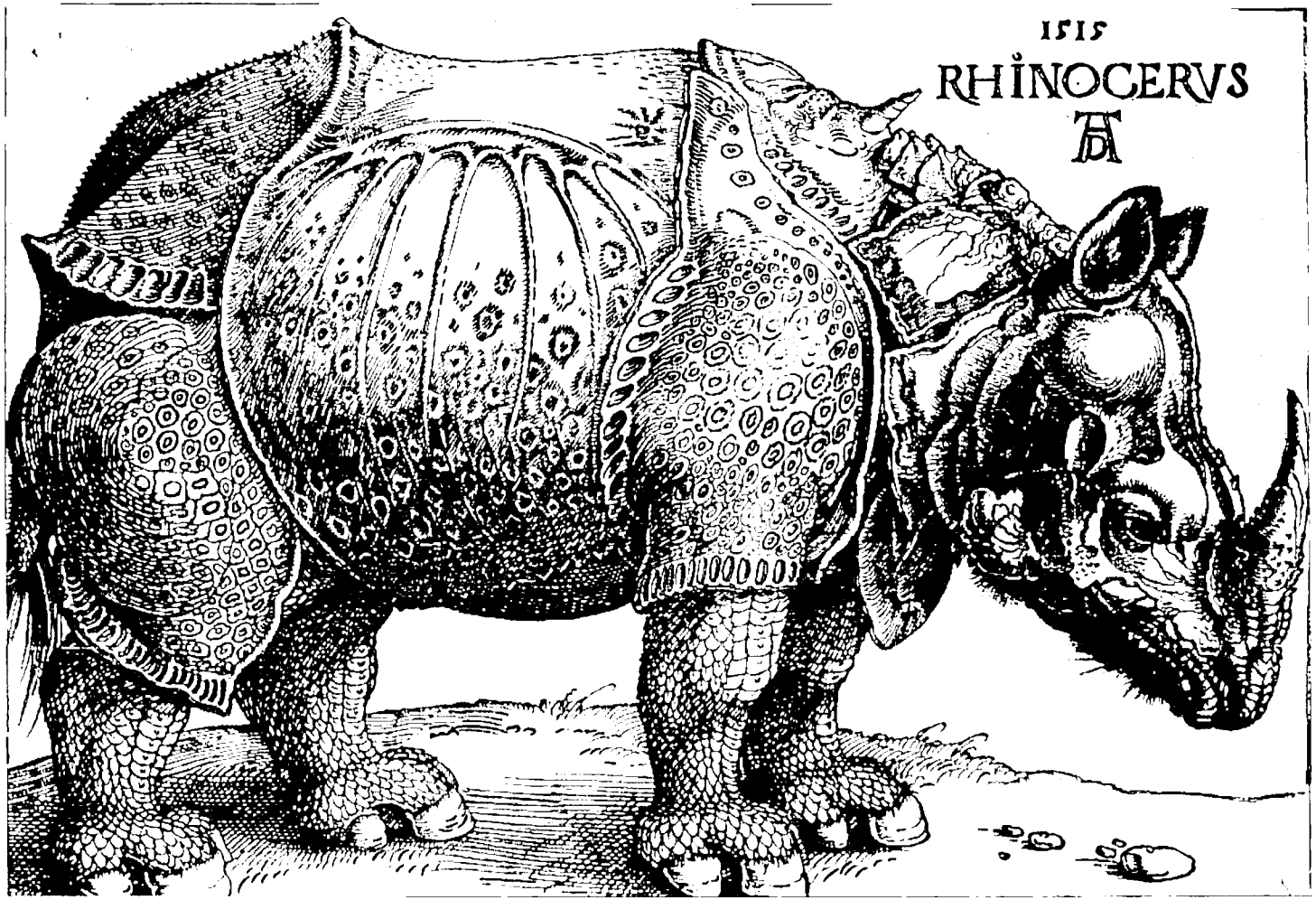
RHINOCEROS HUSBANDRY

RESOURCE MANUAL

AMERICAN ZOO AND AQUARIUM ASSOCIATION
RHINO TAXONOMIC ADVISORY GROUP

INTERNATIONAL RHINO FOUNDATION



Depicted above is a rhinoceros woodcut by Albrecht Dürer produced in 1515 from a description and the notes of a Spanish explorer. Executed entirely from memory, Dürer's rendition [illegible]

Albrecht Dürer, *Rhinoceros*, Woodcut. The Metropolitan Museum of Art, Rogers Fund, 1922

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PREFACE

This manual represents more than 4 years of research, planning and production. At the American Zoo and Aquarium Association (AZA) National Conference in September 1992, the AZA Rhino Taxonomic Advisory Group (TAG) organized a rhinoceros husbandry committee (M. Fouraker, chair) to produce a husbandry manual for all rhino species in captivity in North America. In July 1993, an initial meeting was held at the White Oak Conservation Center (Yulee, FL) to address white rhino husbandry. In January 1995, the committee met for a second workshop at White Oak to review data on the white rhino and discuss husbandry of the black and greater one-horned species. Management of these three rhinoceros species, well established in captivity in North America, is the focus of this manual. Life histories and distributions of the other two recognized rhino species, the Javan and Sumatran, are discussed in the chapter on Taxonomy and Conservation Status, and management concerns specific to the small North American captive population of Sumatran rhinos are given in Appendix I.

While much data have been compiled for this manual, many holes in our knowledge base still exist. It is our intention that this manual be the catalyst for scientific inquiry into the management of rhinos in captivity. This manual presents recommended guidelines for the successful maintenance of rhinos in captivity given the scientific data currently available. With respect to exhibit design, guidelines are given for the renovation of existing captive rhino facilities or the construction of new exhibits. These guidelines represent current optimal recommendations for participation in the AZA's Species Survival Plans (SSPs)© and in no way reflect U.S. Department of Agriculture (USDA) minimum standards. Although necessary for participation in rhinoceros SSPs, the guidelines do not supersede USDA mandates for the exhibition of rhino species.

Additional information concerning these recommendations may be gathered by contacting the respective SSP Coordinators. (See Resources on back cover.) It should also be emphasized that these recommendations are guidelines, and in all cases, common sense concerning enclosure design and routine captive animal management should be used. Parameters exclusive to an individual institution also need to be considered (e.g., climate, local and state laws, animal personalities, etc.).

Acknowledgments

The editors would like to acknowledge several people and organizations for their contributions to this manual: the International Rhino Foundation as well as Bob Reece and the AZA Rhino Taxonomic Advisory Group for funding and resource support; Tom Foose for his tireless commitment to rhinoceros conservation; John Lukas and the White Oak Conservation Center for sponsoring both husbandry workshops; Bruce Read and Jack Grisham for their constructive comments on earlier drafts of this document; Greta McMillan and the Knoxville Zoo Conservation Research Department for organizing the first husbandry workshop; all chapter authors and husbandry workshop participants for their expertise and contributions; Margie Adkins for the manual design; Olmsted-Kirk Paper Company for the donation of paper used to print this manual; and finally, the Fort Worth Zoo for dedicating staff time and resources to the completion of this important project.

(Photo: Fort Worth Zoological Park)

TAXONOMY & CONSERVATION STATUS

T.J. Foose, Ph.D.

Despite a glorious past, rhinoceroses have a gruesome present and a grim future. Rhinocerotidae is a family of mammals in crisis, with four of the five surviving species (the Asian black rhino, greater one-horned, Sumatran and Javan) on the verge of extinction. The fifth species (the African white rhino) has two distinct subspecies. One (the southern white rhino) has recovered to population levels less precarious than those of the other rhino species, but even this subspecies suffers from limited distribution and increasing threats from poachers. The other subspecies (the northern white rhino) is the rarest of all rhinos. It is possible, and even probable, that rhinos will be extinct in the wild by the end of this century or very early in the next unless there is drastic reversal of their fortunes. The following chapter outlines the taxonomy of rhinoceroses, their life history characteristics and their current conservation statuses.

A Brief History and Overview of Rhinos

The family Rhinocerotidae has had a glorious history. Since the first rhinoceros appeared about 50 million years ago, the rhino family has enjoyed abundance and diversity, with many different species that assumed a wide variety of forms and occupied a broad range of niches often associated with other kinds of animals today. Some extinct rhinos had horns; others did not. Some rhinos appeared and acted like horses, others like hippos, some like tapirs, at least one like a small elephant, and several even like giraffes. Indeed, the largest land mammal that ever lived was a rhino.

Moreover, rhinos have not always been confined to Africa and Asia. During most of the last 50 million years, they also inhabited Europe and particularly North America. Rhinos were the commonest of the large herbivores in North America for 40 million years and became extinct only because of drastic climatic changes about 5 million years ago. Today, five rhino species survive: three species in Asia and two in Africa.

In numerous respects, rhinos are typical ungulates. Ecologically, they function as primary consumers, or herbivores, and like most ungulates their weapons are primarily defensive rather than offensive. Rhinos generally inhabit savannahs, shrubby regions and forests in tropical and subtropical regions. Moreover, they are usually restricted to areas in which a frequent trip to water or mud holes is possible. Mud wallowing is especially effective in accelerating heat loss, as mud takes more than an hour to dry and absorbs body heat in the process. A thick coating of mud also helps protect against insects and parasites and keep skin supple.

Generally speaking, rhinos require large individual areas because of their size and daily nutritional requirements. Most are fairly territorial, defending their home ranges to ensure adequate food and minimal reproductive competition. Territories are most often marked

with urine or dung, as rhino vision is poor but olfactory abilities are well-developed. Flakes of skin left on trees used as rubbing posts, as well as dried mud that falls from the skin, also carry individual scents and thus help establish territorial boundaries. Wide variation does exist, however, among the rhino species with regard to the size of individual ranges, the degree of territoriality, and social organization. General species descriptions are provided in Owen-Smith, 1975; Kingdon, 1979; Estes, 1991; Laurie, 1982; and Nowak, 1991. The species descriptions below are summaries; specific ecological studies may cite data that slightly differ from these general descriptions. Word-origin information was obtained from Borror (1960).

GREATER ONE-HORNED RHINOCEROS

Scientific Name and Origin

- *Rhinoceros unicornis*
- *Rhinoceros*: from the Greek *rhino*, meaning "nose" and *ceros*, meaning "horn"
- *unicornis*: from the Latin *uni*, meaning "one" and *cornus*, meaning "horn"

Common Names

- Asian greater one-horned rhinoceros: referring to the single large horn
- Indian/Nepalese rhinoceros: referring to the species' endemic range

Distribution and Habitat

- Northern India, southern Nepal
- Floodplains, riverine grasslands

Size

- 1,800 to 2,200 kg (4,000 to 5,000 lb)
- 1.75 to 2.0 m (5.75 to 6.5 ft) tall at shoulder
- Single horn 20 to 61 cm (8 to 24 in.) long
- Largest land mammal (after elephants) along with the African white rhino

Physical Description

- Brownish-gray, hairless, with rivet-plated (armor-plated), knobby skin
- One horn
- Upper lip semi-prehensile

Life History Characteristics

- Grazer (primarily; will consume some browse)
- Mostly solitary; groups of females and young or temporary groups of subadults
- Females sexually mature at 5 to 7 years of age; males at 10 years
- Gestation period approximately 15 to 16 months; interbirth interval of 3 years

Greater one-horned rhino (*Rhinoceros unicornis*) (*Photo: T. Foose, Ph.D., The Wilds*)

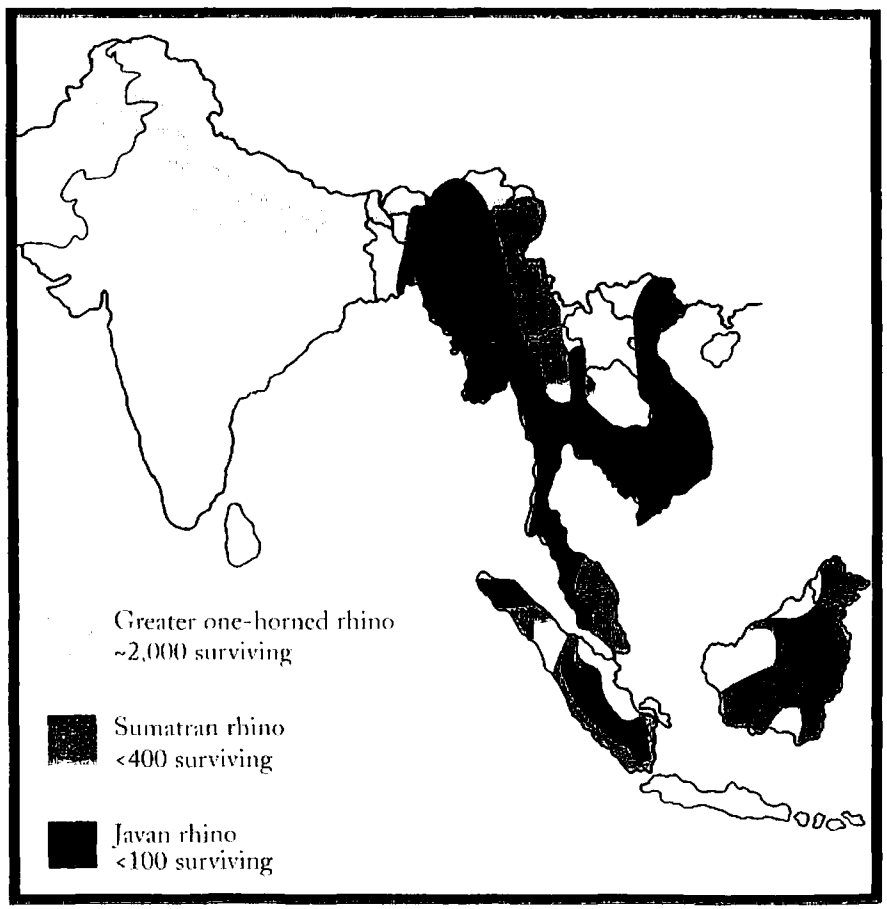


Figure 1. Asian rhino species' historical distributions and current country totals (*Map: N. van Strien*)

JAVAN RHINOCEROS

Scientific Name and Origin

- *Rhinoceros sondaicus*
- *Rhinoceros*: from the Greek *rhino*, meaning "nose" and *ceros*, meaning "horn"
- *sondaicus*: probably referring to the Sunda islands in Indonesia. (Latin *-icus* indicates a locality.) "Sunda" means "Java."

Common Names

- Javan rhinoceros
- Asian lesser one-horned rhinoceros: in contrast to the greater one-horned rhino because of the single, comparatively smaller horn

Distribution and Habitat

- Indonesia and Vietnam
- Lowland tropical rainforests

Size

- 900 to 1,400 kg (2,000 to 3,000 lb)
- 1.5 to 1.7 m (5 to 5.5 ft) tall at shoulder
- Single horn 25 cm (10 in.) long

Physical Description

- Gray, hairless; lesser, but still apparent, armor plating
- One horn

Life History Characteristics

- Mostly a browser but some grazing
- Generally solitary except for mothers and young or mating pairs
- Females sexually mature at 3 to 4 years of age; males at 6 years
- Gestation period approximately 16 months; interbirth interval of 4 to 5 years

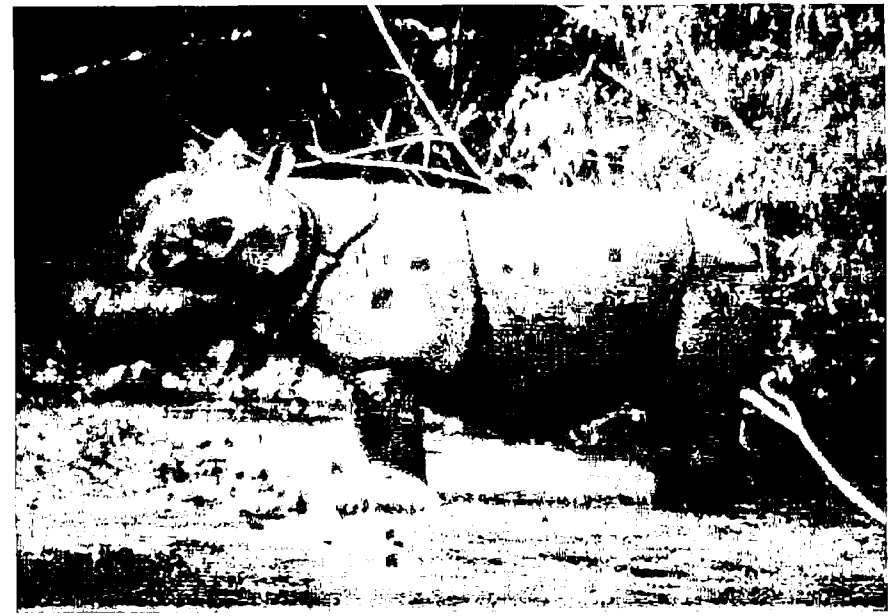
SUMATRAN RHINOCEROS

Scientific Name and Origin

- *Dicerorhinus sumatrensis*
- *Dicerorhinus*: from the Greek *di*, meaning "two"; *cero*, meaning "horn" and *rhinus*, meaning "nose"
- *sumatrensis*: referring to Sumatra (with the Latin *-ensis*, meaning a locality)

Common Names

- Sumatran rhinoceros



Javan rhino (*Rhinoceros sondaicus*) (*Photo: T. Foose, Ph.D., The Wilds*)

Sumatran rhino (*Dicerorhinus sumatrensis*) (*Photo: T. Foose, Ph.D., The Wilds*)

- Asian two-horned rhinoceros: the only two-horned rhino in the Asian region
- Hairy rhinoceros: refers to the long, shaggy hair found on the species in contrast to the other, hairless species.

Distribution and Habitat
- Southeast Asia (primarily Indonesia and Malaysia)
- Montane rain forests

Size
- 600 to 800 kg (1,300 to 1,700 lb)
- .09 to 1.5 m (3 to 5 ft) tall at shoulder
- Larger horn 25 to 79 cm (10 to 31 in.) long

Physical Description
- Reddish-brown coat sparsely covered with long hair, pronounced in younger animals
- Fringed ears
- Two horns

Life History Characteristics
- Browser
- Solitary with the exception of females with calves; males solitary but visit female territories to mate
- Sexually mature at 7 to 8 years of age (males and females)
- Gestation period 510 to 550 days; interbirth interval of 3 to 4 years

WHITE RHINOCEROS

Scientific Name and Origin
- *Ceratotherium simum*
- *Ceratotherium*: from the Greek *cerato*, meaning "horn" and *therium*, meaning "wild beast"
- *simum*: from the Greek *simus*, meaning "flat-nosed"

Common Names
- African white rhinoceros: from the Afrikaans word describing its mouth: *weit*, meaning "wide"
- Square-lipped rhinoceros: lacking a prehensile "hook"

Distribution and Habitat
- Southern and central Africa
- Long- and short-grass savannahs

White rhino (*Ceratotherium simum*) (*Photo: Knoxville Zoological Gardens*)

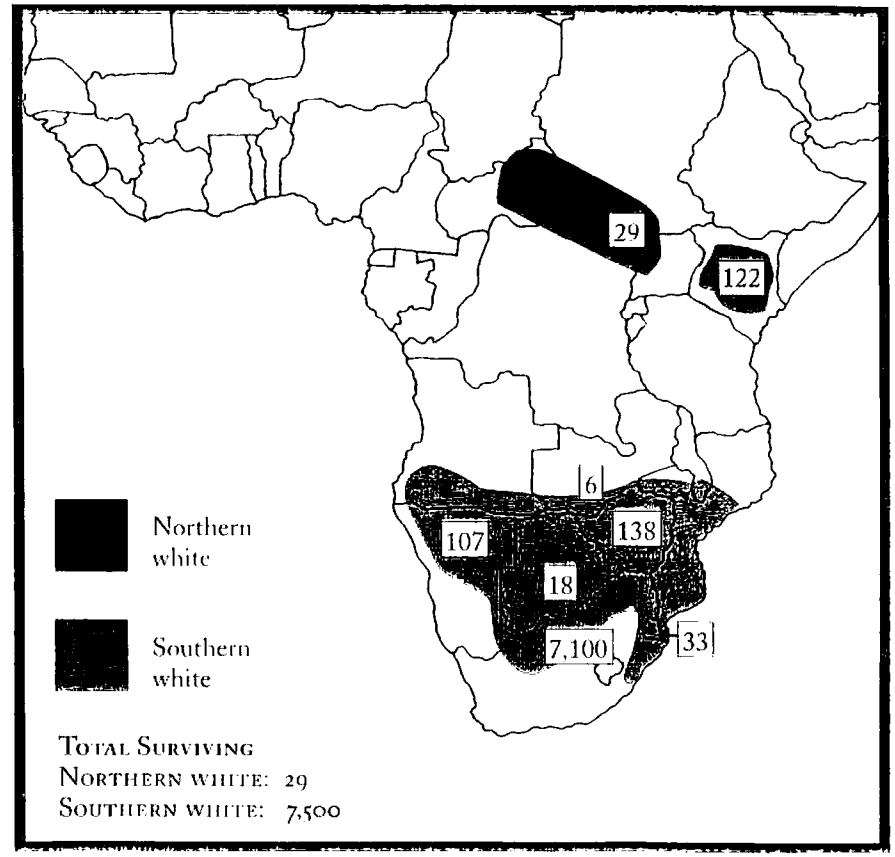


Figure 2. White rhino historical distribution and current country totals (*Map: N. van Strien*)

Size
- 1,800 to 2,200 kg (4,000 to 5,000 lb)
- 1.5 to 1.8 m (5 to 6 ft) tall at shoulder
- Larger horn 94 to 102 cm (37 to 40 in.) (northern subspecies), 94 to 201 cm (37 to 79 in.) (southern subspecies)
- Largest land mammal (after elephants) along with the greater one-horned rhino

Physical Description
- Neutral gray, almost hairless
- Two horns

Life History Characteristics
- Grazer
- Semi-social and territorial; females and subadults rarely solitary; bulls typically solitary, though satellite males may reside within one another's territories
- Females sexually mature at 6 to 7 years; males at 10 to 12 years
- Gestation period approximately 16 months; interbirth interval of 2 to 3 years

BLACK RHINOCEROS

Scientific Name and Origin
- *Diceros bicornis*
- *Diceros*: from the Greek *di*, meaning "two" and *ceros*, meaning "horn"
- *bicornis*: from the Latin *bi*, meaning "two" and *cornis*, meaning "horn"

Common Names
- African black rhinoceros: Not black at all, the black rhino probably derives its name from the dark-colored local soil covering its skin from wallowing.
- Prehensile-lipped rhinoceros: The upper lip of the black rhino is adapted for feeding from trees and shrubs and is the best distinguishing characteristic.
- Hook-lipped rhinoceros: also referring to the prehensile lip

Distribution and Habitat
- Sub-Saharan Africa
- Tropical bushlands and savannahs

Size
- 800 to 1,350 kg (1,750 to 3,000 lb)
- 1.4 to 1.7 m (4.5 to 5.5 ft) tall at shoulder
- Larger horn 0.5 to 1.3 m (1 ft 8 in. to 4 ft 4 in.) long

Black rhino (*Diceros bicornis*) (*Photo: M. Fenwaker, Fort Worth Zoological Park*)

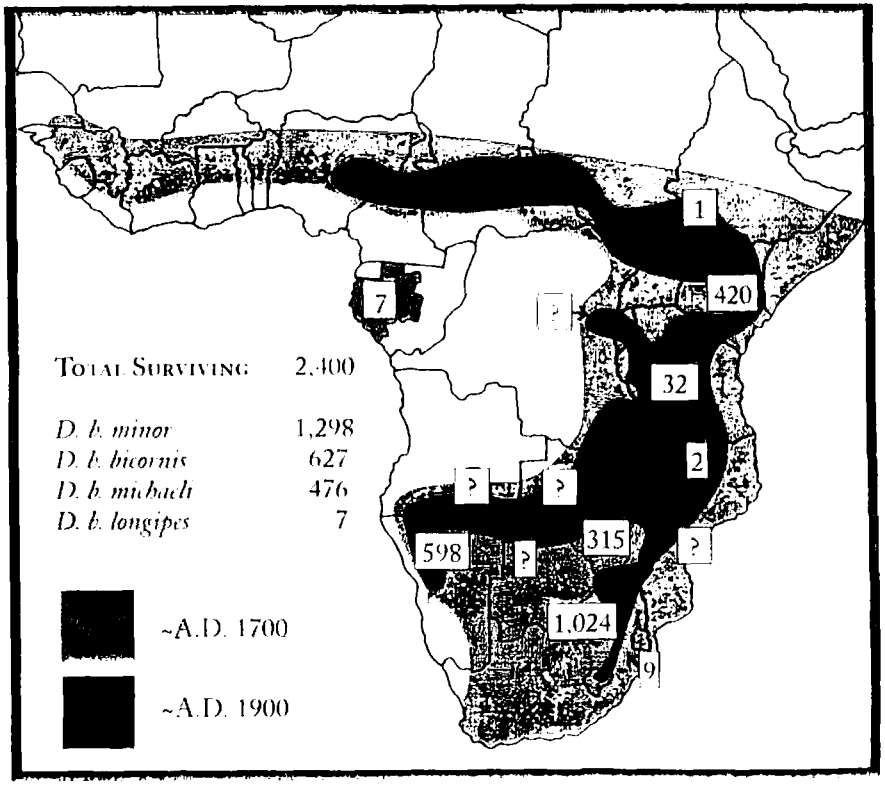


Figure 3. Black rhino historical distribution and current country totals (*Map: N. van Strien*)

Physical Description

- Gray to brownish-gray, hairless
- Two horns

Life History Characteristics

- Browser
- Not as solitary as is commonly portrayed; adult females share overlapping home ranges; males usually solitary and possibly territorial
- Females sexually mature at 4 to 7 years of age; males at 7 to 10 years
- Gestation period approximately 15 to 16 months; interbirth interval of 2.5 to 4 years

THE CRISIS FOR RHINOS

In the middle of the last century, all five rhino species were widely distributed and most abundant throughout Asia and Africa. As of the close of this century, only about 12,800 rhinos of all kinds survive in the wild. Another 1,000 exist in captivity (Table 1). However, more than half these rhinos, both in the wild and in captivity, are of a single species, the white rhino, and of only one of the two distinct subspecies of this species. Of the other four species combined, fewer than 5,000 individuals survive. The situation is even worse because some of the species are divided into subspecies, which conservationists currently believe may be different enough that they should be conserved as separate kinds.

