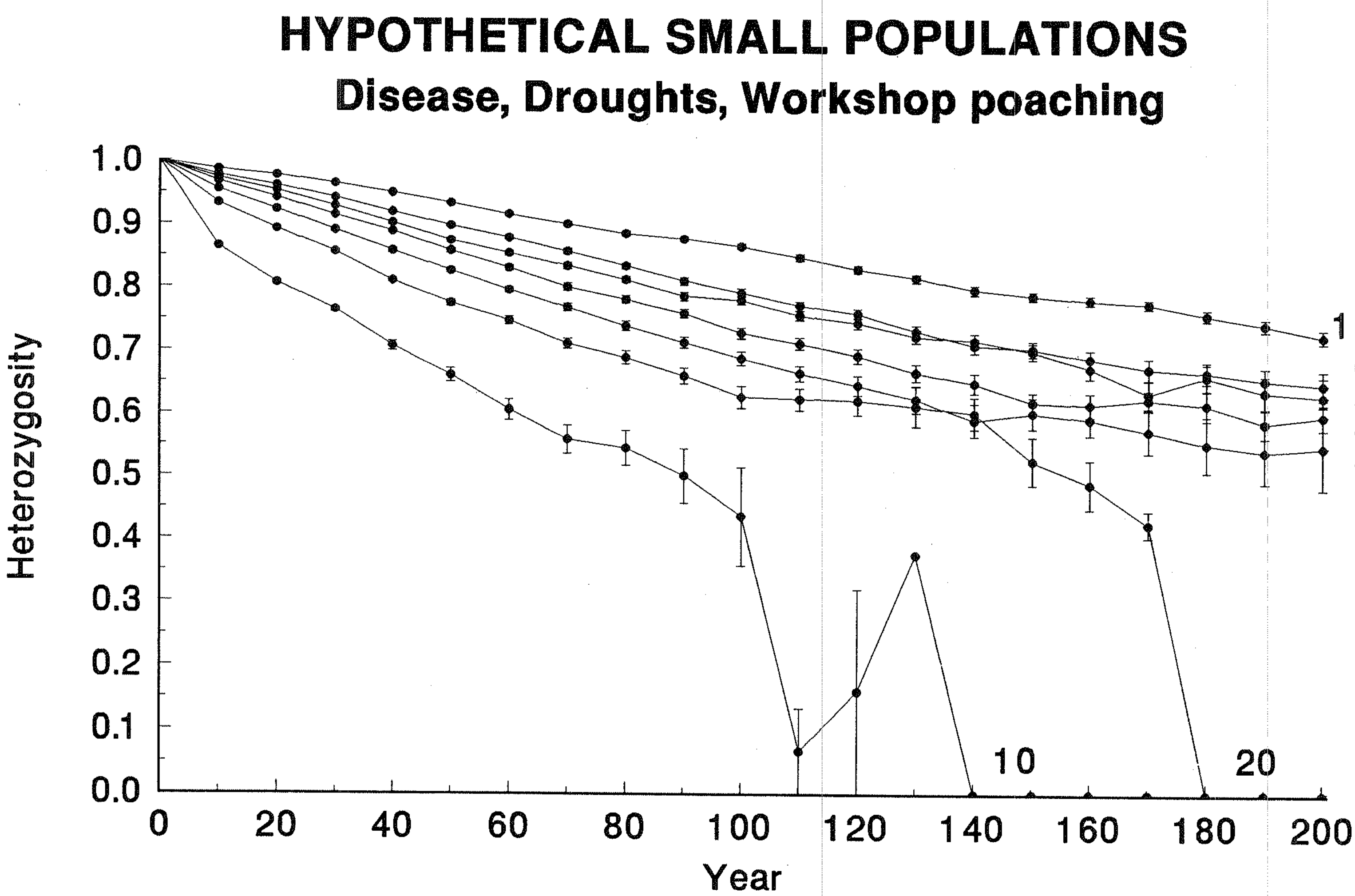

HYPOTHETICAL SMALL POPULATIONS
Disease, Drought, Workshop poaching
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
10
20
30
40
50
60
100

Figure 6b.



HYPOTHETICAL SMALL POPULATIONS
Disease, Droughts, Workshop poaching
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
10
20

Figure 7a.

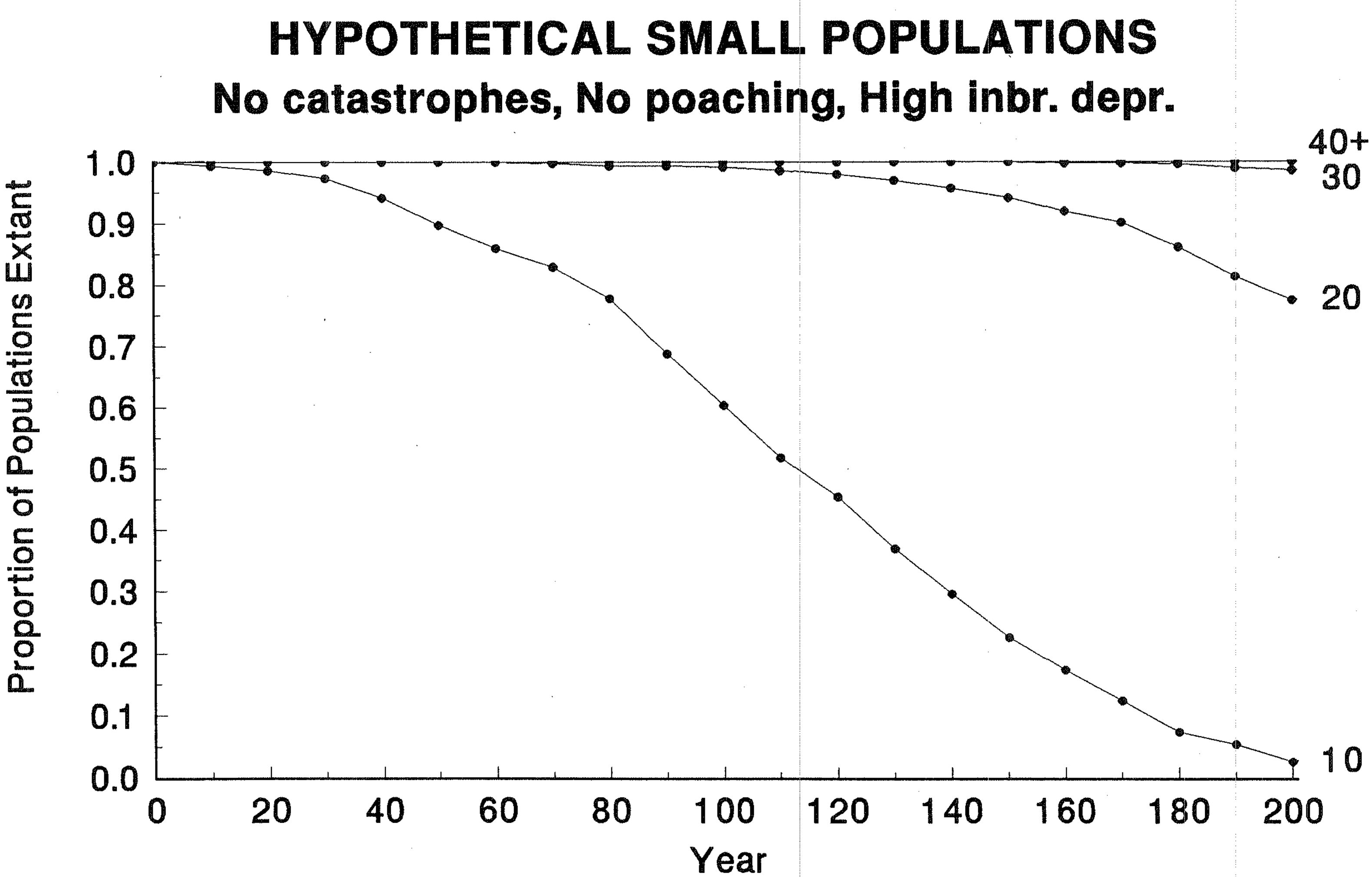
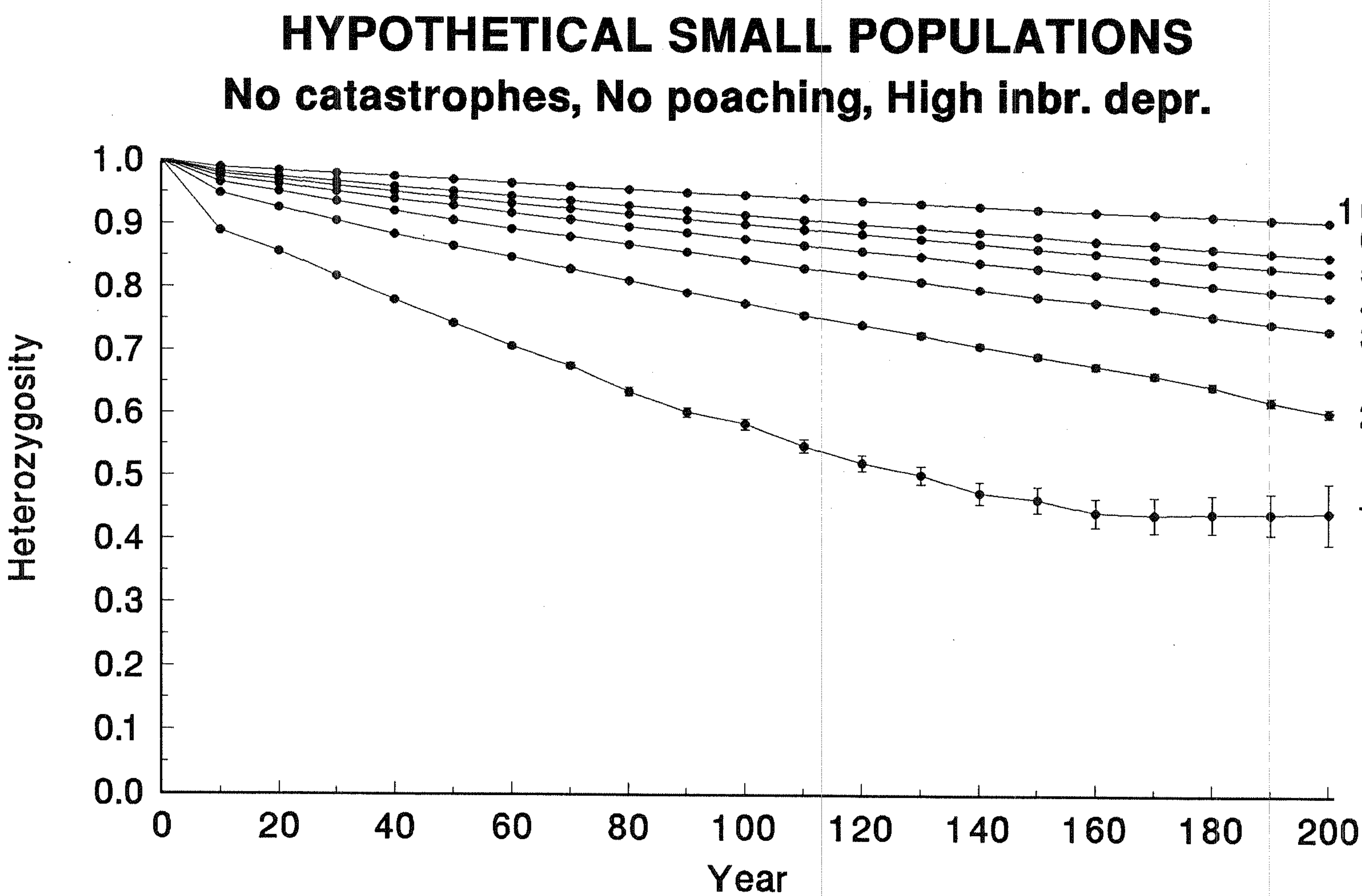

HYPOTHETICAL SMALL POPULATIONS
No catastrophes, No poaching, High inbr. depr.
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
40+
30
20
10

Figure 7b.



HYPOTHETICAL SMALL POPULATIONS
No catastrophes, No poaching, High inbr. depr.
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 8a.

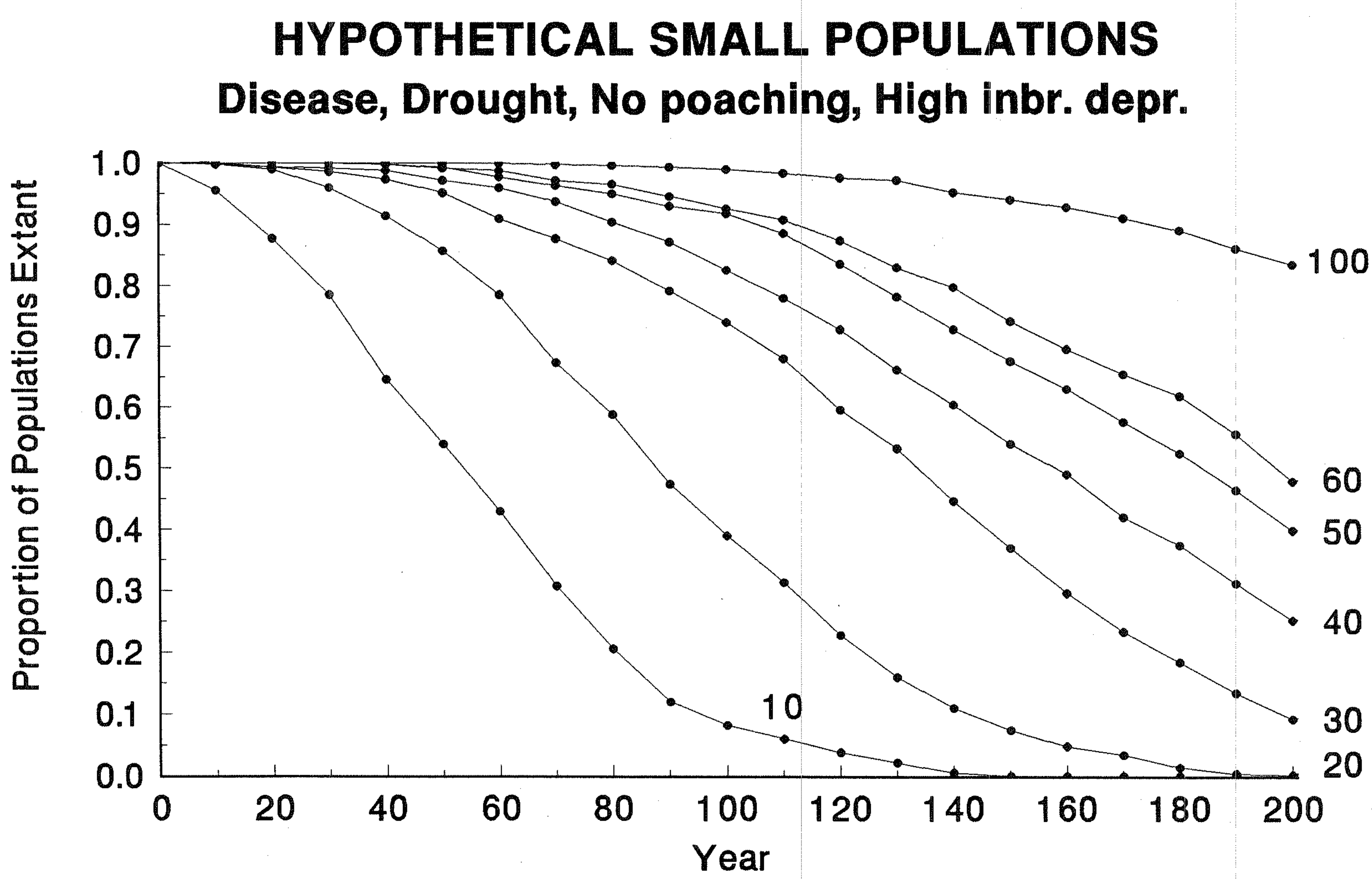
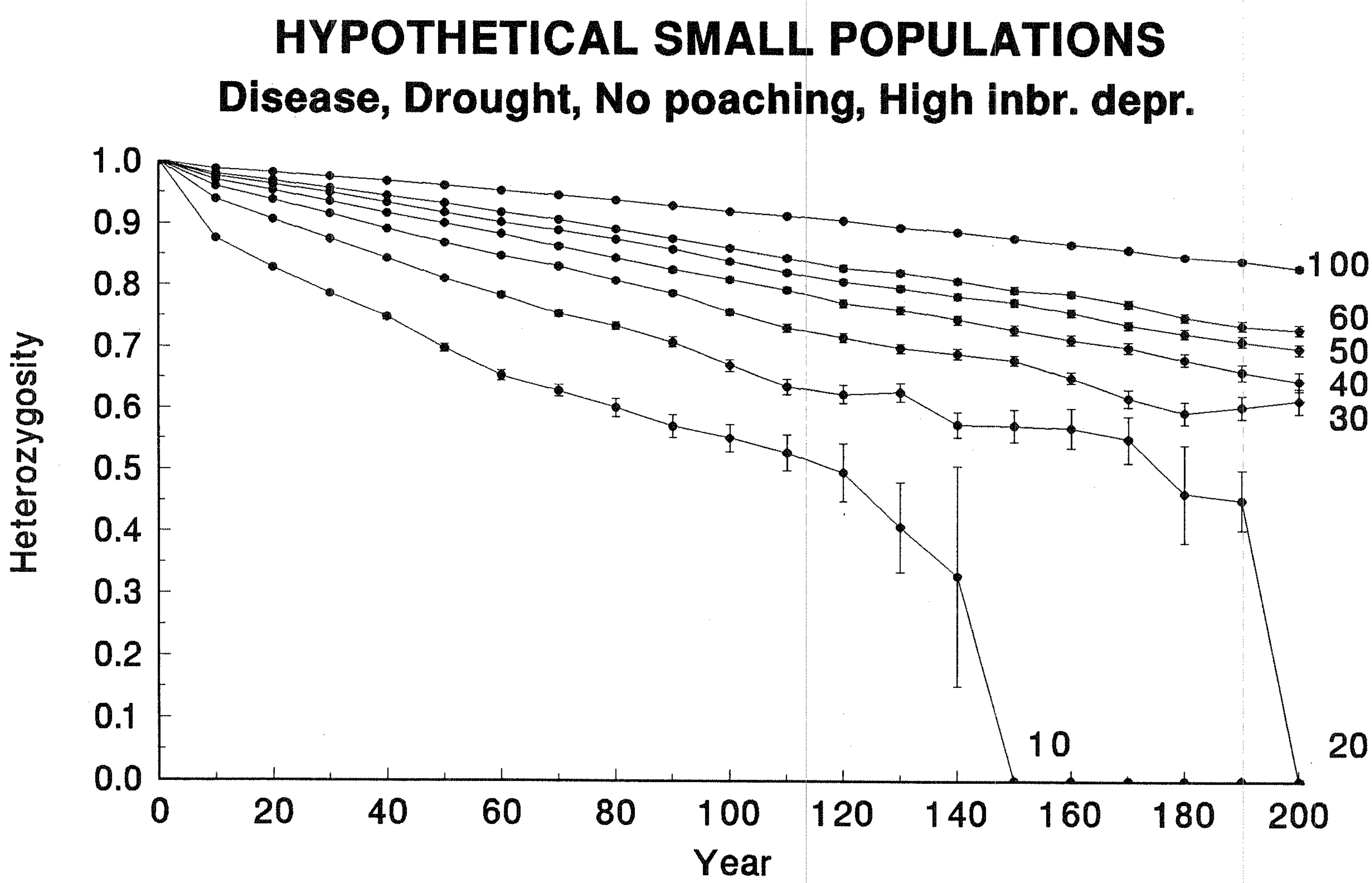
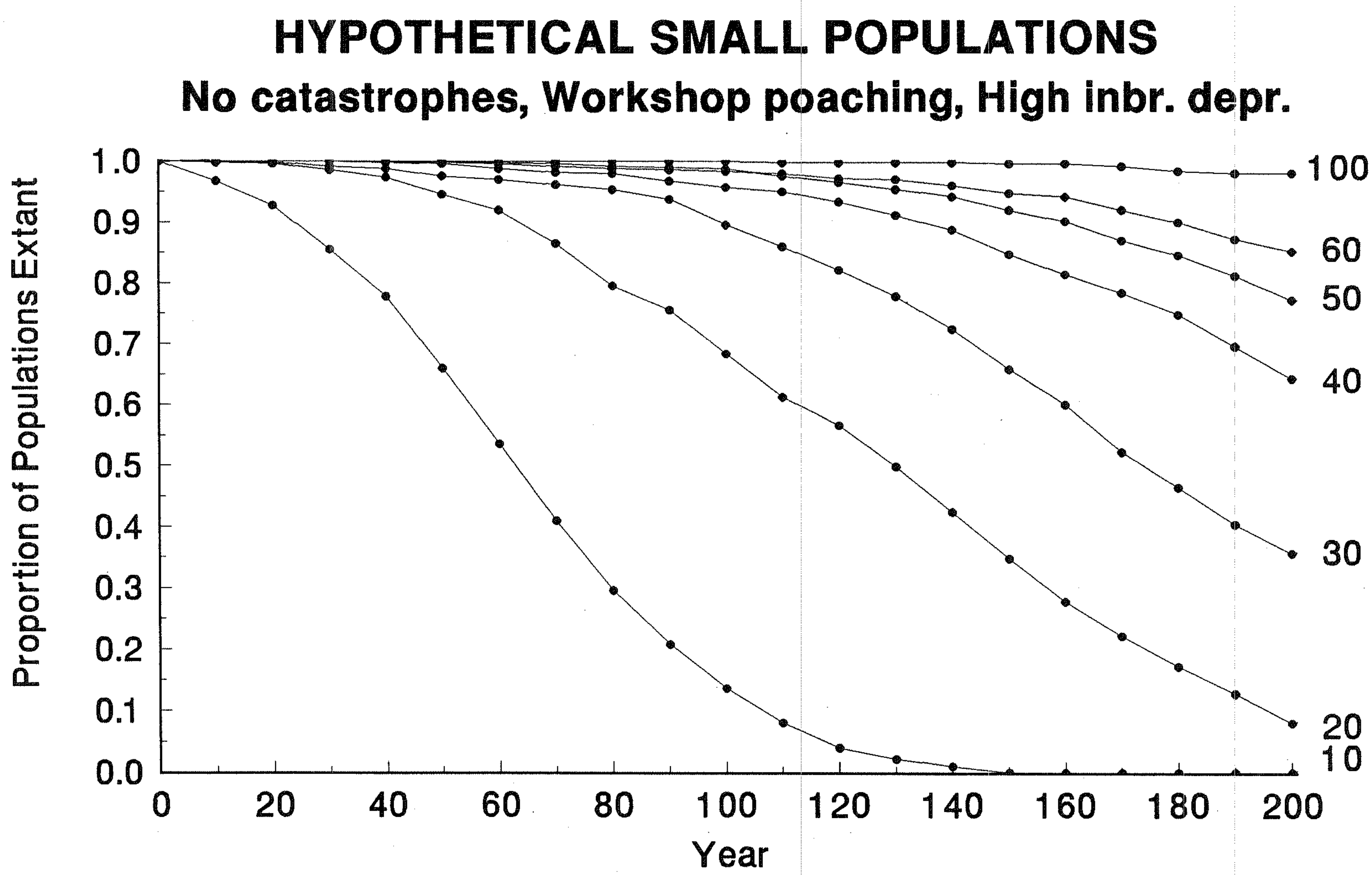

HYPOTHETICAL SMALL POPULATIONS
Disease, Drought, No poaching, High inbr. depr.
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 8b.



HYPOTHETICAL SMALL POPULATIONS
Disease, Drought, No poaching, High inbr. depr.
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
10
20

Figure 9a.



HYPOTHETICAL SMALL POPULATIONS
No catastrophes, Workshop poaching, High inbr. depr.
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 9b.

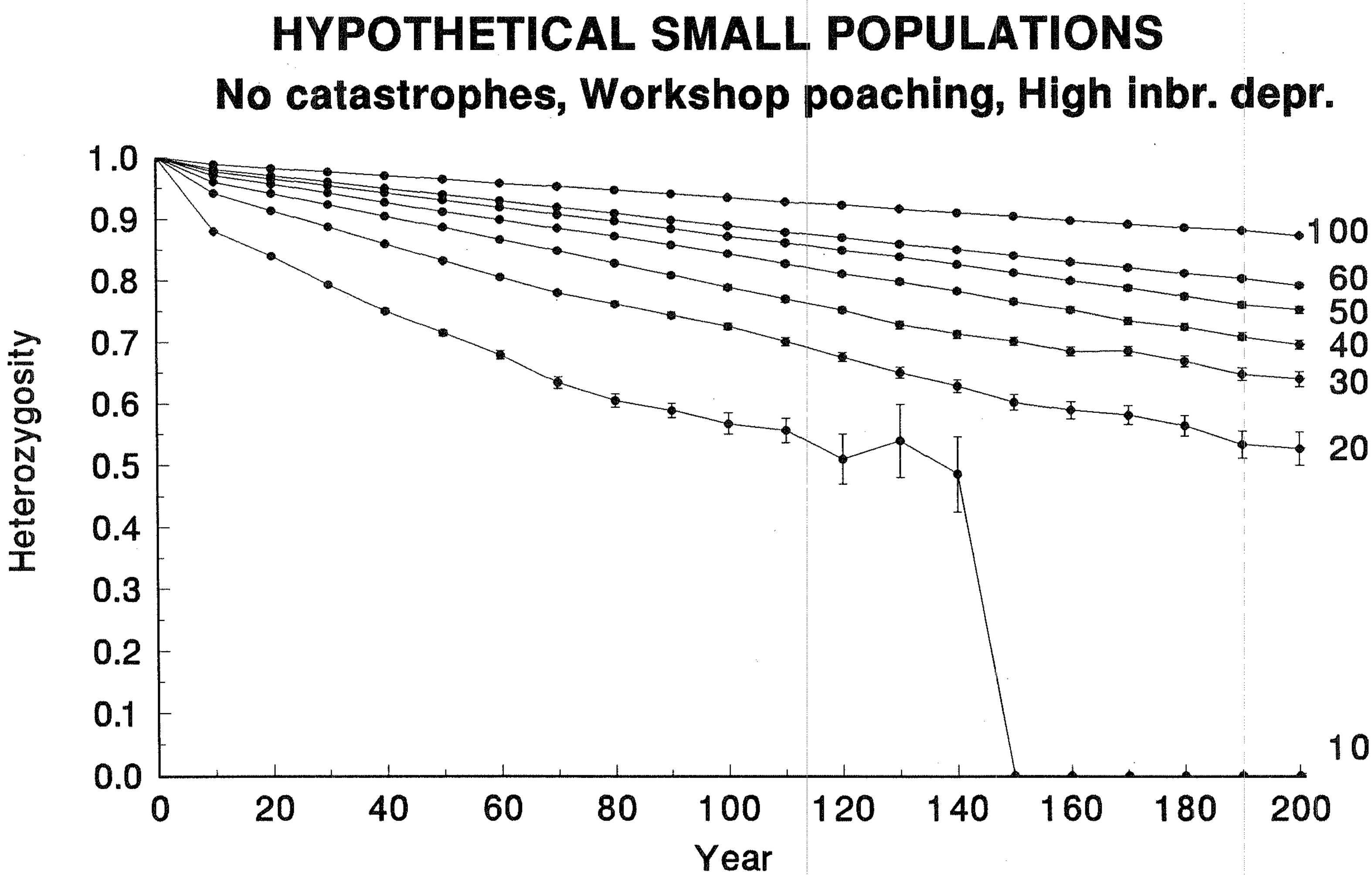

HYPOTHETICAL SMALL POPULATIONS
No catastrophes, Workshop poaching, High inbr. depr.
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 10a.

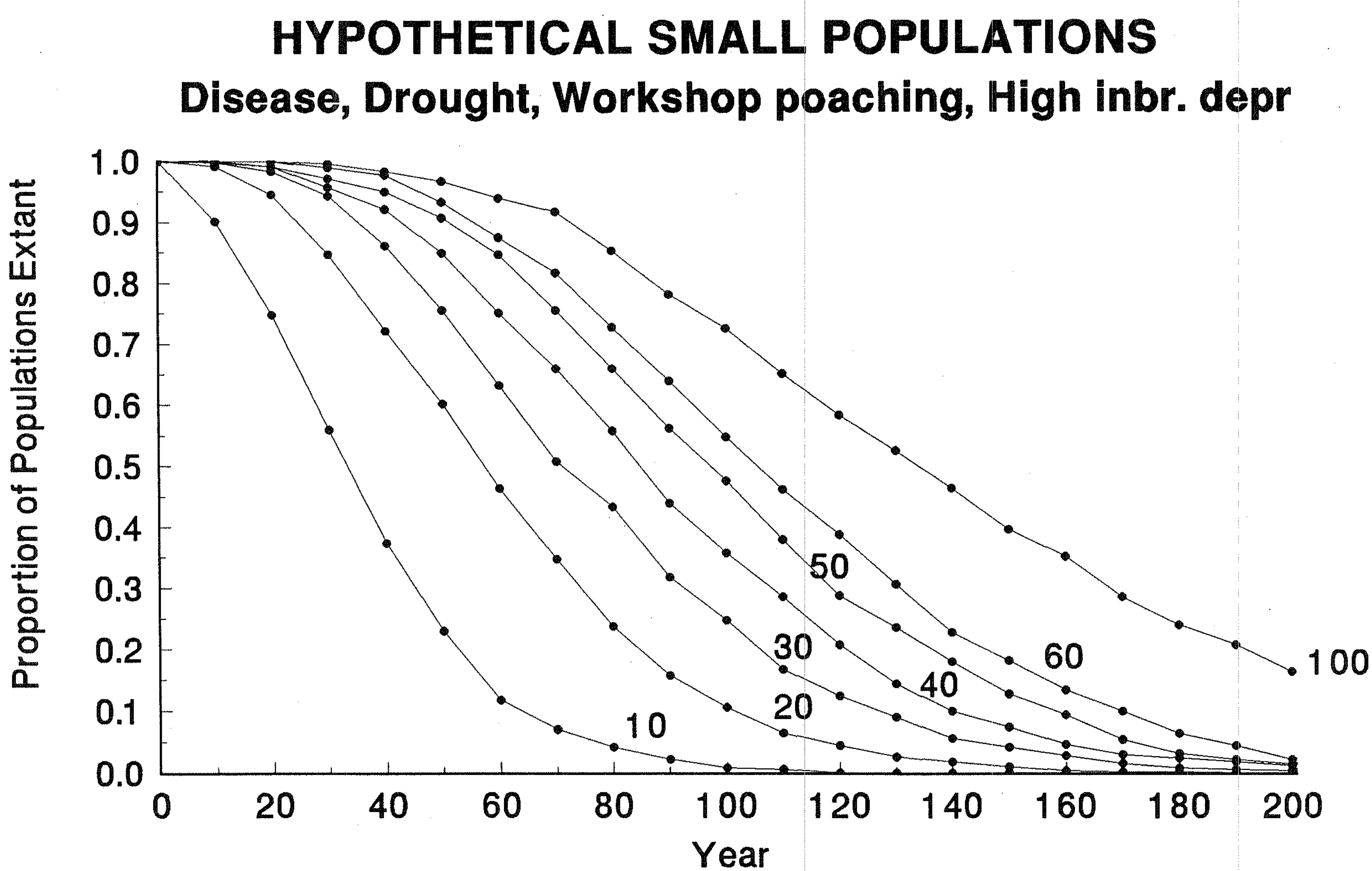
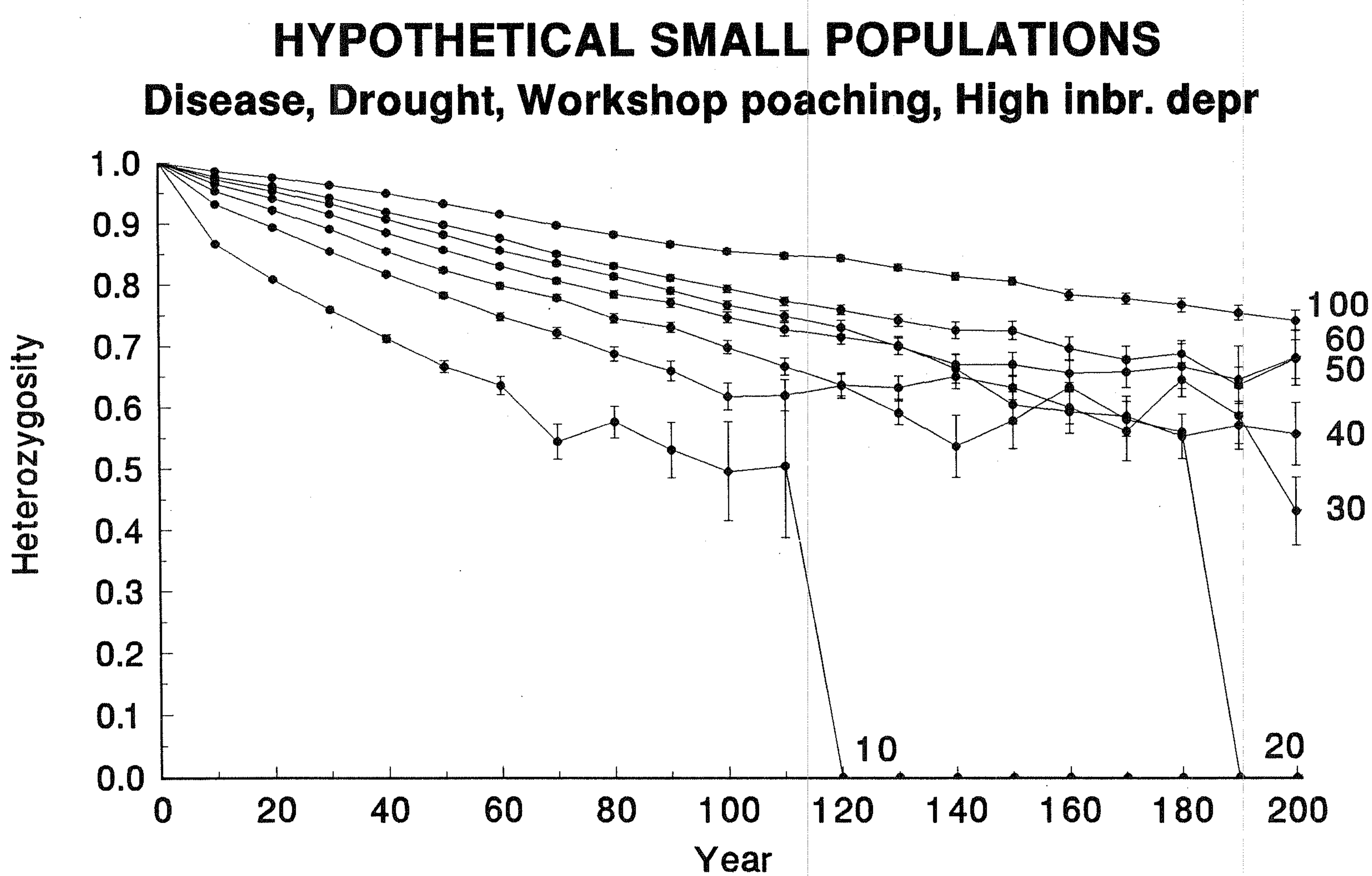
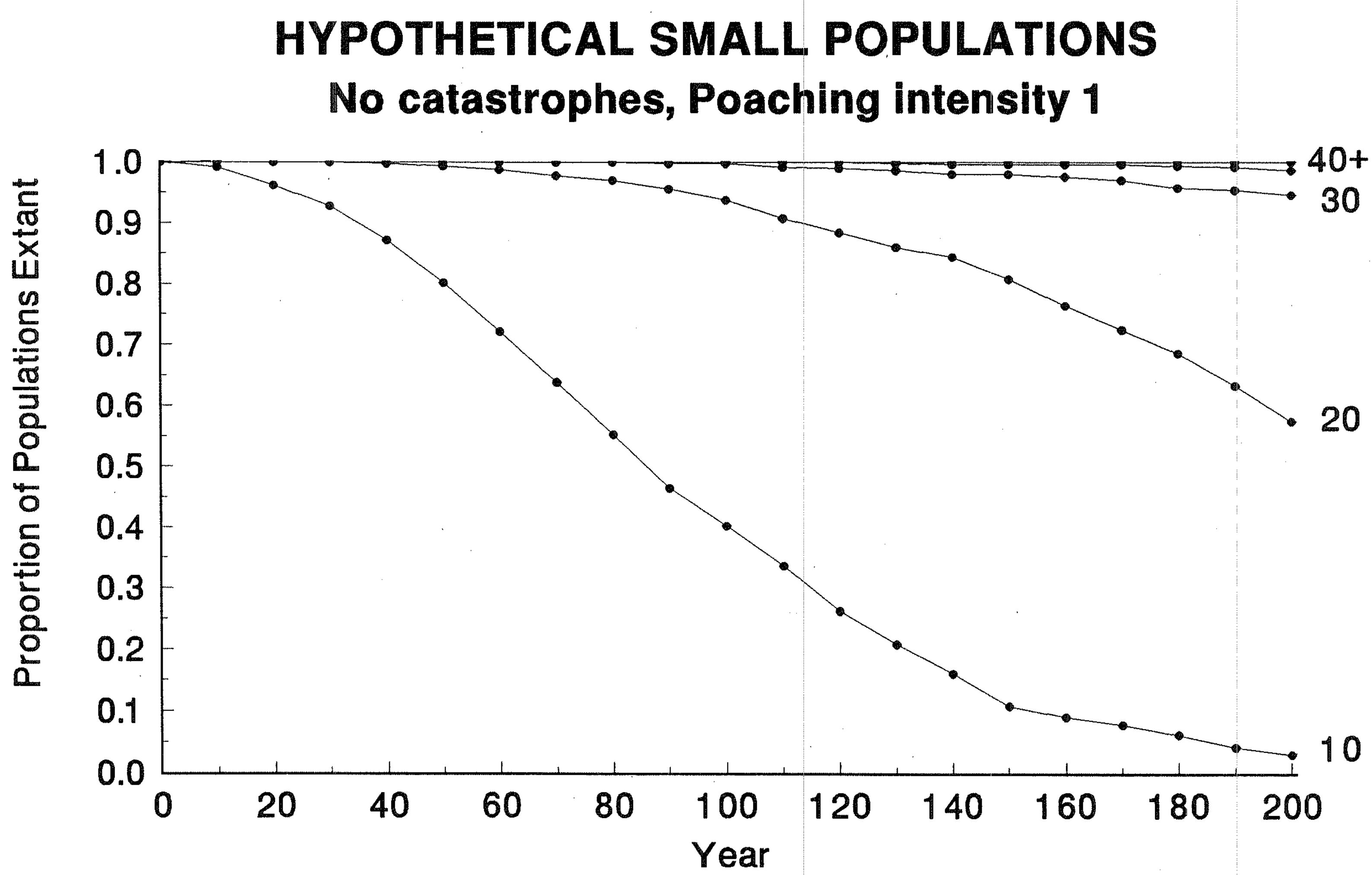

HYPOTHETICAL SMALL POPULATIONS
Disease, Drought, Workshop poaching, High inbr. depr
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
10
20
30
40
50
60
100

Figure 1 0b.



HYPOTHETICAL SMALL POPULATIONS
Disease, Drought, Workshop poaching, High inbr. depr
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
10
20

Figure 11 a.



HYPOTHETICAL SMALL POPULATIONS
No catastrophes, Poaching intensity 1
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
40+
30
20
10

Figure 11b.

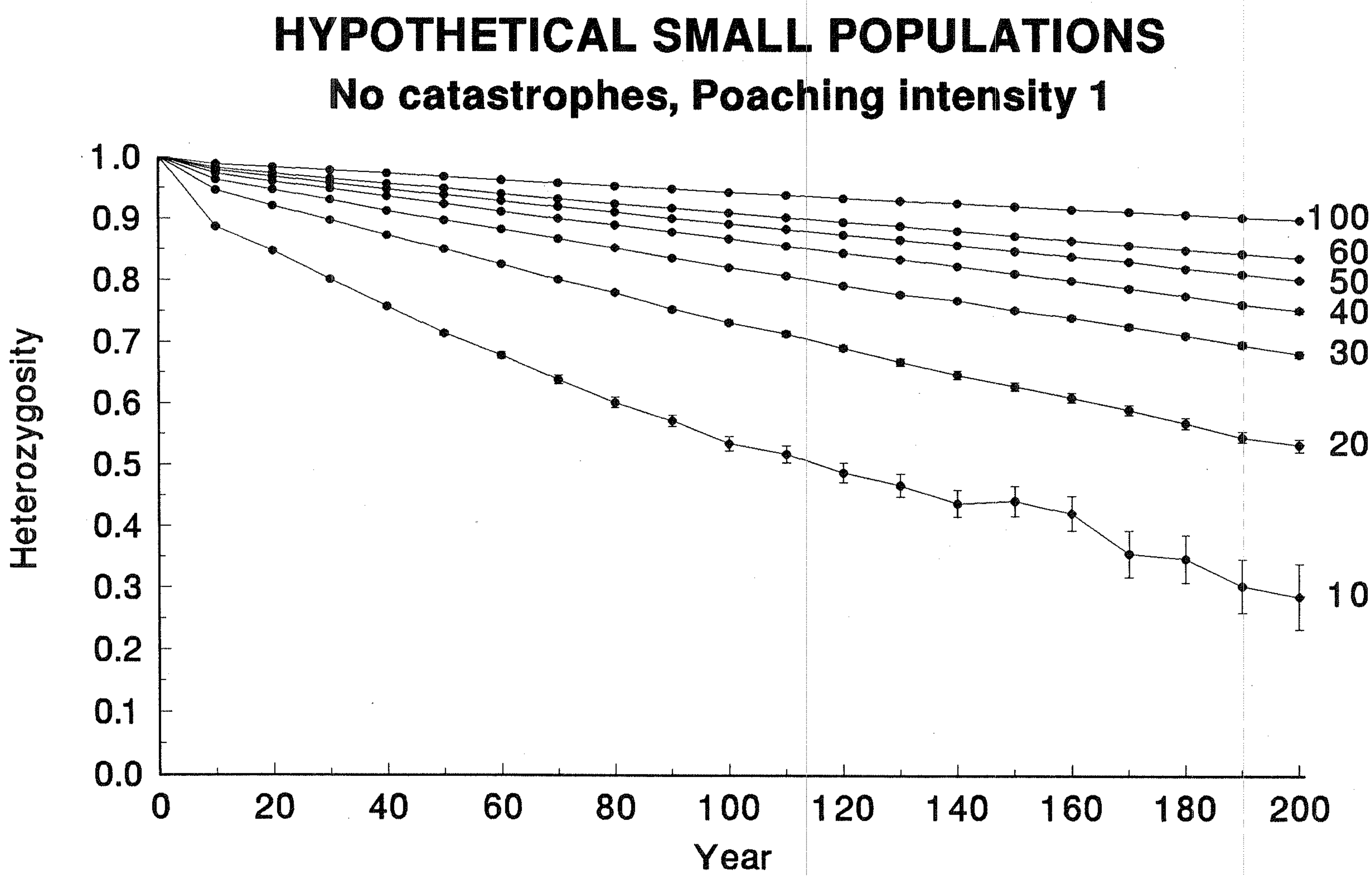

HYPOTHETICAL SMALL POPULATIONS
No catastrophes, Poaching intensity 1
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 12a.

