HUSBANDRY MANUAL FOR THE GREATER ONE-HORNED OR INDIAN RHINOCEROS *RHINOCEROS UNICORNIS* Linné, 1758

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1. PREFACE (G. Guldenschuh)

To date two husbandry guidelines for Rhinoceroses have been published, the *Husbandry Guidelines for Rhinoceroses*, edited by Reinhard Göltenboth et al., published in the EEP Yearbook 1994-95 and the *AZA Rhinoceros Husbandry Resource Manual*, edited by Michael Fouraker & Tarren Wagener (1996). Both guidelines cover all five living rhino species. The Indian or Greater one-horned rhino, however, is in many aspects somewhat atypical. As the International Studbook Keepers and the EEP Species Coordinators we felt the need to have a more specific manual at hand. Using the two general guidelines as a basis, we compiled this mono-specific husbandry manual for the Indian rhino.

The Basel Zoo has been continuously keeping Indian rhinos for almost half a century. So far 27 calves have been born in Basel, including the first captive-born Indian rhino worldwide (male Rudra, 1956). The experiences of a wide variety of collaborators, former and current, of the Basel Zoo, with very different points of view have been summarized in this paper - keepers, technicians, researchers, veterinarians, curators and directors. Further important input came from many other European and American zoos currently keeping Indian rhinos.

These guidelines emphasize the practical aspects of keeping Indian rhinos. In animals with as slow a reproduction as the Indian rhinos, it is often impossible to give recommendations based on statistically sound data. Many observations have been made only a couple of times over a keeper's professional life. Nonetheless, they can give us hints about how to improve our understanding of these beautiful creatures. However, intuition, common sense and good nerves are as important as quantifiable facts if you want to keep Indian rhinos successfully.

2. CONSERVATION STATUS & TAXONOMY (G. Guldenschuh)

The historic distribution of the Indian or Greater one-horned rhino *Rhinoceros unicornis* Linné, 1758, covered the huge floodplains of the Indus, Ganges and Brahmaputra on the Indian subcontinent (Pakistan, India, Nepal, Bhutan, Sikkim, Assam, Bangladesh, Myanmar). Today, their remaining population is restricted to two little areas in the northeast of their former range, one in southern Nepal, one in Assam. The Nepalese (western) population has an estimated number of 652 individuals of which about 600 live in the Chitwan Valley National Park. The Indian (eastern) population counts about 1'868 individuals of which about 1'649 live in the Kaziranga National Park, giving a total of 2'520 animals in the wild in the year 1999 (Foose, van Strien & Rookmaaker, 2000).

The very restricted ranges of distribution, the loss of habitat, the genetic bottleneck the species has gone through (only less than 100 animals survived the century-long massacre) and the still relatively small size of the slowly recovering population make the Indian rhinos still very vulnerable to inbreeding problems and epidemic diseases. Also poaching is an ongoing vital threat: the losses to poaching between 1986 and 1995 are an estimated 450 in India and 50 in Nepal (Foose & van Strien, 1997).

The worldwide living captive population of the Indian rhino in the year 2000 counts 137 animals (72.65) in 50 institutions. 39 specimens come from the wild, 98 (56.42 = 72 %) are zoo born (Wirz-Hlavacek, 2001).

3. BEHAVIOR & MANAGEMENT (G. Guldenschuh)

Indian rhinos are basically solitary animals, seldom grouping except for cow-calf pairs. If there are groupings, they are in general either all female or all male at wallows or grazing areas.

3.1. GROUP SIZE

It is recommended that average sized zoos keep one to three females and one breeding male. Extremely large facilities like ranches, safari parks and the like may maintain an even higher number of females, or, from a genetic point of view, may want to keep several, separated pairs allowing more males into the reproductive process. Only under urgent circumstances and for as short a time as possible should single individuals be kept since they are most likely to develop stereotypical behavior.

3.2. GROUP COMPOSITION

In average sized zoos the females may be kept on the same outdoor enclosure, usually separated from the breeding male except for mating (see 3.3.3. Introductions of a Female to a Male for Breeding Purposes). Extremely large facilities may keep numerous females along with the breeding male on an ongoing basis.

Considering the endangered status of the Indian rhino and the small number held in captivity, it is strongly recommended that all animals be held with the intent of breeding. Exhibit-only animals should be limited to those males over represented in the gene pool and pre- or post-reproductive males or females.

The keeping of bachelor groups may be possible, and in the future even necessary, although it has not been attempted to date. A potential advantage would be bulls reaching full maturity in the absence of females and corresponding pheromones (see also 3.5.4. Offspring Management).

3.3. INTRODUCTIONS

Because Indian rhinos are primarily solitary and territorial, great care must be given when introducing animals to one another. Proper introduction procedures can minimize injury from aggression. Animal disposition, enclosure size and design (see 4.1. Outdoor Enclosures), personnel experience and competence, and general environmental conditions (such as high temperatures, slippery ground, construction site noises, and so forth) must be taken into consideration. These factors will influence the time requirements for introductions. Aggression should be expected in all introductions, regardless of the sex, age or disposition of the animals involved.

It is strongly recommended, physical introductions take place on the largest available enclosure, preferably outdoor. Before animals are introduced they should have the opportunity of getting familiar with the enclosure to be used.

Besides the curator and the head keeper a veterinarian with immobilization equipment should be present for first-time introductions, with a possible need for additional keepers for observation and animal safety purposes. Experienced rhino keepers armed with whips or other noise producing instruments might be positioned at trouble spots (such as a dry moat). More serious interventions may require high-pressure fire hoses, electroshock devices, CO_2 fire extinguishers and / or, on larger facilities, vehicles for separation of the animals. Never try to intervene by stepping in physically. An aroused bull in a mating frenzy would not give in to any attempt to stop him and he might even attack. Although they may not look like it, they are very, very fast! If a barn is opened and used to separate individuals, only one animal should be allowed to enter a stall and must not be allowed to become trapped by an aggressor. Even when fighting escalates, aggression may quite effectively be mollified by widely distributing preferred food (browse, apples, bread, carrots, etc.) throughout the enclosure.

It is necessary for the enclosure to provide ample space, visual barriers and hideout, ensuring escape with no opportunity for an animal to be cornered or trapped. Smaller enclosures should be designed with central structures (rubbing rocks, pools, etc.) as run-arounds (see 4.1. Outdoor Enclosures). It is recommended to drain deep-water pools and fill them with substrate to prevent injury. On the other hand, shallow pools filled with water are ideal 'buffer zones' to slow down pursuits and to cool down the 'opponents'. To avoid dry moat accidents, visual barriers or electric wires (if the animals are familiar with them) should be positioned at the moat edges. These should already be in place, as a newcomer gets familiar with an enclosure prior to introduction.

3.3.1. Introduction of a New Female - or Subadult Male - to Female(s)

In preparation for physical introduction provide first auditory and olfactory, followed by visual contact between the newcomer and the established female(s). Next, allow tactile contact through bars. If an animal displays prolonged stress-related behavior including but not limited to excessive pacing, running, vocalization, and / or escape attempts from its stall, introduction should revert to the just previous level. Before actually being physically introduced the animals should no longer show aggression toward each other. In average sized zoos it is recommended introductions begin with the most 'sociable' and 'obliging' individual of the group. On larger enclosures a newcomer may be introduced to an entire group directly.

However, it should be noted that successful introduction of individuals is largely dependent on the introduced animal's personality. Introductions should be avoided if any involved female is in estrus.

At facilities where animals usually stay together 24 hours a day, newly introduced animals should be left together as long as supervision is available. If it is necessary to separate them at night for either supervisory reasons or climatic conditions, it should be for the shortest period of time possible. This will help to settle the newly established hierarchy quicker given it will not have to be re-established anew every morning. Maintain a high level of monitoring until aggressive behavior subsides.

3.3.2. Reintroduction of a Female with a New Calf to Female(s)

Cows with newly born calves are reintroduced to the other female(s) between 3 weeks and 3 months (with an average of 6 weeks), depending on the mother's group rank and her maternal experience. A cow-calf reintroduction follows the same procedures as a new female introduction (see 3.3.1. Introduction of a New Female). It is preferable for safety reasons for the cow-calf pair to acclimate to only one individual female at a time. For these physical introductions the pair should be first on the enclosure with the other female allowed access only after the cow-calf pair has relaxed.

Special precautions must be taken regarding pools and / or water moats to eliminate the risk of a calf drowning.

If two or more mothers with calves are on the same enclosure, some calves might try to feed on several females. Close observation is needed because some cows react pretty aggressively toward such attempts.

3.3.3. Introduction of a Female to a Male for Breeding Purposes

Whenever possible connect the female's enclosure with the male's, but only if two large gates create a 'run-around' situation. If this is not possible, use the largest enclosure available. In preparation of the physical introduction, both animals should be allowed to get familiar with the enclosure(s) to be used. If the enclosure is not his own, the male should be given the time to mark it. Dung heaps should not be removed. In preparation for physical breeding, the female should be first onto the joint enclosure, eliminating the possibility of an overly enthusiastic male from pushing the cow back into her stall and cornering her.

Successful breeding is a timing issue. The duration of estrus is only 24 hours. When (often in the early morning) a female is observed displaying suspected estrus behavior (raspy 'whistling' breathing, frequent urination and nervous pacing), the potential breeding pair should be allowed visual and tactile contact. If the female's breathing becomes more labored with urination increasing to frequent squirts (every 15 to 20 seconds) and the male shows interest, the physical introduction should be immediately pursued (see 3.4.2. Estrus and Courtship). If your bull is known to be aggressive and rambunctious, delaying visual and tactile contact a few hours is recommended. This has proven effective in calming down the bull during the courtship process. It is common to observe a bull responding more strongly to a female during the two days prior to peak estrus. A possible explanation might be that in the wild a solitary female would need to attract males to her in time for mating at peak estrus.

It must be stressed that, particularly in Indian rhinos, successful mating is often preceded by several hours of aggressive behavior that sometimes escalates into serious wound inflicting fighting that may get out of control at any stage. It is a cyclical process of aggression (with the male charging, chasing and / or sparring with the female, and vice versa) and recovery (one or both lying down, often with the still standing animal prodding the other to rise). Preparations should be made for any necessary intervention given the aggressive nature of the courtship. However, do not intervene too quickly; profusely bleeding superficial wounds should be expected and are a natural part of the Indian rhino courtship. In general, young and / or inexperienced males tend to be pushier and more aggressive than older more experienced bulls.

Patience is essential given courtship is a long process that may take many hours, with actual mounting and copulation often occurring late at night. Install in advance a powerful source of illumination so you can continue to monitor the activities in the enclosure after dark. At the conclusion of a successful copulation (which usually lasts for about an hour (see 3.4.3. Copulation) the animals are so exhausted they usually separate willingly and are easily led to their stalls.

3.3.4. Reintroduction of a Post Partum Female to a Male for Breeding Purposes

Allow the cow a one-year break after delivery before rebreeding her. If the management of your bull requires an earlier breeding (see 3.5.6. Specific Breeding Recommendations), wait at least one estrus cycle (two or three cycles are better) before the re-breeding. The calf should be separated from its mother before the bull has access to the cow. This separation has to be trained beforehand to keep the calf from constantly calling its mother (see 3.4.5. Calf Development).

After a stillbirth or a calf's death shortly after birth, 3-4 estrus cycles should pass before reintroducing the female to the male, especially if the cause of death is not clear. This allows to diagnose and treat any hidden infections prior to the cow's next pregnancy. Furthermore, the success rates of matings are lower shortly after births and stillbirths. Considering the relatively high level of aggression during courtship and mating, it seems reasonable to limit attempts to periods of high potential for conception.

3.4. BEHAVIORAL ASPECTS OF REPRODUCTION

Indian rhinos in captivity have a possible 40-year life expectancy; in the wild it is in the range of 30 years. In captivity, bulls show no drop in fertility throughout their lives. Females in captivity reproduce between the ages of 4 and 32 years, with a declining reproduction rate starting in their mid-twenties. The average generation time is 15 years (Wirz-Hlavacek, 1998).

In the wild, birth intervals are about 3 years. The mother and her calf stay together until the cow's following birth; when she will, for at least a few months, not allow her now grown-up offspring to get close to her and the new calf. Following this period, the cow, recognizing her offspring lifelong, will tolerate them in her vicinity when she would normally chase another rhino away. Her tolerance will be greater for her daughters than her sons.

3.4.1. Sexual Maturity

In the wild, the Indian rhino will reach sexual maturity at approximately nine years for males and five for females. As recorded in captivity to date, with ages approximate, males have successfully fertilized at six years and three months and a female has become pregnant at two years and eleven months, giving birth at the age of four years and 77 days. However, a three-year old female is not yet full-grown and a big bull may be too heavy for her.

Seemingly, rhinos' sexual maturity is trending to be earlier the longer the species is kept in captivity. For males, a contributing factor may be the unnatural absence of dominant older bulls.

3.4.2. Estrus and Courtship

Based on data currently available, estrus cycle lengths have been recorded from 34 to 48 (58) days, differing from individual to individual. This broad time frame needs to be looked at cautiously since estrus is not always easily recognized or readily noticed. However, for a breeding female the recurrence of her cycle in regular intervals is more important than the length of her cycle in days. Peak estrus lasts only 24 hours; experienced personnel familiar with the animals can be helpful in managing breeding preparations by recognizing the early, subtler indicators of its imminence.

Over many years at least two females at Basel Zoo have shown a 'double estrus' in the sense that they display signs of estrus for one day, have a break of one to three days, and then go into full estrus for 24 hours. Some bulls show more interest during this 'pre-estrus' than during the real heat. This 'pre-estrus' might serve to attract bulls over a great distance, to draw them into close proximity ensuring availability during the short real estrus.

The first symptoms of estrus include 'whistling', more frequent urination, indifference to food, and restlessness (such as an animal lying down but almost immediately getting back up). It should be noted that some females have gone directly into peak estrus within 30 minutes, displaying none of these early indicators. If animals are kept separately at night, an imminent peak estrus is easily recognizable from the state of the stall in the morning: the walls will be marked with urine; the food trampled and not eaten; and bedding material will be wet and in a state of disarray. Peak estrus signs are labored, raspy 'whistling' breathing, frequent (every 15 to 20 seconds) spraying and squirting of urine, nervous pacing, and vulva swelling with winking and occasional mucous discharge. Intensity of these signs will most likely differ from animal to animal and should not be viewed as an indication of breeding readiness or fertility: It does, however, make it more difficult to recognize an individual animal’s onset of peak estrus.

Bulls usually only show signs of interest in females at estrus. During visual and tactile contact (see 3.3.3. Introduction of a Female to a Male for breeding purposes), they will, in no particular order, start the same 'whistling' breathing, to spray urine frequently, to display a 'flehmen' response (a grimace like uplift of the upper lip) and to show a partial erection. Upon physical introduction, bulls usually start chasing the female with short interruptions for genital inspections and licking, nudging her with

their horn, and trying to rest their chin on her rump. During courtship, the role of aggressor will change between the male and female numerous times. Coincidental with genital inspections it is common for both sexes to attempt to lift their partner from behind by lifting their head between the hind legs or from the side by hooking their horn in the hind leg skin fold. Lift attempts are also made from the front in similar fashions. Horn use by Indian rhinos in aggression during breeding is not as dangerous as for African species since their horns are shorter and, at least in captivity, blunter. Instead, their protruding pair of very sharp, lower incisors more frequently inflicts deep wounds. While chasing and pushing their partner, animals often chafe against enclosure structures causing minor bleeding from superficial abrasions, with common injuries ranging from scraped skin knobs to the loss of large epidermal patches. These wounds usually look much worse than they are. Of greater concern is the possibility of the bull flipping the female over (risk of breaking vertebra) or pushing her into the dry moat. Depending on the depth and width of the dry moat, it might be advisable to cover the bottom with straw bales.