The Javan rhino is the rarest of the species, with a total population estimated at fewer than 100 in the wild and none in captivity. The Sumatran rhino has probably become the most critically endangered of all the rhino species and perhaps of any large mammal. While the Javan rhino is fewer in number and the black rhino has declined more rapidly in recent years, the combination of low numbers (only 400) and rapid decline (50% over the last 10 years) in the Sumatran rhino population is exceptional. The black rhino has suffered one of the most rapid declines (more than 97% in 25 years or slightly more than one rhino generation, perhaps 85% in just the last 10 years) known for a large mammal. The northern white rhino is the rarest distinct taxon of rhino and again perhaps of any large mammal: 29 in the wild, nine in captivity.

The distribution of the few surviving rhinos is also fragmented. Significant rhino populations survive in just 10 countries. It is also true that they survive in only about 40 major areas (national parks and wildlife reserves).

The Cause of the Crisis

As with all endangered species, loss of habitat is an important, but not the major, cause of the rhino's decline. The greater problem is overexploitation through poaching for the horn. The rhino is a spectacular example of a species that is disappearing much more rapidly than its habitat (in contrast to endangered species like the California condor or the spotted owl). The main use of rhino horn is in Chinese traditional medicine, in which it is the drug of choice to reduce fever associated with serious illness. It is also used as an aphrodisiac,

TABLE 1. The conservation status of the rhinoceros

Species or Subspecies	Wild Population[1]	Global Captive Population
Southwestern black rhino	625	0
Northwestern black rhino	30	0
Eastern black rhino	475	165
Southern black rhino	1,300	45
Total black rhino	2,400	210
Northern white rhino	29	9
Southern white rhino	7,500	630+
Total white rhino	7,500+	640
African rhino species	~9,900	850
Greater one-horned rhino	2,000	134
Javan rhino	<100	0
Eastern Sumatran rhino (Borneo)	<100	5
Western Sumatran rhino (Sumatra/Malaya)	300	16
Total Sumatran rhino	400	21
Asian rhino species	~2,900	155
All species	12,800	1,000

although the extent of this usage may have been exaggerated. A third market has been in the Middle East, where the horn is used to make dagger handles that confer social status. In recent years, with the end of the rhino in sight, yet another economic force has entered the picture. Rhino horn has been a speculator's commodity in the Far East to the extent that the speculation might be controlling the price more than the consumer market does.

The result of this excessive hunting is the drastically reduced and almost absurdly fragmented distribution of rhinos. The estimated 400 Sumatran rhinos are dispersed over at least 35 locations in southeast Asia in remnant populations so small that they have little hope of survival without intensive management.

Extinction pressure on the rhino has been occurring for some time. In fact, two of the species (the white rhino in Africa and the greater one-horned rhino on the Indian subcontinent) were almost lost around the turn of the century, but effective protection reversed this trend and kept most rhino populations reasonably unthreatened until after the second world war. Then rhino poaching resumed rampantly, especially during the 1970s and 1980s. The most spectacular decline in recent years has been suffered by the black rhino in Africa, down from 60,000 in 1970 to approximately 2,400 today.

As Box 1 indicates, Africa has been the backdrop for a domino effect as the rhino population has crashed in country after country due to poaching. Only South Africa, Namibia and perhaps Zimbabwe remain as rhino strongholds in Africa. The situation in South Africa is cause for particular concern. Eighty percent of all African rhinos (40% of black and 97% of white) live in South Africa. If the turmoil of political transition becomes severe, there could be yet another, perhaps the greatest of all, catastrophe for the African rhino. Appreciable poaching is already occurring in South Africa for the first time in decades. Similar to the African populations, the Asian rhino populations are confronted by increasing assualts (Box 2).

Rapid decrease in numbers due primarily to poaching is the major, but not the only, problem encountered in the conservation of rhinos. In some emerging terminology of modern conservation biology, there are "declining-population" paradigm problems. However, when populations become as small and fragmented as the rhinos', another set of threats to survival exist. These are the so-called "small-population problems" (i.e., the "small-population paradigm," Box 3).

Conservation of Rhinos

In the wild, it is obvious that rhinos must be intensively protected and managed if they are to survive. Wild sanctuaries for rhinos are becoming megazoos. Indeed, a spectrum of options is needed in a diversified strategy for rhinos. These options differ only in the level of intensive management required.

Zoos and other captive conservation centers are an important part of the spectrum. Zoos can play at least three important roles in rhino conservation:

(1) providing reservoirs through captive propagation, (2) conducting research that

BOX 1. Rhino population decline in Africa

Country	Status
Uganda	The rhino, black and white, was exterminated during the 1970s.
Kenya	Numbers of black rhinos declined from an estimated 20,000 in 1970 to a low of perhaps 400 by the 1980s. (Numbers have stabilized and may be recovering, temporarily.)
Zaire	The northern white rhino was reduced from several thousand to a low of 16 by 1984.
Zambia	The 4,000 black rhinos in the Luangwa Valley were annihilated from 1980 to 1985.
Tanzania	Black rhinos declined from an estimated 5,000 to perhaps 200 in the late 1980s.
Zimbabwe	Fewer than 300 black rhinos survive from an estimated 1,700 just 5 years ago. From January to May of 1993, virtually all the 100 white rhinos in Hwange were killed by poachers. Moreover, the poaching occurred despite the fact that the horns of virtually all of these rhinos had been removed by the wildlife department to deter poachers. De-horning has been a drastic measure with very uncertain effects, as a number of de-horned rhinos have been lost and there is some evidence that removal of the horns does disrupt the rhino's biology.

BOX 2. Rhino population decline in Asia

The second largest population (Manas) of greater one-horned rhinos in India has been decimated, and the largest population (Kaziranga) is under increasing assault. Many rhinos are also being poached in Nepal. Until recently, India and Nepal were among the success stories in rhino conservation, but now the trend may be in peril.

Illegal trade of Sumatran rhino horn continues in significant numbers, and the species has virtually vanished from some "protected" areas where populations had been most dense.

The population of Javan rhinos in Indonesia is stagnating, and one conclusion is that poaching is preventing increase.

will help rhinos in the wild as well as in captivity, and (3) educating all levels of society about the problem and attracting support, financial and otherwise.

However, it must be emphasized that captive populations and programs are not an end in themselves. The purpose is to support survival or recovery of the species in the wild.

As the rhino crisis intensifies, captive propagation becomes more and more important. However, captive breeding for conservation is rather different in its objectives from what was once the case and what is now the case with highly controlled breeding programs for other species such as domestic horses and dogs. The goal is not to produce the "best" rhino by selective breeding, but rather to ensure that captivity changes the rhino as little as possible so that it emerges from the captive "ark" in as natural a condition as possible. Achieving this objective requires that rhinos be managed genetically in captivity.

Zoos are attempting to manage and propagate endangered species through highly organized and scientific programs. In the United States and Canada, these programs are known as Species Survival Plans (SSPs). SSPs have traditionally been managed by Species Coordinators and Management Committees. More recently, Taxon Advisory Groups (TAGs) have emerged. Among other functions, TAGs provide strategic perspectives and technical advice for SSPs.

Each SSP develops a masterplan for management and propagation of its species. These masterplans specify how many rhinos from the wild are needed to establish a captive population with a sufficient sample of the gene pool. The plans also indicate how large captive populations must become to avoid genetic and demographic problems. They also then indicate who should be mated with whom to maximize preservation of genetic diversity. SSP-type programs are now in progress worldwide in major regions of the zoo world, although the titles and acronyms change, producing a real alphabet soup. These regional SSPs cooperate and coordinate through what is known as the Global Captive Action Plan (GCAP) for rhinos as a family and as Global Animal Survival Plans (GASPs) for each species.

Captive management, however, is not all genetics and demography of populations. Basic husbandry, how to maintain healthy individuals and induce them to breed, is fundamental. There are major challenges for rhino husbandry in captivity. Indeed, rhinos have presented some of the most formidable challenges of any species for captive husbandry. As a consequence, all taxa of rhinos are in some degree of demographic difficulty in captivity. The demographic problems are causing genetic difficulties because some lineages are at risk of being lost because their representatives are not reproducing. Clearly, husbandry, demography and genetics interact; and all three are crucial to the conservation of rhinos, especially in captivity. Currently, husbandry problems may be impeding intensive management of rhino species (Table 2). Specific problems include poor survivorship and high mortality, poor reproductive success and a fundamental lack of knowledge regarding basic rhino biology.

BOX 3. THE RHINOCEROS AND THE SMALL-POPULATION PARADIGM

Small populations are vulnerable to catastrophes like epidemic disease and natural disasters. (The last population of Javan rhinos in Indonesia lives in the shadow of Krakatoa Volcano, which erupted spectacularly in the 1880s.)

Small populations are subject to deleterious fluctuations in demographic performance. For example, a significant demographic problem has been developing with the SSP population of the eastern black rhino (*Diceros bicornis michaeli*). From 1990 to 1995, 15 of the 18 surviving individuals born in the North American population were males, and only three were females. This skew in the sex ratio will probably destabilize the population demographically. The future of the population may be in jeopardy.

Small populations lose genetic diversity and become inbred. Genetic diversity is needed both for the vigor of individuals and for the ability of populations to adapt as their environments change rapidly under human influence. In small populations, gene pools become gene puddles that evaporate into extinction. Moreover, the effects on small populations interact. Small size causes inbreeding, which causes reproduction and survival to decline, which produces yet a smaller population. The result is an extinction vortex. The Javan rhino may be in such a vortex right now.

Poor Survivorship/High Mortality

At least two rhino species, black and Sumatran, have problems with poor survivorship/high mortality under intensive management. Rhinos don't always prosper in captivity. The black rhino in particular has been afflicted with many health problems (e.g., hemolytic anemia, severe ulcers on skin and mucous membranes, liver dysfunction) that all seem to be related to and to derive from a peculiarity of the red blood cells. These cells seem to be low in energy levels and deficient in enzymes. This condition may be an adaptation against blood parasites in the wild but becomes a serious health problem when rhinos are placed under stress, particularly chemical stress, as they often are in captivity or under other intensive management.

Poor Reproductive Success

Reproduction in all four of the species that have been maintained in captivity is less than optimal. In general, greater one-horned, black and, to a lesser extent, white rhinos reproduce well in captivity if certain (the "right"?) conditions are provided. But what exactly are these conditions? Another species, the Sumatran, has not reproduced in recent times under intensive management. For no species of rhino in captivity is reproduction reliable or routine.

Poor Understanding of Basic Biology

Compared with many other groups of organisms under intensive management, the basic (nutritional, reproductive, behavioral) biology of rhinos is poorly known. Nutritional problems are suspected to be of particular significance to the health and perhaps the reproductive difficulties of rhinos. Behavioral problems including stress are probably also interfering with successful husbandry. Various physiological and psychological stressors are believed to be underlying causal factors for many of the specific disease syndromes in rhinos.

In recognition of husbandry problems, a major goal of SSPs and the TAGs that facilitate them is the production of husbandry manuals, documents of equal importance to the SSP masterplans for successful management and propagation of species in captivity.

The Future

It is ironic that long before the bison, rhinos were native North Americans. For more than 40 million years, rhinos prospered in North America but then became extinct. Since then and until recently, rhinos prospered in Africa and Asia. Now rhinos are becoming extinct on those continents but have returned to North America and Europe as refugees (and to Australasia as immigrants). The future for the rhinoceros in Africa and Asia lies not in the survival of native rhinos, but in the recolonization sometime in the next century by descendants of the refugees and immigrants from North America and other continents with zoos.

Captive populations can contribute positively to the conservation of rhino species, but only if captive stewards of the rhino know how to provide improved and proper husbandry during the period of intensive management rhinos will require over the next several decades at least.

TABLE 2. The status of captive rhino populations within the AZA (Foose & Reece, 1994)

Species	Status
Eastern black rhino	This species reproduces rather reliably in captivity, but management has not maximized the reproductive potential, and health/husbandry problems continue to negate the breeding success that has occurred. As a result, the species is in a demographic crisis; thus, it is imperative to increase reproduction through improved management.
Southern black rhino	Reproduction in this species has been moderate, but many of the births in captivity were actually conceived in the wild. Captive reproduction may be on the increase, but mortality has been high (although much is probably due to toxin exposure in Africa).
Southern white rhino	Reproduction in this subspecies has been very uneven with only a few facilities, particularly those able to maintain larger social groups, propagating well. The majority of rhinos in institutions are not breeding at all; thus, the population is in demographic and genetic crises. The age structure of the population is senescing, and not enough of the original wild-caught founders have reproduced.
Northern white rhino	The program for this subspecies has been a failure to date. Only nine individuals survive, and reproduction in captivity has been limited (none in North America and none anywhere since 1989). Intense efforts are in progress to induce reproduction, but the prospects are limited at best.
Greater one-horned rhino	This program has been relatively successful with the annual population growth rate about equal to what is occurring in the wild. However, much of the reproduction to date has been by a limited number of breeders; thus, the genetic diversity in the captive-born population is inadequate. Prospects do seem good for recruitment of more breeders from the existing captive population.
Sumatran rhino	This program has been a failure to date with numbers of individuals and founders low, no reproduction occurring and the death rate high (30% of those imported).

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(Photo: Knoxville Zoological Gardens)

MANAGEMENT & BEHAVIOR

AZA Rhino Husbandry Committee

While rhinos species are similar in many ways, they vary widely in social structure, ranging from the relatively solitary greater one-horned rhino (Laurie, 1982) to the moderately social black rhino (Kingdon, 1979) and the more gregarious white rhino (Owen-Smith, 1975). Therefore, recommended management protocols differ across species in such areas as captive group composition and reproductive parameters. Following is a set of recommendations for basic husbandry procedures, including social groupings, reproduction, identification methods, keeper issues, day to day management, training methods and introduction protocols for managing conflict among individuals.

Group Composition in Captivity

Reproductive success in captive rhinos across North America has been inconsistent at best (Table 3). Currently, the SSPs for all rhino species face numerous challenges. In the case of the greater one horned rhino program, which has been relatively successful, much of the reproduction to date has involved a limited number of breeders. Additionally, the captive black rhino population suffers from high mortality rates; thus, while reproductive success is relatively good, the population is not growing. The white rhino population is in a demographic crisis and, as illustrated in Table 3, first-generation captive-born individuals are currently not reproducing in significant numbers. It has been proposed that substantial improvement of captive husbandry is needed if these programs are to contribute significantly to rhino conservation (Foose & Reece, 1994).

Much is yet to be learned regarding the social structure of rhinos in their natural surroundings; thus, the establishment of comparable social groupings in captivity has been difficult. What is evident to date, however, is that greater one horned, black and white rhinos differ in social organization. The greater one horned rhino is generally considered the most solitary of the three species. Apart from cow-calf pairs, groups are rare (Laurie et al., 1983). Occasionally, temporary associations of a few subadult or adult males may be observed at wallows or in grazing areas. As with all rhino species, olfactory communication is important, and animals of all ages and both sexes may defecate at a communal dung heap.

The black rhino may not be as solitary as is commonly portrayed. Black rhinos share overlapping ranges, often associating briefly at water holes or salt licks. Although females are rarely observed alone, adult males are usually solitary and possibly territorial (Estes, 1991). Cows with calves tend to stay alone; however, the twosome sometimes allow an unrelated immature male or female to join them until that individual reaches maturity (Goddard, 1967). Furthermore, bulls may tolerate other males provided they remain submissive (Hitchins, 1968).

The white rhino is considered the most gregarious of the rhino species. This species is considered semi-social, though adult males appear to be somewhat territorial and basically soli-

TABLE 3. Captive rhino reproduction in North America

	White rhino[a,b] n=88.137		Black[a,c,d] n=47.52		Greater one-horned[a,c] n=26.24	
	Males	Females	Males	Females	Males	Females
Percentage of total population reproductively successful	29.5	32.1	61.7	59.6	34.6	58.3
Percentage of wild-born population reproductively successful	39.1	34.5	58.6	64.3	33.3	41.7
Percentage of captive-born population reproductively successful	4.2	19.0	66.7	54.2	30	60

[a] Data from historical population studbook analyses (reproductively mature animals only in a potential breeding situation)

[b] Individuals assumed reproductively mature at age 7 (males) and age 6 (females), data current to 11/1/95

[c] Individuals assumed reproductively mature at 4 years of age (both males and females)

[d] It should be noted that while gross reproductive success is high within the North American captive black rhino population, mortality is also high; thus, the population as a whole remains in trouble.

tary. Multiple subordinate males have occasionally been observed in the same ranging area as "satellites" to a resident dominant male (Estes, 1991). Adult females occupy overlapping home ranges, typically associating in pairs consisting of a female and her most recent offspring. Furthermore, a calfless cow may tolerate one or more juveniles, or two calfless cows may associate together. Stable groups of as many as six rhinos may be formed in this way, while larger temporary aggregations of up to 12 animals have been observed.

These data on rhinoceros social organization, combined with preliminary analyses of parameters affecting reproductive success in captivity, may be used to generate recommendations regarding possible social groupings in captivity (Tables 4 and 5). It should be noted that numerous variables affect the probability of success with any captive social group, including the animals' dispositions and available holding space. Furthermore, depending on space and animal and staffing availability, institutions may be categorized as breeding or exhibit-only. Facilities that wish to hold rhinos for exhibit purposes only are advised to maintain two animals (1.1 or 0.2). In the case of the white rhino, bachelor male groups have been maintained in very large enclosures (e.g., game parks or ranches). The desire to hold exhibit animals should be expressed to the appropriate species coordinator so that pre- or post-reproductive or single-sex animals may be assigned.

For institutions that have the space and staff available for rhino breeding, it is recommended that managers commit to two pairs if holding black or greater one-horned rhinos and one male and two or more females (and a back-up male) if holding white rhinos. In addition, breeding institutions must also have space for offspring to be held for up to 3 years after birth. Within a single exhibit or holding area, the recommended minimum numbers for breeding are 1.1 (black), 1.2 (white) and 1.1 (greater one-horned). In general, it is recommended that mature males not be held together because of the increased likelihood of serious aggression. Furthermore, breeding success may be enhanced by separating males from females as little as possible, except in the case of the greater one-horned rhinoceros; males and females of this species should be kept separately and introduced only for breeding purposes. (See Introductions, this chapter.)

Grouped or multiple-species exhibits are possible for greater one-horned, black and white rhinos if ample exhibit space is available. Examples of institutions that have successfully maintained mixed-species exhibits include Fossil Rim Wildlife Center, San Diego Wild Animal Park, Columbus Zoo, Lowry Park Zoo and Riverbanks Zoo. Species that have been successfully paired in an exhibit with rhinos include saurus cranes, herons, some antelope species (nilgai, blackbuck, gaur, Persian gazelle), mouflon, zebra and some deer species. In all cases, the dispositions of the individual animals, as well as adequate space and exhibit structure (i.e., visual barriers, refuge areas, etc.), are cited as important considerations prior to attempting a mixed-species exhibit.

White rhinos are the most gregarious of the rhino species, and captive reproductive success may be correlated to herd size. Except in the case of large enclosures, black rhinos should be housed as pairs, and male and female greater one-horned rhinos should be held separately except during breeding introductions.
(*Photo: Knoxville Zoological Gardens*)

TABLE 4. Possibilities for rhino social groupings in captivity (same exhibit)

	Multiple animals of same sex		Multiple animals of opposite sexes
Rhino species	Adult males	Adult females	
White	rare (possible in very large exhibits only)	possible and recommended	possible and recommended for breeding (optimal: one male and two or more females)
Black	not recommended	possible (in very large enclosures only)	possible and recommended for breeding (optimal: 1.1 minimum)
Greater one-horned	not recommended	possible (in very large enclosures only)	pairings recommended only during peak estrus (with the exception of very large exhibits, which may hold a single male and female together consistently)

In all cases, success of various groupings will depend on the individual animals' dispositions as well as the exhibit or holding space available. Additionally, separation capabilities should be available within all rhino-holding institutions to separate animals of either sex if necessary.

1 (*Photo: Fort Worth Zoological Park*)

2 (*Photo: St. Louis Zoological Park*)

3 (*Photo: Fort Worth Zoological Park*)

4 (*Photo: St. Louis Zoological Park*)

5 (*Photo: San Diego Zoological Society*)

Aggression in rhinos ranges from ritualized to true aggression. Face-to-face staring (1) is often seen at the beginning stages of ritualized aggression and may be an opportunity for the participants to "size each other up." Ritualized aggression may subsequently proceed to fencing or sparring (2) and then charging with (3) or without (4) an open mouth threat. Aggression becomes more serious as one animal begins chasing the other (5), which may also include or lead to horn strikes and gores. At this point, aggression is more serious and may warrant intervention at the manager's discretion. Vocalizations such as snorts and bellows usually accompany aggressive encounters.

It is important to note that ritualized aggression among rhinos is commonplace. Aggression that involves chases, horn strikes and goring resulting in arterial blood flow is more serious and in the latter case requires intervention.

INTRODUCTIONS

Changing captive social groupings of rhinos through the introduction of additional individuals to an established individual, pair or group is a process requiring much care. As discussed, rhino species vary widely in social structure, and rhinos periodically vary their grouping patterns in the wild according to such factors as reproduction and the rearing of young. Social groupings in captivity, therefore, should also vary according to species, as well as to the circumstances within each institution. Rhinos may be very protective of their individual boundaries, but proper introduction procedures can minimize injury from conflict and aggression. The following section outlines general considerations for any rhino introduction and provides systematic descriptions of aggression, procedural recommendations, and descriptions of potential species-specific introduction types.

General variables that must be considered in any introduction include individual animal personalities, staff experience and confidence level, and enclosure type (i.e., indoor/outdoor, public/off-exhibit, relatively small/large). Barrier types and temperature should also be considered. Introductions often result in aggression, and it should be noted that captive rhinos of both sexes have been the aggressors (Smith, pers.comm.). Territorial defense is often limited to ritualized confrontations, in which two rhinos advance toward each other but stop nose-to-nose and engage in a staring contest to guage each other's size and strength. Also as a part of this ritual, the two individuals may touch horns, back apart and wipe their horns on the ground (Nowak, 1991).

More intensive conflicts involve head-on charges and the infliction of injuries by horning or ramming. In general, behaviors that have been noted during rhino introductions are listed in Table 6.

It is important to note that what is often perceived as serious or dangerous aggression between rhinos is, in fact, normal behavior requiring no intervention of any kind. Along with increased size and thick skin comes decreased vulnerability compared with many other animals. Table 7 lists a descriptive hierarchy of aggression levels in rhinos.

In some cases, aggression may proceed to a point at which management should intervene to prevent serious injury. Captive managers should allow some aggression during an introduction but be prepared to intervene in the event that aggression threatens the lives of one or more rhinos. Guidelines for intervening may vary across institutions, but in general, careful consideration should be given to intervening in an introduction before aggression reaches Level 5 (acute subcutaneous wounds in which arterial blood loss is involved or likely to occur). Stopping an introduction at a level prior to this will not lessen aggression during a subsequent introduction attempt. Animals that are allowed to "settle their differences" will establish some territorial boundaries and will usually not engage in serious aggression again, with the exception of a male attempting to approach an estrus female. In sum, moderate aggression is commonplace in any rhino introduction; sparring and fighting will occur and

TABLE 5. Recommended numbers for institutional holding

Rhino species	Recommended minimum groupings for breeding[a]	Preferred optimal holding for a breeding institution	Exhibit only (per institution)
Black	1.1	2.2 (2 pairs)	1.1 or 0.2
White	1.2	2.4 (1 herd/ 1 back-up male)	1.1 or 0.2[b]
Greater one-horned	1.1[c]	2.2 (2 pairs)	1.1[c] or 0.2

[a] See Design. Breeding institutions must have space for offspring to be held for up to 3 years following birth.

