EAZA Best Practice Guidelines

Greater one-horned rhinoceros (*Rhinoceros unicornis*)

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EAZA Preamble

Right from the very beginning it has been the concern of EAZA and the EEPs to encourage and promote the highest possible standards for husbandry of zoo and aquarium animals. For this reason, quite early on, EAZA developed the "Minimum Standards for the Accommodation and Care of Animals in Zoos and Aquaria". These standards lay down general principles of animal keeping, to which the members of EAZA feel themselves committed. Above and beyond this, some countries have defined regulatory minimum standards for the keeping of individual species regarding the size and furnishings of enclosures etc., which, according to the opinion of authors, should definitely be fulfilled before allowing such animals to be kept within the area of the jurisdiction of those countries. These minimum standards are intended to determine the borderline of acceptable animal welfare. It is not permitted to fall short of these standards. How difficult it is to determine the standards, however, can be seen in the fact that minimum standards vary from country to country.

Preamble

The EAZA greater one-horned best practice guidelines are an update of the first husbandry manual for greater one-horned rhinos written in 2002 and include the experiences and information from many zoo professionals keeping this species.

In addition, the best practice guidelines for Black rhinos, published in 2013 by Mark Pilgrim and Becca Biddle have served as a model. Their outline was mostly followed in this publication in order to make it easier for zoo staff to compare the similarities and differences when keeping these two rhino species in captivity.

In summary, these EAZA best practice guidelines focus in the first section on the biology and field data of greater one-horned rhinoceroses. This information is essential in order to translate the rhinos' needs into good husbandry, good husbandry is needed to keep a healthy, self-sustainable captive population, which itself serves as a backup for the wild population. These data also show that ex situ breeding efforts and support for in situ rhino conservation projects have become an important role for each zoo keeping rhinos. The current poaching crisis is dramatic and threatens the in situ populations. Cooperation between in situ and ex situ rhino conservation partners is more important than ever and it is one of the aims of the EAZA Rhino TAG to link in situ rhino conservation efforts with ex situ rhino conservation efforts.

The second section deals with the zoo management of this species. Greater one-horned rhinoceroses have been kept successfully in zoos for over sixty years now. These EAZA best practice husbandry reflects the long-term experience gained for this species in captivity and summarizes the latest information available.

The key husbandry issues in this species are chronic foot disease and aggressive behaviour during introduction for breeding. Both subjects are discussed in great length in this paper and ideas are presented how to prevent foot problems and how to improve breeding.

A further key point in these guidelines is the management of this species and their feeding regime. Both aspects play an important role in maintaining their mental and physical health in captivity.

In these EAZA best practice guidelines for the greater one-horned rhinoceroses the author has not included any information of how large a stable or an outdoor enclosure should be. It is important to notice that some countries have legal requirements that stipulate sizes and those need to be followed.

The thought behind these guidelines is that by providing profound information about the greater one-horned rhinoceros biology and management, each zoo will be able to define for their own situation the best requirements for their housing facilities. The quality of an exhibit is not described by size alone but by the way an exhibit is structured, furnished and finally managed. With these best practice guidelines, each zoo should be able to learn enough about this species in order to create an environment for this species that keeps them mentally and physically healthy.

At the end of the best practice guidelines a full reference list can be found. In order to download publications, the webpage of the Rhino Resource Center has been very helpful (http://www.rhinoresourcecenter.com). Most publications cited in this document can be downloaded there. As this is a fantastic service, a donation fee to the RRC is always welcome.

All sections, unless otherwise mentioned, were written by the author. If questions arise, please contact vonhouwald@zoobasel.ch.

I would like to thank Beatrice Steck and Dr. Christian Wenker for their valuable inputs.

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Introduction

To date five 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, the *AZA Rhinoceros Husbandry Resource Manual*, edited by Michael Fouraker & Tarren Wagener (1996), the Husbandry Manual for greater one-horned or Indian rhinoceros (Rhinoceros unicornis) edited by G. Guldenschuh & F. v. Houwald (2002), the Best Practice Guidelines for the Black rhinoceros (Diceros bicornis), edited by M. Pilgrim & B. Biddle (2013) and the Rhino Husbandry Manual, edited by L. Metrione and A, Eyre in 2014.

Since the last publication of the greater one-horned rhinoceroses husbandry manual, some years of intensive management of this species have passed by and a wide array of new aspects of how to keep this species in zoological institutions have been gained.

This gave rise to update the first edition and to turn it into the EAZA Best Practice Guidelines for the greater one-horned rhinoceros.

Zoo Basel has been continuously keeping greater one-horned rhinos for over 60 years now. So far 34 calves have been born in Basel, including the first captive-born and successfully raised greater one-horned rhinoceros worldwide (male Rudra, 1956). The experiences of a new model in keeping this species, together with information received and exchanged with many institutions and individuals over the past years are summarized in this new edition.

These guidelines emphasize the practical aspects of keeping greater one-horned rhinos. In animals with as slow a reproduction as this species, 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 and teach us to never stop observing and improving the husbandry standards.

The worldwide living captive population of the greater one-horned rhino in the year 2014 counts 207 (105.100.2) animals living in 73 zoological institutions (von Houwald, 2015).

EAZA members have established Taxon Advisory Groups (TAGs) for different groups of animal species that are kept in zoos and aquariums. One of the main tasks of a TAG is to develop Regional Collection Plans (RCP) that describe which species are recommended to be kept. The TAGs also identify which species need to be managed in a European breeding programme called EEP.

The Mission of the EAZA Rhino TAG is to ensure all captive populations are healthy, self-sustaining and genetically viable and are capable of being an effective tool in support of rhino conservation in the wild.

The Vision of the EAZA Rhino TAG is a healthy, viable population of free ranging and intensively managed rhinos ranging through intact ecosystems, where they are valued and cherished both, locally and globally.

The goals of the EAZA Rhino TAG are:

Population management

- To ensure each EEP population is self-sustaining and genetically viable in the long term.
- To ensure each taxon has ambitious targets for the retention of maximum Gene Diversity (~ 90% GD per century).
- To work more closely with other regions to support effective population management.
- To work to overcome obstacles which impinge upon population and genetic management goals; e.g. international transfers and importation of new founders.

Husbandry & Welfare

- To ensure each EEP drives ongoing welfare and husbandry improvement.
- To ensure husbandry guidelines are in place for all EEPs by 2012 and reviewed at least every second year.
- To develop an audit process to ensure all holders are compliant with husbandry guidelines by 2015.
- To identify and support research priorities which advance husbandry & welfare and support the development of husbandry guidelines.

Education & Research

- To ensure the captive populations provide a significant educational and research resource capable of contributing to rhino conservation.
- To recruit an education advisor to the TAG.
- To measure the impact of zoo based education specific to rhino conservation & assist in the improvement of zoo based education.
- To set up a research advisor team to the TAG.
- EEP coordinators to identify research priorities prioritising projects conceived to improve captive management, reproduction & welfare.
- EEP coordinators to collate research activities.
- Research advisor to report on activities and facilitate TAG wide research activities.

Section 1: Biology and field data

Biology

1.1 Taxonomy

1.1.1 Order: The greater one-horned rhinoceros is placed in the order Perissodactyla, the odd-toed ungulates.

1.1.2 Family: The order Perissodactyla is made up of three families: Equidae (horses), Tapiridae (Tapirs) and the Rhinocerotidae to which the rhinos belong (Nowak 1999).

1.1.3 Genus: There are four recent genera and the greater one-horned rhinoceros is placed in the Rhinocerotinae.

1.1.4 Species: The genus Rhinocerotinae has two species: The Rhinoceros unicornis and the Rhinoceros sondaicus. The name Rhinoceros comes from the Greek 'rhino' meaning nose and 'ceros' meaning horn and unicornis originates from Latin meaning uni – single and cornis – horn.

1.1.5 Subspecies: There is no known subspecies for the greater one-horned rhinoceros.

1.1.6 Common names: Greater one-horned rhinoceros referring to the single large horn,

Indian and/or Nepalese rhinoceros referring to the species range.