However, courtship does not have to be aggressive at all. Occasionally, bulls, especially older ones, may quickly lose interest. After an initial charge and a few circlings, they prefer lying in the shade or standing in the pool, leaving the female to take the active role. It may take hours of prodding and encouragement to 'persuade' the bull to actively continue the courtship.

3.4.3. Copulation

The bull will only develop a full erection when mounting the female. The penis is long and slender, capable of probing for the female's vulva. Nonetheless, it may take him some time to enter her. It is not uncommon for failed attempts to lead to repeated mounts. Full copulations average about an hour (ranging from 30 to 80 minutes, usually late at night), with ejaculations every few minutes. At conclusion, the animals show signs of fatigue and, usually, are easily separated and lead to their stalls.

3.4.4. Pregnancy and Parturition

Indian rhino gestation lasts an average of 479 days, with records indicating a range of between 459 and 496 days (Samuel Zschokke, in Wirz-Hlavacek, 2001). The *AZA Rhinoceros Husbandry Resource Manual* (Fouraker & Wagener, 1996) mentions 516 days as the longest known gestation period.

Pregnancy in Indian Rhinos can be monitored using fecal steroid analyses (Schwarzenberger et al., 2000). Two fecal samples per week should be collected over a period of 8 weeks (frozen) and then be sent to Franz Schwarzenberger (see 10. 3. Addresses for Further Requests).

One month before parturition teat size increases, which is more visible in previously suckled mothers. Also in this time frame, the first movements of the fetus may be visible. Two weeks prior to birth there is further enlargement of the teats with a development of wax plugs. Sometimes, an early swelling and dilation of the vulva may be observed. 48 to 24 hours before birth, the udder grows rapidly; the female becomes increasingly more irritable and restless (frequently laying down and standing up), and loses interest in food.

Indicators of early labor, which may last for hours, include the rhino behaving as if very uncomfortable; pacing; laying down first on one side, then the other, and rising up again almost immediately; pushing her rump against walls or bars and then inspecting the area with her nose and lips; vocalizing; frequently urinating and performing a flehmen response; and, in some instances, beginning to drip milk.

Hard labor is marked by more and more intensive contractions during which the cow often lies on her side; lifting her upper hind leg, and bearing down, coincidental with the contractions. At this time, her vulva becomes fully dilated and will often have a mucous discharge. At some point during hard labor, water break will occur. It then usually takes 1-2 hours, sometimes as little as 15 to 30 minutes, until birth. Deliveries very often occur at night, frequently in early morning hours.

Although births are usually headfirst, breech births are not uncommon. The actual delivery of the calf happens very quickly once the fetal envelope shows. The mother is usually lying during birth, seldom standing. Upon delivery, she immediately stands up, turns (tearing the fetal envelope away) and nuzzles her baby. The fetal envelope may dangle from her vulva until the placenta is discharged, usually right after the birth. In many cases the mother ingests both.

For the infant to be able to stand up, it is necessary to prepare a non-slippery floor surface, especially, if the birth happens on smooth stable tiles. Since hay and straw are often pushed aside during a birth, the use of sand is recommended. It is more effective and can easily be applied locally around the infant while it is trying to get up; but spread only by a staff member the mother is comfortable with given the sensitivity of the moment.

Mothers should be given as much peace and quiet as possible. Only persons the animal is familiar with should be present; and even they should stay away from her unless urgent medical or technical problems arise. The house should be closed to the public. Background disturbances as well as foreigners may cause the female to hold back. Avoid all changes in surroundings that are familiar.

Video cameras are very useful for observing the mother without disturbing her. Use equipment with high light sensitivity so you can work without additional illumination. To allow the mother to get familiar with it, install the camera a few weeks before the expected birth date.

3.4.5. Calf Development

Average birth weight is 64.3 kg (44 to 90.6 kg, n = 36) (Samuel Zschokke, in Wirz-Hlavacek, 2001). And, to date only single calf births have been observed.

Calves commonly get on their feet within 15 minutes, but may take 1 to 2 hours before being coordinated and balanced enough to walk.

First nursing normally begins within 2 hours of birth but can take up to 24. Sometimes a calf tries to suckle at walls, bars and so forth before discovering its mother's teats. Suckling usually begins with the mother upright and the calf standing under her belly. Later the mother may lie on her side with the calf suckling from an upright lying position, in which the infant may fall asleep. During the first few days a calf drinks about every hour for 3-5 minutes, later every 1½ -2 hours for 4-7 minutes.

The calf has to learn to follow its mother reliably before the cow-calf pair should go onto the outdoor enclosure. This may take 3-5 days.

It is recommended that a calf between 4 and 6 weeks of age be separated from its mother for short periods of time, e.g. 10 to 15 minutes for cleaning the stall. Determination of when to begin this training should be based upon the mother's disposition. With time, the length of separation should gradually be extended. Mother and calf will soon get used to it. It will facilitate the daily handling of the animals and will help to separate the calf during the rebreeding of its mother.

When the mother is in estrus, her milk production drops and she becomes irritable and temporarily disinterested in her calf. These behavioral changes are short-lived so intervention is not required. The calf will start to eat solid food within a few days, especially fruits. These attempts are more playful pastime than eating. Solid food will be ingested after about one month. For at least six months, it will stay dependent on its mother's milk at which time weaning is possible, but not desirable for any other than well-being issues. An infant should not be separated permanently from its mother before it is at least one year old.

Wait three to four weeks before giving a calf access to pools, especially when there are parts deeper than the calf is tall. During this 'dry period' shower the calf regularly with temperate water.

First defecation seems to take place between two and ten days of age, but is hardly ever detected. Since a calf often defecates immediately upon entering water, its feces are usually first seen by a keeper at this time. The calf's 'milk' feces are a very light brown roll that remains floating, and are noticeably different from an adult's dung.

It is normal for a calf to gain an average of 1.9 kilograms (n = 10) per day for the first eight to ten weeks. But there are pretty remarkable individual differences; the increase in weight may be as little as 1.5 kilograms or as much as 2.2 kilograms.

Although rare, it is occasionally necessary to hand rear an Indian rhino calf. When there is a need, it most often arises out of the infant's failure to nurse, the mother's rejection of the calf, or medical problems of either the mother or infant. Hand raising an infant must be considered very carefully. And, unless the mother shows aggression toward her calf or has medical problems, the infant should always remain with its mother. Separation for bottle feedings is necessary only if the mother is kept hands-off (see 7. Hand Rearing).

3.4.6. Reproduction by Artificial Means

To date the techniques for artificial insemination for the Indian rhino are still being developed. Great progress has been made in the last couple of years with Black and White rhinos.

Indian rhinos are quite easily bred, in contrast to extremely rare species such as the Sumatran rhino. So at this time pursuing artificial means of reproduction for Indian rhinos is not a priority. If, however, an easy and successful technique is developed, it could be used to further the efforts of greater gene diversity within the captive population as well as to introduce new genes from the wild, without additional animal removals, into the captive population.

3.5. MANAGEMENT

3.5.1. Identification

Although the captive population is small and the Individuals can quite easily be identified, it is recommended to implant transponders soon after birth behind the left ear. Transponder identification numbers need to be reported to the studbook keeper. Distinguishing traits (such as scars, uncommon pigment variations, ear irregularities, etc.) should be documented through photographs and / or drawings. If an animal is transferred, these records, or copies of them, should go with the animal to the new facility.

3.5.2. Keeper Training and Interaction

Indian rhinos can be kept hands-off or hands-on depending on the facility's policy, with enclosure design consistent with the chosen method.

In very large facilities the hands-off method is standard. In average sized zoos Indian rhinos can quite easily be kept hands-on, and in large facilities at least some hands-on training is recommended. A day-to-day, set-routine interaction with the animals will facilitate medical and foot care, introductions, births and separations. Usually Indian rhinos are quiet, gentle and easy to handle but they have their moments and show only subtle signs of growing irritation. The animals should not be taken complacently. It is crucial for an experienced keeper to teach keeper-trainees what to look and listen for and what action to take. A well-designed enclosure will provide many possible escape routes for keepers, especially considering rhinos are not very talented jumpers or climbers (see 4. Design of Enclosures and Housing). A keeper should always take a whip onto the enclosure (for cracking only and not for striking the animal). Although one keeper can handle the daily regimen on an outdoor enclosure, for safety reasons there should always be at least two staff members present when action must be taken in an animal occupied stall (for example, wintertime foot care).

3.5.3. Keepers' Regimen

3.5.3.1. The Daily Regimen

- Ensure drinking water is always available and change it, if it is not supplied by an automatic fill or continuous flow device.
- Clean and disinfect the drinking trough to inhibit algae and bacteria growth.
- Provide straw and/or hay ad libitum and distribute the other food items (see 6.1. Food and Feeding) throughout the day in small portions.
- Clean natural substrates and hard-surfaced areas, by raking, sweeping or hosing as appropriate.
- Clean indoor housing surfaces.

- If it is necessary to keep the animals indoors for weeks at a time during the winter months, give animals permanently or at least once a day access to the indoor pool. When an animal does not have access to the pool due to technical or management reasons, it should, at least, be showered with temperate water.
- Indian rhinos are particularly sensitive to hay and straw dust; consequently, special attention needs to be paid to minimizing the dust in their environment (see 5.4.3. Lungs).
- Following a well-structured daily time pattern will facilitate the handling of the animals tremendously.
- In hands-on facilities, approach, caress and speak to lying animals often: this enables them to become familiar with your voice and touch, and it builds trust. This is very important for foot and veterinary care.
- Keep a daily log of animal behavior, needed maintenance and technical problems.
- This regimen is undoubtedly not practical for very large facilities with free ranging herds. Their requirements, such as the need to remove dung heaps, turn the soil and scatter manure to reduce parasitic loads, and so forth, are very different. They would best be dealt with by each facility based on their individual circumstances, like size of enclosure and herd, climate, etc.

3.5.3.2. Work to Do as Conditions Dictate

- Change water in indoor and outdoor pools, timing dependent on number of animals, frequency of use, size of pool and climate.
- Provide, as often as possible, manipulative objects, hidden food items, hung browsers, and so on; varying, at least every few days, locations, times and applications (see 3.6. Enrichment).
- Mud wallows, although of great benefit to and absolutely loved by the animals, are stinky, ugly, fly attracting hygiene problems. Keep them as clean as possible and replace the really dirty parts regularly to prolong the intervals between renovations.
- Keep an enclosure's substrate in good maintenance to prevent health problems resulting from the ingestion of sand, pebbles or stones by an animal.
- Prepare for and be present at (or on stand-by for) introductions, births and transfers.

3.5.3.3. Seasonal Variations in the Regimen (in Temperate Zones)

Indian rhinos should be left outside as much as possible, temperature permitting. To lock them outside, a minimum outdoor temperature of 10-15° C is required, with consideration given to sun, wind chill and rain. If exposed only for a short period of time (e.g. for cleaning purposes) in dry weather conditions, temperatures may be as low as 5° C. Do not let them out in icy conditions, not only because of frostbite, but also because of slippery footing.

In warmer climates, indoor housing is not essential, even when night-time temperatures get close to freezing, as long as daytime temperatures warm the animals up again (air temperature above 20° C) and there is shelter against rain and wind. Rhinos suffer from long-term exposure to temperatures around or below 10° C, especially when combined with rain, high humidity or wind chill. In these conditions indoor housing is vital and should be heated to 18-20° C, locally even to 24° C. Although the indoor temperature may drop to approximately 13° C during the night, it should heat back up to 18-20° C during the day, and with young calves to 22-24° C.

During the cold season, water pools should be drained (and eventually filled with substrates to avoid falls); mud wallows should be dredged out.

3.5.4. Offspring Management

It is necessary for breeding facilities to have the space capacity for holding offspring for up to at least 3 years. Cow-calf pairs need to be held separately for a period of time after birth until such time that they may be reintegrated with the other female(s) (see 3.3.2. Reintroduction Cow-Calf). Male offspring may stay with their mothers and other females for 5 to 7 years, until they start displaying early sexual behavior and harassing the females. Young unrelated males who are ultimately to mate with the present females, should be held separately once they reach 5-7 years of age, when they start showing interest in females' dung heaps and begin spraying urine. If not separated, they might develop a 'mother-son' or a 'sister-brother' relationship with the females, which could cause behavioral problems at mating time. Ideally one would keep two young males of about the same age together until they reach sexual maturity and start fighting. Female offspring can remain in the herd, if in compliance with the studbook recommendations and if the breeding bull is not the sire.

3.5.5. General Breeding Recommendations

The following general breeding recommendations are based on the SSP® central dogma (Dee, Foose & Willis, 1994):

1. The first priority is to breed individuals of lowest mean kinship. The genes of these individuals are underrepresented and, therefore, these individuals possess the rarest alleles in the population.
2. Among individuals with low mean kinship, the second priority is to breed with those whose alleles may be lost soon, i.e. with individuals nearing reproductive senescence.
3. During pairing, pair individuals according to the following ordered criteria:
   a) Mate individuals with roughly similar mean kinship to avoid combining rare and common alleles in offspring, which reduces long-term gene diversity
   b) Mate individuals whose offspring will have low inbreeding coefficients for the best probability of viable, healthy offspring
   c) Maximize mating success on the basis of the knowledge of age of individuals, mate-choice, social structure, etc.
   d) Minimize logistic difficulties (distance and cost of transport of individuals, quarantines, interinstitutional conflicts, etc.)

3.5.6. Specific Breeding Recommendations

It is recommended that successfully breeding males becoming over represented in the gene pool be periodically exchanged with genetically important but so far underrepresented bulls, in accordance with the studbook keeper. Currently, the four best-represented founders have contributed more than half (53.3%) of all genes found in the living captive-born population. Therefore, breeding with individuals imported from the wild and with offspring from underrepresented founders should be encouraged; these individuals can be identified by their low mean kinship values (Samuel Zschokke, in Wirz-Hlavacek, 1999).

Although the number of Indian rhinos in captivity is still very low, an average birth interval of 3 years is recommended over a cow's reproductive life, with progressively longer intervals, as she gets older. Further, the female's estrus cycle will restart shortly after the delivery of a calf, but a wait of at least one year is recommended before re-breeding. A possible disadvantage to this yearlong wait without a new pregnancy is that during each estrus the cow may have short-term behavioral changes, becoming irritable and disinterested in her calf. It may also lead to a bull going berserk while the cow is in heat, especially if they are kept in close proximity to each other. So, re-breeding may be an option after 2 or 3 estrus cycles if you have an easygoing male. But, if there is a risk of serious injury during breeding because your male is young and rambunctious, it might be preferable to deal with the bull and wait the longer time period.

3.6. ENRICHMENT

3.6.1. Structural Enrichment and Furniture

Enclosure design can be the first step toward animal enrichment with greater complexity creating more stimulation. A variety of structural features, like pools, mud wallows, sprinklers, rubbing posts and rocks, visual barriers, dirt mounds, etc. will improve the potential for animal well-being. Manipulative items such as logs, laying or suspended, boomer balls, tires and large plastic drums for pushing, and whole trees fixed at one end on a raised rock or other hard surface for lifting by horn or shoulder will extend periods of physical exercise. Artificial items (balls, tires, drums) have the same enrichment value to the animals as natural ones but are questionable from the educational point of view. Care should be taken when introducing items to easily frightened or nervous animals.

3.6.2. Behavioral Enrichment

The grouping of animals on an enclosure provides a very stimulating enrichment; in average sized zoos the grouping of females on a single enclosure and in the larger facilities by holding the male with the females. A calf will generate much interest and activity; consequently its inclusion in the group, as soon after birth as possible (see 3.3.2. Reintroduction of Cow-Calf), is encouraged. Where males are held separately, further enhancement comes from enclosure swapping between the male(s) and female(s), with dung heaps left in place. In the least, allow male-female visual contact and olfactory access.