[b] Multi-male bachelor groups have been maintained in very large enclosures.

[c] In the case of greater one-horned rhinos, males and females should be introduced only during the female's estrus period. Institutions with very large enclosures (e.g., San Diego Wild Animal Park) may be able to hold opposite-sex animals together consistently.

TABLE 6. Behaviors noted during rhino introductions (partial listing, all species)

Non-aggressive behaviors	Ritualized confrontations	Potential stress-related behaviors	Aggressive behaviors
Follow	Head sweep	Pacing	Charge/chase
Touch/rub/lick	Face-to face stare	Running (excessive)	Open-mouth threat
A/G investigation		Vocalization (excessive)	Sparring
		Diarrhea	Goring

See Appendix II Management Ethogram for behavior descriptions.

result in minor injuries (cutaneous wounds). However, in most cases, aggression levels prior to Level 5 may be allowed to continue using the discretion of management.

The introduction process requires much planning and cooperation among captive managers. Table 8 outlines recommended steps involved in any introduction. Familiarization through visual, olfactory and tactile contact should be permitted if at all possible prior to a full-scale introduction. If the facility permits, this may be accomplished by first placing individuals in the same barn or in nearby outdoor lots. As the animals acclimate, managers may move them to adjacent barred stalls or fenced outdoor yards. These barriers prevent confrontations leading to serious injury but allow acclimation and familiarization prior to introduction.

The actual introduction should be attempted in the largest available enclosure. Enclosures should be large enough to allow ample space for chasing, mock-fighting, aggression and defense. Prior to an attempted introduction, water pools in an outdoor enclosure should be filled with substrate to prevent injury in the event of serious aggression. The enclosure should contain visual barriers such as brush or earth piles ("run-arounds"), which give rhinos places to hide without becoming cornered or trapped and may even lessen overt aggression if a rhino is able to escape the sightline of another. An enclosure should not contain dead ends in which an individual may become trapped by an aggressor. Enclosures should allow for the use of high-pressure fire hoses, CO_2 fire extinguishers and/or vehicles to aid in separating individuals.

Animal personality and disposition should always be considered in introductions. A subordinate animal should be introduced to a more dominant animal in an enclosure familiar to the subordinate. In the case of multiple-animal introductions (such as white rhino/introduction of a new female to an established male-female group, discussed below), the most subordinate animal should be introduced to the next most subordinate, and so on. Additionally, greater aggression may be noted in some individuals in the presence of an estrus female; therefore, any introduction attempt at this time should be especially well-monitored or possibly avoided if the attempt involves a male. (Greater one-horned rhinos should be introduced only during the female's estrus period; see below.)

Appropriate personnel for first-time introductions include the primary animal manager, a vet with immobilization equipment, and the curator and keepers most familiar with rhinos. In addition, others may be needed at critical vantage points around the enclosure's perimeter so that the animals may be observed at all times in case separation becomes necessary. It should be noted that if a barn is opened and used to separate individuals, only one individual should be allowed inside the barn and must not be trapped inside by an aggressor.

Following are specific introduction protocols delineated by species and introduction type. As indicated previously, because of the differences in social organization and group composition, different introduction types are possible and/or recommended according to species. It should be noted again that the time required for each introduction can vary depending on the individual animal(s) and staff management expertise.

TABLE 7. Levels of aggression in rhinos

Level of Aggression	Definition
1	Rhinos are charging each other but making no physical contact.
2	Rhinos are charging each other with physical contact resulting in some cuts and scrapes to the facial area(s) of one or both of the animals.
3	Rhinos are charging each other with physical contact resulting in cuts and scrapes to the facial areas and bodies of both animals.
4	Charging and/or pursuit has proceeded to the point that one or both rhinos have been knocked down at least once. Scrapes and cuts are now deeper and more numerous.
5	Aggression and pursuit have proceeded to the point that one or both rhinos have subcutaneous wounds or arterial blood flow.

Manager's discretion must be used in evaluating levels of aggression. Duration of aggressive bouts will vary.

It should be noted that one animal may break away from the confrontation and attempt to escape. The aggressor will often pursue and begin horning the underbelly of the escapee as the two gallop around the enclosure. Often a rear leg is hooked and held aloft while the pursuit continues. If the escapee does not stop and resume a defensive posture, the animals will continue until heat or exhaustion becomes a critical factor. Aggression at this point is more serious.

WHITE RHINO

As recommended, white rhinos are preferably maintained in herd-like (male and multiple female) groups in captivity; therefore, many types of introductions may need to be attempted. Following are recommended protocols for potential white rhino introduction types.

Introduction of a New Male to a Female (or Vice Versa) to Form a Pair

The introduction should occur in the largest lot available, following the general introduction protocols stated previously. If a single large lot is not available, adjoining lots should be opened to form a large area for the introduction. If the latter strategy is used, care should be taken to modify any resulting dead ends in the exhibit where a rhino may become trapped during an aggressive interaction.

Introduction of a New Female to an Established Male-female Group

If given the opportunity, female white rhinos will establish social bonds with one another. A new female should be introduced to a group one female at a time. As each subgroup of females is stable, additional females may be introduced one at a time. Finally, the stable female group (including the new female) should be introduced to the male. The time required for stable integration ranges from 1 to 10 weeks.

Introduction of a New Male to an Established Female Group

A group of females to which a male is to be introduced should be a compatible group prior to the introduction of the male. Unlike the introduction of a female to a group of females, the male should be introduced to the group as a whole rather than to one individual at a time. The reported time required for stable integration has been estimated at 5 weeks.

Reintroduction of a Female with New Calf to a Male-female Group

Following parturition, the reintroduction of a female and her new calf to a group should be treated as a first-time introduction of a female to an established group. The two should be allowed to acclimate to one female at a time, successively forming larger and larger female-female-calf subgroups. The final step is introducing the entire female group (including the new female and her calf) to the male. Institutions have placed infants and their mothers back with the herd or single male as early as 2 weeks after birth.

BLACK RHINO

The social nature of the black rhinoceros is intermediate between that of the white and greater one-horned species. In general, a 1.1 pair is the recommended group size. However, when adequate space is available (See the Design chapter.), single-male-multiple-female groups are possible. Additionally, in comparison with the other rhino species, black rhinos have a much longer average birth interval. In an effort to decrease this interval and re-breed females earlier, a female black rhino should be temporarily reintroduced to the male for breeding following her first post-parturition heat. (See Calf Development for separation periods.) Following are recommended protocols for potential black rhinoceros introduction types.

TABLE 8. Steps in the introduction process

Step	Description
1	Animals in the same barn or multiple outdoor lots should have olfactory and auditory exposure to each other. If the animals are not housed near each other (i.e., enclosures on opposite sides of the zoo, etc.) they should be moved to the same exhibit area.
2	Animals should be given visual contact with each other in addition to the above sensory modalities. (Animals may be shifted within a barn or in adjacent outdoor lots.) If at any point during this process the animals display symptoms associated with stress (e.g., pacing, diarrhea, excessive vocalizations) for more than 2 to 3 hr, the introduction should return to the previous step.
3	If animals are not already positioned adjacent to each other, they should be moved closer together (e.g., to adjacent stalls or adjacent outdoor enclosures).
4	The actual introduction (full tactile exposure) should take place in the largest enclosure available and follow guidelines stated in this chapter. Preferably, the enclosure should be familiar to the least dominant animal and include ample "run-arounds."
5	Within institutions in which rhinos can be left together 24 hr a day, they should be separated during the first several nights or until they show only minor aggression.

Time spent at each step will vary and should be left to the discretion of management. Variables that must be considered in any introduction include the following: individual animal personality, staff experience and confidence level, enclosure type (i.e., indoor/outdoor, public/off-exhibit, relatively small/large), barrier type and temperature.

If an acutely stressful situation results at any stage (animals exhibiting stress-associated behaviors for more than 2 to 3 hr), the introduction should return to the previous step. Note, however, that careful consideration should be given before intervening in an introduction before Level 5 aggression is reached.

Introduction of a New Male to a Female (or Vice Versa) to Form a Pair

The introduction should occur in the largest lot available, following the general introduction protocols stated previously. If a single large lot is not available, adjoining lots should be opened to form a large area for the introduction. If the latter strategy is used, care should be taken to modify any resulting dead ends in the exhibit where a rhino may become trapped during an aggressive interaction.

Introduction of a New Female to an Established Male-female Group (if adequate space is available)

Unlike white rhinos, female black rhinos generally do not tend to form strong pair bonds. Therefore, a new female should be introduced to an established male-female group one individual at a time, but it is not necessary that she be introduced to all females before being introduced to the male. For breeding introductions, a calf should be trained to be temporarily separated from its dam so that she can be introduced to a male. (See Calf Development, this chapter.)

Introduction of a New Male to an Established Female Group (if adequate space is available)

As previously discussed, female black rhinos do not generally tend to form strong pair bonds. However, if a multiple-female group is established and managers perceive that the females have formed strong bonds, the new male should be introduced to the females as a group rather than to one female at a time. If the females are not as compatible as managers would like but an introduction is necessary (SSP recommendation, breeding, etc.), the new male should be introduced to each female individually. Following all successful male-female introductions, the male should be introduced to all the females at the same time.

Reintroduction of a Post-partum Female (Without Calf) to a Male

The reintroduction of a post-partum female to a male is usually recommended for the dam to be re-bred. Therefore, this type of introduction is usually temporary, and following breeding, the female should be placed back with the newborn calf. In order to attempt this introduction, the calf must be trained to be separated from the female. (See Calf Development, this chapter.) The introduction of the post-partum female to a male should be attempted following the first post-partum heat.

GREATER ONE-HORNED RHINO

Because of the relatively more aggressive, territorial nature of greater one-horned rhinos, introductions should be attempted only for breeding purposes (one male to one female). With the exception of very large facilities, individual rhinos should be held separately in all other situations.

Introduction of a Female to a Male for Breeding Purposes

Introductions should occur only for breeding purposes and when the female is in estrus. (See Table 9 for behaviors believed to be associated with estrus.) The introduction should take place in the largest area available. If two adjoining yards are opened to create a larger intro-

TABLE 9. General reproductive behaviors observed during estrus and courtship (partial listing, all species)

Female	Male
Vocalizations	Vocalizations
Urine spray/squirt	Frequent urination; urine spray/squirt
Urogenital changes (e.g., vulva swelling)	Erection
Vulva wink	Genital inspection of female (A/G investigation)
Stands for male	Flehmen response
Aggression toward male (Charge/chase; spar)	Charge/chase female
Inappetance	Chin rest
Nuzzles male's belly and/or genitals (e.g., touch/rub/lick)	Mounts female
Vaginal discharge	Follows female
Maintains proximity to male	Maintains proximity to female

Estrus behaviors in the absence of a male are often difficult to distinguish. In general, increased activity, agitation, vocalizations, spray-squirting urine and a vaginal discharge have been cited. As a female approaches peak estrus, these behaviors usually intensify in frequency.

Some female rhinos have been reported to successfully breed without exhibiting any overt behavioral signs of estrus.

duction area, the female should be placed in the yard she is most familiar with first and allowed to acclimate. After she is acclimated to the yard, the male should be introduced to her. As stated in the general introduction protocols, if the facility allows, preliminary visual and tactile contact may increase the likelihood of mating success. If intervention is required because of aggression between the rhinos, the introduction should cease and be attempted at a later date. If possible, the female should be kept from entering a barn if the individuals cannot be separated in the outdoor enclosure. In all likelihood, the male will follow her into the barn, and the chances of serious injury will increase. Because the introduction should occur during estrus, an introduction may be required at any time of the day or night (Table 10; estrus duration is 24 hr, and peak conception occurs between hours 8 and 12). The rhinos should be monitored and separated following breeding.

Reintroduction of a Post-partum Female (Without Calf) to a Male

An introduction of a post-partum female to a male for breeding should occur only during the female's estrus period. It may be advisable to wait until after the first post-partum estrus cycle. The calf should not be introduced with the female when she is introduced to the male; therefore, the calf should be trained to be separated from the female to allow for the introduction of a male. (See Calf Development, this chapter.)

REPRODUCTION

Table 10 lists data currently available from captivity regarding the reproductive biology of greater one-horned, white and black rhinos. It should be noted that much is yet to be learned. In general, reproduction in the rhinoceros is characterized by a host of specialized behaviors. Though some variation may exist among the three species in terms of reproductive behaviors, data are insufficient to strictly delineate them. Particularly, estrus-specific behaviors in females are not clearly defined (Table 9). Close attention to male-female courtship interactions may provide better indicators of the onset of estrus.

Rhino courtship behavior can be very aggressive, but that is not the rule. The following is a general account adapted from Estes (1991) and husbandry workshop discussions. A bull that detects a female approaching estrus (by sampling her urine with a pronounced grimace or flehmen response) may become her consort. The courtship process may be a protracted one, as the bull remains in close proximity to the female and follows her until she comes into full estrus and will accept contact. Prior to full estrus, a female will often drive back a bull through mock charges and defensive threats. In the case of the white rhino, the bull in the herd may attempt to split any female groupings apart during courtship and breeding attempts. In some cases, these bonds may interfere with breeding success if the females are able to continually drive off an approaching male. In all rhinos, bull courtship behaviors may include retreats, circles and/or dominance and threat displays (including rushing, jabbing, puffing, and nudging with the horn or head). Aggression at this point (if the interaction becomes aggressive) may proceed to Level-4 or -5 aggression as described in Table 7. It should be noted that both sexes may participate equally in the aggression. Again, managers should use their discretion as to when to separate the rhinos if aggression proceeds to a point at which it endangers the animals.

TABLE 10. North American captive rhino reproductive statistics

	Black[a]	White[b]	Greater one-horned[c]
Gestation[d]	492-552 days (n=4)	485-518 days (n=8 births; 3 inst.)	470-516 days (n=18)
Breeding season	Peaks in May, June and Sept.	Peaks in July, Sept. and Dec./Jan.	Peaks in Jan., Mar./Apr. and Sept./Oct.
Birth peaks	Oct.-Jan., Mar., Aug.	April/May, June/July, Nov.-Jan.	Dec./Jan., May, July/Aug.
Birth intervals	mean=36.1 mo. (n=72)	mean=30 mo. (n=109)	mean=26.2 mo. (n=14)
Estrus cycle length[d]	21-28 days; peak estrus lasts 24-48 hr	27-44 days; male interested 24-48 hr, but female receptive only for 12-18 hr	34-42 days; peak estrus lasts 24 hr with optimal conception hours 8-12
Age at birth of first calf[e]	Female: mean= 7.6 yrs., range= 3.5-20.5 yrs. Male: mean= 7.6 yrs., range= 5.3-9.7 yrs.	Female: mean= 10.7 yrs., range= 5.6-23.5 yrs. Male: mean= 15.5 yrs., range= 7.2-25.2 yrs.	Female: mean=10 yrs., range=4.6-16.4 yrs. Male: mean=16.8 yrs., range=9.2-30.9 yrs.
Age at birth of last calf[e]	Female: mean= 16.1 yrs., range= 3.5-27.7 yrs. Male: mean= 10.8 yrs., range= 6.9-25.2 yrs.	Female: mean= 17.1 yrs., range= 7.2-31.1 yrs. Male: mean= 19.7 yrs., range= 7.2-29.2 yrs.	Female: mean=13.4 yrs., range=9.8-22.2 yrs. Male: mean=10.1 yrs., range=12.8-36.6 yrs.

[a] Data compiled from historical studbook analyses, B. Read, Walt Disney World Co. Data for captive-born individuals only.

[b] Data compiled from historical studbook analyses, T. Wagener, Fort Worth. Data for both captive- and wild-born individuals (n=5 for captive-born reproductively successful individuals.)

[c] Data compiled from historical studbook analyses, Lindburg and Millard, San Diego Wild Animal Park. Data for captive-born individuals only.

[d] Data compiled during husbandry workshop discussions; systematic data are needed.

[e] Data compiled by calculating the age of the sire/dam at the birth of the first/last calf. For husbandry purposes, an approximate age at first/last successful breeding may be calculated by subtracting an estimated gestation period from the reported age of the sire or dam.

As the female comes into full estrus, she will begin to accept the bull placing his chin on her rump. (See Appendix II Management Ethogram, "chin rest.") The bull may proceed from this stage to perform repeated preliminary mounts until the female eventually stands with her tail curled for full penetration. It has been noted that the black rhino may mount with or without an erection, whereas the other two species (white and greater one-horned rhinos) generally have been reported to mount before an erection occurs. In the case of the white rhino, successful copulations have been observed in the presence of the female's calf or juvenile companion as well as other adult females. Table 9 outlines general reproductive behaviors observed in rhinos during estrus and courtship.

As previously described, greater one-horned rhinos should be introduced only when the female is in estrus. More serious aggression between opposite-sex individuals of this species has been cited. As the female rhino approaches peak estrus (as indicated by such behaviors as increased urine spraying, inappetance, increased vocalizations and vulva winking), an introduction should be attempted. It has been noted that peak estrus lasts approximately 24 hr and optimal conception chances occur between hours 8 and 12 (Table 10).

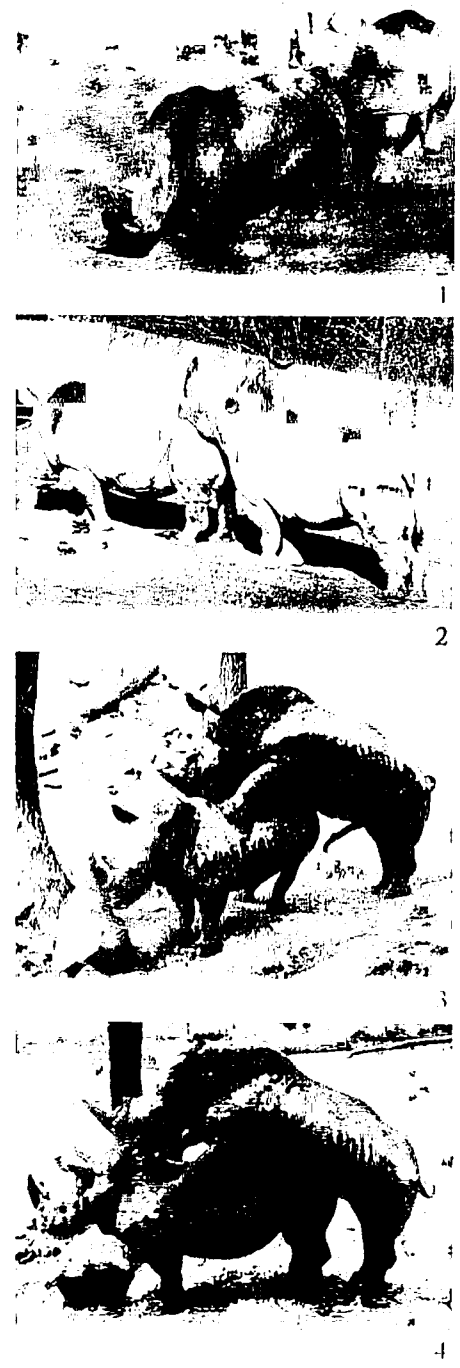
Copulation

Copulation in the rhinoceros has been described as typically equine in position. At the culmination of courtship behaviors, a female indicates her receptivity by standing still and allowing the bull to rest his chin on her rump. He then mounts her and achieves an erection at this time if he has not already. Following repeated preliminary mounts, at full copulation, rhinos may remain coupled for 30 min to 1 hr, with ejaculations every few minutes, and multiple mounts/breedings may occur. Following breeding, the two animals show signs of fatigue and part company, although the male may remain in close proximity to the female for 2 to 6 days. Note that data on black rhinos, unlike that reported on other species, indicate that they may continually breed throughout gestation.

In captivity, breeding generally occurs throughout the year, though slight peaks may be seen in the spring and fall (Table 10). Some differences among species have been noted, but these may result from management and therefore not represent true species differences. Rhinos may successfully breed at as early as 3.5 to 5.5 years of age (females) and 5.5 to 9 years of age (males). To date, few data are available concerning behavioral indicators of sexual maturity outside of overt sexual behaviors. In the case of male white rhinos, however, increased aggression has been cited (Fouraker, pers. comm.). The average breeding lifespan of rhinos is approximately 20 to 25 years, as both males and females have not successfully bred past 36 years of age (Table 10). Please see Table 10 for species-specific trends in reproduction.

Pregnancy and Parturition

Gestation periods for the three rhino species are listed in Table 10. Table 11 lists behaviors associated with pregnancy and impending birth. In general, pregnant white rhinos will cease behaviors associated with estrus and exhibit a lack of breeding behavior. As previously described, black rhinos may breed continually throughout gestation. In all species, there may be a mucus discharge, noticeable weight gain or increase in girth size, as well as increased frequencies of defecation and urination throughout gestation.



Courtship in rhinos can be a protracted affair. A male rhino may remain in close proximity to a female and may follow her until she comes into full estrus and accepts contact. As the female comes into full estrus, she will accept the male sniffing her (1) and placing his chin on her rump (2). The male may then begin a series of mounts (3) until she will eventually stand for a full mount and copulation (4). (*Photos Knoxville Zoological Gardens*)

In both black and white rhinos, pregnant females have been observed isolating themselves from other individuals. If pregnancy is confirmed (Preliminary fecal hormone tests are available.) and/or the breeding date is known, the physical separation of the pregnant female from the bull/herd should take place as early as 30 days and as late as 24 hr prior to birth. Institutions with very large enclosures have had successful births in the yard with the male present; however, the cow and any males should be watched very closely.

The onset of birth often takes place at night or in the early morning and may last 1 to 3 hr. Parturition usually lasts 10 to 12 hr from water break, though first-time mothers may take longer to calve. The presentation of a calf is generally head-first, although rear feet presentations do occur and may take longer than head-first births. Capabilities for monitoring births remotely are advisable.

Calf Development

A single calf is generally the rule. Few data are available on birth weights, but in general, calves weigh the following at birth: 27 to 41 kg (60 to 90 lb) (black, n=4), 54 to 70 kg (120 to 155 lb) (white, n=5), and 65 to 81 kg (144 to 178 lb) (greater one-horned, n=9). Immediately following birth, the newborn calf is usually cleaned by its mother and first stands within 30 min to 5 hr of birth. A newborn calf may require traction material to help steady itself. Traction materials may include sand, gravel, straw, hay or rubber matting. In all cases, both the dam and calf should be monitored closely to prevent their ingestion of the added substrates. A calf should begin nursing within 1 to 2 hr of standing (though in a single case, a calf removed from its dam for medical intervention nursed 16 hr post-birth). The dam will nurse her calf while standing or lying on her side.

Infants less than 2 months old may nurse hourly, while older calves nurse at intervals of about 2.5 hr. Few data are available on nursing durations and frequencies, but it has been reported that as the calf ages and grows stronger, nursing will usually increase in duration but decrease in frequency. It has been reported that calves may gain up to 4.54 kg (10 lb)/day for the first 10 days. The first defecation has been reported at 2 to 10 days of age (n=2). Calves may nurse for up to 2 years, although they have been observed first sampling solid food at less than 1 week to 1 month of age. Calves may be offered supplemental feedings of milk if the dam is believed to be a poor milk producer or the calf is not gaining weight. (See Hand-rearing in the Nutrition chapter.) Infant rhinos have been successfully pulled from their mothers because of rejection, medical issues related to the mother or infant, or from a failure to nurse. Otherwise, it should be noted that weaning for management purposes can be accomplished if necessary at 6 months, but 1 year is preferable. One attempt to use a surrogate mother was unsuccessful; however, hand-reared infants have been assimilated into existing groups and have shown reproductive success.

Depending on the facility and the species, a cow and her newborn calf may be reintroduced to the male/herd after 2 weeks (white rhinos) or following the cow's first heat (black rhinos). (See Introductions above for further details.) If the facility is able to run multiple female greater one-horned rhinos together, the cow and calf should not be introduced to the others for approximately 4 months following birth.

TABLE 11. Physiological and behavioral indicators of impending parturition in female rhinos (partial listing, all species)

30 days prior to birth	2 weeks prior to birth	24 to 48 hr prior to birth
Increase in teat size	Nipples enlarge	Udders increase dramatically in size
Beginnings of milk production	Nipples develop wax plugs	Inappetance
Milk may be expended with pressure on the teats	Vulva swelling occurs	Becomes irritable and aggressive to stimuli, including staff
Female may prolapse vaginally when defecating		Mucus plug forms
		Increased vulva dilation
		Increased restlessness, lies down often

Immediately following birth, the newborn calf is cleaned by its mother and should first stand within 30 min to 5 hr of birth. (*Photo: San Diego Zoological Society*)

Few data are available on the behavioral ontogeny of rhino calves. Both black and greater one-horned calves generally do not have peers to play with, though they are generally very curious and often chase and mock-fight with their dams or occasionally keepers. White rhino calves exhibit these behaviors toward any male, female, calf or juvenile in the herd. Non-aggressive sexual behaviors may be exhibited at as early as 18 months of age in males.