German: Panzernashorn

French: Rhinocéros unicorne del'Inde

Spanish: Rhinoceronte Unicornio Indico

1.2 Morphology

1.2.1 Sizes and weights

Body weight in the wild:	Up to 2000kg
Body weight in captivity:	Males: 1800 - 2500kg
	Females: 1500 - 2100kg
Birth weight in captivity:	64.5kg (44 - 91kg)
Shoulder height in the wild:	150 – 180cm, with males being taller
Shoulder height in captivity:	Males up to 195cm, females up to 172cm
Head-body-length:	Between 3 -4m (with captive animals usually being taller and larger than wild animals).
Horn length in captivity:	Typically between 20 – 60cm

The horn of wild GOH has a wide base and becomes soon narrow and pointed

1.2.2 General description

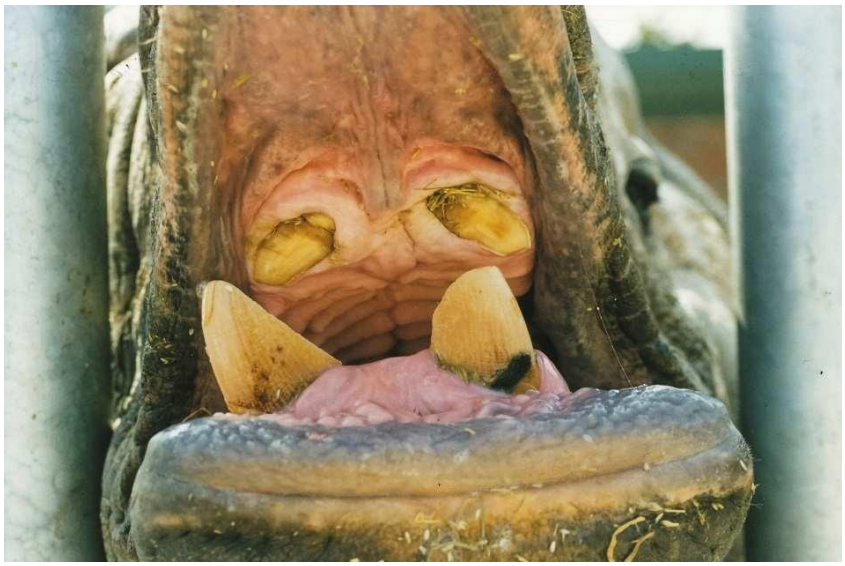
In captivity there is a difference in size between males and females. Unlike in the wild, males are taller. The greyish skin is folded at various regions of the body. Specifically at those areas, which need protection (from attacks, bites), such as the shoulders, the lower part of the neck, where the jugular vein runs, the caudal area of the elbow, where the heart finds protection, or the cranial area of the knee, where the inguinal area is protected.

Wild as well as captive adult males have massive neck and upper shoulder muscles which makes them easily differentiated from females.

Unlike the African rhinoceroses, the Asian rhinos have long (in greater one-horned rhinoceroses up to 8 cm in males and up to six cm in females) incisor, just like tusks. They are used for fighting and can inflict large biting wounds to others.

The greater one-horned rhinoceros has the following dentition:

Incisor	canines	Pre-molar	Molar	Total
1 (2)	0	3-4	3	26 -30
0	0	3-4	3	



The lower incisor are rather sharp and up to 8cm in bulls

Short legs carry a massive, rather plump body. The legs have a knock-kneed appearance with the feet turning partly outside, especially in the standing position. They have specialized feet for weight bearing, with three digits (II, III, IV) and a large expanding digital cushion. The digits are aligned in a semi-circular way around the pad with the hooves touching the ground when standing. The palmar/plantar aspect of the foot is curved. The front feet appear rounder and broader than the hind feet, which appear more elongated. The hind feet are generally larger than the front feet. Although they appear massive and therefore unable to move quickly, a rhinoceros can turn very fast and run at the speed of 50km/h.

The greater one-horned rhinoceros has – like the name suggests – one horn. The base of the horn is wide but the horn itself is rather short. In the wild it is usually thinner and shorter (up to 25cm) than in captive animals, where the horn is often curved backwards, is thicker and longer (up to 60cm). The horn is not used for fighting but for digging for roots and used at mineral licks to dig up the earth.

The ears have the shape of cones and their sense of hearing is well developed. The eyes are located at the sides of the head and the sight is poor, with the horn in the middle, making 3D vision almost impossible. Their sense of smelling is well developed.

Wild GOH in Kaziranga NP: notice the plumb body, the short legs, round ears and the location of the eyes on the side of the head.

1.3 Physiology

Captive animals (Fowler 2003):

Body temperature:	34,5 – 37,5°C (rectal temperature)
Respiratory rate:	6 – 12 breaths per minute (through observation)
Pulse:	30 – 40 beats per minute (stethoscope)

1.4 Longevity

Animals in captivity live on average up to 35 - 40 years, with 45 being very old.

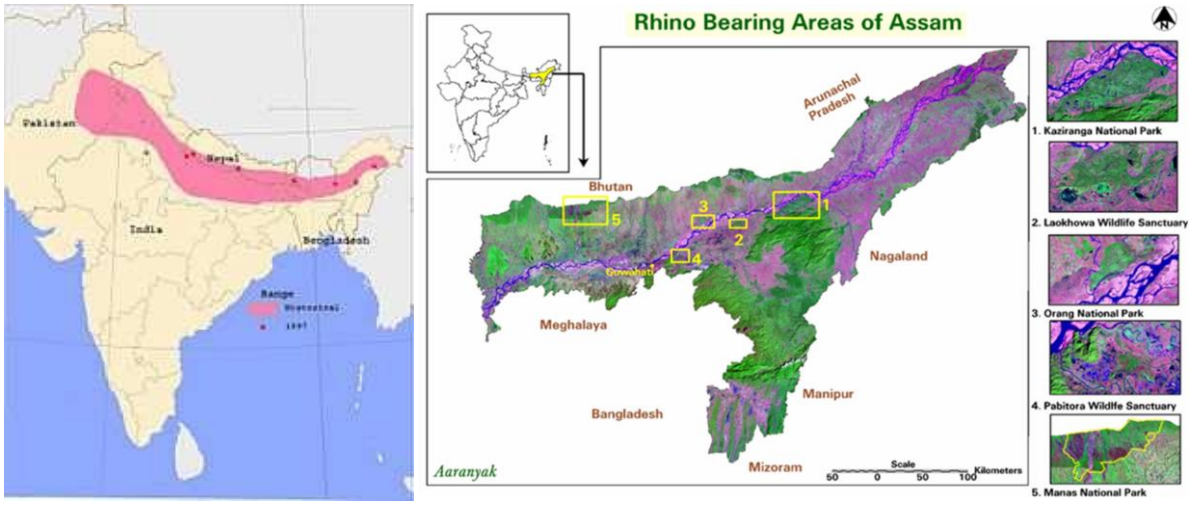
Field data

1.5 Zoogeography / Ecology

1.5.1 Distribution

The historic distribution of the greater one-horned rhino *Rhinoceros unicornis* covered the huge floodplains of the Indus, Ganges and Brahmaputra on the Indian subcontinent (Pakistan, India, Nepal, Bhutan, Sikkim, Assam, Bangladesh, and Myanmar). (See map 1)

Today, their remaining population is restricted to two areas in the northeast of their former range, one in southern Nepal, one in Assam. The Nepalese population occurs mainly in Chitwan, smaller populations are found in Bardia and Suklaphanta. The Kaziranga National Park in Assam is still the stronghold of this species, with over 2400 rhinos. Further places with up to 100 rhinos are Pobitora WS, Laokhwa WS and Orang NP. As a result of translocation, a small population is now to be found in Manas NP.



Map 1: Recent (left) and current (right) distribution of greater one-horned rhinoceros in Assam

1.5.2 Habitat

Greater one-horned rhinoceroses flourish in what are arguably the world's tallest grasslands. The floodplains of Royal Chitwan and Kaziranga NP support terraces of elephant grasses that reach 6 – 8 m by the end of the monsoon (October). Theses alluvial grasslands are as threatened as are the rhino populations with only a small fraction of the original habitat remaining. The best conserved examples of floodplain grasslands are in Royal Chitwan National Park, Sukla Phanta Wildlife Reserve, Manas National Park, Dudhwa National Park and to a lesser extent Bardia NP, all part of what is known as the Terai –Duar Grasslands and Savannas ecoregion. This ecoregion, which sits along the base of the outermost foothills of the Himalayas, ranges from Dehra Dun in Uttaranchal, India, across the Nepalese Terai Zone, to the Duar Grasslands of Bhutan (Dinerstein 2012).

Average temperatures in Kaziranga NP: in summer 32°C and 10°C in winter

GOH prefer the tall elephant grass but also open areas to graze

Water is essential for GOH

1.5.3 Population and Conservation status

The greater one-horned rhinoceros is listed by the IUCN red list as vulnerable and within CITES under Appendix 1.