Food is an ideal enrichment tool. Although Indian rhinos are more grazers than browsers, browse branches and mulched branches spread throughout the enclosure will keep rhinos busy for a long time. (Make sure that no poisonous species like Acacia have been mulched.) Miscellaneous food items hidden in the substrate, with time and location varied, will also help keep the animals occupied. Hide food on hard surfaces that are covered with mulched branches to avoid the ingestion of sand or pebbles while the animals are digging for the hidden items (Neugebauer, 2000). Food, like apples, beets or salad, floating in the water pool will often evoke play behavior, especially in calves and subadults. Branches fixed in solid steel or concrete tubes in changing locations on the enclosure will keep the animals busy much longer than browsers lying on the floor.

Also operant conditioning training (see 3.8. Rhinoceros Training) can be a nice additional change in the animal's daily routine.

3.7. MIXED-SPECIES EXHIBITS

Some facilities have successfully created mixed-species exhibits, including birds and hoofstock, on outdoor enclosures. It is critical that there is sufficient exhibit space structured with adequate refuge areas and visual barriers. The dispositions of the individual animals involved are also crucial.

At 'The Wilds' in Cumberland, Ohio, they kept single Indian rhinos together with a wide variety of hoofstock, e.g. a female IR with Bactrian camels, Onager, Urial sheep, Pere David's deer and Banteng (on 25 hectares), or an IR bull with Bisons, P-horses, Pere David's stags and male Musk ox (on 50 hectares). Exept some playful chasing of a Banteng by the cow, no interspecific interactions were observed, (Mark Jacobs, pers. com., 2000).

3.8. RHINOCEROS TRAINING

There are, of course, different levels of training, from getting the animal used to being touched to having it obey voice commands to ultimately a full operant conditioning program (OCP). Fouraker and Wagener in the *AZA Rhinoceros Husbandry Resource Manual (1996)* describe both voice commands and operant conditioning in length. Indian Rhinos seem to be as trainable as other rhinos; therefore, there is nothing specific to Indian rhinos to add. A high level of training will definitely help to facilitate procedures like blood collection, ultrasonic tests and general veterinary care. But to date, at least in Europe, only few institutions run a full OCP, because it requires time, much coordination and cooperation among staff members, and a lot of expertise.

Nonetheless, a few basic training steps, helpful in daily handling and foot care, can easily be accomplished.

Rhinos are very 'conservative' animals; therefore, consistency in daily routine and training is paramount. Basic training should first be carried out by the person closest to the animals, usually the head keeper. Once the commands are reliably executed, additional personnel may be included.

For daily handling teach your rhinos a few basic commands. Fouraker & Wagener (1996) recommend the following voice commands:

Move up	to make the rhino move forward
Back	to make it move back
Over	to make it step over
Steady	to make it hold its position
Come	to make it come to the keeper
Foot	to make it present its foot
All right	to release the animal

Of course, you can use any kind of commands, as long as you use them consistently and as long as they are easy to distinguish. It might, nonetheless, be helpful to use these standard commands (even in non-English speaking countries), to avoid a mix of 'command languages', when animals are transferred to other institutions.

Only train one animal at a time. Always start the training at the same time and in the same specific part of the enclosure. Work for ten to thirty minutes per day per animal. Train a command until it is reliably executed before using it together with other commands. Reward the animal with apples, carrots, bananas, pellets, etc., whenever it performs the desired behavior or at least an approximation of it. Always combine a reward with an affirmation like 'good' or 'well done' and, if possible, with a tactile stimulation like caressing or patting. (Many Indian rhinos love being stroked between the front legs, in the skin folds behind the shoulder or between rump and hind legs.) Do not reward if another behavior is performed, even if this behavior is performed correctly. Only reward during the training sessions.

If your institution runs no training programs at all, at least make sure foot care can be performed without sedation (see also 5.1. Foot problems). With this aim in mind, use every opportunity when an animal is lying on its side, to approach it. Talk to avoid startling it. Reward it when it stays down. Start touching, patting, rubbing and caressing the animal and reward it when it lets it happen. Lean on it (with the necessary respect, they are incredibly fast when getting up!). When the animal gets more and more familiar with this close contact and relaxes (which may take weeks), include another person, still without performing any foot care. Only when the rhino 'trusts' both people (no quick head rising, no snorts, no standing up), may you start working on its feet. Make sure you do not touch sore spots during the first couple of treatments. The second person feeds and caresses the animal and watches for signs of annoyance, because the person working on its feet has to concentrate on his or her work. Females relax when you knead their teats; in males you caress the preputium. But when doing so beware of the hind legs: rhinos can kick very violently and incredibly fast should the treatment hurt.

3.9. SHIPPING PROTOCOL

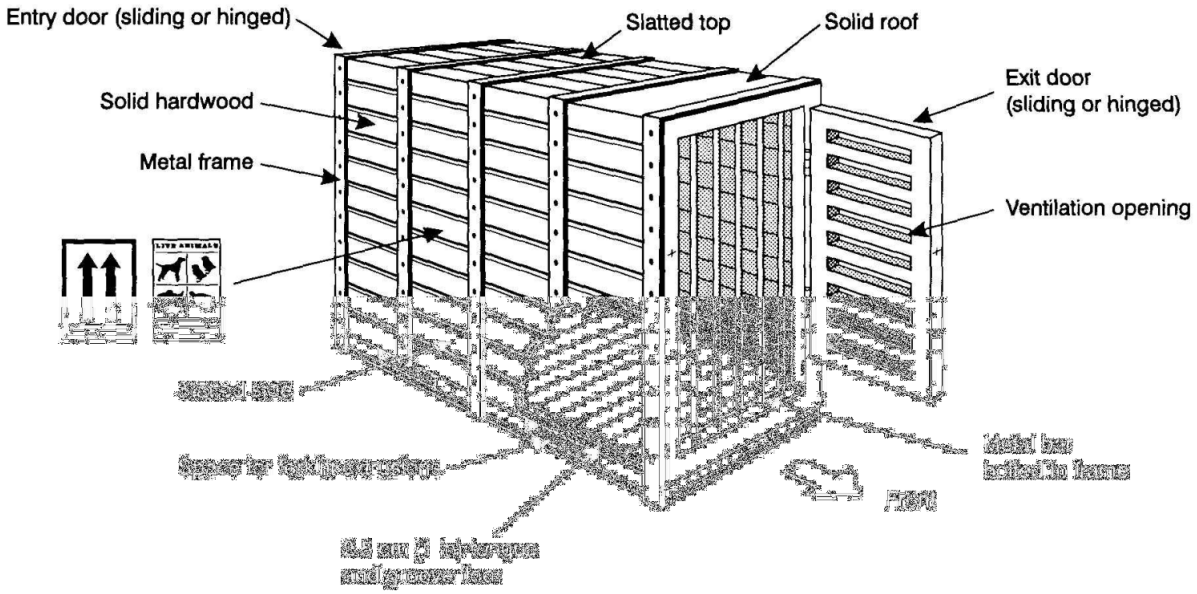
Adult Indian rhinos are extremely powerful, with average males weighing from two to three tons. Do not attempt to force them into a crate. It is highly recommended to either go through crating training or sedate / tranquilize the animal before the procedure.

3.9.1. Pre-Shipment Legal and Medical Procedures

As an Appendix I species, Indian rhinos require CITES export and import permits. The international traffic of rhinos, as odd-toed ungulates, is relatively simple compared to even-toed ungulates. Most governments require no or only very few medical examinations. Some may ask for TB tests, brucellosis serology, fecal screens for salmonellosis or endoparasites. In special cases vaccinations for clostridial diseases, leptospirosis or rabies may be required.

3.9.2. Design of Crate

This paragraph and the construction plan have been taken from the IATA Live Animals Regulations (2001) with only slight modifications (see bottom of paragraph).



The International Air Transport Association (IATA) defines the crate design specifications. Check the newest specifications when planning a transport; they are regularly reedited. Crate dimensions are determined by an animal's size.

3.9.2.1. Materials

- Metal & hardwood

3.9.2.2. Principles of Design

- Strong metal frame lined with solid hardwood sides. Vertical metal bars[1] should be bolted in place at entry and exit with sliding or hinged wooden doors on 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[2] and slatted over the loin and hindquarters for ventilation.
- 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[3].
- The floor must be at least 2.5 cm thick tongue-and-groove or its equivalent and be provided with a smooth but non-slip surface.
- For airline transport, the container must be constructed in such a way that the floor and lower sides are leak-proof [4].
- In view of the diversity in size, strength and temperament of the individuals, the size and strength of the container must be sufficient to restrict the movement of and restrain the animal. Dimension must be large enough to prevent cramping without allowing unnecessary movement. In general the crate should be 30 cm longer and wider than the animal when it is lying on its side.
- Only nuts and bolts should be used in the construction of 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 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.

3.9.2.3. Recommended Modifications

[1] The crate's design should allow for the vertical bars at the head end to be inserted individually (see below, 3.9.3. Crating Training), with a heavy-duty security device keeping them from slipping out.

[2] Indian rhinos develop an incredible power when they slam their head and horn upwards. Make the roof above the head VERY strong and solid! Thick plywood would be a good choice.

[3] The wooden exit door with the ventilation openings should hang in hinges that can be opened on both sides, making it possible to remove the door completely. This is important when the crate stands in the confined space of a cargo airplane with no room for swinging the door open.

[4] Most airlines will require a waterproof crate because of the amount of urine. This is difficult to achieve in the heavy crates needed for rhinos. Discuss in advance the possibility of putting the crate onto a heavy plastic foil or a tarpaulin, covered with wood shavings or sawdust, which is tied up half a meter around the crate.

3.9.3. Crating Training

Crating training should always be given preference to sedation / tranquilization. Indian rhinos are always eager to eat and will do almost anything for a tidbit. Intensive training will require 7 to 14 days, depending on the animal's personality and its general level of training, whereas, acclimation done by the keeper in addition to his normal daily regimen will take up to six weeks. It is recommended that the trainer / keeper accompany the animal during the whole transport.

If you have the structural possibility, let the animal move from the indoor housing to the outdoor enclosure through the crate, opened on both ends, heavily strutted, and fixed so it cannot be moved. The animal should not have access to the sides of the crate from the outside.

As the first step of acclimation, let the animal just walk through both ways for a couple of days. It helps tremendously when a trainer permanently stays with the animal, coaxing it with voice commands and giving additional rewards combined with affirmations like 'good' and patting (see 3.8. Rhinoceros training), whenever the animal walks through. Later make it stop in the crate by offering preferred food items like browse, apples or bananas. It is essential to have a crate with heavy steel bars at the forward end, which can be inserted one by one (see 3.9.2. Design of Crate). Train the animal to hold position in front of a single steel bar leaning against the frame in the center of one of the openings (voice command 'steady'), reward it, take away the bar and make it move forward and out again (voice command 'move up'). Increase the number of bars. Include two staff members in the training program as soon as the animal reliably executes these steps, both will be needed to close the entry door of the crate once you really get serious. It is paramount that only these three people, the trainer and the two staff members, are present during the actual crating process: no trucks, forklifts, journalists, cameras, flashlights, etc.!

If a walk-through situation is technically not possible, fix the crate securely along an enclosure wall and make sure all metal frame parts and bolts are covered, rounded or flattened, because the animal might take the crate as structural enrichment and try to move or lift it. Next, give the animal its daily amount of grass, hay, straw and browse near the crate's entrance, gradually moving it deeper and deeper. Continue as described above.

3.9.4. Crating with Chemical Sedation / Tranquilization or Immobilization

For completely untrained and especially for 'hands-off' animals sedation / tranquilization with an anxiolytic agent (Diazepam, Acepromazine or Haloperidol) might be helpful. You may also want to keep a certain level of tranquilization during the whole transport to avoid self-damaging hyperactivity (see 5.9. Sedation / Anaesthesia).

Full immobilization (e.g. with etorphines like M 99® or LA Immobilon®) should only be chosen if all other alternatives have failed, because the gentle handling of a lying two ton animal would be rather difficult and pushing it into a narrow crate would hardly be possible without causing abrasions or even more serious damage. Minor immobilization, where the animal can still walk, is a dosage problem (see 5.9. Sedation / Anaesthesia), but with some experience it seems to work pretty smoothly (Fouraker & Wagener, 1996). However, after an immobilization, an animal should be observed for renarcotizing symptoms for 24 hours, before it is loaded for the transport, or a veterinarian should accompany it.

3.9.5. Transport

At least a light tranquilization of an animal is recommended for transports taking longer than a couple of hours. Even a quiet animal tends to throw tantrums when annoyed; and can easily injure itself, even break its horn, when banging its head against the roof of the crate.

Adequate climatic conditions during transport are important since Indian rhinos (especially if sedated or tranquilized) may develop a thermoregulation problem. Therefore, use open trucks only for short distances in moderate climates. For longer land transportation and in very hot or cold weather conditions, an enclosed, climate controlled truck is necessary. Air transport is recommended for trans-oceanic relocation because ship transport takes too long.

Do not accept aluminum air cargo boxes. They would lead to overheating and ventilation problems.

Make sure in advance that the cargo hold of the airplane will be heated. Freighters often cool the hold because of perishable goods like vegetables or fruits.

Accompanying keepers or trainers should carry the necessary amounts of tranquilizers (see 5.9. Sedation / Anaesthesia), in case the animal gets annoyed or excited. Indian rhinos will always accept tidbits, even in a state of heavy agitation. Therefore, oral application of a tranquilizer, for instance in a banana, is pretty simple.

Carry large amounts of carrots, apples, bananas, hay, etc., because you can always soothe even a very bad-tempered Indian rhino with a considerable load of favorite food. Be careful with food if the animal has been sedated / tranquilized for crating. Check first with the responsible vet. Also, large quantities of water are important, not only for drinking, but also for showering the animal, if necessary, to cool it down.

4. DESIGN OF ENCLOSURES AND HOUSING (G. Guldenschuh)

Enclosure and housing design for Indian rhinos requires careful consideration with varying levels of complexity being dictated by the purpose and composition of the group. Installation of several connectable in- and outdoor enclosures, separation facilities, pools, mud wallows, run-arounds, shelters, visual barriers and so forth will be dependent on if the animals are kept for breeding or exhibition only; or in the future as bachelor groups (see 3.1. Group Size and 3.2. Group Composition).

4.1. OUTDOOR ENCLOSURES

Indian rhinos should only be kept in latitudes where they can stay outdoors for the greater part of the year, at least during daytime.

Since adult Indian rhinos, and especially the males, are pretty territorial, at least two outdoor enclosures are recommended. In Germany and Switzerland, minimal legal outdoor requirements are in the range of 500 m^2 for two animals and another 150 m^2 for every additional individual. (Once weaned, calves have to be considered adults for purposes of determining space requirements. Facilities should be capable of holding offspring for up to 3 years.) Consequently for 1.1 animals at least 650 m^2 useable and accessible surface should be available. A desirable size for 2-3 females with possible offspring lies between 1'000-2'000 m^2. It makes the management of a group of females much easier if part of the outdoor enclosure can be temporarily partitioned off (e.g. for mothers with newborn calves, for a sick individual, for training single animals, etc.). Think big, your group will hopefully grow!

Indian rhinos in the wild spend an average of 70% of the day in the water, feeding and dozing. On land, they primarily walk on soft muddy, sandy or gravelly alluvial substrates. Their feet are highly adapted to this amphibious way of life (see 5.1.2. Causes of Foot Problems in Indian rhinos). Up to 100 % of the mature bulls and more than 50 % of all cows in European and US zoos show serious foot problems; many otherwise healthy bulls have had to be euthanized because of chronic foot infections. Rhino foot problems are mainly due to hard, abrasive substrates; the lack of permanent access to water pools or mud wallows; and improper foot care (see 5.1. Foot Problems).

4.1.1. General Features

Males usually have to be kept separately except for breeding (see 3.3. Introductions and 3.4. Reproduction). Ideally the bull's and the females' enclosures can be connected by two gates for mating.