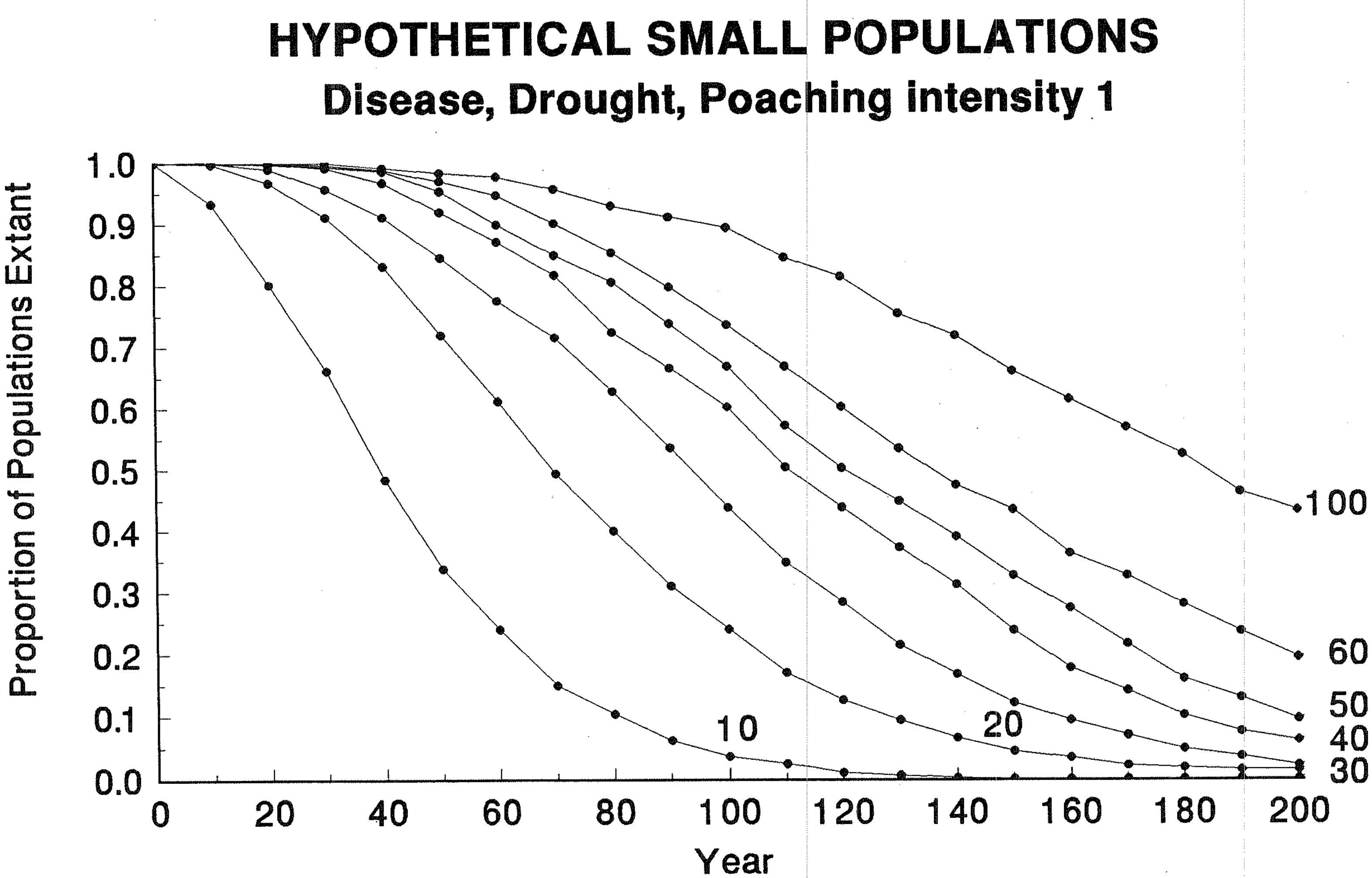

HYPOTHETICAL SMALL POPULATIONS
Disease, Drought, Poaching intensity 1
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 12b.

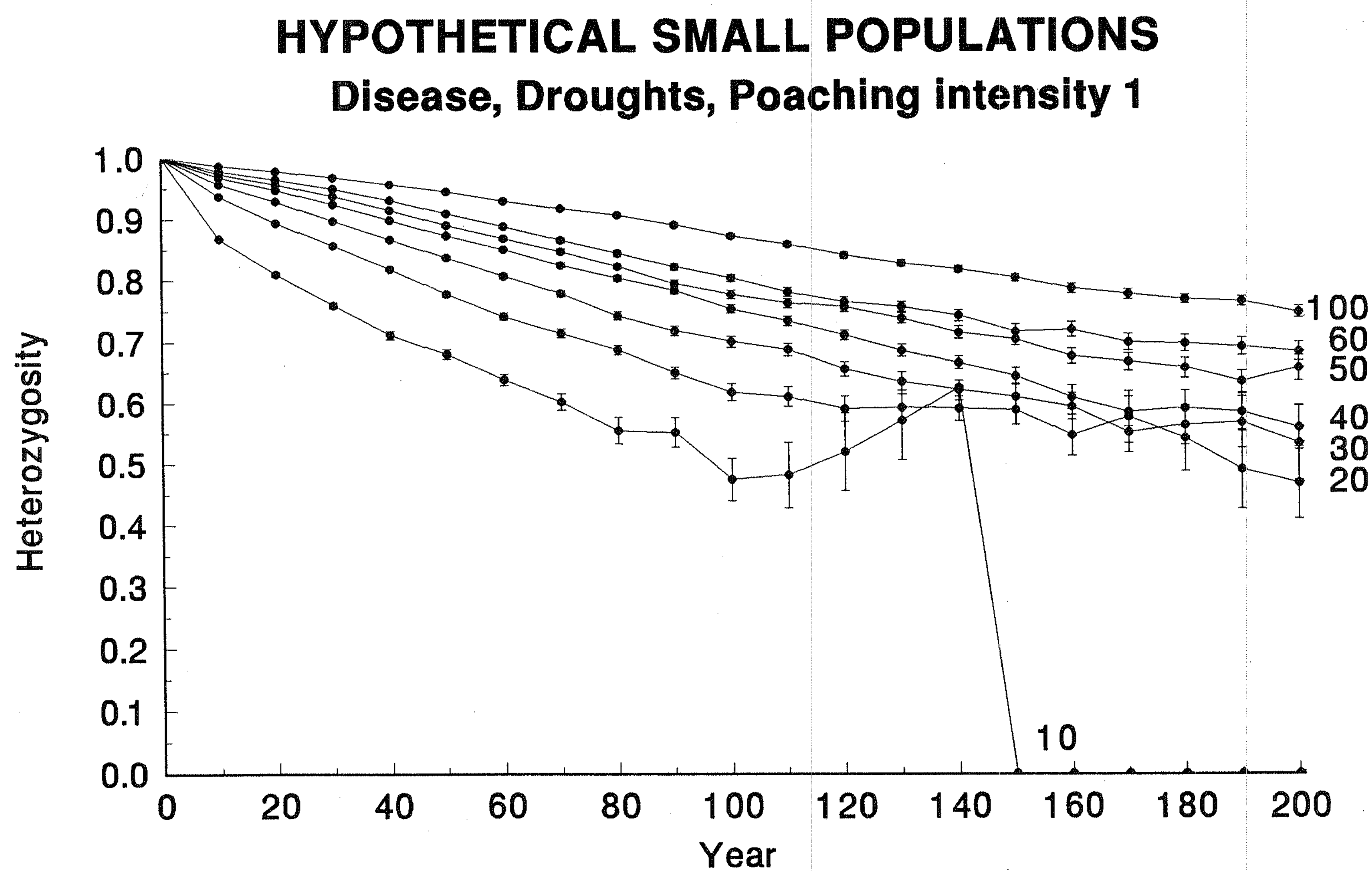
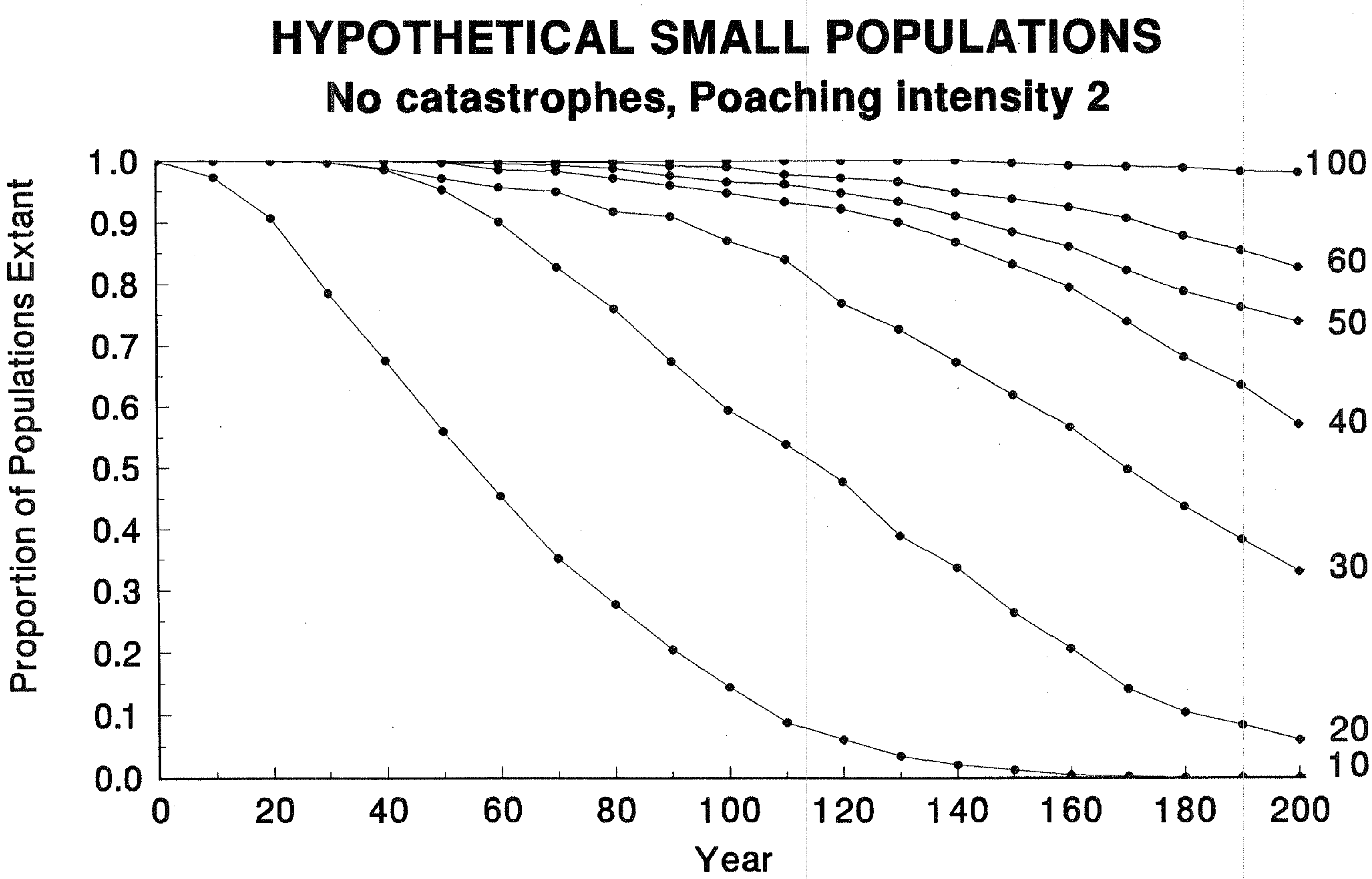
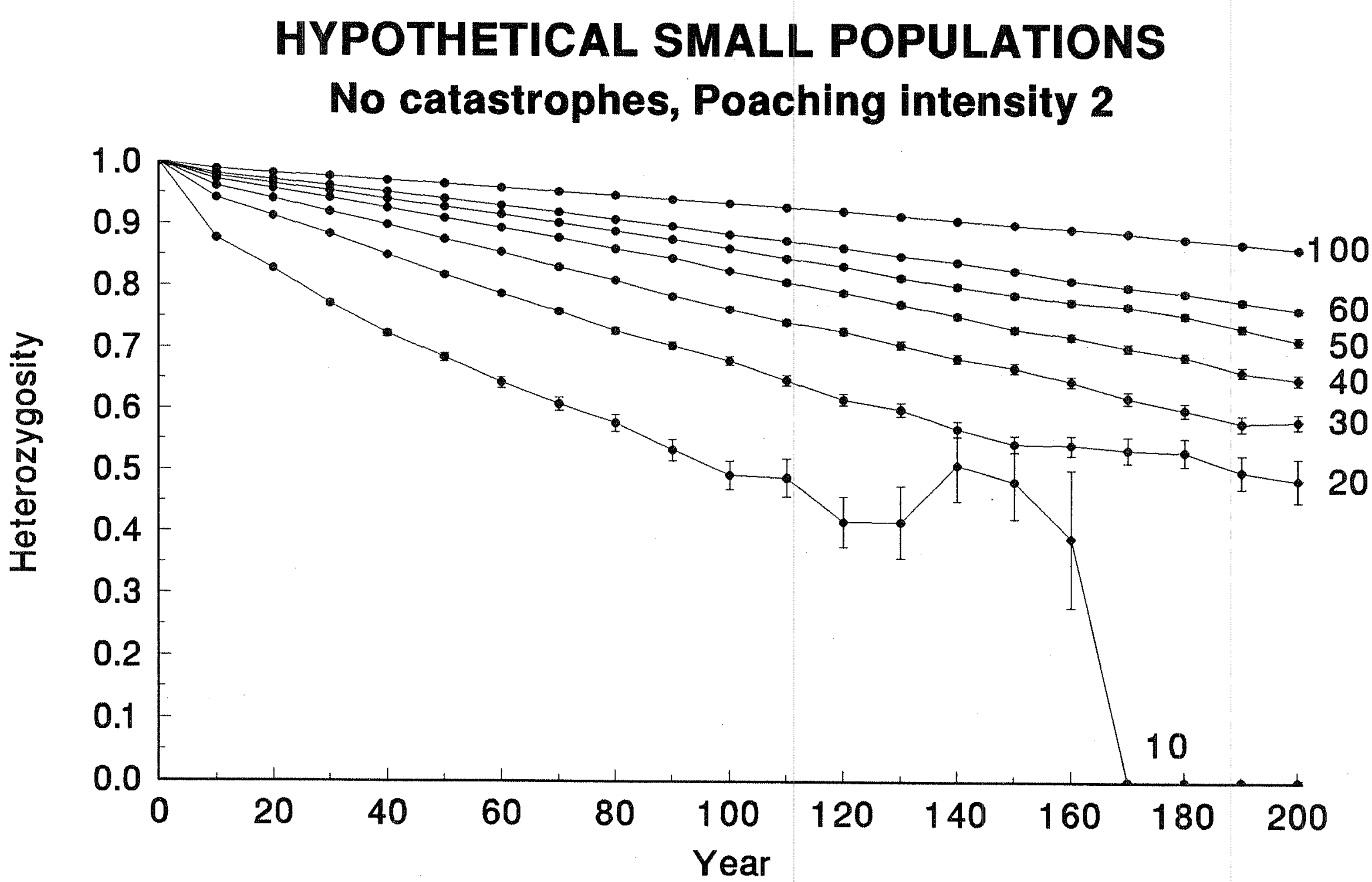

HYPOTHETICAL SMALL POPULATIONS
Disease, Droughts, Poaching intensity 1
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 13a.



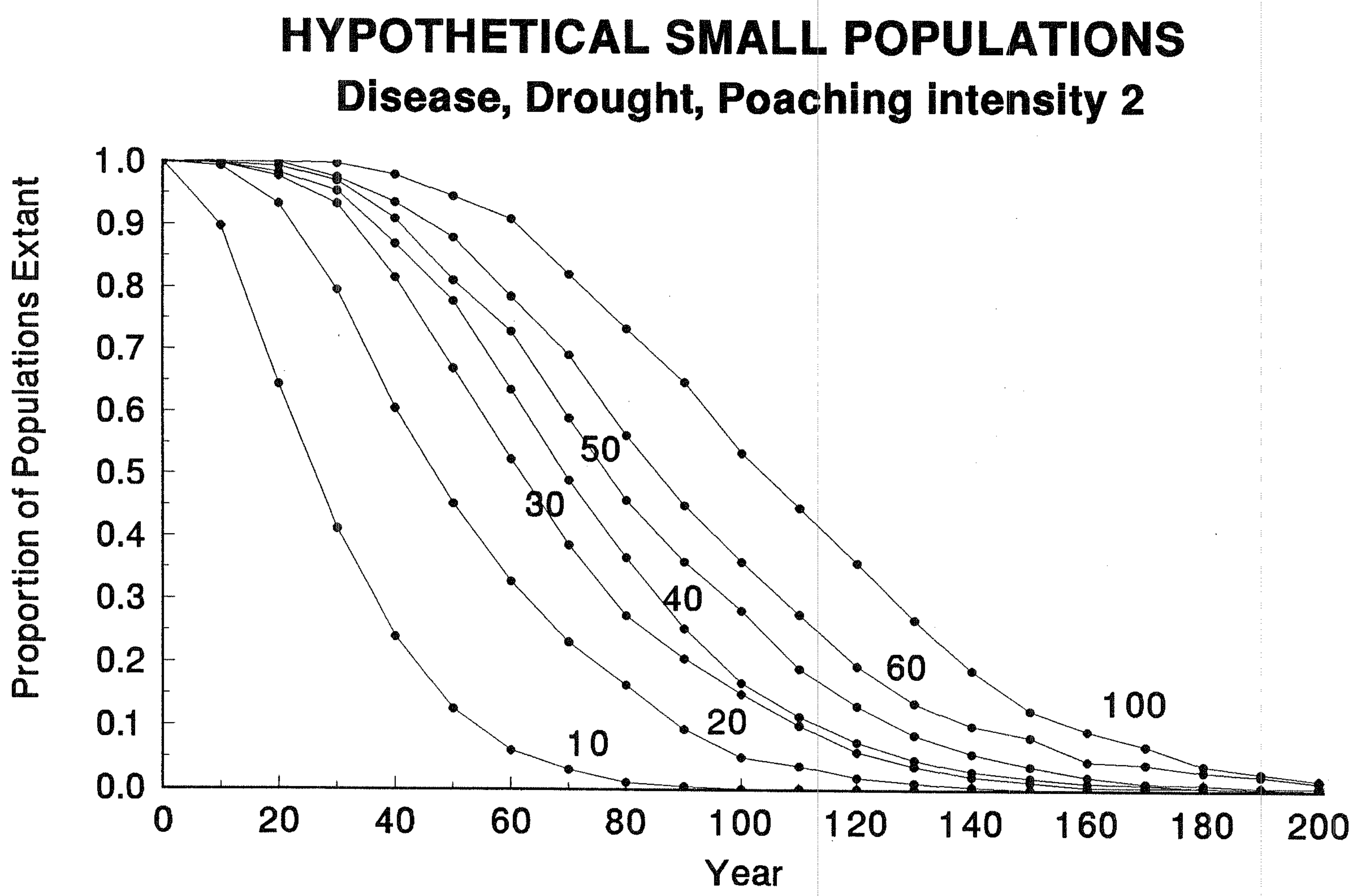
HYPOTHETICAL SMALL POPULATIONS
No catastrophes, Poaching intensity 2
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 13b.



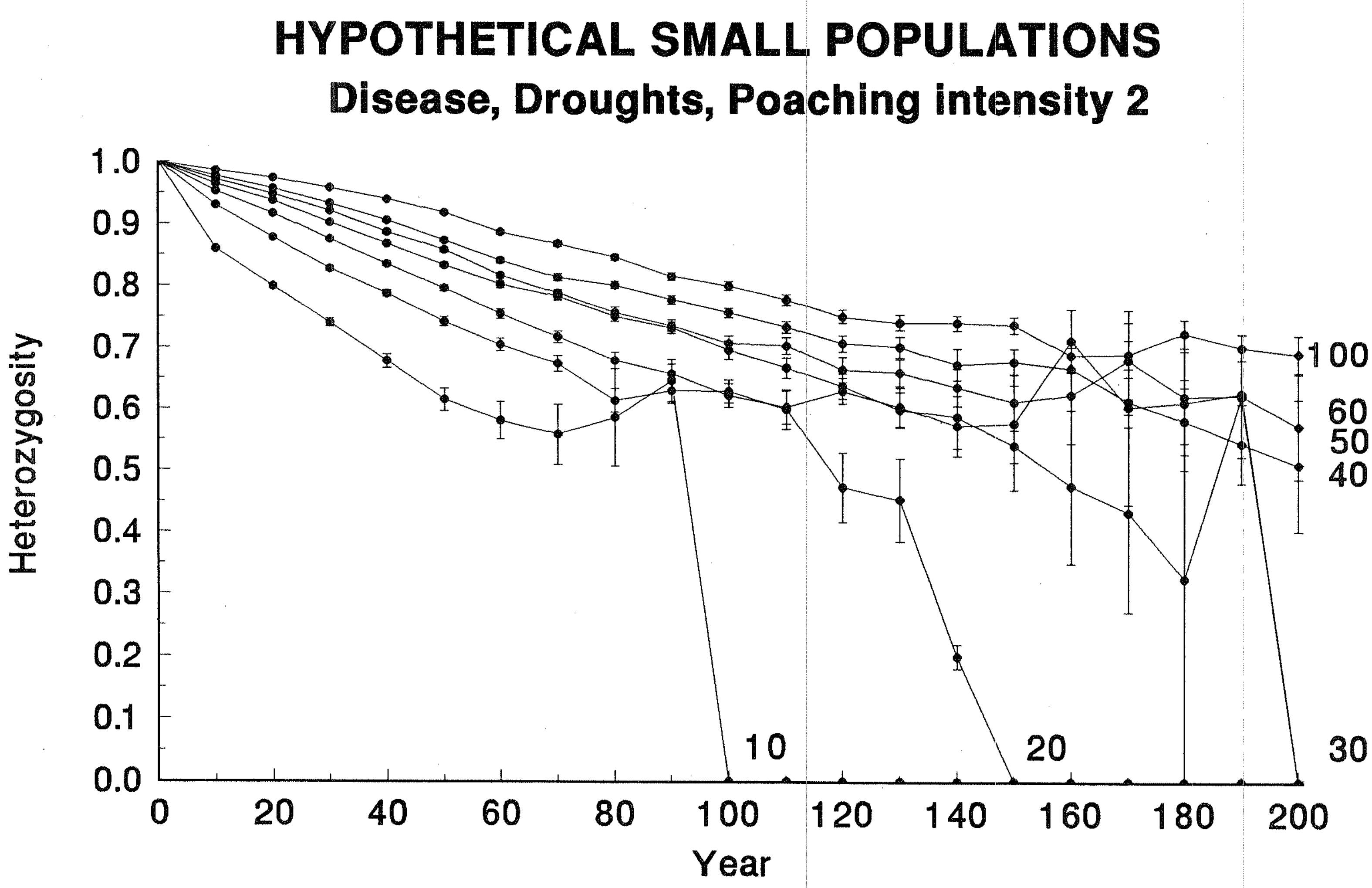
HYPOTHETICAL SMALL POPULATIONS
No catastrophes, Poaching intensity 2
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
30
20
10

Figure 14a.



HYPOTHETICAL SMALL POPULATIONS
Disease, Drought, Poaching intensity 2
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
10
20
30
40
50
60
100

Figure 14b.



HYPOTHETICAL SMALL POPULATIONS
Disease, Droughts, Poaching intensity 2
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
100
60
50
40
10
20
30

Figure 15a.

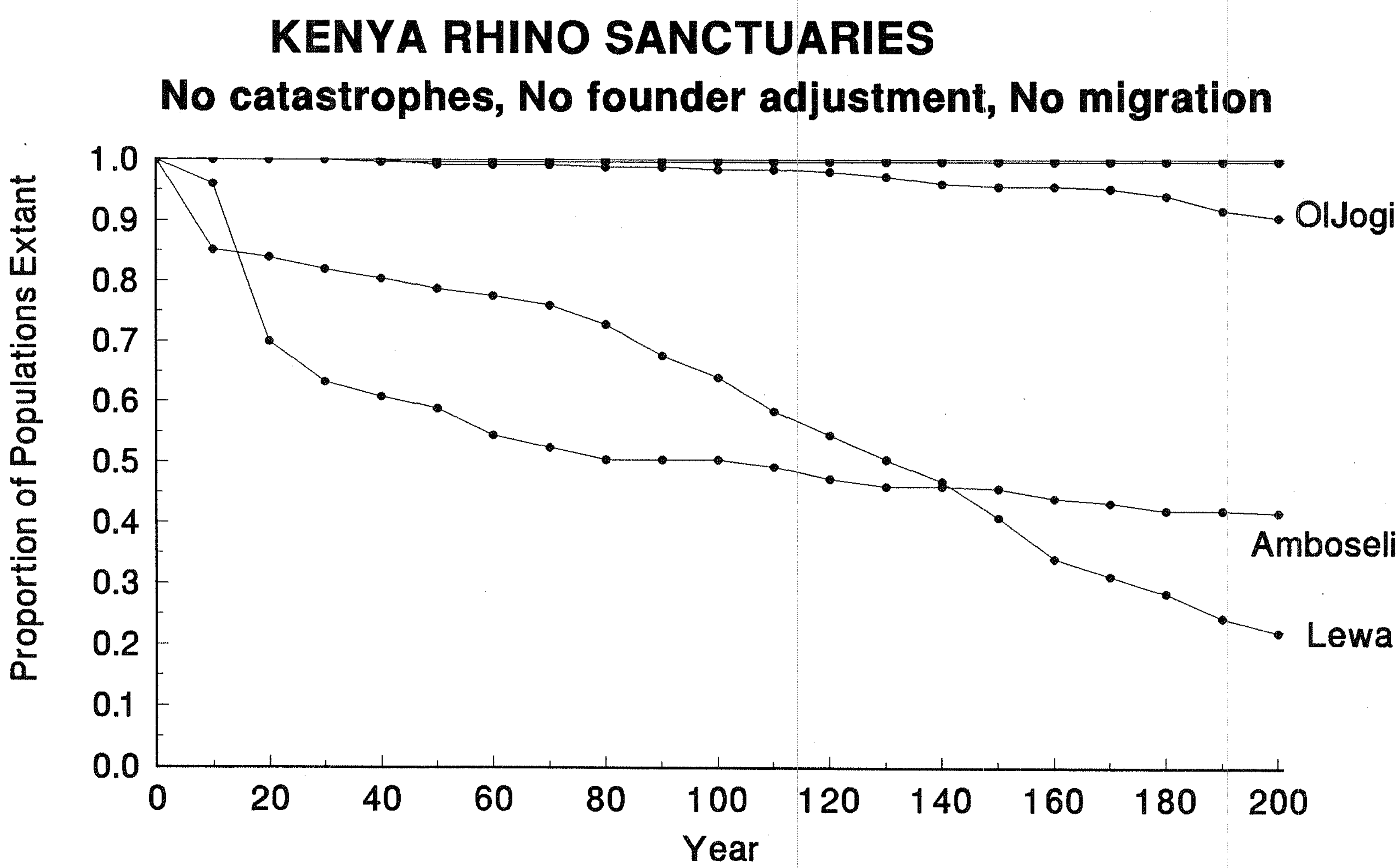

KENYA RHINO SANCTUARIES
No catastrophes, No founder adjustment, No migration
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
OlJogi
Amboseli
Lewa

Figure 15b.

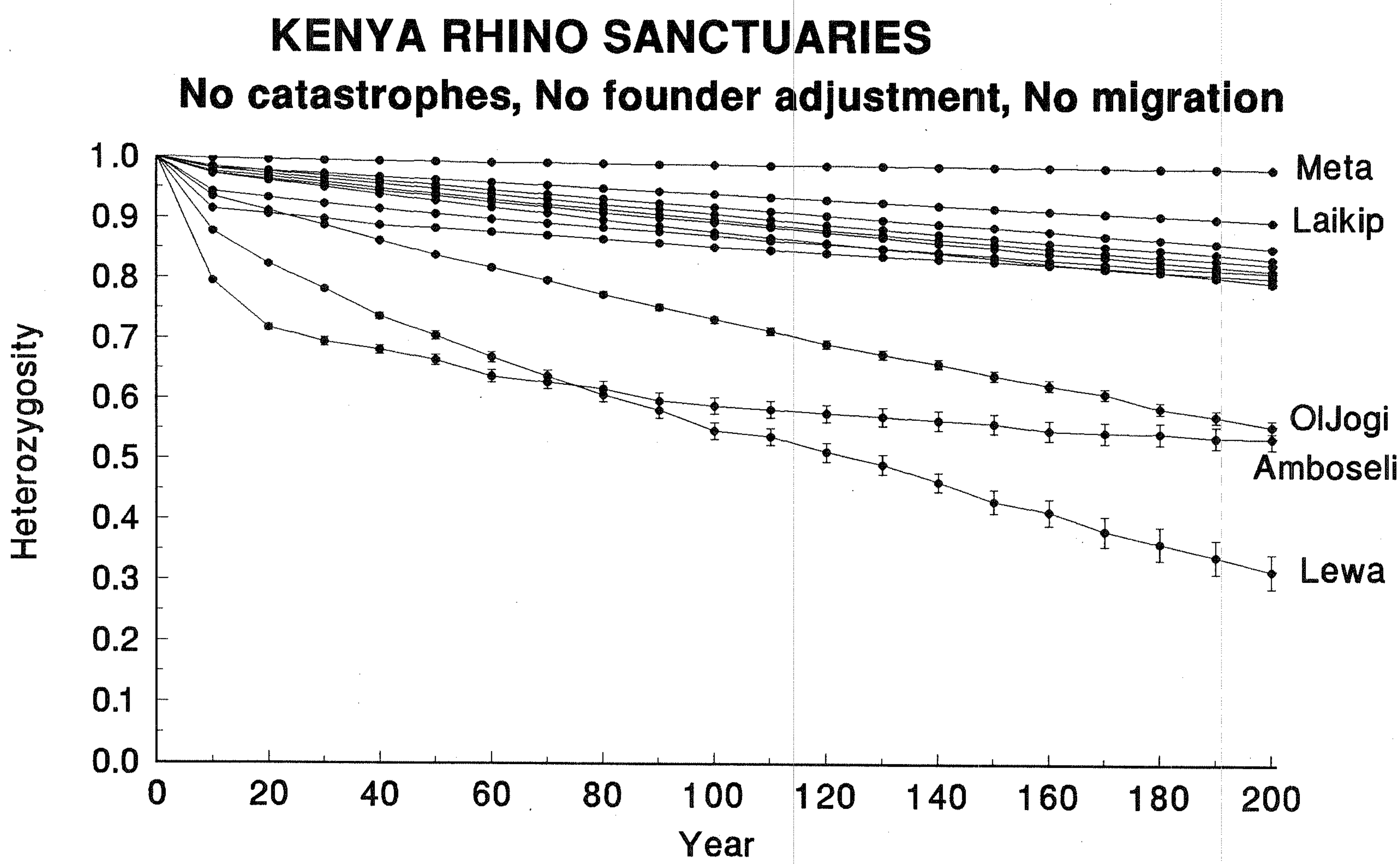
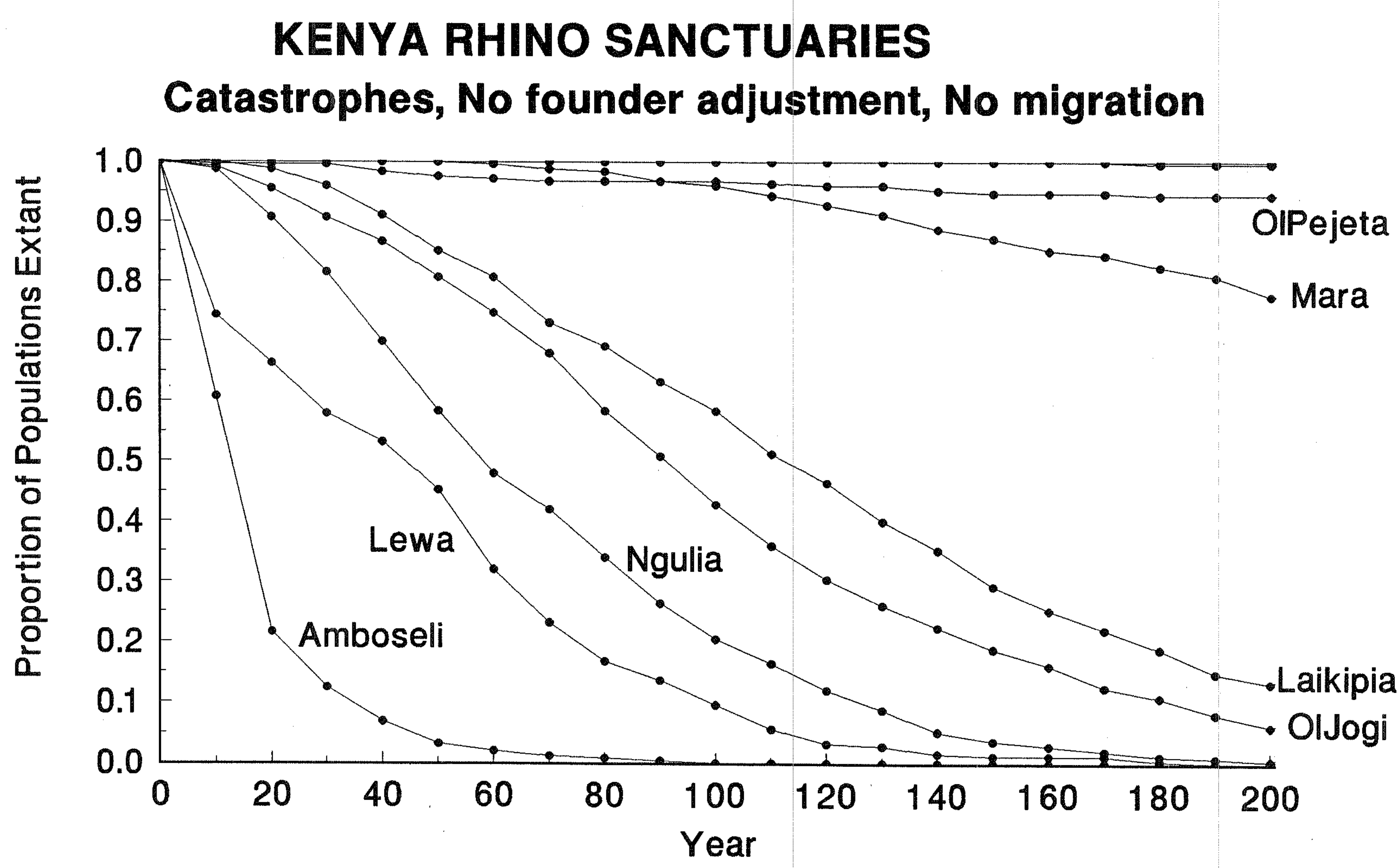
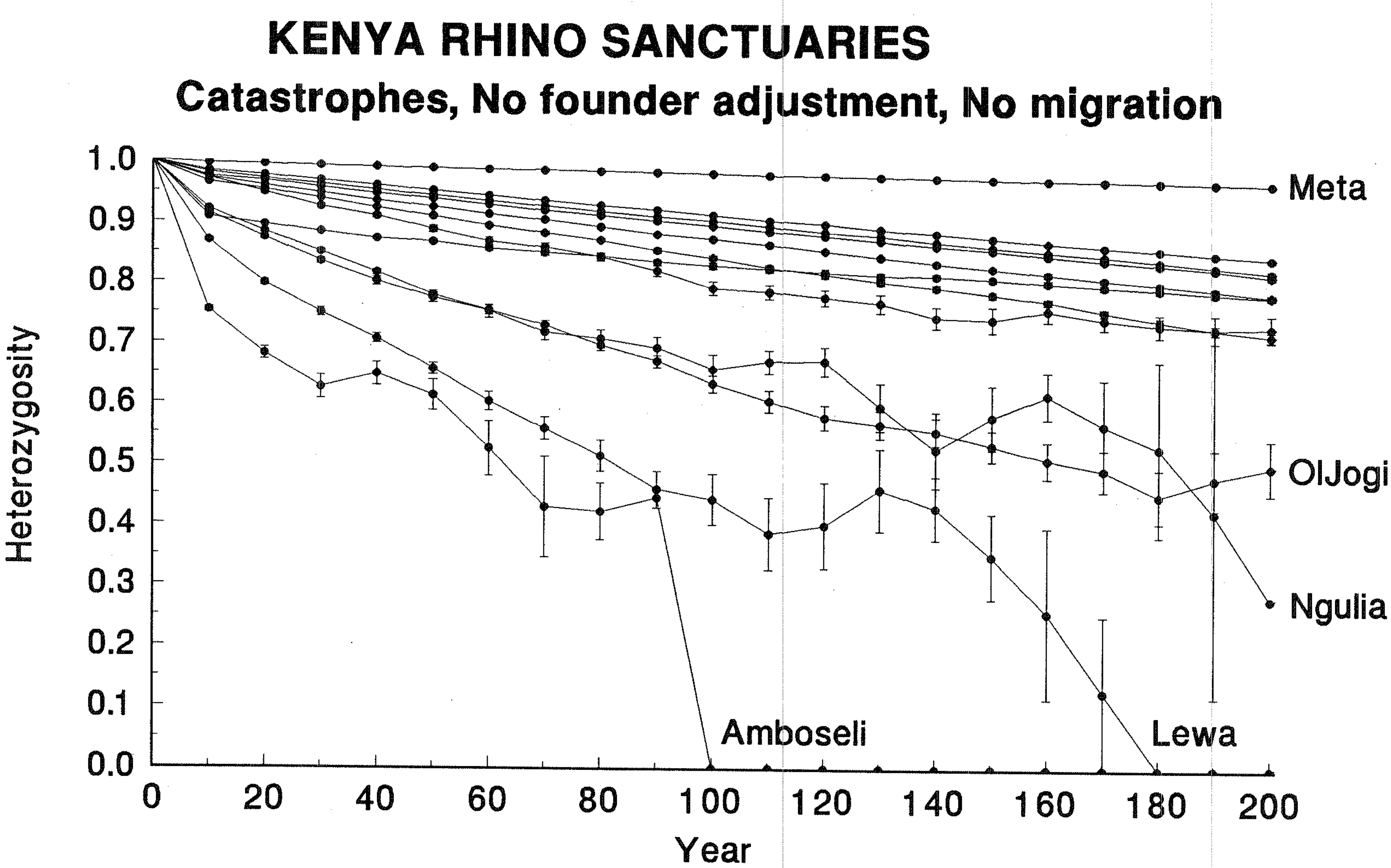

KENYA RHINO SANCTUARIES
No catastrophes, No founder adjustment, No migration
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
Meta
Laikip
OlJogi
Amboseli
Lewa

Figure 16a.



KENYA RHINO SANCTUARIES
Catastrophes, No founder adjustment, No migration
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
OlPejeta
Mara
Lewa
Ngulia
Amboseli
Laikipia
OlJogi

Figure 16b.



KENYA RHINO SANCTUARIES
Catastrophes, No founder adjustment, No migration
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
Meta
OlJogi
Ngulia
Amboseli
Lewa

Figure 17a.