Current numbers (census in India 2012 / 2013) mention a few more than 2800 individuals in India and Nepal has recently reported that numbers rose up to 645 in Chitwan NP. (National Rhino Count 2015 http://www.ntnc.org.np/news/national-rhino-count-2015-645-individual-rhinos-nepal)

Country/State	Protected Area/Locality	Estimate	Source/ Year
INDIA		**2,867**	
Assam	Kaziranga National Park	~2,400	2013 Census
Assam	Pobitora Wildlife Sanctuary	~93	2012 Census
Assam	Manas National Park	18	2014 Census
Assam	Rajib Ghandi Orang National Park	~100	2012 Census
Uttar Pradesh	Dudwha National Park	29	
West Bengal	Gorumara National Park	43	2011 Genetic Survey
West Bengal	Jaldapara Wildlife Sanctuary	184	2013 Census
NEPAL		**676**	
Chitwan District	Chitwan National Park	645	2015 Nepal Rhino Census
Bardiya District	Bardiya National Park	24	2011 Nepal Rhino Census
Far-Western Region	Suklaphanta Wildlife Sanctuary	7	2011 Nepal Rhino Census
		3,543	

Table 1: Number of greater one-horned rhinos in Asia

1.5.4 Threats

Poaching, loss of habitat and habitat fragmentation are rising threats to any rhino population. In contrast to Africa, there are no wildlife zones or protected areas around a National Park. Farmers, who cultivate their land next to the National Parks, often encounter rhinos on their rice fields. Those encounters lead to ongoing human wildlife conflict.

A further aspect, often overlooked, is the fact that the landscape of the NPs are frequently changing as they are lying next to or within the large rivers. A river changing its course will carry away a lot of material, changing the face of a landscape and therefore that of a National Park as well. Previously precious land can turn into land of no use for rhinos.

Invasive plant species, such as *Mikania micrantha*, have also changed the use of certain areas (Murphy et al. 2013). This fast growing plant species renders the areas where they grow inaccessible and of no use for rhinos, leading to a further reduction in land mass for this megaherbivore.

Invasive plant species such as *Mikania micrantha* covering much of the plants GOH feed on

1.5.5 Conservation action

Over 75% of the rhino population is found in north-eastern India's state of Assam, largely within the borders of the famous Kaziranga National Park (KZNP). As poaching became more and more a serious threat, primarily to the KZNP population being an easy target and out of fear for stochastic events, the project Indian Rhino Vision 2020 (IRV 2020) was set up with the aim to support a viable rhino population with over 3000 individuals living in several protected areas in Assam. Since the beginning of this project in 2005, more secured areas have been found and opened up, so that translocations already took and will take place in the future.

Manas National Park, Assam, India. GOHs have been translocated to this World Heritage Site.

Zoos interested in supporting rhino conservation field programs are invited to contact the EAZA Rhino TAG Conservation Advisor, Cathy Dean, Executive Director from Save the Rhino https://www.savetherhino.org/ Cathy@savetherhino.org or Dr. Susie Ellis, Executive Director from the International Rhino Foundation http://www.rhinos.org/ s.ellis@rhinos.org. Both NGOs have a long history in working closely with rhino field experts and the zoo community and help to link in situ and ex situ rhino conservation efforts.

1.6 Diet and feeding behaviour

1.6.1 Food preference / feeding

Greater one-horned rhinos feed predominantly on grass, but are known to consume a wide range of other plants, such as water plants, leaves, branches, shrubs, cultivated crops and fruits. In addition, the rhinos frequently visit areas rich in minerals. In Royal Chitwan NP they have been recorded to feed on 183 species of plants from 57 botanical families (Laurie 1975). In prime habitat they concentrate their feeding along the floodplains of large rivers and streams. The dominant grass is often *Saccharum spontaneum*, a wild sugar cane. This plant has among the highest protein to fibre ratios of all grasses and faecal analysis showed that this grass species accounts for 50% of the diet in almost every month of the year. (Dinerstein 2012)

They use their prehensile lip for ripping off branches and twigs and their horns for digging in the ground for roots or at mineral licks.

They have been observed to feed on water plants in water, a behaviour that can also be seen in captivity.

On the left: mineral 'lick' in Orang NP, Assam. Visible are the traces of the horn that is used to loosen the mineral layers. On the right abundant water plants cover a lake and its edges. GOH like to feed on them (pictures from KZNP).

1.7 Reproduction

The sex determination system of XX / XY is applicable to greater one-horned rhinoceros, where the males have XY and females have XX chromosomes. They have a total of 82 chromosomes (Nowak 1999).

1.7.1 Sexual maturity

Females may conceive as early as three years in captivity. Wild females at this age are often still with their mother and do not breed. Age at first reproduction is likely sensitive to forage condition (Dinerstein 2012).

In males, breeding is delayed until they have reached sexual maturity. In captivity, this can possibly start at the age of six years, but most bulls successfully mate later, at the age of eight years. In the wild, young males searching the proximity of a female in oestrus are chased away by the dominant male and are even sometimes killed. One field study estimated that most bulls likely did not have a chance to breed until at least the age of 13 – 15 years, at which time they would be strong enough to challenge the dominant male for access to females (Dinerstein 2003)

1.7.2 Seasonality of cycling

There is no seasonality in cycling reported for this species, neither in the wild, nor in captivity. The fact that fewer calves are born in January – March in captivity might be attributed to the fact that some zoos do not bring their rhinos together during winter time (low temperatures) for breeding.

1.7.3 Reproductive cyclicity in females

Greater one-horned rhinoceroses appear to exhibit several species specific reproductive characteristics among the Rhinocerotidae (Stoops et al. 2004): changes in oestrogen concentrations are readily measured in the urine and / or faeces and reflect cyclical patterns. The growth of very large follicles appears also characteristic for this species (10 – 12cm). The cycle length ranges from 36 to 61 days. The follicular phase of the greater one-horned rhinoceros appears to be the longest among species in the Perissodactyla order (14 days).

Bulls detect the onset of oestrus 3 – 7 days before the behavioural oestrus of the female starts. During this time, the males will be restless; they will not eat well, will frequently spray urine and are very eager to be near the female. The female does not show any interest at all at this stage. Signs of behavioural oestrus in the female are also restlessness, lack of appetite, frequent squirting of urine / marking and repetitive whistling sounds.

1.7.4 Gestation period

Greater one-horned rhino gestation lasts an average of 479 days, with records indicating a range of between 459 and 496 days (Wirz-Hlavacek 2001). The *AZA Rhinoceros Husbandry Resource Manual* (Fouraker et al. 1996) mentions 516 days as the longest known gestation period.

Pregnancy in greater one-horned rhinos can be monitored using faecal steroid analyses (Schwarzenberger et al. 2000).

1.7.5 Birth

Birth takes place often at night or early in the morning. Average birth weight is 64.3 kg (44 to 90.6 kg, n = 36) (Wirz- Hlavacek 2001). Shoulder height is about 70cm. To date only single calf births have been observed.

1.7.6 Calf development

Calves commonly get on their feet within 15 minutes, but may take 1 to 2 hours before being coordinated and balanced enough to walk. They usually drink for one year, but start to eat other food items at the early age of 1 – 2months. They grow very fast, gaining in the first weeks up to 2kg daily.

1.7.7. Interbirth intervals

Interbirth intervals in wild rhinos (study performed on 13 known greater one-horned rhinoceroses in Nepal, Dinerstein 2003) were 46 months. Among 87 females studied, older females tended to exhibit a longer interbirth interval.

1.8 Behaviour

1.8.1 Activity

This species shifts its activities with the seasons and reveals the following patterns:

In the hot –dry season (mid-February – mid-June) there are two peaks in grazing: in the pre-dawn hours and around dusk. Browsing is very infrequent as is wallowing with no real peak activity in these behaviours. Resting peaks at midday, occasionally at dawn and around midnight.

In the monsoon (mid-June to mid-October) wallowing increases dramatically and stays high throughout the diurnal period. Browsing is infrequent and there are two main grazing bouts, just after midnight and from late afternoon through dusk. Resting bouts are scattered through the day.

During the cool season (mid-October to mid-February) wallowing is infrequent, grazing peaks in the late afternoon and browsing increases dramatically lasting from just after dark until dawn.

Wallowing is very important for greater one-horned rhinoceroses. The primary function is assumed to be heat regulation, escape of biting insects and possibly social communication by scent marking (males often urinate in the wallow). It is interesting to note that greater one-horned rhinos wallow less in the wild during the hottest, driest month of the year (April) and graze instead. During hot, humid periods (monsoon), they can spend much of the day in the wallow.

1.8.2 Locomotion

The usual pace is the walk. When excited, they will start trotting head up, stopping occasionally to search for the cause of excitement. When scared, they will run away in a fast gallop. A female with a calf will not hesitate to attack cars, elephants or other obstacles in the protection of her offspring. Rhinos can become very agile in their movements, especially if startled, and can turn around within a second. The same applies for speed. Sometimes they can run faster than a car can drive on a dirt road.

1.8.3 Predation

Healthy adult rhinos are too big and powerful to be at risk from predators, apart from humans, but calves are much more vulnerable. Predation by tiger accounts for 10% of calf mortality in greater one-horned rhinos in one study where the two species overlapped. All of the calves were less than eight month old. Adult male rhinos will also kill calves, presumably the offspring of rival males (Laurie 1997).