In general, the long-term social effects of removing rhino calves from dams should be investigated. For all species, weaning or permanent separation of the calf except for medical reasons should not occur before 1 year of age. A calf can, however, be temporarily separated from its mother at as early as 1 month of age for short periods of time (e.g., re-breeding of dam). Generally, the procedure is to separate the calf for short periods of time (e.g., 15 to 20 min during cleaning) and gradually increase the separation time. If a dam is not scheduled to be re-bred, her calf may remain with her until it reaches sexual maturity (at approximately 4.5 to 5 years of age). It should be noted that available data indicate that nursing does not inhibit conception. In a herd-like situation, a female white rhino may temporarily abandon her calf during estrus and rejoin it immediately after breeding until the birth of her next calf. The first calf may be forced away before parturition of the second calf as the dam seeks to isolate herself. Following the birth of the second calf, the first calf, then a subadult, may rejoin its mother and her new calf in a social group for up to 4 years or until it reaches sexual maturity.

MANAGEMENT

Identification

Although physical characteristics such as horn size and shape make individual rhinos fairly easy to distinguish from one another, sound captive management requires that animals be identified through permanent and reliable methods. Trovan® transponders, implanted at the base of the left ear during post-natal examination or as soon after birth as possible, provide a means of permanent primary identification for all individuals. Adults that are not currently tranpondered should be when the opportunity arises. Note that transponder numbers, which are assigned for identification, need to be reported to the studbook keeper. In addition to a transponder, each individual should have a secondary visual means of identification, such as an ear tag or ear notch. Photographs or sketches in the animal's records may also serve this purpose.

Keeper Training and Interaction

As with any position involving the management of large animals, rhinoceros keepers should have as much formalized training and experience as possible and should be familiar with rhino behavior and husbandry. In order to ensure safety and to properly meet the requirements of management, it is recommended that more than one keeper be responsible for the care of these animals on a daily basis. Keeper interaction should be restricted to designated areas and should be conducted in accordance with institutional protocols. Finally, consistency of routine is vital in daily interaction.

Keeper interaction with rhinos is a necessary part of successful management. It is recommended that interaction be limited to designated areas and protocols (such as treatment regimens or training programs). (*Photo: Fort Worth Zoological Park*)

There are no conclusive data to indicate the effects of different styles of keeper interaction on rhinoceros behavior or reproductive success in captivity. Interaction styles range from no contact at all to daily hands-on contact. In an effort to create an environment patterned after the wild, however, at no time should relationships with keepers substitute for natural interaction among individuals.

It is important that rhinoceros personnel keep a daily log, noting any unusual behavioral changes. It is the responsibility of management to supply all pertinent data to the studbook keeper.

Daily Regimen

Fresh water should be available at all times and should be changed daily or supplied by an automatic-fill or continuous-flow device. Regular cleaning and disinfecting should occur at a rate that inhibits the growth of algae and bacteria. Water devices should be constructed to prevent upset, spillage or leakage. Rhinos need access to water pools and/or mud baths to keep their skin healthy; mud wallows should be renovated periodically to prevent contamination. (See the Design chapter for more information on pools and wallows.)

Natural substrates should be spot-cleaned and raked daily, and hard-surfaced areas not exposed to the elements should be dry-cleaned or hosed daily and disinfected at least weekly. Indoor housing surfaces, as well as walls and rub areas, should be cleaned daily. For institutions holding free-ranging herds, these daily cleaning procedures are not practical, but periodic removal of dung heaps and the turning of soil and scattering of manure with proper equipment are necessary to reduce parasite loads. Additionally, the daily hosing or showering of rhinos in the barn with temperature-controlled water is recommended to promote healthy skin during the winter months.

In order to facilitate participation in many research programs involving rhinos, it is recommended that institutions implement training programs following the protocols recommended in the Rhinoceros Training section of this chapter. Additionally, it is recommended that some form of environmental/behavioral enrichment be integrated into daily rhino management.

ENRICHMENT

Behavioral enrichment is a well known concept in primate literature (e.g., Tripp, 1985; Bloomsmith et al., 1988; O'Neil et al., 1991) and to a lesser extent in the ursid, felid and elephant literature (e.g., Carlstead et al., 1991; Forthman et al., 1992; Hartnett, 1995; Knights, 1995). Enrichment is not commonly emphasized in ungulate management in general or with rhinos specifically. This deficit, however, should not de-emphasize the potential benefits of behavioral and environmental enrichment in rhino management.

In general, enrichment may be defined as the addition of objects or modification of management guidelines that causes a change in animal behavior to more closely resemble that of a healthy, wild conspecific (Mellen & Shepherdson, 1992). Enrichment may serve various

1 (*Photo: Fort Worth Zoological Park*)

functions, including (1) improving well-being by reducing the levels of abnormal and injurious behavior, increasing exercise, satisfying "behavioral needs" and optimizing the level of stimulation that animals receive; (2) educating zoo visitors by increasing the levels of natural and interesting behaviors, visibility and activity levels; and (3) conserving endangered species by improving the success of captive breeding and reintroduction programs (through modulation of social interactions, maintenance of health, promotion of normal physiological and psychological development, and maintenance of behaviors required for survival in the wild) (Shepherdson, 1992).

The development of an effective enrichment program requires examination of both the physical and social environments of captive rhinos. As discussed, rhino species vary in social organization. However, while the greater one-horned rhino may be considered the least social of the rhino species commonly maintained in captivity, data from wild populations indicate that individuals even of this species associate with one another at communal wallowing or grazing grounds (Nowak, 1991). Optimal group size and composition is discussed elsewhere in this chapter; however, the potential impact of group size is discussed here. Individuals and subgroups of white rhinos separate and unite frequently in both captivity and the wild (Fouraker, pers. comm.; Estes, 1991). If captive conditions allow, white rhinos should be managed in such a way as to approximate this pattern. This may involve temporarily separating an individual or individuals from the group or, conversely, allowing rhinos access to each other 24 hr a day (as conditions allow, either indoors or outdoors). Black rhinos are considered moderately social compared with white rhinos; however, institutions with larger enclosures may house them in more herd-like situations. Again, allowing compatible individuals to spend as much time as possible with each other may prove beneficial. It is recommended that greater one-horned rhinos be housed separately (except in the case of very large enclosures); however, individuals should be given both visual and olfactory access to each other.

Exhibit design may incorporate many features that provide enrichment to rhinos. For the most part, however, systematic data are not available to discern the specific effects of these guidelines. Many of the following recommendations are also covered in the Design chapter of this publication. In general, the larger the enclosure, the better. Preliminary trends indicate that reproductive success of white rhinos may be greater in larger enclosures (though this may be confounded by social group composition). In any case, because all rhino species can be aggressive, variability in enclosure topography and plantings are recommended. Plantings (protected from rhinos by rock aprons, etc.), rock piles and dirt mounds (or other forms of visual barriers) may help ease social tensions by partially blocking rhino sightlines. For all species, the incorporation of a mud wallow is particularly important for skin health as well as potential behavioral enrichment. Greater one-horned rhinos should also have access to a pool because of their affinity for water. Rubbing posts placed throughout the enclosure assist in the removal of dead skin and may also serve as partial visual barriers.

The husbandry routine can also serve as a form of enrichment for rhinos. Because of the natural feeding behaviors of rhinos, browse can be an effective enrichment tool (as well as an important dietary component; see the Nutrition chapter). Varying the placement or fre-

2 (*Photo: Oklahoma City Zoological Park*)

3 Behavioral or environmental enrichment can be a vital part of captive management. While not commonly associated with rhinos, enrichment can include large, movable objects such as boomer balls (1), rubbing posts or trees (2) or simply increasing the complexity of the enclosure(s) (3). (*Photo: Fort Worth Zoological Park*)

quency of browse feedings may increase rhino activity levels and stimulate the natural grazing/browsing behavior of rhinos. Training or operant conditioning programs may also serve as a form of enrichment (discussed in detail later in this chapter). Rhinos rely heavily on their olfactory sense to presumably obtain information regarding other individuals. This fact can be effectively incorporated into both the design of the indoor holding and exhibit areas as well as management regimes. Designing indoor holding so that each rhino must pass through a common area prior to its individual stall allows rhinos to consistently sniff and mark one another's dung piles. The same holds true if individuals pass through one another's exhibit lots to enter their own. Again, if animals are compatible and may be held in groups (particularly white rhinos), group indoor stalls should be incorporated into design specifications. Males, though, should be held separately when indoors. Within reason, it is recommended that dung piles not be totally removed during cleaning. This again allows rhinos to obtain information about each other using their well-developed olfactory ability. With vet and management approval, dung may be exchanged with another zoo and placed in the rhino enclosure. The novel dung may stimulate sexual activity or increase territory marking behavior. If the institution houses more than one rhino species or subgroups of the same species, the same effect may be obtained by exchanging dung in-house.

Rhinos may also benefit from the addition of various manipulable objects. Movable objects such as stumps, logs, hard plastic balls or metal kegs may be rolled or tossed by rhinos and result in an increased activity level. Table 12 is a summary of enrichment ideas that have been successful with rhinos. In all cases, it should be noted that variability is a key to enrichment. Systematic observation of rhinos pre- and post-enrichment will help managers assess the effectiveness of each idea. Observations may vary from a simple keeper checksheet to a well-developed behavioral study. In either case, such an evaluation will enable managers to most effectively modify the captive environment for rhino well-being.

RHINOCEROS TRAINING

Physical examininations, as well as numerous nutritional, reproductive and veterinary research projects, often require hands-on contact with rhinos. An alternative to manual or chemical restraint of an individual is an operant conditioning program that utilizes positive reinforcement. Such a program has many benefits, including reduced stress to the animal, more reliable sample collection, reduction of any effects of stress on the samples, less need for structural modifications to restrain animals, and behavioral enrichment (Bloomsmith, 1992; Laule, 1992). Numerous institutions have successfully trained rhinos for such procedures as blood collection and ultrasound tests, as well as basic husbandry procedures including skin and foot care (e.g., Eyres et al., 1995; Mehrdadfar, 1995; Michel & Illig, 1995; Nicholson, pers. comm.). The following section relies heavily on these works to describe the basic principles underlying a rhino-training program, as well as to document specific procedures for implementing such a program.

The first step prior to beginning any training program is to establish program goals and requirements. A training program will require much coordination among staff members including keepers, curators, veterinarians and even zoo management, as exhibit schedules

TABLE 12. Enrichment possibilities for rhinos

Structure/Furniture
Loose, heavy chain fastened at both ends 61 to 91 cm (24 to 36 in.) from the ground for rhinos to push and test strength against (acts as an artificial sparring partner)
Water pools and mud baths for bathing or wallowing
Rubbing posts to stimulate the removal of dead skin
Large, movable items such as stumps, logs, boomer balls or 208-liter (55-gallon) plastic drums
Yards connected by gates
Logs suspended on chains
Sprinklers
Increased complexity of the enclosure (e.g., dirt mounds, visual barriers)
Management
Initiate an operant-conditioning or training program
Place browse branches on the ground or hang them in high places or on stumps
Offer feed throughout the day in various places (e.g., apples in the pool)
Allow dung piles to accumulate in outdoor facilities
Exchange dung with other zoos (with vet approval; new scents may stimulate sexual activity and increase territory-marking behavior)
Vary social groupings by occasionally splitting up a herd (with approval of SSP Coordinator)

Modified from Grams & Ziegler (1995)

may be modified during training. In general, it must be understood by all parties that consistency in routine is paramount for training and that modifications will undoubtedly be made to the pre-training routine to accomplish the program goals. The feasibility of a training program should initially be evaluated by examining the tractability of the animal(s) and considering staff time and expertise. Animals should be evaluated based on their basic dispositions as well as previous histories with medical procedures. Especially nervous animals will more than likely adapt to a training program, though substantially more time may be required to meet program goals. In general, training personnel may include keepers (e.g., Michel & Illig, 1995), curators or an individual strictly responsible for training or enrichment at an institution. In any case, it is recommended that the individual(s) have a thorough understanding of basic training techniques. However, it should be emphasized that rather than the specific personnel involved, consistency in routine and a strong understanding of animal behavior are the critical elements for a successful program.

The training process itself will generally include three basic steps: (1) habituating the animal to the trainer, (2) constructing and introducing "targets," or visual areas of ideal placement for the rhino, and (3) establishing the commands necessary to steer the animal to these target areas. Additionally, although the ultimate training goal may be to collect blood from a rhino for hormonal evaluation, the accomplishment of this goal will require many steps, including training the rhino to (1) approach the trainer, (2) "target" to a specific object and/or area, (3) remain stationary for a given period of time and (4) tolerate the procedure. The duration of time at each step will vary widely across individuals, but in general, rhinos have been successfully trained for daily blood collection in as few as 3 to 5 months.

It is recommended that training begin with one individual as the primary trainer. Once the rhino reliably executes the desired behaviors, additional personnel may be included as needed. Ultimately, given the appropriate stimuli, the rhino will ideally execute the desired behaviors for a number of different personnel. Similarly, it is recommended that training be initally performed in a specific area of the enclosure. Again, however, flexibility is important so that the rhino will perform the desired behavior(s) (e.g., target to a specific area and remain stationary) in more than one area if necessary. In both cases, it should be emphasized that training commands, targets and rewards should be used only during training sessions. Additionally, at least until the desired behaviors are established, training sessions should occur in a given treatment area with no interaction other than conditioning taking place in the specific training area. The chosen commands and target objects should be carefully evaluated prior to beginning the training program. (For example, if "shift" is routinely used to shift rhinos, a more appropriate training command may be "come.") In an effort to maintain consistency across institutions and various conditions, Table 13 lists recommended voice commands to be used in rhino training.

Specific training areas and objectives will vary across institutions. Closed- or free-stall chutes (See the Health chapter.) work well for medical procedures, provided there is ample access to the animal and safety for personnel. Additionally, treatment may involve a specific section of the enclosure (e.g., requiring the animal to target parallel to enclosure cables).

TABLE 13. Recommended voice commands for rhino-training programs (adapted from AZA Elephant SSP protocols)

Command	Behavior
Move up	Move forward
Back	Move back
Over	Side step
Steady	Hold position
Foot	Present foot
Come	Come to keeper
Target	Place head or body part at specific area
All right	Release

Successful training involves many steps including conditioning the rhino to "target" to a specific area and remain stationary. Up to 9 weeks has been reported as the maximum time necessary to train a rhino to target and remain stationary. (*Photo: Milwaukee Zoological Society*)

To habituate the rhino to the presence of the trainer, regular 10-min training sessions may be effective. Again, it should be emphasized that the amount of time required will depend on the tractability of the individual; conditioning may take longer for certain animals. During these sessions, the primary objective is to establish trust. By noting generalized behaviors and body positions of the animal, the trainer should be able to discern the point at which the rhino is relaxed with his/her presence. At this point, the trainer may begin shaping the desired behavior. If, for example, the desired behavior is standing for blood collection from the ear, the first step is to encourage the rhino to approach the trainer using voice commands (e.g., "come"). Following each successive approximation of the behavior, another command should be given, such as "good," which serves as a "bridge" to link the behavior to the reinforcement, which is given concurrently. A positive reinforcer should increase the frequency of the desired behavior. Examples of successful reinforcers include food (e.g., apples, bananas, grain) and, to a lesser extent, tactile stimulation (e.g., belly scratching with a push broom, Michel & Illig, 1995). It is important to note that the bridge and the reinforcement should be given only for the approximation of the desired behavior. Otherwise, additional behaviors performed in conjunction with the desired one will also be reinforced.

After the successful completion of the approach behavior (after a few weeks), the trainer can introduce a "target," or object easily visible to the rhino [e.g., the trainer's hand or a 2.54-cm- (1-in.)-diameter lid to a 18.9-liter (5-gallon) bucket] for the placement of a specific body part (e.g., head or hindquarters). At this point the trainer should encourage the rhino to approach the target on command (e.g., "target") using the same basic procedure of reinforcing approximations of the desired behavior. Training sessions at this point should last 10 to 30 min. Alignment with both head and body targets places the rhino in position for such procedures as blood collection from the ear vein, rectal temperature readings or venipuncture. Following successful targeting, the next step is encouraging the rhino to remain stationary for a given period of time (using the command "stay" or "steady," for example). Up to 9 weeks has been reported as the time necessary to train a rhino to consistently perform these behaviors.

Once these behaviors have been established, the final step involves desensitizing the rhino to the medical equipment (if applicable). At this point, additional personnel who will be performing the procedure (if applicable) can be introduced to the process. Initially, the collection area should be manipulated (e.g., touching and pinching the ear, cleaning the colon of feces). Any materials that will be used should slowly be introduced (e.g., probe, tourniquet, iodine, tube and syringe). These introductions should continue until the rhino shows no reaction to the equipment. The final stage prior to the actual procedure may include pressure from a blunt needle or insertion of a reproductive probe until the rhino shows no reaction.

There are some general considerations that should be noted during all phases of conditioning. If at any point during training there is regression, the trainer should revert to a point in the training where the rhino is comfortable and then slowly proceed again. While this may add to the total time required for conditioning, the probability of overall success is increased. Additionally, once the procedure is routine for the rhino, the trainer should periodically lead

Target training is an especially effective form of conditioning. Training a rhino to follow a target enables zoo personnel to position the animal for such procedures as blood collection, rectal temperature readings, venipuncture or ultrasonography. (*Photo: Fort Worth Zoological Park*)

the rhino in performing the desired behaviors if they are not otherwise performed regularly (e.g., weekly blood collection for hormonal analyses). In the absence of regular performance, this variable reinforcement will help prevent the behaviors from extinguishing.

RHINOCEROS SHIPPING PROTOCOL

Pat Morris, DVM, and Michael Fouraker

The crating and shipping of rhinos is one of the most difficult shipment procedures in zoos. While rhinos themselves are fairly hardy, the limitations of temperament, peculiarities of chemical immobilization, and rigorous shipping equipment necessitates a strict yet flexible protocol for optimizing successful crating and shipping.

Pre-shipment Medical Procedures

Communication at the veterinary level between receiving and shipping institutions prior to rhino translocations is essential in order to discuss specific institutional and/or state requirements. Standard medical procedures for all moves should include the following: (1) a TB test within 6 months of shipment or as particular state, federal or international requirements dictate, (2) brucellosis serology, (3) a visual physical examination, (4) two negative fecal screens 30 days prior to shipment and (5) a review and update of innoculations. (See the Health chapter.) In addition, medical or research protocols defined by the SSP should be reviewed during the planning process.

Crating

Crating is the recommended transport method, although transport in trailer stalls has also been successful. It is important in the latter case that a reinforced trailer be used. In all situations, the animal's behavior and conditions should be constantly monitored. Typical problems that can occur in shipping include the following: (1) animals destroying and/or climbing out of the crate top; (2) animals becoming inverted in the crate and unable to right themselves; (3) animals destroying end panels or doors, resulting in eye, horn or facial injuries; and (4) prolonged, excessive exertion resulting in hyperthermia and/or myopathy.

Design

The International Air Transport Association (IATA) crate design specifications are illustrated in Figure 4. Crates are usually constructed of wood or wood with steel reinforcements. Crate dimensions should be determined by the animal's size (Table 14), but in general, the crate should be 0.3 m (1 ft) longer and wider than the animal when it is lying on its side. Crates with bars situated at the head end will decrease injuries to the head and face. Horizontal bars at the head end should be avoided, as they tend to cause horn breakage and/or damage. Crates with bars and doors at both ends are optimal.

TABLE 14. Approximate crate dimensions by species (modified from IATA, 1995)

Species	Length	Height
Black rhino	271 cm (107 in.)	191 cm (75 in.)
White rhino	475 cm (187 in.)	221 cm (87 in.)
Greater one-horned rhino	335 cm (132 in.)	201 cm (79 in.)

Crate dimensions should be determined by the animal's size, but in general, the crate should be 0.3 m (1 ft) longer and wider than the animal when it is lying on its side.

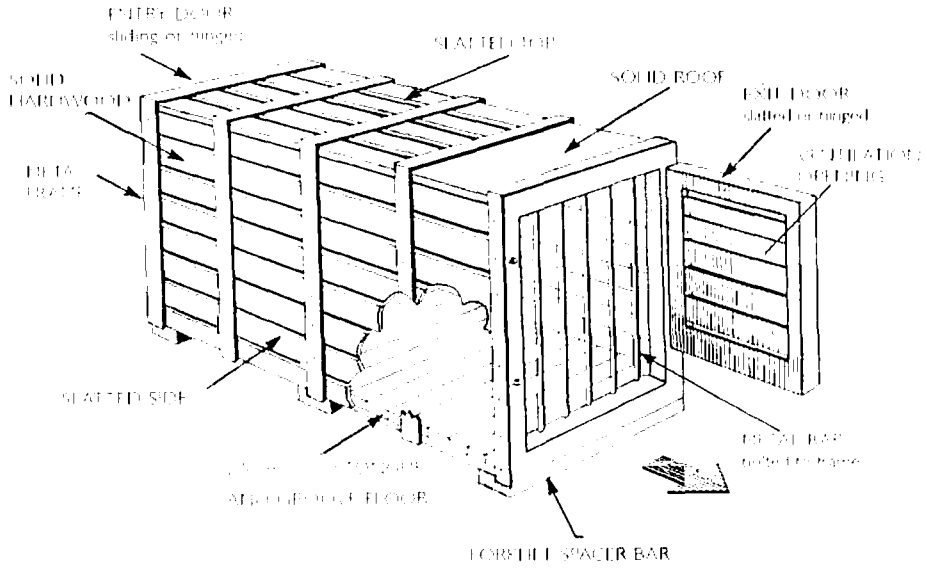


Figure 4. Rhino crate design specifications (modified from IATA, 1995)

Materials

- metal
- hardwood

Principles of Design

- Strong metal frame lined with solid hardwood sides. Vertical metal bars should be bolted in place at entry and exit with sliding or hinged wooden doors to the exterior of the bars. The upper third of the wooden doors must have ventilation spaces or openings. IATA specifies that the roof must be solid over the animal's head and slatted over the loin and hindquarters for ventilation. For ground transportation, however, removable panels or hinged doors over the animal's head can be useful in administering to medical needs and monitoring the animal. Hatches also allow for more ventilation when an animal is standing calmly.

- The interior must be smooth with no projections.

- Entry and exit doors must be closed and bolted in strategic places to be strong enough to resist the animal.

- The floor must be at least 2.5 cm (1 in.) thick tongue-and-groove or its equivalent and be provided with a non-slip surface.

- The container must be constructed in such a way that the floor and lower sides are leak proof. [a]

- In view of the diversity in size, strength and temperament of rhinos, the size and strength of the container must be sufficient to restrict the movement of and restrain the animal. Dimensions must be large enough to prevent cramping without allowing unnecessary movement. In general, the crate should be 0.3 m (1 ft) longer and wider than the animal when it is lying on its side.

- Only nuts and bolts should be used in the container.

- At the front of the container, there must be provisions for water and food access at the base of the door and between the bars, if present. This access point must be clearly marked FEEDING and be adequately secured when not in use. [a]

- A water container must be provided and must be sufficiently large for the entry of the animal's muzzle.

- Entrance and exit must be clearly indicated. [a]

[a] for airline transport only

The above recommendations are modified from IATA standards to include specifications for ground transport. Before shipping by air, consult the current IATA specifications and/or the airline.

Acclimation Training

Crate acclimation can require 2 to 6 weeks, although several zoos have crate-trained rhinos in 7 days or less. Training should be completed by a method of approximation (with reinforcement given as rhinos approximate desired behaviors). The first step is to introduce the crate as a non-interactive part of the animal's environment. Gradually, the food is moved toward and finally into the crate. If the animal acclimates to the point of completely entering the crate and will allow the door to be shut, the door should be left closed for short acclimation periods under close observation. If the rhino does not completely acclimate to entering the crate, partial immobilization (standing restraint) may need to be utilized for shipping.

In situations in which crate training is not possible, immobilization should be incorporated. Forced crating without training or immobilization is strongly discouraged.

Crating with Chemical Immobilization

Immobilization offers a fairly simple way of crating a rhino. First, it should be noted that the usual pre-immobilization procedures (e.g., fasting, detainment in an adequate holding area, etc.) should be observed for any procedure requiring the use of chemical immobilization/tranquilization agents. For rhinos, entorphine (M-99) remains the drug of choice, although several alternatives are available. For specific drugs and dosages, refer to the Health chapter of this publication. The duration of immobilization without the administration of an antagonist may range from 30 min to 2 hr.

Following crating, all rhinos should be held for 24 hr at the loading location for observation or accompanied by a veterinarian during transport. This step is necessary because renarcotization is common in hoofed animals, especially rhinos, given opioids. This step, however, may not be necessary if the butorphanol+detomidine anesthetic protocol is used (Morris, pers. comm.). Trained personnel should be present to administer the correct reversal agent(s) in the likely event of a renarcotization. Any other complications of crating can be managed more easily and effectively in-house rather than en route.