Animals in separate enclosures should have visual and tactile contact with one another. This will facilitate any kind of introduction.

Olfactory communication is very important among Indian rhinos. Communal dung heaps serve as 'news centers' and they should be respected and even encouraged (they also make the cleaning of the enclosure easier).

Exhibit only facilities should have, at least, an outdoor enclosure and an indoor holding area, both with separation capabilities.

4.1.2. Walls and Fencing

Despite their stockiness, Indian rhinos (especially subadults) can climb and jump over fairly high obstacles. Primary barriers should be a minimum of 1.5 m high.

Solid concrete and rock are the most commonly used materials for walls. The surface of concrete, however, should not be smooth due to the likelihood of the rhinos chafing their horns, causing abnormal wear. Instead shape concrete walls with irregularities: protruding stones, pimples, little crevices, hollows, etc.; rhinos prefer even surfaces for horn chafing. An irregular surface will provide good skin rubbing, and, as a positive side effect, nature-like walls definitely look better.

Both vertical and horizontal fences are possible, but vertical fences have two distinct advantages: In case of an aggression it is much easier for a keeper to get out between vertical bars and the rhinos cannot push their horns under a pipe or cable and uproot the fence. For vertical fences use concrete or wooden posts, or steel pipes; for horizontal fences, steel pipes or steel cables (protected with plastic hoses against horn chafing).

Wooden posts must not be treated with toxic chemicals, such as creosote, as the animals often lick the wood.

All posts, poles, pipes and cables should be spaced no more than 25-30 cm apart. A conflict does exist, however, between the relatively large space needed between two bars to let a keeper get out in case of an emergency and the relatively small size of a newborn calf: It may be necessary to temporarily fix horizontal wooden planks to hold the calf back.

To protect living trees, fence lines, the backsides of pools and so forth, use aprons of heavy rocks, 1.8-2 m wide.

4.1.3. Dry and Wet Moats

Dry moats with vertical walls are not recommended because of the risk of serious injuries should an animal slip, fall or being pushed into the moat.

Much safer are dry moats with a gradual slope, not exceeding 30°, on the animal's side so the rhinos may also use it. The advantage of this type of moat is that the surface of the moat adds to the total enclosure's surface area, the disadvantage being that the animals may lay in the moat for hours, staying out of the sight of the visitors. The floor space in such a moat should be a minimum of 1.5 m across. This area has to be well drained; otherwise you will create an unintentional mud wallow out of sight of the public. The surface substrate of the moat's slope must provide stable footing even under wet conditions, suitable materials being gravel, sand, marl, etc.

Deep, vertical wet moats are not recommended due to the danger of drowning, especially if young calves are kept on the enclosure.

Considering the importance to the animals for constant access to water and the limited available space in average zoos, spacious wet moats (see also 4.1.7. Mud Wallows and Pools) used as primary barriers are an attractive solution from the point of view of blending animal health and well-being with close but safe visitor proximity.

The wall on the public's side should be overhanging, with the distance between the bottom of the moat and the upper rim being not less than 2.2 m and a minimal water depth of 2.0 m. As a secondary barrier you might consider a rim of heavy rocks with uneven, sharp and pointed surfaces to discourage any attempt to climb out of the enclosure. In new-to-build, pool-like wet moats the installation of solar panels to warm up the water would prolong the length of time the animals would spend in the water per day and over the season.

4.1.4. Gates and Doors

Enclosure gates are an exhibit's weakest points. Adequate hinge and lock strengths are very important, with sliding gates being optimal as they may be only partially opened. Gates should be a minimum of 1.5 m wide and 2.2 m high (the tallest living bull in Europe measuring 1.94 m on his hindquarter <von Houwald, 2001>). If a gate uses a bottom track, care should be taken in the design of the track to prevent injuring the animal's feet as they run through gates, for instance during introductions. There should be no gap between the floor and the gate to avoid that hooves can get caught.

Doors connecting indoor housings with outdoor enclosures are usually of wood reinforced with steel; especially the bottom part of a door should be reinforced with steel plates to minimize possible damage. If the animals have permanent access to the door, it might be necessary to cover smooth surfaces with vertically fixed rounded timbers spaced 30 to 40 cm apart, in order to prevent the abrading of the horn. If this is not possible, keep them from the door with a hot wire.

In general, gates between outdoor enclosures are made of heavy galvanized steel pipes. Space between bars should be in the 25-30 cm range to allow keepers to pass through to the other side in case of an emergency.

All gates have to be usable without entering rhino space. Outdoor facilities must have at least one entrance / exit for heavy trucks and maintenance machinery.

4.1.5. Substrate

Because of the frequency of foot problems, a not too dry surface with give that still provides adequate footing is recommended (see 5.1.2. Causes of Foot Problems in Indian Rhinos). Various natural materials such as thick alluvial sand (rounded, not broken), wood or bark chips, mulch or clay are acceptable. Concrete, sharp sand, compressed marl or solid rock are bad for the animals' feet. Concrete and rock should only be utilized in the small locations used as feeding stations; Indian rhinos tend to ingest sand and pebbles which can cause serious health problems, like sand impactions and obstructions of the intestines. Use different kinds of substrates without mixing them, because their quality might change over the seasons (e.g. the influence of humidity and temperature, but also the importance of quickly warming up in the sun and the ability to store heat or to provide sure footing during cold periods).

4.1.6. Drinking Water and Feeding Areas

In hot climates, a single rhino may drink between 100-200 liters per day. Fresh drinking water should always be available and changed daily, or be supplied by an automatic-fill or continuous-flow device. Non-automatic troughs need to be of an appropriate size. Regular cleaning is necessary to avoid algae and bacteria growth. Watering devices should be solidly and smoothly constructed to prevent problems like horn cracks due to trapped horns and foot injuries caused from climbing and slipping, etc.

Provide, at least, as many feeding areas as there are animals on an enclosure. Always give food on concrete surfaces, rocks or on racks to avoid the ingestion of sand or pebbles. At least part of the feeding areas should be sheltered against rain so hay or straw will stay dry (Indian rhinos love rain, but they don't like wet straw or hay).

4.1.7. Mud Wallows and Pools

Mud wallows are highly recommended, in hot climates even a must. They should be sized to provide plenty of space for each animal on the exhibit. Wallows contribute to skin and foot health, thermoregulation and behavioral enrichment (and they are a real attraction for the visitors, especially when there are calves present). Real mud wallows (without a concrete foundation) have to be dredged out at least once a year to prevent contamination. And, because only few bacteria resist direct sunlight, exposure to the sun helps keep a mud wallow healthy. Still, in very hot climates, a shaded configuration is preferable. Given a start with a water hose, rhinos often create their own wallow.

For the Indian rhino, pools are an absolute must. Depending on the number of animals on an enclosure, the pools should have a minimal size of 30-40 m^2 with a depth between 0.9 in the shallow and 2 m or more in the deep parts. When a calf is on the enclosure, pools should be drained to 0,45 m or less in depth. Ramps are better than steps for access. Slopes should be no steeper than 15°-20°. If steps are used, they should have a 20-25 cm rise with a 40-60 cm step depth. Multiple entries into the pool are essential to prevent 'dead-ends'. Design of pools should accommodate cleaning by keepers. Pool substrate should be smooth, but not slippery. Abrasive surfaces flatten water-softened nails, causing hard-to-heal hairline cracks that may extend to the coronary band of the lateral nails (see 5.1.1.2 Cracks in the horn wall). Good results were achieved with two component rubber coatings like Relatex® or Horsefriends®.

4.1.8. Shelter and Visual Barriers

The rhinos must always have the opportunity to get out of the sun and in cooler climates, also, out of the rain. Adequate shelter, natural or constructed, is indispensable. In parts of the enclosure wind protection should be provided, unless the topography of the enclosure ensures that the animals can always find protected spots.

Visual barriers like boulders, deadfall, bushes and dirt mounds are important to defuse potentially aggressive situations. They should be large and high enough to allow an animal to pass from a pursuer's sight.

Critical enclosure design characteristics are visual barriers and escape routes, for the hiding by and preventing the cornering of pursued animals. Although gates can be used as escape routes, any kind of dead-end must be avoided. 'Run-arounds' like rubbing rocks, feeding mounds or water ponds with partially impassable embankments need to be incorporated into the design. If the enclosure is big enough, a hilly layout is advantageous as it allows animals to get out of sight of their co-inhabitants naturally.

4.1.9. Additional Furnishings

Several scratching posts or suitable natural or artificial rocks should be provided. Deadfall or logs buried upright in concrete sewer culverts and fixed with gravel, produce easily replaceable and natural-looking rubbing posts.

At least one feeding station should be equipped with a mineral salt lick.

4.2. STANDARD INDOOR HOUSING

The following recommendations are for institutions in temperate climates with a distinct winter season; indoor housing is imperative for climate zones where the temperature may drop to under 15° C for days in a row. In subtropical climates, where even in winter the animals can spend some hours on the outdoor enclosure and have daily access to a pool and / or a mud wallow, the requirements for the housing facilities are less stringent. The recommendations regarding the substrate remain the same.

Undoubtedly, near future developments in Indian rhino husbandry will lead to a new concept of Indian rhino housing; with it becoming more similar to modern elephant housing in which groups of females are in a free-roaming in-house situation, with the possibility of single boxes for overnight. The following recommendations are for already existing or to-be-rebuilt facilities (standard facilities). Under 4.3. you will find recommendations for built-new housings (future facilities).

4.2.1. General Features in Standard Facilities

The minimum space recommendation for each animal is 25 m^2, each stall wall being at least 5 m long. If an animal is to spend an extended period of time indoors (hard, long winters), more space is required. Every animal needs a stall of its own and one additional off-exhibit stall should be at the manager's disposal. An additional 50 % of adult space should be provided when a calf is present.

Separate the single stalls with solid walls (concrete or wood) to avoid visual contact between the individuals. These walls should be no less than 2 m high. A minimum shed height of 3.5 m leaves at least 1.5 m open-space for acoustic and olfactory communication.

For training and medical purposes, the construction of the facility should allow safe access to the animals from the front (commands) and the side (manipulation).

To prevent the chafing of horns on concrete walls and other flat surfaces, rounded timbers should be vertically mounted, spaced 20 to 30 cm apart. All mounting nuts and screws must be countersunk to prevent injuries. Although less common, horn chafing may also occur along wall edges.

Corridors used by the animals to go to the outdoor enclosure or the indoor pool should be no wider than 1.6-1.8 m to keep, at least, adult animals from turning around. One side of the corridor must be of vertical pipes or bars giving the keeper an emergency exit route. Long corridors should have pipe or bar doors that can be closed after the animal has passed.

Sliding or hinged steel pipe doors are recommended for between the stalls and traffic corridors (see 4.1.4. Gates and Doors). The pipe door of a cow-calf stall must be equipped with a heavy but easy to fix, smooth wooden panel that covers the lower inside part of the door and keeps newborn calves from walking out between the pipes. For the off-exhibit separation stall, a similar panel should be ready for covering the inside of the whole door to keep an agitated animal from hurting itself between the pipes.

In stables open to the public, a fence or a dry moat can be the primary barrier (see 4.1.2. Walls and Fencing and 4.1.3. Wet and Dry Moats). Vertical moats should be made safe with an additional steel cable-fence or with a rock apron and must have exits on both sides, especially if the bottom is too narrow for an animal to turn around. When animals have access into a sloped moat, it is important to keep enough distance between visitors and rhinos to make public feeding difficult.

Maintaining indoor temperatures at between 18-20° C, with calves between 22-24° C, is recommended. Humidity should be kept at no less than 60%. At Dvur Králové Safaripark (Czech Republic), where winters are pretty long, they keep the indoor temperatures between 15-17 ° C, trying to avoid too large differences between indoor and outdoor temperatures. So far no animal ever showed rhinitis or respiratory problems (Kristina Tomášová, pers. com.).

Adequate ventilation, with 4-6 air exchanges per hour, must be provided. Ammonium fumes should be drawn off near the floor, but without causing a draught. Floor heating, if used, should cover only 30-40 % of every stall, thus allowing the animals to choose their most comfortable temperature range.

Equip all indoor stalls with solid troughs. Self-operating water sources are not recommended indoors because individual stalls without automatic-fill devices allow for easy control of the water consumption of every animal. Troughs must be easy to clean and refill. The water should be at room temperature.

It is very practical for one stall to be equipped with a door, against which a crate can be placed, without blocking any passageways: an animal to be transported in winter can be trained to feed in the container.

In temperate climates, provide Indian rhinos with an indoor pool of at least 30 m^2, ramp or steps included (see 4.1.7. Mud Wallows and Pools). The water temperature should not drop below 18-20° C, the optimal temperature being 22-24° C.

Since rhinos have very sensitive hearing, houses should be acoustically muffled to deaden loud noises from the visitor's area.

4.2.2. Separation Capabilities in Standard Facilities

Facilities should have an off-exhibit stall of approximately 45 m^2 to isolate cows with newborn calves or to quarantine sick animals. Both of the following options should be available for the door, open steel pipes for visual and maybe even tactile contact and, if needed, a smooth, solid surfaced panel mounted on the inside of the steel pipes to keep an agitated animal from hurting itself.

4.2.3. Substrate and Bedding in Standard Facilities

Ideal stable floors for Indian rhinos have 'give'; and are non-abrasive, non-slippery, well draining while holding some humidity, and should be easy to clean. Polyurethane floor coverings like Tartan have most of these desirable characteristics but have a tendency to crack and peel off under the ongoing impact of a two- or three-ton animal standing up or lying down. Better results were achieved with two component rubber coatings like Relatex® or Horsefriends®. Hoofed-stock rubber matting works, but some animals may play with it and chew it to shreds. In addition, rubber matting is very heavy and, therefore, difficult to move for cleaning under. The best results you will get when you glue them directly to the floor. Stable tiles like Stallit or brushed or broom-finished concrete floors have a rough surface, getting even more abrasive when they get corroded by power washing machines or by fruit acid (food on the floor). When rhinos are recumbent, rough floor covers cause a thinning of their lateral nails that lead to hard-to-heal cracks; the injuries gape apart with every step due to the animal's heavy body weight. Additional straw or hay bedding is recommended to avoid foot problems. The floor should slightly slope into a drain.

4.2.4. Special Features

Video cameras may be helpful for observing the animals during introductions. They are recommended in the cow-calf stall to observe mothers in labor without disturbing them (see 3.4.4. Pregnancy and Parturition).

Access to a scale is desirable and strongly recommended, best positioned in a race-way doubling as a restraint chute.

All service doors and corridors should be big enough to allow access to little trucks or big forklifts (maintenance and removal of dead animals). Heavy steel rings on the ceiling for block and tackle or even crabs may be helpful during medical emergencies.

4.3. FUTURE INDOOR HOUSING

Facilities in temperate zones planning new housing for Indian rhinos, should consider building a hall where the animals can roam freely, at least during the day.

4.3.1. General Features in Future Facilities

Such a hall should comprise a large indoor enclosure for the cows and their offspring and a smaller enclosure for the bull. Each animal older than 3 years should have a stall of its own, with a cow's measuring 25-30 m^2 and a bull's 30-40 m^2. Further, the bull's stall should be accessible from both the bull's and cows' enclosures. In case a mother with a newborn calf or a sick animal occupies his stall, the bull can sleep in his enclosure.

A corridor between the outdoor and indoor enclosures would aid in the leading of animals into their individual stalls and would also be useful for the placement of a scale and a restraint chute. This walkway may be part of the house or a simple fence construction, depending on the climatic conditions. The restraint chute should be accessible from all sides.

The single stalls would ideally open on one side to the indoor, and on the other to the outdoor enclosure. In addition, there must be a great gate from each indoor enclosure to its associated outdoor enclosure, big enough to allow trucks access to the indoor areas (e.g. to exchange the substrate).