Photo left credit to Randy Rieches, Kaziranga NP. Right © IFAW: young rhino, surviving the attack of a tiger.

1.8.4 Home range

Home ranges of greater one-horned rhinos in Royal Chitwan National Park are remarkably small for a megaherbivore. Adult female ranges averaged 2.9m2 (+/- 0.9km), and showed almost no variation among the three seasons of the year (cool, hot-dry, monsoon). Males also had small annual home ranges (3.3km2). Rhinos live in prime habitat dominated by a highly nutritious forage plant, their stable food, the wild sugar cane (*Saccharum spontaneum*). When in prime habitat, rhinos tend to be rather sedentary (Dinerstein 2012).

1.8.5 Social structure and behaviour

Adult males are solitary. Their territory varies according to food availability and according to his status. A dominant bull occupies the best feeding range and allows females to forage within.

Non-breeding males do not seem to use prime grazing areas dominated by S. spontaneum and by dominant males. Young males do congregate in small groups, it is thought that this behaviour assures some protection against dominant males and play fights will enable them to learn techniques important for survival later on.

Females are often found with their previous calf, which can stay with the mother until the next calf is born.

1.8.6 Communication

Greater one-horned rhinoceroses communicate vocally but also by scent marking (faeces and urine). As they smell and hear better than they can see, these senses are very important. At least 10 different vocalizations have been noted. They use sounds when in oestrus (squeak-pant), when chasing (honk, very loud, made by the one that is followed), roar uttered in intense encounters or the moo-grunt, the contact call between mother and calf.

1.8.7 Sexual behaviour

Courtship in greater one-horned rhinoceros is rather wild and can lead in the wild as well as in captivity to serious wounds. Before mating occurs, the dominant male will chase the female for quite some time (up to 2km). Copulation last for one hour. After mating, the male will stay with the female for some time (days in the wild) but no futher copulations will take part.

Section 2: Management in Zoos

Introduction

The following section suggests best practice management for greater one-horned rhinoceroses (GOH) in the zoo environment. Information for this section is taken from the first husbandry manual for greater one-horned rhinoceroses and the experiences made at various zoos in the past 15 years. Enclosure, feeding, social structure, breeding, behavioural enrichment, handling and veterinary medicine will be described.

As greater one-horned rhinoceroses originate from subtropical Asia, the need for proper indoor as well as outdoor enclosures in the European climate is evident. Each enclosure should be designed to meet the species specific needs and to thrive for best results in health and reproduction. For the greater one-horned rhinoceros the biggest challenge is the substrate on which this species lives and the fact that they need access to water for their wellbeing. This species is prone to foot problems due to the abrasive nature of indoor and outdoor surfaces (von Houwald 2001). A further challenge is breeding greater one-horned rhinoceroses. Their rather violent nature during courtship is a challenge not only for the management but also for the thoughtful design of the enclosures in order to avoid serious injuries and to breed successfully.

Today, it is recommended to keep 1.1 or 1.2 animals. Given the territorial nature of adult bulls, at least two outdoor enclosures are needed. Not all females will tolerate the proximity of another female, but many zoos do manage to keep more than one female in the same exhibit. In order to allow for good management in times where those females are incompatible (birth, first weeks with offspring, illness), considerations should be made to divide one outdoor exhibit or to have even a third outdoor area available.

2.1 Indoor enclosure

2.1.1 Group composition

Most zoos provide a stable for every animal. This has worked very well in the past. New approaches have now tried to keep two cows, two young bulls, two cows with one calf, two cows with two calves, a cow with one older calf and a younger calf) together. Careful planning is needed for such a concept but it seems that greater one-horned rhinos really do get along well with each other when:

- Feeding places are accessible for each individual
- No animal is blocked / trapped
- The system is changeable in case tension is building up between individuals
- Possible run-arounds are available or can be installed (big logs, etc. hanging / lying in the middle)

2.1.2 Size

The size of the indoor enclosure needs to be carefully evaluated. Depending on the climate where a new exhibit is planned and therefore the time animals can stay outside or have to stay inside, the size of the stable should be planned. In climatic zones, where the weather is not permitting the animals to stay outside for a longer time of the day, the size of the indoor enclosure should be large enough to allow for other activities and enrichment ideas. The length of an adult rhino is about 4m. This should be kept in mind when calculating the appropriate space for movement and activities of each animal.

Certain countries have by law a minimum standard. This should be kept in mind when planning.

2.1.3 Multiple use of the exhibit

The use of an indoor enclosure has been carefully evaluated in the past years. Experience was made in allowing rhinos (bull, cow with or without calf) free access to the stable and to the outdoor exhibit during day and night, by giving them the option to choose for themselves. This has increased activities patterns and has worked well.

Most zoos have a separate stable for the bull and the cows. But some zoos provide a design where the bull can be shifted to the cows and the cows to the bull enclosure. This is nice enrichment for both sexes.

The more flexible an indoor enclosure is build the better the use according to age and breeding and health status.

Each indoor exhibit should have one stable which serves as a separation box. Be it for giving birth, holding and introducing a new animal or sick animal.

As adult bulls become very excited when a female is in oestrus (up to one week before the female shows behavioural oestrus signs), it is recommended – in order to ease the stress on the bull – to have a visual / olfactory separation between the male and the female sector. A bull that has visible contact with a female in oestrus becomes very excited and might damage himself.

2.1.4 Corridors and doors

In order to move an adult rhino safely from one area to another, the corridors should not be wider than 2m, making it impossible for an adult GOH to turn. Doors should be wide enough (at least 2m). There are various systems used in zoos. Important information are that rhinos like to bang their head at doors and that – when

scared or excited– can start running through a half open door. Manually operated doors have the advantage that no technical default will cause a dangerous situation.

All gates have to be usable without entering rhino space.

2.1.5 Indoor boundary

There are several possibilities:

Bars or solid walls are used by several zoos. As greater one-horned rhinos are known to rub their horn on solid flat walls, such a wall needs to be topped with wooden panels as a rhino will only rub the horn on 'non-bumpy' surfaces. It is advantageous to have at least one side covered with bars. This area can also be used for training purposes, for controlling the animals, etc. The width between the bars at Zoo Basel is 30 - 35cm.

The disadvantage of bars is that rhinos like to bang the head between the bars, especially when expecting to go outside (in case doors are made of bars), to be fed, etc. This can – depending on the location – become very noisy in the house.

The separation box should – when possible – have only solid walls. This is also easier for sedation as rhinos tend to stick their horn through bars (esp. when using Immobilon®), risking the damage of the horn / neck when going down. A temporary board can also help to diminish this problem to occur.

A low barrier (up to 80cm high from the ground) helps to avoid that a calf may pass through the bars at very young age.

Horizontal bars are also used. Sometimes rhinos like to climb on them, using the head by laying it onto the bar and thus moving the body up. To avoid that the foot might slip to the wrong side (out) and gets trapped, a square bar can be used. One edge of the bar should be facing top, so that one flat side is facing inside with a 45degree angle. If a foot is lifted on this side now, it will more likely slip back inside and not out.

The boundary towards visitors should be wide enough to avoid feeding and touching by the visitors.