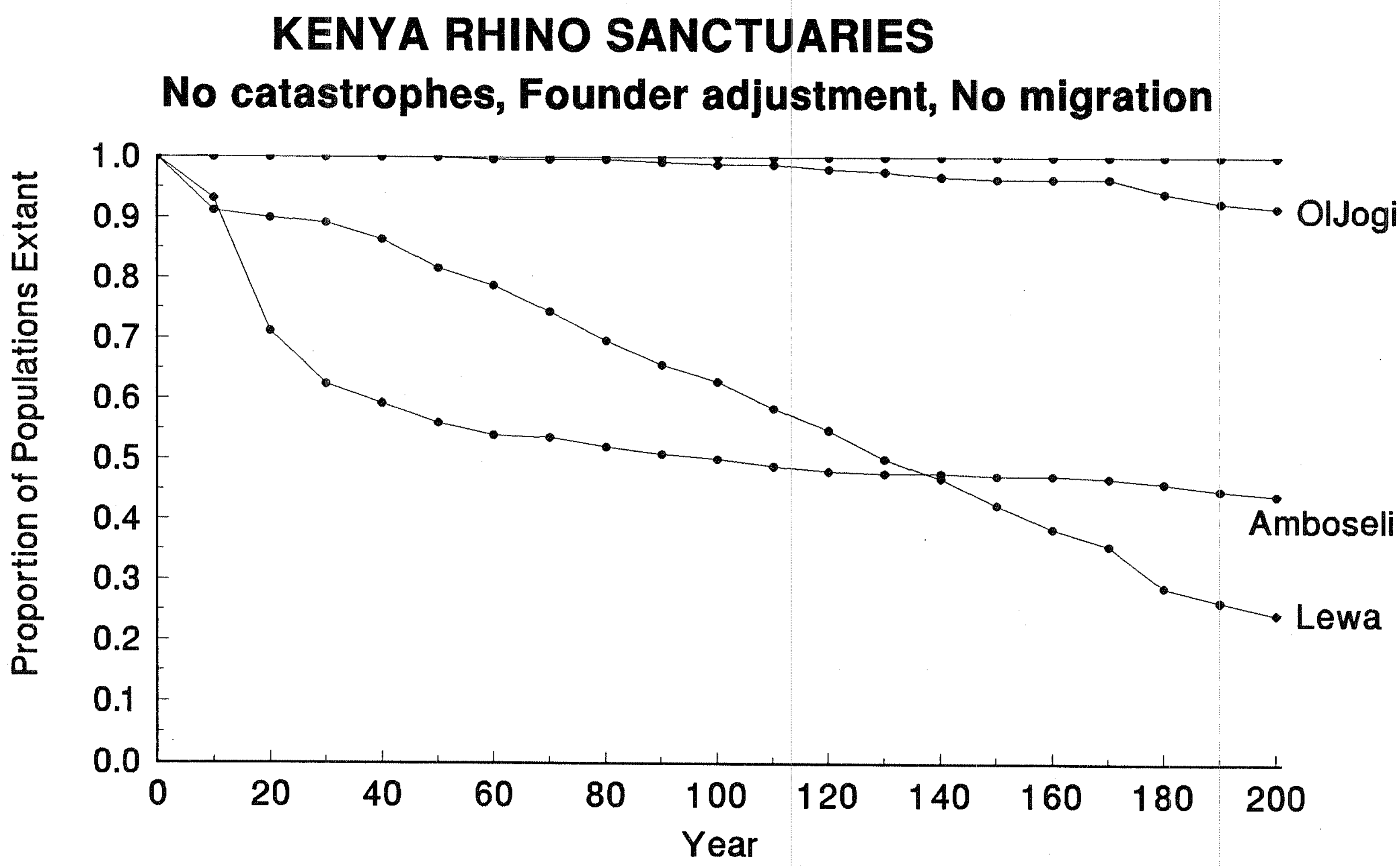

KENYA RHINO SANCTUARIES
No catastrophes, Founder adjustment, No migration
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
OlJogi
Amboseli
Lewa

Figure 17b.

KENYA RHINO SANCTUARIES

No catastrophes, Founder adjustment, No migration

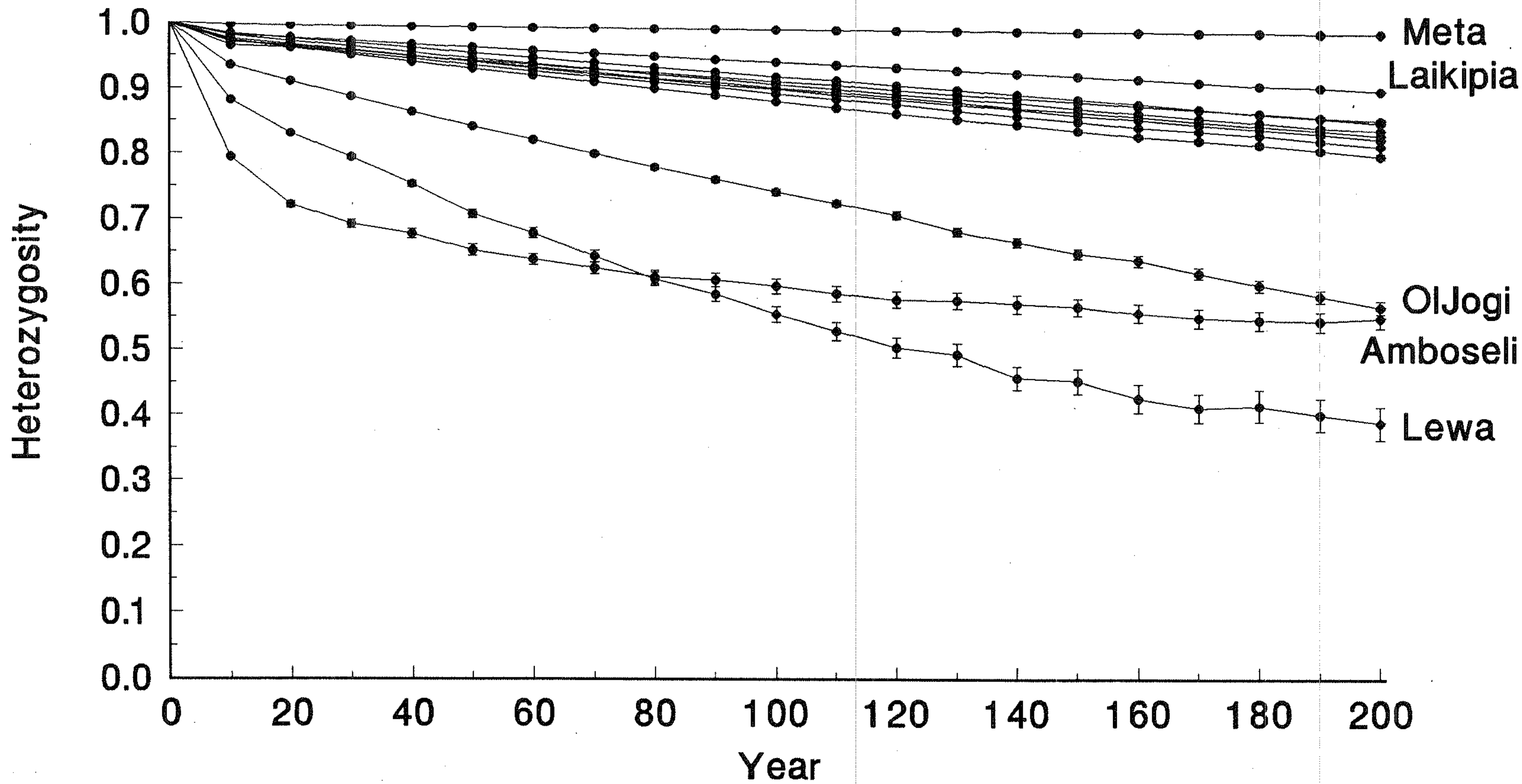


Figure 18a.

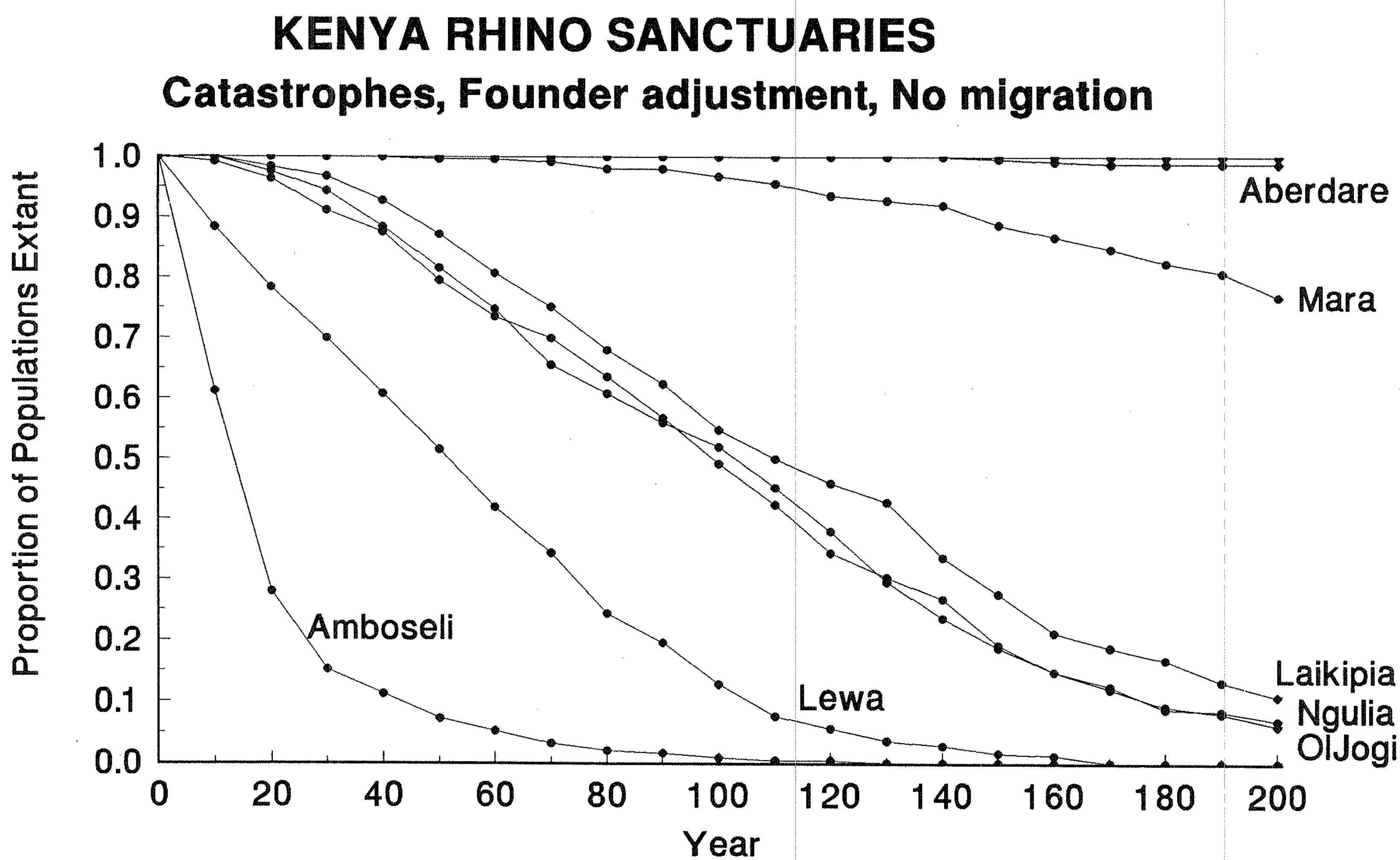

KENYA RHINO SANCTUARIES
Catastrophes, Founder adjustment, No migration
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
Aberdare
Mara
Laikipia
Ngulia
OlJogi
Lewa
Amboseli

Figure 18b.

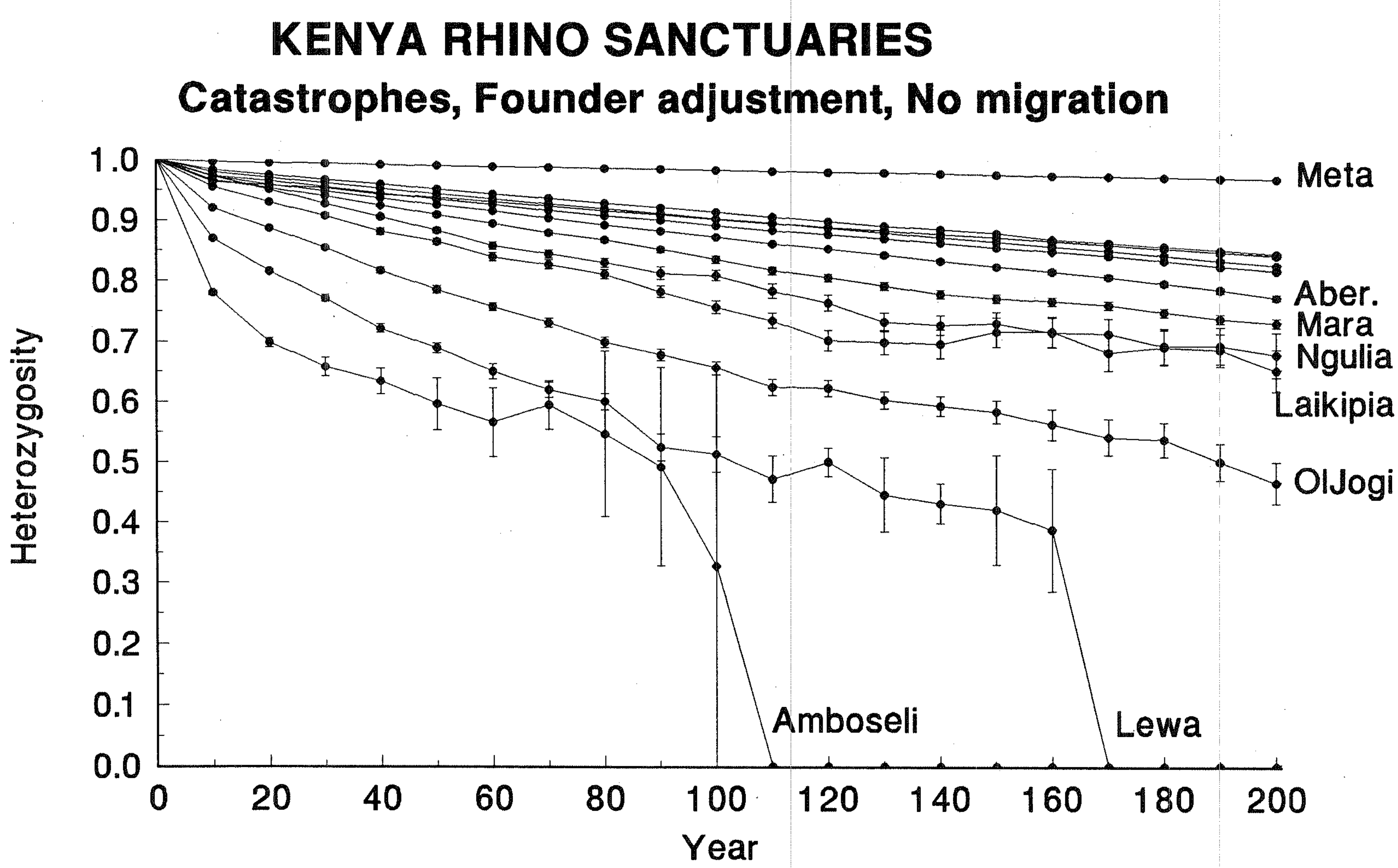

KENYA RHINO SANCTUARIES
Catastrophes, Founder adjustment, No migration
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
Meta
Aber.
Mara
Ngulia
Laikipia
OlJogi
Amboseli
Lewa

Figure 19a.

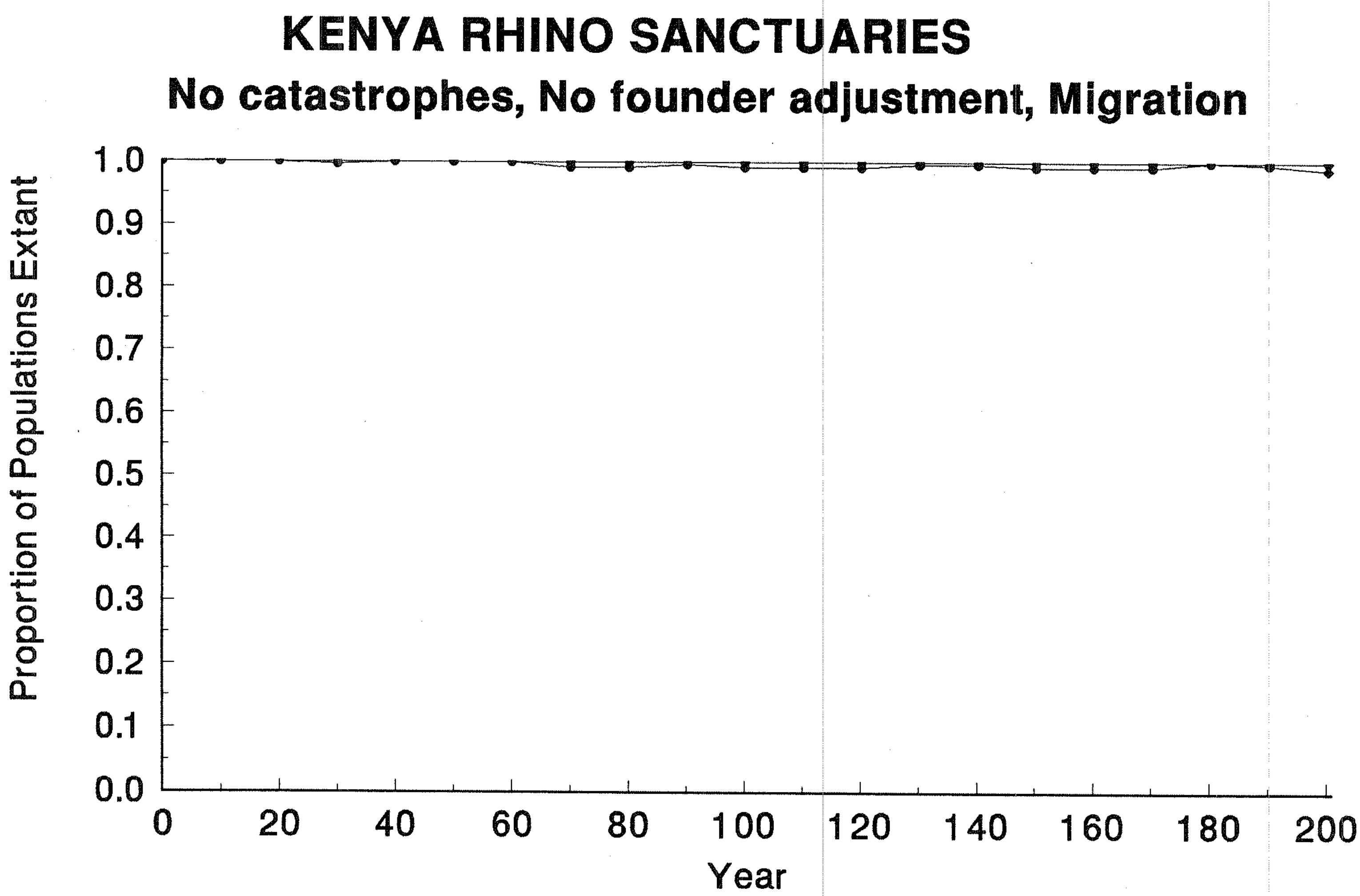

KENYA RHINO SANCTUARIES
No catastrophes, No founder adjustment, Migration
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year

Figure 19b.

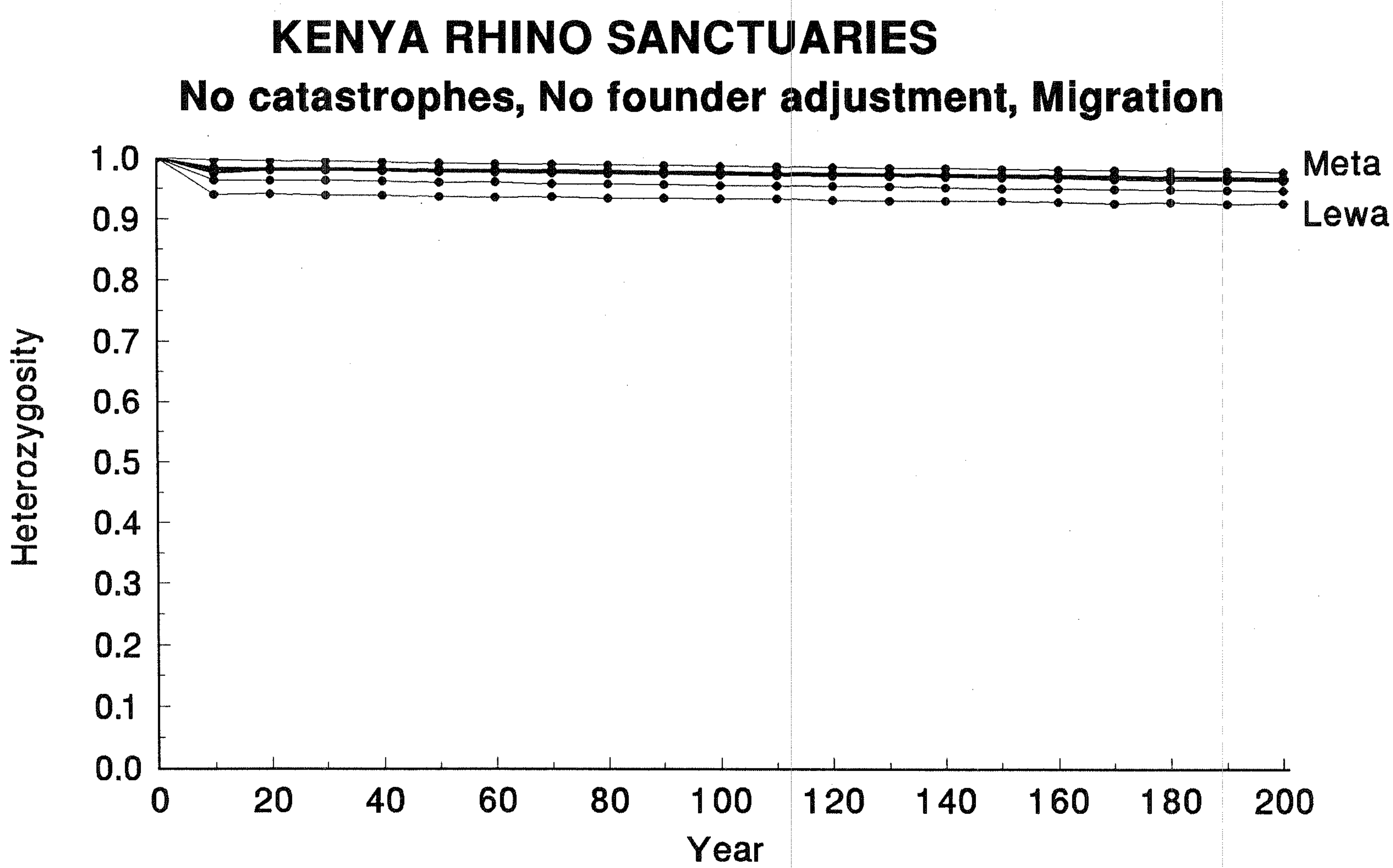

KENYA RHINO SANCTUARIES
No catastrophes, No founder adjustment, Migration
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
Meta
Lewa

Figure 20a.

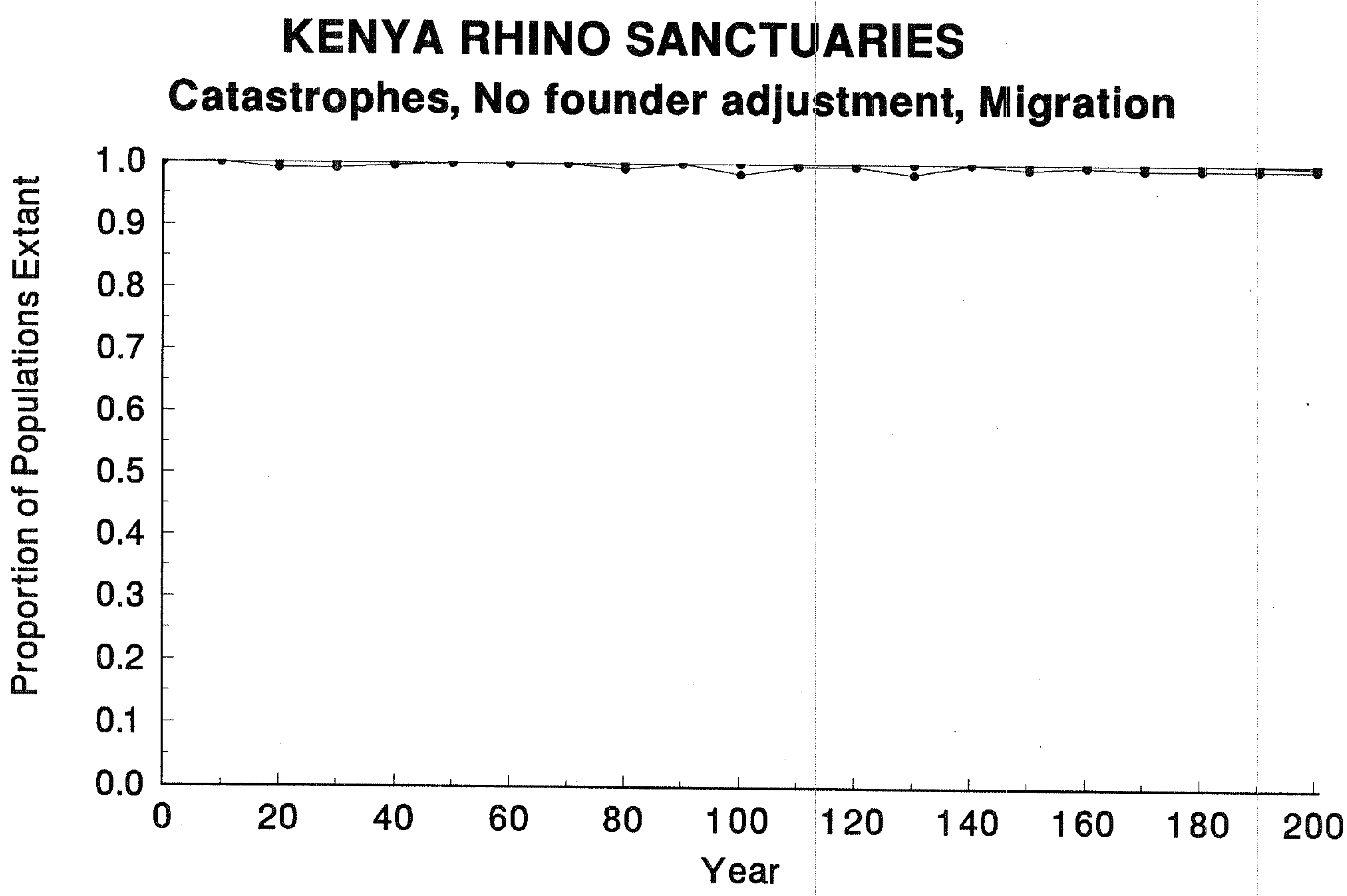

KENYA RHINO SANCTUARIES
Catastrophes, No founder adjustment, Migration
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year

Figure 20b.

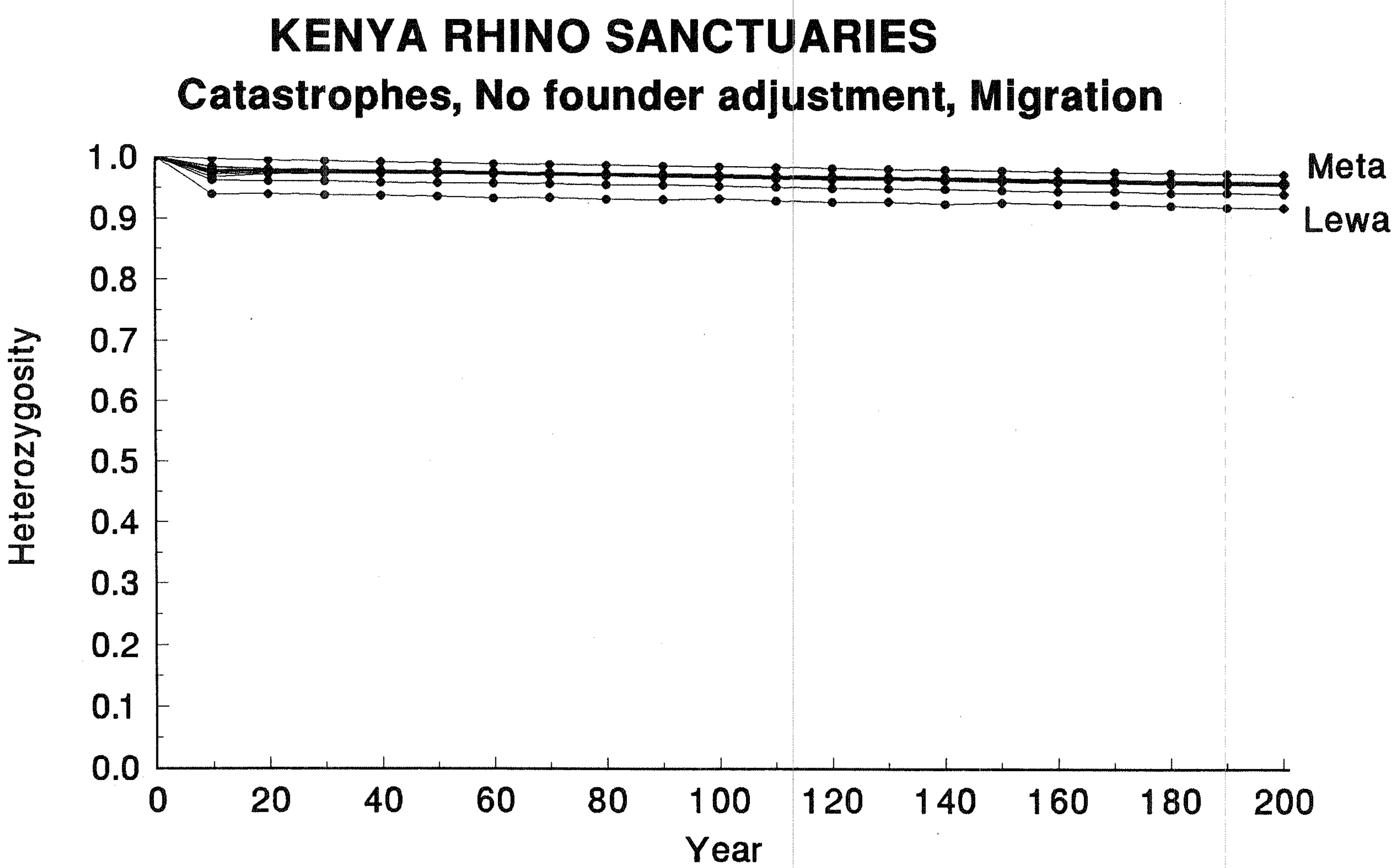

KENYA RHINO SANCTUARIES
Catastrophes, No founder adjustment, Migration
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
Meta
Lewa

Figure 21 a.

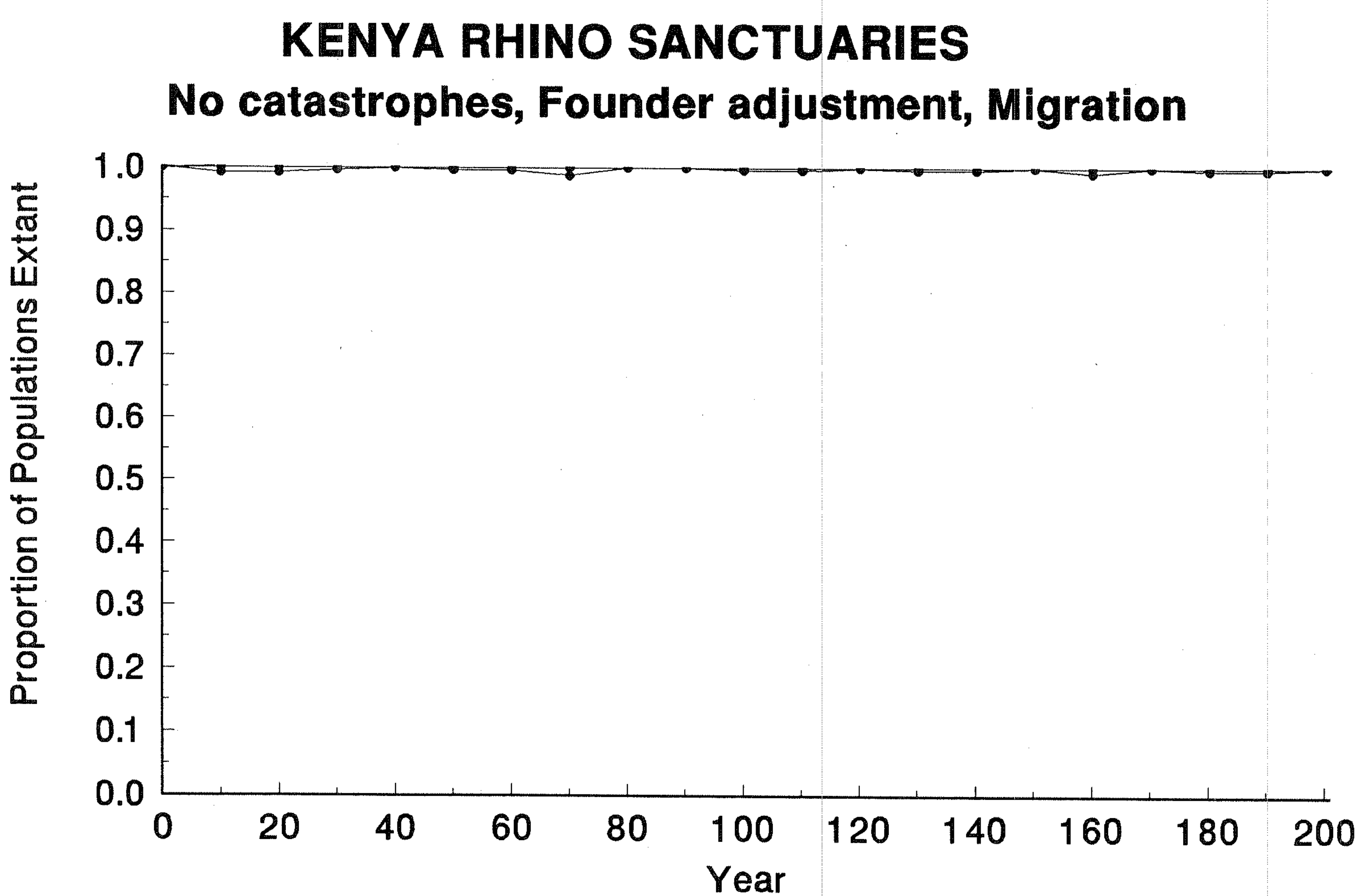

KENYA RHINO SANCTUARIES
No catastrophes, Founder adjustment, Migration
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year

Figure 21 b.

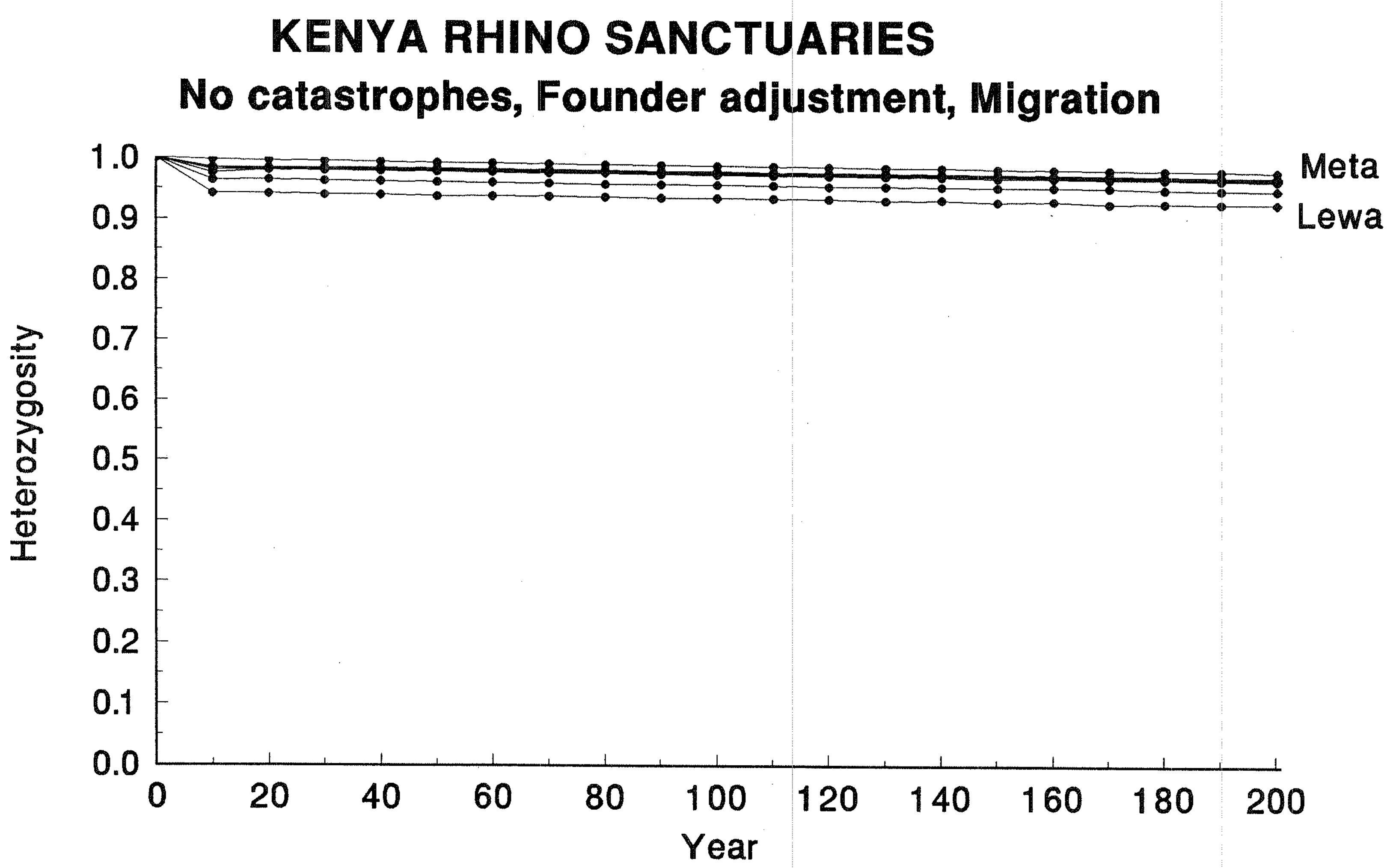

KENYA RHINO SANCTUARIES
No catastrophes, Founder adjustment, Migration
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
Meta
Lewa

Figure 22a.

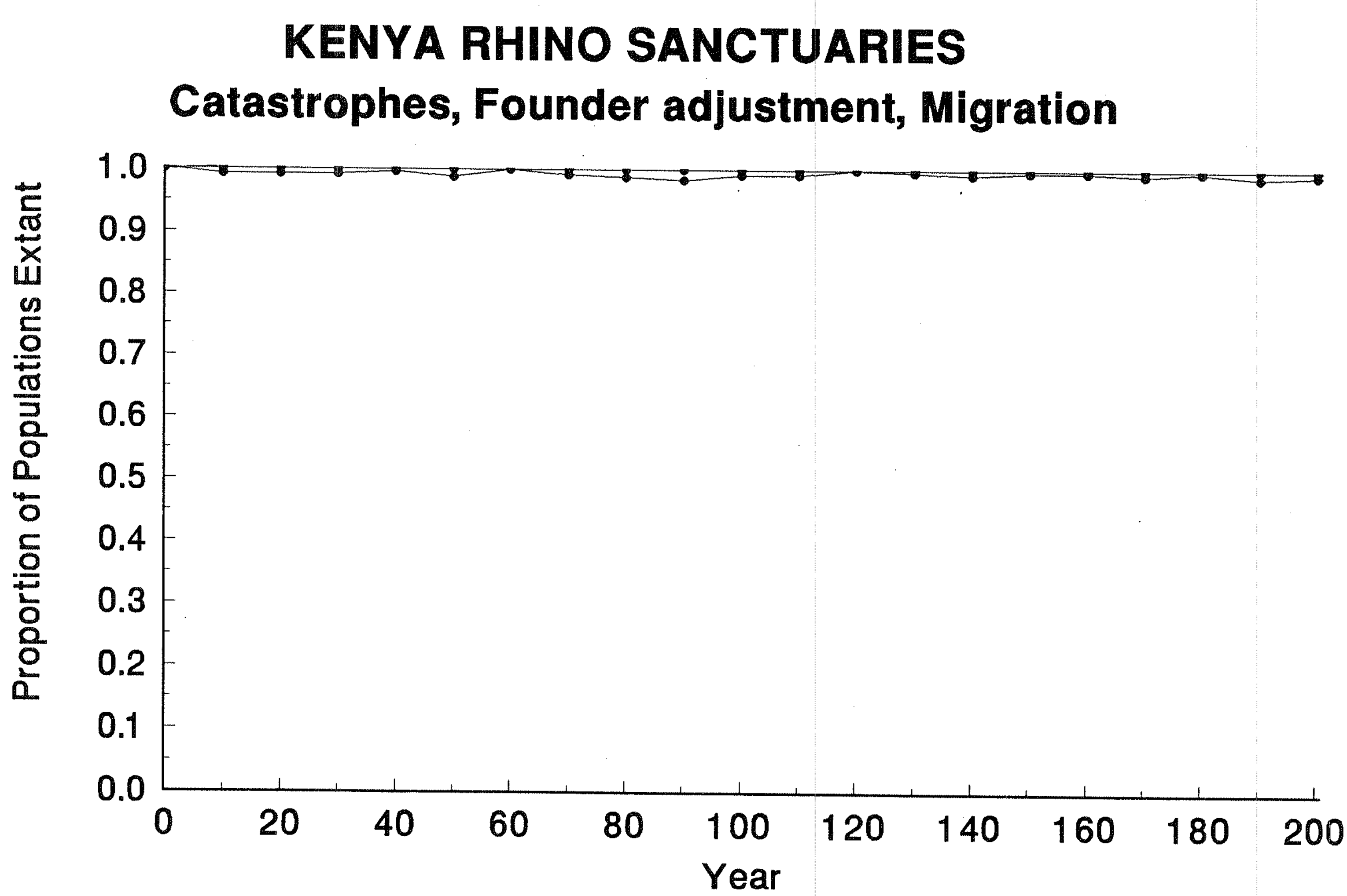

KENYA RHINO SANCTUARIES
Catastrophes, Founder adjustment, Migration
Proportion of Populations Extant
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year

Figure 22b.