Transport

Numerous options for transporting rhinos are available. Each method has its advantages, and each should be scrutinized by evaluating the distance to be traveled, the personnel needed and the temperatures to which the animals will be subjected. A flat-bed truck and open trailer is temperature-restrictive. Note that a crate within an open trailer should be protected from excessive wind, rain and sun. Enclosed trucks or trailers are other options that are necessary in extreme hot or cold temperatures. In any case, the transport vehicles must be climate controlled. Air transport, rather than ship transport, is the preferred option for any transoceanic translocation. Transport by ship is undesirable because of the excessive time at sea, variable conditions and more intensive personnel requirements. When transporting by air, it should be noted that some airlines may require the rhino crate to be placed in an aluminum air cargo box, which can restrict ventilation and subject the rhino to excessive heat buildup during both the airplane-loading process and transport.

Crating is the recommended transport method for rhinos. Crate acclimation can require 2 to 6 weeks, although several zoos have crate-trained rhinos in 7 days or less. (*Photo: S. Murray, Fort Worth Zoological Park*)

During all rhino shipments, the shipper must be aware that any animal that has been immobilized (and to a lesser extent, some that have not) will be less capable of thermal homeostasis than a normal animal. If the shipper cannot provide adequate climatic conditions for the animals under these circumstances, he or she should be held solely responsible for any injury or death resulting from shipment. If during the course of a transport procedure a situation arises in which the safety of the animal may be jeopardized, a decision should be made through the appropriate channels to postpone or cancel the shipment. Leaving the decision of whether to transport an animal to the transporter or the recipient may be disadvantageous to the animal's welfare. In many cases, the shipper is ignorant of pertinent medical facts and practical husbandry information, and recipients are at a disadvantage because they are often not present.

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In designing facilities to maximize rhino health and reproductive success, it is important that the captive environment resemble the natural environment as closely as possible. (For more detailed information on the natural habitats of the various rhino species, see the Taxonomy and Conservation Status chapter.) The species to be exhibited will dictate the design of rhino facilities, as species differ in their group compositions and enclosure requirements. Additionally, whether an institution wishes to maintain exhibit-only or breeding individuals will act as a determining factor in the design of rhino enclosures. Whenever possible, institutions are encouraged to plan for breeding capabilities, but the various SSP Coordinators and Rhino TAG chairs recognize the educational need for display-only exhibits. These exhibits serve the rhino conservation effort by holding non-reproductive and single-sex specimens. The following section outlines design considerations for indoor and outdoor rhino facilities, as well as aspects of chute design for rhino restraint.

Enclosures

The design of captive enclosures for rhinos requires an understanding of rhino biology, behavior and social organization. As previously stated, black, white and greater one-horned rhinos vary in their levels of sociality and thus have different housing requirements. Tables 15 and 16 list the recommended animal numbers for institutions holding rhinos (See also the Management and Behavior chapter.) and the enclosure types recommended depending on institutional goals. It is important to note that for the most part, exhibit and holding-space availability will dictate an institution's designation as either a breeding or an exhibit facility. Design elements for a breeding facility should include an outdoor primary enclosure (with separation capabilities), indoor holding and an isolation area. Additionally, breeding institutions must have space for any offspring to be held for up to 3 years of age. Exhibit-only facilities should have an outdoor primary enclosure and indoor holding areas (both with separation capabilities). It will be recommended that exhibit-only facilities receive pre- or post-reproductive-age or single-sex groups of surplus animals.

In general, it is recommended that enclosures be designed such that animals may be kept outdoors as much as is possible within the following temperature constraints. Rhinos should not be locked outside when the temperature is below 4.4° C (40° F); sun, wind chill and rain should be considered in calculating temperature. During extremely cold weather, rhinos should not have access to pools or mud wallows; pools should be drained and mud wallows filled with substrate. Animals should not be let out if enclosures are icy. Temporary exposure to temperatures below 4.4° C (40° F) for cleaning is left to the discretion of management. Localities that experience average daily temperatures below 10° C (50° F) (average of high and low temperatures over a 24-hr period), should provide heated facilities capable of maintaining a minimum temperature of 13° C (55° F).

TABLE 15. Recommended numbers for institutional holding

Rhino species	Recommended minimum groupings for breeding[a]	Preferred optimal holding for a breeding institution	Exhibit only (per institution)
Black	1.1	2.2 (2 pairs)	1.1 or 0.2
White	1.2	2.4 (1 herd/ 1 back-up male)	1.1 or 0.2[b]
Greater one-horned	1.1[c]	2.2 (2 pairs)	1.1[c] or 0.2

[a] Breeding institutions must have space for offspring to be held for up to 3 years following birth.

[b] Multi-male bachelor groups have been maintained in very large enclosures.

[c] In the case of greater one-horned rhinos, males and females should be introduced only during the female's estrus period. Institutions with very large enclosures (e.g., San Diego Wild Animal Park) may be able to hold opposite-sex animals together consistently.

The design of rhino enclosures depends on the species, the type of rhino program (exhibit-only or breeding) and the number of animals. In all cases, the larger and more varied the enclosure, the better. (*Photo: Oklahoma City Zoological Park*)

OUTDOOR HOUSING

Several general outdoor enclosure designs are recommended that incorporate the data available on the behavior and ecology of wild black, white and greater one-horned rhinos. As previously described, rhinos of all species are considered to be less solitary than was originally thought. Given very large yards or ranch situations, even opposite-sex greater one-horned rhinos (considered the least social of the commonly held rhino species) may be housed together. For the most part, however, rhinos are considered somewhat territorial; therefore, more than one outdoor yard is strongly recommended. To provide a large area for introductions of black and greater one-horned rhinos, a communal yard adjacent to individual yards should be available. If the space is not available, two adjacent yards may be opened for male/female introductions. In many respects, the critical enclosure characteristic is the availability of escape routes and visual barriers, which serve to hide or prevent access to a pursued animal. Gates may be used as escape routes, provided that care is taken to prevent dead-end corners and create run-arounds so that an animal can enter or leave the yard without an aggressor blocking or guarding the only exit.

Enclosure size depends on whether rhinos are kept for exhibit-only or breeding purposes (Table 16). It should be noted that a calf is considered an adult with respect to minimum space requirements after weaning; this fact should be considered in determining minimum enclosure size. Institutions should expect to hold offspring until they reach 3 years of age.

Primary Barriers

The barrier between rhinos and the viewing public is a critical element in the design of the outdoor exhibit. This primary barrier should allow visitors a clear view of the animals from a safe location. Many types of primary barriers are available, the most common of which are walls, fencing, dry moats and water moats. One consideration in choosing fence type should be the size of the enclosure. For example, smaller exhibits should be constructed with barriers that provide as much visual exposure as possible.

Fencing

Because any of the rhino species may climb, a primary barrier should be a minimum of 1.5 m (5 ft) high and non-climbable. Within small enclosures, particular attention should be given to the climbing ability of rhinos and to the need for separating aggressive animals. A secondary barrier or a taller primary barrier may serve to counter these problems.

Recommended materials for primary fencing include solid concrete or rock walls, horizontal pipe or cable spaced 25 to 30 cm (10 to 12 in.) apart and vertical pipe or posts spaced 25 to 30 cm (10 to 12 in.) apart. Note that cable should be used only for horizontal fences. The size of the exhibit to be fenced will determine the strength and type of fencing material used, as each type has both advantages and disadvantages. Concrete surfaces and bare steel cable create surfaces that may encourage rhinos to horn-rub excessively, causing abnormal horn wear. Whenever necessary, surfaces should be covered with a non-abrasive material. Inserting the cable through plastic pipe or hose can prevent this problem, and concrete surfaces can be covered with non-toxic wood.

TABLE 16. Recommended enclosure types and sizes for captive rhinos by species [in sq m and (sq ft)]

	Individual Holding (per rhino)		Exhibit Only (per rhino)		Breeding/Communal	
	Indoor	Outdoor	Indoor (as primary exhibit area)	Outdoor	Indoor	Outdoor
Black	18 (200)	186 (2,000)	204 (2,200)	771 (8,300)	not recommended	2,322 (25,000)
White	30 (320)	186 (2,000)	215 (2,320)	929 (10,000)	not recommended	2,787 (30,000)
Greater one-horned	30 (320)	186 (2,000)	215 (2,320)	929 (10,000)	not recommended	2,787 (30,000)

1 (*Photo: Knoxville Zoological Gardens*)

If poles are used, each should be approximately 30 cm (12 in.) in diameter and set in concrete with approximately 1.8 m (6 ft) underground. Poles should be spaced as closely together as possible to prevent rhinos from getting their horns through and uprooting the fence. *Creosote-treated poles, which are dangerous to rhinos, should not be used.*

It is important to consider fence spacing and keeper access/exit in the event of an emergency. Rocks or a rock apron can be utilized to protect the poles or other objects in the exhibit from damage. A rock apron should extend 1.8 m (6 ft) from the leading edge of the object to offer adequate protection. If small rocks are used, they should be several layers thick; otherwise, a single layer of very large rocks is probably adequate.

Dry Moat

The use of a dry moat requires one vertical wall, which should be a minimum of 1.5 m (5 ft) high, located on the public side. The second wall should be sloped at a maximum of 30° so that the animals can climb out. This gradual decline of the exhibit substrate down to a solid wall can be used to create a moat effect, but *ditch moats with two vertical walls are considered dangerous to rhinos and are not recommended.* The floor space in the moat should be a minimum of 1.5 m (5 ft) across to prevent rhinos from being trapped, and surface substrate for the moat should provide stable footing. (Recommended materials include dirt, gravel, sand, etc.)

Water Moat

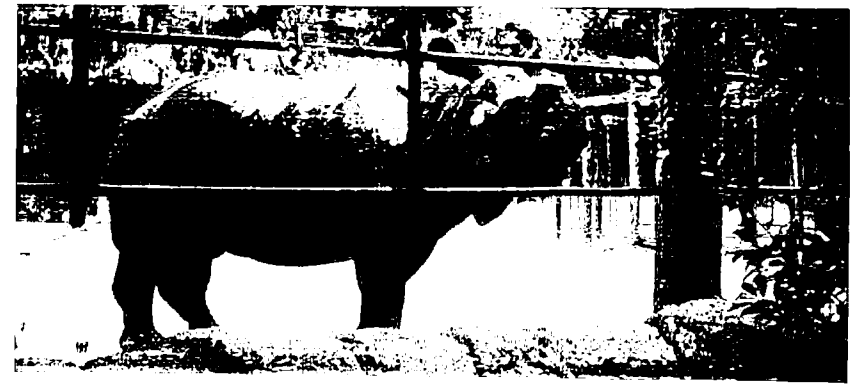
Water can be utilized as a primary barrier, although it carries the risk of drowning or injury, especially for calves. Dimensions and specifications for a water moat should be the same as those listed above for a dry moat. Pools may also serve as primary barriers, provided the walls are high enough [at least 1.5 m (5 ft) high] to prevent animals from climbing out. Once a rhino has its chin over the top of a wall, it can get its front feet over as well.

Secondary Barriers

Though not critical to the design of outdoor enclosures, secondary barriers may protect exhibit features or lessen stress on primary barriers. Recommended types are butt rails, vertical poles and electrically charged, or "hot," wire. Plantings can also serve as a secondary barrier when used to create a visual screen. For example, the use of plantings that extend above a low wall can give the appearance of a bigger wall [though the primary barrier height minimum of 1.5 m (5 ft) still applies]. Electric fencing can be used to deter animals from destroying plantings, trees and other secondary barriers. Rock aprons may also be used around trees and fence lines as secondary barriers.

Gates

Enclosure gates can be the weakest points of the exhibit; therefore, adequate hinge and lock strengths are very important. Interior doors are usually constructed of heavy-gauge galvanized steel or pipe that is hinged or sliding. Sliding gates are optimal, as they may be partially opened, and should be a minimum of 1.8 m (6 ft) wide and 2 m (6 ft 8 in.) high. If the gate uses a track, care should be taken in the construction of the track to avoid injuring the feet of the animals as they run through gates during introductions. Exterior building doors



2 (*Photo: Fort Worth Zoological Park*)

3 (*Photo: Fossil Rim Wildlife Center*)

4 (*Photo: Fort Worth Zoological Park*)

Primary fence options for rhinos vary. Depending on the type of exhibit, one type may be more suited than another. Walls (1) may be effective in exhibits that are viewed from above. Cables (2) are particularly effective for exhibits in which the visitor is on equal footing with the rhino. Another option in this case is a more typical fence structure (3). Water moats (4) can be effective also, though a secondary barrier is recommended and care should be taken when calves are in the exhibit.

are usually made from wood reinforced with steel, with the lower part covered by a steel plate to minimize damage. Gates should be constructed to allow keepers to open and close them without entering rhino space. Also, where appropriate, vehicle access to an enclosure should be provided.

Substrate

The outdoor enclosure should have a well-drained surface that provides adequate footing for rhinos. Greater one-horned rhinos require substrates that "give," including mulch (such as hardwood), grass (Irrigation should be planned for all natural areas if needed.) and bedding because of the incidence of foot problems. Black rhinos should be maintained on grass if the space is available, but limestone is adequate. Substrate options for white rhinos include grass, limestone, sand and other natural materials in combination. For example, one institution reported an outdoor enclosure substrate composition of 75% grass and 25% sand, rocky areas and decomposed granite. Rhinos should be carefully observed upon introduction to a new substrate, as excessive ingestion of the substrate from feeding on the ground has caused impaction in other rear-gut digesters.

Water

Fresh, potable water should be available at all times. Water should be changed daily or supplied by an automatic-fill or continuous-flow device. Regular cleaning and disinfecting should occur at a rate that inhibits the growth of algae and bacteria. Water devices should be substantially constructed to prevent injury, upset, spillage or leakage.

Mud Wallows

All rhinos need access to pools and/or mud wallows for skin health, temperature regulation and behavioral enrichment. The size of mud wallows should be gauged by the number of animals in the exhibit to allow ample room for each individual. It should be noted that given a start, rhinos may construct their own mud wallows. Mud wallows should be renovated periodically to prevent contamination.

Pools

Pools constructed in rhino enclosures should be of approximately equal dimensions (length x width). When a calf is in the enclosure, pools should be modified or drained to a depth of 0.45 m (1.5 ft) or less. For entry into the pool, ramps are preferable to steps. They should be placed in at least two or three locations around a pool, if not the entire perimeter, to ensure safe access in and out of the pool. Ramp slopes should be no greater than 15 to 20°. If steps are used rather than ramps, they should have a 20- to 25-cm (8- to 10-in.) rise with a 41- to 61-cm (16- to 24-in.) step. Note that multiple entries to a pool prevent it from being a "dead end" in the enclosure. In the design of slopes or steps, keeper access for cleaning should be considered. The pool substrate should be broom-swept concrete. Table 17 lists pool specifications by species.

Visual Barriers

When rhinos are maintained together in a more herd-like situation, naturalistic visual and physical barriers (refuges) in an outdoor enclosure may help decrease aggression by permit-

1 (Photo: San Diego Zoological Society)

TABLE 17. Specifications for exhibit pools by species

	Overall Size	Depth	Comments
Black	13.9 sq m (150 sq ft)	0.3 to 0.9 m (1 to 3 ft)	Optional; rarely used except in warmer regions
White	37.2 sq m (400 sq ft)	0.4 to 1.5 m (1.5 to 5 ft)	Recommended
Greater one-horned	37.2 sq m (400 sq ft)	at least 0.9 m (3 ft); optimally 1.5 m (5 ft)	Recommended

ting animals to separate themselves from others if necessary during introductions or in a group situation. Barriers should be large and high enough to provide "safe zones" that allow an animal to pass from another's sight but should not hinder public viewing. Types of visual barriers include deadfall, logs and run-arounds (boulders), as well as trees and natural plantings. Trees and plantings may be protected from rhinos by pipe caging, rock aprons or barrier fencing. If permanent physical structures are not available as barriers, dirt mounds may be used to give individuals additional visual barrier points in the enclosure.

Shade/Rain Shelter

Access to shade is a necessity as well as a USDA requirement under the Animal Welfare Act. A variety of both natural and constructed options is possible. It is recommended that rhinos have access to a shaded area during daylight hours. It is also important that a shade option be adequate as a rain shelter if barn shelter is not always accessible; therefore, trees may not be completely adequate. Because some species use pools heavily, pools should be located in areas that are shaded at least part of the day.

Additional Furnishings

Additional furnishings for the outdoor exhibit should include scratching posts, which may be particularly effective if placed near mud wallows or pools. Post material must be non-toxic to rhinos (i.e., non-creosote). Several institutions have buried deadfall or logs upright in concrete sewer culverts, which are routed in place with 0.9 to 1.2 m (3 or 4 ft) of gravel. This enables managers to remove and replace posts as they rot. In addition, feed should be available at all times in the form of browse feed stations and mineral salt licks.

INDOOR HOUSING

Indoor housing is recommended for additional separation capabilities (beyond the primary enclosure) and is critical for those institutions in colder latitudes. At no time should rhinos be subjected to temperatures below freezing; animals should have access to radiant heat if needed. An indoor facility in the winter should be heated to a minimum of 13° C (55° F) with the capability of maintaining some areas of the barn at 23.9° C (75° F).

The humidity level should be maintained at 40 to 70%. Supplemental heat may be needed when dealing with infants or with sick or older animals. Note that some acclimation may be necessary before moving animals from a warm barn to the outdoors during winter months. Indoor facilities should be maintained with a negative air pressure, and ventilation should be provided to accomodate at least four air exchanges per hour (USDA recommendations for a cold-weather heated barn). Institutions are encouraged to check with their local authorities for air-exchange requirements when the public or personnel occupy the facility. Shower sprays or water baths should be offered in areas of relatively low humidity. Within any indoor facility, areas must be provided for food and water.

Fresh water should be available at all times and should be changed daily or be supplied from an automatic-fill or continuous-flow device. Regular cleaning and disinfecting should occur at a rate that inhibits the growth of algae and bacteria. Water devices should be constructed

2 Rhinos of all species need access to mud wallows (1) and/or pools (2) for skin health, temperature regulation and behavioral enrichment. The size of mud wallows should be guaged by the number of animals in the exhibit. Recommended sizes for rhino pools are listed in Table 17. (*Photo: San Diego Zoological Society*)

Visual barriers such as this "run-around" may help decrease aggression among rhinos by permitting animals to separate themselves from others if necessary. Barriers should be large enough to provide "safe zones" for the animals but not hinder public viewing. (*Photo: Oklahoma City Zoological Park*)

to prevent upset, spillage or leakage.

For black and greater one-horned rhinos, isolated stalls are essential; for white, they should be available when needed but may not be necessary. The indoor enclosure should include a minimum of 30 sq m (320 sq ft) per animal for white and greater one-horned rhinos and 18 sq m (200 sq ft) per animal for black rhinos (AZA Mammal standards) (Table 16). An additional 50% of adult space should be provided when a calf is present. This may be achieved by using more than one stall. Following weaning, a calf should be treated as an adult individual with respect to space requirements.

If the institution has only indoor facilities in which to maintain and/or exhibit rhinos, the minimum requirement is 186 sq m (2,000 sq ft) per rhino [15.2 x 12.2 m (50 x 40 ft)] plus the recommended indoor holding [30 sq m (320 sq ft) per individual for white and greater one-horned rhinos and 18 sq m (200 sq ft) per individual for black rhinos].

Separation Capabilities

The indoor facility should have the capacity to separate individuals for a variety of purposes. For white rhinos, although females may be housed together in a community barn following the guidelines of 30 sq m (320 sq ft) per animal, males should always be stalled individually. As indicated above, black and greater one-horned rhinos should be kept in individual stalls. The facility should also have an extra space or large stall to isolate mothers and calves or quarantine sick animals.

Currently, no quantitative data are available on the visual, olfactory or auditory capabilities of rhinos in relation to breeding success. Based on species ecology and behavior, however, it is believed that rhinos rely heavily on both olfactory and auditory senses for social communication. It is therefore recommended that indoor facilities allow these types of communication at certain times among individuals. Options include partial walls or pipe fencing to allow for physical separation without visual, auditory or olfactory separation.

Substrate and Bedding

A brushed or broom-finished concrete floor that is well-drained and insures adequate footing is recommended. Dirt flooring as the main substrate is not recommended. In addition, floor heat is recommended in colder climates. Bedding materials such as hay, wood shavings and hoofed-stock rubber matting are recommended for greater one-horned rhinos and optional for black and white rhinos. Other situations in which bedding is required include barns with rough substrates (which may cause skin ulcerations) or for additional warmth for sick animals or young calves. When introducing rhinos to new substrates, careful observations should be made to avoid the animals' excessive ingestion of the novel substrate, which could potentially lead to health problems such as impaction. The use of a power washing machine is recommended to disinfect barn areas. Additionally, rubber matting and bedding materials should be disinfected or changed regularly to prevent contamination.

Lighting and Special Features

Normal light cycles seem to be adequate for rhinos. However, if an animal is to be held

indoors for more than 12 hr (e.g., winter in cold-climate institutions), facilities should provide artificial or natural light sources to simulate natural cycles. Fluorescent lighting is an efficient light source that provides broad-spectrum illumination; however, skylights should be included whenever possible. Additionally, because greater one-horned rhinos are introduced for breeding purposes for a limited amount of time and closely observed, lighting is also necessary in outdoor enclosures for the observation of breeding at night.

Any new exhibit should include the capability for video systems. In addition, a scale for weighing animals is desirable and strongly recommended, though not required. Vehicle access to an indoor facility is also recommended. A restraint device or an area for restraint should be included in the design of every facility.

PHYSICAL RESTRAINT DESIGNS

Numerous institutions have constructed permanent physical devices to restrain their rhinos when necessary. Such "chutes" can be very valuable for physical exams as well as nutritional, reproductive or veterinary research projects. In addition to the following general information, please consult the Health chapter of this publication as well as Schaffer (1993) and Eyres, et al. (1995). Also, U.S. institutions that currently have chutes and may be able to provide additonal information include Henry Vilas, St. Louis, Sedgwick County, Oklahoma City, Henry Doorly, Cincinnati, Caldwell and Milwaukee County zoos and Fossil Rim Wildlife Center. Companies that may assist in chute design and construction include Animar Systems, Inc. (Springfield, MO; 417-889-4245) and Cummings and Son, Inc. (Garden City, KS; 316-277-2293). In general, it is highly recommended that institutions modifying rhino exhibits or constructing new ones incorporate a physical restraint area or device into their design considerations.

Several physical restraint designs are effective for rhinos. These range from a small restricted area in which to contain the animal to an area that contains one or more hydraulics that will "squeeze" together to restrict an animal's movement. In general, major restraint chute design considerations include strength, durability, type and function. It should be noted, however, that available space and animal size and disposition vary across institutions and should be individually addressed.

In general, both captive managers and researchers emphasize that the general restraint area should be an active component of daily rhino management. Methods to accomplish this vary. A restraint chute or restraint area can be designed so that the rhinos must pass through it to exit the barn into their yard. If rhinos are fed indoors, part of the feed (e.g., produce, grain) can be offered in the chute area. Finally, more extensive conditioning (See Rhino Training in the Management and Behavior chapter.) can be particulary effective in habituating rhinos to physical restraint. Such a program should be attempted prior to detaining a rhino in a chute for an exam.

Rhino chutes should be manufactured out of steel or a combination of steel and steel-rein-

forced wood. Some institutions have also used steel-strength aluminum (6061-T52 aluminum). Aluminum of this type is lighter and more maneuverable than steel, as well as potentially less stressful to rhinos because of "deader" sound properties than steel (i.e., when metal scrapes metal).

Permanent pass-through indoor restraint chutes (similar to those constructed for elephants) are especially effective for rhinos. With training, this type of chute may allow for daily rhino observations. Furthermore, inclement weather will not affect the use of an indoor restraint chute. The chute should allow restraint of the animal when it is passing through in either direction so that the shifting routine of the animal is not interrupted (Schaffer, 1993). The width of the chute should limit side-to-side movement while still allowing the animal to comfortably lie down. However, animals can become wedged in tight-fitting chutes if the sides cannot be released. To alleviate excessive forward movement of the animal when it lowers its head, two vertical bars that push in from the sides of the chute to the shoulders of the rhino may be utilized. Quick release of these shoulder bars often relieves agitated animals without having to release them completely.

High-walled chutes or bars over the top keep the animal from climbing or rearing up. Horizontal bars in the chute's entry gates and sides are hazardous for examiners when the animal lies down. Vertical bars on the sides can trap researchers' arms if the animal can move forward. If the animal's forward and side-to-side mobility can be limited, vertical bars or walls on all sides are recommended. The distance between these bars along the sides of the chute should be great enough to prevent the animal's foot from becoming wedged if the animal rolls on its side in the chute. For researcher safety, this distance can be divided with removable vertical bars.