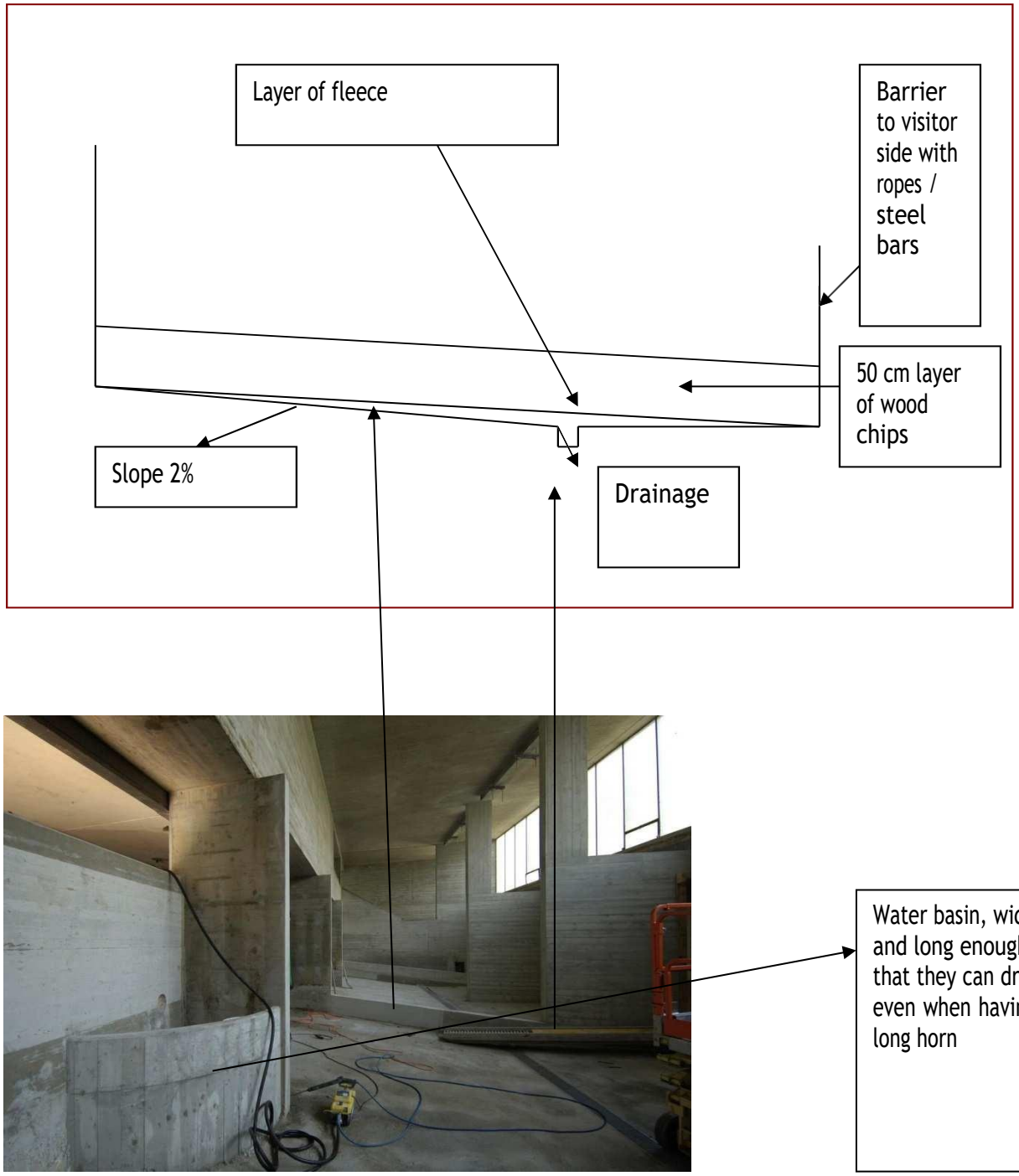
A ditch as a barrier towards the visitors has been used in the past by several zoos and led to many accidents. It is therefore no longer recommended.

Historic picture when GOH were housed next to the elephants at Zoo Basel.

2.1.6 Surface

The surface is the most important issue when keeping greater one-horned rhinoceroses. It needs to be non-abrasive. Given the fact that the animals will spend a lot of time in the stable, this issue needs good considerations. Some zoos tried rubber (mats as well as pour-on rubber). The experience with both materials (especially with the pour-on rubber) showed poor results. Abrasions still occurred. (For more details on foot problems see vet. chapter). The best experience so far was made with a deep 50cm layer of wood chips. Attention should be paid not to use wood from pine trees or other trees which contain etheric oils. Those can cause skin rash. Brushed concrete is not recommended to be used for greater one-horned rhinos.

The sketch below demonstrates one way of how to construct a stable with wood chips.



Visitor area

Drinking water basin

The sketch above shows the construction of an indoor stable at Zoo Basel which is covered with wood chips. This concept started in 2006 and has led to good results regarding foot health. The construction is as following:
Concrete on the bottom, on top a commonly used layer of fleece (material which keeps the finer substrates on lop and leaves water through). It is not nailed to the concrete, just laid on top. As the slope is very gradual it does not move.

Prevents that IR rub horn on flat surface

Feeding trough: Vertical bars (steel covered with wood, 80cm apart, width to the wall should be 1,3m to avoid rubbing of horn. Depth 30cm, gentle slope to one side to facilitate cleaning

2.1.7 Furnishing:

Feeding area

When using wood chips, where to feed becomes an issue and an area within the stable must be found that avoids that the food is not mixed with the wood chips. At Zoo Basel, a feeding trough was built alongside one wall with vertical bars. The bars are made of steel, covered with wood and are 80cm apart. The trough is 6m long (allows for 2 – 3 animals to feed next to each other) and should be 30cm deep and over 130cm wide, to allow the horn enough room and to avoid that it touches and damages itself and the wall.

This system has worked very well and has provided also a nice bed for a young calf (they prefer lying next to the head of the mother) while the mother is eating.

Water

The water basin should hold a large amount of water (especially if more than one rhino is anticipated to be kept in the indoor exhibit, the basin should hold 150l – 200l), needs to be easily cleaned and refilled daily. As young calves do drink water at young age, it should not be too high up. A young calf can theoretically swim, but a calf falling into a water basin might injure itself and might than not be able to climb out. The basin should be able to be adjusted according to its needs.

As GOHs like rubbing horn on flat areas, this needs to be kept in mind when designing the basin.

In order to be able to supervise the amount of intake by a sick rhino, a non-automatic basin has proved useful. Given the long nature of the horn, basins need to be wide enough.

Enrichment devices

Wooden logs, trees, etc. should be provided. They offer the rhinos to rub their skin on but also allow them to play fight with (especially when hanging from the ceiling).

Inside the stables various devices should be installed to be able to fix trees and to hang up logs, etc.

2.1.8 Pool

Greater one-horned rhinos need an indoor water basin. In the wild they spend – especially during the hot humid season – many hours in the water or wallows. In zoos, pools are especially important during those times, when the access to an outdoor pool is not possible.

Experiences from the past decades have shown that GOHs are hesitant to use steep and narrow steps when going into a pool. One can get the impression that they seem to have difficulties in finding the right way into the water. Further experience has shown that GOHs spend more time in the water when it is not too deep. All Asian rhinos can swim and dive, but in zoos, they usually use the water to rest. Only young animals (esp. two young bulls) love the water to play in. When constructing a pool, it is therefore more important to provide a shallow entrance (and an entrance and an exit or a wide entrance to allow two animals going in and out) and maybe a less deep pool (80 -90cm) than a deep pool (2m) with steep steps entering the deep pool. Of course it is nice to offer different depths to the rhinos, but if the choice has to be made, it is more important to increase the resting time than not to use the pool at all.

Temperatures over 22°C favour the use of the water. A filter system is needed as they like to defecate into the water. To avoid that the feet are damaged by the concrete floor, rubber mats have proved useful.

Tress and logs can be added / hang into the water for enrichment.

2.1.9 Indoor environment

The house should be heated. Temperature over 18°C is favourable. Humidity does not play a major role as access to an indoor pool should be provided when the animals are housed inside.

Various standard heating systems have been used for rhinos. Preferably heat should not come from the floor but from the top. When using wood chips, a heated floor system is not advisable. Wood chips will dry out very fast and dust develops.

To avoid heat loss, heavy duty plastic stripes can be used at the doors. The experience with those stripes has been good, the rhinos learn fast to go through (start hanging the stripes from outside first, leaving the inner section open, than add one by one).

Like all animals, rhinos do not like draught. Each indoor enclosure should be built in a way that the rhinos can retreat from extra wind / heat / cold.

Natural light should be provided as much as possible. Especially during the winter time, artificial or natural light sources should be provided to stimulate the natural cycles.

2.1.10 Indoor maintenance

A stable designed to hold a 50cm layer of wood chips needs less maintenance than a stable with concrete on a daily base. When designing such a stable, it needs to be considered that wood chips need to be replaced (access possible with a truck, etc.). At Zoo Basel, the material of the indoor stables is completely changed approximately every 8 years. In between, they receive a refill. As GOH defecate usually at the same spot, this area could have a solid floor (or wooden panel) to facilitate cleaning. Walls that are getting dirty can be washed occasionally, but not on a daily bases. Some considerations are given to those areas where the rhinos urinate more frequently. They should be cleaned and refilled. To avoid dust development, the wood chips should be sprayed as needed. It is important to have enough wood chips as this is an important feature for the natural bio-floor mechanism. Such systems have been used successfully in other species, such as Great Apes as well. They are less smelly and sticky than all other floors.

As rhinos like to lay with the head up, wood chips can be modelled in a way to comfort the animals as well.

2.2 Outdoor enclosure

2.2.1 Group composition

Keeping 1.1 GOH requires two outdoor enclosures. Keeping 1.2 GOH requires at least two outdoor enclosures with the option to have a further outdoor area available in case 0.2 do not get along, are sick, have a calf and are aggressive, etc.

2.2.2 Size

Certain countries have a law that clearly states the dimensions of an enclosure for wild animals. So far there are no scientifically based studies performed that give clear indications of what dimensions are needed. Looking at the nature of this species and thriving for best animal husbandry and care, each zoo needs to define them. The design and the structure within the exhibit are often more important than the size alone and more emphasis is put in these best practice guidelines on the latter.