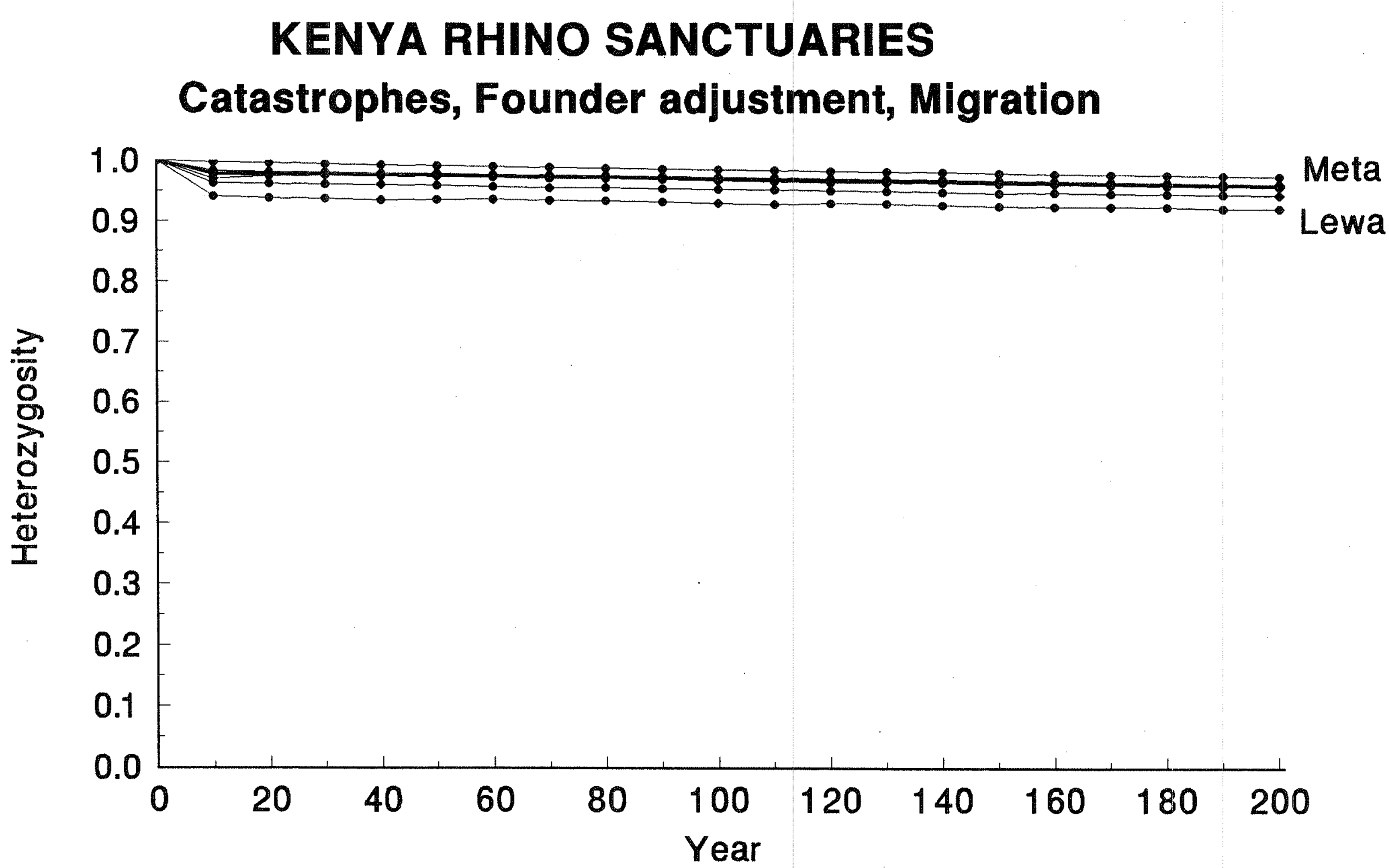

KENYA RHINO SANCTUARIES
Catastrophes, Founder adjustment, Migration
Heterozygosity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
Year
Meta
Lewa

Figure 23a. (Smaller Lewa Version.)

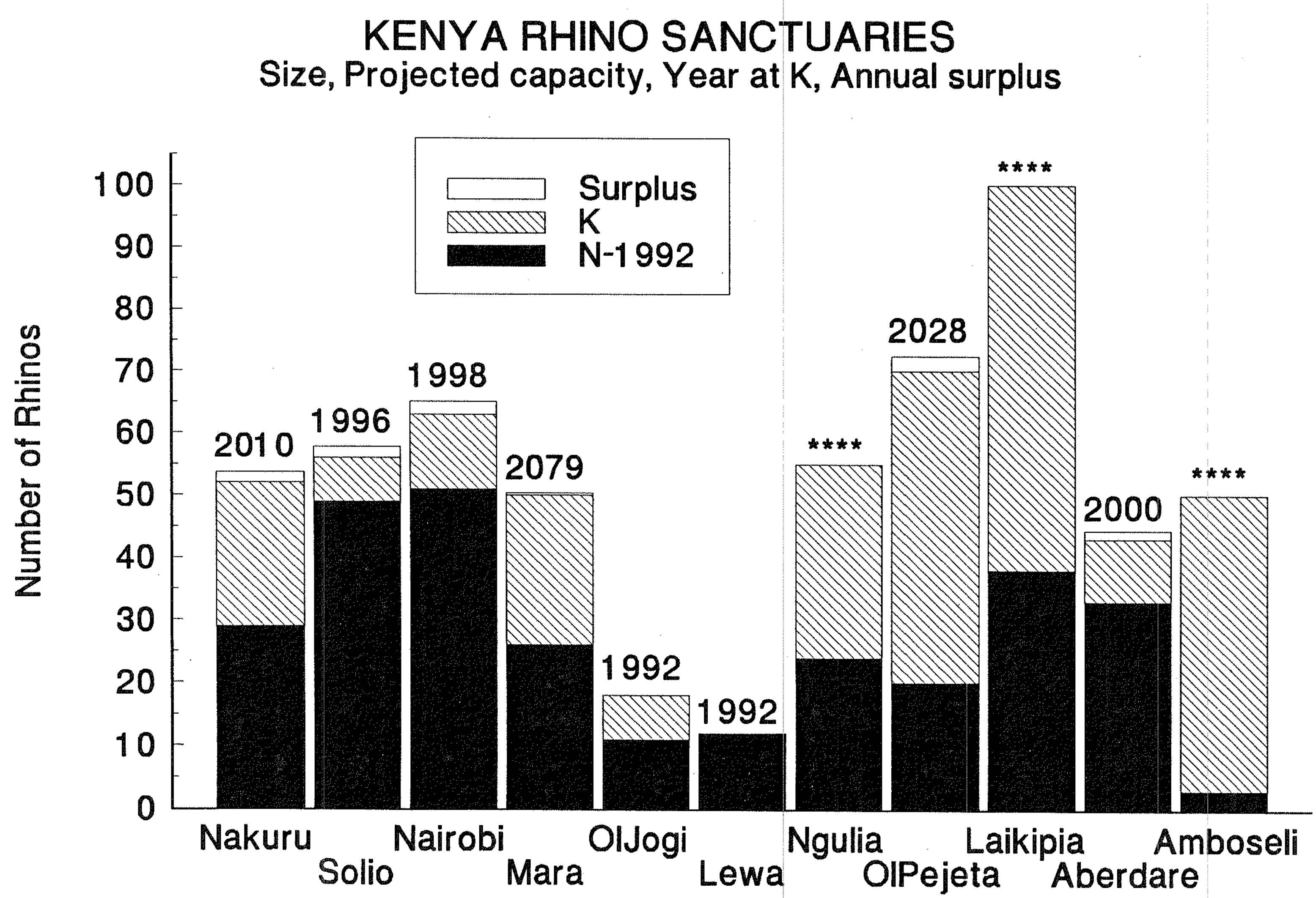
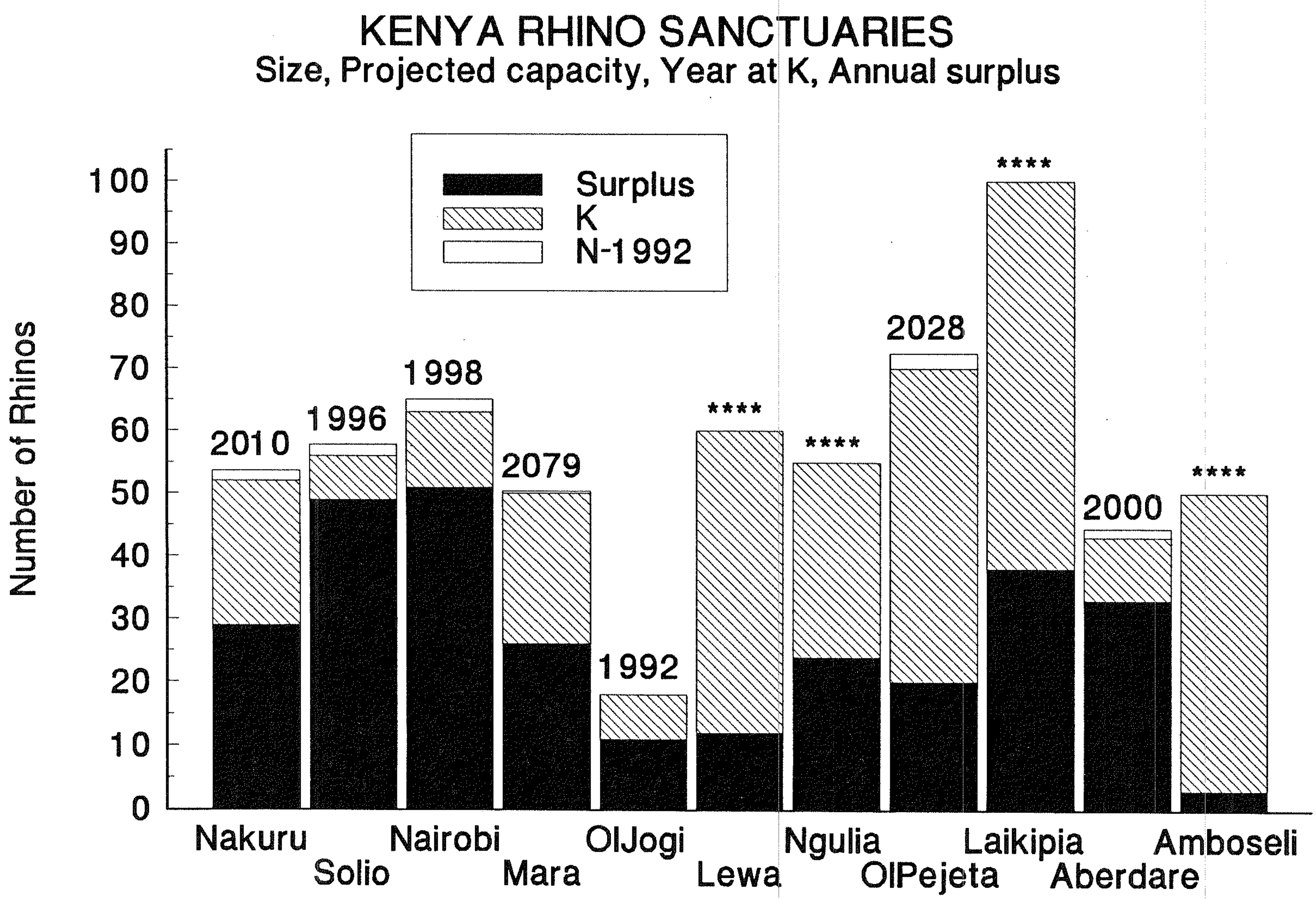


Figure 23b. (Larger Lewa Version.)



KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKSHOP REPORT

1 May 1993

SECTION 6
WORKING GROUP REPORTS

KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKING GROUP REPORT

RHINO ECOTYPES/RACES

Is there evidence for recent divergence of populations, e.g. subspecies, or a recent speciation involving highland versus lowland forms? If a significant association is found between the highland lowland ecosystems and the recent phylogeny of a variety of animals (mammals), then there may be reason to examine the likelihood that rhinos too might have evolved adaptations for highland lowland ecosystems.

Genetics:

Only extremely low levels of genetic diversity of m-dna has been found in Kenya rhino pops.

There is evidence for genetic variation in Kenyan rhinos in the form of heterochromatin polymorphism e.g. chromosomal variation. However, it is not possible to correlate any of the data on chromosome variation with highland vs. lowland origin of the animals, as only zoo animals have been examined and to date no one has identified exact points of origin of specific animals in the studbooks of zoos.

Would it be possible to fill in the missing data from reports from trappers still alive that contributed to the zoo populations. There is also the possibility that individuals shipped from Kenya could have also been brought in from Uganda and Tanzania by the trappers and claimed to be Kenyan.

Definitions of highland/lowland:

Definition of highland/lowland is based on geographical / ecological criteria (altitude, temp, rainfall, topography).

Habitat -- Impact of other browsers will be different between highland and lowland. Different animal communities in highland/lowland. Vegetation differences in terms of tannins, etc. Highland less seasonal variation in availability of browse and quality of browse. Highland habitats are more closed vegetation/ so close cover might select for different behavioral responses (e.g. predation avoidance). Size of home range would be related to habitat quality and characteristics. Density of herbivore community would be linked habitat characteristics.

Differences in parasite distribution and as vectors for disease. Differences in temp/rainfall, evapotranspiration, seasonality...Water -- highland water sources are different from lowland water sources in relationship to purity and disease as well as range distribution and convergence of other species. Heat stress/shading, effect on activity budgets.

Behavioral adaptation to environment:

Translocation of different types of rhino may put that individual at risk immediately after translocation because of differences in phenotypic behavioral (adaptive) responses not appropriate to the new habitat. Two directions: highland to lowland; lowland to highland.

Important behavioral adaptations -- from lowland to highland:

Generalized concentrate selector with site-specificity selection. Easy adaptation. Water -- easy adaptation. Topography/problems of climbing. Heat -- no problem. Cold -- pneumonia??? Altitude -- stress factor? Humidity -- pneumonia/sores. Density of conspecifics ----?? competition Density of competitors ---- lower ??? Predation/cover -- antipredatory strategies ??? lower predatory density. Change in seasonality of forage --- less seasonal bottleneck.

Highland to lowland:

Generalized concentrate selector with site-specificity selection. Easy adaptation. Problem of adaptation to seasonal availability of forage, especially root materials. Water -- difficulty of adaptation; restricted availability, distribution, quality, competition, concentration of disease factors. Topography -- no problems of climbing. Heat -- potential heat stress because of actual temperature, less cover (behavioral problem). Heat/water balance/evapotranspiration. Cold -- no problem. Altitude -- no problem. Humidity -- see above. Density of conspecifics -- less competition. Density of competitors -- higher. Predation/cover -- antipredatory strategies ??? increased predatory density. Change in seasonality of forage -- seasonal bottleneck.

The main criterion is the presence or absence of potentially pathogenic parasites and their vectors.

Phenotypic differences:

-- Is the corrugated skin pattern noted in some captive lowland rhino a general phenotypic pattern? The claim is that corrugated mothers have corrugated babies. This could be tested by experimental mating manipulation.

-- In the past, Akamba claim that there is a difference in aggressiveness between highland and lowland rhinos.

-- Horn size?

Disease:

Theileriosis (tick transmitted) and tryps (tsetse fly) and microfilaria worms (?) are the major disease differences between highland and lowland with these present in the lowland areas because of the distribution of the vectors for these disease. Does susceptibility differ between highland and lowland rhino? Two highland rhino translocated to a lowland area have become infected with tryps and have recovered without intervention.

Most rhinos sampled have antibodies to tryps indicating earlier exposure to tryps (only lowland rhino sampled). Frank infections are only found in young animals. All species of tryps infections which are found in Kenya are found in rhinos (vivax, brucei, congolense).

More samples are needed to do both genetic and disease analysis. It is recommended that blood and skin biopsy specimens be collected from six healthy adults of highland origin and lowland origin, in addition to samples collected from any sub-adults during translocations.

Dispersal:

To determine if dispersal has happened recently, we could test Ngeng Valley population for antibodies to parasites which would indicate a lowland origin for that animal. This would be a test for an animal dispersing within the last few years.

In 1983, a male translocated from Nairobi Park into Amboseli, after release walked across Kimana about 70 km before it was speared by Masai. Mara individuals disperse to Loita about 30 km (but movement of 70 km has been noted).

Reproductive success

Although there are rhino populations in sanctuaries that consist of both highland and lowland individuals and although these sanctuary populations are expanding, the appropriate determination of the decrease (or increase) in fitness of offspring of mixed highland/lowland ancestry is made by examination of the reproductive success of individuals with one parent of highland origin and one parent of lowland origin. What data exist that may be applied to this analysis. In future, these data should (continue to) be collected. The success of highland animals in lowland regions needs to be investigated. Despite their survival, it would be important to look at the comparative reproductive success of translocated highland animals in lowland populations.

No effects upon reproductive physiology would be expected between these groups of animals however, some effects on reproductive success would be expected because of nutrition, disease, etc.

Skin quality/differences as effects of environment:

Effects of parasites, heat and dryness, different wallowing habits.

KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKING GROUP REPORT

HEALTH AND DISEASE CONSIDERATIONS - KENYA 1991

The only proven pathogen leading to mortality in the wild situation is trypanosomiasis and even with this the evidence from early papers is scanty. This disease is difficult to manage and considerable research is required to prevent losses during translocation.

Until relatively recent times, the interaction between rhinos and domestic stock has been minimal. With the concentration of the remnant populations into conservancies sometimes on ranches there is potential for epidemic disease e.g. Tuberculosis however we have no evidence of this to date.

In the history of managed rhino populations the only significant large mortality event has been attributed to habitat change (starvation) rather than primary disease. The tsavo drought in the early 1960's is the only notable mortality event of a similar nature.

Disease related mortalities (e.g. 8.5% McCulloch) were recorded in early studies when overall translocation mortalities were in the order of 20-40% hence interpretation attributable to disease is problematic.

<u>Parasites:</u>

Trypanosomes:

McCulloch and Achard	: 8.5% mortality due to tryps whilst translocating rhinos
Clausen	: 3.0%

Heartworm evidence of antibody in Zimbabwe?

Babesia sp
Theileria
Helminths
Ticks

In general parasites will be more of a problem with young animals probably not significant in adults except where the animal is ill for other reasons e.g. starvation.
Aneurysms may be associated with migrating larvae but presence of strongylus has not been established in rhino.

Stephanofilaria

Bacterial Infections:

Anthrax
Leptospirosis
Tuberculosis
Salmonellosis
Infected wounds (secondary to e.g. flies etc)

Viral Infections:

Rabies
Herpes
? African Horse Sickness
? Pneumonitis
? Influenza

Fungal Infections:

Aspergillosis
other mycosis

Nutritional and metabolic Disorders:

Vitamin A E C

Stress related pathology (ruptured aneurysms, myopathy, mild to severe haemolysis with haemosiderin deposition in tissues ?metabolic disturbance.)

SUMMARY

(1) Stochastic disease events in static and dynamic populations cannot at present be quantified in the Black rhinoceros. The data set is insufficient but a reasonable estimate based on other mammals is 1 disease catastrophe every 100 years in a given contiguous population causing 80% mortality.

(2) Disease complications from translocations can be estimated at 5% +/- 20. An arbitrarily large coefficient of variation has been chosen to take account of the uncertainties.

(3) Trauma related mortality before, during and after translocation can be estimated at 5% +/- 2.5. This is expected to decrease with experience to 1% +/- 1.

(4) Data needs to be gathered on potential disease factors in managed populations. More finance for specific disease studies in the rhinoceros would be invaluable.

KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKING GROUP REPORT

HABITAT EVALUATION

Factors affecting the ecological carrying capacity of ten areas were evaluated. The areas were divided into three categories: recipient sanctuaries or parks; donor sanctuaries or parks; and other. The recipient areas were: Ngulia Rhino Sanctuary/Tsavo West National Park, Aberdares National Park (Salient, only), Aberdares National Park (remainder), and Ol Pejeta Game Reserve. The donor areas were: Solio Game Reserve, Nairobi National Park, and Nakuru National Park. Lewa Downs Rhino Sanctuary, Ol Ari Nyiro Ranch and Ol Jogi Game Reserve were classified as "other".

A matrix of factors affecting the ecological carrying capacity over the next five years of both producing and consuming rhino sanctuaries was developed. This matrix included the following factors: giraffe, elephant, other browsers, water availability, browse availability, fire occurrence, nutrient status, non-browse cover, predators, susceptibility to drought and poaching. Giraffe, elephant and other browsers were scored in the context of their impact on the rhino's habitat. The category of browse availability was not independent of the impacts of current rhino densities or the actual or predicted impacts of giraffe and other browsers.

A scoring system was developed and applied to the above factors. This system was as follows:

--	=	strong negative impact	=	1
-	=	negative impact	=	2
0	=	no impact/neutral	=	3
+	=	positive impact	=	4
++	=	strong positive impact	=	5

The scores on these factors were totalled for each area, divided by 11 (# of factors) and the deviation from 3 (neutrality) was reported. This deviation was taken as an indicator of potential carrying capacities in the areas considered over the next five years.

The coefficients of Variation (CV) were calculated for each factor. The CV's varied from 7% (water) to 36% (browse availability).

Estimated Carrying Capacities (c-c)

(1) Solio Ranch was used as a baseline because of its excellent history of breeding success. At one point it had 1.5/sq. km., at which point there was no sign of reduction in breeding rate, but there was an adverse effect on A. drepanolobium. Therefore, we assume the current 1.0/sq. km. is a sustainable c-c. This high figure is partly due to the contribution of the swamp to an improved c-c.

(2) Nairobi currently has 0.54/sq. km. Nairobi may be at c-c because of the observed incidence of fighting and the risk of mortality due to aggression.

(3) Ol Pejeta is less good habitat than Solio because there is no swamp vegetation available, and is less diverse than Nairobi N.P.'s vegetation. Ol Pejeta's vegetation is thought to be more diverse and better than Nairobi N.P., thus its c-c is felt to lie between Solio and Nairobi (ie 0.75/sq. km.).

(4) Aberdares' Salient density now is 0/62/sq. km., which is believed to be close to c-c, having recovered from poaching, but certainly not in excess of c-c. The rest of the Aberdares is too large and heterogeneous to estimate c-c, but it will be, on average, less than in the Salient (ie. < 0.62).

(5) Nakuru's c-c estimate was based on the areas of bush and forest in the relevant satellite images, totalling 70 sq. km. out of the total 140 sq. km. While Nakuru N.P. has forest, unlike Solio, it has no swamp habitats, and Tarconanthus camphoratus (leleshwa), a highly unpalatable species and often an indicator of declining range quality, is believed to be spreading rapidly in some local areas within Nakuru Park. We estimate Nakuru's c-c to be no more than 75% of Solio's. Thus, the available habitat would support 52 rhino or 0.74/sq. km.

(6) The rhino population of Ol Ari Nyiro Ranch is currently at 0.25/sq. km. in the area of ranch used. In the past, approximately 90 animals were reported in an area twice the size in the neighbouring vicinity. This would suggest that 0.25/sq. km. may be a reasonable estimate of c-c for all northern Laikipia ranch areas -- Ol Ari Nyiro, Ol Jogi, ad Lewa. Ol Pejeta and Solio have special mitigating factors, of higher rainfall, lesser drought susceptibility and, in the case of Solio only, swamps. The skewed sex ration (2:1 in the adults) on Ol Ari Nyiro may be depressing the breeding rate below its potential.

(7) Lewa Downs (Ngare Sergoi Rhino Sanctuary) is now at 0.28/sq. km. It is drought-prone and the vegetation is not browse-rich for rhinos. Therefore, the current c-c is estimated to be approximately correct. We would set the c-c at 0.25/sq. km.

(8) Ol Jogi is currently 0.15/sq. km. The best opinion is that it should basically be the same as Lewa, ie. 0.25/sq. km.

(9) Goddard (1970) estimated the rhino population at 1.0/sq. km. in the vicinity of the current Ngulia Rhino Sanctuary. Acknowledging the current and potential impact of elephant concentrations within the sanctuary, plus potential social problems upon addition of animals, it will be more prudent to set the c-c at 0.75/sq. km.

Caution should be taken in the interpretation of these estimated carrying capacities. The potential number of animals which can be introduced to a recipient site will not necessarily be the difference between the current density estimate and the potential ecological c-c. Introductions in to previously "empty" areas may be totally different, in nature, than introductions into already established populations. Introductions into established populations may disrupt social dynamics leading to mortalities/injuries due to aggression and, therefore, the actual number of introduced rhinos must be adapted to the existing social conditions. In cases where additional introductions could lead to these problems, the potential c-c should be achieved through natural increase and not further introductions. In cases where further introductions are necessary for other purposes (such as manipulation of the age/sex structure) these might be more successfully achieved through the transfer of compatible groups rather than on a one-by-one basis.

In general, the estimated c-c's for the areas considered agreed with the summary results of the factor scores in the table. Nairobi N.P. is already at its potential c-c and the low scores for ecological factors reflect this. Interestingly, the potential c-c's estimated for Ngulia and Nakuru are more optimistic than would be indicated by the matrix of factors in the table.

HABITAT EVALUATION MATRIX

LOCATION	GIRAF	ELEPH	H_2O	BROWS	NUTRI	COVER	OTHER	PRED	DROUG	POACH	FIRE	TOTAL	DEVN	C.C.	KM^2
RECIPIENT:														$/KM^2$	
NGULIA	2	2	5	4	3	5	3	3	1	2	2	32	-0.10	0.75	73
ABER-SALIENT	3	2	5	5	2	5	3	2	4	3	3	37	+.36	0.62	70
OL PEJETA	2	3	5	5	4	4	3	5	3	4	3	41	+.73	0.75	93
ABERDARES	3	4	5	4	2	5	3	3	5	3	3	40	+.55	<0.62	70
DONOR:															
SOLIO	3	3	5	5	4	4	3	4	2	4	3	40	+.66	1.00	56
NAIROBI	2	3	5	2	3	4	2	3	3	5	2	34	+.09	0.54	117
NAKURU	2	3	4	4	2	5	2	2	4	5	3	36	+.27	0.74	142
OTHER:															
LEWA	3	3	5	2	3	2	3	5	2	5	3	36	+.27	0.25	40
OL JOGI	1	3	5	2	3	4	2	5	2	5	3	35	+.18	0.25	73
OL ARI NYIRO	3	2	5	3	2	4	3	5	2	4	1	34	+.09	0.25	390

KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKSHOP REPORT

1 May 1993

SECTION 7
CAPTIVE POPULATIONS

RHINO

GLOBAL CAPTIVE ACTION PLAN (GCAP)

FIRST EDITION

1 SEPTEMBER 1992

EDITED BY
THOMAS J. FOOSE, PH.D.
IUCN /SSC CBSG

A Joint Endeavor of the

IUCN/SSC Captive Breeding Specialist Group
&
Regional Captive Propagation Programs

with Input from the

IUCN/SSC Asian Rhino Specialist Group
&
IUCN/SSC African Rhino Specialist Group

Regional Captive Propagation Program

GLOBAL CAPTIVE ACTION PLAN

GOALS

- **Affirm that the paramount purpose of captive programs for rhino conservation is the survival and recovery of all distinct taxa in the wild.**

- **Contribute to rhino conservation by:**

  - **Developing, maintaining, and using captive breeding programs to provide a genetic and demographic reserve to re-establish or revitalize wild populations when the need and opportunity occurs.**

  - **Conducting problem-oriented research that will contribute to management of rhino in both captivity and the wild; collaborating on such research where appropriate with field researchers; communicating and transferring the results of such research to managers of other captive and wild populations**

  - **Providing where possible financial as well as technical support for *in situ* conservation.**

OBJECTIVES/RECOMMENDATIONS

- **Conduct captive breeding programs for selected taxa of rhino. 7 taxa currently selected are:**

- *Diceros bicornis michaeli*	Eastern Black
- *Diceros bicornis minor*	Southern Black
- *Ceratotherium simum simum*	Southern White
- *Rhinoceros unicornis*	Indian/Nepali
- *Dicerorhinus sumatrensis harrisoni.*	Borneo Sumatran
- *Dicerorhinus sumatrensis sumatrensis I**	Sumatra Sumatran
- *Dicerorhinus sumatrensis sumatrensis II**	Mainland Sumatran

(* Peninsular Malaysian and Sumatran populations treated as distinct taxa)

- **Additionally, conduct a crash effort to initiate a captive breeding program for *Ceratotherium simum cottoni*, using the founder stock already in captivity.**

  If this program were successful, space could and would be allocated, perhaps by reducing the captive habitat occupied by southern white rhino.

- **Form a special task force to conduct the crash program for the Northern white rhino.**

  The initial members appointed to this group are: Larry Killmar, Nick Lindsay, Bob Reece, Ollie Ryder, Kristina Tomasova, Tom Foose.

- **Consider other taxa for captive breeding at the request and recommendation of the SSC Rhino Specialist Groups in the future if the situation in the wild dictates and in captivity permits (space, husbandry): e.g. *Rhinoceros sondaicus*, the Javan.**

- **Adopt a policy of recognizing the maximum number of distinct taxa for conservation action until or unless further information indicates a taxon no longer should be treated as a separate unit.**

- **Assist the SSC Rhino Specialist Groups in collecting information needed to decide what constitute distinct taxa of rhino and recognize the Specialist Groups as the ultimate authority on this issue.**

- **Use the assistance available from zoos for the other taxa to support *in situ* efforts.**

- **Establish captive target populations in general sufficient to preserve 90% of the gene diversity of the wild populations for 100 years.**

- **Attain designated target populations (Table 1) for the taxa in captivity within 1 rhino generation (~ 15 years) for the Eastern Black, Southern White, and Indian/Nepali; within 2 generations (~30 years) for the Southern Black and the 3 Sumatran taxa.**

Taxa	Current Population	Target Population	% Increase	
			Total	Per Year
Eastern Black	163	200	22%	1.3%
Southern Black	52	175	337%	4.0%
Southern White	570	300	- 49%	4.2%
Indian/Nepali	120	230	92%	4.5%
Borneo Sumatran	2	150	750% *	7.0%
Mainland Sumatran	8	150	750% *	7.0%
Sumatra Sumatran	13	150	750% *	7.0%

* Based on premise that Current Population, consisting of founders, will be rapidly augmented by rescue of more rhino from wild so that initial number will be 20.

- **Distribute responsibilities for the captive populations over the various Regions of the zoo world as indicated in Table 2.**

- **Expand the captive capacity for rhino from 928 to 1355, i.e. 427 new spaces, an increase of 46% over a 15 year period (i.e. 1 rhino generation).**

  This rate of expansion will require creation of about 30 new spaces/year in zoos worldwide.

- **Reallocate existing rhino space (785 African spaces of which 570 are for southern white rhino; 143 Asian spaces) to achieve the target distribution of 675 African spaces, 680 Asian spaces.**

  A conclusion of these calculations is that most new rhino spaces will need to be "Asian".

- **Redistribute founder material among the Regional Programs for selected taxa to provide more viable genetic foundations within all of the Regions.**

  This is especially true for the Indian/Nepali Rhino where movement of new founder material into Europe and from Asia to both Europe and North America would be beneficial.

- **Obtain additional founders from the wild for several of the taxa to be propagated in captivity in order to provide a viable genetic foundation for the population.**

	Existing	Additional	Total
Borneo Sumatran	2	18	20
Mainland Sumatran	8	12	20
Sumatra Sumatran	13	7	20

- **Accord the highest priority to research in 3 areas which are critical for conservation programs for rhino:**

  - **Genetic studies to clarify taxonomic status of "subspecies", i.e. geographically defined populations;**

  - **Veterinary and husbandry investigations to ameliorate the disease syndrome that afflicts the Black, and possibly other browsing rhino, in captivity, and probably in the wild.**

  - **Development of effective methods of assisted reproduction, especially with the objective of using these techniques to expand more rapidly the populations of the taxa in desperately low numbers, e.g. northern whites and perhaps eventually Javan.**

- **Establish a research collection of White Rhino (100 total) in both North America (50) and in Europe/UK (50) at a site determined by the Regional Coordinators.**

- **Develop aggressively the funding needed for the research priorities.**

- **Formulate a plan with defined objectives and schedules to initiate systematic genetic resource banking of rhino taxa.**

  This would be the assignment of a special task force to be formed by Dr. Betsy Dresser and Dr. Tom Foose.

- **Collaborate on habitat and population viability analyses (PHVAs) for selected taxa.**

  The most immediate need identified is a PHVA for the Indian/Nepali rhino.

- **Accept as a challenge, the objective of providing $1,000,000/year for 10 years to *in situ* rhino conservation, especially through "Adopt-A-Park" programs.**

  Distributed over the 200 "hard currency" rhino institutions (Table 2), this level of contribution is equal on the average to $5,000/institution. Considered from another perspective, this level of contribution represents just a little over $1,000 per rhino currently maintained in the zoos of the world; it will represent $ 740 once captive target populations are attained. It has been estimated that the annual cost of protecting and managing minimally viable populations of rhino in the wild is about $20,000,000/year. The level of support proposed for zoos is thus only about 5%, but if effectively applied could be very catalytic and crucial support. A number of institutions (Table 3) are already contributing to *in situ* rhino conservation at or above this level.

- **Specifically, to initiate the *in situ* program:**
  - **A. Attempt to secure $250,000/year for "adopt-a-park" programs for an additional 10 high-priority protected areas for Asian rhino by recruiting the 30 "hard currency" zoos with Asian rhinos to contribute $8,500/year for 3 years.**
  - **B. Also attempt to secure $14,000 per year to support the annual costs of the IUCN SSC/Asian Rhino Specialist Group by recruiting an additional $7,000/year from North American Zoos, $ 3,500/year from European Zoos, and $3,500/year from Australian Zoos with interests in Asian rhino.**
  - **C. Attempt to secure $250,000/year for "adopt-a-park" programs for an additional 10 high-priority protected areas for African rhino by recruiting 100 "hard currency" zoos with African rhinos to contribute $2,500/year for 3 years.**
  - **D. Also attempt to secure $27,000 per year to support the annual costs of the IUCN SSC/African Rhino Specialist Group by recruiting an additional $11,000/year from North American Zoos, $ 11,000/year from European Zoos, and $5,000/year from Australian Zoos with interests in African rhino.**

- **Establish an active Global Management and Propagation Committee to further develop and coordinate the Global Captive Action Plan.**

- **Support a paid, initially part-time position of Global Captive Rhino Coordinator to implement the Global Captive Action Plan in a timely manner; the estimated cost would be $ 20,000/year which if distributed over the 200 "hard currency" rhino institutions would be $100/year.**

- **Establish Taxon Advisory Groups (TAGs) for rhino in the Regions where they do not yet exist: Europe, Asia.**

- **Develop and implement a business plan to achieve the goals and objectives of the Global Captive Action Plan.**

  The total cost per zoo if the proposals presented above are implemented would be ~ $9,000/year for institutions with Asian rhinos and ~ $ 3,000/year for African rhino institutions.

TABLE 1
CONSERVATION ASSESSMENT & MANAGEMENT PLAN
RHINO

	TAXON		WILD POPULATION									RSRCH	CAPTIVE PROGRAM	
	SCIENTIFIC NAME		RANGE	EST#	SUB POP	TRND	AREA	M/L STS	THRTS	PVA/ WKSP	WILD MGMT	TAX/SRV/ HUSB	NUM	CAP REC
	Diceros	bicornis												
	Diceros	b. bicornis	Namibia	400	2	I	A	E	H			T,H	0	
	Diceros	b. longipes	Cameroon, C.A.R.	<100	2	D	A	C	H			T,S,H	0	
	Diceros	b. michaeli	Kenya, N. Tanzania	600	15	S	A	C	H	Y		T,S,H	52	90/100 I
	Diceros	b. minor	S.Tanzania, Zambia, Zimbabwe, S.Africa	2,300	7	D	A	E	H			T,H	163	90/100 I
	Ceratotherium	simum												
	Ceratotherium	s. cottoni	Zaire, Sudan (?)	31	1	I	A	C	H		Y	H	10	NUC II
	Ceratotherium	s. simum	S.Africa, Zimbabwe, Kenya	5,560	6	I	A	V	H,L				570	90/100 I
	Rhinoceros	unicornis	India, Nepal	1,700	10	S	A	E	L,H	Y			120	90/100 I
	Rhinoceros	sondaicus												
	Rhinoceros	s. annamiticus	Vietnam	<25	2	D	A	C	H			S	0	
	Rhinoceros	s. sondaicus	Java (Indonesia)	<75	1	S	A	C	L,H		Y		0	
	Dicerorhius	sumaterensis												
	Dicerorhinus	s. harrisoni	Kalimantan, Sabah, Sarawak	100	3	D	AA	C	L,H			T,S	2	90/100 I
	Dicerorhinus	s. lasiotus	Burma (?)	?	?	D	A	C	L,H			S	0	
	Dicerorhinus	s. sumatrensis I	Peninsular Malaysia	150	4	D	A	C	L,H			T,S,H	8	90/100 I
	Dicerorhinus	s. sumatrensis II	Sumatra (Indonesia)	600	3	D	AA	E	L,H			T,S,H	13	90/100 I

Refer to Section 13 for an explanation of the column categories.