Both indoor enclosures have to be equipped with a pool and, if possible, a mud wallow. To save space, use the pool as a barrier to the visitors' area. To save energy, heat the pools with sun collectors, the water temperature should be in the range of 22-24° C or even warmer (see also 4.1.7. Mud Wallows and Pools).

4.3.2. Separation Capabilities in Future Facilities

Ideally the cows' and bull's indoor enclosures would be connectable with two gates for mating during cold seasons. The bull's stable might serve as a second connecting passage (avoid dead-end situations).

The cows' enclosure has to be temporarily dividable with bars, posts, pipes or cables (see 4.1.2. Walls and Fencing) for births, medical treatments and introductions. Even with this separation in place, at-will access to the pool from each side of a divided enclosure should be ensured.

4.3.3. Substrate and Bedding in Future Facilities

It is advisable - out of practical reasons - to use a rubber coating next to the water, the mud wallow, the exit to the outdoor enclosure and the stalls (see 4.2.3. Substrate and Bedding in Standard Facilities). The remaining area should be constructed as a well-drained hollow, which can be covered with a 60-100 cm deep layer of bark or wood chips.

Depending on the climatic conditions of the facility, the installation of a sprinkler system might be advisable to keep the substrate moist.

4.4. PHYSICAL RESTRAINT DESIGNS

Numerous papers have been published about the design of rhino chutes (Schaffer, 1993; Eyres et al., 1995; Schaffer et al., 1998).

Use of a restraint is facilitated when the restraint area is an active component of daily rhino management, e.g. if the rhinos must pass through it to exit into the yard from the barn. Part of the feed can be offered in the chute area. Finally, more extensive conditioning in habituating rhinos to physical restraint can be particularly effective. Such a program should be attempted prior to detaining a rhino in a chute for an exam.

Indian rhinos have no specific chute requirements. Fouraker & Wagener, 1996, describe in length different types of chutes with all the necessary construction details.

5. HEALTH (F. von Houwald)

Indian rhinos (IR) in zoological gardens are generally considered to be healthy. In some respects this may be true when compared to Black rhinos; however, chronic foot disease (CFD) is becoming increasingly recognized in the captive IR population. The health chapter will concentrate on CFD and other diseases known specifically from IR, as well as on anaesthesia. For general health aspects and physiological normals of rhinos, I refer to the 'health' chapter written by Eric Miller in the Rhinoceros Husbandry Resource Manual (Fouraker and Wagener, 1996). Further 'normal values' for Indian rhinos, such as weight, height, and several other body and foot measurements are listed in von Houwald (2001). Blood values can be obtained from Göltenboth (1995).

5.1. FOOT PROBLEMS

5.1.1. Clinical Findings

IR suffer from different foot problems in zoological gardens (von Houwald, 2001).

5.1.1.1. Cracks between the Sole and the Pad

Description and prevalence

All breeding bulls in European collections suffer from cracks, which form alongside the central sole and the adjacent pad. More than half of the breeding females in Europe are affected by these cracks as well. Over 25 % of the world captive population is recorded to have these problems (von Houwald and Flach, 1998). These cracks occur rarely in young animals (under the age of 5). They often start to develop on the medial side and can reach all the way to the lateral part of the pad. They can extend very deep into the tissue, leading to the formation of granulation tissue and the production of poor horn quality. The exuberant growths of granulation tissue leads to further irritation and prevents the tissue to fully regenerate.

Clinical signs

Clinical evidences of foot problems likely to be noticed, are blood tracks on the floor and exuberant granulation tissue on the sides of the central hoof. Lameness occurs only in severe cases. Under close observation and previous cleaning of the feet even very small cracks become easily visible.

When standing, the animal often relieves the strain on the affected foot by lifting it partly up. Most animals tend to remain recumbent and prefer access to water. Pain appears to be tolerated during mating.

Due to the large amount of granulation tissue forming around the affected areas, some animals start to put more weight on the palmar / plantar part (hind part) of the pad, which can eventually lead to a change in conformation of the hoof and the associated joints.

Diagnostics

Close observation is the most effective diagnostic tool.

On several occasions, swabs have been taken for microbiology. In general the lesions are infected with common bacteria, very seldom with fungi. It is believed that the bacteria and fungi are secondary invaders, and have no role, concerning the primary development of the cracks, but do delay the healing process.

5.1.1.2. Vertical Cracks in the Horn Wall

Description and prevalence

At least 38% of the Indian rhinos in European collections show vertical and / or horizontal cracks in the horn walls of their hooves. They can reach from the coronary band to the sole or can run horizontally across the horn wall. Vertical cracks are more often found in side hooves and can even reach across the whole length of the sole surface (footing surface). They are often not diagnosed since the hooves are covered by dirt. They can appear from one day to the next.

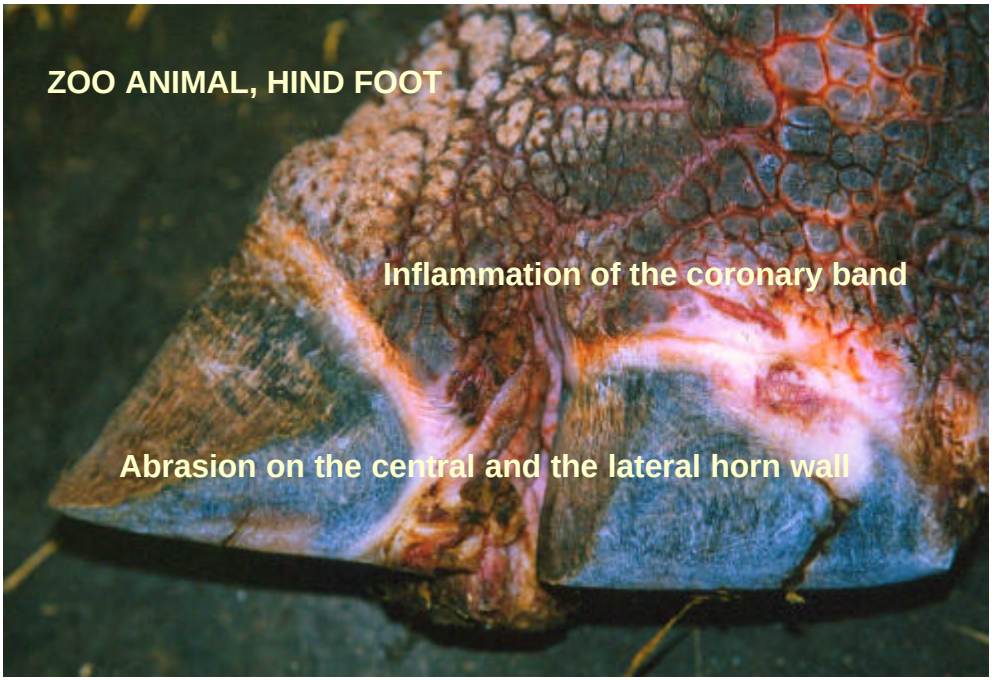
Clinical signs

During ambulation, the cracks open and close due to the weight shift. An infected horn wall can lead to complications such as sole abscesses, 'loose wall' (‘break down’ between the horn and the living tissue), and abscesses along the coronary band.

5.1.1.3. Abraded Horn Wall

Description and prevalence

At least 70 % of captive European IR have abraded lateral horn walls. This is mainly visible on the hind but also on the fore feet. The medial hooves are less affected. The coronary band is often reddened and sometimes infected. Cracks, as mentioned above, are often seen in association with highly abraded horn walls.



Clinical signs

Inflammation and reddening of the coronary band. In general the animal shows no direct sign of discomfort, unless the inflammatory process also includes the horn wall.

5.1.1.4. Ulcers and Lesions of the Pad

Description and prevalence

16% of the Indian rhinos in Europe exhibit ulcers on different locations on their pad. The lesions can reach deep into the subcutis of the pad. While cleaning, one can sometimes follow a track into the soft tissue for several centimetres.

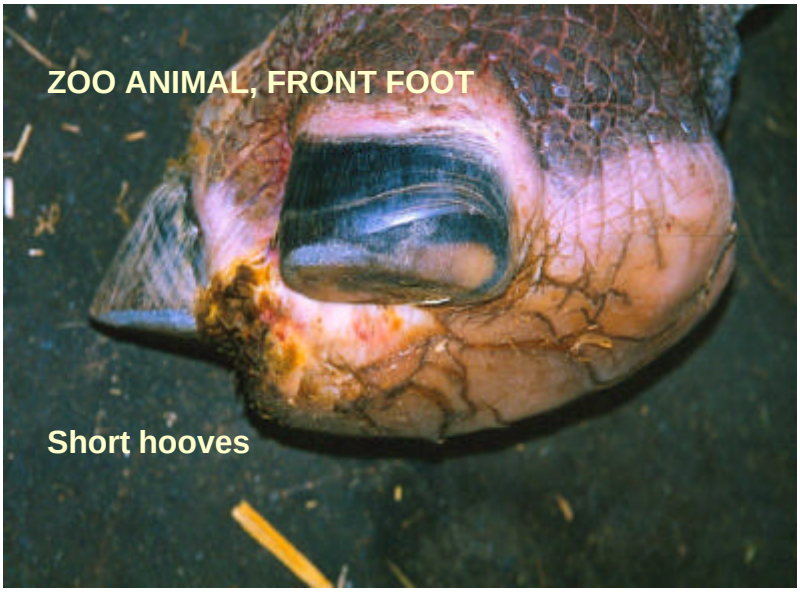
5.1.2. Causes of Foot Problems in Indian Rhinos

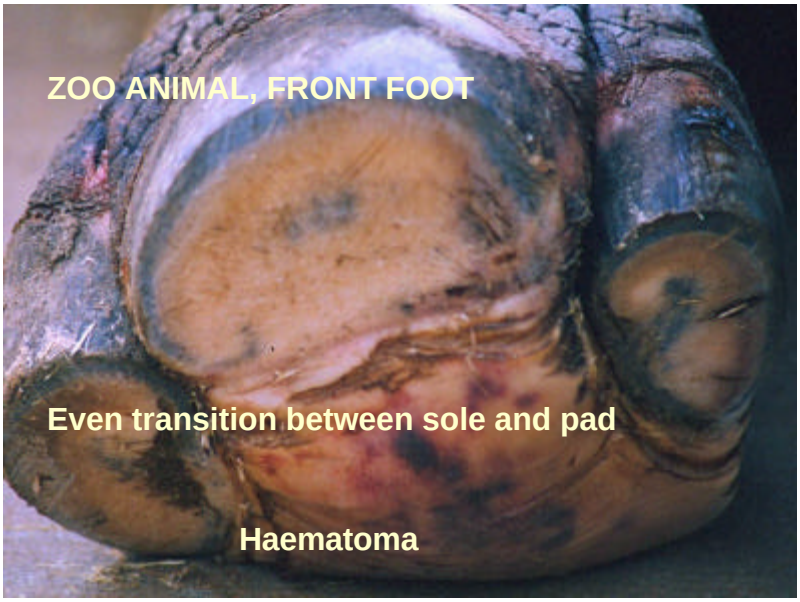
Studies of the anatomical structures of captive and wild Indian rhinoceros feet have helped to recognize the high prevalence and understand the causes for the occurrence of the different types of foot problems in Indian rhinos.

Captive animals

1. They have whitish, flat, and thin foot pads (often affected by haematoma).
2. The horn walls are short.
3. The soles are short, flat, and adjoin the adjacent pad at an even level.
4. The side parts of the hooves (in particular the lateral hooves) are abraded and show white, thin, and flattened horn walls.

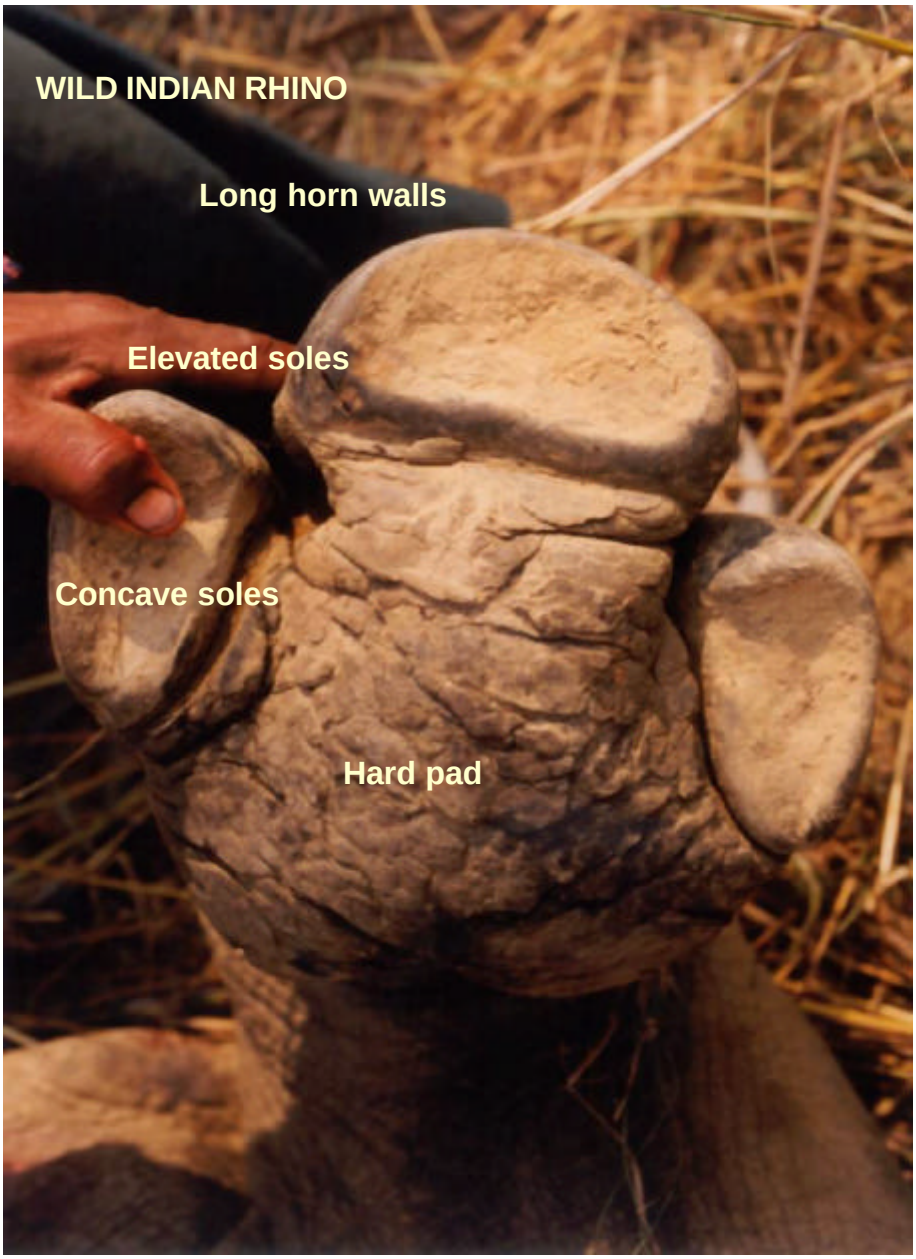

ZOO ANIMAL, FRONT FOOT
Haematoma in the pad


ZOO ANIMAL, FRONT FOOT
Short hooves


ZOO ANIMAL, FRONT FOOT
Even transition between sole and pad
Haematoma

Wild animals

1. The foot pad is grey, appears strong and shows minor cracks. Those cracks seem to be of superficial nature only.
2. The horn walls are long. The side hooves are slightly curved backwards, resembling the shape of a claw.
3. The soles are long and concave. They do not join the adjacent pad at an even level and appear ‘higher’ than the pad. There is a well visible elevated dark rim (2 cm wide) in the palmar / plantar (hind part) of the sole. The main weight seems to be carried by that dark rim and the weight-bearing border of the hooves.
4. Of the feet examined, no signs of abrasion, crack formation or other pathological findings were visible on the side or front hooves nor on the pads themselves. The horn of the horn wall had a shiny appearance.