GOH can run very fast, can have a very violent courtship behaviour and have sharp lower incisors that can inflict serious wounds in case one animal gets trapped.

2.2.3 Multiple use of the exhibit

The exhibits should be built in a way that all outdoor exhibits can be accessed by either males or females, depending on the management. To have these options gives more flexibility for various situations such as breeding, young animals, enrichment, seasonality, etc.

2.2.4 Boundaries and gates

Bulls are solitary animals. In the wild they tolerate females in their territory but only meet for mating. Females avoid the males. If they meet without being in oestrus, serious fighting can occur. To keep stress levels down, the enclosures should be built in a way that the bull does not (permanently) see the female(s).

Both outdoor enclosures should be ideally interconnected to enlarge the space when needed and it should be possible to move either sex on either site. This is especially important for breeding preparations.

Due to the violent nature when mating, the exhibit where breeding will take place should have several escape routes, run-arounds, and by no means a dead end. Also pools need to have an entry and exit. When a male is chasing a female it must be assured that she never gets trapped.

As boundaries, several features have been used: solid walls, stones, wooden panels, steel fences (horizontal and vertical), etc. Certain zoos have used and still use ditches. A U-shaped moat is not recommended as an animal easily can fall in when being chased and injure itself. A V-shaped moat with a moderate slope can be used, but again it must be assured that a male chasing a female cannot trap and injure her in such places. The walls / fences should be at least 1,4m high or even higher. Young rhinos love to climb and can jump quite well.

Contact zones through bars / doors can be provided. The space between bars should be around 30cm. This allows a keeper to potentially move through a gate without being trapped.

Calves are very curious and will explore an outdoor exhibit thoroughly once they become confident in the new area. Therefore the enclosure should be designed that no calf can escape or climb on structures (they are very good climbers).

As secondary barriers (in front of doors to avoid horn rubbing) electric fences have been used successfully.

When GOH are excited an electric fence will be ignored and will not serve to keep an animal inside /outside. In fact, this can become really dangerous as they might rip it off and the fence might get stuck along the horn, etc.

Manually operated gates as well as sliding doors have been used. When using sliding doors, the track needs to be clean to work properly. See indoor chapter for preference of manually operated doors. Doors should be locked in a way that they are secured and that no rhino can open them by lifting the door. In order to operate doors properly the keeper needs to be able to see if it is safe to open a gate or not.

The public should not be able to touch or feed the rhinos, nor should disturbance be too much. An enclosure should have an area where the animals can retreat from the noise.

Each outdoor exhibit should have a gate that is large enough for a truck to enter the enclosure. This is useful for the maintenance of the floor, replacement of trees, etc.


Boundaries need to be safe to keep the rhinos away from the visitors


Gates can be additionally secured by using an electric fence in front of it. Solid walls should be at least 1,4m high and should not be flat, otherwise the rhino might rub its horn.

2.2.5 Surface

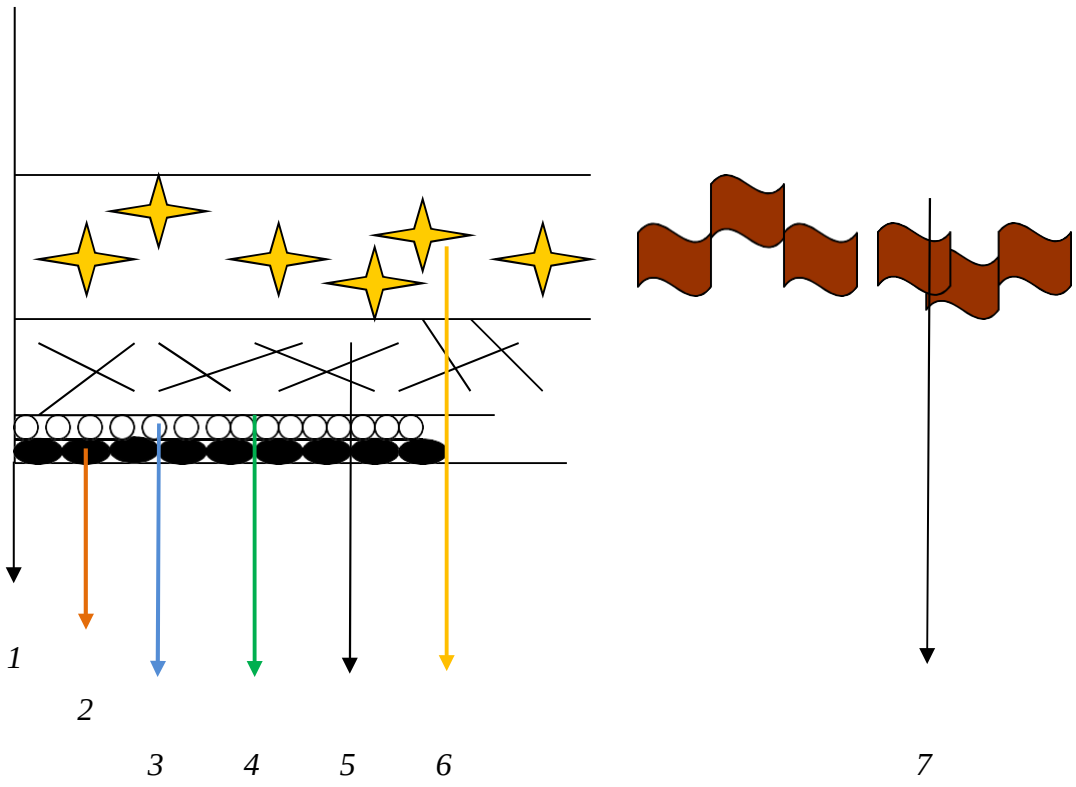
Natural flooring such as grass, earth, sand, wood chips is ideal. All material that is non-abrasive can be considered a good material to be used for keeping GOH. Sand needs to be used with care as sand impaction has occurred in this species. This can be avoided by offering either slightly elevated feeding places or by using other material around the feeding areas. Still one should not forget GOH will collect leaves fallen into the exhibit and will eat them no matter if sand or not is attached. They also play and calves have been observed to eat sand.

In zoos that do not have a natural floor, wood chips can be used. Bark from pine trees has been used with no adverse effect (skin reaction to the etheric oils). But pine chips (branches which were cut) have caused a skin rash when being used. All GOH will eat wood chips from branches / bark. This is natural as they also eat branches in the wild. Usually they will stop doing this after a few days.

The biggest challenge is the drainage and the maintenance of such an outdoor enclosure with wood chip. Even though GOH like to walk in mud the aim of the surface is not to transform completely into a mud wallow when rainy days hit the region.

As Zoo Basel is a city zoo with no natural surface, a new concept has been developed and tested in the past years. The experience so far has been very positive.

Sketch of the surface of the greater one-horned rhino outdoor exhibit at Zoo Basel



Layers

1 - Asphalt (what is commonly used on roads)

2 - A very hard plastic drainage system, used for outdoor riding horse places (hard enough that it can bear the weight of a truck) there are various types on the market, important is that it is around 5 cm high, has enough holes on many areas to allow water to go through