T.J. Foose
15 June 1992

TABLE 2
GLOBAL AND REGIONAL
CURRENT AND TARGET POPULATIONS FOR
RHINO IN CAPTIVITY

	WORLD			AFRICA		ASIA		AUSTRALASIA		EUROPE		N. AMERICA		C.& S. AMERICA	
RHINO TAXON	**WILD POP**	**CPTV POP**	**CPTV TRGT**	**CPTV POP**	**TRGT POP**	**CPTV POP**	**TRGT POP**	**CPTV POP**	**TRGT POP**	**CPTV POP**	**TRGT POP**	**CPTV POP**	**TRGT POP**	**CPTV POP**	**TRGT POP**
Eastern Black	600	163	200	5	5	35	40	2	0	55	65	67	90	6	?
Southern Black	2,300	42	175	4	15	2?	0	0	80	6	0	30	80	0	?
Southwestern Black	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North & West Black	<100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern White	31	10	?	0	?	0	0	0	0	6	?	4	?	0	0
Southern White	5,560	570	200 + 100 Rsrch	24	0	150	0	14	60	210	70 + 50 Rsrch	132	70 + 50 Rsrch	40	?
Indian/Nepali	1,700	120	230	0	0	45	78	0	0	32	76	40	76	1	?
Javan (Java)	< 75	0	?	0	0	0	?	0	0	0	0	0	0	0	?
Javan (Vietnam)	< 25	0	?	0	0	0	?	0	0	0	0	0	0	0	?
Mainland Sumatran	150	8	150	0	0	8	50	0	0	0	100	0	0	0	?
Sumatran Sumatran	600	13	150	0	0	7	50	0	0	2	0	6	100	0	0
Borneo Sumatran	100	2	150	0	0	3	50	0	100	0	0	0	0	0	0
African Rhino	**8,991**	**785**	**675**	**33**	**20**	**189**	**40**	**16**	**140**	**266**	**185**	**233**	**290**	**46**	**?**
Asian Rhino	**2,650**	**143**	**680**	**0**	**0**	**63**	**228**	**0**	**100**	**34**	**176**	**46**	**176**	**1**	**?**
All Rhino Taxa	**11,641**	**928**	**1355**	**25**	**20**	**252**	**268**	**16**	**240**	**300**	**361**	**279**	**466**	**47**	**?**

T.J. Foose
15 June 1992

TABLE 3
STRATEGIC SUPPORT OF *IN SITU* PROTECTED AREAS FOR RHINO BY THE GLOBAL AND REGIONAL CAPTIVE COMMUNITIES

TAXON	NUMBER OF SIGNIFICANT *IN SITU* SANCTUARIES	SUPPORTED BY ZOOS FROM					
		AFRICA	ASIA	AUSTRALASIA	EUROPE	N. AMERICA	S. AMERICA
Eastern Black	7				3	2+ ?	
Southern Black	7			1		1 ?	
Southwestern Black	2						
North/West Black	?						
Northern White	1				1		
Southern White	5						
Indian/Nepali	6					1	
Javan (Java)	2					1	
Javan (Vietnam)							
Mainland Sumatran	2						
Sumatra Sumatran	3						
Borneo Sumatran	4						
African Rhino	**20**						
Asian Rhino	**20**						
All Rhino Taxa	**40**						

T.J. Foose
15 June 1992

TABLE 4
ANNUAL COSTS FOR CONSERVATION OF VIABLE POPULATIONS OF RHINO

TAXON	TARGET POPULATION	DENSITY (km/rhino)	AREA (km^2) REQUIRED	COST per km^2	ANNUAL COST
N. Black	2,000	3	6,000	$400	$2,400,000
S. Black	2,000	3	6,000	$400	$2,400,000
S.W. Black	2,000	3	6,000	$400	$2,400,000
N.W. Black	2,000	3	6,000	$400	$2,400,000
N. White	2,000	1.5	3,750	$400	$1,500,000
S. White	2,500	1.5	3,750	$400	$1,500,000
Indian/Nepali	2,500	0.5	1,250	$250	$300,000
Borneo Sumatran	2,000	10	20,000	$100	$2,000,000
Sumatra Sumatran	2,000	10	20,000	$100	$2,000,000
Mainland Sumatran	2,000	10	20,000	$100	$2,000,000
Javan	2,500	5	12,500	$100	$1,250,000
TOTALS	**23,500.00**	**50.50**	**105,250.00**	**$3,050.00**	**$20,150,000.00**

T.J. Foose
15 June 1992

TABLE 5
RHINO INSTITUTIONS

TAXON	WORLD	AFRICA	ASIA					AUSTRALASIA	EUROPE	N.A.	S.A.
			CHN	IND	JPN	S.E.	M.E.				
Eastern Black	55	3	2	3	4	1	1	1	11	24*	4
Southern Black	14	1	0	0	1?	0	0	1	2	9	0
Southwestern Black	0	0	0	0	0	0	0	0	0	0	0
North/West Black											
Northern White	2	0	0	0	0	0	0	0	1	1	0
Southern White	215 **	12	6	3	23	6	6	6	87	45*	21
Indian/Nepali	45 *	0	1	12	3	1	0	0	14	13*	1
Mainland Sumatran	2	0	0	0	0	1	0	0	0	0	0
Sumatra Sumatran	8	0	0	0	0	5	0	0	1	4	0
Borneo Sumatran	1										
Javan (Java)	0	0	0	0	0	0	0	0	0	0	0
Javan (Vietnam)											
African Rhino	**266**	**16**	**8**	**5**	**29**	**6**	**8**	**7**	**95**	**70**	**23**
Asian Rhino	**52**	**0**	**1**	**12**	**3**	**5**	**0**	**0**	**15**	**11***	**1**
All Rhino	**290 *** **	**16**	**8**	**13**	**30**	**7**	**8**	**7**	**101**	**74***	**23**

* San Diego Zoo & San Diego Wild Animal Park = 1 Institution
** 139 of the white rhino institutions maintain ≤ 2 individuals
*** ~ 200 "Hard Currency" Zoos with rhinos
~ $ 1 billion annual operation budgets

T.J. Foose
15 June 1992

TABLE 6
DEMOGRAPHIC PERFORMANCE OF GLOBAL AND REGIONAL POPULATIONS OF RHINO IN CAPTIVITY

	WORLD		AFRICA		ASIA		AUSTRALASIA		EUROPE		N. AMERICA		S. & C. AMERICA	
TAXON	λ		λ		λ		λ		λ		λ		λ	
	HIST	81-92	HIST	81-92	HIST	81-92	HIST	81-92	HIST	81-92	HIST	81-92	HIST	81-92
E. Black	.97	.97	-	-	.94	.9	-	-	.96	.98	.97	.99	-	-
E. Black Core											1.02	1.03		
S. Black	< 1	< 1	-	-	-	-	-	-	-	-	< 1	< 1	-	-
S.W. Black	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N.W. Black	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N. White	0	0	0	0	-	-	-	-	-	-	-	-	-	-
S. White	?	?	?	?	?	?	?	?	?	?	< 1	< 1	?	?
Indian/Nepali	1.02	1.02			1	.98			1.04	1.02	~ 1	1.03	-	-
Javan (Javan)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Javan (Viet.)														
M.Sumatran	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S.Sumatran	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B.Sumatran	-	-	-	-	-	-	-	-	-	-	-	-	-	-

λ < 1 = decreasing population
λ = 1 = stationery population
λ > 1 = increasing population
e.g. 1.02 = 2% increase/year
.97 = 3% decrease/year

T.J. Foose
15 June 1992

TABLE 7
GENETIC COMPOSITION IN TERMS OF FOUNDERS OF GLOBAL AND REGIONAL POPULATIONS OF RHINO IN CAPTIVITY

	WORLD		AFRICA		ASIA		AUSTRALASIA		EUROPE		N. AMERICA		S. & C. AMERICA	
TAXON	FOUNDERS		FOUNDERS		FOUNDERS		FOUNDERS		FOUNDERS		FOUNDERS		FOUNDERS	
	#	Unq	#	Unq	#	Unq	#	Unq	#	Unq	#	Unq	#	Unq
E. Black	95	80	7	7	24	15	3	3	36	25	44	26	9	4
S. Black	38	38	4	4	2	2	0	0	4	4	28	28	0	0
S.W. Black														
N/W Black														
N. White	7	4	0	0	0	0	0	0	4	1	4	3	0	0
S. White	> 100	0	?	?	?	?	?	?	?	?	99	?	?	?
Indian/Nepali	62	44	0	0	38	22	0	0	14	6	26	16	3	0
Javan (Java)														
Javan (Viet.)														
M.Sumatran	8.5	8.5	0	0	8.5	8.5	0	0	0	0	0	0	0	0
S.Sumatran	15	15	0	0	7	7	0	0	2	2	6	6	0	0
B.Sumatran	3	3	0	0	3	3	0	0	0	0	0	0	0	0

# = Number of Potential Founders
Unq = Founders Unique to Region

T.J. Foose
15 June 1992

TABLE 8
GENETIC COMPOSITION IN TERMS OF FOUNDER GENOME EQUIVALENTS OF GLOBAL AND REGIONAL POPULATIONS OF RHINO IN CAPTIVITY

	WORLD		AFRICA		ASIA		AUSTRALASIA		EUROPE		N. AMERICA		S. & C. AMERICA	
TAXON	F.G.E.		F.G.E.		F.G.E.		F.G.E.		F.G.E.		F.G.E.		F.G.E.	
	A	P	A	P	A	P	A	P	A	P	A	P	A	P
E. Black	30	80	1	5	8.3	21	1	2	14.8	24.9	15	32	1	4.5
S. Black	11	34	50	87.5	50	75	0	0	2	4	8	24.5	0	0
S.W. Black														
N/W Black														
N. White	2	7	0	0	0	0	0	0	2	3.4	0	4	0	0
S. White			?	?	?	?	?	?	?		18	97	?	?
Indian/Nepali	7	55	0	0	4.9	34.5	0	0	3.7	9.4	5.7	20	1	0
Javan (Java)														
Javan (Viet.)														
M.Sumatran	.5	8.5	0	0	0	8.5	0	0	0	0	0	0	0	0
S.Sumatran	0	15	0	0	0	7	0	0	0	2	0	6	0	0
B.Sumatran	0	3	0	0	0	3	0	0	0	0	0	0	0	0

F.G.E. = Founder Genome Equivalents
A = Actual
P = Potential

T.J. Foose
15 June 1992

TABLE 9
GENETIC COMPOSITION IN TERMS OF GENE DIVERSITY OF GLOBAL AND REGIONAL POPULATIONS OF RHINO IN CAPTIVITY

	WORLD		AFRICA		ASIA		AUSTRALASIA		EUROPE		N. AMERICA		S. & C. AMERICA	
TAXON	GENE DIVERISTY		GENE DIVERSITY		GENE DIVERSITY		GENE DIVERSITY		GENE DIVERSITY		GENE DIVERSITY		GENE DIVERSITY	
	A	P	A	P	A	P	A	P	A	P	A	P	A	P
E. Black	98.3	99.4	50	92.9	94	97.6	50	0	96.6	98	96.7	98.4	50	89
S. Black	95.1	98.5	0	87.5	50	50	0	0	75	87.5	93.8	98	0	0
S.W. Black														
N.W. Black														
N. White	75	92.9	0	0	0	0	0	0	71.5	85.3	0	87.5	0	0
S. White	99	99	?	?	?	?	?	?	?	?	96.5	99.5	?	?
Indian/Nepali	92.8	99	0	0	89.7	98.6	0	0	86.5	94.7	91.2	97.5	50	0
Javan (Java)														
Javan (Vietnam)														
M.Sumatran	0	94.1	0	0	0	94.1	0	0	0	0	0	0	0	0
S.Sumatran	0	96.7	0	0	0	96.7	0	0	0	0	0	91.7	0	0
B.Sumatran														

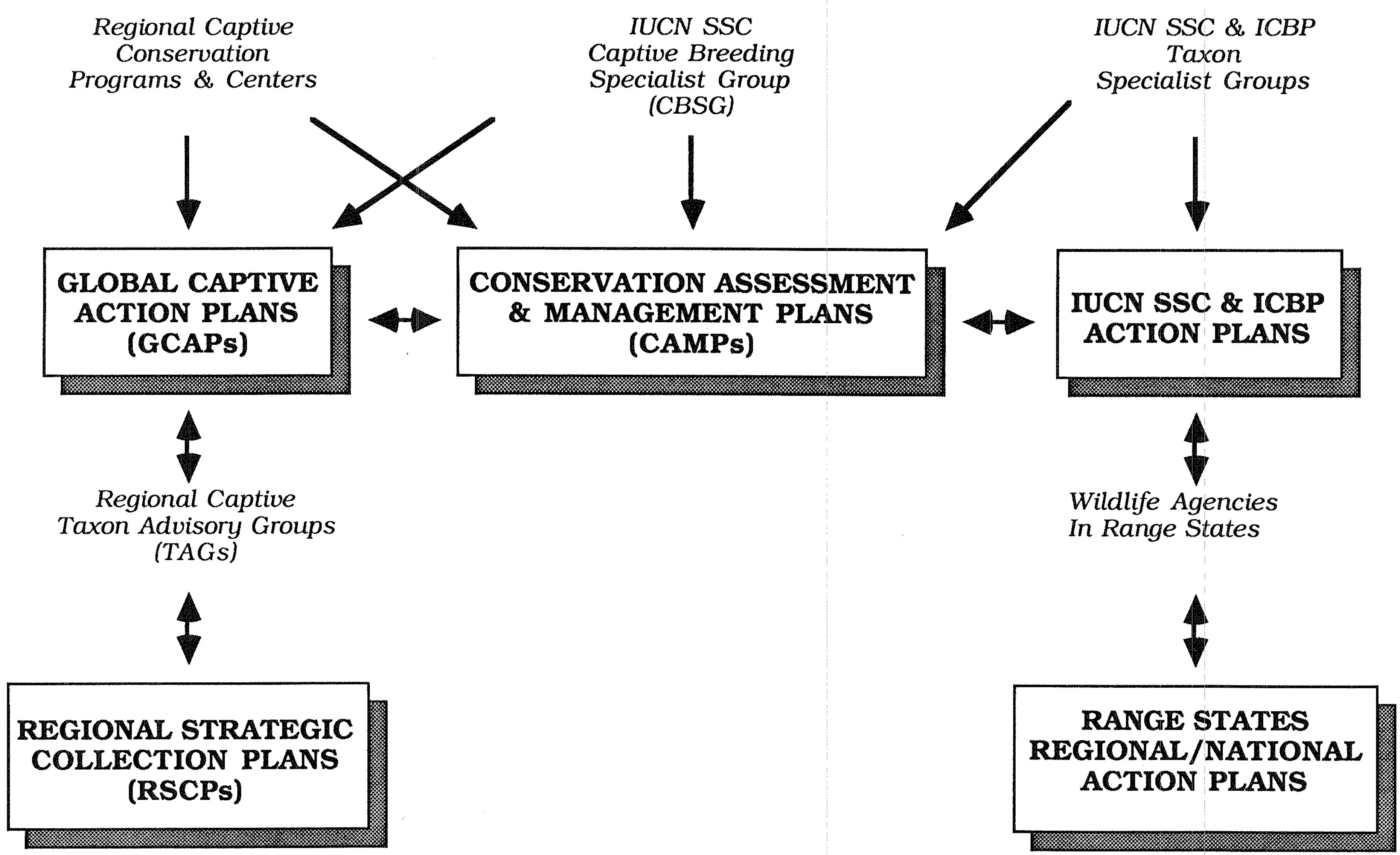
T.J. Foose
15 June 1992

TABLE 10
MACE/LANDE CATEGORIES AND CRITERIA OF THREAT

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

FIGURE 1

GLOBAL AND REGIONAL STRATEGIC CONSERVATION ACTION PLANS



T.J.F./CBSG
1 August 1992

FIGURE 2

GLOBAL CAPTIVE PROPAGATION AND MANAGEMENT GROUP

CHAIR: T.J. Foose, CBSG Executive Office (Pro Tem)

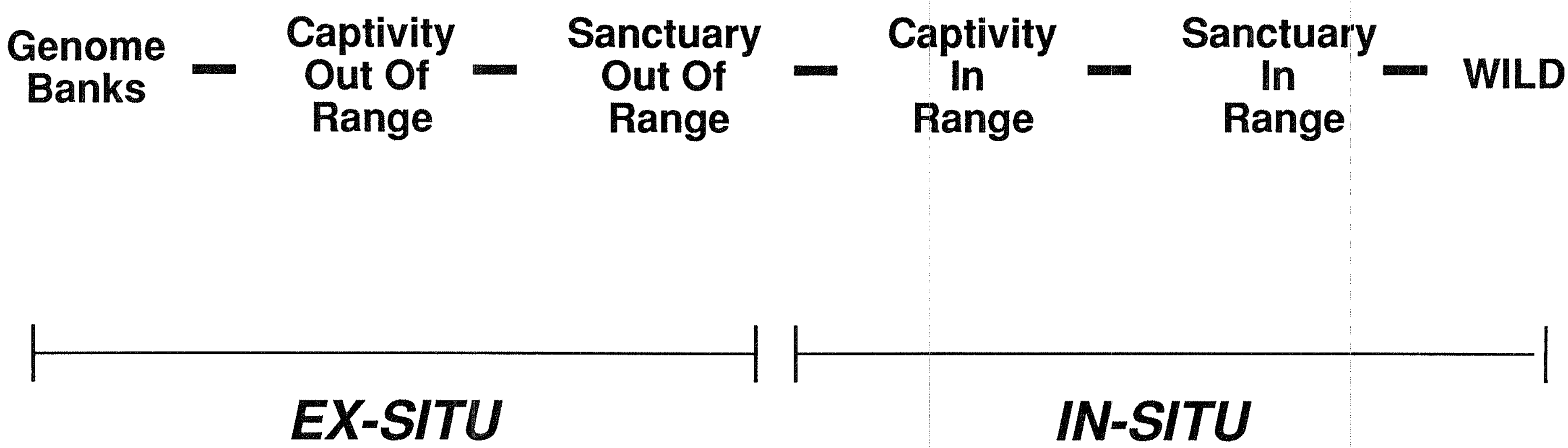
REGIONAL COORDINATORS:

		African			Asian		
	TAG	**Black**		**White**	**Indian/Nepali**	**Sumatran**	**Javan**
Africa (PAAZAB, ZDNAPWM, KWS)		V. Wilson M. Kock R. Brett					
Asia							
Japan (SSCJ)	M. Masui	Otsu					
India (IESBP)	(To be Appointed by the Central Zoo Authority of India)						
S.E. Asia (SEAZ)					B. Harrison	Tajuddin Jansen M.	
Australasia (ASMP)		J. Kelly		P. Garland		D. Miller (All Asian)	
Europe (EEP/JMSG)		R. Frese	A. Dixon N. Lindsay (UK)	K. Tomasova	K. Tobler	C. Furley	
North America (AAZPA SSP)	R.Reece	E. Maruska D. Farst J. Jackson		R. Rockwell	M. Dee	J. Doherty J. Dolan	

Advisors:	M. Brooks	Chairman, African Rhino Specialist Group	G. Amato	E. Miller
	M. Khan	Chairman, Asian Rhino Specialist Group	O. Ryder	
	N. Van Strien		B. Dressser	

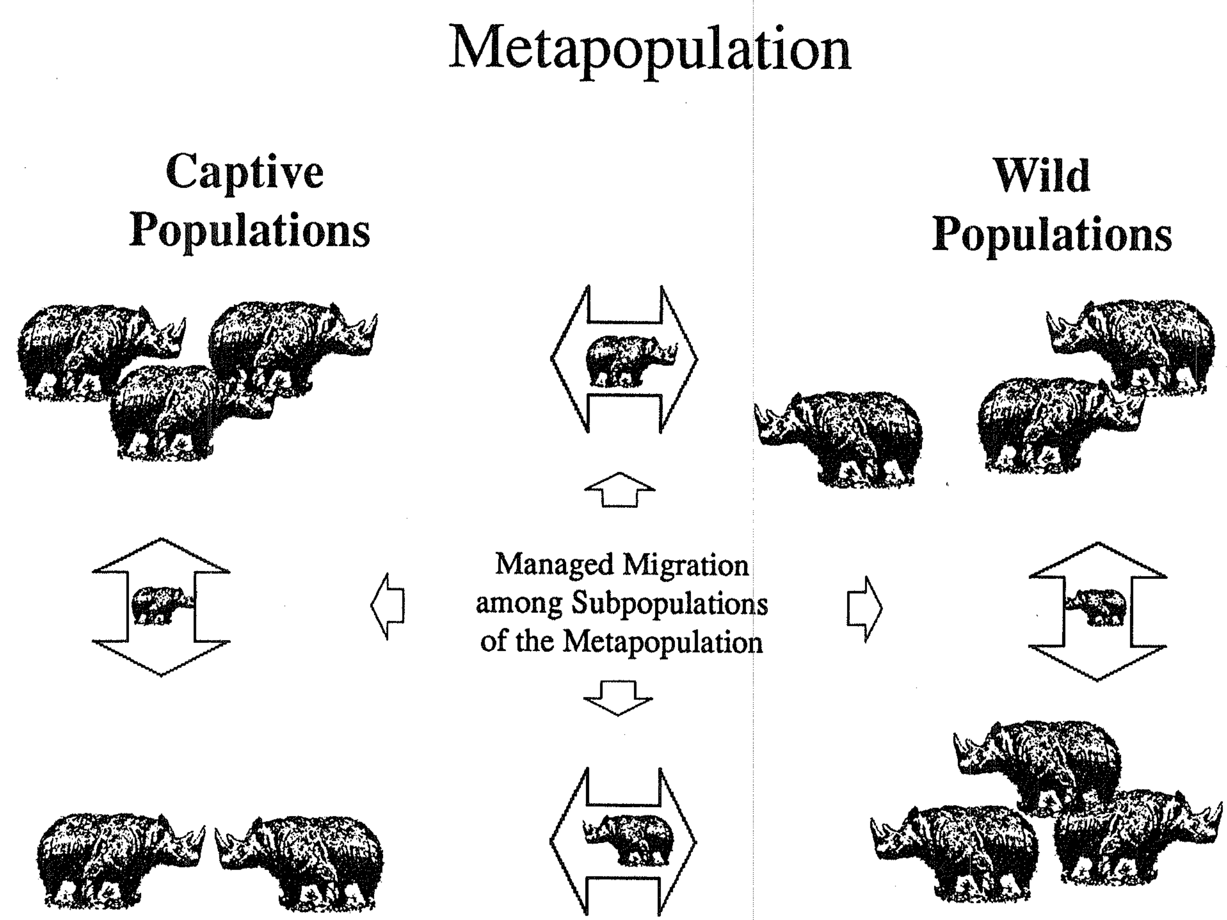
FIGURE 3

OPTIONS FOR RHINO CONSERVATION



Modified from Mark Stanley-Price (1991)

FIGURE 4


Metapopulation
Captive Populations
Wild Populations
Managed Migration among Subpopulations of the Metapopulation

BLACK RHINO WORKING GROUP

<u>Working Group:</u> *(Chairperson) Reinhard Frese, (Recorder) Bruce Read, Christian R. Schmidt, Mitsuko Masui, Charlie Hoessle, Koen Brouwer, Betsy Dresser, Vivian Wilson, Alexandra Dixon, Jim Jackson, Simon Wakefield & Kristina Tomasova*

<u>Goal</u>: Establish target captive populations for four geographic areas 1) Africa 2) Austral-Asia 3) Europe 4) Americas.

<u>Facts</u>: When reviewing the age structure of the captive population in the studbook we observe that we have an aging population that has most of the reproduction in the founder and 1st generation.

<u>Data</u>: Michaeli

Living Population

75 Males
94 Females

Surviving Active Breeding Animals (1987-1990)

11 Males (born between 1956-1981)
21 Females (born between 1961-1982)

Animals kept in institutions with out the opposite sex.

7 Males
6 Females (between 6-25yrs of age + 2 over 25yrs)

Post Reproductive Animals (assumption that female on the average stop reproducing at 25 yrs of age)

- Males (can breed until they die)
16 Females over the age of 25 yrs.

Pre Reproductive Animals (animals under 6 years of age)

20 Males
20 Females

<u>Result</u>:

1) Of the 94 females in the population 31 females are of reproductive age and are at institutions with males, but are not reproducing. Therefore, not contributing to the gene pool.

2) Of the 75 males 37 are old enough to breed and are not contributing to the gene pool.

Mortality/Births

Year	1987	1988	1989	1990	Total
Births	2	7	8	7	24
Deaths	5	5	6	7	23
0-6					9/39%
6-25					7/30%
26+					7/30%

Target Goal: To increase the recruitment rate and carrying capacity of the captive population through: 1) increasing the birth rate; 2) enlarging the number of holding facilities; 3) increasing the holding space at existing facilities.

Recommendations:

1) A target captive population for Michaeli of 200 animals globally in the four geographic regions.

Support for this recommendation: a) By adding the additional females to the breeding population (31 and 6) we are estimating that 1/2 of these will begin to produce offspring. The rate of mortality of the youngest age group was kept at 39%. This doubled the rate of recruitment; b) By breeding females at the age of 3-4 yrs we have lowered the average age of reproduction and c) By shortening the birth interval we have increased the number offspring produced.
Effective size of 20 - Lambda of .05 - generation length 13 - program length 100 yrs. (reflect the ratio of .3 if the ratio is .2 we are looking at a population of 250).

Goals: a) increase the number of breeding animals; b) increase the number of births per lifetime; c) manage for equal family size; d) achieve target founder representation.

2) A target captive population for Minor of 125 animals globally in three regions (Africa, Australia and North America).

Support for this recommendation: a) All the animals that are in the captive population are in the age bracket for potential reproduction or younger and will soon be in this age bracket; b) This population is just being formed and can learn from the problems of the existing East African rhino population; c) The wild population is larger than the East African one. Effective size of 20 - Lambda 1.03 - generation length 15 - program length 100 yrs. (123 reflects a ratio of .3 if the ratio is .2 we are looking at a population of 185).

Goals: a) increase the captive population size by recruitment from the wild and increased birth rate; b) achieve target founder representation; c)

Recommendation for implementation:

1) Look at the possibilities of expanding the captive holding space by: a) increase the number of animals held at each breeding institution; b) expand the total number of holding and breeding facilities in the four geographic areas; c) encourage those institutions that have open holding space to move animals in; d) to utilize unsuitable white rhino space for black rhino.

2) Increase the recruitment rate by: a) pairing up single animals (for example the single female in Rome); b) place young (3 yr old) females in breeding situations; c) shorten the birth intervals of producing females (two - four years); d) identify and evaluate female in reproductive situations that are not reproducing.

3) It is essential to move all 31 presently non breeding females and 6 isolated females into a breeding situation.

4) Of the 7 isolated and 37 presently non reproductive males it is a priority to identify the potential founder animals and transfer them into a breeding situation.

5) Micheali should be kept in Africa, Asia (excluding Australia), North America, South America & Europe.

6) Minor should be kept in Africa. Australia & North America.

7) All regional coordinators should cooperatively establish guidelines for captive management of black rhino within their region.

8) All potentially reproductive animals need to be brought in the breeding nucleus. If this effort is not effective this population will not stabilize and will become extinct.

Age Pyramid Report

Restricted to: EASTERN BLACK RHINO Studbook

Dates: As of End of 20/04/1992 <= date

```
===============================================================================
Taxon Name: DICEROS BICORNIS MICHAELI
===============================================================================
Age                                       Males|Females
---             N =  74                ---------------             N =  89
 42-                                         X|
 41-                                          |
 40-                                          |
 39-                                         X|
 38-                                          |
 37-                                         X|XX
 36-                                          |X
 35-                                          |
 34-                                          |
 33-                                        XX|XXX
 32-                                          |
 31-                                          |X
 30-                                          |XXX
 29-                                        XX|
 28-                                          |X
 27-                                       XXX|XXX
 26-                                          |
 25-                                         X|XXX
 24-                                         X|X
 23-                                          |XXXX
 22-                                   XXXXXXX|XXXXXXXXX
 21-                                        XX|XXXXX
 20-                                        XX|XXX
 19-                                        XX|XXXXXX
 18-                                        XX|XXX
 17-                                          |XX
 16-                                         X|XXX
 15-                                        XX|XXX
 14-                                    XXXXXX|X
 13-                                      XXXX|X
 12-                                       XXX|X
 11-                                        XX|
 10-                                         X|XXXX
  9-                                       XXX|XXXX
  8-                                        XX|XX
  7-                                       XXX|XXX
  6-                                       XXX|XXX
  5-                                       XXX|XX
  4-                                       XXX|
  3-                                        XX|XXXXXX
  2-                                      XXXX|XXX
  1-                                       XXX|XXX
  0-                                        XX|
- - - - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - - -
        32  28  24  20  16  12  8   4           4   8   12  16  20  24  28  32
                                   Number of Animals
```

X >>> Specimens of known sex...
? >>> Specimens of unknown sex...

Age Pyramid Report

```
Restricted to:             EASTERN BLACK RHINO Studbook
 Locations: AFRICAN  /
 Dates: As of End of 20/04/1992 <= date
===============================================================================
Taxon Name: DICEROS BICORNIS MICHAELI
===============================================================================
Age                                  Males|Females
---             N =   3            ---------------              N =   3
 33-                                    X|
 32-                                     |
 31-                                     |
 30-                                     |
 29-                                     |
 28-                                     |
 27-                                    X|
 26-                                     |
 25-                                     |
 24-                                     |
 23-                                     |
 22-                                     |
 21-                                     |
 20-                                     |
 19-                                     |
 18-                                    X| X
 17-                                     | X
 16-                                     |
 15-                                     | X
 14-                                     |
 13-                                     |
 12-                                     |
 11-                                     |
 10-                                     |
  9-                                     |
  8-                                     |
  7-                                     |
  6-                                     |
  5-                                     |
  4-                                     |
  3-                                     |
  2-                                     |
  1-                                     |
  0-                                     |
- - - - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - - -
       32  28  24  20  16  12   8   4       4   8  12  16  20  24  28  32
                                  Number of Animals

 X >>> Specimens of known sex...
 ? >>> Specimens of unknown sex...
```

Age Pyramid Report

Restricted to: EASTERN BLACK RHINO Studbook
 Locations: ASIA /
 Dates: As of End of 20/04/1992 <= date

Taxon Name: DICEROS BICORNIS MICHAELI

Age	Males (N = 18)	Females (N = 17)
37-	X	X
36-		X
35-		
34-		
33-	X	
32-		
31-		
30-		
29-	X	
28-		
27-		X
26-		
25-	X	XXX
24-		
23-		XX
22-	XXX	X
21-		X
20-	X	
19-	XX	XX
18-		
17-		
16-		X
15-		X
14-	XXX	
13-		
12-	X	X
11-		
10-		
9-	X	
8-	X	
7-		X
6-		
5-		X
4-		
3-	X	
2-		
1-	X	
0-		

32 28 24 20 16 12 8 4 | 4 8 12 16 20 24 28 32
Number of Animals

X >>> Specimens of known sex...
? >>> Specimens of unknown sex...

Age Pyramid Report

EASTERN BLACK RHINO Studbook

Restricted to:
 Locations: EUROPE /
 Dates: As of End of 20/04/1992 <= date

```
==============================================================================
Taxon Name: DICEROS BICORNIS MICHAELI
==============================================================================
Age                                Males|Females
---              N =  19         ---------------              N =  29
 33-                                    |X
 32-                                    |
 31-                                    |
 30-                                    |X
 29-                                   X|
 28-                                    |X
 27-                                  XX|X
 26-                                    |
 25-                                    |
 24-                                    |
 23-                                    |X
 22-                                  XX|XXXX
 21-                                   X|X
 20-                                    |X
 19-                                    |X
 18-                                    |XX
 17-                                    |
 16-                                   X|
 15-                                   X|
 14-                                  XX|X
 13-                                  XX|X
 12-                                    |
 11-                                    |
 10-                                    |XX
  9-                                   X|X
  8-                                   X|XX
  7-                                 XXX|X
  6-                                    |
  5-                                    |X
  4-                                    |
  3-                                    |XX
  2-                                   X|XX
  1-                                   X|XX
  0-                                    |
- - - - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - - -
        32  28  24  20  16  12  8   4       4   8   12  16  20  24  28  32
                                  Number of Animals
```

X >>> Specimens of known sex...
? >>> Specimens of unknown sex...

Age Pyramid Report

Restricted to: EASTERN BLACK RHINO Studbook

Locations: N.AMERICA/

Dates: As of End of 20/04/1992 <= date

Taxon Name: **DICEROS BICORNIS MICHAELI**

Age	Males (N = 32)	Females (N = 35)
42	X	
41		
40		
39	X	
38		
37		X
36		
35		
34		
33		X
32		
31		X
30		XX
29		
28		
27		X
26		
25		
24	X	X
23		X
22	X	XXX
21	X	XXX
20	X	XX
19		XX
18	X	
17		
16		X
15	X	X
14		
13	XX	
12	XX	
11	XX	
10	X	XX
9	X	XXX
8		
7		X
6	XXX	XXX
5	XXX	
4	XXX	
3	X	XXXX
2	XXX	X
1	X	X
0	XX	

32 28 24 20 16 12 8 4 | 4 8 12 16 20 24 28 32

Number of Animals

X >>> Specimens of known sex...
? >>> Specimens of unknown sex...

```
                        Age Pyramid Report
Restricted to:             EASTERN BLACK RHINO Studbook
 Locations: CHICAGOBR/CINCINNAT/DENVER   /LOSANGELE/METROZOO /SAN ANTON/ST LOUIS
            SAN FRAN /SD-WAP   /SANDIEGOZ/
 Dates: As of End of 20/04/1992 <= date
===============================================================================
Taxon Name: DICEROS BICORNIS MICHAELI
===============================================================================
Age                                  Males|Females
---             N =  18             --------------               N =  19
 27-                                      |X
 26-                                      |
 25-                                      |
 24-                                     X|X
 23-                                      |X
 22-                                     X|XXX
 21-                                     X|XX
 20-                                     X|XX
 19-                                      |X
 18-                                     X|
 17-                                      |
 16-                                      |X
 15-                                     X|X
 14-                                      |
 13-                                    XX|
 12-                                     X|
 11-                                     X|
 10-                                      |X
  9-                                     X|X
  8-                                      |
  7-                                      |X
  6-                                     X|XX
  5-                                      |
  4-                                     X|
  3-                                      |
  2-                                    XX|
  1-                                     X|X
  0-                                    XX|
- - - - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - - -
        32  28  24  20  16  12  8   4       4   8   12  16  20  24  28  32
                                  Number of Animals

 X >>> Specimens of known sex...
 ? >>> Specimens of unknown sex...
```

BIRTHS & DEATHS - 1981 TO 1991 IN NORTH AMERICAN CAPTIVE POPULATIONS OF *Diceros bicornis michaeli*

ENTIRE POPULATION

YEAR	BIRTHS	DEATHS	BIRTHS/FEMALES>AGE 7
1981	4 (2.2)	2 (1.1)	4/31
1982	6 (2.4)	6 (3.3)	6/30
1983	3 (2.1)	2 (1.1)	3/30
1984	0 (0.0)	0 (0.1)	0/29
1985	7 (2.5)	4 (3.1)	7/28
1986	7 (4.3)	8 (4.4)*	7/27
1987	2 (2.0)	4 (3.1)	2/24
1988	5 (2.3)	2 (1.1)	5/26
1989	4 (2.2)	5 (1.4)	4/29
1990	5 (2.3)	2 (0.2)	5/27
1991	1 (0.1)	1 (0.1)	1/27
	43 (20.23)	37 (18.19)	4/28 (14%)

* 5 (4.1) are estimated dates of death for animals in St. Felicien, Oklahoma, and Granby.

BIRTH INTERVAL DATA:
Number of intervals: 24 — Number of females: 13
Range: 494 - 1633 days — Median: 808 days — Mean: 909 days

CORE POPULATION *

YEAR	BIRTHS	DEATHS	BIRTHS/FEMALES>AGE 7
1981	3 (2.1)	2 (1.1)	3/20
1982	3 (0.3)	1 (0.1)	3/20
1983	2 (2.0)	0 (0.0)	2/21
1984	0 (0.0)	1 (0.1)	0/21
1985	5 (1.4)	1 (0.1)	5/20
1986	5 (2.1)	1 (0.1)	5/19
1987	2 (2.0)	1 (1.0)	2/19
1988	5 (2.3)	1 (1.0)	5/20
1989	2 (1.1)	4 (0.4)	2/23
1990	5 (2.3)	1 (0.1)	5/21
1991	1 (0.1)	1 (0.1)	1/21
	33 (14.17)	14 (3.11)	3/20 (15%)

BIRTH INTERVAL DATA:
Number of intervals: 20 — Number of females: 11
Range: 494 - 1633 days — Median: 753 days — Mean: 878 days

* CORE: Chicago Brookfield, Cincinnati, Denver, Los Angeles, Metrozoo Miami, San Antonio, San Francisco, St. Louis, San Diego Wild Animal Park, San Diego Zoo

Fecundity & Mortality Report
EASTERN BLACK RHINO Studbook

Restricted to:
Locations: N.AMERICA/
Dates: During 01/01/1981 <= date

Taxon Name: **DICEROS BICORNIS MICHAELI**

Age Class	Fecundity [Mx]... Male	N	Female	N	Mortality [Qx]... Male	N	Female	N
0- 1	0.00	19.4	0.00	22.2	0.16	24.3	0.12	25.3
1- 2	0.00	19.3	0.00	18.4	0.05	19.5	0.11	17.7
2- 3	0.00	18.5	0.00	14.8	0.00	18.5	0.13	15.3
3- 4	0.00	19.5	0.00	11.1	0.00	19.5	0.09	10.9
4- 5	0.00	18.7	0.00	9.9	0.00	18.7	0.11	9.5
5- 6	0.00	15.9	0.00	10.7	0.00	15.9	0.00	10.7
6- 7	0.13	11.4	0.05	10.2	0.00	11.4	0.00	10.2
7- 8	0.13	12.0	0.05	9.2	0.00	12.0	0.00	9.2
8- 9	0.14	11.0	0.04	11.8	0.09	11.0	0.00	11.8
9-10	0.14	10.4	0.03	14.6	0.10	10.3	0.07	14.4
10-11	0.20	10.0	0.13	15.8	0.00	10.0	0.00	15.8
11-12	0.15	9.8	0.09	16.9	0.00	9.8	0.06	15.9
12-13	0.24	8.5	0.06	16.1	0.00	8.5	0.06	16.0
13-14	0.06	7.7	0.11	19.0	0.00	7.7	0.00	19.0
14-15	0.00	6.1	0.14	17.5	0.17	6.0	0.27	15.0
15-16	0.17	6.0	0.09	16.1	0.00	6.0	0.00	16.1
16-17	0.25	8.0	0.16	15.8	0.00	8.0	0.06	15.6
17-18	0.13	8.0	0.11	14.0	0.00	8.0	0.07	14.0
18-19	0.13	7.6	0.14	14.0	0.00	7.6	0.00	14.0
19-20	0.06	9.0	0.07	14.4	0.00	8.5	0.07	15.1
20-21	0.07	7.3	0.03	14.6	0.14	7.3	0.00	14.6
21-22	0.07	6.8	0.13	11.4	0.00	6.8	0.09	10.9
22-23	0.09	5.3	0.00	8.8	0.47	4.3	0.00	8.8
23-24	0.13	4.0	0.00	7.3	0.00	4.0	0.00	7.3
24-25	0.00	2.4	0.16	6.3	1.00	1.9	0.00	6.3
25-26	0.00	3.0	0.00	6.0	0.00	2.5	0.00	6.0
26-27	0.26	3.8	0.00	7.0	0.33	3.0	0.00	7.0
27-28	0.00	3.0	0.08	6.3	0.00	3.0	0.00	5.8
28-29	0.11	4.5	0.00	5.8	0.25	4.0	0.20	5.0
29-30	0.13	4.0	0.00	5.0	0.00	4.0	0.00	5.0
30-31	0.13	4.0	0.00	5.0	0.00	4.0	0.00	5.0
31-32	0.00	5.0	0.00	3.3	0.00	5.0	0.00	3.3
32-33	0.00	5.0	0.00	3.0	0.00	5.0	0.00	3.0
33-34	0.12	4.2	0.00	2.3	0.50	4.0	0.00	2.3
34-35	0.00	3.0	0.00	1.1	0.00	3.0	1.00	1.0
35-36	0.17	3.0	0.00	1.0	0.00	3.0	0.00	1.0
36-37	0.00	2.9	0.00	1.0	0.50	2.0	0.00	1.0
37-38	0.00	2.0	0.00	0.3	0.00	2.0	0.00	0.3
38-39	0.00	2.0	0.00	0.0	0.00	2.0	0.00	0.0
39-40	0.00	1.3	0.00	0.0	0.00	1.3	0.00	0.0
40-41	0.00	1.0	0.00	0.0	0.00	1.0	0.00	0.0
41-42	0.00	1.0	0.00	0.0	0.00	1.0	0.00	0.0
42-43	0.00	0.3	0.00	0.0	0.00	0.3	0.00	0.0
43-44	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
44-45	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0

Male	Female	
T = 12.603	T = 14.461	30 day mortality: 13%
Ro = 1.347	Ro = 0.596	(6 out of 46)
lambda=1.02	lambda=0.96	

r = 0.024   r = -0.036

46 birth events to known age parents tabulated for Mx...

40 death events of known age tabulated for Qx...

WARNING: Values with small sample sizes (N) warrant less confidence...

Fecundity & Mortality Report

Restricted to: EASTERN BLACK RHINO Studbook
Locations: CHICAGOBR/CINCINNAT/DENVER /LOSANGELE/METROZOO /SAN ANTON/ST LOUIS SAN FRAN /SD-WAP /SANDIEGOZ/

Taxon Name: **DICEROS BICORNIS MICHAELI**

Age Class	Fecundity [Mx]... Male	N	Female	N	Mortality [Qx]... Male	N	Female	N
0- 1	0.00	27.2	0.00	27.7	0.07	29.2	0.15	32.8
1- 2	0.00	22.5	0.00	22.3	0.00	21.8	0.05	21.5
2- 3	0.00	22.7	0.00	20.9	0.00	22.7	0.10	20.0
3- 4	0.00	22.8	0.00	20.8	0.00	22.8	0.00	20.8
4- 5	0.00	23.1	0.00	22.0	0.00	23.1	0.05	21.7
5- 6	0.09	23.0	0.09	23.5	0.00	23.0	0.00	23.5
6- 7	0.12	21.3	0.09	23.1	0.10	20.8	0.00	23.1
7- 8	0.10	20.5	0.05	21.3	0.05	20.0	0.05	21.2
8- 9	0.13	19.7	0.12	21.0	0.05	19.7	0.00	21.0
9-10	0.13	19.3	0.10	21.0	0.00	19.3	0.05	20.8
10-11	0.18	19.0	0.10	20.3	0.00	19.0	0.00	20.3
11-12	0.08	18.7	0.09	21.1	0.00	18.7	0.00	21.1
12-13	0.19	16.2	0.09	21.1	0.13	15.4	0.05	21.0
13-14	0.04	14.1	0.10	21.0	0.00	14.1	0.00	21.0
14-15	0.00	12.2	0.15	20.7	0.08	12.0	0.05	20.0
15-16	0.14	11.0	0.10	19.3	0.00	11.0	0.05	19.1
16-17	0.19	10.6	0.14	18.4	0.10	10.0	0.05	18.2
17-18	0.10	10.0	0.08	18.0	0.00	10.0	0.00	18.0
18-19	0.05	9.3	0.09	17.3	0.00	9.3	0.00	17.3
19-20	0.00	9.5	0.06	16.2	0.00	9.5	0.00	16.2
20-21	0.05	9.3	0.00	14.6	0.00	9.3	0.00	14.6
21-22	0.00	8.8	0.12	12.1	0.00	8.8	0.09	11.6
22-23	0.15	6.5	0.00	9.2	0.38	5.3	0.00	9.2
23-24	0.10	5.0	0.00	8.3	0.00	5.0	0.00	8.3
24-25	0.11	4.6	0.07	7.3	0.00	4.6	0.00	7.3
25-26	0.00	3.5	0.00	6.5	0.00	3.0	0.00	6.5
26-27	0.33	3.0	0.00	6.0	0.00	3.0	0.00	6.0
27-28	0.00	3.0	0.00	5.8	0.00	3.0	0.00	5.8
28-29	0.17	3.0	0.00	5.8	0.00	3.0	0.20	5.0
29-30	0.17	3.0	0.00	5.0	0.00	3.0	0.00	5.0
30-31	0.17	3.0	0.00	4.5	0.00	3.0	0.00	4.5
31-32	0.00	3.0	0.00	3.6	0.00	3.0	0.33	3.0
32-33	0.00	3.0	0.00	2.5	0.00	3.0	0.50	2.0
33-34	0.30	1.7	0.00	2.0	1.00	1.0	0.00	2.0
34-35	0.00	1.0	0.00	1.1	0.00	1.0	1.00	1.0
35-36	0.50	1.0	0.00	1.0	0.00	1.0	0.00	1.0
36-37	0.00	0.9	0.00	1.0	0.00	0.0	0.00	1.0
37-38	0.00	0.0	0.00	1.0	0.00	0.0	0.00	1.0
38-39	0.00	0.0	0.00	1.0	0.00	0.0	0.00	1.0
39-40	0.00	0.0	0.00	1.0	0.00	0.0	0.00	1.0
40-41	0.00	0.0	0.00	1.0	0.00	0.0	0.00	1.0
41-42	0.00	0.0	0.00	1.0	0.00	0.0	0.00	1.0
42-43	0.00	0.0	0.00	1.0	0.00	0.0	0.00	1.0
43-44	0.00	0.0	0.00	1.0	0.00	0.0	0.00	1.0
44-45	0.00	0.0	0.00	1.0	0.00	0.0	0.00	1.0
45-46	0.00	0.0	0.00	1.0	0.00	0.0	0.00	1.0
46-47	0.00	0.0	0.00	0.2	0.00	0.0	0.00	0.0
47-48	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
48-49	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0

T = 15.013	T = 12.632	30 day mortality: 6%
Ro = 1.510	Ro = 0.942	(4 out of 62)
lambda=1.03	lambda=1.00	
r = 0.027	r = -0.005	

62 birth events to known age parents tabulated for Mx...