Histology revealed that the horn of the pad consists of very fine horn tubules and weak intertubular horn cells. In contrast, the horn of the adjacent sole consists of very strong horn tubules, which are arranged in groups. These groups are well visible as a dark rim (the area of the sole adjacent to the pad) and give that structure its great strength.
From the histological point of view, the transitional area between pad and central sole is an area of minor resistance, as two very different horn structures are aligned directly next to each other.

Anatomic investigation showed that the epidermis of the pad is very thin. The maximum height ranges around 1cm.

When comparing wild and captive animals it becomes evident that **wild** Indian rhinos have naturally very strong pads, elevated soles, and long horn walls. They are **'sole-walkers'** as their main weight is carried by the strong horn structures of the soles and hoof walls. The soles are concave and expand during locomotion phases. Almost no weight is put on the front part of the pad.

In **captive** animals the situation looks different. Their footing surface is flat and abraded. They have turned under the current captive situation into **'pad-walkers'**, carrying their main weight on the pad. The front part of the pad is not protected by an elevated structure of the soles and has to bear the massive weight of the animal. Once the pad and sole structures become abraded they are prone to any further impact, such as the high weight, sudden sharp turns, lack of moisture, etc. Those factors finally lead to the development of cracks in those predisposed areas.

5.1.3. Therapy

5.1.3.1. Cracks between the Sole and the Pad

Severely affected animals are very difficult to treat and treatment schemes remained so far palliative. The granulation tissue needs severe débridement. The cracks need to be cleaned and pared out in a way that most strain is taken off that area, when the animal puts its foot down again. These are all attempts to allow the tissue to regenerate. In general this it not possible. The soles are so flat that even with thorough cutting the cracks can't heal properly. Each time the animal will put down its foot the tissue will crack again. In a report by Atkinson (2001), on a long-term treatment scheme, it is mentioned that it was not possible to improve the healing process to 100%. Unsuccessful treatment in severely affected animals led in some zoos to euthanasia. Despite the relatively young age of many animals affected, chronic cases are always associated with a poor prognosis for recovery.

Some zoos manage to keep the problem under control by regularly (every 3 weeks) cutting the small cracks as well as granulation tissue away. This is helpful in milder cases. In general the problem is not resolved, but delayed. Animals can become well trained to tolerate minor manipulations.

In severe cases frequent anaesthesia needs to be performed and it may be the only way to adequately control the problem (Schaftenaar, pers. com., 2000; Atkinson, 2001). It is important to realize that treatment schemes have to be performed quite regularly, even if this means anaesthesia every 6 – 8 weeks. The horn growth is rather quick (about 1cm per month).

Most zoo animals show elongated central hooves in their hind feet. In untrained animals cutting of the horn wall and sole is only possible under anaesthesia. The cutting is often delayed until the horn wall and sole have formed a rather long hoof. At this point interference becomes more than necessary and the long horn walls need to be cut. When doing this, the weight-bearing border becomes well visible as a black line. Under physiological conditions, this black line should always touch the ground. In those cases, where the horn wall looks very long, the weight-bearing border does not touch the footing surface anymore after cutting. The white material underneath is horn of the sole, which is rather weak. In the course of time this horn will wear off, adding to the process of flat soles and feet. It is important NOT to cut the hoof wall too late. If necessary, one should try to cut also some horn of the middle part of the sole away, in order to give it a concave shape. This gives the horn shoe more elasticity.

In Basel Zoo, there are at the moment some investigations underway to find a method of elevating the soles, in order to copy the natural structures of the foot. Previously, wooden blocks have been applied beneath the soles. This has not proven successful on the long run. When using blocks, one has to make sure that all three blocks remain on a foot. As soon as one block drops of, it either has to be replaced immediately or the others need to be taken off at once. Otherwise the animal will put the weight on the pad, adding in the formation of cracks. Applying blocks might be done without anaesthesia but again the animal has to be well trained and there is always a great risk that the animal will get up before the treatment is completed.

5.1.3.2. Vertical Cracks in the Horn Wall

Therapy of vertical cracks should consist of cutting them open by means of a ‘V-shaped’ cut, a technique adapted from hoof care in horses. Close attention needs to be paid to the living tissue.

Therapy of a 'loose wall' or sole abscess requires in most cases sedation of the animal as they are very painful and need aggressive treatment.

Abscesses on the coronary band need to be opened, so does the track below (coming from the sole). It is very important, to find and treat those tracks, otherwise the abscesses will reappear.

Horizontal cracks seem to grow out alone but need monitoring.

5.1.3.3. Abraded Horn Wall

There is no treatment scheme for abraded horn walls. However, one should keep in mind that the thin horn layer of the horn wall (if it is already white instead of black) is VERY sensible. This is important to know, when applying blocks on those hooves by using material that becomes very hot.

5.1.3.4. Ulcers and Lesions of the Pad

These need débridement, cleaning with antiseptical lotions, and application of anti-bacterial and antifungal crèmes.

In general those localised lesions will heal well if they are cut open (funnel-shaped) and monitored regularly. Those injuries result in general from penetration of foreign material such as rocks, flint stones, thorns, etc. They do not seem to correlate with the other pathological changes of the feet.

5.1.4. Prevention

Above mentioned alterations appear due to highly abraded horn structures of the pad, sole, and horn wall. As mentioned, treatment schemes are only palliative and in order to prevent foot problems in Indian rhinos, serious thoughts need to be given to the husbandry conditions in zoological gardens.

The outdoor enclosure should consist of moist, non-abrasive flooring substrates. This can be wood chips (some bark might be eaten), grass, (rounded) sand, earth, mud. A good drainage system helps to avoid that the outdoor enclosure will look like a huge mud wallow in the course of time. It often helps to observe where animals like to spend most of the time. Knowing this, one can use different substrates according to the needs of the animals (mud to cool down, sand to warm up, wood chips to walk on, etc.)

As wild rhinos spend up to 70% of their time in the water, captive animals should have free access to a pool / lake throughout the year. As most animals do not like to go into the water if it is too cold (below 15-18° C) one should consider additional heating systems (solar, etc.) in case it is needed. Animals should not be allowed to go into the water if the outdoor temperature is below 10° C.

In some indoor enclosures a 2 component rubber flooring material has proved successful in the last years. Other materials, mentioned beforehand, are prone to fast degeneration. Despite the fact that this material does not completely withstand the tearing forces of the feet when lying down, it is momentarily recommended as the best solution.

It is easily applied, and broken parts are easily replaced.

Other institutions worked with card box chips, straw, wood chips, etc. With regard to the constructions of most facilities, it is difficult to apply wood chips to the given situation without remodelling the facility. In those cases, rubber seems the better choice. For those institutions that think about building new facilities one should keep the option of wood chips in mind. They have proved very useful in many enclosures.

Each animal should have access to an indoor pool during the day, especially during the winter months, where most animals might have to stay inside for several months.

5.2. SKIN PROBLEMS

5.2.1. Exsudative Dermatitis

Clinical signs

The skin along the medial surface of the hind legs, along the caudal part of the abdomen, and along the edges of the ears looks reddened and show signs of inflammation (it is generally not seen between the skin folds). Pruritus and smelling exudates are often found.

Diagnostic

In several cases microbiology revealed a with mixed infection with:

- ß-haemolytic Streptococci
- Staphylococci without haemolysis
- Malassezia pachydermatis has been reported in rhinos, but seems to occur rarely

One report documented the resemblance of ß-haemolytic streptococci and *S.* dysgalactia by means of biochemical and DNA sequencing tests (Völlm et al., 2000).

Treatment

The following treatment scheme seemed temporarily successful: Bactrim forte®, with a total dose of 4.8 g Sulfamethoxazole + 0.96 g Trimethoprim TMP (containing per tablet: 800 mg Sulfathoxazole + 160 mg Trimethoprim TMP) for 4 days. The skin lesions were treated with Excipcial U Hydrolotion® (emollient in 4% Urea: 1% Chlorhexidine + 2% Clotrimazole + 0.15 % Betamethasone) and a watery inorganic iodine solution (Iodi solutio glycolica, Formularium Helveticum 1.2) (Völlm et al., 2000).

The daily washing with Betadine® soap and spraying with Betadine® solution did not lead to full improvement and stop of pruritus.

In other institutions the recommended dosage for Bactrim forte® is ten times higher than the dose mentioned above (2 mg/kg), i.e. 20 mg/kg. This is given orally, for 5-7 days (Atkinson, pers. com., 2001).

Prevention

The reddening of the skin seems to occur often during the summertime (Göltenboth, 1995), but has also been reported during winter months (Völlm et al., 2000). It is possible that this problem results from too much heat (sweat), increased resting periods, and not enough access to water and / or mud.

Prevention should consist of close monitoring, daily spraying and / or washing of the animal with water and / or the possibility of free access to water and / or mud.

5.2.2. Pustular Dermatitis

Clinical Signs

Multiple pisiform to thumbnail size, seropurulent pustules, which cover most parts of the body. The animal can show signs of apathy and anorexia, but this stage usually appears only in connection with the spreading of the lesion in size and quantity. In most cases the general state of health is not affected.

Diagnostic

Microbiological tests reveal the presence of:

- Staphylococci without haemolysis
- Streptococci with haemolysis
- Other non-specific polybacterial microbial flora (Rietschel, 2000)
- Poxviruses were excluded
- Presumption of herpes, but so far no certain proof exists (Göltenboth, 1995)

Treatment

Depending on the severity, scrubbing with Betadine® shampoo (shampoo works better than lotion, Schaftenaar, pers. com., 2000) for several weeks will help or

Penicillin-streptomycin, corticosteroids, washing with soap-, rivanol- and entozoon-solutions as well as a cover with a sulfonamide-cod liver oil ointment can help the healing process (Rietschel, 2000).

Prevention

It seems likely that insects may be the vector to transmit these common bacteria in indoor / outdoor enclosures. In how far it becomes necessary to use insecticides on the rhinos depends to a great extent on the situation itself.

Other reports mention that flies were not observed to be of any importance.

So far no information exist about the epidemiology and its prevention.

5.3. HORN PROBLEMS

5.3.1. Abrasion / Fracture of the Horn

Almost every zoological garden faces the problem that an animal rubs its horn until it is almost gone (esp. the males), or tries and succeeds in breaking it off.

The former is often associated with stereotypic behaviour and can lead to the demolition of the whole horn (Widuch, 1999). The latter seems to be the result of a trauma. Regarding to literature (Silbermann & Fulton, 1979) horns are easily broken off.

Treatment

Horn will re-grow without any difficulties if the wound is cleaned, disinfected, and all necrotic / broken tissue parts removed. Hygiene is important to avoid maggots to invade the wound, which seems to be a common problem during summer months (Göltenboth, 1995).

Prevention

Stereotypic behaviour is difficult to change and stop. A behavioural enrichment programs is required in order to prevent it from developing at all. To avoid rubbing of the horn (circling / banging the head in front of doors, walls) it has proved helpful to install an electric fence along / in front of the objects of choice. This is only an option for the outdoor enclosure. It is interesting to notice that they tend to rub their horn only against flat surfaces. In indoor enclosures rounded timbers along the wall (see chapter 4.2.1 General features) should be the first choice.

It is important to keep in mind that the animals do need some structures to groom their horn. This is a natural behaviour (Laurie, 1997). Tree trunks for example give rhinos a good possibility to rub body and horn.

5.4. OTHER HEALTH PROBLEMS

The following health problems have been reported but do not seem to be a common problem in this species.

5.4.1. Joints / Bones

Arthritis seems to affect Indian rhinos at old age or due to traumatic impacts (Silbermann and Fulton, 1979). It is interesting to notice that this species seems to be less affected by this problem than elephants or other rhino species.

Osteomyelitis on the second (PII) and third phalanx (PIII) in a front foot has been diagnosed in an old female. *Streptococci equisimilis* were cultured. This infection followed probably a traumatic impact on the front foot (Flach, pers. com., 2000).

Czupalla and Strauss (1997) reported on a case of multiple fractures of thoracic vertebrae in an adult male rhino. This occurred after the animal fell into a moat.

5.4.2. Digestive Tract

5.4.2.1. Teeth

Young animals may encounter difficulties during tooth replacement (Silbermann & Fulton, 1979). The first generation may remain over the next one and this leads to impairment while eating.

Old animals often chew irregularly on their teeth or the teeth have been worn to such an extent that they cannot digest their food.

The symptoms and the treatment are similar to that in equines.

5.4.2.2. Oesophagus

Large food items can lead to the obstruction of the oesophagus with all its known symptoms. Diagnose is only verified when access is possible during sedation (Rietschel, 2000).

5.4.2.3. Stomach

Indian Rhinos may easily be stressed by minor events, undetected things, noises, etc. In several necropsy reports it has been noticed that ulcers developed in the stomach. Those were thought to be associated with stress situations (Göltenboth, 1986).

It is important not only to notice a change of behaviour but also to improve any condition, which might stress the animal. This aspect should be considered when it comes to translocation, introduction of new animals, presence of construction sites, changes in the diet, etc.

Perphenazine has proved very successful in one case to reduce stress (Rietschel, 1998) and it seems to be a good alternative in order to get animals used to an unknown situation.

5.4.2.4. Small and Large Intestines

Several cases of impaction of the colon are reported in the literature (Jones, 1979; Silbermann & Fulton, 1979; Göltenboth, 1995). The ingestion of sand seems to be the main reason for it. The feeding place should be made of concrete and preferably elevated.

Observation of the animals after introducing new material seems the only way to prevent this problem.

Torsions of the colon as well as the small intestine have also been reported. The causes are often not known. In one case it has been associated with mating (Silbermann & Fulton, 1979).

5.4.3. Lungs

Nasal discharge, coughing, elevated breathing, and apathy are common symptoms associated with lung disorders. Since diagnostic work is difficult, first aid therapy often consists of a broad-spectrum antibiotic.

In the seventies, the animals at Basel Zoo suffered from 'Farmers lung' (*Micropolyspora faeni* - chronic interstitial pneumonia), which was associated with the hay. To eliminate the problem the hay was replaced with good quality straw. Since that time, straw is given to the animals after careful preparation (shaking and cutting). Moistening also prevents spores from spreading (Rüedi & Müller, 1975).

5.4.4. Cardiovascular

Sarcoma in the heart and lungs resulted in a sudden death of a Indian rhino (Silbermann & Fulton, 1979). Cardiovascular shock has been reported in an animal during anaesthesia, which suffered from severe foot problems and seemed to be very stressed (Flach, pers. com., 2000). An other animal became recumbent due to severe foot lesions and was not able to get up. He died of cardiovascular shock.

5.4.5. Urinary Tract

One report exists about a suspected case of urinary infection (Göltenboth, 1995).

5.5. BACTERIAL INFECTIONS

5.5.1. Salmonella

Salmonella infantis was associated with the death of a young animal, which suffered several days from diarrhoea and did not respond to antibacterial treatment (Silbermann & Fulton, 1979). In young animals (and esp. wild caught ones), stress associated with transport and the loss of the mother, seems to impair the immune system to such an extent that they become very susceptible to bacterial infection, such as *S. infantis* (Strauss & Wisser, 1995).

Salmonella thyphimurium and *enteritidis* caused the death of adult animals.

Therapy should consist of high dosages of antibiotics (resistance test) and the replacement of fluids. If the animal refuses to drink, the ear vein has proved to be a very helpful place for infusion. The use of an enema is recommended.

5.5.2. Tetanus

This species is likely to be susceptible to tetanus. However, no reports exist. One should consider this aspect when dealing with large wounds or during foot care.