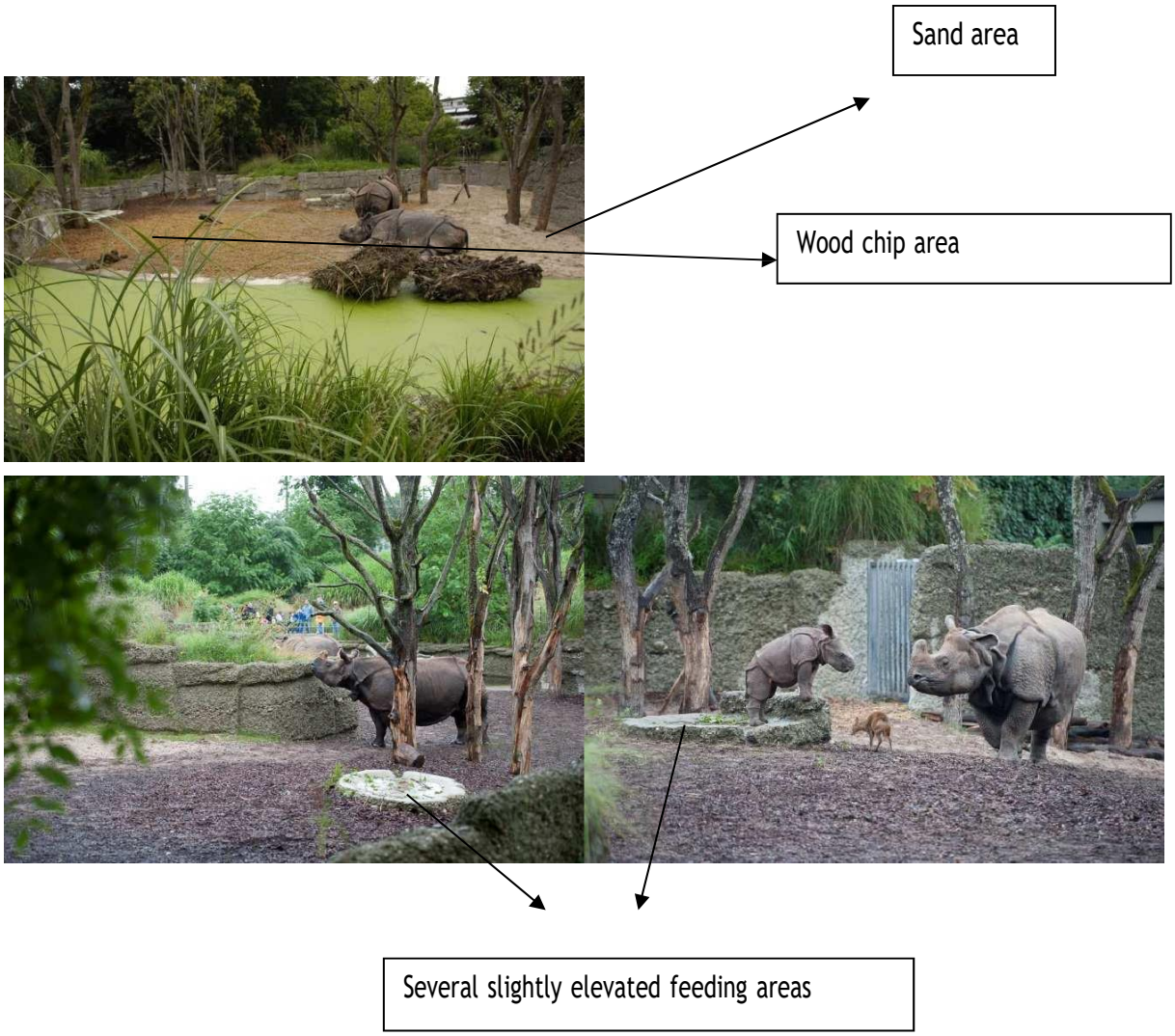
3 - This is filled / topped with a layer of 10 cm of pebbles

4 – On top of the pebbles comes a filtration mat (there are plenty different types on the market and it is easiest to choose something which is commonly used on outdoor horse riding places (and was tested beforehand).

5 –This is topped with a layer (around 40 – 50 cm) of branches from pine trees (freshly cut).

6 – On certain areas sand can be used (rounded and washed) – where animals like to lay (lots of sun) and are NOT offered food. (Sand and wood chips will mix in the course of time and can render the drainage less effective!!!)

7 –In the main area, wood chips can be used. Pine has caused skin rash in some zoos, so other wood should be used (such as beech), unless one can be sure that the etheric oil have evaporated (age of chips… not freshly cut). As the rhinos eat wood chips in the first days, the material needs to come from a source free of toxins. Local material is preferred as it reduces costs and is fast available.



Several zoos have used and still use a hard surface to keep GOH. Marl has been used and has caused foot problems. It is recommended to keep greater one-horned rhinoceroses on a soft ground (non-abrasive) in order to avoid foot problems.

2.2.6 Furnishing

When keeping two females the design of the female enclosure needs to provide enough run-arounds, islands, hills, hide-aways, separate feeding places, etc. to avoid social stress. Not all females appreciate a female companion, but usually the females learn to live together even though occasional fighting might occur. To avoid stress, structures must be chosen which allow the females to move out of sight from each other.

The **feeding stations** should be out of sight of each other. This has proved very helpful when integrating two females with calves. A feeding station should be slightly elevated and easy to clean. Young rhinos will climb, avoid sharp edges. The size should be large enough to allow each animal access to it without struggling to get there.

The breeding enclosure should also be designed in a way that the rhinos can run without being trapped. Several **islands**, hills, etc. have proven very useful. As long as the female can run away and will not be trapped in a corner or dead end, this will slow down and diminish the bull's aggression (and stamina to continue to run). It is worth thinking about a round enclosure design instead of a rectangular design.

Every enclosure needs to have **shady areas**.

Sandy areas should - if at all – be provided at the sunniest and less windy spot. This has proved very convenient during spring and fall when temperatures are still a bit chilly.

Next to the structures mentioned above, a lot of other interesting furnishing tools can be integrated, providing some tools to **play** with. Especially young animals and bulls seem to enjoy banging their head and body against hanging heavy logs / balls, etc. and to move tree trunks / roots / etc. through the exhibit:

- Trees standing / laying serving as rubbing posts, etc.

When laying a tree trunk, one needs to be aware that an adult bull is very strong and can push tree trunks. In order to avoid that he might push such a trunk into the pool or against doors, or other unwanted places, they should be attached. When attaching such logs, it can (and should encouraged as an enrichment tool) happen that the bull will even lift a 2t log.

- Hanging logs
- Devices to hang up food branches
- Boomer balls, etc.

Mud wallow

A mud wallow is much appreciated by many rhinos. In natural exhibits, it has been observed that GOH create their own wallows. The material should be not too sticky in order not to trap a young animal or even an adult.

Maintenance of a mud wallow is often problematic. As rhinos like to urinate and defecate in / at wallows, it might become necessary occasionally to completely renew the wallow and to refill it again.

Scale

Many zoos have incorporated a scale either between indoor or outdoor or inside. The size needed is 4m long and about 2m wide. GOH will stand on integrated scales easily and will even remain on it for food. A scale can also be integrated in a training chute.

Chute

A chute is practical but will not be safe to work on feet. A rhino should never be asked to lay down in a chute as the feet might move between or underneath the bars. When getting up, they might be trapped.

Natural trees and their protection

Trees that are not meant to be destroyed by rhinos can be protected by a ring of large rocks around (young calves like to climb! Caution that they can slip between rocks and tree...), electric wires, and ropes curled around the (big) tree to protect the bark.

Special features

Good light sources that can be used for observation at night during mating are very helpful. This makes it easier for the keeper to know what is happening on the exhibit and to decide when to separate or not to separate the animals.

For security reasons, the plans should include the possibility to install video cameras when needed.

2.2.7 Pool

Every exhibit should have a pool. They are used by rhinos to regulate the temperature, for skin health and for enrichment. It should be at least 80 – 90 cm deep, but more is advisable, as GOH really enjoy submerging completely during hot days in the water for hours.

The pool needs a shallow entrance and it should be non-slippery. In the outdoor exhibit, steps should be avoided as they can become dangerous when a rhino is play running or is chased by another rhino (also young animals playing). A good pool offers areas where the rhino can lay down and areas where they still can walk with head up.

A pool should have an entrance and an exit; otherwise it will be a trap when rhinos are chasing each other.

In very large exhibits, a pool can be deep so that the rhinos have to swim. When rhinos are chasing each other in such large exhibits, it seems that they not necessarily run into the deep water but rely on their natural instinct and choose other run-routes.

In the winter time, when temperatures drop, GOH will not use (unless young, playful animals) the pool. To provide additional space, many zoos drain the pools during the winter time and fill the bottom with wood chips, so that this area still can be used by the rhinos.

Young rhinos can swim right after birth. But it seems that they are not eager to do so in the first days. Several observations at Zoo Basel showed that even if the mother is going into the water, the calf will stay out. A calf will eventually be curious enough to explore the pool. If it is possible to drain the pool to 40cm at the beginning, this will surely help the calf, but if it needs to swim, it will. There are no reports around – unless from the wild, where calves are washed away during the monsoon from their mothers – that they are incapable of getting out of deep water again.

The pool should be cleaned if not being a natural lake as the rhinos will defecate in the water. The frequency of cleaning depends on the size of the pool, the amount of rhinos as well as the season. It is nice for the keeper if a) access to the pool is made convenient and non-slippery b) the drainage hole should be of good size, otherwise it will take – due the faeces – a very long time to drain a pool.

A pool that can be drained, can be used – when covering the floor with wood chips – by the rhinos in the winter.

In addition to the pool, fresh drinking opportunities need to be offered.

Pools should have a shallow entrance

Pool and mud wallows are essential for GOHs

2.2.8 Outdoor environment

GOH live in a climate, where temperatures and humidity vary a lot during the year. A healthy GOH will be able to go out at temperatures below 0°C, BUT care needs to be taken to avoid that ears and tail will suffer from frost bite. A sunny snowy day might be better tolerated than a cold day just below 0C. The experience at many zoos is that they move the animals in and out several times per day but never let them out longer than 30min when it is really cold. Or they provide solid heavy plastic stripes and allow the rhinos to choose for themselves. This has been really helpful and it seems that the rhinos very well know when to come in. This system needs to be applied only when the rhinos are used to it and compatible with each other (not blocking an entrance). A mother with a calf should always be observed and handled by the keepers. The concept of the 'free choice' system, by allowing rhinos to choose for themselves when to go in and out, is a little bit dangerous during the winter for a calf and should be carefully evaluated.