Rhinos may slam swinging doors; thus, sliding or guillotine gates are safer. A rectangular opening in these gates for performing a palpation should not pin the arm of an examiner when the animal is shifting. The distance between the vertical sides of this rectangular opening must be wide enough for researcher safety while still limiting the space through which a rhino could squeeze. Also, the horizontal bottom bar of this rectangle should be only a few inches from the ground, as animals frequently lie down. Solid doors on the outside of these gates can be used to stop rhinos, as they may attempt to charge even small openings. Additionally, good lighting and accessible electrical sources are useful.

A closed chute (Figure 5) is another option that has been used successfully for the treatment of a rhino with a urinary-tract infection and another with infected lesions on its foot (Eyers et al., 1995). As noted in Figure 5, a typical closed chute has both front and back gates. The back gate restricts the rhino's movement by sliding forward. Additionally, the hind end of the rhino is supported by a v-design that prevents it from lying down. This design also allows additional safety for the staff while working with the animal. In many respects, a closed chute does not depend as strongly on conditioning of the rhinos as does a squeeze chute, though acclimation is recommended prior to attempting any treatments within the chute. The design of a closed chute might necessitate an outdoor location in most cases; therefore, the use of this type of chute may be limited by weather.

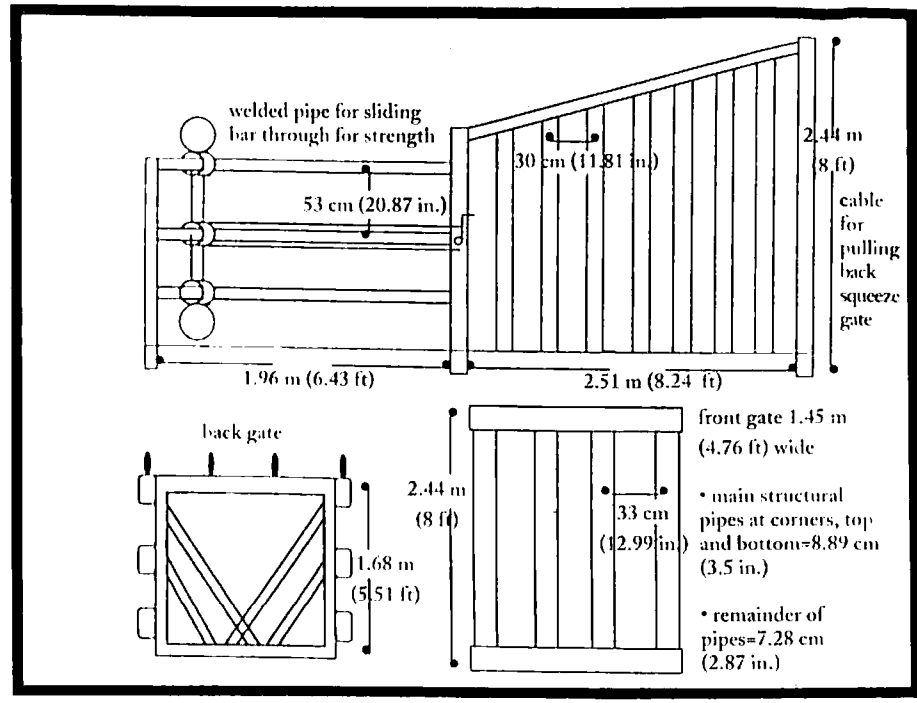


Figure 5. Closed stall rhino restraint chute. Note that a typical closed chute has gates that restrict the rhino's movement and prevent it from lying down. The advantage of a closed chute is that it does not depend as strongly on conditioning as does a squeeze or free stall chute. (*Eyers et al., 1995*)

A free-stall chute can be used for animals more sensitive to a confined enclosure (Figure 6). The design of this type of chute allows the rhino to enter or exit at its will and thus may help to keep rhinos calmer during procedures. Because there is free access, however, rhinos must be conditioned to target or stand still; thus, relatively non-invasive procedures also work best. Procedures that have been accomplished with a conditioned rhino in a free stall include ultrasound and serial collection of blood and feces (Eyres et al., 1995).

A free-stall design can easily be incorporated into an existing pen or stall, indoor or out. As stated, the open back of this type of chute allows the animal to enter and leave the structure at will. Protection of staff when working with the rhino is important, however, and a partial back wall constructed of vertical pipes allows staff to step out of the way (Figure 6).

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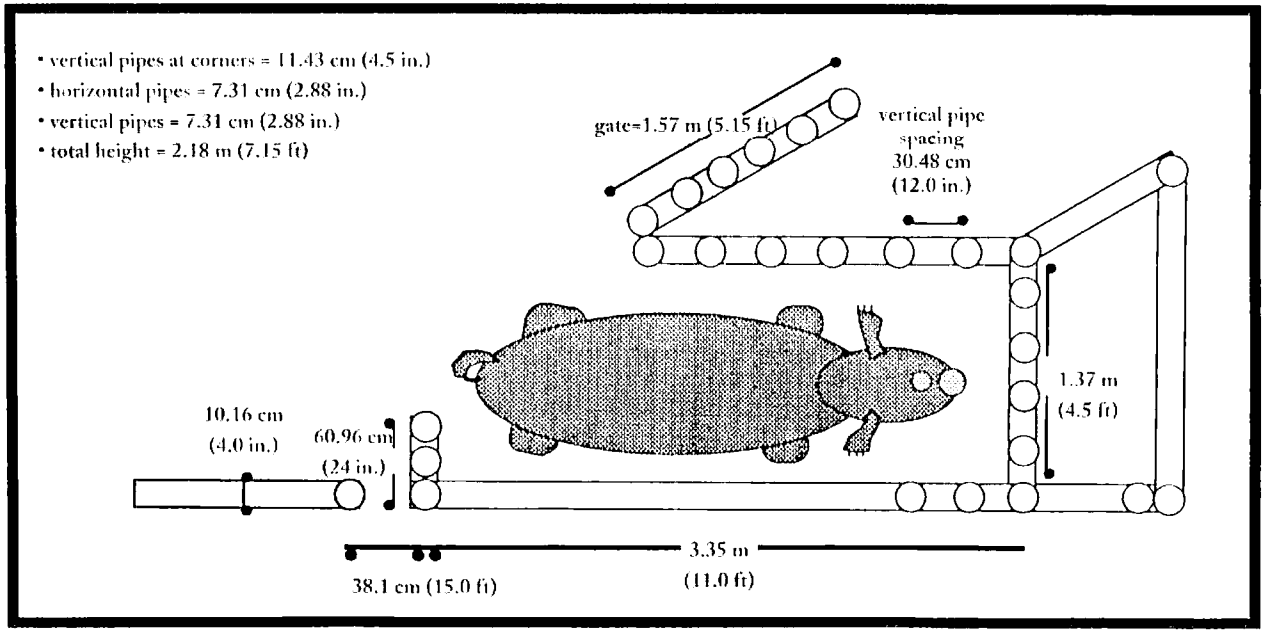

Figure 6. Free-stall rhino restraint chute. The design of a free-stall chute allows the rhino to enter or exit at will and can be used for animals more sensitive to a confined enclosure. This type of restraint chute, however, is best used for relatively non-invasive procedures and with rhinos that have been conditioned to target or stand still. (*Eyres et al., 1995*)

HEALTH

Eric Miller, DVM

This section gives a general outline for the diseases of all rhinoceros species but will often discuss at length those of the black rhinoceros (Diceros bicornis). The reason is twofold: 1) the frequent occurrence of disease has been a major limiting factor in the captive black rhino population, and 2) disease problems have been reported with considerably lower frequency in white (Ceratotherium simum) and greater one-horned (Rhinoceros unicornis) rhinos. Because of the limited number of captive animals, at the present time it is difficult to make general statements regarding disease in Sumatran rhinos (Dicerorhinus sumatrensis).

Much of this chapter provides only a brief overview; references regarding general medicine (Sullivan & Tait, 1979; Jacobs & Klos, 1979; Jones, 1979; Kock & Garnier, 1991; Miller, 1994), capture techniques (Kock & Morkel, 1993; Rogers, 1993), infectious diseases (Ramsay & Zainuddin, 1993) and a bibliography that reviews the veterinary literature pertaining to rhinos (Miller, 1992) are available.

Physiological Normals

Heart and respiratory rates are variably listed as ranging from 12 to 16 and 64 to 67, respectively (Wallach & Boever, 1983). Electrocardiogram studies have been reported from black rhinos (Jayasinghe & Silva, 1972). Rectal temperature ranges from 37 to 39° C (98.6 to 102.2 F). When dosing rhinos, it is important to know the general size and weight of individuals. When weighed on a truck scale, adult black rhinos at the St. Louis Zoo have ranged in weight from 900 to 1,100 kg (1,984 to 2,426 lb). The white rhinoceros is often considered the second largest land mammal, with adult weight ranging from 1,500 to 2,500 kg (3,308 to 5,512 lb). Others report that greater one horned rhinos range from 1,700 kg (3,748 lb) for females to 2,100 kg (4,630 lb) for males (Wallach & Boever, 1983). The Sumatran rhinoceros is the smallest species of rhinoceros, with large adults weighing approximately 1,000 kg (2,205 lb).

Normal values for blood counts and chemistries are available from captive rhinos in the International Species Information System (1989), in several articles and texts (Hawkey, 1975; Seal et al., 1976; Wallach & Boever, 1983; Pospisil et al., 1986) and from free-ranging black (Kock et al., 1990) and white (Van Heerden et al., 1985) rhinos. Most values do not differ markedly from those of domestic horses.

Hematology

Blood collection from rhinos can take place from several sites. Perhaps most commonly used is the ear vein, which is sufficient for collecting small quantities of blood or for IV injections. A larger medial (radial) vein has been identified in black and several other rhinoceros species and allows collection of larger amounts (1 to 8 liters) of blood (Miller et al., 1989). Whenever rhinos are anesthetized for any reason, blood is requested for a wide variety of research projects, which are outlined in a Rhinoceros Blood and Tissue Collection Protocol.

The ear vein is the most common site for blood collection in rhinos. Larger amounts of blood may be collected from a larger medial (radial) vein. (*Photo: S. Murray, Fort Worth Zoological Park*)

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Due to the predilection to hemolysis of the black rhinoceros, Dr. Donald Paglia of the University of California at Los Angeles has suggested avoiding exposing them to drugs and compounds that are known to induce hemolysis in enzyme-deficient human populations. Included in this list are 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 and other pesticides, and strong cleansers, particularly those containing naphthalene) (Paglia & Miller, 1992). Many other drugs have been associated with hemolysis in these patients but with an uncertain or doubtful role. These drugs include aspirin, phenacetin, aminopyrine, acetaminophen, probenecid, vitamin C, dimercaprol, p-aminosalicylic acid and L-DOPA. Any exposure to creosote should also be avoided. Additionally, in view of the hemolysis induced in horses by the consumption of certain oak and red maple leaves, as well as wild onions and members of the Brassica (kale) family in other domestic species, consumption of these species should be avoided. Until more information is known, it is prudent to implement the above recommendations for all rhino species.

Innoculations

There are numerous reports of leptospirosis in black rhinos (Asakura et al., 1960; Douglass et al., 1980; Mikulica, 1986; Miller & Bolin, 1988; Paras, 1989; Jessup et al., 1992). The only vaccination routinely recommended is the biannual administration of black rhinos with either a 5-way leptospiral bacterin (containing *Leptospirosis interrogans serovar icterohemorrhagiae, grippotyphosa, pomona, canicola, hardjo* - available as Leptoferm-5), or a 6-way bacterin containing serovar *bratislava*, available as Brativac. (Both are manufactured by Norden Laboratories, Lincoln, NE 68521.) However, it should be noted that injection site abscesses are relatively common (5 to 10%) and two cases of apparently marked post-vaccinal reactions have been noted (weakness in both cases, a skin slough in one). Additionally, an abortion of a greater one-horned rhinoceros calf was associated with infection with *Leptospirosis interrogans* (confirmed by fluorescent antibody testing) (Cook, 1994).

Although there are only two reports of clostridial disease (one case of tetanus and one of *Clostridium sordelli*) (Mitra, 1983) and in endemic areas, vaccination for these diseases may be considered. One case of rabies has been reported in a greater one-horned rhinoceros (Mukherjee et al., 1984). During the epidemic of raccoon rabies, zoological institutions on the East Coast of the United States vaccinated for rabies with Imrab (Rhone Merieux, Athens, Georgia).

Neonatal Examinations

Whenever possible, neonatal examinations should be performed. These should include weight, a dipstick blood glucose, total solids, CBC, sera chemistry profile, sera/plasma for vitamin-E levels, and, when possible, stored sera. Examinations may include vitamin supplementation and the placement of an identification transponder.

Parasites

Parasites have been of low frequency and are usually not associated with clinical signs in captive rhinos. In newly captured rhinos, consideration should be given to hemic and skin parasites as well as fecal ones.

A biannual fecal examination for parasites is adequate in rhinos established in captivity. In

newly arrived rhinos, blood examination should be performed for hemic parasites (e.g., *Babesia* sp., trypanosomes, theileriasis and leishmaniasis). Treatment has been described by McCulloch and Achard (1969). Skin lesions in wild-caught black rhinos should be biopsied and examined for the presence of *Stephanofilaria dinniki* (Kock & Kock, 1990).

The most commonly found endoparasites have been tapeworms, which have not been associated with disease in the United States. In rhinos established in captive collections, other endo- and ectoparasites have been unusual. Stomach botfly larvae (*Gyrostigma* sp.) have been noted in recently captured white and black rhinos and usually cause minimal clinical signs.

If fecals are positive, treatment should be based on accepted horse parasiticides that possess a wide safety margin (e.g., bendazole derivatives, pyrantel pamoate). Ivermectin has been used with apparent safety in newly captured black rhinos in Zimbabwe. If hemic parasites are found, treatment should be based on those employed previously (McCulloch & Achard, 1969) and after consultation with those in the field. The presence of ticks (particularly *Amblyomma* sp.) in newly imported black rhinos has caused concern with regulatory authorities. Treatment of ectoparasites in newly arrived rhinos has consisted of the application of coumaphos.

DISEASES

Regarding illness, the behavioral repertoire of rhinos is often quite limited. Depression and inappetence are often the only signs of major disease problems. Following is a discussion of reported rhinoceros diseases and associated symptoms, a summary of which is provided in Table 18.

Tuberculosis

Infection with *Mycobacterium bovis and M. tuberculosis* have been reported in several rhinoceros species, and there is no reason to expect that it could not affect all of them (Griffith, 1928; Hamerton, 1942; Takagi et al., 1964; Mann et al., 1981; Dalvosio et al., 1992). It most often presents as a syndrome of chronic weight loss and wasting. No specific treatment or testing regimens for tuberculosis have been established. One report (Ramsay & Zainuddin, 1993) suggests the concomitant use of MOT, bovine PPD and avian old tuberculin initially in tail folds and collection of sera for ELISA testing. In another case, a black rhinoceros that had a positive tracheal culture for *Mycobacterium bovis* was also positive on intradermal testing using PPD bovis in the eyelid (Barbiers, 1994). If a suspicious reaction occurs, the tests should be repeated 2 weeks later in the neck. In suspicious reactions, additional tests should include biopsy of the reaction site and culture of the respiratory tract or gastric lavage samples.

Skin Conditions

Skin conditions have been noted in all rhino species. Parasitic skin ulcers have been noted in wild black rhinos (Kock & Kock, 1990), and a syndrome of oral and skin ulcers of unknown etiology has been frequently noted in captive black rhinos (Ott et al., 1982; Munson, 1992). Fractured or avulsed horns are a frequent entity (See common injuries below.), and their regrowth has been described (Bigalke, 1946; Jacobi, 1957). Treatment generally consists of topical antibiotics and nontoxic (e.g., pyrethrin) fly repellents, and the hemorrhage generally stops over a period of several hours. Abscesses at the coronary, possibly from plantar sur-

TABLE 18. Rhinoceros diseases and symptoms

Diseases Affecting Rhinos	
Disease	Reported Symptoms
Tuberculosis	Chronic weight loss and wasting
Skin conditions	Skin lesions
Gastrointestinal torsion and impaction	Symptoms similar to those of colic in the horse
Encephalomyocarditis infection	Acute death without clinical signs
Syndromes Apparently Specific to Black Rhinos	
Hemolytic anemia	Depression followed by hemoglobinuria
Oral and skin ulcers	Small, self-limiting lesions over points of wear that may progress to large, bullous lesions encompassing significant areas
Fungal pneumonia	May involve infection with *Aspergillus* sp. (often follows corticosteroid therapy); should be considered when an individual suffers from signs of respiratory illness
Encephalomalacia	Acute and profound stupor or hyperexcitability followed by depression (n=1); occurs in young females
Tissue accumulation of iron	Lesions similar to those of chronic iron exposure
Creosote toxicosis	Hepatic failure, which may include hemolytic anemia and skin ulcers in its terminal stages

face infections (e.g., "gravel" in horses), have been noted and have responded to the application of hot water and topical treatment (Ramsay & Zainuddin, 1993).

Gastrointestinal Torsion and Impaction

Gastrointestinal torsion and impaction have been reported in black, white, greater one-horned and Sumatran rhinos and present with signs similar to those of colic in the horse (Nouvel & Pasquier, 1946; Kloppel, 1956; DeVos, 1975; Haigh, 1975; Simmons & Jenke, 1977; Janssen, 1992; Lewandowski, 1987; Montali, 1992). Rectal prolapse has been described in three black rhino calves (Pearson et al., 1967; Ensley & Bush, 1976; Janssen, 1992). Gastric ulcers are commonly seen in ill rhinos, and the addition of carafate or other protective medications should be considered in any chronically ill individual. Salmonellosis has been seen in a greater one-horned rhinoceros (Windsor & Ashford, 1972; Williamson et al., 1973), and other bacterial enteritides have also been noted (Thomson & Priestly, 1949; Zainal-Zahari et al., 1990).

Encephalomyocarditis Infection

Death following infection with encephalomyocarditis virus has been noted in two black rhinos, and other rhinoceros species may be susceptible as well. Although it was feared that rhinos might be susceptible to Venezuelan equine encephalitis during an equine epidemic in the early 1970s, no cases have been identified. Vaccination for the equine encephalitides is not routinely practiced.

SYNDROMES APPARENTLY SPECIFIC TO BLACK RHINOS

Hemolytic anemia has been the most frequent cause of death in adult captive black rhinos (Miller & Boever, 1982; Miller, 1993). Its initial signs are usually limited to depression followed by hemoglobinuria. The progression of the cases is usually acute, death often occurring within 48 hr of the initial signs. Current research indicates that the red blood cell (RBC) of the black rhinoceros is inherently energy-deficient and thus unstable and susceptible to hemolysis. Apparently a number of oxidant stresses and injuries can "trigger" hemolysis of the black rhinoceros RBC. In approximately 50% of all cases, there has been an association with infection with *Leptospirosis interrogans*. Hypophosphatemia concomitant with hemolysis has been noted in some of the cases (Gillespie et al., 1990; Blumer, 1992). At the present time, recommended treatment includes high-dose penicillin therapy, IV supplementation with phosphorus (available in many "milk fever" preparations) and parenteral supplementation with vitamin E. Transfusion has been attempted in one case, but the results were equivocal.

Oral and Skin Ulcers

Oral and skin ulcers of unknown etiology have been noted in more than 45 captive black rhinos (Ott et al., 1982; Munson, 1992). They may be small, self-limiting lesions that most often start over points of wear or may progress to large, bullous lesions encompassing significant areas and lead to death. Treatments have been subjective (e.g., topical antibiotics, disinfectants, etc). Several cases have apparently responded to corticosteroid therapy, but that therapy should be employed only in extreme cases, as the use of corticosteroids has been

associated with a high incidence of fungal pneumonias. (See below.) The use of corticosteroids in pregnant animals should also be avoided.

Fungal Pneumonia

Fungal pneumonia has been reported in at least nine black rhinos. Nearly all the cases have involved infection with *Aspergillus* sp., and at least five of these have followed corticosteroid therapy, sometimes even relatively low doses administered over short treatment periods. However, at least two of the cases have been "spontaneous" (i.e., no prior history of immunosuppressive therapy). Fungal pneumonia should be considered in all black rhinos with signs of respiratory illness.

Encephalomalacia

Encephalomalacia has occurred in four young (2 months to 2 years of age) female black rhinos (Miller et al., 1990; Kinney, 1993). In three cases, it presented as acute and profound stupor. Two of those calves died within 4 days of onset, but a third lived and became a "dummy" calf that was later euthanized. The fourth rhinoceros, a 2 year old, became hyperexcitable, then depressed. The histological lesions were those of profound leucoencephalomalacia, and the etiology remains unknown. These cases emphasize the importance of collecting brain and central nervous system tissue on all rhinoceros necropsies.

Tissue Accumulation of Iron

Adult black rhinos appear to accumulate iron, particularly in their livers (Kock et al., 1992; Montali, 1992). The lesions are not those of a primary iron-storage disease, but similar to those of chronic iron exposure. Further studies may help determine whether the iron results from chronic subclinical hemolysis or from dietary causes.

Creosote Toxicosis

Several black rhinos that died shortly after importation from Africa have had notable elevations of sera bilirubin (both conjugated and unconjugated forms) and marked biliary stasis at necropsy (Blumer, 1992). The findings in these animals are similar to previous rhinoceros deaths associated with creosote exposure (Basson & Hofmeyr, 1973; Hofmeyr et al., 1975; Kock et al., 1994).

Common Injuries and Treatments

Skin lacerations are relatively common occurrences, and unless deep and/or badly apposed, they normally heal well without significant medical intervention. As noted above, it is difficult to differentiate abrasions over points of wear from early skin ulcers; they should be closely monitored.

Horn avulsions occur with some frequency. (The use of horizontal bars under which rhinos can hook their horns should be avoided.) There may be notable hemorrhage from the base of the horn, but this usually stops with little or no intervention. Treatment is generally limited to the topical application of antibiotics and non-toxic (e.g., pyrethrin) fly repellents.

POST-MORTEM PROTOCOL

Minimally, it is vital that frozen liver, kidney, fat, skeletal muscle, heart and spleen be saved after death. Frozen gut contents should be saved in cases of suspected toxicosis. If a death is anticipated, veterinary coordinators and researchers should be contacted for updated tissue requests. (See inside the back cover for the names and addresses of pathology coordinators.)

RESTRAINT AND ANESTHESIA

Evan Blumer,VMD

Intensive management of rhinos in captivity necessitates occasional procedures that require restraint of the animal for physical examination, sample collection or medical treatment. The unique anatomy, physiology and temperament of rhinos present many challenges to physical or chemical restraint. However, a number of techniques and facilities have been developed that provide safe options for handling these species. Following is a summary of approaches used by managers both in captivity and in the field. It should be noted that significant variation exists among individual rhinos with respect to the methods outlined below. The following should be used as a guideline only.

PHYSICAL RESTRAINT

A number of approaches to the physical restraint of rhinos have been attempted in recent years.

Box stall/Free stall

A basic box stall is the simplest and often the most effective method for minor restraint of rhinos. Visual inspections and minor physical procedures can be performed with animals in these facilities, and certain individuals can be conditioned to accept more manipulative procedures, such as reproductive examinations and blood sampling. Many institutions have incorporated a box stall within a transfer alley by adding additional gates (at the head and tail) to complete the stall. Several institutions have incorporated a box stall in the corner of a holding pen. The animals are regularly fed inside the stall, and a rear gate can be closed if and when it is considered necessary.

Several principles should be applied in the construction of a box stall. These principles should also be considered when constructing any of the other types of physical restraint devices discussed below.

- The height at the front of the stall should be great enough that the rhinoceros cannot place its chin over the top. If the chin can be placed over the top, the animal may attempt to climb out the front of the stall using its chin for leverage. Additionally, horizontal bars should be avoided in the construction of the front of the stall, as they may provide a step for the animal, which facilitates attempts to climb out the front of the stall and may increase the animal's likelihood of breaking a horn. For these reasons, this author recommends that either smooth surfaces or vertical structures (e.g., steel pipe) be used in the construction of the front portions of a box stall.
- If reproductive examinations and/or rectal palpation procedures will be conducted

A free-stall chute that is incorporated into an enclosure can be particularly effective for relatively non-invasive procedures. Note how the angled entry and safety pipes allow a veterinarian or researcher access to the rear of the animal without the possibility of the animal's backing straight out. (*Photo: Fossil Rim Wildlife Center*)

in the stall, close attention should be paid to the construction of the rear portion of the box stall. Most managers believe that a series of removable vertical structures provide both adequate safety and access to the animal.

- Regardless of the specific design or placement of a rhinoceros restraint device, the most critical factor in the success of physical restraint procedures is conditioning of the animals to a restraint. Whenever possible, placement of a restraint device should be such that it can be incorporated into the daily routine of the animals.

Several other basic designs have been developed for more complete physical restraint of rhinos.