5.5.3. Tuberculosis

Indian rhinos are susceptible to *Mycobacterium bovis* and *tuberculosis* (Silbermann & Fulton, 1979). Since the last 20 years there have been no reports on tuberculosis infections in European collections regarding this species.

5.6. VIRAL INFECTIONS

5.6.1. Herpes

The presence of a Herpes virus in connection with skin problems is still presumptive (Göltenboth, 1995).

5.7. ENDOPARASITES

Anoplocephala gigantea seems to occur quite often in this species. Proglottids in the faeces are easily diagnosed.

Treatment consist of 7,5 mg/kg BW Fenbendazole (Panacur®) or 1 mg/kg BW Praziquantel (Droncit®) p.o. three times in monthly intervals (Göltenboth, 1995; Rietschel, 2000).

5.8. MEDICAL ASPECTS OF REPRODUCTION (F. von Houwald / R. Hermes)

Despite the fact that the captive population is slowly growing it is interesting to notice that some females have never bred successfully in captivity.

5.8.1. Female Reproductive Disorders

Female Indian rhinos become sexually mature at the age of 3 - 4 (5) and have an average cycle length of 44 (34 - 48) days. A common problem in zoos is that the female does not show any overt signs of oestrus (see 3.4.2. Oestrus and Courtship) and / or is not willing to tolerate the male for mating. There are numerous reports in the literature concerning females, who gave birth once or even more often and then never again.

5.8.1.1. Leiomyomata

The most prominent alteration in the female genital tract, which is held responsible as one reason for a reduced rate of reproduction are leiomyomata, benign muscle tumours located in the uterus, cervix, and vagina (Montali et al., 1982; Göltenboth, 1995; Hermes, pers. com., 2001). None of the females affected by these tumours became pregnant as leiomyomata are believed to hinder the sperm transportation, the supply of an embryo with nutrients, and the implantation of an embryo in the uterus. Tumours have mainly been identified during post mortems. The development of leiomyomata in the female genital tract is reported from many other species including humans. It is thought that their occurrence is linked to a permanent oestrogen influence on the genital tract and especially on the uterus originating from an continuous oestrous cycle activity without conception. Advancing age in combination with regular oestrous cycle are thought as reason for the progressive development of these tumours reaching up to 50 kg in rhinos. The pathological mechanisms have not

been elucidated up until now and the whole field still needs more research. Recent advances in diagnostic ultrasound in different rhino species facilitated *in vivo*

diagnosis of these tumours by the performance of reproductive ultrasound examination. The reproductive assessment of all genital organs by ultrasound was used to determine potentially present pathological alterations and to evaluate the remaining breeding potential of a female. Uterine tumours were found in females with regular oestrous cycle as well as in females in which the cycle activity had ceased. Close housing of the male next to the females has been discussed to play a potential role as well (Göltenboth, 1995).

5.8.1.2. Endometritis

Endometritis has occurred in Indian rhinos and was treated successfully with antibiotics and flushing of the genital tract with a disinfectant (Rietschel, 1992). In some cases endometritis was linked to abnormal oestrus cycles and abortion (Göltenboth, 1995).

5.8.1.3. Ovary cysts

Ovary cysts have been reported to occur in Indian rhinos (Hermes, pers. com., 2001). The causes for their occurrence remain still presumptive and it is likely that they stand in close correlation with a hormonal imbalance. In the wild, Indian rhinos cycle maybe 15 times during their whole life. The rest of the time they are either pregnant or are lactating. The wild population cycles therefore every second year, before conceiving again. Under captive conditions most females cycle much more often before they get pregnant. They also become sexually mature at an earlier age than wild Indian rhinos. At the moment research projects are investigating the question in how far cysts and tumours might be related to a hormonal imbalance of the genital tract (Hildebrandt, pers. com., 2001).

Modern reproductive management of rhinoceros in captivity implies the transportation of potential breeders. The described reproductive disorders in female rhinos emphasize a critical need for enhanced reproductive assessment in animals with missing breeding success. This becomes especially important before translocation to other facilities.

5.8.2. Male reproductive disorders

Males tend to have fewer organic disorders than females. A young bull, coming to the zoo at the age of 3 was kept with two females. He did not become sexually active by the age of 7. There is the impression that he regarded the females more like mother / sister than as a potential mate. In how far bulls should not be kept in the proximity of females after weaning is difficult to assess and depends to a high degree on the facilities. If male rhinos tend to show a more docile behaviour and do not reproduce at a certain age after being kept together with females, this might have an effect on husbandry and breeding aspects. This field needs further evaluation.

In contrast to the research undertaken in White and Black rhinos regarding sperm quality and success of breeding (Hermes, 2001) only little research has been per-

formed on the Indian rhino. In the White rhino e.g. it was reported that more than two males housed in one facility induced a status of subfertility in all but one dominant breeding male. Female dominance behaviour over males also reduced sperm production and sperm quality. Some questions such as sperm quality of bulls kept in bachelor groups, might be of great interest for the Indian rhino too. Especially if some facilities would be able in the future to hold a group of young bulls until they become sexually mature.

5.9. SEDATION / ANAESTHESIA

Many zoo rhinos, which are used to humans, are kind and good-natured. They tolerate minor manipulations and will lie down when being rubbed between the legs, stomach, mammary gland, or preputium. Nevertheless, one should always keep in mind that they can be up on their feet within seconds. Chute training can and should be used for minor manipulations such as blood sampling, etc. The following dosages are meant to serve as guidelines. The character of each individual should be considered prior to any procedure. The safety of personnel should be given very high priority, not only due to the nature of the animal but also due to the potential agents used in chemical restraint procedures.

5.9.1. Light Sedation / Tranquillisation

Light sedation is indicated for minor manipulations (blood sampling in untrained animals, translocation, etc.). There are different drugs on the market, which vary with regard to onset and duration of the sedative effect. The choice of drug depends therefore on when and how long a tranquillising effect is desired.

These drugs have been used on a variety of occasions: To reduce anxiety, aggression and capture / transport related stress (Atkinson, pers. com., 2001). The experience with these drugs has shown that they proved highly effective in transports and pre-transport related training. During transportation most animals remained calm, were eating and fewer problems occurred when reaching a new zoo / enclosure / environment, than those which were crated and transported without any drugs. Especially for long distance transportations some of these drugs should be given serious considerations. All drugs have side effects, which are often associated with over dosage. More detailed information on tranquillisation can be obtained from Mark Atkinson, The Wilds, Ohio, USA.

<u>The following drugs are recommended</u>:

Diazepam (Valium®)
0.5-1.0 mg/kg BW per os (Göltenboth, 1995), lasting for 60-90 min.

Azaperone (Stresnil®)
0.05-0.1 mg/kg IM. (Atkinson, pers. com., 2001), 100-200 mg total dose for an adult IR. Will last for 2-3 hours.

Acepromazine (Vetranquil®, Aceprom®, Combistress®, Neurotranq®)
0.5-1.0 mg/kg BW per os (Göltenboth, 1995), lasting for 4-8 hours.

Detomidine HCL (Domosedan®)
8 – 14 mg IM total dose for adult White Rhino alone or in combination with Buthorphanol (Butomidor®, Turbogesic®) 8-14 mg IM total dose. Onset IM 20 minutes, duration 1-2 hours. Can also be used IV at a reduced dosage of 4-6 mg Detomidine plus 4-6 mg Buthorphanol. (Used by Walzer in approx. 60 minor procedures). Can be used as an adjunct in Ethorphine anaesthesia (see below).

Haloperidol USP (Serenace®, Haldol®)
0.05-0.1 mg/kg per os (Atkinson, pers. com., 2001) (max. 200 mg for an adult male IR), lasts up to 16 hours.

Zuclopenthixol acetate (Clopixol-Acuphase®)
up to 300 mg for an adult rhino (Atkinson, pers. com., 2001). Onset of action 1 hour after administration, tranquillisation effect will last for 72 hours.

Perphenazine enanthate (Trilafon LA®, Decentan®)
Average dosage for an adult IR: approx. 200-300 mg (50-150 mg in juveniles and sub-adults). The effects are seen 10-16 hours after deep IM injection, peak effect is usually reached after approx. 72 hours. Duration of this form is described as being up to 7 days (Atkinson, pers. com., 2001).
500 mg (2.800 kg bull) s.c. (behind the ear) were used by Rietschel (1998).

5.9.2. Anaesthesia

General comments
Monitoring of anaesthesia is essential in rhinos. In procedures in which the animal is recumbent, ventilation / perfusion mismatches will occur. Initial respiratory acidosis can furthermore be aggravated through a metabolic component. Minimum monitoring requires the use of a dedicated person and a pulsoxymeter. Ideally sequential arterial blood gas analysis should be performed.

Make sure that both nostril airways are free and off the floor – provide additional oxygen through a nasal tube.

Etorphine-acepromazine (Large Animal Immobilon®)
is the 'drug of choice' for anaesthesia in rhinos and is often used in combination with detomidine (Domosedan®), butorphanol (Turbugesic®), ketamine (Ketaset®, Narketan®, Vetalar®), and xylazine (Rompun®, Xylazine Injectable®). As pre-medication some of the drugs mentioned under 5.9.1. have been used as well.

Others prefer the combination of etorphine, ketamine, and detomidine (Atkinson, 2001). The combination of butorphanol, detomidine, and etorphine was successfully used in White rhinos (Walzer et al., 2000).

There are numerous approaches for anaesthesia in Indian rhinos. The three most common ones are listed here:

APPROACH 1:

Dosages
Some zoos use Large Animal Immobilon® alone (dosages see below) and top up either with ketamine or LA Immobilon® during anaesthesia (Göltenboth, 1995).

LA Immobilon® (per ml: 2.45 mg etorphine HCL and 10 mg acepromazine) 1.2-1.6 ml (2.94 mg-3.92 mg) for an **adult** animal.

In some cases the dosage of LA Immobilon® increased to1.8-2.0 ml (4.32 mg-4.9 mg) for females and 2.5-3 ml (6.13 mg-7.35 mg) for males with the frequency of sedation (Flach, pers. com., 2000).This high dosage can be avoided by combining LA Immobilon® either with a previous dosage of perphenazine (see above) or with ketamine / xylazine or xylazine alone. Stress symptoms were significantly reduced and the combination led to a good anaesthesia.

A 10-year-old Indian rhino female, being eight months pregnant, was safely anaesthetised by using 1.5 ml LA Immobilon® (Schaftenaar, pers. com., 2000).

Ketamine/Xylazine	30-50 mg (each)
Xylazine	50 mg
Perphenazine	500 (300) mg per adult animal, given three to five days prior to anaesthesia, s.c.

Reversal
Diprenorphine (Revivon LA® per ml: 3.26 mg diprenorphine HCL). This drug has agonistic and antagonistic properties. 1 ½ -2 the amount of LA Immobilon® half IV, half IM.
NB! Beware the agonistic properties especially in White rhinos.

APPROACH 2:

Dosages
The combination of etorphine, detomidine, and ketamine had been used successfully in over 24 anaesthetic procedures of an adult male Indian rhino (6-8 weeks interval), (Atkinson, 2001).

Etorphine (M99®)	3.7 mg in combination with
Detomidine	14 mg and
Ketamine	400 mg

All drugs were given together IM. During anaesthesia, ketamine was used (100-250 mg IV) for maintaining a good sedation.

Reversal
Naltrexone (Trexonil®, Trexan®)
It is a pure opioid antagonist, which avoids the problems associated with 'renarcotization' (150-300 mg divided IV / IM).

APPROACH 3:

In White rhinos, the following combination was successfully used in over 80 procedures (Walzer et al., 2000).

Dosages
Butorphanol 10-15 mg per adult animal and
Detomidine 10-15 mg per adult animal

Wait 15-20 minutes, then apply
LA Immobilon® 0.8-1.4 ml

Dosages depend highly on age, state of health, and nature of the animal. In safari park - large enclosure situations - 200 mg ketamine is additionally added to reduce the 'pacing effect' of the etorphine. Animals remain 'glued' to the ground.

Reversal
250 mg **naltrexone** (Trexonil®) and 20 mg **atipamezole** (Antisedan®), given combined IV. Omit the use of atipamezole if you want slight sedation due to alpha-2 agonist post procedure.

Important considerations before and during anaesthesia

- No stressed, nervous animal should be sedated. The risk of fractured bones, pulled tendons or broken horns is high.
- Stressed animals also need a higher dosage for full anaesthesia. This might increase the risks. (One 6-year old rhino died under anaesthesia of heart failure. He had been sedated with LA Immobilon® on several occasions before, due to severe foot problems. He needed increasing doses for induction due to aggression, possibly associated with the pain from the foot lesions. In addition he was topped up as well during anaesthesia (Flach, pers. com., 2000).
- Rhinos tend to push their head between bars when going down. This can be avoided by using appropriate covers of heavy wooden panels. Enough staff should also be available. (The staff has to be experienced, informed about how to proceed and has to be aware of the risks!) The use of adjuncts to the etorphine anaesthesia also reduces the 'head press' effect.
- No slippery substrates should be on the floor for sedation. The animals tend to slip when going down. Rubber mattresses, which cover the whole ground are ideal, sand might prove helpful as well. Straw bales should be available to cover hard edges etc.
- No food for at least one day (esp. hay, straw) ? minimises the risk of regurgitation.

- Helpful tools:
  Straw bales (to assist in comfort when the animal goes down).
  Ropes (to pull / hold the animal in case this is needed).
  Non-translucent blankets (to cover the eyes as soon as the animal lays down).
  Water (to cool the animal under sedation if needed. Immobilisation on hot days should generally be avoided).
- Ear plugs to reduce the effect of noise
- Oxygen (essential in order to ensure adequate supply, especially if the head lies in an awkward position), emergency case (Doxapram®, 10 mg Nalorphine, naloxon, antidote), pulsoxymeter (clip on the tongue, ear or vulva).
- Make sure you have the human antidote naloxon (Narcanti®) ready **before** drawing up etorphine.
- Injection site: muscles of the neck, between the folds, or the medial side of the leg. Use adequate needle length, at least 55 mm.
- After injecting etorphine, it takes on average 10 minutes for the animal to become recumbent.
- Ensure intravenous access (ear veins). Eye ointment should be applied before covering the eyes with a blanket.
- Close monitoring of heart and breathing rate. Average parameter under anaesthesia are:
  - Heart rate: (50) 65-90 / min
  - Respiratory rate: 6-10 / min
  - $Sa0_2$ - mean: 77-89 % (very optimistic at least in White rhinos)
- For surgical work on the feet, straw bales should be available to put the legs on. Hard material should not be used as it might lead to temporary nerve damage as a result of prolonged compression of the neural tissues.
- Duration of anaesthesia should not exceed 1 ½ hours but this it not a general rule! Decision should always be based on monitoring! The first 20 minutes seem to be the most critical ones. In longer procedures ensure that the area underneath the animal is padded with straw / hay, etc.
- Reversal takes about 1-2 minutes (it is possible that the animal becomes 'renarcotized' during the following hours if not enough Revivon® has been applied, esp. when the animal had to be topped up with Immobilon®). By using naltrexone, a pure antagonist, one can avoid the risk associated with 'renarcotization'.

Size and weight

Male:	front: 166-187 cm; hindquarter: 175-194 cm
Weight adult:	2000-2800 kg (max. recorded 3600 kg)
Female:	front: 154-166 cm; hindquarter: 159-170 cm
Weight adult:	1600-2300 kg

6. NUTRITION (F. von Houwald)

6.1. FOOD AND FEEDING

6.1.1. Nutritional Requirements

Indian rhinos eat a huge variety of different plant species in the wild. They are grazers and browsers, which means that they have a higher need for hemi-cellulose and protein than for example a pure grazer like the White rhino. Over 180 plant species have been counted (Laurie, 1978) to make up their seasonal menu.

In the wild high growing, reedy grass is the main food, followed by short grass and some water plants, herbs, shrubs, bushes, twigs, branches, and leaves.