35 death events of known age tabulated for Qx...

WARNING: Values with small sample sizes (N) warrant less confidence...

Fecundity & Mortality Report

Restricted to: EASTERN BLACK RHINO Studbook

Locations: CHICAGOBR/CINCINNAT/DENVER /LOSANGELE/METROZOO /SAN ANTON/ST LOUIS SAN FRAN /SD-WAP /SANDIEGOZ/

Dates: During 01/01/1981 <= date

Taxon Name: DICEROS BICORNIS MICHAELI

Age Class	Fecundity [Mx]... Male	N	Female	N	Mortality [Qx]... Male	N	Female	N
0- 1	0.00	17.0	0.00	16.6	0.06	18.0	0.16	19.4
1- 2	0.00	12.1	0.00	9.7	0.00	12.0	0.11	9.4
2- 3	0.00	8.7	0.00	4.5	0.00	8.7	0.25	4.0
3- 4	0.00	7.6	0.00	4.0	0.00	7.6	0.00	4.0
4- 5	0.00	7.1	0.00	5.5	0.00	7.1	0.00	5.5
5- 6	0.00	7.0	0.00	6.0	0.00	7.0	0.00	6.0
6- 7	0.22	6.8	0.00	5.1	0.00	6.8	0.00	5.1
7- 8	0.13	8.0	0.15	3.3	0.00	8.0	0.00	3.3
8- 9	0.21	7.0	0.16	3.2	0.14	7.0	0.00	3.2
9-10	0.14	7.3	0.10	5.0	0.00	7.3	0.21	4.8
10-11	0.27	7.5	0.13	7.5	0.00	7.5	0.00	7.5
11-12	0.17	8.7	0.14	11.0	0.00	8.7	0.00	11.0
12-13	0.27	7.4	0.08	12.1	0.00	7.4	0.08	12.0
13-14	0.00	6.7	0.12	13.0	0.00	6.7	0.00	13.0
14-15	0.00	6.0	0.20	12.7	0.00	6.0	0.08	12.0
15-16	0.20	5.0	0.08	12.1	0.00	5.0	0.00	12.1
16-17	0.30	5.0	0.20	12.4	0.00	5.0	0.08	12.2
17-18	0.20	5.0	0.13	12.0	0.00	5.0	0.00	12.0
18-19	0.12	4.3	0.13	11.3	0.00	4.3	0.00	11.3
19-20	0.00	4.5	0.10	10.2	0.00	4.5	0.00	10.2
20-21	0.00	4.3	0.00	9.6	0.00	4.3	0.00	9.6
21-22	0.00	3.8	0.21	7.1	0.00	3.8	0.15	6.6
22-23	0.17	3.0	0.00	5.2	0.43	2.3	0.00	5.2
23-24	0.00	2.0	0.00	4.3	0.00	2.0	0.00	4.3
24-25	0.00	1.9	0.15	3.3	0.00	1.9	0.00	3.3
25-26	0.00	1.5	0.00	2.5	0.00	1.0	0.00	2.5
26-27	0.50	2.0	0.00	2.0	0.00	2.0	0.00	2.0
27-28	0.00	2.0	0.00	1.8	0.00	2.0	0.00	1.8
28-29	0.25	2.0	0.00	1.8	0.00	2.0	1.00	1.0
29-30	0.25	2.0	0.00	1.0	0.00	2.0	0.00	1.0
30-31	0.25	2.0	0.00	1.5	0.00	2.0	0.00	1.5
31-32	0.00	2.0	0.00	1.0	0.00	2.0	0.00	1.0
32-33	0.00	2.0	0.00	1.0	0.00	2.0	0.00	1.0
33-34	0.48	1.1	0.00	1.0	0.00	1.0	0.00	1.0
34-35	0.00	1.0	0.00	0.1	0.00	1.0	0.00	0.0
35-36	0.50	1.0	0.00	0.0	0.00	1.0	0.00	0.0
36-37	0.00	0.9	0.00	0.0	0.00	0.0	0.00	0.0
37-38	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
38-39	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0

Male	Female	
T = 18.509	T = 13.570	30 day mortality: 8%
Ro = 2.955	Ro = 0.823	(3 out of 37)
lambda=1.06	lambda=0.99	
r = 0.059	r = -0.014	

37 birth events to known age parents tabulated for Mx...

16 death events of known age tabulated for Qx...

AAZPA ANNUAL REPORT
on conservation and science

AAZPA
ANNUAL REPORT ON CONSERVATION AND SCIENCE 1990-91

Edited by

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First Edition
1991

RHINOCEROS ADVISORY GROUP

Chair:
Robert W. Reece, Wild Animal Habitat, Kings Island

Primary Goals

The AAZPA Rhinoceros Advisory Group was officially recognized in January 1991 by the AAZPA's Wildlife Conservation and Management Committee (WCMC). While still in the formative stages, the group has the following long-term objectives: (1) to establish a regional management plan for rhinos which focuses on the efficient use of existing resources, the development of new resources, and the encouragement of effective relationships with other regional breeding programs (e.g., EEP, ASMP, etc.); (2) to develop strategies for the support of *in situ* conservation efforts through increased communication and interaction between SSP institutions, range country managers, NGO's and field scientists; (3) to identify research priorities and assist in the development and implementation of an aggressive research program with specific objectives in those areas of greatest concern; (4) to maintain current information on the status of all captive and wild rhino populations; and (5) to assess the implementation of all rhino SSP Master Plans and provide assistance wherever possible.

Data Table

	Current year
# of meetings	0
# of studbooks under umbrella	4
# of SSPs under umbrella	4
# of new studbook petitions submitted	0
# of new studbooks approved	0
# of new SSP petitions submitted	0
# of new SSPs approved	0

Special Concerns

It has become increasingly apparent that there is a real need to facilitate communication among and between people and programs involved with rhino conservation. Many are convinced that there are conflicting and competing agendas at work and that to support one aspect or approach necessarily detracts from another. Misinformation concerning the efficacy of the various approaches, especially captive breeding, needs to be eliminated. The AAZPA Rhino Advisory Group will use *Around The Horn, The Rhino Conservation Newsletter* to disseminate factual information and serve as a conduit through which individuals and institutions can communicate with everyone involved in the preservation of rhinos.

There must be a concerted effort to increase the amount of resources available to rhino conservation, especially in terms of money and space. While space allocation can be more efficient, the cost of developing and maintaining rhino programs such as research and *in situ* projects will be considerable. As a result, methods will have to be developed to provide these resources.

Progress Toward Goals

(1) The Rhino Advisory Group is in it's formative stages and has only begun to develop specific long- and short-range objectives. The membership selection process is nearly complete and is intended to be flexible so as to allow for the greatest influx of ideas and discussion.

(2) A Rhino strategic planning meeting was held at the New York Zoological Park in July 1991. Much progress was made in identifying major concerns and in outlining various programmatic needs. An additional meeting will be held in connection with the 1991 AAZPA Annual Conference in San Diego.

Short-term Goals for Upcoming Year

(1) Complete an assessment of captive holding space and how it is currently allocated in the North American region.

(2) Initiate an assessment of the rhino husbandry and management practices in institutions holding black and white rhinos.

(3) Formalize a research subcommittee and charge it with the responsibility of developing an aggressive research strategy designed to assist in the veterinary, husbandry and reproductive management of rhinos.

(4) In conjunction with the CBSG Rhino Captive Action Plan Working Group, initiate a concerted effort to address and resolve the black rhino subspecies question.
(5) Begin the development of a unified Regional Collection Plan for all rhinos under the TAG umbrella.

BLACK RHINOCEROS (*Diceros bicornis michaeli* and *D. bicornis minor*)

Species Coordinator: Edward J. Maruska, Cincinnati Zoo and Botanical Garden
Subspecies coordinator: Don Farst, D.V.M., Gladys Porter Zoo
International Studbook Keeper: H.G. Kloss, Berlin Zoo

Introduction

Population genetic analyses have shown that the minimum viable population size (MVP) for black rhinos necessary to maintain 90% of original genetic diversity for 200 years is 150 animals split up into 75 *michaeli* and 75 *minor*. At the present time, there are 67 *michaeli* in 23 institutions and 19 *minor* in seven institutions for a total of 86 animals in 30 institutions in North America. Even though the goal is to preserve 90% of the average heterozygosity in the gene pool for 200 years, in the case of the black rhino, there seems to be some "intuitive logic" in modifying this objective in terms of rhino generations; 10 rhino generations would represent 150-170 years.

At present growth rates, *michaeli* , with a population of 67, should be expected to reach the target "carrying capacity" of 75 in about five years. With a current population of *minor* at 19, it will obviously be some time before the SSP population can attain its target "carrying capacity" of 75. The black rhino SSP is in the mature stage.

In summary, the long-term goals of the Black Rhino SSP are: (1) to propagate black rhino in North America to reinforce wild populations in Africa as part of the IUCN global strategy; (2) toward this goal, to attempt to preserve 90% of the average heterozygosity obtained from wild populations for a period of at least 170 years (10 black rhino generations) and perhaps longer; (3) to respect, at least initially, the four geographical varieties and potential e.s.u.'s recognized by the 1986 Cincinnati African Rhino Workshop; (4) to develop an SSP population of 150 black rhino in North America; (5) to expand the captive habitat for black rhino in North America and emphasize reproduction of black rhino in the management recommendations to insure the self-sustainment and expansion of the captive population against the appreciable mortality still occurring.

Data Table (current through 1 July 1991)

D.b. michaeli

	One year ago	Current year
Participating institutions	22	23
Captive Population	31.35	31.36
# SSP animals managed	66	67
# SSP animals not required to meet goals	0	0
# animals in non-participant collections but desirable to SSP	2	2
Total births in SSP program	5	1
# surviving to one year	4	1
# of desired births	5	1
# of undesired births	0	0
# of deaths of SSP animals	2	1
# of imports	0	0
# of exports	0	0
# of founders with represented descendants	78	78

D.b. minor

	One year ago	Current year
Participating institutions	7	7
Captive Population	7.12	7.12
# SSP animals managed	19	19
# SSP animals not required to meet goals	0	0
# animals in non-participant collections but desirable to SSP	0	0
Total births in SSP program	1	1
# surviving to one year	1	0
# of desired births	1	1
# of undesired births	0	0
# of deaths of SSP animals	0	1
# of imports	0	0
# of exports	0	0
# of founders with represented descendants	11	11

Current Population Status

The population of *michaeli* is approaching the proposed MVP of 75 animals as it currently numbers 67. The birth rate is minimum at best with an increase of only three animals in 1990 and one born in 1991 to date. Because the black rhino population in the wild dropped 85% in only thirty years, from 60,000 in 1960 to under 3,000 today, more emphasis needs to be focused on captive breeding in order to increase the birth rate for both *michaeli* and *minor*. In 1990, only one *minor* was born and in 1991, to date, only one has been born but it died the same day. There have been no imports or exports in 1990-1991. All black rhinos in the population are SSP non-surplus animals and two *michaeli* in the Mexico City Zoo have not been included in the North American population because they have not signed a Memorandum of Participation. The population size of *minor* needs to be increased.

Demographic Trends

The Black Rhino SSP is attempting to manage two of the four potential evolutionarily significant units (e.s.u.'s) for black rhino: *michaeli* and *minor*. Reproduction is occurring as explained above, but at a slower rate than is desirable. There have been no recommendations made to remove any animals from the breeding population. The Black Rhino Master Plan has been closely followed and almost every recommendation has been quickly accomplished.

Population Genetics

The addition of ten new founders of *minor* for the North American population is being planned through the International Black Rhino Foundation agreement with the Zimbabwean government. The U.S. Fish and Wildlife Service received a permit number on 1 July 1991 and it is anticipated that they will issue the permit by October. At the present time there are only 11 founders with represented descendents of *minor* in the North American population. There is an ongoing effort to increase founder representation. In Malaysia at Zoo Negra there is an adult male *michaeli* that may become available for import (in exchange for a pair of white rhino) and there is a 15 year-old female *michaeli* at the Buenos Aires Zoo, Argentina that may be available (in exchange for a young pair of black rhino).

Special Concerns

The population of *minor* needs to be increased and currently there is a dearth of space for *michaeli* which may have an eventual impact on space for *minor*. The Black Rhino SSP has been working with the White Rhino SSP in hopes of moving white rhino from selected institutions to open up more space for black rhino. The Black Rhino SSP may be forced to send some animals out of the U.S. in order to solve this problem. Presently there is a request from the San Diego Zoo to send a male to Japan. This male will probably be sent with the prerequisite that the Yokohama Zoo participate in the SSP. The question of whether or not to keep *michaeli* and *minor* as two subspecies still begs an answer and genetic analyses are ongoing even though there are no apparent morphological differences. Also, biochemical analyses to date have not yet demonstrated any differences between *michaeli* and *minor*.

It will be extremely important to evaluate and determine, over the next five years, the nutritional requirements for captive black rhino.

Research

Current research involves reproduction studies such as hormonal evaluations of urines, bloods, saliva, feces; ultrasound evaluations for pregnancy, ovarian observations and anatomy; semen freezing; anatomical studies at necropsy; development of instrumentation for embryo transfer; nutritional studies involving vitamin E; and disease related studies. There needs to be an increased focus on nutritional studies and problems involving diseases such as hemolytic anemia.

Field Conservation

The International Black Rhino Foundation agreement with the Zimbabwean government will help support field operations in Zimbabwe. Monies raised from the efforts of Michael Werikhe as he walks across the U.S. will benefit black rhino conservation in Africa.

Progress Toward Goals

(1) Completion of negotiations (through the Black Rhino Foundation) with the Zimbabwean government to obtain 10 new founders for the SSP population.

Short-term Goals for Upcoming Year

(1) Make all recommended transfers. The proposed number of *michaeli* transfers during the upcoming year should be approximately six or more depending upon numbers of births and sexes of calves.
(2) Attempt to breed to conception all recommended females.
(3) Make and communicate recommendation to wean calves as soon as possible to be able to expose post-lactational cows to bulls.
(4) Carefully evaluate management of new *minor* founders so that the entire population will be enhanced.
(5) Seek more space for both *michaeli* and *minor* in order to achieve the MVP of 150 animals.

AAZPA
ANNUAL REPORT ON CONSERVATION AND SCIENCE 1991-92

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1992

RHINOCEROS ADVISORY GROUP

Chair:
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Primary Goals

Recognizing that the ultimate objective of captive breeding and related scientific efforts is to preserve wild populations, and that the preservation of wild populations requires the protection and management of habitat and the commitment of people and the governments of the range countries affected, it is the mission of the AAZPA Rhino Advisory Group to: (1) support and/or initiate basic and applied research which contributes to the management and conservation of rhinos, both *in situ* and *ex situ*; (2) strengthen field conservation efforts by developing and exporting useful management technologies; (3) develop, maintain, and use sustainable captive populations of rhinos to insure that animals will be available to augment existing or reestablish extirpated wild populations as needed; (4) promote communication and sharing of information between individuals and organizations working in rhino conservation worldwide; and (5) encourage our member institutions to support *in situ* conservation efforts whenever possible.

Data Table (current through 1 July, 1992)

	One year ago	Current year
# of meetings this year	0	3
# of studbooks under umbrella	4	4
# of SSPs under umbrella	4	4
# of new studbooks petitions submitted	0	0
# of new studbooks approved	0	0
# of new SSP petitions submitted	0	0
# of new SSPs approved	0	0

Special Concerns

Of particular concern to the Rhino Advisory Group is not only the development of self-sustaining captive populations of the various rhino taxa, but the further development of the technology and methods necessary to make these populations truly useful in supporting *in situ* populations. Much needs to be accomplished to increase our knowledge of the behavioral, nutritional and physiological requirements. Assisted reproduction technology holds great promise in helping to manage both *in situ* and *ex situ* populations and to facilitate the flow of genetic material between small and/or remnant groups.

The communication of information and ideas among the regions and between the *in situ* and ex *situ* communities remains paramount. Discussions have been held to focus on methods which may be useful in facilitating the flow of information. During a recent meeting of the Rhino Advisory Group, members expressed the need for more emphasis on personal approaches instead of waiting for meetings and publications.

Finally, there is a critical need to raise funds to support the efforts being made or which need to be made on behalf of the rhino. Finding solutions to such devastating medical conditions as hemolytic anemia requires that financial resources be identified to support those working on the problems. Nutrition and reproduction studies must be conducted as well as the need for funding *in situ* projects.

Progress Toward Goals

(1) In it's first year, the Rhino TAG held three meetings. The first general meeting at the San Diego AAZPA annual meeting was intended largely as organizational and provided a forum for identifying the mission and objectives of the TAG and assigning a limited number of tasks. A second meeting of a subcommittee of the entire membership was held in Cincinnati in the Spring of 1992 in order to develop input for the Global Action Plan meetings in London and to begin work on developing management strategies for the regional plan. Finally, another subcommittee met at White Oak Plantation to begin work on a husbandry manual for all of the rhino taxa.

(2) A research committee has been established to identify and prioritize objectives and to develop a plan for their implementation.

(3) Participation with representatives of the other regions in developing a global action plan for rhinos helped to focus the TAG's long term management strategies.

Short-term Goals for Upcoming Year

(1) Develop and promulgate a long range strategy for the region.
(2) Raise funding to support critical medical research projects.
(3) Complete a comprehensive husbandry manual.
(4) Identify and promote research designed to provide information and technology supportive of our conservation management strategies.

BLACK RHINOCEROS (*Diceros bicornis michaeli* and *Diceros bicornis minor*)

Species Coordinator: Edward J. Maruska, Cincinnati Zoo & Botanical Garden
Subspecies Coordinator: Don Farst, Gladys Porter Zoo
North American Studbook Keeper: Betsy L. Dresser, Center for Reproduction of Endangered Wildlife, Cincinnati Zoo & Botanical Garden
International Studbook Keeper: H.G. Kloss, Berlin Zoo

Introduction

Population genetic analyses has shown that the minimum population size (MVP) for black rhinos in order to maintain 90% of original genetic diversity for 200 years is 150 animal spaces split up into 75 *michaeli* and 75 *minor*. At the present time, there are 68 *michaeli* in 24 institutions and 28 *minor* in 11 institutions for a total of 96 animals in 35 institutions in North America. Even though the goal is to preserve 90% of the average heterozygosity in the gene pool for 200 years, in the case of the black rhino, there seems to be some "intuitive logic" in modifying this objective in terms of rhino generations; ten (10) rhino generations would represent 150-170 years.

At present growth rates *michaeli*, with a population of 68, should be expected to reach the carrying capacity of 75 in about four years. With a current population of *minor* at 28, it will obviously be some time before the SSP population can attain its carrying capacity of 75. The black rhino SSP is in the mature stage.

Data Table: *D.b. michaeli* (current through 1 July, 1992)

	Two Years ago	One Year ago	Current year
Participating Institutions	22	23	24
Captive Population	31.35	31.36	33.35
# SSP animals managed	66	67	68
# SSP animals not required to meet goals	0	0	0
# animals in non-participant collections but desirable to SSP	2	2	2
Total # of births in SSP program	5	1	3
# surviving to one year	4	1	3
# of SSP recommended births	5	1	3
# of non recommended births	0	0	0
# of deaths of SSP animals	2	1	2
# of imports	0	0	0
# of exports	0	0	0
# of founders w/ represented descendents	78	78	78

Data Table: *D.b. minor* (current through 1 July, 1992)

	Two Years ago	One Year ago	Current year
Participating Institutions	7	7	11
Captive Population	7.12	7.12	10.18
# SSP animals managed	19	19	28
# SSP animals not required to meet goals	0	0	0
# animals in non-participant collections but desirable to SSP	0	0	0
Total # of births in SSP program	1	1	1
# surviving to one year	1	0	1
# of SSP recommended births	1	1	1
# of non recommended births	0	0	0
# of deaths of SSP animals	0	1	1
# of imports	0	0	10
# of exports	0	0	0
# of founders w/ represented descendants	11	11	13

Current Population Status

The population of *michaeli* is approaching the proposed MVP of 75 animals since it currently numbers 68 even though the population has only increased by one animal since 1991. The birth rate is minimal at best with only this increase represented by three births and two deaths in 1991. Since the black rhino population in the wild dropped 85% in only 30 years, from 60,000 in 1960 to under 3,000 today, more emphasis needs to be focused on captive breeding in order to increase the birth rate for both *michaeli* and *minor*. All black rhino in the population are SSP non-surplus animals and two *michaeli* in Mexico City have not been included in the North American population because they have not signed the Memorandum of Participation so are not managed as part of the SSP. In 1991, it was deemed that the MVP for *minor* needs to be increased. In regard to this goal, ten *minor* (4.6) were imported on 21 April 1992, seven founders and three calves assumed to be offspring of one of the imported founders. These animals were placed at four new holding institutions: Fossil Rim Wildlife Center, Santillana Ranch, El Coyote Ranch, all in Texas and at White Oak Plantation in Florida. Unfortunately, 1.1 died at Fossil Rim in June 1992. This acquisition was made possible through the International Black Rhino Foundation agreement with the Zimbabwean government. These animals were all wild-caught in Chete Wildlife Reserve.

Demographic Trends

The Black Rhino SSP is attempting to manage two of the four potential evolutionarily significant units (esu's) for black rhino: *michaeli* and *minor*. Reproduction is occurring as explained above, but at a slower rate than is desirable. There have been no recommendations made to remove any animals from the breeding population. The Black Rhino Masterplan has been closely followed and almost every recommendation has been quickly accomplished. A new Masterplan will be completed by 1 September 1992 in order to place unpaired animals in breeding situations and also disperse younger animals to more holding institutions.

Population Genetics

At the present time there are only 13 founders with represented descendents of *minor* in the North American population. There is an ongoing effort to increase founder representation. In Malaysia at Zoo Negara there still is an adult male *michaeli* that is available for import in exchange for a pair of white rhino, but the logistics of exchanging this animal are proving to be difficult. There is a 15 year old female *michaeli* at the Buenos Aires Zoo, Argentina that will be joining the SSP when it arrives in the U.S.

Special Concerns

The population of *minor* continues to be increased and currently there is a dearth of space for *michaeli* which may have an eventual impact on space for *minor*. The Black Rhino SSP has been working with the White Rhino SSP in hopes of moving white rhino from selected institutions to open up more space for black rhino. The Black Rhino SSP may be forced to send some animals out of the U.S. in order to solve this problem. Presently there is a request from the Yokohama Zoo, Japan, for a young male black rhino from the San Diego Zoo. This male will probably be sent there under the prerequisite that the Yokohama Zoo participate in the SSP. The question of whether or not to keep *michaeli* and *minor* as two subspecies still begs an answer and genetic analyses are ongoing even though there are no apparent morphological differences. Also, biochemical analyses to date have not yet demonstrated any differences between *michaeli* and *minor*. There have been several thoughtful letters written by researchers to describe reasons to both merge these populations as well as keep them separate. Work is continuing on this issue. As the wild population continues to decline and space is at a premium, this problem needs to be more quickly resolved.

Research

Current research involves reproduction studies such as hormonal evaluations of urines, bloods, saliva, feces; ultrasound evaluations for pregnancy, ovarian observations and anatomy; semen freezing; anatomical studies at necropsy; development of instrumentation for embryo transfer; nutritional studies involving vitamin E; disease related studies (not much change since 1991). There continues to be a need to increase the focus on nutritional studies and problems involving hemolytic anemia and ulcerative stomatitis that frequently occurs in this species.

Field Conservation

The International Black Rhino Foundation agreement with the Zimbabwean government will help support field operations in Zimbabwe. Funds raised from the efforts of Michael Werhike as he walked across the U.S. will hopefully benefit many AAZPA institutions as well as black rhino in Africa.

Progress Toward Goals

The top five specific goals for the black rhino program that are guiding the program are:

(1) Propagate black rhino in North America to reinforce wild populations in Africa as part of the IUCN global strategy.

(2) Toward this goal, attempt to preserve 90% of the average heterozygosity obtained from wild populations for a period of at least 170 years (ten black rhino generations) and perhaps longer.

(3) Respect, at least initially, the four geographical varieties and potential esu's recognized by the 1986 Cincinnati African Rhino Workshop.

(4) Develop an SSP population of 150 black rhino in North America (carrying capacity).

(5) Expand the captive habitat for black rhino in North America and emphasize reproduction of black rhino in the management recommendations to insure the self-sustainment and expansion of the captive population against the appreciable mortality still occurring.

Progress toward the above stated goals has been described throughout this report.

Short-term Goals for Upcoming Year

These goals are also the Long-Term Target Goals of Black Rhino Working Group (Meeting of this group convened in London on 1 July 1992 as part of the Rhino Global Captive Action Plan)

(1) To increase the recruitment rate and carrying capacity of the captive population through: a) increasing the birth rate; b) enlarging the number of holding facilities; c) increasing the holding space at existing facilities.

(2) Recommendations will be made to wean calves as soon as possible to be able to expose post-lactational cows to bulls.

(3) Management of new *minor* founders will be carefully evaluated to enhance the entire populations.

Five Year Goal

It will be extremely important to evaluate and determine, over the next five years, the nutritional requirements for captive black rhino as well as continue to provide resources to enhance study of reproduction and disease related problems.

KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKSHOP REPORT

1 May 1993

SECTION 8
HEALTH ISSUES

either dangerously close to or below viable population levels. He saw the future for rhinos lying in managed metapopulations consisting of *in situ* subpopulations and *ex situ* captive breeding subpopulations between which controlled movement of breeding animals would be necessary to maintain genetic diversity and demographic security. Highest priority should be placed on increasing both wild and captive bred populations immediately to escape deleterious stochastic threats. Foose felt that the situation had reached a stage where it was undesirable that any taxa of rhino should be reliant on a single political authority for its survival. While advocating the value of captive breeding programs, Foose observed the need for improvement in husbandry.

Leader-Williams presented a powerful case that the only effective conservation of rhinos to date had occurred *in situ* in areas where adequate budgets and manpower had been provided. He presented data to show that, to date, the contribution of *ex situ* captive breeding programmes to conservation of rhinos (and several other species) had been negligible and costly. He expressed caution at experimenting with captive breeding at a stage when many populations needed immediately to be increased to more secure levels.

Martin, also, felt that *in situ* protection of rhinos was of the utmost priority. He highlighted the fact that adequate budgets for such efforts could be obtained sustainably within the three southern African countries which now contain over 90% of Africa's black and white rhinos by taking advantage of the inherent economic value of rhino. A controlled trade in legal government stocks of rhino horn and/or the raising of revenues from a small quota of animals for sport hunting could provide the necessary funds. Current contributions to rhino conservation from the international community were small compared to the budgets allocated by those African governments who had achieved successful conservation of rhino, and these governments sought to remain self-sufficient in funding through sustainable conservation measures. Zimbabwe had made a secondary commitment to *ex situ* captive breeding by its intent to provide a viable founder population of black rhino. It saw this as an ultimate form of insurance in the very long term against extinction possibilities but did not in any way view this as reducing the *in situ* conservation requirements.

In summary:

1. The paramount goal should be the maintenance or restoration of viable wild rhino populations.
2. More money needs to be directed toward this effort either by greater donor involvement or by sustainable utilization of the species including the use of its high economic value.
3. Captive propagation could offer an ultimate insurance against extinction provided that better husbandry, management, and breeding performance can be achieved.

Plenary VIII - Summary and Working Group Report
Health, Disease, Nutrition and Pharmacology: Veterinary Aspects of Rhinoceros Conservation

E. Miller, chair: *Health concerns and veterinary research in the North American black rhinoceros (*Diceros bicornis*) population*
C. Furley: *Diseases and management of black and Sumatran rhinoceroses at the Howletts and Port Lympne zoos*
L. Geldenhuys: *Capture and translocation of black rhino in Namibia*
D. Jessup: *Health data gained from black rhinoceroses immobilized for relocation*
M. Kock: *Capture and translocation of the black rhinoceroses (Diceros bicornis) in Zimbabwe: Management modifications to reduce stress and mortalities*
R. Kock: *Veterinary management of three species of rhinoceroses in zoological collections*
R. Montali: *Pathological findings in captive rhinoceroses*
P. Morkel: *Translocation and dehorning of wild black rhinoceroses*
L. Munson: *Mucosal and cutaneous ulcerative syndrome in black rhinocerso (Diceros bicornis)*

In view of the role that health and nutritional problems in the maintenance of captive rhinoceros populations (eg, as a limiting factor in the growth of the captive black rhinoceros population), and that they have presented concerns in wild populations and their translocations, the following points for consideration and action are recommended:

1. Continued investigation of health problems in wild and captive rhinoceroses. New and continued research should be organized and encouraged in the following areas:

All morbidity and mortality data from captive, and where possible, wild populations should be compiled and reviewed annually under the auspices of the regional species management plans and national wildlife programs, and those regional data reviewed under the auspices of the IUCN/CBSG Rhinoceros Action Plan. Such studies should include evaluation of post-capture and post-translocation mortalities.

Investigation of fertility and the incidence and prevention of management related disease and trauma.

Additionally, monitoring the fertility of all rhinoceros populations with particular attention to fertility in Indian rhinoceroses and abortion rates in black rhinoceroses.

Enhancement of baseline data for normal values from free-ranging and captive rhinoceroses of all species is of critical importance to all fields of research.

Epidemiology of health problems in captive and wild rhinoceros populations and comparison of patterns in each. Such research should include seroprevalence surveys for infectious diseases and evaluation of internal and external parasites and their health significance.

Continued sharing and refinement of immobilization regimens between wildlife and zoo veterinarians should take place. Narcotic agents (etorphine and carfentanil) are the primary drugs used for immobilization, and further investigations are needed to establish preferable supplemental tranquilizers, particularly long-acting neuroleptic agents.

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

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

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

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

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

Oral/skin ulcers

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

Fungal pneumonia

Encephalomalacia.

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

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

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

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

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

Planning for Rhinoceros Conservation

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

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

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

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

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

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

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

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

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

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

Working Group Report Conservation of the Northern white rhinoceros

Ceratotherium simum cottoni

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

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

In situ population

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

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

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

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

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BLACK RHINOCEROS VETERINARY RESEARCH UPDATE 1991

R. Eric Miller, DVM
Veterinary Advisor
Black Rhinoceros (*Diceros bicornis*) SSP Committee
Rhinoceros Taxon Advisory Group

Under the auspices of the SSP, animal health research in the black rhinoceros is an ongoing effort. This report will serve as an update to the 1990 veterinary report to the Black Rhinoceros SSP. Obtaining tissue and sera from all species of captive and wild rhinoceroses remains a priority. Central storage facilities exist for formalinized rhinoceros tissues (Dr. Richard Montali, National Zoological Park) and for frozen serum and tissue (Dr. Eric Miller, St. Louis Zoological Park). These banks have provided readily available sources of materials for comparative and retrospective studies. "Normal" values from wild black rhinoceroses (80+ animals) in Zimbabwe has been published by Dr. Michael Kock, Raoul du Toit, et. al. (1).

Four diseases in black rhinoceroses continue to be notable for their unusual nature and relatively high frequency of occurrence. Although hemolytic anemia has been the leading cause of death among captive animals (43 episodes of hemolysis noted in 34 rhinoceroses; 23 rhinoceroses died from their anemia), no deaths from "primary" hemolysis (not associated with other systemic disease) have been noted since 1986. It is too soon to determine the full significance of this, but it may be a hopeful sign that leptospirosis vaccination and dietary improvements have had some effect. Additionally, no new cases of encephalomalacia have been identified since 1988.

Fungal pneumonias (*Aspergillus* and less commonly phycomycetes) continue to be noted; at least 6 cases have been identified in black rhinoceroses in North America. Four occurred in black rhinoceroses receiving immunosuppressive therapy for other conditions and 2 cases were "spontaneous." The occurrence of these infections suggests an altered immunological response and has led to research on the immune status of black rhinoceroses (see Dr. Slavin's project below, Dr. Herron's project on the 1990 report). Last, but not least, is the occurrence of oral/skin ulcers. Twenty-six cases have been noted, ranging from mild skin ulcers to severe ulcerative lesions of the skin, mucosal junctions and gastrointestinal tract. Death may result from secondary complications. Dr.

Linda Munson is reviewing tissues from these cases (see description of her project below).

Prior to the 1991 International Rhinoceros Conference at the San Diego Zoo, Dr. David Jessup (International Wildlife Veterinary Services) organized a meeting of veterinarians active in rhinoceros medicine and research. Attendees represented zoo and wildlife veterinarians from the US, Great Britain, Zimbabwe and Namibia. The meeting presented an excellent opportunity for wildlife and zoo veterinarians to share clinical and research experiences and to identify areas of common interest and cooperation. A statement that resulted from this meeting and the Veterinary Session of the Rhinoceros Conference is attached. Two areas were identified that warrant further research: 1) immunological function (for reasons noted above) and 2) additional nutritional studies.

Following is an updated list of animal health projects that have either been initiated or active in the past year:

1. <u>Project</u>: T-Lymphocyte Stimulation Testing and Immunological Evaluation for Fungal Infections

   Researchers: Dr. Raymond Slavin and Dr. Allan P. Knutsen, St. Louis University School of Medicine, St. Louis, MO 63104, and R. Eric Miller, DVM, St. Louis Zoological Park, St. Louis, MO 63110, USA.

   Currently being designed, this project will employ various immunological tests to identify black rhinoceroses infected with <u>Aspergillus</u> sp. (primarily pneumonia as noted above) and to evaluate their response to fungal organisms. A more general immunological study will evaluate the response of black rhinoceros lymphocytes to in mitogen stimulation studies.

2. <u>Project</u>: Nutritional studies

   Researchers: Dr. Craig Thatcher, Virginia-Maryland Regional College of Veterinary Medicine, Blacksburg, VA 24601, USA, R. Eric Miller, DVM, St. Louis Zoological Park, St. Louis, MO 63110, USA.

   See Nutritional Report to the Black Rhinoceros SSP Committee.

3. <u>Project</u>: Evaluation of oral and skin ulcers

   Researcher: Dr. Linda Munson, College of Veterinary Medicine, University of Tennessee, Knoxville, TN 37901-1076, USA.

   Due to the occurrence of oral and/or skin ulcers in captive black rhinoceroses (3), biopsy and postmortem tissues from all cases are being reviewed by Dr. Munson. Twenty-six captive black rhinoceroses in the US have had mucosal and/or cutaneous ulcers; 3 cases have been noted in the past year. Most of the rhinoceroses have had recurrent ulcers. Microscopically, the oral and skin lesions appear as chronic ulcers, though, as of yet no single histologic pattern has emerged. In these captive rhinoceroses there has been no evidence of the dirofilarid parasite Stephanofilaria dinniki. The etiology remains unknown. Dr. Munson is preparing a paper describing the ulcerative "syndrome."

4. Project: Leptospirosis evaluation by microagglutination titers and fluorescent antibody testing.

Researcher: Dr. Carol Bolin, National Veterinary Services Laboratory, Ames, IA 50010, USA

On the basis of fluorescent antibody (FA) tests, infection with Leptospirosis interrogans has noted in 3 of 4 cases of fatal hemolytic anemia in black rhinoceroses (2). Additionally, in the past year, another FA+ case was noted in a female that died in 1990 at the Cincinnati Zoo with severe skin ulcers and anemia. The relationship of L. interrogans infection with disease in this animal is unclear. Currently titer data from captive and wild (Zimbabwe samples supplied by Drs. Michael and Nancy Kock and David Jessup and Raoul du Toit, Namibian samples supplied by Dr. Peter Morkel and Louis Geldenhuys) are being submitted for publication. Of interest is evidence of exposure to varying serovars (strains) of L. interrogans in different areas of Zimbabwe and Namibia (no evidence of exposure in 3 rhinoceroses from the latter's arid habitat). The presence of infection with L. interrogans in some of the hemolytic cases and the titer data continue to support the previous recommendation that all black rhinoceroses be vaccinated biannually with a bacterin that contains at least 5 serovars of L. interrogans including icterohaemorrhagiae and grippotyphosa. Leptoferm-5 (Norden Laboratories, Lincoln, NE 80809, USA) is recommended. Opportunistic postvaccinal sampling of black rhinoceros continues to demonstrate responses in microagglutination titers that would be considered appropriate and protective in domestic species.

Note: Though leptospiral infection may be indicated in 50%-75% of the fatal cases of hemolytic anemia, it is important to note that it has not been identified in all cases. Ongoing studies are attempting to identify other factors that may contribute to red blood cell instability.

5. Project: Further evaluation of red blood cell metabolism.

Researcher: Dr. Donald Paglia, University of California - Los Angeles, Los Angeles, CA 90024, USA

ATP levels in the black rhinoceros RBC are approximately 5% - 20% of those in most other mammalian species. The impact of this finding is uncertain, but it raises the possibility that the black rhinoceros RBC may use alternative energy pathways (4). Further analysis of rhinoceros RBC metabolism and substrate usage is ongoing at UCLA as heparinized blood samples become available. Funding sources need to be identified to maintain and continue this project.

6. Project: Aspergillus sp. pneumonia in black rhinoceroses.

Researcher: Dr. Scott Citino, Metro Miami Zoo, Miami, FL 33176, USA and Dr. Eric Miller, St. Louis Zoological Park, St. Louis, MO 63110, USA.

Fungal pneumonia caused by Aspergillus sp. has been noted in at least 6 captive black rhinoceroses. At least 4 of the 6 affected animals were on immunosuppressive therapy for ulcers (see Dr. Munson's project above). However, 2 of the cases were apparently spontaneous. The occurrence of fungal pneumonia in captive black rhinoceroses warrants further studies regarding their immunocompetence (see Dr. Slavin's project).

7. Project: Cross matching of black rhinoceros sera and red blood cells

Researcher: Dr. Ann Bowling, School of Veterinary Medicine, University of California, Davis, CA 95616

Red blood cells (citrated samples) from 9 black rhinoceroses have been cross-matched with sera from 18 black rhinoceroses. In agglutination testing, weak to moderate reactions have been observed in 13 of the 18 sera samples. One sera sample has produced weak lytic reactions against 7 of the 8 animals tested. Interpreted in light of experience in domestic animals, no evidence has been found that would suggest a clinically obvious problem being defined by these tests. However, it is tempting to speculate that a pattern is emerging from these reactions which may define one or more naturally occurring anti-red cell antibodies. Hopefully, further samples will help in interpreting these observations.

8. Project: Complete blood counts and serum chemistries.

Researcher: Dr. Steven Stockham, College of Veterinary Medicine, University of Missouri, Columbia, MO 65211

Because of variability between laboratory methods, a request was made that complete blood counts and serum chemistries from all rhinoceroses be submitted to a central laboratory. To date, 35 samples have been received from 15 black and 6 white rhinoceroses. Data are currently being reviewed.

9. Project: Serum iron levels and iron binding proteins

Researcher: Dr. Joseph Smith, College of Veterinary Medicine, Kansas State University, Manhattan, KS 66506

Due to the elevated tissue levels of iron noted at necropsy in many black rhinoceroses, additional tissue iron levels from necropsies and serum levels of iron and iron transporting proteins in living animals are being assayed. Thirty-seven sera samples (29 black, 7 white, and 1 Indian), and 17 liver and/or splenic samples (14 black, 3 white) samples have been evaluated. When the data from black rhinoceroses are compared to the white rhinoceroses included in the study, they do not appear to differ significantly. Further analysis is underway to determine if initial impressions that black rhinoceroses accumulate iron in the liver and spleen as they age, and if the serum iron and TIBC of adult black rhinoceroses are higher than that of younger animals or white rhinoceroses.

10. Project: Evaluation for hepadnovirus.

Researcher: Dr. Mike Worley, Zoological Society of San Diego, San Diego, CA 92103, USA.

This study continues to evaluate rhinoceros serum samples for antibodies to hepatitis B-like virus. Additional testing is in progress in an attempt to more definitively identify viral isolates.

-next page-

JUL 10 1991

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Charles H. Hoessle
Director

Robert Hyland
President, Zoological Commission

July 3, 1991

Dr. Ulysses Seal
CBSG
c/o Minnesota Zoological Garden
13000 Zoo Boulevard
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Dear Ulie:

Please find enclosed the data regarding the occurrence of hemolytic anemia in black rhinoceroses that you requested at the at the Bronx Zoo meeting. You had specifically suggested that we could have the mortality data analyzed for significance of the apparent decrease in deaths since 1986 (in New York, I forgot to mention a death that occurred in 1990 - #367 - an animal that developed hemolytic anemia after a severe caudal nasal cavity infection and I'm still not sure if to count this as a "primary" case or not, see ** on chart below).

Additionally, I could not remember if I had already sent you a copy, so I've also enclosed a draft of the paper I submitted for the upcoming version of Fowler's zoo medicine book. The numbers do not agree between the papers as I have added additional cases to the data below. I have also included copies of my data "scratch sheets" if you wish to identify individuals.