Head/Shoulder Gates

Several institutions have attempted the development of a head/shoulder gate system that further restricts the movement of the animal. This approach consists of an elongated box stall with the addition of a mechanism to restrict forward motion. These mechanisms generally consist of vertical bars that are moved in from the sides or a "yoke" that is lowered from above and fits along the side of the neck in front of the shoulders. Difficulties with this approach generally include problems with the placement of the head/shoulder restraint with animals of varying sizes and a tendency of some individuals to "fight" the head/shoulder restraint.

Restraint Chutes

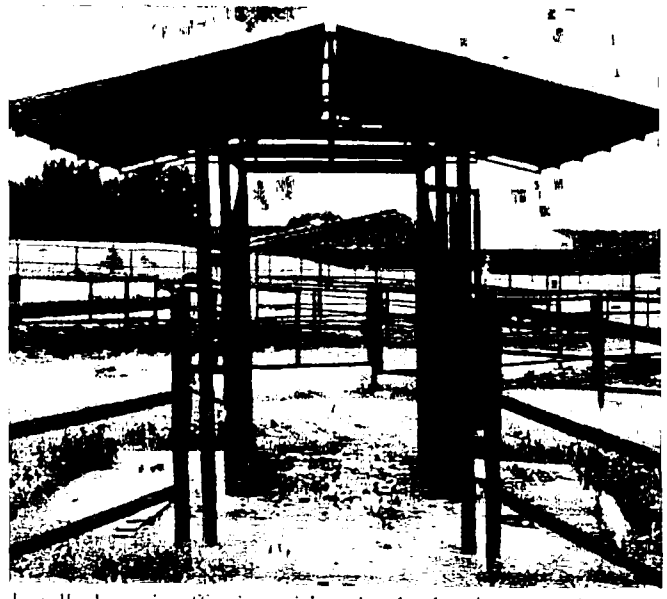
A number of institutions have developed mechanical "squeeze chutes" to further the physical restraint of rhinos. In this design, one or more of the walls are mobile and can be moved to further restrict the area in which the rhino is held. The basic differences between the designs are whether the chutes are adjustable laterally, longitudinally or both and whether the drive mechanism is manual, pneumatic/hydrolic or motor driven. From this author's experiences, the most successful approach to "squeezing" a rhinoceros is to provide a narrow area to prevent lateral movement and to "squeeze" the animal longitudinally from the rear. Methods of powering the drive mechanism are primarily a matter of personal or institutional choice; however, it should be noted that the "squeeze mechanism" should function to restrict the motion of the rhinoceros as opposed to forceably restraining it.

CHEMICAL RESTRAINT

In situations in which the physical restraint of rhinos is not possible or practical, a number of options exist for their restraint through chemical means. Many of the drug regimens outlined below may be used for varying levels of tranquilization (from mild sedation to full anesthesia). Specific decisions as to which regimen is most appropriate must be based on clinical experience, drug availability and the specifics of the case.

Several principles should be followed to increase the safety of chemical restraint procedures for both the animals and personnel:

- When applicable, antagonists to the restraint drugs should be prepared prior to the initiation of the procedure and should be available for rapid administration.
- Careful monitoring of the patient (auscultation, ECG, pulse-oximetry, etc.) will help to rapidly identify problems should they develop and allow early intervention.
- The large size of an adult rhinoceros may result in further complications during anesthetic procedures. Efforts should be made to maintain the animal in sternal



A closed-stall chute is effective with animals that have not been conditioned, although acclimating the animal to the chute is recommended. Both back and front gates in a closed chute design can restrict the rhino's movement by sliding forward. (*Photo: Fossil Rim Wildlife Center*)

recumbency when possible to minimize respiratory complications, and if the procedure is to last more than 30 min, efforts should be made to "pad" the area under the animal (with mattresses, inflated innertubes, straw/hay bedding, etc.) to minimize the effects of pressure on the limbs.

Etorphine

Etorphine (M-99) remains the "drug of choice" for a wide range of restraint procedures with rhinos. The particular sensitivity of rhinos to narcotics results in the ability to induce effects ranging from mild sedation and "standing restraint" to surgical anesthesia. Recently, etorphine has not been available for purchase in North America; however, a new manufacturer is awaiting Food and Drug Administration approval and expects to have a product available for shipment soon.

The particular effect of etorphine varies with the dose, and a desired level of restraint can often be achieved by carefully titrating the dose. Table 19 lists dose ranges for etorphine for the three most common rhinoceros species.

Several additional drugs are often used in conjunction with etorphine to moderate its pharmacological effects. Xylazine or detomidine is often used to improve muscular relaxation during anesthesia (See below.), and hyaluronidase has been used to increase the rate of absorption of the drug following intramuscular injection.

Antagonism of the effects of etorphine can be accomplished through the use of diprenorphine (2 to 3X etorphine dose), naloxone (100X etorphine dose) or naltrexone (50 to 100X etorphine dose). It should be noted that rhinos seem to be particularly sensitive to recycling or "renarcotization" following etorphine anesthesia and antagonism with diprenorphine. This problem seems less likely to occur if naltrexone is used as the antagonist.

Nalorphine

Nalorphine, an additional narcotic antagonist, has been used extensively in both Africa and Europe to moderate the effects of narcotic anesthesia in rhinos. In many cases, especially when elevated narcotic dosages are used to achieve rapid restraint (as in field-capture operations), respiratory suppression may be pronounced. Administration of nalorphine results in an increase in the rate and depth of respiration, increased blood pressure and, depending on the dose, an elevation of the plane of anesthesia. Recent work (Allen & Kock, pers. comm.) has demonstrated that administration of small amounts (10.0 to 15.0 mg IV) of nalorphine leads to a dramatic increase in the rate of oxygen saturation (PO_2) in anesthetized rhinos without significant arousal.

Carfentanil

With the recent unavailability of etorphine, several institutions have begun to experiment with carfentanil as an alternative anesthetic agent. Successful anesthesia has been achieved in black rhinos using 0.9 to 1.2 mg (total dose/adult animal), and in white rhinos using 1.0 to 1.5 mg (total dose/adult animal). As of the time of this writing, carfentanil has not been used to anesthetize a greater one-horned rhinoceros. Most experienced veterinarians believe that carfentanil should be effective in this species at dosages similar to those for white rhinos.

Very few attempts have been made to use carfentanil for standing restraint in rhinos. Although it should be effective for this purpose, the rapid induction seen with carfentanil

TABLE 19. Dose ranges for etorphine anesthesia

Species	Standing Restraint	Full Recumbancy
White rhino	0.5 - 1.0 mg total dose	2.0 - 4.0 mg total dose
Black rhino	0.25 - 0.75 mg total dose	1.0 - 3.0 mg total dose
Greater one-horned rhino	0.5 - 1.0 mg total dose	2.0 - 4.0 mg total dose

Dose ranges listed above are for adult animals in a captive situation. Exact dosage should be determined based on the size of the individual and the conditions in which the procedure is performed.

(when compared to etorphine) may limit the "window" before the animal may become recumbent. At this time, the best dosage recommendation for standing restraint is 25% of the dose used to achieve full recumbency.

Antagonism of the effects of carfentanil can best be achieved with naltrexone at a dosage rate of 100 to 200X the carfentanil dose.

Xylazine and Detomidine

Xylazine (Rompun) and detomidine (Dormosedan) have been used frequently as additions to etorphine and carfentanil anesthetic protocols and independently for more minor chemical restraint. As an addition to narcotic anesthetics, they improve muscle relaxation and may have a synergistic effect that reduces the induction time. Typically, 100 to 150 mg of xylazine or 10 to 15 mg of detomidine is administered per adult rhino either as a pre-medication (15 to 20 min prior to narcotic administration) or mixed as a "cocktail" with the narcotic of choice. Additionally, these drugs may be used alone to achieve mild to moderate sedation or to relieve pain. Dosages of these drugs when used independently must be based on clinical assessment but generally are 2 to 3X those listed above for use with narcotic anesthetics.

Both xylazine and detomidine have depressant effects on heart rate, respiratory rate and blood pressure, and careful monitoring is essential to ensure patient safety. The antagonist yohimbine may be administered (0.1 mg/kg) to counteract the effects of xylazine; however, yohimbine is only marginally effective as an antagonist to detomidine. Although it is not yet widely available in the United States, the antagonist atipamazole is effective with both xylazine and detomidine.

Butorphanol + Detomidine

In recent months, due to the continued unavailability of etorphine, several institutions have begun to use a combination of butorphanol and detomidine to achieve standing restraint in several rhinoceros species. Although a relatively small number of these procedures have been performed, Table 20 lists dosages recommended as "starting points."

Neuroleptics

Several neuroleptic drugs have been used to reduce anxiety and stress during transport and handling procedures. These drugs have the advantage of calming the animal without significant sedation. Azaperone has been used frequently, but dosages vary widely. Use of haloperidol has been reported for only one individual. In that case severe excitation was noted; however, the individual was later diagnosed with a serious neurological disease (encephalomalacia), and the deleterious effects appear to have been unrelated to the administration of haloperidol. Based on its efficacy and safety in a wide range of other species and the successful use of related compounds in rhinos, further investigation into the use of haloperidol for rhinos is warranted.

Long-acting Neuroleptics (LANs)

Several LANs have been used extensively on rhinos in Africa and Europe. Zuclopenthixol acetate (Clopixol - Acuphase) is effective for 2 to 3 days, and perphenazine enanthate (Trilafon) is effective for 5 to 7 days. Unfortunately, these compounds are not readily available in the United States at this time.

TABLE 20. Dose range for combination butorphanol and detomidine anesthesia

Type	Drugs	Comments
Standing sedation	150 mcg/kg butorphanol + 30 mcg/kg detomidine	Sufficient for blood collection, physical exam and minor manipulations
Full recumbancy	300 mcg/kg butorphanol + 60 mcg/kg detomidine	Produces bradycardia and hypoxemia. Treat hypoxemia with 100% oxygen via nasal catheter. Bradycardia has not proven to be clinically significant.
Antagonism	500 mcg/kg naltrexone + 300 mcg/kg yohimbine	Administer IV; effects abolished in 1 to 2 min

Note: Drugs 1 and 2 are given in combination. Further information on this anesthetic protocol may be obtained from Dr. Pat Morris, Associate Veterinarian, San Diego Zoo.

Additional Information

For additional information, please refer to the following references: Kock & Morkel, 1993; Kock & Garnier, 1991; and Rogers, 1993.

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(*Photo: Knoxville Zoological Gardens*)

NUTRITION

Ellen S. Dierenfeld, Ph.D

It is believed that many of the health problems identified in captive rhinos may be linked to inadequate diets. Rhinos consume a large number of species of plants with a diverse array of physical characteristics and nutrients. They represent a range in feeding strategies and consequently diet, from browsers (or selective feeders) to unselective grazers. Captive diets may include possible imbalances in some species in dietary fats (particularly essential fatty acids such as LA), and available carbohydrates, as well as minerals and vitamins. This chapter will present dietary information for maintaining rhinos in captivity and includes a section on hand rearing.

Nutritional Requirements

Due to similarities in digestive tract morphology, the domestic horse probably represents the best nutritional model for all rhinoceros species. Until further information is obtained, diets should be formulated using current National Research Council (NRC) (1989) recommendations for horses of various physiological stages. Minimum nutrient requirements are listed in Table 21.

Good quality forages should provide primary nutrients for all herbivores, with concentrate feeds used to balance energy, protein, minerals or vitamin needs. Hay storage is particularly important for ensuring proper dietary management. Moldy or dusty hay may cause colic and/or heaves. Large amounts of poor-quality hay should not be fed to rhinos, as it may be so poorly digested that impaction and/or colic will result. Very high-quality legume or small-grain hay may be so readily digested that when fed with concentrates, loose feces or colic may result. High quality legume hays often necessitate mixing with grass hays.

The larger, grazing rhino species (greater one-horned and white) should be fed high-quality grass hays, while browsing species (black and Sumatran) should be fed mixed grass: legume hays and/or a mixture of legume hay and less digestible browse. Hay and fresh water should be available *ad libitum*; the concentrate portion of the ration should be given in at least two feedings daily for better utilization. When practical, a small feeding of hay should be encouraged prior to each concentrate feeding.

In studies of intake, digestion and passage in zoo herbivores, Foose (1982) measured dry matter intakes of approximately 1% of body mass when greater one-horned (n=3), white (n=5) or black (n=3) rhinos were fed grass hays, and slightly higher levels (1.2 to 1.6% of body mass) when fed alfalfa hay. Diets were 43% (black rhinos eating grass) to 67% (white rhinos eating alfalfa) digestible. Thus, a guideline for as-fed diet quantity would be approximately 1.5% of body mass; for grazing species, no more than a third of total calories should be obtained from the concentrate portion (horse feeds or high-fiber ungulate pellets). Larger pellets (>1.0 cm diameter) work well with grazing species, while smaller pellets can be readily manipulated by browsing species.

TABLE 21. Nutrient concentrations in total diets for horses and ponies (dry matter basis, modified from NRC, 1989)

	Growing	Mature/ Maintenance	Pregnant/ Lactating
Nutrient			
Dig. Energy (Mcal/kg)	2.45 - 2.90	2.0	2.25 - 2.60
Crude Protein (%)	12 - 15	8.0	10 - 13
Ca (%)	0.6	0.3	0.4
P (%)	0.3	0.2	0.3
Mg (%)	0.1	0.1	0.1
K (%)	0.3	0.3	0.4
Vit A (IU/kg)	2000	2000	3000
Vit D (IU/kg)	800	300	600
Vit E (IU/kg)	80	50	80

Concentrations of Na, S, Fe, Mn, Cu, Zn, Se, I and Co should be provided at the following levels, respectively: 0.1%, 0.15%, 50 mg/kg, 40 mg/kg, 10 mg/kg, 40 mg/kg, 0.1 mg/kg, 0.1 mg/kg and 0.1 mg/kg.

Browse, which may be essential to the dietary health of rhinos, also serves as an effective form of behavioral enrichment. (*Photo: San Diego Zoological Society*)

Animals can sometimes be encouraged to consume less palatable forages if hays are soaked in water or sprinkled with molasses. Applesauce had proved to be helpful in administering unpalatable medications and/or supplements.

Feeding Location

As with all zoo species, feed should be offered on a concrete pad or in livestock troughs or bins. Sand impaction has previously been documented in rhinos (Nouvel & Pasquier, 1946); therefore, feeding directly on the ground is not recommended. To reduce competition for food, individual feeding stations or adequate space at communal feeders is recommended.

Supplements

Dietary supplements should be unnecessary in properly formulated rations. A possible vitamin-E deficiency has been suggested but not confirmed in zoo rhinos; current recommendations based on natural browse composition suggest that diets should contain 150 to 200 IU vitamin E/kg dry matter. Salt blocks and water should be available at all times. If grown in an area prone to soil selenium (Se) deficiency, forage should be tested routinely for determination of Se content in order to provide data needed for balancing rations.

Problematic Diets

High-quality alfalfa as an exclusive forage is unnecessary and may lead to mineral imbalances, colic and diarrhea. The consumption of fresh red maple browse has been associated with hemolytic anemia in horses and should therefore be avoided. Feeding cabbage, kale and onion to rhinos should also be avoided.

Browse

Particularly for the browsing rhino species, the addition of fresh and/or frozen browse may be essential to dietary health. Browse may contribute required nutrients that have not yet been quantified and may also be of benefit to dilute a captive diet that is too digestible. Table 22 lists North American browse species that have been successfully fed to rhinos.

TABLE 22. North American browse species acceptable for rhinos (partial listing)

Crabapple	*Malus* sp.	Weeping Willow	*Salix babylonica*
Silver Maple	*Acer saccharinum*	Black Willow	*Salix nigra*
Sugar Maple	*Acer saccharum*	Fragrant Honeysuckle	*Viburnum* sp.
Alder	*Alnus* sp.	Grape	*Vitis vinifera*
Hackberry	*Celtis occidentalis*	Banana	*Musa acuminata*
American Beech	*Fagus grandifolia*	Torch Ginger	*Phaeoamerica* sp.
Weeping Fig	*Ficus benjamina*	Sweetgum	*Liquidambar styraciflua*
Forsythia	*Forsythia* sp.	Prickley Pear	*Opuntia leptocaulis*
Kentucky Coffee Tree	*Gymnocladus dioicus*	Huisache	*Acacia farnesiana*
Hibiscus	*Hibiscus rosa*	Brazil	*Condalia obovata*
White Mulberry	*Morus alba*	Catclaw	*Acacia roemeriana*
Golden Bamboo	*Phyllostachys aurea*	Mesquite	*Prosopis juliflora*
White Poplar	*Populus alba*	Granjeno	*Celtis pallida*
Black Locust	*Robinia pseudoacacia*		

HAND-REARING

Ann Ward, M S

A limited number of rhino calves have been and are currently being raised using various formulas. Reports and published information must be carefully scrutinized for measures of success and methodology in milk-sample analysis. The following information uses the ungulate hand-rearing chapter in the AZA Infant Diet Notebook as a base for general feeding guidelines and formula selection (Reiter et al., 1994). This recommendation is to be used as a guideline for standardization of a hand-rearing diet. For current information, contact the author.

TABLE 23. Compositions of rhino hand-rearing formulas

Ingredients	Parts by Volume	
	Formula 1	Formula 2
Water	32	9
Skim milk	32	9
Karo Syrup	1	1

While not common, hand-rearing of rhinos has been accomplished by North American institutions. (*Photo: Knoxville Zoological Gardens*)

Milk Composition and Formula Selection

Based on available data, rhinoceros milk is more dilute than milks of other ungulate species. It is low in solids, low in protein, very low in fat and high in sugar compared with milk of equids, bovids and cervids (Oftedal, 1984). Formula selected (Table 23) should mimic mother's milk in composition as much as possible (Table 24). Two formulas are presented: Formula 1 has been used to raise a calf to 1 year of age; Formula 2 more closely mimics mother's milk.

Though rhinoceros' milk is different from cow's milk, the latter may still be appropriate for hand-rearing rhinos if used in combination with other ingredients. Cow's milk is low in iron; consequently, an iron source such as Fer-in-sol should be added to the formula at two drops per 100 g of formula. In addition, infant vitamins, such as Major Multi-Vita Drops, should also be added to the formula at two drops per 100 g of formula. Some infant vitamins, such as Mead Poly vi-sol with Iron, contain added iron. The animal may also benefit from the addition of Lactaid at one drop per 100 g of formula. Lactaid aids in carbohydrate digestion and helps prevent possible gastrointestinal tract distress.

If the neonate is less than 24 hr old, colostrum diluted 50% with water or an electrolyte solution for ungulates, such as Replenish, should be administered for the first 24 hr. Though species specific colostrum is preferred, cow colostrum may be used. Products such as Colostrx may also be used (Table 25).

To avoid gastrointestinal distress, a diluted formula should be offered beginning on day 2. The formula can be gradually increased to full concentration depending on the animal's health, including weight gain and stool condition.

Feeding Regimen

Quantity fed should range from 10 to 13% of body weight. Animals should be fed every 2 hr. Because infants suckle during daylight hours, feeding should be equally spaced in a 12-hr period not to exceed 3% of body weight at any one feeding. It is recommended that feeding begin with 10% of body weight split equally into 12 feeds 1 hr apart during daylight hours. The quantity of formula fed should be adjusted daily based on the animal's weight. Animals should be weighed at the same time each day. Fresh water should be available at all times.

If diarrhea occurs, the quantity of formula fed should be decreased or the formula diluted until stool condition returns to normal. If diarrhea is persistent, an electrolyte solution can be used to dilute the formula, replacing some or all of the water. In addition, the number of feedings can be increased to lessen the quantity fed at any one time.

Formula can be prepared ahead of time and warmed as needed. Water should be boiled to decrease possible contamination due to pathogens, then refrigerated before being added to the formula. The formula should be refrigerated and used within 72 hr. Prior to feeding, the formula should be warmed to the animal's body temperature. Calf nipples work well with large species. Bottles should be boiled before use. Diluted bleach may be used as a disinfectant. Formula left over from each feed should be discarded.

TABLE 24. Nutrient compositions of rhino milk (Gregory et al., 1965) and recommended formulas (as-fed basis)

	Percent as Fed			
Formula	Solids	Protein	Fat	Sugar
Rhino milk	8.8	1.4	0.2	6.6
Formula 1	10.3	3.3	0.3	5.9
Formula 2	8.3	1.7	0.2	6.6

TABLE 25. Products used in hand-rearing diets

Product	Manufacturer/Distributor
Colostrx	Protein Technology, Inc. Minneapolis, MN 95403 1-800-645-3839
Replenish	Fermenta Animal Health Co. Distributor Kansas City, MO 64153
Fer-in-sol Poly-vi-sol with Iron	Mead Johnson Nutritionals Bristol-Meyer Co. Evansville, IN 47721
Major Multi-Vita Drops	Major Pharmaceutical Corp. Distributor Chicago, IL 60612
Lactaid	Lactaid, Inc. P.O. Box 111 Pleasantville, NJ 08232

Weaning

Weaning may begin at as early as 6 months and should be completed in 1 year. Weaning is a slow process involving carefully monitoring body weight and solid food consumption. Animals should have access to solid food at all times. A nutritionally complete pelleted diet such as Calf Manna, horse feeds or high fiber ungulate pellets, in addition to alfalfa hay, is appropriate. Formula may be decreased by gradually eliminating the number of feeds or decreasing the amount offered per feed and gradually decreasing the number of feeds.

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RESEARCH

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Due to a long history in captivity, rhinos have been subjects of limited research and are thus poorly understood compared with many other captive species. This chapter provides an overview of research priorities dealt with the goal of improving captive management of all rhinoceros species. The following outline groups rhinoceros research topics under the categories of health, reproductive biology, behavior, and systematics and population biology. Table 26 provides a summary of captive rhino research priorities.

ANIMAL HEALTH

Nutrition

Direct and indirect evidence to date suggests possible imbalances in dietary fats (particularly essential fatty acids), soluble and insoluble carbohydrates, minerals and vitamins as underlying causes for many of the health problems identified in captive rhinos. Additionally, a different spectrum of nutritional problems are perceived to occur in free-ranging rhinos, a situation that will be compounded as more individuals are maintained in sanctuaries or intensive protection zones (IPZs).

Research objectives:

- Develop optimal diets for rhinos under intensive management through the analysis of:
  - diets currently used in captive facilities,
  - fatty-acid composition,
  - carbohydrate content of natural browse,
  - trace minerals,
  - carotenoids and other antioxidants, and
  - amino acids.
- Develop nutritional standards for free-ranging populations under intensive management (i.e., sanctuaries or IPZs) through analyses.

Stress

Various physiological and psychological stressors are believed to be underlying causal factors for many disease syndromes in rhinos. Identifying those stressors and their effects may help decrease or eliminate them, thereby helping prevent some diseases.

Research objectives:

- Develop non-invasive methods of assessing stress levels;
- Develop baseline information and identification of stressors;
- Identify chronic stress as a factor in rhino morbidities and mortalities;
- Develop behavioral measures of stress and identify social and behavioral stressors.

Comparative Cell Metabolism

Previous studies have established a number of unique biochemical, enzymological and hematological characteristics of rhinoceros red blood cells, yet it remains unclear whether these characteristics cause any or all of the observed disorders in these species. Further, it is

TABLE 26. Summary of captive rhino research priorities

Animal Health	Reproductive Biology	Behavior	Systematics and Population Biology
Nutrition	Characterization of the female reproductive cycle	Mate compatibility, courtship and aggression	Definition of subspecies distinctions and conservation units
Stress	Characterization of male reproductive activity	Behavioral indicators of estrus and parturition	Genetic and demographic management of populations
Comparative cell metabolism	Reproductive pathology	Social behavior and group structure	
Specific disease studies	Development of assisted reproductive techniques	Neonatal development and weaning	
Sample and data acquisition and storage		Behavorial measures of stress	

Research priorities identified by E. Blumer, research advisor to the Rhino TAG

unclear whether these or similar metabolic deviations exist in other tissues also and play a causal role in the genesis of other disease syndromes in rhinos.

Research objectives:

- Establish intra- and inter-specific biochemical and enzymatic profiles of various tissues;
- Determine the effects of these biochemical and enzymatic characteristics on cellular processes;
- Assess the value of these variations on biomarkers of vulnerability to certain diseases;
- Identify potential therapies to modify the effects of these cellular processes.

Specific Disease Studies

The captive populations of several rhinoceros species have been limited by disease. Previous research has helped clarify the pathological processes involved in some of these diseases.

Research objectives:

- Investigate specific causal factors and possible treatments for:
  - hemolytic anemia,
  - mucocutaneous ulcerative disease,
  - cholestatic hepatopathy,
  - encephalomalacia,
  - fungal pneumonia/immunological status, and
  - epidemiological processes and patterns.

Sample and Data Acquisition and Storage

Sample and data acquisition, storage and distribution are critical to the success of rhinoceros research programs. Adequate samples from captive animals are critical to understanding disease conditions in captivity. Field samples have inherent value for comparative purposes with the captive population.