All required essential nutrients should be provided by feeding good quality forage. The diet should be balanced, containing the necessary energy and protein (depending on age, sex and reproductive status) components as well as mineral and vitamin supplementation.

It is estimated that an adult Indian rhino will eat 1% of its body weight daily.

In zoological gardens most rhinos are fed a mixed diet of hay / straw, pellets (special formulated rhino pellets), cavalino (pressed hay), fruits (apples, bananas), vegetables (carrots, salads, etc.), grass, branches, and leaves. Alfalfa pellets should not exceed 20% of the total pellet intake. Pellets should not exceed 1/3 of the daily total intake of energy rations as it can lead to overweight animals. Bread is also not recommended.

The following companies supply specially formulated pellets for rhinos (enriched with Vit. E and biotin):

- EL-E-Vite, Code 853914; Mazuri Zoo Foods SDS, UK
- Pachyderm (Rhino) Supplementary Diet; Mazuri Zoo Foods SDS, UK
- Zoo-Herbivore Pellets, Code: 3691; Provimi Kliba SA, Kaiseraugst, CH
- Herba Rolls Toscana, Code: 5258; Provimi Kliba SA, Kaiseraugst, CH (these rolls contain mainly pressed hay)

Depending on sex, age, activity pattern, and breeding status 2-9 kg of pellets per animal are fed daily. All available food should be examined with regard to their components.

If pellets of balanced dietary requirements are not available the following should be added to the diet on a regular basis:

- Vitamins and minerals
- Fruits and vegetables (apples, pears, and carrots, 4-5 kg per animal per day)
- Branches with leaves

The amount of food should always be monitored and should stand in close correlation to the requirements (growing, sub-adult, lactating female, activity pattern). The distribution of branches on different locations within the enclosure can lead to an increase in activity and is recommended, especially if animals tend to show stereotypic behaviour.

The animals should also be fed several times per day.

6.1.2. Feeding Location

In Basel Zoo straw is given at one spot and all animals (2-3) eat at the same time without showing any aggression. Pellets are given individually in the stables or at different spots in the enclosure. The food should always be offered from a clean surface to avoid the intake of foreign material (sand, stones, etc.), which might lead to impaction and / or obstruction.

Vegetables and fruits can be offered in the pool, mainly for enrichment purpose.

If possible, rhinos should be trained to take bits from the keeper. This proved helpful to control supplementation and / or medication.

6.1.3. Supplements

Licking salt, with or without minerals, should be at disposal at all times. Forage should be routinely tested for mineral content to gain data for balanced dietary demands. Biotin supplementation is provided through the pellets. Some zoos provide additional biotin. It is supposed to harden the horn structures but does not help in the regeneration of cracks within the soles.

6.1.4. Problematic Diets

In Basel Zoo hay was taken off the rhino diet as one animal developed serious lung problems due to *Micropolyspora faeni*, a fungus with a high affinity to hay and lungs. They are fed straw instead. Before the straw is fed to the rhinos it is cut and shaken to get rid of dust, etc. This has been done for over 25 years now with no adverse affect.

In captivity it is common to see overweight animals. Indian rhinos are very susceptible to gain weight as they are very docile and ‘relaxed’ animals. The amount of energy they burn over the day does often not stand in correlation with the amount of food they consume. This is an important aspect with regard to foot problems.

6.1.5. Browse

Encourage foraging, grazing, browsing. It is essential to know that the provided branches / leaves were not chemically treated previously (especially branches from fruit trees, which are commonly fed in winter / spring).

Browsing is very important for the health and dietary demands of an animal and contributes to its overall well being.

Preferred fodder plants at Basel Zoo are: Maple (Acer sp.; Ahorn), Beech (Fagus sp.; Buche), and branches from fruit trees such as cherry, apple, etc. The variety offered depends on the regional availability of certain tree species. At other places poplar (Populus sp.; Pappel), Alder (Alnus sp.; Erle), elm (Ulmus sp.; Ulme), Willow (Salix sp.; Weide) are offered. Plants known to be toxic to the horse should not be fed.

In total it can be stated that more research is needed in order to fully understand the dietary needs (especially with regard to vitamin and mineral supplementation or even basic data such as digestibility, etc.) of Indian rhinos.

7. HAND-REARING (F. von Houwald)

Hand-rearing should be avoided but has been carried out successfully in several cases. A few very practical and general comments on hand-rearing a Black rhinoceros calf are given by Eulenberger et al. (2000). The calf should be intensely taken care of in the first 5 days. The use of an low-fat artificial milk (e.g. Salvana® foal exchanger milk) proved very successful (Rhinoceros milk is very low in fat). An upper limit per feeding is suggested. Access to an unlimited portion of an electrolyte solution (e.g. Lytavit®, Albrecht) should be provided (high liquid demand, up to 25 l per day at the age of about 6 months). The weight should be controlled daily and serves as a criteria for quantity and quality (percentage of milk exchanger and lactose to ease the feeding) of the meal. Faeces as well as the general state of health should be checked continuously. Any case of bacterial imbalance of the gut should be stabilized with an initial substitution of gamma-globulines and para-immunity inducers. Furthermore, it seems advisable to give prebiotics. Antibiotics should be omitted (as far as possible).

Colostrum of the cow in the first 24 hours is surely the best start. Data of milk components are given in Göltenboth (1995). The additional supplementation of the artificial milk with vitamins and minerals is recommended (for data see Göltenboth, 1995; Eulenberger, 2000).

The calves should gain around 2 kg body mass daily in the first weeks. By the age of three months, a calf can drink up to 35 l daily (Puschmann, 1983).

There seems to be a large individual acceptance of hay, leaves, flakes, grated carrots and bananas. Bananas were taken at the age of 12-15 days. Additionally to the milk, boiled rice, flakes, hay, soft fruits, and carrots were eaten from the 4th week onwards (Puschmann, 1983). In another case the calf was trying the feed for the first time at the age of 70 days and ate on its own by the age of 4 respectively 5 months (Wallach, 1969; Eulenberger, 2000). Constipation may occur during hand-rearing. Adding fig juice to the milk may prove helpful (Wallach, 1969). The coming through of the teeth begins at the age of about 70-80 days and may cause mild fever, diarrhoea, and loss of appetite. Providing cool water to wallow may help in those situations (Wallach, 1969).

Some individuals may feel ‘lonely’ when separated from the mother and / or the group. The youngsters might be stressed by this. Giving the calf a companion, such as a goat or sheep has proved helpful in some cases. In other zoos, the keepers kept the calf ‘busy’. Some recommend not to initiate too strong a bonding between the calf and the keeper in order to facilitate the later reintroduction to the group.

8. POST- MORTEM PROTOCOL (John Trupkiewicz)

8.1. GENERAL COMMENTS

Those individuals who may be charged with performing a necropsy examination should formulate a plan of action in the case of the sudden, unexpected death of a rhinoceros. Due to their large body size, the internal temperature will be retained for an extended period post-mortem, so autolysis will proceed rapidly. Also, the animal will have most likely died in its exhibit or holding area, thereby limiting the amount of time available for the post-mortem examination. Even in the case of planned euthanasia, transporting the animal to a necropsy laboratory may not be practical.

All necessary equipment and supplies to perform the post-mortem examination must be readily accessible and prepared for transport to the animal's enclosure. Consideration should also be given in advance to identifying additional pathologists, veterinarians, or other staff to assist with the necropsy – the more assistants, the better. Although one individual will need to oversee the entire post-mortem (generally the institutions pathologist or chief veterinarian), it may also be helpful to divide additional staff into separate teams to assure that all systems are examined and the proper samples collected. For example, 2 or 3 individuals may be assigned to examine the digestive tract, one individual to examine the heart and lungs, one for the urogenital tract, etc. This 'team' approach will reduce the likelihood that samples are overlooked or improperly collected.

All staff should be briefed on research protocols and other samples to be collected prior to the start of the necropsy. The relevant medical history and other historical information should be reviewed and recorded.

In general, the 'standard procedures' of pathology should be followed. Body weight should be collected, if possible, and an external exam performed. Note any evidence of trauma, skin lesions, tags or other distinctive markings, musculoskeletal condition, ectoparasites, discharges from body orifices, etc. If possible, the body should be placed in left lateral recumbency prior to opening the abdomen with a ventral midline incision from mandible to pelvis. Note amount and appearance of fluid accumulations and obtain a swab for bacterial culture and / or a sample for cytologic examination. Note the appearance, size, color, and position of all abdominal viscera. Open the diaphragm, and enter the thoracic cavity by cutting the ribs, again assessing the volume and appearance of thoracic fluid, and collect samples for culture. Collect samples of heart blood for bacterial cultures. Additional samples should be saved at minus 70° C as whole blood and serum. Internal organs are removed and examined systematically.

Every effort should be made to collect accurate weight and size measurements for internal organs. Currently, there is limited information on organ size and weights in Indian rhinoceros, and additional information is needed.

Samples of all internal organs and tissues, along with representative samples of all lesions, should be collected for histopathologic examination, as well as samples for culture, virus isolation, electron microscopy, toxicology, and other studies as appropriate. It is advisable to freeze samples of heart, lung, liver, spleen, kidney, adipose tissue, intestine, and brain (if possible) at minus 70° C for future research. Small samples of these organs and all lesions can also be minced (1 mm cubes) and

placed in Trump's fixative, 2% glutaraldehyde, or other fixative for electron microscopic examination. Multiple samples of heart muscle should be saved, to include left and right ventricular free walls, papillary muscles, valve leaflets, and interventricular septum.

If the skull is to be saved for a museum or educational specimen, then the brain cannot be examined - removal of the brain will likely result in extensive damage or destruction of the skull. If the brain is removed, it should be placed in 20% Formalin. Eyes may be placed in Bouin's fixative (preferred) or the globe may be incised and placed in Davidson's fixative or (least preferred) 10% Formalin.

Samples for histopathology should be placed in 10% Formalin (volume of Formalin 10 times the volume of tissue collected). Tissue samples should be not more than 0.5 cm thick to assure adequate fixation.

Additional samples from neonatal animals should include examination and sampling of the placenta and fetal membranes, if available. The fetus should be measured, (weight, crown-rump length). The umbilicus should be examined and described, and sample of the umbilicus saved for histopathologic examination. Examine the oral cavity for cleft palate, and the heart for septal defects, persistent ductus, or other anomalies. Stillbirth can be determined by placing a sample of lung tissue in Formalin – if the lung sinks, the animal is likely stillborn, and did not breathe.

A copy of the necropsy report, and (if possible) re-cuts of all slides (or replicate samples of all tissues fixed in Formalin) should be sent to:

In Europe:

Dr. Friederike von Houwald
Veterinary Advisor Rhino Tag
Basel Zoo
Binningerstrasse 40
CH-4054 Basel, Switzerland
vonhouwald@zoobasel.ch

In the USA:

Dr. John Trupkiewicz
Director of Pathology
Philadelphia Zoo
3400 W. Girard Ave
Philadelphia, PA, 19104, USA
Trupkiewicz.John@PhillyZoo.org

Commonly affected organs in Rhinoceros

The stomach may be affected by ulcers, which may be related to stress, and can serve as an indicator of husbandry conditions.

Liver, Gallbladder, Gastrointestinal tract: parasitism is common, especially in newly imported animals or those housed on larger enclosures.

Fungal pneumonia, e.g. chronic interstitial pneumonia caused by *Micropolyspora faeni* (Farmer's lung), can stand in correlation with bad quality hay fed to the animals.

Vaginal and Uterine leiomyomas have been frequently identified in rhinoceros. Ovarian cysts are also common.

Chronic pododermatitis in captive Indian rhinoceros has been described at several institutions, and careful examination and description of the feet, with photographic documentation of any lesions, is suggested.

The Post-mortem procedures for wildlife veterinarians and field biologist, written by Woodford, Keet & Bengis (2000), give also valuable information concerning pathological procedures and preparation of the examination.

8.2. NECROPSY REPORT FORM (compressed version)

Institution: _____	Date of Death: _____
Address: _____	Necropsy Date: _____
_____	Necropsy # : _____
_____	Prosector: _____
Animal ID: _____	Contact Phone _____
Sex: _____ Age: _____	or e-mail: _____

Clinical History (Diet, captive born vs. wild caught, prior movements or relocations, prior medical history, recent clinical signs, pertinent laboratory results, treatments, circumstances of death, etc.):

Gross Necropsy Examination:

Weight: _____ kg / lb Actual / Estimated

External exam: Nutritional Status, Skin, Condition of Body, Wounds, Tags

Musculosceletal: Bones, Joints, Muscles

Body Cavities: Fat Stores, Abnormal Fluids

Hemic-Lymphatic:	Lymph Nodes, Spleen, Thymus, Bone Marrow
Cardiovascular:	Heart, Pericardium, Aorta, Vessels
Respiratory:	Nasal Cavity, Larynx, Trachea, Lungs
Digestive:	Oral Cavity, Teeth, Tongue, Esophagus, Stomach, Intestines, Cecum, Colon, Liver, Pancreas
Urinary:	Kidneys, Ureters, Bladder, Urethra
Reproductive:	Gonads, Uterus, Vagina, Penis, Prepuce, Prostate, Accessory Glands, Mammary Glands, Placenta
Endocrine:	Adrenal, Thyroid, Parathyroid, Pituitary Glands
Nervous:	Brain, Spinal Cord, Peripheral Nerves
Special Senses:	Eyes, Ears

Organ Weights:

Heart: _____ g / Kg LAV: _____ mm / cm RAV: _____ mm / cm

PULM: _____ mm / cm AOR: _____ mm / cm

L Wall: _____ mm / cm R Wall: _____ mm / cm

Septum: _____ mm / cm

Lungs: left: _____ g / kg right: _____ g / kg

Kidney: left: _____ g / kg right: _____ g / kg

Adrenal: left: _____ g / kg right: _____ g / kg

Liver: _____ g / kg

Brain: _____ g / kg

Thyroid: left: _____ g / kg right: _____ g / kg

Tissues and Samples Saved:

In Formalin ( )

_____

In Electron Microscopy Fixative ( )

_____

Freezer / Ultracold ( )

_____

Embedded in Paraffin Blocks ( )
Microscope Slides ( )
Photographs ( )

_____

Tissue Collection Checklist:

Skin		Liver		Gonad	
Muscle		Pancreas		Uterus	
Nerve		Tongue		Vagina	
Diaphragm		Esophagus		Prostate	
Lymph Nodes		Stomach		Accessory Glands	
Spleen		Duodenum		Eye	
Thymus		Jejunum		Brain	
Heart		Ileum/Cecum		Spinal Cord	
Aorta		Colon		Adrenal	
Trachea		Kidney		Thyroid/Parathyroid	
Lung		Ureter		Pituitary	
Other		Bladder		Bone	

Samples for Laboratory Analysis:

Gross Diagnosis:

9. RESEARCH (2002)

For **Europe** it is planned to discuss and update this chapter regularly during the Indian rhino EEP-meeting taking place during the annual EAZA conference.

The minutes of this meeting will be sent to all holding facilities and they will include a list of the current research projects and the defined needs of the involved researchers (e.g. what kind of samples, preparation, fixation, storage, transportation).

New projects coming up between the annual meetings should be reported to the EEP Species Coordinator (guldenschuh@zoobasel.ch) and they will be communicated via e-mail to all the European species representatives.

For the **USA**, John Trupkiewicz (Trupkiewicz.John@PhillyZoo.org) is the pathology coordinator for the Indian rhino (see 8. Post-mortem Protocol) and the SSP species coordinator Mike Dee (mdee@zoo.ci.la.ca.us) is coordinating all the other research projects.

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If you know about or have Indian rhino publications mentioned neither in the general or the medical references nor in the bibliography of this manual, please contact Kees Rookmaaker or Gerry Guldenschuh. We try to have at least copies of all the papers cited in the reference lists and to make them, on request, available to everybody.