I've identified 43 episodes of presumed hemolysis (hemoglobinuria, in a few cases red discoloration to the urine associated with severe anemia), in 34 black rhinoceroses in North America, Europe and Japan. I am currently having a Japanese article translated that I believe will add additional cases due to leptospirosis, and Tom Beggs of Howletts Park reported on additional cases in Great Britain, not all of which I have been able to identify. Twenty-three deaths occurred during hemolytic events (counting #367 mentioned above as a hemolytic death).

I have listed the data as to when the hemolytic events occurred and whether or not the animals **died** (numbers listed in bold type) or survived (listed in regular type) their

BLACK RHINOCEROS DEATHS IN NORTH AMERICA

1991

STDBK # NAME	SEX	DOB	DOD	CAUSE OF DEATH
239 Nanyuki SD-WAP	F	15OCT76	13JUN91	Ruptured liver, trauma
2066 No Name Bentsen	M	20JUL91	20JUL91	Weak, possibly premature

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Respectfully submitted,

R. Eric Miller, DVM
Associate Veterinarian
St. Louis Zoological Park

September 1, 1991

episodes. By year, the occurrence of hemolytic anemia was as follows:

YEAR*	TOTAL	BREAKDOWN (DIED/SURVIVED)
1962	2	(1/1)
1963	1	(1/0)
1969	1	(0/1)
1971	2	(2/0)
1973	1	(1/0)
1975	1	(1/0)
1976	1	(0/1)
1977	3	(3/0)
1978	1	(0/1)
1979	6	(3/3)
1980	5	(3/2)
1981	2	(1/1)
1982	1	(1/0)
1984	2	(1/1)
1985	2	(1/1)
1986	4	(3/1)
1987	2	(0/2)
1990	3	(1/2)**

* Years known on 40 of the 43 episodes, not known from 2 rhinoceroses at the Nagoya Zoo (#237 and 238) and the first episode in "Katharina" at the Frankfurt Zoo.

** A male (#296) at the Mexico City Zoo accounted for the 2 episodes in which a rhinoceros survived - in both spirochetemia was noted and he presumably had leptospirosis, he was not vaccinated. The fatal case (#367) developed hemolytic anemia after a prolonged illness with a caudal sinus cavity infection. Difficult to call a "primary" hemolytic anemia - why I forgot to mention it in New York as a recent death from hemolysis. The animal had not been vaccinated for leptospirosis since OCT88. I am currently submitting liver tissue to Dr. Bolin for FA (not submitted by the Caldwell Zoo and I am checking if we have stored tissue).

The British had commented that their cases tended to occur in the winter. In past compilations, seasonality was not present, but I recalculated with the present data. Months are known for 35 of the 43 hemolytic events, they are as follows:

JAN - 2
FEB - 4
MAR - 1
APR - 5
MAY - 4
JUN - 3
JUL - 3

AUG - 2
SEP - 2
OCT - 1
NOV - 4
DEC - 4.

I've also presented these data in an attached bar graph. These data do not seem to present strong evidence of seasonality. Would you agree and can this also be statistically analyzed?

Hemolysis in 10 of the rhinoceroses above was either suspicious of or definitively diagnosed (FA+) as occurring concurrently with leptospiral infection. Liver tissue was submitted from 4 black rhinoceroses dying during hemolysis and 3 were positive (#187, Cheyenne Mountain Zoo was -). The leptospirosis cases/ suspects are:

ANIMAL	INSTITUTION	DATE	DIED OR SURVIVED	DIAGNOSTIC METHOD
#293	Granby	DEC86	D	FA+(titers were-)
#155	Tampa	JAN85	D	FA+
#186	St. Louis	MAY81	D	FA+
#179	Memphis	JUN79	S	^ titers (greater than 1:8000 to <u>L. int. ictero-hemorrhagiae</u>
#199	Memphis	JUN79	D	died in association with #179 above
#126	Memphis	JUN79	D	died in association with #179 above
#218	Dvur Kralove	NOV79 FEB80 MAR81	S S S	^ titers (1:12800 <u>L. int. grippo-typhosa</u>, died of "complications of anemia"
#170	Dvur Kralove	?78 NOV79	S D	^titers (1:6800 <u>L. int. grippo-typhosa</u>
#209	Osaka	?84	D	silver-stained spirochetes in tissues

#296	Mexico City	FEB90	S	spirochetemia on exam, sera to be sent to US for FA testing.
		MAY90	S	

Please contact me if I can supply any further data or answer any questions about it. You and Tom also requested neonatal mortality data and I will start work on that in the coming week and forward it to you both when I get it compiled.
I will also work on drafting a letter that will serve as a "leptospirosis vaccination reminder" to be distributed to the Black Rhinoceros SSP institutions. Thank you again for your interest and your support in New York.

Sincerely,

Eric

R. Eric Miller, DVM
Associate Veterinarian

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BLACK RHINOCEROS VETERINARY RESEARCH UPDATE 1992

R. Eric Miller, DVM
Veterinary Advisor
Black Rhinoceros (*Diceros bicornis*) SSP Committee
and Rhinoceros Taxon Advisory Group

Under the auspices of the Rhinoceros Taxon Advisory Group (TAG) and the Black Rhinoceros SSP, veterinary research to address the many medical issues affecting this species remains an active and ongoing effort. Unfortunately, deaths from a number of diseases that are still not completely understood, most notably hemolytic anemia and oral/skin ulcers, continue to limit the growth of the captive black rhinoceros population.

Perhaps the most significant problem in the past year has been the deaths of 3 of 10 black rhinoceroses imported from Zimbabwe in April 1992. At necropsy, the animals marked biliary stasis in their livers was noted. Diagnostic tests and final diagnosis in these cases are still pending.

Additional cases of note include hemolytic anemia in a 27 year old female (studbook #121) at the Oklahoma City Zoo that survived a bout of acute hemolysis (PCV=18%) after antibiotic therapy and extensive IV phosphorous supple-mentation. A 4 month old calf at the Denver Zoo has apparently developed encephalomalacia as previously reported.[6] If confirmed, this would be the fifth case of encephalomalacia and again emphasizes the importance of collecting brain tissue from all rhinoceros necropsies.

On a more encouraging note, the interest spurred by these events has resulted in the initiation of several new research projects, most notably by Drs. Evan Blumer (nutritional studies in cooperation with Purina Mills and fecal steroid analyses) and Janet Stover (potential electron microscopic studies of liver and a bile acid study described below), and the augmentation of several preexisting studies.

Also on a positive note, Dr. Paglia's laboratory at UCLA has reported dramatic new findings in the metabolism of the black rhinoceros red blood cell (RBC) (see below and attachment).[8-10]

Several practical clinical suggestions have resulted, including a renewed emphasis on avoiding compounds known to cause hemolysis in human enzyme deficiencies and more aggressive treatment of acidosis and hypophosphatemia[1] in hemolytic black rhinoceroses.

Funding of rhinoceros research remains an ongoing problem. Until recently, Dr. Paglia's project had been funded by an NIH grant (which was not renewed). At the time of this report, his laboratory has obtained partial funding via a $5000 donation from the Cincinnati Zoo and $10,000 from an AAZPA Conservation Endowment Fund (CEF). A concerted effort from the Rhinoceros TAG is underway to support that project and several others that are currently in need of financial support. Included in this potential funding list are a dietary review of by a team assembled by Dr. Craig Thatcher at the Virginia-Maryland Regional College of Veterinary Medicine, a immunological and fungal studies by Dr. Slavin at St. Louis University, and support for Dr. Linda Munson's work on the ulcerative syndrome.

Lastly, a Rhinoceros Veterinary Bibliography, containing over 385 references, was compiled and distributed to veterinarians at all rhinoceros holding institutions in North America, rhinoceros coordinators worldwide, and researchers who have been active in rhinoceros health matters.[5]

Following is an updated list of animal health projects that have been initiated or active during the past year:

1. Project: Continued studies of red blood cell metabolism in rhinoceroses.

   Researcher: Dr. Donald Paglia, University of California -Los Angeles, CA 90024, USA.

   Dr. Paglia's laboratory continues to document a marked deficiency of energy (ATP) in black rhinoceroses red blood cells (RBCs). Thus the compromised status of the RBCs apparently makes them susceptible to hemolysis "triggered" by a variety of "stresses" (eg, oxidant compounds such as drugs, infections such as leptospirosis).[8-10] Another promising breakthrough is the discovery that the enzyme catalase is nearly absent in black rhinoceros RBCs. In man, acatalasemia is associated with oral ulcers and in black rhinoceroses; this finding may link both that syndrome and hemolytic anemia. Interestingly, although the RBCs from the 2 white rhinoceroses tested to date were also energy deficient, they had catalase levels similar to those in normal human cells. This finding encourages further research to address the role of catalase deficiency in some of the unique disease problems of black rhinoceroses. A summary of these findings was distributed to veterinarians at rhinoceros holding institutions and will be presented at the AAZV meeting (copy enclosed).

2. Project: Comprehensive nutritional review of captive diets.

Researcher: Dr. Craig Thatcher, Virginia-Maryland Regional College of Veterinary Medicine, Blacksburg, VA 24601, USA.

Initiation of this project is awaiting funding ($25,000). Dr. Thatcher has assembled a team of that includes nutritionists, an epidemiologist and an infectious disease specialist to assist in the review of captive rhinoceros diets. It is hoped that this project will provide a basis on which to build additional studies of specific nutritional factors.

3. Project: Evaluation of oral and skin ulcers

Researcher: Dr. Linda Munson, College of Veterinary Medicine, University of Tennessee, Knoxville, TN 37901.

Dr. Munson continues to review tissues from biopsy and necropsy samples from these cases.[7] She has identified 32 cases. Histologically, the lesions have been characterized by ballooning degeneration and intraepithelial vesicle formation. Publication of her findings is pending.

4. Project: Leptospirosis evaluation by microagglutination titers and fluorescent antibody testing.

Researcher: Dr. Carole Bolin, National Veterinary Laboratories, Ames, IA 50010, USA.

Dr. Bolin's laboratory continues to perform microagglutination titers on sera and fluorescent antibody (FA) testing on rhinoceros tissue samples. FA tests on the two rhinoceros deaths at Fossil Rim were negative. A paper summarizing the results from both captive and translocated rhinoceroses in Zimbabwe is in press.[2]

Titers from the recent importation of 10 black rhinoceroses from Zimbabwe found evidence of exposure in all animals to the serovar *Leptospirosis interrogans* serovar *bratislava*. Due to these findings, a revised leptospiral vaccination protocol has been recommended that includes this serovar. We are now recommending biannual vaccination with a 6-way serovar (*canicola, grippotyphosa, hardjo, icterohemorrhagiae, pomona,* and *bratislava*). This vaccine is commercially available as Brativac, a swine product from Norden Pharmaceuticals (Lincoln, NE, USA) that comes in 10 or 50 dose units.

5. Project: Evaluation of bile acid levels and their effect on platelet function in black and white rhinoceroses.

Researchers: Dr. Roger Clemens, College of Veterinary Medicine, University of Florida, Gainesville, FL 32610-0103, Dr. Janet Stover, White Oak Plantation, Yulee, FL 32907.

Bile acid levels appear to be elevated in several black rhinoceroses tested. Interference of the test with other compounds in the blood is being evaluated. In the horse, elevated levels of bile acids have been associated with increased red blood cell fragility and altered platelet function. Results from normal and abnormal black and white rhinoceroses are pending.

6. Project: Complete blood counts and serum chemistries.
Researcher: Dr. Steven Stockham, College of Veterinary Medicine, University of Missouri, Columbia, MO 65211.

Testing of blood and sera samples continues. These values will further establish "normal" values in the captive black rhinoceros population, and provide comparative information with data previously published from free-ranging black rhinoceroses.[3]

7. Project: Evaluation of iron levels and metabolism.

Researcher: Dr. Joseph Smith, College of Veterinary Medicine, Kansas State University, Manhattan, KS 66506, USA.

Dr. Smith is continuing to measure iron and iron binding proteins in samples submitted to Kansas State. In general, his quantitative measurements indicate increased levels of hepatic iron in captive black rhinoceroses and that sera iron and TIBC of black rhinoceroses are higher in older than younger animals, and are higher than in white rhinoceroses. A publication summarizing his data is pending. Of related interest is a recent publication that suggests that the accumulation of hepatic iron may be a function of the length of time spent in captivity.[3]

8. Project: Evaluation for hepadnovirus.

Researcher: Dr. Mike Worley, Zoological Society of San Diego, San Diego, CA 92103, USA.

This study continues to evaluate rhinoceros sera samples for antibodies to hepatitis-B like virus. Additional testing is in progress in an attempt to more definitively identify viral isolates.

9. Project: Cross-matching of black rhinoceros sera and red blood cells.

Researcher: Dr. Ann Bowling, School of Veterinary Medicine, University of California, Davis, CA 95616.

Citrated samples of whole blood from 20+ black rhinoceroses have been cross-matched with sera from 18 other black rhinoceroses. Although the pattern emerging from these reactions may define one or more naturally occurring anti-red blood cell antibodies, no evidence has been found that would suggest a clinically obvious problem with transfusions being defined by these tests.. No obvious patterns or differences in reactivity were noted between the Eastern and Southern subspecies (*D. b. michaeli* and *D. b. minor*).

10. Project: Evaluation of the immune response in rhinoceroses with particular emphasis on aspergillosis infections.

Researchers: Drs. Raymond Slavin and Alan P. Knutsen, St. Louis University School of Medicine, St. Louis, MO 63104, USA.

The general immune response in the rhinoceros will be determined by comparing anti-leptospiral antibodies in rhinoceroses affected with aspergillosis pneumonia and unaffected individuals. Cellular immunity will be measured by *in vitro* lymphocyte response to phytohemagglutinin. The specific response to aspergillus will be determined by detection of precipitating antibodies; measurement of IgG anti-aspergillus antibody in the serum, and *in vitro* lymphocyte proliferative response to aspergillus. This project is awaiting funding ($5000).

Respectfully submitted,

R. Eric Miller, DVM
Veterinary Advisor,
Rhinoceros TAG,
Black Rhinoceros SSP

-OVER FOR MORTALITIES/REFERENCES-

BLACK RHINOCEROS DEATHS IN NORTH AMERICA 1992

STDBK # LOCATION	SEX	DOB	DOD	CAUSE OF DEATH
74/San Francisco	M	1JAN54	7NOV91	Ruptured hepatic tumor
2064/ Denver	F	10APR90	30JAN92	Euthanized due to encephalomalacia
2078/Fos. Rim	F	Adult	12JUN92	Hepatic bile stasis, dystocia, oral/skin ulcers, anemia, imported from Zimbabwe 22APR92
2077/Fos. Rim	M	Adult	27JUN92	Hepatic bile stasis, oral/skin ulcers, imported from Zimbabwe 22APR92
#188/ Columbus	F	1970	25JUL92	Metritis? Pending histology.
/Wh. Oak	M	Adult	22AUG92	Hepatic bile stasis, oral ulcers, thoracic hemorrhage, imported from Zimbabwe 22APR92

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ERYTHROCYTIC ATP DEFICIENCY AND ACATALASEMIA IN THE BLACK RHINOCEROS (*Diceros bicornis*) AND THEIR PATHOGENIC ROLES IN ACUTE EPISODIC HEMOLYSIS AND MUCOCUTANEOUS ULCERATIONS

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R. Eric Miller, D.V.M.*
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Sudden episodes of severe hemolytic anemia are the leading cause of death among captive black rhinoceroses (accounting for 25 deaths in 33 affected individuals) and mild to severe oral and/or skin ulcerations also occur commonly in this species.[9] In regard to hemolytic anemia, studies to detect potential hemoglobinopathies,[3] autoimmune phenomena,[2] or exposures to specific toxins have been negative.[6] Although leptospirosis appeared to be involved in a high percentage of the cases,[4,7] it has not been identified in all hemolytic crises.[4,7] To date, studies of the mucocutaneous ulcerations have not determined a definitive etiology.[9]

Hemolytic syndromes in humans are commonly caused by enzyme defects which impair metabolic pathways required to neutralize oxidants in red blood cells (RBCs). The most common defect is hereditary deficiency of glucose-6-phosphatate dehydrogenase (G-6-PD), which predisposes affected individuals to hemolysis secondary to oxidant stress. Earlier studies at the UCLA Hematology Research Laboratory established that black rhinoceros erythrocytes possess RBC enzyme profiles which differ radically from all other known species. The black rhinoceros RBCs contain only 2%-5% of human RBC ATP levels and are relatively deficient in many RBC enzymes. Additionally, even though rhinoceros RBCs had abundant G-6-PD activity, they were found to be very susceptible to oxidants *in vitro*.

More recent studies indicate that low ATP concentrations in the rhinoceros erythrocyte may be rate-limiting in the anti-oxidant activity of the hexomonophosphate (HMP) shunt. Glutathione instability of rhinoceros erythrocytes has been corrected by incubation of the cells with adenosine and glucose which raised intracellular ATP levels to human equivalents.

In the small group of black rhinoceroses tested to date, adenosine kinase activity segregated into two groups, one with about half the activity of the other. This is consistent with a heterozygous deficiency that could increase susceptibility to oxidant-induced hemolysis, since this is the enzyme principally responsible for maintenance of ATP levels, already precariously low in rhinoceros RBCs. Glucose catabolism is essential for ATP salvage via the adenosine kinase pathway, thus it is crucial to avoid and correct conditions that inhibit glycolysis, such as acidosis or hypophosphatemia. Currently, this provides the metabolic rationale for aggressive correction of these two conditions which may occur as complications of other disorders.

In humans, there is strong evidence that G-6-PD deficiency and decreased RBC ATP concentrations may have evolved as a protection against malarial parasitism.[5] It seems reasonable to speculate that ATP deficiency may confer a similar protective advantage for rhinoceroses which are subjected to numerous hemic parasites in the wild.

An additional highly significant recent finding has been the marked deficiency of catalase activity (acatalasemia) in black rhinoceros RBCs. In some catalase deficient human populations, gangrenous oral ulcers (Takahara's disease) are a notable consequence of this deficiency.[11] In recent testing, one rhinoceros calf, exhibiting both leucoencephalomalacia and skin ulcers, was found to have only 2% of the catalase activity present in human erythrocytes. Since then, all additional black rhinoceroses tested, including several with ulcerative disease, have been acatalasemic, whereas, two white rhinoceroses (*Ceratotherium simum*) have not. In combination with impaired HMP shunt metabolism, acatalasemia may further decrease the ability of black rhinoceros cells to neutralize oxidant stresses and therefore may contribute to both mucocutaneous ulcerative disease and acute episodic hemolysis. Since white rhinoceroses nearly all the other metabolic characteristics of the blacks, but are not susceptible to hemolysis or ulcerative disease, it appears likely that catalase plays a pivotal role in the morbidity and mortality of these syndromes in the blacks.

Studies at UCLA to further outline the metabolism of the black rhinoceros RBC are continuing. In the interim, it seems prudent to regard all rhinoceroses as though they were clinically equivalent to G-6-PD deficient humans and to protect them from drugs and agents known to cause hemolysis in man. These include several classes of pharmaceutical compounds: antimalarials, sulfonimides, sulfones, nitrofurans, acetanilid, chloramphenicol and some vitamin K analogs, fava beans, and a number of chemical compounds (including wood preservatives, rodent control poisons or other pesticides, strong cleansers, particularly those containing naphthalene). In man, many other drugs have been associated with hemolysis, but their precise role is uncertain. These include aspirin, phenacetin, aminopyrine, acetaminophen, probenecid, vitamin C, dimercaprol, p-aminosalicylic acid and L-DOPA. Additionally, due to the induction of hemolysis in horses and other domestic species by consumption of certain oak and red maple leaves and wild onions and members of the *Brassica* (rape, kale) family,[1] these should be avoided as well.

In G-6-PD deficient patients, viral, bacterial, and rickettsial infections may also induce hemolysis. In black rhinoceroses approximately 50+% of the hemolytic cases studied had indications of infection with serovars of the spirochete bacterium *Leptospirosis interrogans*. Semi-annual vaccination of all black rhinoceroses with a killed bacterin (Leptoferm-5, Norden Pharmaceuticals, Lincoln, Nebraska 68521, USA) containing *L. interrogans* serovars *icterohaemorrhagiae*, *grippotyphosa*, *canicola*, *pomona* and *hardjo*) is recommended.[7]

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KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKSHOP REPORT

1 May 1993

SECTION 9
SMALL POPULATION OVERVIEW

KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKSHOP REPORT

1 May 1993

SECTION 10
VORTEX

VORTEX
SIMULATION MODEL OF POPULATION DYNAMICS AND VIABILITY

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Version 5.1, 13 April 1992

Stochastic simulation of population extinction

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 variability in demographic processes. When a population is small and isolated from other populations of conspecifics, these random fluctuations can lead to extinction even of populations that have, on average, positive population growth. The VORTEX program (earlier versions called SIMPOP and VORTICES) is a Monte Carlo simulation of demographic events in the history of a population. Some of the algorithms in VORTEX were taken from a simulation program, SPG, written in BASIC by James Grier of North Dakota State University (Grier 1980a, 1980b, Grier and Barclay 1988).

Fluctuations in population size can result from any or all of several levels of stochastic (random) effects. Demographic variation results from the probabilistic nature of birth and death processes. Thus, even if the probability of an animal reproducing or dying is always constant, we expect that the actual proportion reproducing or dying within any time interval to vary according to a binomial distribution with mean equal to the probability of the event (p) and variance given by $Vp = p * (1 - p) / N$. Demographic variation is thus intrinsic to the population and occurs in the simulation because birth and death events are determined by a random process (with appropriate probabilities).

Environmental variation (EV) is the variation in the probabilities of reproduction and mortality that occur because of changes in the environment on an annual basis (or other timescales). Thus, EV impacts all individuals in the population simultaneously -- changing the probabilities (means of the above binomial distributions) of birth and death. The sources of EV are thus extrinsic to the population itself, due to weather, predator and prey populations, parasite loads, etc.

VORTEX models population processes as discrete, sequential events, with probabilistic outcomes determined by a pseudo-random number generator.
VORTEX simulates birth and death processes and the transmission of genes through the generations by generating random numbers to determine whether each animal lives or dies, whether each adult female produces broods of size 0, or 1, or 2, or 3, or 4, or 5 during each year, and which of the two alleles at a genetic locus are transmitted from each parent to each offspring. Mortality and reproduction probabilities are sex-specific. 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. The mating system can be specified to be either monogamous or polygynous. In either case, the user can specify that only a subset of the adult male population is in the breeding pool (the remainder being excluded perhaps by social factors). Those males in the breeding pool all have equal probability of siring offspring.

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. Each animal in the initial population is assigned two unique alleles at some hypothetical genetic locus, and the user specifies the severity of inbreeding depression (expressed in the model as a loss of viability in inbred animals). The computer program simulates and tracks the fate of each population, and outputs summary statistics on the probability of population extinction over specified time intervals, the mean time to extinction of those simulated populations that went extinct, the mean size of populations not yet extinct, and the levels of genetic variation remaining in any extant populations.

Extinction of a population (or meta-population) is defined in VORTEX as the absence of either sex. (In some earlier versions of VORTEX, extinction was defined as the absence of both sexes.) Recolonization occurs when a formerly extinct population once again has both sexes. Thus, a population would go "extinct" if all females died, and would be recolonized if a female subsequently migrated into that population of males. Populations lacking both sexes are not considered to be recolonized until at least one male and at least one female have moved in.

A population carrying capacity is imposed by a probabilistic truncation of each age class if the population size after breeding exceeds the specified carrying capacity. The program allows the user to model trends in the carrying capacity, as linear increases or decreases across a specified numbers of years.

The user also has the option of modelling density dependence in reproductive rates. I.e., one can simulate a population that responds to low density with increased (or decreased) breeding, or that decreases breeding as the population approaches the carrying capacity of the habitat. To model density-dependent reproduction, the user must enter the parameters (A, B, C, D, and E) of the following polynomial equation describing the proportion of adult females breeding as a function of population size:

$$\text{Proportion breeding} = A + BN + CN^2 + DN^3 + EN^4,$$

in which N is total population size. Note that the parameter A is the proportion of adult females breeding at minimal population sizes. A positive value for B will cause increasing reproduction with increasing population sizes at the low end of the range. Parameters C, D, and E dominate the shape of the density dependence function at increasingly higher population sizes. Any of the values can be set to zero (e.g., to model density dependence as a quadratic equation, set D = E = 0). To determine the appropriate values for A through E, a user would estimate the parameters that provide the best fit of the polynomial function to an observed (or hypothetical) data set. Most good statistical packages have the capability of doing this. Although the polynomial equation above may not match a desired density dependence function (e.g., Logistic, Beverton-Holt, or Ricker functions), almost any density dependence function can be closely approximated by a 4th-order polynomial.

After specifying the proportion of adult females breeding, in the form of the polynomial, the user is prompted to input the percent of successfully breeding females that produce litter sizes of 1, 2, etc. It is important to note that with density dependence, percents of females producing each size litter are expressed as percents of those females breeding, and the user does not explicitly enter a percent of females producing no offspring in an average year. (That value is given by the polynomial.) In the absence of density dependence, the user must specify the percent of females failing to breed, and the percents producing each litter size are percents of all breeding age females (as in earlier versions of VORTEX). Read the prompts on the screen carefully as you enter data, and the distinction should become clear.

VORTEX models environmental variation simplistically (that is both the advantage and disadvantage of simulation modelling), by selecting at the beginning of each year the population age-specific birth rates, age-specific death rates, and carrying capacity from distributions with means and standard deviations specified by the user. EV in birth and death rates is simulated by sampling binomial distributions, with the standard deviations specifying the annual fluctuations in probabilities of reproduction and mortality. EV in carrying capacity is modelled by sampling a normal distribution. EV in reproduction and EV in mortality can be specified to be acting independently or jointly (correlated in so far as is possible for discrete binomial distributions).

Unfortunately, rarely do we have sufficient field data to estimate the fluctuations in birth and death rates, and in carrying capacity, for a wild population. (The population would have to be monitored for long enough to separate, statistically, sampling error, demographic variation in the number of breeders and deaths, and annual variation in the probabilities of these events.) Lacking any data on annual variation, a user can try various values, or simply set EV = 0 to model the fate of the population in the absence of any environmental variation.

VORTEX can model catastrophes, the extreme of environmental variation, as events that occur with some specified probability and reduce survival and reproduction for one year. 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 catastrophe occurs, the probability of breeding is multiplied by a severity factor specified by the user. Similarly, the probability of surviving each age class is multiplied by a severity factor specified by the user.

VORTEX also allows the user to supplement or harvest the population for any number of years in each simulation. The numbers of immigrants and removals are specified by age and sex. VORTEX outputs the observed rate of population growth (mean of N[t]/N[t-1]) separately for the years of supplementation/harvest and for the years without such management, and allows for reporting of extinction probabilities and population sizes at whatever time interval is desired (e.g., summary statistics can be output at 5-year intervals in a 100-year simulation).

VORTEX can track multiple sub-populations, with user-specified migration among the units. (This version of the program has previously been called VORTICES.) The migration rates are entered for each pair of sub-populations as the proportion of animals in a sub-population that migrate to another sub-population (equivalently, the probability that an animal in one migrates to the other) each year. VORTEX outputs summary statistics on each subpopulation, and also on the meta-population. Because of migration (and, possibly, supplementation), there is the potential for population recolonization after local extinction. VORTEX tracks the time to first extinction, the time to recolonization, and the time to re extinction.

Overall, VORTEX simulates many of the complex levels of stochasticity that can affect a population. Because it is a detailed model of population dynamics, it is not practical to examine all possible factors and all interactions that may affect a population. It is therefore incumbent upon the user to specify those parameters that can be estimated reasonably, to leave out of the model those that are believed not to have a substantial impact on the population of interest, and to explore a range of possible values for parameters that are potentially important but very imprecisely known.

VORTEX is, however, a simplified model of the dynamics of populations. One of its artificialities is the lack of density dependence of death rates except when the population exceeds the carrying capacity. Another is that inbreeding depression is modelled as an effect on juvenile mortality only; inbreeding is optimistically assumed not to effect adult survival or reproduction.

VORTEX accepts input either from the keyboard or from a data file. Whenever VORTEX is run with keyboard entry of data, it creates a file called INPUT.BAT that contains the input data, ready for resubmission as a batch file. Thus, the simulation can be instantly rerun by using INPUT.BAT as the input file. By editing INPUT.BAT, a few changes could easily be made to the input parameters before rerunning VORTEX. Note that the file INPUT.BAT is over-written each time that VORTEX is run. Therefore, you should rename the batch file if you wish to save it for later use. By using data file input, multiple simulations can be run while the computer is unattended. (Depending on the computer used, the simulations can be relatively quick -- a few minutes for 100 runs -- or very slow.) Output can be directed to the screen or to a file for later printing. I would recommend that VORTEX only be used on a 80386 (or faster) computer with a math co-processor. It should run on slower machines, but it might be hopelessly slow.

The program can make use of any extended memory available on the computer (note: only extended, not expanded, memory above 1MB will be used), and the extra memory will be necessary to run analyses with the Heterosis inbreeding depression option on populations of greater than about 450 animals. To use VORTEX with expanded memory, first run the program TUNE, which will customize the program EX286 (a Dos Extender) for your computer. If TUNE hangs up DOS, simply re-boot and run it again (as often as is necessary). This behavior of TUNE is normal and will not affect your computer. After TUNEing the Dos Extender, run EX286, and then finally run VORTEX. TUNE needs to be run only once on your computer, EX286 needs to be run (if VORTEX is to be used with extended memory) after each re-booting of the computer. Note that EX286 might take extended memory away from other programs (in fact it is better to disable any resident programs that use extended memory before running EX286); and it will release that memory only after a re-boot. If you have another extended memory manager on your system (e.g., HIMEM.SYS), you will have to disable it before using EX286.

VORTEX uses lots of files and lots of buffers. Therefore, you may need to modify the CONFIG.SYS file to include the lines

FILES = 25
BUFFERS = 25

in order to get the program to run.

VORTEX is not copy protected. Use it, distribute it, revise it, expand upon it. The program is copyrighted by the Chicago Zoological Society, and any derivative works (e.g., programs) should acknowledge the extent to which they are based on VORTEX. I would appreciate hearing of uses to which it is put, and of course I don't mind acknowledgement for my efforts.

A final caution: VORTEX is continually under revision. I cannot guarantee that it has no bugs that could lead to erroneous results. It certainly does not model all aspects of population stochasticity, and some of its components are simply and crudely represented. It can be a very useful tool for exploring the effects of random variability on population persistence, but it should be used with due caution and an understanding of its limitations.

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KENYA BLACK RHINO METAPOPULATION WORKSHOP

WORKSHOP REPORT

1 May 1993

APPENDIX
MINUTES

KENYA BLACK RHINO METAPOPULATION WORKSHOP

ROUGH MINUTES

SATURDAY - 2 NOVEMBER 1991

Participants: ***Rashid Aman, Rob Brett, Holly Dublin, Jim Else, Richard Emslie, Tom Foose, Helen Gichochi, Kes Hillman-Smith, Richard Kock, Bob Lacy, Richard Leakey (opening), Tom MacDonald, Esmond Martin, Steve Mihok, Pius Mulwa, Samuel Ngethe, T. Oloo, Oliver Ryder, Rebecca Seal, Ulie Seal, Shirley Strum, Evelyn Wanjohi, Fred Waweru***

LEAKEY Introductory comments. Refers to success of just completed Tana River PHVA Workshop. Very complex. If can resolve problems in this system, many others will be facilitated. PHVA approach seems to have much value for solving conservation problems in Kenya.

Issues here very different. Rhino situation has received less publicity than elephant in Kenya even thought situation more serious. Rhino is of great concern and will continue to be as expect value of horn to remain high. Need for maximized security will remain high. Sanctuary approach, private and governmental is plan for immediate future. With only 400, are small populations problems that Must be considered. Kenya has had plan. Hope this PHVA will be foundation for next 5 years of the Kenya plan and program. Hope this program will lead to Know has been much discussion about ex situ and in situ program. Believe would be premature for Kenya to commit. Will certainly be receptive to sound arguments on all strategies. Kenya needs to concentrate on in situ. Is prepared over next 5 years. Would not want to convey impression have lost hope and therefore would want to resort to external alternatives. Currently have 3 births to every death. Now accidents are more significant cause of death than poaching. (They fall off cliffs). Wants to acknowledge the very significant contribution of private land owners. Carried the rhino situation through a very critical time when rhino on government land very insecure. Are some white rhino in Kenya, but think it might be valuable for this species to remain a "non-Kenyan" species. May facilitate some aspects of management.

BRETT: Distributes briefing book and describes as reference for meeting. Must establish goals and objectives. Is a long list. Desire to simplify. Want this Workshop to be the basis of the new plan. Plan may be for damage control. Basic goal of Kenya plan is to expand population as rapidly as possible. Are 400 animals but are in groups that range in size from 1 to 60. Want to consider all populations, but especially the sanctuary ones. How use all the rhinos in concert to achieve goals.

In second section of book is information on the Kenya rhino. In particular, delineates the 11 sanctuary populations. There may possibly be as many animals outside sanctuaries as inside sanctuaries. Want to try to consider all rhino populations.

Don't think we should concentrate only on genetics. Also have expertise at workshop on disease and reproductive physiology.

Have decided that Kenya rhino should be managed as one population. Want to use sanctuaries to provide animals to repopulate other areas.

Issue of upland and lowland provenance of rhino. About 60% of populations are now hybrids of upland and lowland. This is another issue that needs to be considered

Invites Seal and Foose to express their objectives. Re-emphasizes that Kenya wants to expand population as rapidly as possible. Genetic and more intensive population management can then be regarded as a safety net or for damage control.

SEAL Suspect still encumbered by name of Specialist Group. Still detect undercurrent about implications of captive propagation. States are in process of changing name to Species Management Group. Kenya confronting many of same problems that zoos have in past. Managing and expanding small populations to achieve long term viability and security. Hence zoos have been experimentalists in developing the methodologies for such management. So don't be misled by name "Captive".

Would consider an encompassing objective of workshop is to evaluate current situation. Explore the variety of options for managing and expanding. genetics is one part but demography often equally or more important.

FOOSE Issues relating to captive programs not to establish or reinforce the existing ex situ population, but it might assist the efforts to restore the subspecies to viability in Kenya and environs in East Africa. Is already a captive population of about 150 michaeli rhino. So issue is how existing captive population might assist this objective.

Believe goals that Brett has articulated are:

- Securing black rhino
- Expanding black rhino
- Managing as a single population.

Ground rules:

- Conservation of species is paramount goal of everyone at Workshop.
- Corollary is that defer political, financial, logistic, personal agendas while consider the biological realities and scenarios.

EMSLIE Must not lose sight of the practical limitations of moving around for genetic management.

SEAL Appreciates practical limitations, but do not want that to preclude discussion of biological options. May modify options that

- Integrity of every individual will be respected. All will be permitted full opportunity to express opinions. Invites and encourages persons to submit their comments and thoughts in writing.
- Will maintain minutes and circulate each day for review and revision.
- Is a lot of shared history among participants in meeting. So hope can concentrate on biology. Please try to be concise.
- Want to try to have draft document on table Monday. Some elements will not be complete, especially some of the computer analyses.

- To produce document will divide into working groups that will prepare reports that will be iteratively reviewed and revised by series of working group and plenary sessions.

FOOSE Presents slide show on small population problems and management

LACY Will expand on discussion of Foose and discuss tools and models available to develop some of population goals and objectives. (Insert stuff from Tana River Workshop here).

Best way to determine viable population sizes would be empirically (e.g. the Joel Berger big horn sheep study), but with endangered species don't have enough populations to do so.

Sensitivity analysis, e.g. comparing mortality rates, can identify critical factors and hence indicate areas where better data from more research would be beneficial or where management could have a significant effect.Will extend and reinforce what Foose presented last night. Will describe some approaches to PVA. Describe some models available. The try to apply to monkeys. Small populations are unstable and insecure. Small populations subject to a number of factors or forces that don't impact large populations. So even if factors that originally reduced population from large to small are redressed. Population may become extinct if long-term deterministic trend is not negative. Small pops more subject to good luck and bad luck than to anything else. Some examples. Birth and death processes are random. So even if average births 10% greater than deaths, if variance is 30% may go extinct. Genetic processes also corrupted in small populations. Gene pool more determined by genetic drift rather than natural selection. Also means that it is just as likely that maladapted forms may become established just as adapted forms. Small population inherently unstable ecologically and genetically. Short-term stochastic factors rather than long-term trends predominate. Hence is very difficult to predict fate of population. First of all, virtually impossible to use intuition. Also difficult to manage. People not good at operating probabilities. Factors interact; extinction vortices. PVA's methods use to analyze and manage. Are various methods. Best perhaps empirical (big horn sheep data). Unfortunately, with endangered species don't have multiple species that can be observed for empirical data. Are analytical models, e.g. Goodman in Kinnaird & O'Brien paper. Are also simulation models. Models that population biologists use to predict population fates often described as black box or voodoo methods by wildlife managers. Believes in part is due to fact that critics don't comprehend models well. Models used all the time. Human brain uses models to integrate much information. One of advantages of models is that they require us to be explicit. What are assumptions. How do various factors interact. What are quantitative consequences of models. Benefits: can be challenged or replicated; also requires explicit identification of all relevant factors; also requires us to consolidate and evaluate what data are (and are not) available. Next stage of modelling is playing "what if" games. Will always be uncertainties and unknowns in any model. Is important to know if our ignorance will have significant consequences on results of models, i.e. sensitivity analyses. Also can guide research. Models also permit us to explore consequences of various management options. Can also validate models by comparing predictions with actual behavior of system. So can also evaluate assumptions. Also can use to measure performance of models and programs. Models are tools not endpoints.

Analytical models, e.g. Goodman. Haven't been used much. One reason is that are very simplistic. Hence results are crude. Another problem is that despite fact are only 3 variables in model (r, V, and K) are almost never available for any population. Model extremely sensitive to values of V. Are also analytical genetic models. A problem has been that no one has yet formulated an analytical model that combines both demographic and genetics.

Simulation models is an alternative approach. In conception and practice is easier. Can incorporate as many factors, i.e. both genetics and demography, into model as long as can explicitly indicate how factors affect population. Major kinds of stochastic problems: environmental (normal and catastrophic, demographic, and genetic.) Are now about half a dozen of these kinds of models out there. Will use VORTEX. Describes how he envisions these kinds of stochasticity might affect population. For population parameters, need to know mean, variance, and catastrophes (frequency and severity).

Describes VORTEX. How operates. What input and output is.

Interlude on effects of inbreeding. Inbreeding depression (reduction in survival and fecundity) observed in most mammals investigated. Degree does vary. Most, maybe all species do manifest some effects. Don't know how inbreeding will affect rhino. May be able to speculate by comparison with results for other mammals.

Don't really know how inbreeding operates. Are two basic models. One in which fitness continues to decline with increasing inbreeding (Heterosis Model). The other permits population to eventually purge deleterious genes so after period of decline in fitness will recover (Recessive Lethals Model). However, most endangered populations do not survive long enough to recover from this fitness (dip). Not enough data to decide which model predominates. Both may depending on species.

Almost every time have applied model, discovered other components that need to be incorporated.

EMSLIE Think should consider what kinds of data need and how might arrange for standard collection in all the regions of Africa with the rhino.

Are there other factors not currently incorporated in model that others might think important.

SEAL Will do when go through VORTEX model.

RYDER Reiterate that models are tools. Output may have high variance. May limit use of models.

LACY Two sources of variance. Stochastic variances of model (i.e. model error) Also variance in output because of input? Suspect will get enough models done to decide which way things are going.

BRETT Provides overview of Kenya Rhino Population. Knowledge and security of rhinos to great extent a function of well can observe them. More visible (e.g. Nairobi) surveillance and security high. Populations in bush area not as well known or secure. Much of what documented knowledge on Kenya is based on individual identification. In 11 well documented populations, rhinos individually known. Historically, when population large strongholds in 2 or 3 areas: Tsavo 5,000 in the 1970's, 1 rhino/sq km or higher in high density areas, could support this number again if security adequate; upland forest areas in Aberdare and Mt. Kenya (densities at least 1 rhino/sq km if not higher); Laikipia Plateau.

Nairobi Park: Now 60 rhinos. In late 60's animal trappers got to keep rhino for; about 30 placed in there in 1968 from lowlands near Tsavo; in 1978 others in there from highland. (Documented in paper by Hamilton/King in East Africa Wildlife Journal); after 1960's population rather flat. In 1968, census documented about 60. Stocked from highland and lowland, at least 5 sources; high calving rate about 5 per year; lambda about 10%.

Solio: 23 rhino imported (1970-1980) from local (highland) and other (Tsavo, lowland) sources. 8 sources. By 1986 were 90. This was what caused everyone to realize potential for rhino sanctuary. Perceived by most parties that was overpopulation. Decided to use surplus to stock Nakuru.

Aberdares: Remanent of very large wild populations. Don't know how many. At least 33-40. Very hard to know what is occurring. Based on observations at ARK think is doing fairly well. Potential for repopulating Aberdares is very great. 100's or 1000's.

Laikipia: Believe were 100 there in 1970's. Now about 40. Some now dispersing from ranch. Breeding record there poor. Skewed sex ratio., Males 2:1.

DUBLIN Masai Mara: Confusing about history. Maybe 108 about 1980? But probably already some poaching. In 1970's densities similar in Serengeti to Tsavo. Masai less clear. Poaching from 1970-1984 poaching rampant. In 1984, population down to 11. Current 24-25. Know the 11 to 24 is by breeding (lambda 12-14%). Has been much invested in surveillance activities. Seems poachers no longer operating in area. Did lose one, due to political reason, in late 1980's.

Loita Hills. Recent report. Confident are at least 13 there. Animals are moving between Loita Hills and Masai Mara. Greta movements. May have suggestions for enclosed populations. May be moving 30-40 km.