Research objectives:

- Establish regional "distribution points" for processing and redistributing samples;
- Develop blanket permits for movement of samples;
- Establish enhanced centralized storage facilities to make samples accessible to all interested parties;
- Develop a centralized database in conjunction with an epidemiologist for generation and maintenance of basic and specialized data on individual rhinos.

REPRODUCTIVE BIOLOGY

Although there has been much interest and considerable activity in reproductive research on rhinos, results have been desultory at best. The basic reproductive biology has yet to be adequately characterized in any of the species. Part of the difficulty has involved challenges inherent in rhinos themselves: large size, reproductive tract configuration and peculiarities of hormonal metabolism. Additionally, there has been an insufficient number of rhinos available for research. Finally, there has not been a systematic and coordinated program of research.

Research addressing rhino behavior, biology and management is needed. Priorities identified by the North American Rhino TAG include animal health, reproductive biology, behavior, and systematics and population biology. (*Photo: Knoxville Zoological Gardens*)

Female Reproductive Biology

Research objectives:

- Develop methods of determining reproductive status of individuals;
- Determine normal versus abnormal reproductive characteristics;
- Develop methods of estrus detection and ovarian activity, including time of ovulation by:
    - Developing methods of hormonal monitoring through regular collection and analysis of blood, feces and urine,
    - Developing methods of ultrasonic monitoring of ovarian activity, and
    - Developing methods of behavioral observation;
- Develop methods of determining and monitoring pregnancy.

Male Reproductive Biology

Research objectives:

- Develop methods of determining reproductive status of individuals;
- Determine normal versus abnormal reproductive characteristics;
- Develop methods of processing sperm for artificial insemination or cryopreservation;
    - Develop reliable methods of collecting semen;
    - Evaluate electroejaculation versus artificial vaginas;
    - Document anesthesia considerations.

Reproductive Pathology

Research objectives:

- Determine a clear understanding of normal anatomy for males and females of each species;
- Evaluate the incidence of pathological conditions;
- Evaluate the impact of reproductive pathology on reproduction and population growth;
- If this impact is significant, evaluate medical or surgical methods to ameliorate the negative effects on reproduction.

Assisted Reproduction Techniques

Research objectives:

- Develop methods of manipulating female reproductive cycle through the use of various hormones or exogenous substances in order to develop protocols for estrus synchronization, ovulation induction and superovulation;
- Develop methods of safe and optimal semen collection, processing, storage and use;
- Develop methods of artificial insemination;
    - Determine best methods of sperm deposition in female tract: anterior vagina, cervix, uterus;
    - Develop modified artificial insemination guns;
- Develop methods of rescuing male or female gametes from gonads of recently deceased individuals;
- Develop specialized hardware and techniques for rhino reproductive work;
- Develop methods of determining and/or manipulating sex of offspring;

- Develop methods of collecting and using gametes or embryos via *in vitro* fertilization, embryo transfer or micromanipulation.

BEHAVIOR

Mate Compatibility, Courtship and Aggression

The courtship behavior of rhinos is vigorous and often aggressive. Captive managers have had difficulty differentiating a truly dangerous situation (especially in smaller captive facilities where flight distance is limited) from the normal, and possibly required, amount of aggressive behavior during courtship.

Research objective:

- Identify "normal" behavior that delineates both the patterns that occur in the wild (how and when males and females come together) and the patterns and management practices that have occurred in captive facilities with successful rhino breeding programs.

Behavioral Indicators of Estrus and Parturition

Efficient reproductive management in captivity requires clear understanding of the timing and occurrence of several reproductive events. Currently, some managers can identify events such as estrus and impending parturition through changes in an animal's behavior. However, these indicators appear to have considerable variability among individual animals, and the ability to recognize them varies among managers.

Research objective

- Develop a reliable set of behavioral indicators of estrus and parturition for each of the rhino species currently managed in captivity.

Social Behavior/Group Structure

Little is documented about the behavior of extant rhinoceros species, either in the wild or in captivity. Attempts to integrate available information on rhino behavior have been hampered by the lack of standard methods of measurement and reliable ethograms to describe their behavior.

Research objectives:

- Develop standard methods of measurement and reliable ethograms to describe behavior of rhinos;
- Examine husbandry practices, facility design, animal densities and sex ratios to determine the factors most critical for reproductive success.

Neonatal Development/Weaning

Of the rhino species maintained in captivity, only black and greater one-horned rhinos have enjoyed a significant degree of reproductive success. However, it has recently been suggested (Read & Smith, pers. comm.) that the interbirth interval may be significantly longer for captive individuals than for their wild counterparts and that this interval must be reduced if the captive population is to grow at the necessary rate (approximately 5% per year). Assuming consistent reproduction, the interbirth interval can best be reduced by returning females to a breeding situation as soon as possible after parturition and possibly weaning infants earlier.

Research objective:

- Develop a clearer understanding of neonatal behavior and maternal interactions, which is necessary for the identification of the periods critical for the development of normal socio-sexual and parenting behavior and an understanding of the effects of early weaning.

Behavioral Measures of Stress

Stress has been implicated as an underlying causal factor for many of the disease syndromes identified in captive rhinos (especially black rhinos).

Research objectives:

- Identify and decrease these stressors, thereby reducing the causal factors of some diseases;
- Develop reliable behavioral measures of stress in conjunction with efforts to develop non-invasive, physical measures of stress;
- Evaluate the impact of facility design, management practices and social factors as primary stressors.

SYSTEMATICS AND POPULATION BIOLOGY

Definition of Subspecies Distinctions / Conservation Units

Definition of conservation units and confirmation of evolutionarily significant units have been issues of extreme importance in conservation and management of rhinos. Amid the crisis for rhino conservation, an optimal definition of conservation units has great significance in terms of demographic viability and economic feasibility. These issues are becoming particularly acute for the black rhinoceros, which is confronting a demographic crisis. Genetics is a critical tool in the definition process. However, the process must also integrate other areas of rhino conservation biology, including morphometrics, ecology and biopolitics.

Research objective:

- Use existing information or develop new information to confirm or modify current definitions of conservation/management units of rhinos.

Genetic and Demographic Management of Populations

As rhinoceros populations become smaller and more fragmented, the ability to measure and manage them genetically and demographically becomes more critical. A number of PHVAs have been initiated with workshops on various rhino species; however, PHVAs are a continuing process.

Research objectives:

- Measure genetic variation within and between populations to assist in intensive management;
- Develop and apply biochemical measures of relatedness/pedigree construction and confirmation;
- Apply PHVA techniques to the management of *in situ* populations.

APPENDIX I • SUMATRAN RHINOCEROS

Sumatran rhinos in captivity in North America have not fared well. The current North American Sumatran rhino population consists of three animals. Additionally, there has been no captive reproduction in North American institutions. It should be emphasized, therefore, that in general, much of the captive husbandry information regarding Sumatran rhinos is not known. The following information is derived from an IZ/Rhino TAG husbandry workshop as well as an internationally attended review of Sumatran husbandry. The latter incorporates information from zoological professionals in Bogor, Indonesia and Malaysia. Much of the general husbandry information given in earlier chapters (e.g., enrichment, general husbandry, general design) is applicable to Sumatran rhinos, and it is recommended that managers from institutions holding Sumatran rhinos carefully review the entire manual in addition to this section. Health, nutrition and research concerns for Sumatran rhinos are described in their respective chapters. Sumatran specific information regarding group composition, introductions, sleeping and design is described below.

MANAGEMENT AND BEHAVIOR

Group Composition in Captivity

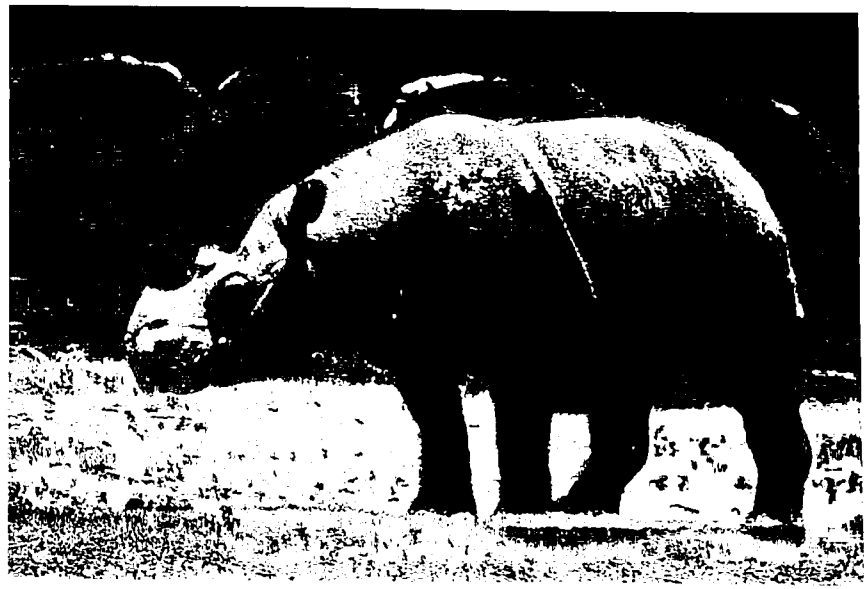
Sumatran rhinos are generally considered solitary outside of breeding (Nowak, 1991). Females are thought to be territorial and to avoid one another. Males are also thought to be solitary but to visit the territories of females and possibly fight over them after calves are weaned. Prior to weaning, females are commonly found with their offspring.

Based on these data on Sumatran rhino social organization as well as collective experience in captivity, it is recommended that adult animals be housed separately and introduced only for breeding purposes. It is also recommended that institutions housing Sumatran rhinos commit to holding at least a pair of animals.

Introductions

General considerations for any introduction are reviewed in detail in the Management and Behavior chapter of this manual. It is important to note that introductions may result in aggression and that captive rhinos of both sexes have been the aggressors. Territorial defense is often limited to ritualized confrontations, although more intensive conflicts involving head on charges and the infliction of injuries by horning or ramming do occur. It is important to note that what is often perceived as serious or dangerous aggression between rhinos is, in fact, normal behavior requiring no intervention of any kind. Refer to Table 7 in the Management and Behavior chapter for a descriptive hierarchy of aggression levels in rhinos.

Because of the relatively more aggressive, territorial nature of Sumatran rhinos, introductions should be attempted only for breeding purposes (one male to one female). With the exception of very large facilities, individual rhinos should be held separately in all other situations.



Much is yet to be learned regarding Sumatran rhino husbandry. In modern times, only one Sumatran rhino has been born in captivity (Zoo Malacca, Malayasia), though it was conceived in the wild. *(Photo: R. Hudson, Fort Worth Zoological Park)*

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Introduction of a Female to a Male for Breeding Purposes

Introductions should occur only for breeding purposes and when the female is in estrus. (See Table 9 in the Management and Behavior chapter for behaviors believed to be associated with estrus.) The introduction should take place in the largest area available. If two adjoining yards are opened to create a larger introduction area, the female should be placed in the yard she is most familiar with and allowed to acclimate. After she is acclimated to the yard, the male should be introduced to her. If the facility allows, preliminary visual and tactile contact may increase the likelihood of mating success. If intervention is required because of aggression between the rhinos, the introduction should cease and not be attempted until a later date. When individuals cannot be separated in the outdoor enclosure, the female should be kept from entering the barn if possible; in all likelihood, the male will follow her inside, and the chance of serious injury will increase. Because the introduction should occur during estrus, an introduction may be required at any time of the day or night. (Estrus duration is believed to be approximately 24 hr, with peak conception chances occurring during hours 8 to 12). The rhinos should be separated and monitored following breeding.

Shipping Protocol

General information regarding crating and shipping rhinos is described in the Management and Behavior chapter. Based on IATA crate design specifications (IATA, 1995), a shipping crate for a Sumatran rhino should be approximately 310 cm (122 in.) long and 180 cm (71 in.) high. In general, the crate should be 0.3 m (1 ft) longer and wider than the animal when it is lying on its side.

DESIGN

Design elements for a breeding facility should include an outdoor primary enclosure (with separation capabilities), indoor holding and an isolation area. Additionally, breeding institutions must have space for any offspring to be held for up to 3 years of age. Table 27 lists the recommended enclosure types and sizes for captive Sumatran rhinos.

It is recommended that enclosures be designed such that animals may be kept outdoors as much as is feasible within the following temperature constraints. Sumatran rhinos should not be locked outside when the temperature is below 10° C (50° F); sun, wind chill and rain should be considered in calculating temperature. During extremely cold weather, rhinos should not have access to pools or mud wallows; pools should be drained and mud wallows filled with substrate. Animals should not be let out if enclosures are icy. Temporary exposure to temperatures below 10° C (50° F) for cleaning is left to the discretion of management. Localities that experience average daily temperatures below 10° C (50° F) (average of high and low temperatures over a 24-hr period) should provide heated facilities capable of maintaining a minimum temperature of 13° C (55° F).

Outdoor Housing

Sumatran rhinos are considered somewhat territorial, and more than one outdoor yard is strongly recommended. To provide a large area for introductions, a communal yard adjacent

TABLE 27. Recommended enclosure types and sizes for captive Sumatran rhinos [in sq m and (sq ft)]

Individual Holding (per rhino)		Breeding / Communal	
Indoor	Outdoor	Indoor	Outdoor
18.6 (200)	371.6 (4,000)	not recommended	1,114.8 12,000

to individual yards should be available for introductions (Table 27). If a communal yard is not available, two adjacent yards may be opened for male/female introductions. In many respects, the critical enclosure characteristic is the availability of escape routes and visual barriers, which serve to hide or prevent access to a pursued animal. Recommended primary barrier types are described in the Design chapter. As with other rhino species, a primary barrier should be a minimum of 1.5 m (5 ft) high and non-climbable.

Both pools and mud wallows are recommended for Sumatran rhinos. The size of the mud wallow should be gauged by the number of animals in the exhibit to allow ample room for each individual. A pool should be of approximately equal dimensions (length x width). The recommended size is 13.9 sq m (150 sq ft) and 0.3 to 0.9 m (1 to 3 ft) deep. Refer to the Design chapter for additional general specifications regarding pool design.

Access to shade is a necessity as well as a USDA requirement. Sumatran rhinos are naturally found in thick jungle habitats; therefore, ample shade for this species is especially critical. It is recommended that rhinos have access to a shaded area during daylight hours.

Indoor Housing

Indoor housing is recommended for additional separation capabilities (beyond the primary enclosure) and is critical for those institutions in colder latitudes. Isolated stalls are essential for Sumatran rhinos. The indoor enclosure should include a minimum of 18.6 sq m (200 sq ft) per rhino. Stalls should have concrete floors that are easy to clean and have proper drainage. Some animals have developed foot problems on hard concrete floors. Rubber mats and proper bedding should therefore be provided as necessary. Dirt is not an acceptable substrate.

Refer to the Design chapter for additional information regarding temperature, humidity, ventilation and lighting recommendations. Because Sumatran rhinos are introduced for breeding purposes for a limited amount of time and closely observed, lighting is also necessary in outdoor enclosures for the observation of breeding at night.

When Sumatran rhinos are indoors, isolated stalls are essential. Introductions should occur only for breeding purposes and when the female is in estrus. (*Photo: R. Hudson, Fort Worth Zoological Park*)

Literature Cited

International Air Transport Association (1995). Live animal regulations, 22nd Edition. Montreal: International Air Transport Association.

Nowak, R. M. (Ed.). (1991). Walker's Mammals of the World, Vol. II. Baltimore: Johns Hopkins University Press.

AZA Rhino TAG Behavior Group

It is believed that behavior may be a critical link in understanding rhinoceros biology in captivity. While numerous researchers have evaluated various aspects of rhino behavior, much is yet to be learned. To date, it also remains unclear whether significant differences exist across species in either the form or frequency of behavior. Therefore, the following ethogram is a collection of general rhino behaviors, is not delineated by species and is not comprehensive. It is intended that captive managers use this ethogram as a descriptive guide to rhino behavior to assist in day to day management. Our understanding of rhino behavior will undoubtedly expand as systematic research continues.

GENERAL BEHAVIOR (may be associated with more than one context)

Locomote	Moves about
Wallow	Rolls or moves about in an area that is wet or muddy
Forage	Searches for food such as hay, grain or grass
Object toss	Tilts or lifts inanimate object off the ground
Horn rub	Rubs against an object with its horn
Head sweep	Has head to ground moving it laterally, rooting air with horn
Hind leg drag	Walks with hind legs stiff and straight
Mouthing	Makes repeated chewing or gumming motion with mouth open; not associated with eating
Nurse	Calf becomes still and suckles; tail may wag

ELIMINATION BEHAVIOR

Urinate	Discharges or passes urine in a stream
Defecate	Discharges fecal material
Hind foot scrape	Rapidly alternates hind feet against ground while remaining stationary; often associated with elimination (before or after urination or defecation)

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Urine spray (*Photo: J. Jacobsen, Fort Worth Zoological Park*)

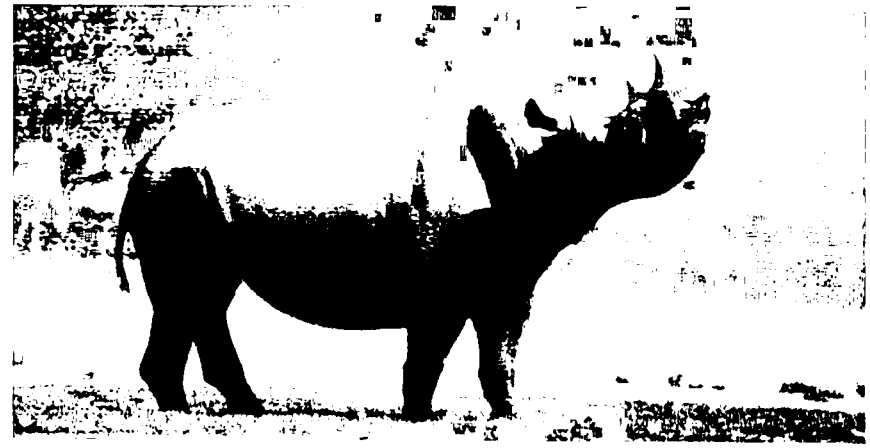
Urine spray/squirt	Projects urine in a strong spray or in distinct squirts (may, though not always, be directed on a substrate)
Urine/feces investigation	Sniffs urine pool or feces
Defecation on pile	Defecates on an area that has been used repeatedly as a dung pile
Social Behavior	
Proximity	Rhinos are within one body length of each other
Face-to-face stare	Rhino is less than one body length from and facing another
Touch/rub/lick	Touches, rubs or licks other animal
Follow	Locomotes to remain within close proximity (1.5 body lengths) of another animal
Charge	Locomotes rapidly with head lowered toward another animal
Chase	Locomotes rapidly with head lowered toward another animal and follows in pursuit at a trot/run if other animal retreats
Open-mouth threat	Threat in which rhino faces another, opens mouth and may bellow, also associated with charge/chase behavior
Spar	Rhinos use horns in offensive or defensive manner, may contact heads/horns and move laterally
Horn strike	Rhino strikes another with its horn
Gore	Pierces or wounds another with its horn
Vocalization	
Call	Vocalization resembling a cry (may be emitted in anticipation of food or upon physical separation from another animal)
Snort	Vocalization in which air is forced through the nasal passages, sounding like a sigh, usually aggressive in context

Face-to-face stare (*Photo: Fossil Rim Wildlife Center*)

Bellow	Vocalization during a charge or other aggressive confrontation, sounds like a snort but much more intense, sometimes accompanied by open-mouth threats

Reproductive Behavior

Flehmen	Raises head and curls underside of upper lip up; often seen in males in response to estrus females
A/G investigation	Sniffs anogenital region of other animal
Erection	Penis is in erect position
Penis unsheathed	Male has partial erection
Stand	Female remains stationary during a chin rest or mount
Chin Rest	Male rests chin on female's back or hindquarters in preparation for copulation
Mount	Male's weight is on hind legs, head over female's withers; copulation posture
Mis-mount	Male mounts female but not in proper orientation
Copulation	Male and female couple or join (mate)
Vulva wink	Female has rapid contractions of vulva, exposing clitoris
Vulva swelling	Female exhibits swelling, color change and/or dilation of the vulva



Flehmen response (*Photo: San Diego Zoological Society*)

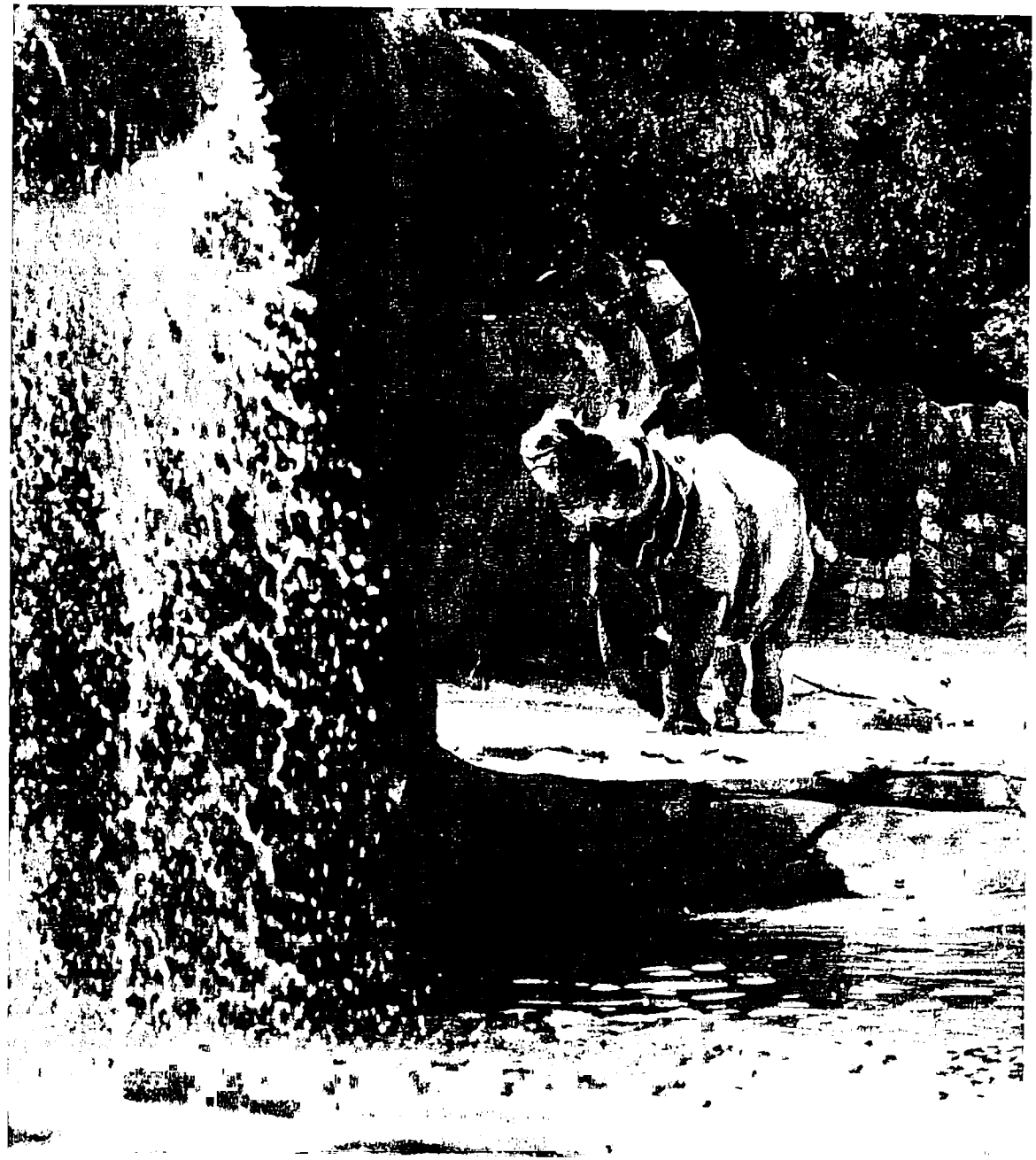
Mis-mount (*Photo: Fossil Rim Wildlife Center*)

(Photo: Rhinoceros Technical Consultants)

APPENDIX III • DATA NEEDED

Despite intensive rhino conservation efforts by zoos worldwide, data are lacking in many basic areas. To facilitate our understanding of rhino biology and behavior, please submit any of the following rhino data to the editors for incorporation into updated editions of this manual.

- Hand-rearing efforts (both successful and unsuccessful) including formulas, dam milk analyses, schedules
- Basic physical data (weights, girth measurements, birth weights and growth data of calves, etc.)
- Narrative accounts of introductions (both successful and unsuccessful), including histories of animals involved, steps, behaviors noted, etc.
- Gestation lengths
- Estrus associated behaviors (both male and female)
- Behaviors associated with sexual maturity
- Developmental landmarks (behavioral and physical)
- Behaviors associated with pregnancy



(Photo: Fort Worth Zoological Park)

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