EMSLIE Somewhat greater than 17+ km in Natal.

RYDER Both sexes?

DUBLIN Yes.

EMSLIE Are computer models and software in Natal to extrapolate from individual observations and data.

DUBLIN Habitat changes are significant. Poaching may have been dominant but habitat is changing.

BRETT Habitat change may be factor in Laikipia dispersal.

GICHOHI Elephants certainly have influences on habitat quality for rhino.

EMSLIE Agrees habitat changes can be dramatic and rapid. Can cause major changes in population numbers (increase or decrease).

BRETT Lake Nakuru: First government rhino sanctuary. Stocked in 1987 with 15 from Soli; 1 Lewa, 1 from Nairobi. Since then 4 more from Nairobi. Were 2 resident that never bred. One founder from Solio removed because of aggression. No other cases of aggression. Already at least 6 calves. All but 1 female has had calves. Population now at 29. Is hybrid. Most from Solio, itself of diverse provenance. Most believe area is improving in habitat for rhino.

Habitat monitoring very crude at moment. Estimates of carrying capacity based on general rule-of-thumb of 1 rhino/sq km.

SEAL Will get to habitat more later.

BRETT Ngeng Valley: About 20 rhino. Knowledge poor. Security difficult. Not certain what to do with this population.

Lewa Downs: Relatively small sanctuary. High fence. Stocked in 1984 from "doomed" animals from highland areas. Extraordinary range of success and failures. Virtually same number there as introduced. Number of births and deaths (none do to poaching). Reflects difficulties of managing rhino.

Ngulia (Tsavo West): Fence, just to keep rhino in, not to provide security; around 70 sq km. Rhino poached in 1989. Stocked with 6 females in 1987; resident male there. 3 calves born. Recently moved 2 more there from Nairobi (an upland) to Tsavo (a lowland area). So is a restocking type sanctuary. Is remanent population in Tsavo (15). One from outside nearly broke in a couple of years ago. Eventually, will open fence. Now 11-12 there.

Loita Hills: Satellite to Masai Mara Reserve. Large area.

Ol Jogi. 50 sq km. Original founders 2/1 in 1980. 2 males from Tsavo; female from nearby. Produced 3 calves in 6 years. May have an inbreeding problem. One father daughter calf, which died. Has been 1 other female from Solio. Interbirth interval of 24-25 months.

RYDER So could assemble pedigree for this population.

BRETT Yes, and for several others.

Ol Pejeta. 93 sq km. Potentially a Solio. 7 founders from Solio (were 8; 1 died) Want to stock with 20 founders eventually.

Amboseli: A disaster for a number of years. 3 have been speared this month. 2 have emigrated. So only 3 (2/1).

Outliers: Refer to Brett chart. Decision about what to do with them is largely a matter of security. Tana River: very poor security situation. Tentative decision to remove.

FOOSE How many of 304 rhinos could be placed in a pedigree.

BRETT Pedigree on many of the 304 rhino in 11 sanctuaries. Are some physical characteristics that may be inherited (e.g. corrugations on side). Could with exception of Aberdares, Laikipia, and some of Solio.

RYDER Systematics and taxonomy: Presentations here are occurring must be in context of goals. If goal is survival, must be long-term. Taxonomy reflects systematics which is manifestation of evolution. Black rhino in Kenya considered a single subspecies. But important to consider basis for this recognition. Population divergence usually manifested as distinguishable characteristics. Minimum regret strategy is to conserve maximal evolutionary divergence. Upland, lowland divergence of Kenya rhinos may be a case in point. How are we going to measure important differences and hence divergences in heritable traits: morphology, ecology, genetics. Direct and indirect methods. So measure lots of traits and see if correlate with geography or other population characteristics: e.g. upland, lowland. Tools of molecular genetics are a powerful tool: population divergence. About rhinos: knowledge incomplete. Is a traditional systematics. Too few samples from too few populations, not all are standardized or comparable. Is some new evidence emerging. Most recent information on systematics were presented at San Diego Rhino Conference Black and white divergence 5-8 million years ago. Earlier divergence of Asian from African rhinos concordant with all molecular data. Within black rhino, are 7 subspecies. 3 subspecies have been investigated molecularly (michaeli, minor, bicornis). 4 main contributors: Eric Harley, Mary Ashley, George Amato, Matthew George. Harley did one type of study and had only one michaeli from Addo. Ashley all based on 11 zoo rhinos (from Kenya but probably from different source populations). Matthew also mostly on zoo rhinos, some overlap with Ashley data set. Also Aman is investigating Kenya populations. Using mitochondrial DNA. Summarize results. Geographical origin of rhinos can be identified through matrilines. But differences are low so may not be valid to distinguish as subspecies. Using chromosomal structure (number same but arms different) can also distinguish Kenya from Zimbabwe rhino. This kind of chromosomal difference in distinguishing subspecies has been used in rodents and primates. At this point what is specifically absent is samples from Kenya rhino of known origins. So are diagnostic differences between Kenya and Zimbabwe rhinos. All differences are small. How much is enough to define a different conservation unit. Is possible for analysis to proceed further. Probably means these difference are recently evolved and if so are probably random not adaptive.

Population structure: Largely not investigated yet. Know something about captive populations because of studbooks.

AMAN Will describe what have done and intending to do with rhino. Commenced 2 years ago. Inspired by Jim Else. Ryder secured technology transfer grant from PEW. Rhino selected as one of study species. Were a body of samples from the sanctuary translocations.

To date have samples from 17 individuals from Solio to Nakuru. Have added to this collection. Now have 33 samples. KWS has been very cooperative. Recently received material from the Amboseli casualties. Are conducting various analyses including RFLP and PCR and DNA fingerprinting. Hope workshop will provide guidance on priorities, e.g. paternity, provenance variations.

Concerning sample collection. Have been receiving opportunistically. However, believe every opportunity must be exploited. Should consider biopsy darting techniques. Has succeeded with elephants. Would like to use with rhino. But will need guidance and concurrence of rhino managers.

RYDER No evidence yet (based on mitochondrial studies) of more than one e.s.u. within Kenya rhinos.

BRETT Concerning zoo animals, if could get names of trappers, might be able to localize capture origins.

EMSLIE Could you elaborate on how investigate inbreeding: techniques, no. samples required,

RYDER Would collect information in 2 ways. Assemble information from group of individuals and treat them without any assumptions (i.e. all possible parents and offspring from area). Other way if have any information on animals in area over time, should be possible to determine paternity if can get samples from animals involved.

EMSLIE Did Harley discover that minor and bicornis very similar. But maybe are ecological adaptations in two areas that are critic for survival.

BRETT Of 300 rhino in 11 sanctuary populations (i.e. considering only 3 in Amboseli), 178 are in mixed populations; 111 in pure populations; i.e., 70% are from mixed origins. 6 populations mixed: Nairobi, Solio, Nakuru, Ol Jogi, Ol Pejeta, Lewa Downs. 4 populations; Mara, Laikipia, Abdedare, and Amboseli. Ngulia omitted for moment. All rhino (about 83 animals) in outlier populations on Brett table presumably are pure populations. (Get Brett to clarify these numbers).

LACY Demonstrates VORTEX and solicits initial parameters for investigation. Will indicate what kinds of data need. Can refine and diversify input later in week.

Lots of discussion about whether density dependence. Consensus is that probably is operative at high densities. Will try to develop estimate of pattern later.

Can use age structures of real population with what are generated by entered mortality rates to validate these parameters.

3 approaches to developing models; optimistic, pessimistic, try both and compare differences.

MIHOK Given reasonable estimates of rhino parameters, what are consequences of non-management of current small populations.

Then, if move around how do these consequences change.

SCHMIDT Discussing habitat changes in salient of Aberdare National Park. Diversity of vegetation caused by exogenous factors. Grassland and secondary bushland, originally created by fire and cultivation caused by man, maintained by activities of herbivores. Significant changes in habitat in 40 years.

DUBLIN Has observed changes in quality of habitat relevant for rhino in about 10 years.

MIHOK Describes work on tsetse flies and activities because of death of rhino moved to Ngulia. Died proximally of aggression after an immobilization but was infested with ""X. So concern about possibility of highland animals being susceptible to ""X. Two papers on subject: one Tanzania and other Kenya with large numbers of rhino. Both comment on problem of trypanosomas. Do now know that wild animals do suffer from trypanosomas. But only in trouble when under stress. Death of first animal was that first animal placed in area of very high tsetse density and at time of year when most activity. Have conducted two experiments since then. Moved animal to areas with lower densities: one in dry other in wet season. Very different results. One in dry season, not much challenge from bites, no problems, symptomology. Other in wet season, much challenge as far as bites, was infested and many symptoms. Animal did recover. Think when move animals from highland, will always get infestation. But don't know what effects will be or what treatment to use. Need to know more about vectors. So at moment most rhino in highland sanctuaries. Eventually will want to move to lowland. So will need to develop protocols. Also comments that has never observed the hemolytic anemia that is described in captivity. But thinks that disease will be an important factor to consider. Challenge is greater in wet season but can also provide better care for animal, especially nutritionally.

GICHOHI Is there a way to prepare an animal for challenge before move.

MIHOK Has been tried for domestics. Nothing has worked yet. Don't think vaccine likely. Better approach is to monitor animals before and after move and be prepared to support animal when is challenged.

KOCK Are a host of diseases that should be considered in both source and destination environments of rhino to be translocated. Stress seems to render animals vulnerable to infectious disease. So try to minimize stress. Important to monitor before and after.

SEAL Zimbabwe has body of experience with capture, translocation, and maintenance.

EMSLIE Zimbabwe problem may be with suboptimal equipment and technology. South Africa has much better record. Period of maintenance does seem to be important before translocation to reduce stress. Vitamin supplementation useful.

KOCK Does seem to be vitamin E problem in captive rhino.

BRETT Good boma period seems to be important in moves of rhino from Nairobi to Tsavo. Not only for condition (disease resistance) but also site attachment. Have decided will move no more animals in dry season. Although challenge is greater in wet season, ability to provide support for animals in wet season.

HILLMAN Boma period and preparation of release site with dung very important in Pilanesburg.

SEAL Organize into working groups

- One to provide data for some simulations. Provide range of estimates. Don't try to explain range yet. Important to get simulations of scenarios initiated. (Brett, Emslie)

- Another to consider the disease problems and management options. Combination of two things: situation now. Second: the probable catastrophe scenarios. (Mihok, Kock)

- Third is a habitat group. One consideration is matter of carrying capacity: quality, change. Other is estimates of severe climate or other habitat catastrophe events. (Dublin)

BRETT One of results desires from workshop is how many of populations should be producers, consumers, rescues.

SEAL Do basic scenarios first. Then can examine range of management scenarios.

SUNDAY - 3 NOVEMBER 1991

SEAL: Decides to modify agenda.

Also requests that a group form to prepare explicit statement on the possibility of differential adaptation of rhino from lowland and highland origins. The about possibilities that with proper management translocated rhino from highland areas might develop/recover immunocompetency in lowland areas.

BRETT: How are we going to develop recommendations about population objectives.

SEAL: Will do more interactive VORTEX modelling.

Some smaller populations may develop demographic problems sooner than genetic.

Can suggest how often animals should move solely for genetic and demographic reasons. The can consider management problems and difficulties in implementing these movements.

Can project growth rates and productivity.

BRETT: There are a range of states of rhino sanctuaries. Desire to designate certain sanctuaries as producers.

EMSLIE: Isn't carrying capacity an important consideration because will affect productivity. Hence must manage adaptively. Shouldn't the goal be to develop security and viability in sanctuaries before harvest for establishment of new populations.

SEAL: Models permit to compare intuitively anticipated with computed probable performance.

LACY: Describes results of attempts to estimate basic scenario parameters for the Kenya rhinos. Discussion that these parameters provide for mean annual growth rate of about 5%. Considering rhino biology, maximal rates are about 9-10% but achievable only with interbirth intervals of 2 years. Simulated populations of size 10,20,30, 50, 60, 100 with these parameters, both with and without catastrophes. Results of preliminary simulations indicate that demographically (without catastrophes) populations of 10 and perhaps 20 not stable or secure. If add catastrophes, none of populations demographically secure. Genetically, loss appreciable (<90% retained) in smaller populations (<50)

DUBLIN: Report of Habitat Group. Describes matrix of environmental factors affecting rhino. Get table from Seal. Elephants a real dilemma. Are competitors with rhino, but also important for maintaining plant diversity beneficial for rhino. Giraffe consistently negative impact on rhino.

PRICE: Nairobi may be a optimal state now as far as rhino habitat. Expect area is going to deteriorate in this respect over next 5 years. Part of rhino habitat will be lost to road. Giraffe a problem that will only get worse.

PRICE: Carrying capacity a consideration for recipient areas. Maximal harvest more relevant consideration for the producer areas.

LACY: Maximum number year would be product of optimal growth rate and number of adult females, which is probably near carrying capacity.

SEAL: Working group needs to explore harvest strategies. Needs to include age class strategy for removal.

MIHOK: Report of Disease/Ecotype Group. May be a risk of about 5 2.5 % disease risk associated with movement of rhino. In addition another 7 5% of other risks associated with moves. On ecotypes, have produced a document. Presents factors and summaries, but does not present conclusions. Tried to concentrate on a number of areas. Genetics, information low. Have proposal to investigate genetics of highland/lowland forms. Suggestion that might be useful to compare reproductive performance of mixed versus pure (in terms of highland/lowland origin) populations. Estimate of disease catastrophe is once every 100 years with an effect of losing 80% of population.

EMSLIE: Only evidence of disease from South Africa is loss of 41 animals in Hluhluwe, but also associated with clearance of bush. Only possible case is from anthrax.

KOCK: In past rhinos may have been lucky. Now that are more exposed to domestic livestock and may be more concentrated, risk may increase.

GAKAHU: Refers to higher incidence of reported problems in zoos. Is there a severe risk of introducing something that could be devastating.

KOCK: Animals in captivity under stress which may increase susceptibility to disease.

SEAL: Is going to be a symposium on this problem of translocating diseases with animals in November 1992.

BRETT: Requests that Habitat Group try to estimate drought risk for each of populations. Also carrying capacity.

ELEY: Carrying capacity is important in Nairobi. Currently, 18 males and 18 females. Maybe that best plan is to replace 9 males with 9 females to maximize productivity.

MONDAY - 4 NOVEMBER 1991

SEAL Commence today with a few reports. Will distribute minutes for review and revision. Also if have something want to be included, please submit in writing.

MARTIN Will discuss trade in reference to future of Kenya's rhino. Will pressure continue at same level. Answer is yes. 8 tons/annum from 1972 to 1979 onto the market; almost all African. In early 1980 declined to 3 tons In mid 1980's 1.5 ton. Then under that as is now. Has been major decline in demand because of shutdown of several Asian markets, e.g. Japan. Others not consuming, e.g. Malaysia. Demand is still there in 4 or 5 countries: South Korea (for bowls; only from African horn; Martin can't go safely); China (use 650 kg/year); Thailand (widely sells on market; adding more African horn lately mostly from Tanzania); Taiwan (Largest single market; probably mostly from Zimbabwe maybe Mozambique through South Africa); Yemen (40% in 70's; 50% in 80's; now using under 150 kg/yr;

amount of new horn entering small; can no longer afford high price taiwan paying; are also using substitutes). With supply so low, the demand is high, price high and increasing. Two different prices: East African in Yemen horn In October 1990, middle man paying $1300/kg; claim horn from Sudan and Tanzania. In Far East until 1987, price stable. The Taiwan entered market, price there determined by pharmacists in Taipei itself, $2000/kg. Can't get Yemen to pay even $1500/kg. Huge pressure on Taiwan to stop internal trade. Recently have agreed to compile an inventory of their stock: 1,500 kg. TRAFFIC, office just opened, estimates is double. China stock: 10,000 kg. Biggest problem is South Africa. Horn from Zimbabwe. Poaching bad. 70-80 animals may have been killed this year. Another problem is that 2 southern African countries have requested CITES down list rhino from I to II. Will encourage additional poaching, even if horn doesn't get through. So will stimulate poachers. Zimbabwe (requested downgrading of both species) and South Africa (requested only white). Complicates effort to eliminate trade. Price of ivory is also increasing. Market at bottom so people acquiring. Average black rhino carries about 3 kg for the 2 horns; white 5.5-6 kg per animal. Is stockpile of horn in Africa. Zimbabwe has minimum of 1.5 tons; S. Africa 2 tons; all Africa 4 tons. Zimbabwe has also submitted proposal to ranch rhino. Relative to Kenya, do not expect price will decline in U.S.$. Don't know if countries will want to sell old stock. In Kenya poachers have concentrated on either rhino or elephant depending on price. So in future thinks pressure on rhino will be greater. Unless can close 4 markets down in Southern Africa. CITES status of the 4 market countries: S. Korea (have indicated will join but don't know when); Thailand (member but does not enforce; CITES ban on any wildlife trade with Thailand); Taiwan (since China member, Taiwan can't be; but do have strong internal regulation; but not enforced); China (member of CITES; has not banned internal sale; do contend they do not export medicines; but is available retail all over country; so Singaporeans, Hong Kongese just enter and purchase).

EMSLIE Rationale of Southern Africans to sell horn is render wildlife profitable so locals will appreciate and protect as sustainable resource. Has had queries about possibility of ranching rhino. Definitely mixed feelings in South on ivory trade. Believe decline of trade has been a good thing, but also has been hardship on countries that have managed the species well.

MARTIN Ranches can still produce lots of money from white rhino without selling horn through trophy hunting. George Hughes wants to sell Natal horn to generate revenue. Martin has suggested to use to increase admission fees to Parks, which are low. So Martin has suggested that also hunt old black rhino; estimates could get $300-400,000/rhino.

KOCK With the continued and perhaps greater threat you have projected for Kenya rhino, do you think dehorning an option.

MARTIN No. In Namibia are no predators; in Kenya are. In Namibia can observe in advance if rhino hornless; not visible in Kenya. Horn regrowth about 5 cm/year. So would have to harvest every 2 or 3 years. Very expensive.

SEAL Is anti-predator defense only biological impediment?

MARTIN May also affect feeding and mating.

EMSLIE Even at high densities, cost is about 1000 S.A. Rand. Other biological consideration, in thick bush can't locate all animals. So would have some with and some without which would create disparities during conflict. Would like to have Martin's arguments articulated more widely in Southern Africa. Maybe if do see light at end of tunnel, is the wrong time. In Pilanesburg, have modified the trophy hunt to darting animals that are to be moved.

MARTIN Agrees with the catastrophic poaching scenarios that have been formulated, i.e. only in Ngukia, Mara, and Amboseli. Frequency once every 20 years. Severity about 33% of population would be killed.

SEAL From where is poaching likely to emanate.

MARTIN Still from Somalia and Ethiopia.

WAWERU Does rate of horn growth vary with age.

MARTIN Is paper by Hitchins and Hall-Martin. May vary but average is 5 cm/year and is same for both sexes.

HILLMAN Report on Garamba. Positive and negative news. Most had been at San Diego Conference. Population growth rate since start of project: March 1984 15; March 1991, 28; growth rate was 9.68/annum. Since San Diego have had 2 or 3 more calves (June, July, Sept.). Population now 30-31. So doubling time of about 7-8 years. Inter-calf interval 2.5 years. Age at first parturition 7 years. 1:1.2 adult:sub-adult,juvenile. Very similar to the Umfolozi 1969-1973 data (9.5 lambda; 2.4 inter-calf interval; 1:1.4 age ratios). One female is producing at every 1 yr, 9 months years. Is interested in modelling and in biopsy darting. Fire is an important factor in Garamba. Park is mostly open grassland. Encircled by forest. If have very widespread fire rhinos might evacuate park. Very long grass dominates. So useful as food for rhino only at limited times of year. At these times, rhinos very restricted. So habitat may be limited. When 1000 rhinos in Park maintained pastures in shorter state. Now only hippo areas being maintained this way. The negative aspect of situation is political instability. Garamba is as far away from Kinshasa as possible. But is on Sudan border. Is a refugee camp nearby. Has been one armed incursion. Do seem to be more guns around. Does appear that the Sudanese rebels (SLA) are supportive of conservation. At moment are 2 rival governments in Zaire. Probably neither can operate effectively, because economy has collapsed. So far no problem at Park. Has been some looting at nearby town. Inflation horrendous in 1984 was 50 Zaires to $1; now 20,000 Zaires to $1. Guards paid ICZN; 250 guards may be without salaries soon. (Cost of $1,000/month total to pay guards). Guards, conservator, etc. do get some supplement. Support of project from WWF and Frankfurt. Right now are trying to sustain support. Assure them that international community. Fraser Smith is returning today to try to keep things in order. Has been suggested that if IZCN does break down, may try to pay salaries. Mankoto in Switzerland now negotiating. Must be careful, because anything too aggressive might be interpreted as political interference. Would be problem of how to convert foreign currency into local notes. Still not much reflection locally of the upheaval, but do expect situation to get worse over short term. Greatest threat is risk that army will get completely out of control. Was what occurred in past with elephant and rhino poaching.

BRETT Summarizes GAPPS analyses.

RYDER Presents results. Is a model. lacy had described models in general earlier. General Population Projection System. Operates with information on individuals. Projects demographically and genetically. Used originally on grizzly bears, esp. in Yellowstone. Are about 200 animals. Were once part of larger population. So model developed to investigate if this population would be viable.

GAPPS and VORTEX different. If they produce similar results, then can have more confidence that they are robust. Not that they produce precisely the same predictions, but if indicate same factors have similar effects. Describes results depicted on 4 graphs provided in Briefing Book. For Lewa Downs. Compares 3 situations. For first 50 years, population survives. But general trend is downward, even with immigration (1 effective animal per generation). For Nakuru, survival of populations better, especially with immigration. So is another model that can be used. VORTEX will provide more sophisticated results. May be useful to compare.

BRETT Immigration occurred only during first 50 years. After workshop, want to try to use mortality schedule developed for VORTEX in GAPPS.

PRICE Was there limit to carrying capacity? Was immigration only for genetic reasons.

RYDER Yes carrying capacity at Nakuru was 71. Immigration was fixed at 1 individual per generation, so can have both genetic and demographic effects. But immigration allowed only in first 50 years.

PRICE Comments on reintroduction. At moment, are considering wild to wild translocations. So simplifies. Key is to simulate social environment. Since rhino is basically solitary, may be easier. But experience with rhino after translocations varied, often contradictory. Need to know more about how rhino perceives environment. Need to know more about rhino sociology. Need to know spatial and temporal pattern of habitat use. Distinguishes between social and ecological carrying capacity. Is a lot of experience that should be collated; believes pattern will emerge. Suggests that African Rhino Specialist Group do. When release rhino is problem of wandering and of fighting. Doesn't just involve adult males. Moving animal only part of successful translocation; animal must successfully reproduce in new environment. Again needs to be collation of existing experience and data and some actual experimentation. Refers to the dung preparation methods being used in Pilanesburg and Namibia. Need a more systematic and experimental approach. Have already at this Workshop developed some analysis of habitat conditions in various sanctuaries. Another aspect is manageability of rhino, especially the social problems. Know is a risk with translocation and release. Are declining. Must move quickly toward experimental releases.

EMSLIE Corroborates that it is not just males that have conflicts when translocated. Also agrees with importance of the dung methods. Even in large areas may be problems for newcomers because rhino move around.

HILLMAN-SMITH First group rhino (direct from transport) in Pilanesburg, moved 11.5 km in first month, 5 or 6 first day. Next group, 22.5 km in first month presumably because were already rhino resident. When released from bomas, moved considerably less 11.2, 1 first day.

BRETT Certainly believes rhino will behave differently. But however, released must try to minimize aggression. Relates some varied results and experiences with Nakuru. Boma attachment can form site attachment.

PRICE Thinks more is required than people just keep in touch. Maybe someone should do a master's thesis.

SEAL Agrees

SEAL Invites discussion of Zimbabwe and South African Plan.

BRETT Kenyan Plan very much based on South African Plan.

DUTOIT Summarize Zimbabwe Plan. In difficult position with development of strategy. Tried to be too ambitious. Confused action plan with strategy. Provided for protection in wild that would require doubling of government of expenditure. Thinks would have been better to have concentrated more on a conservation biology approach for minimum viable populations and gotten that approved. Then could have considered how to obtain funds and to implement. Do have new minister who is developing an overall framework. So has been bogged down in government. Main points of strategy is protection of large populations in protected of the wild. Other components is development of interior breeding nuclei in securer areas. Has been no poaching in these areas. Have realized is a range of monitoring and management necessary in these areas. About 150 rhinos there. Raoul in charge of this program. Third is ex situ in Zimbabwe. Fourth is ex situ program outside Zimbabwe. With poaching in Zambezi have had to confront levels of manpower and money required for protection. Have used models. Results were a twofold increase in expenditure (permitting US $200/sq km; 1 person/20 sq km). Expenditure has been $ 94/sq km; 1 person/100 sq km. Believes too much concentration in past on paramilitary units not enough on effective screens (public relations, etc.). Internal nuclei is attempting this approach; also requires no government expenditure.

Conservancy program (consortia of ranches for internal nuclei). Not trying to develop sanctuaries, yet. May be necessary in future. Instead large free-ranging groups on large areas of internal land. Fortunately, poaching has not been a problem. Are developing the conservancies in commercial venture. So all private funds. Do have grant from Bide Trust. Now realize must be concerned with other Two conservancies are 3200 and 1500 sq km. Found with 40 animals in each conservancy; permit expand to at least 100. In Zimbabwe have been able to use rhinos as catalyst for develop of conservancies on broad range of wildlife. Internally in Zimbabwe are moves to establish captive breeding center near Harare. Will be more of a holding/research center than a captive propagation facility.

Is increasing interest in utilization of rhinos. Are on common lands and conservancies. Owners want to derive revenue. Campfire associations want to consider trophy safaris for animals on common lands. DuToit prefers darting safaris. Establishes better precedent for how will utilize on conservancies.

Need to preempt possibility of internal poaching by improving internal security screen described earlier. Believes can protect large populations of rhino in wild by using innovative methods.

SEAL Observes that two IUCN themes have been sustainable utilization and local involvement for conservation. Zimbabwe has been a leader.

DUTOIT Realize that moving rhinos around is not simple, easy, or cheap. Zimbabwe trying to render rhino conservation self-sustaining financially and biologically. Have had 4 rhinos dying from malnutrition in internal areas. Animals from lowland in Zambezi were not able to adapt to highland veldt environment. Were, and in past have been, mothers with calves. Has been limited resources and manpower to move rhinos. Another problem has been inter-species conflict. Since 1986, Have introduced 160 rhinos moved into internal areas; 47 deaths; of those 2 poaching cases (1 a calf shot by bow and arrow as a warthog for food; other by internal security force); 25% of deaths directly or partially as result of fighting; malnutrition, translocation stress, etc. Believes more successful to introduce all rhinos in area at once; thinks will reduce conflicts; also believes should de-horn as means of reducing injurious conflict. Main problems with dehorning in Zimbabwe are expense. Concerning aggression, mortal wounds usually occur fast. No problem with rhino breeding without horns. Other consideration about rhino using horn for browsing not observed. Aren't any predators in the conservancies.

Thinks commercial rhino poaching is matter of simple economic models. If can reduce economic incentive as well as intensifying internal expenditure, can effectively protect rhinos. States this despite fact that Zimbabwe rhinos are declining. But believes is hope if change approach.

BRETT How many owners in largest conservancy.

DUTOIT 17 different landowners, 3 of which have converted completely to wildlife. Conservancy has Z$ 1 million to construct perimeter fence around conservancy.

BRETT What happens when land change hands.

DUTOIT Conservancy constitution goes as far as possible under Zimbabwe law to insure land remains part of conservancy. Conservancy members must have first option on land for sale. If sold outside conservancy, then seller must compensate conservancy for conservancy improvements on their land. Ranch owners are approaching rhino from an economic rather than conservational perspective. Matching funds: Z$1 million from Bide; Z$1 million from conservancy.

DUBLIN What are other causes of mortality.

DUTOIT Stress (applies up to 3 months after translocation). Mortality during capture has been minimal. Nutrition in boma in past has not been as good a s possible. Also suffered a lot of physical trauma. Had used sleds for moment; often on for 7 hours. Recent mortalities in midlands are suspiciously due to nutritional; have been moving in dry season because cool time of year, but may be worst time as far as nutrition.

MIHOK Working on KC. All infected latently with T. brucei. Is there any evidence of stress activating these brucei?

DUTOIT Don't seem to have problems that have been described in East Africa (e.g., Clausen). May be some relation between parasites and red-cell problems. Desert animals may be good control because are not affected by parasites.

KOCK In Zimbabwe, translocation from low to high so reverse of Kenya area. Is a case of 5 white rhinos from high to low in Zimbabwe, all died with louse suspected.

PRICE Think right that poaching problem in Zambezi Valley is economic model. Will downgrading on CITES hurt or help.

DUTOIT Thinks next 5 years critical. Have tried a moratorium. Believes should try alternative method.

SEAL In San Diego was suggestion that poaching and productivity of rhinos in balance. Interpret comments today as indicating poaching has now increased above this balance.

DUTOIT Although is diverse opinion in Zimbabwe, believes there is general recognition that situation is deteriorating under conventional approaches with current resources.

EMSLIE In South Africa, have almost identical goals to Kenya Plan: minor to 2000; bicornis to 2000; michaeli to 100. All to be expanded as quickly as possible. Do have rather limited sanctuaries so management and protection moderately intensive. Is a Rhino Management Group. Each of conservation bodies that have black rhino elect one representative to Management Group. Is an advisory and catalytic group. How maximize expansion to target population. Desire maximum yield. Many models. Not sure which applies. So much of management tends to be adaptive. Depends on quality of data collection. Have tried to standardize data collection throughout the region. Every year each rhino reserve submits report with standard information: pop. sizes and trend; pop. composition (age and sex); calf survival rates; predation rates; mortality data (including age as estimated by Hitchins age classes); fecundity; inter-calving intervals; age at first calving. Aren't developing plan upon a priori estimated carrying capacities. Also collecting data on translocation. Is also a subgroup working on security. Has been some recent increase in poaching. Also agree with DuToit that need to involve local people more (a hearts and minds campaign). Was a poaching outbreak at Mkuzi (5 rhinos) to snares from surrounding community, but a good neighbor policy has eliminated problem. With normalizing of politics in South Africa, hope can be more interactions with Zimbabwe and Kenya. One of questions hope data collection with answer is when density dependence will become operative. So to summarize, key part of strategy is the data collection as basis for adaptive management.

Mortality rates due to translocation lower than in Zimbabwe. In S.A. 40 moved, another 37 darted. Of these 0 died from capture; 0 from post-release stress; 5 from post-release injuries (of these 5 3 were 2-3 year olds). In Namibia, 34 moved. Of these: 1 died during capture, 2 died from post-capture stress. Overall in Southern African Region: (excluding the young rhino < 3 years old): 1/108 (captured and darted) = .9% from capture; 2/71 = 2.8% died from stress; 2/71 = 2.8% died from injury. Overall about 6.5% mortality during capture/translocation.

Do use a boma acclimation method. Are nutritional studies of natural foods. Poaching has increased: 6 whites, 1 black in 1990. In Namibia, 23 in 1989-90 in Etosha; this year 2. In North, down from 6 to 2.

Carrying capacity densities much lower than estimated in Kenya. In South Africa, .25 to .3 rhino/sq km.

DUTOIT In Zimbabwe rhino densities are .25 to .1 rhino/sq km.

LACY Summarizes results of simulations. Catastrophes are what cause the populations to go extinct for demographic and environmental reasons. To extent, they can be managed, situation may be ameliorated. Refer to tables. Most useful discussion maybe to consider where to go next. One suggestion is to initiate populations with their original founder numbers rather than current sizes. Also should add some migration rates. Higher level of inbreeding increases adverse effects about 20%.

BRETT Would like to get some idea of what kind of production can expect.

LACY Can actually calculate from the average lambda.

BRETT Would also like to see what happens if complete initial stocking as proposed.

PRICE All simulations to this point assume all animals in initial population not related. Yes.

LACY Right. So the reason that it may be interesting to initiate population with actual founders or smallest size population has been through.

PRICE For managed migration, would there be benefit in selecting animals from most distant neighbors.

LACY Since don't know what genetic variation is across Kenya, no clear advantage.

RYDER The producer sanctuaries are Solio, Nairobi, and Nakuru. Do have information that may permit us to determine something about genetic structure in these populations.

SEAL Seem to be two problems: one is the genetic structure of the producer and hence derived populations. The other is production. Average growth rate of about 4% a year with a population of about 300 animals would translate into about 12 animals per year. If can use more than this, then need to consider increasing yield scenarios.

BRETT Must not impose false carrying capacities on new populations. Need to identify areas where can accommodate more than 100 animals. Ultimate population goal for Kenya is 2000 animals.

SEAL At about 4% per year, could get from 300 to 2000 in about 50 years.

PRICE Perhaps should try to locate other areas that might become producer areas (Ol Pejeta) and permit grow to carrying capacity rather than placing a few animals in places like Ngulia which may be continuing consumers. Then could try to move large number into Ngulia from producers.

LACY To great extent, difference between positive and non-positive growth rates is the poaching catastrophe. So maybe shouldn't place rhino in these areas.

PRICE So if place all surplus now in Ol Pejeta for next 3 years, could move this sanctuary into a producer situation as soon as possible.

DUTOIT Feels obligated to comment again on the much higher densities being projected here than seems to apply in Southern Africa. Suggests consulting long term ecological data to evaluate long-term carrying capacity and its variance in the various sanctuaries. On poaching, episodic catastrophes have been associated with periods of internal corruption and civil order.

HILLMAN-SMITH Carrying capacity (.74 rhino/sq km X 142 sq km) needs to be revised. Density based on optimal habitat which does not cover all 142 sq km.

DUBLIN Think should be attentive to the comments on carrying capacity from the Southern African participants. Perhaps have been too liberal.

SEAL May want to consider a multinational strategy to achieve capacity for 2000 rhino.

EMSLIE May want to re-examine population parameters because are suggesting somewhat lower growth rates than have been achieved, i.e. 6-7%/year.

SEAL Seems focus in discussion is changing. Instead of primary attention to yield now seems to be more discussion of evaluation of areas. A second comment is that may be thinking about management over next few years. In meantime do have a site Ol Pejeta to place surplus from producer sanctuaries.

DUTOIT Agrees that needs to be more work on interactions between rhino and plants. Vegetation may change in quality (especially secondary compounds) as well as quantity. So maybe under selective pressures, perhaps associated with climatic variation, plants become more variable. Hence, maybe should concentrate on areas that because of size will be able to accommodate largest populations in future.

DUBLIN Even with vastly improved protection of KWS, if real challenge again may not be able to protect.

DUTOIT Should reevaluate larger areas to determine if carrying capacity might not be larger than estimated because have been considering in terms of a sanctuary not an open-ended environment. Focus on small sanctuaries has derived from past pressure of poaching. If are through the crisis on poaching, perhaps should concentrate on the larger areas, e.g. Tsavo or Laikipia.

PRICE Are suggesting that adverse changes in quality of vegetation may be caused by browsing pressure. So in the concentrated sanctuaries might definitely want to limit other browsers, esp. giraffe.

NGETHE If didn't have poaching problem in Tsavo, it is still the typical rhino habitat.

DUTOIT Have introduced 18 rhino into 3200 sq.km. Haven't dispersed over entire area. Have concentrated.

EMSLIE Same experience in Kruger.

PRICE Perhaps could remove bits of fence at Ngulia. Sanctuary is in patch of very good rhino habitat that still has some wild rhino.

PIUS If place too many animals there too soon and too freely may have to evacuate them again.

MIHOK Works in Ngulia. Has impression that area is under surveillance by poachers. Level of security that would be required over large area is much higher than in sanctuary.

KAGELE Was there when expanded Ngulia sanctuary. Rhinos didn't expand ranges. Occasionally do still detect poacher trucks near Ngulia. But if can be protected, do think is good place.

BRETT Once do become psychologically limited by fence experience, perhaps founder nucleus will remain attached to site and fence can be removed very soon.

DUTOIT Are using transponders with readers embedded in soil near water holes. Maybe could use water holes as focus/facilitator for security rather fences.

EMSLIE Are some other technologies developing, e.g. microwaves.

PRICE In Indonesia, are using photographic census technique. Have identified 13 individual rhino after 7 months. However, system not that simple. Must be able to identify from a later photo. Also mathematics of extrapolating from sample of photos rather complicated.

EMSLIE Are considering photo census for Ndumu.

SEAL Do you need any more guidance for modelling. Good discussion. But has not suggested any needs for more urgent modelling over next 24 hours. So unless receives some request/recommendation won't worry about it.

PRICE May be useful technique for Tsavo.

BRETT Do have request for Bob. Repeat without catastrophes at 2 levels of inbreeding. Then with 2 levels of removal and addition. Would there be benefit in placing more animals into Ol Pejeta (perhaps 40 rather than 20). Also suggests use only lower level of inbreeding.

HILLMAN With small populations that aren't doing well, can you model how much subsidy through managed migration to sustain them.

PIUS Aberdare rhinos probably related to rather closely to Solio animals because were stocked at about same time. Also on last visit observed 12 female rhino, 9 had calves.

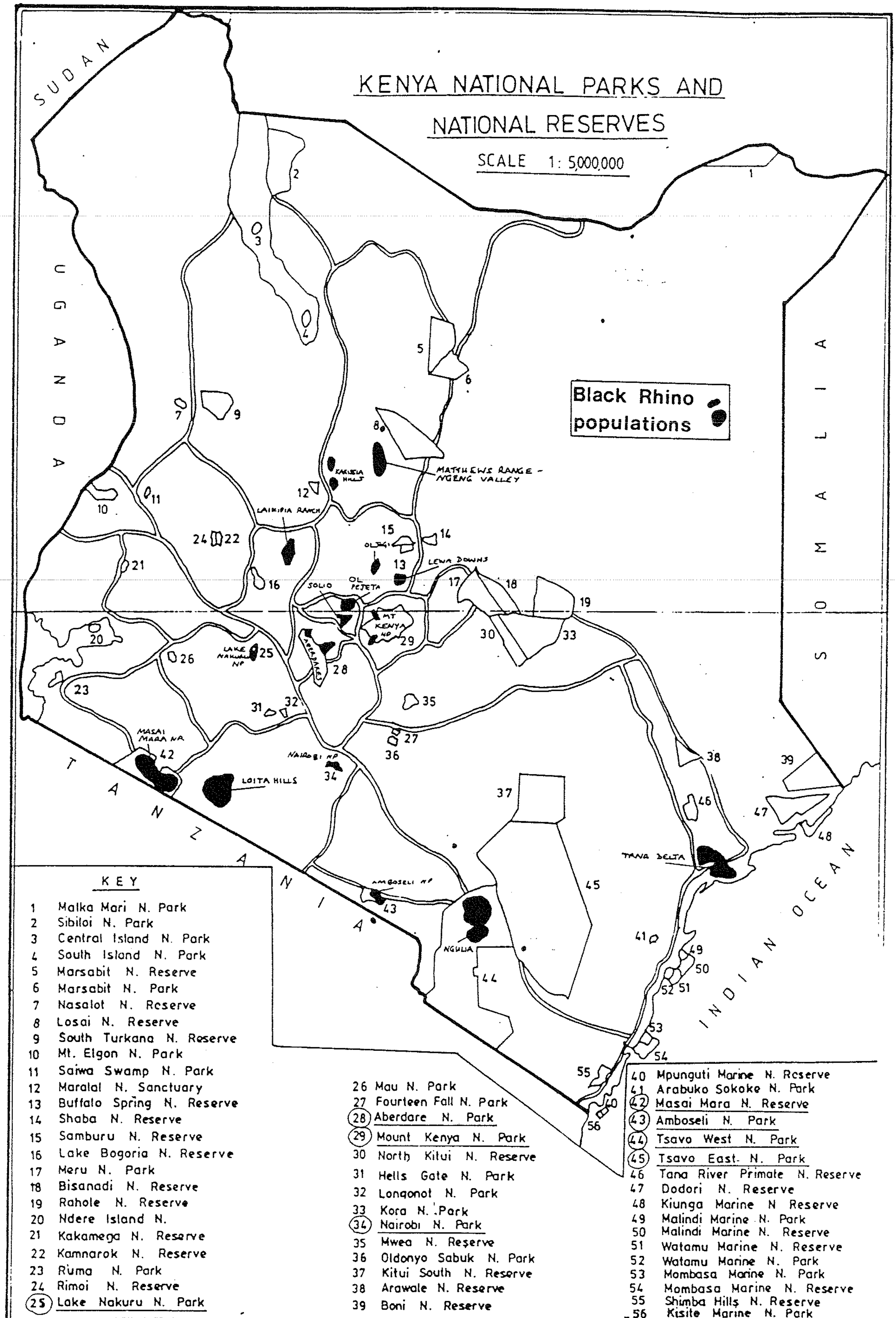
DUTOIT To respond to immediate crisis, have had to concentrate on sanctuaries. Period of time that had to collect data is very short. Again thinks to achieve long-term goals recommended by conservation biologists, need to be thinking about larger areas as soon as possible. If are going to consider rhino conservation over longer periods, must expand horizons as soon as possible. Concerned that sanctuary mentality may develop in minds of politicians.

LACY Certainly agree that what modelling has been doing is crisis management. How long will need to get out of crisis.

DUTOIT Thinks fact that Kenya situation is crisis management needs to be clearly emphasized. Concerned about perspective of Sumatran rhino analysis in Soule Viable Populations book. Captivity and sanctuaries may be means to an end, must never lose sight that goal is survival/restoration of species in wild.

SEAL Must be very sensitive to deciding when time arrives

DUTOIT Must distribute rhinos over diversity of management strategies and situations. And should move to that as soon as possible.



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