2.2.9 Outdoor maintenance

To maintain an enclosure that is made up of wood chips, the keeper needs some technical assistant. Especially at the very beginning, removing faeces from such an exhibit can be hard work as the wood chips have not sunken yet and pushing a wheel barrow is very difficult. Some zoos are using small tractors and remove the faeces once a week. As GOH defecate also in the wild at 'common toilets' this behaviour is also seen in zoos and can even be used as an educational tool to explain the rhino behaviour / use of senses to the visitors. It is advisable never to spot clean those toilets, otherwise the rhinos will choose another area and that might be more difficult to reach. Some zoos have even 'trained' their rhinos to defecate at a certain spot by leaving faeces constantly at a certain area.

In the course of time, the wood chips will collapse and will be decomposed, leading to an earth like look. Even though this is wanted, this can lead to a very firm upper part and water from rain will not drain properly, so leaving poodles, etc. To avoid this, it is advisable to plough the enclosure occasionally. Of course this depends of how many animals are kept on how much space and each zoo will make its own experiences of what will work and what not.

Enclosures that consist of natural substrates should be cleaned daily, apart from the common toilet. This should never be removed completely unless a new area is in more favour.

2.3 Feeding (Dr. Marcus Claus)

2.3.1 Cues from the natural diet

The greater one-horned rhinoceros (*Rhinoceros unicornis*) is often called a 'mixed feeder' or 'intermediate feeder' – in contrast to the strict browser Black rhinoceros (*Diceros bicornis*) and the strict grazer White rhinoceros (*Ceratotherium simum*) (Owen-Smith 1988). For the feeding of zoo animals, these terms should be of little relevance and the composition of the actual diet should be considered. Unfortunately, there is a tradition in the zoo community to consider 'browsers' or 'mixed feeders' as animals that require higher-digestible food, although there is no scientific evidence for this (Clauss and Dierenfeld 2008). Therefore, calling the greater one-horned rhino a 'mixed feeder' could still induce some institutions to use a diet made up of some highly digestible compounds, even though this is in stark contrast to the real diet of these animals in the wild.

Different studies have yielded different results as to the natural diet composition of GOHs. Depending on the season and on the region, the diet will vary. However, from the various studies, it is undoubted that the major diet item of these animals is grass (Laurie 1982; Steinheim et al. 2005; Wegge et al. 2006; Pradhan et al. 2008), with browse making basically up for the other portion of the diet. GOHs actually have salivary tannin-binding proteins (Clauss et al. 2005a), and indication for evolutionary adaptation to diets that consist partly of browse. Although nutritional analyses of the diet of free-ranging GOHs are lacking so far, it is reasonable to assume high contents of dietary fibre, based on analyses of grass and browse items ingested by other large herbivores, and by nutritional analyses of those grass species eaten mainly by greater one-horned rhinos made in other, not rhino-related studies (Clauss and Hatt 2006).

Greater one-horned rhinos have been reported to consume wild fruits – however, this is not unequivocal, with at least one study reporting that they did not ingest fruits in the study period (Dinerstein and Wemmer 1988; Wegge et al. 2006). Unfortunately, the information that animals eat fruits in the wild often leads, automatically, to the feeding of commercial fruits in captivity – although wild fruits are extremely different from commercial fruits in their nutrient composition (Schwitzer et al. 2009). If one wanted to imitate the nutrient content of wild fruits in captivity, one has to feed green leafy vegetables such as parsley, spinach etc. Additionally, the formulation of diets in captivity have often simply been based on qualitative information such as 'they eat fruit' which then is translated into huge amounts of apples, carrots and bananas. Because humans value such diet items, it is often considered a sign of particular care if they are fed. Such feeding practice has lost the perspective of the biological information from the wild. Clauss and Hatt (2006) demonstrate in a calculation what the report 'they eat fruit' actually means in quantitative terms for the greater one-horned rhino: Dinerstein & Wemmer (1988) report a maximum intake of 5.1 kg of fresh *Trewia nudiflora* fruit per day during the monsoon season, with a dry matter (DM) content of c. 16%. This results in a DM intake from fruit pulp of less than 820 g and, assuming a total daily DM intake of 1.5% of body mass in a 2 tonne Asian rhinoceros, *T. nudiflora* fruits would thus account for ***less than 3%*** of the total daily DM intake! This finding, and the fact that wild fruits do not resemble commercial fruits usually provided for animals in zoos (Oftedal and Allen 1996; Schwitzer et al. 2009), emphasize that offering fruits to Asian rhinoceros in captivity cannot be justified by chance observations of their natural diet. The natural diet of any rhinoceros species is characterized by a high-fibre and low-to-moderate protein content.

2.3.2 Cues from digestive physiology

The anatomy of the digestive system in rhinoceros species roughly resembles that of horses: rhinoceros are monogastric animals with a large hindgut-fermentation chamber (Stevens and Hume 1995). The digestive strategy of the greater one-horned rhino is characterized by a slow ingesta passage and, hence, a high digestive efficiency that is comparable to, and even higher than, that of domestic horses (Clauss et al. 2005b; Clauss et al. 2005c). In contrast to horses, whose nutritional strategy often includes a comparatively

high food intake, rhinos appear to have generally lower food in takes in the range of ruminants (Meyer et al. 2010). These adaptations indicate that greater one-horned rhinos mainly use microbial fermentation of plant fibre in the hindgut to gain energy from their natural diet. Diets fed to these animals should therefore be based on fibre, not on easily-digestible components such as starch from grain products or sugars in commercial fruit.

Given the similarity of the digestive tract appears reasonable to use the dietary requirement data for horses, in particular for minerals and some vitamins, as feeding recommendations for rhinos (Dierenfeld et al. 2005).

2.3.3 Health problems related to diet in captivity

Atkinson et al. (2004) collated evidence that Asian rhinoceros in captivity may be substantially heavier than their free-ranging counterparts. Apart from inappropriate flooring (Von Houwald and Flach 1998), obesity is considered a major contributor to foot problems in Asian rhinoceros (Atkinson et al. 2004). Uterine tumours (leiomyoma) are frequently reported in Asian rhinoceros (collated in Clauss et al. 2005c), and similar problems in humans give rise to the suspicion that obesity may be a contributing factor; of course this does not mean that there will be more important, nutrition-unrelated factors (Hermes et al. 2014). General considerations on energy requirements and utilization efficiency (explained in Clauss et al. 2005c) lead to the conclusion that the maintenance requirements of hindgut fermenters should be c. 0.6 MJ digestible energy per $kg^{0.75}$ metabolic body mass. Digestible energy intakes in excess of this figure have been measured in Asian, White and Black rhinoceros in captivity on conventional zoo diets of hay, pelleted compound feeds, and produce, and even in Asian rhinoceros on ad libitum hay-only diets (Clauss and Hatt 2006).

The importance of the hygienic quality of the hay has been emphasized by cases resembling a `farmer's lung' condition reported in Asian rhinoceros at the Basle Zoo in Basle (Rüedi and Müller 1975; Rüedi 1984); using hay of impeccable hygienic status should help to reduce the risk. Constant monitoring of hay quality, and the disposal of unhygienic batches, must be an integral part of rhinoceros husbandry. Processing hay through a mechanical shaker prior to feeding can significantly reduce dust inhalation by both the animals and keepers.

In parallel to observations in horses (reviewed in Clauss and Kiefer 2003), Göltenboth (Göltenboth 1995) speculated that an increased supplementation with energy-dense feeds, such as grain-based products, could lead to laminitis (founders, inflammation of the hoof-horn producing stratum of the hoof) and contribute to foot problems in rhinoceros species.

Some zoo diets offered to Asian rhinoceros have been found to be deficient (when compared to the recommendations for horses) in several nutrients, such as phosphorus, copper or zinc (Clauss et al. 2005c). Although no clinical syndromes linked to these deficiencies were noted, it appears reasonable to try to avoid such situations.

2.3.4 Historical diets for Indian rhinos

Although Wallach & Boever (1983) already stated that greater one-horned rhinos can be maintained on a hay-only diet, historical diets very often included a source of grains (either as plain grains, or in grain-containing pelleted feed, or as bread) and commercial fruits and vegetables (Rüedi and Müller 1975; Blaszkiewitz 1980; Gutzwiller et al. 1985; Strauss and Seidel 1985; Göltenboth 1986; Clauss et al. 2005c). More than ten years ago, Lintzenich & Ward (1997) already published feeding recommendations for large herbivores (the greater one-horned rhinos was not mentioned specifically). These authors warned against the use of commercial fruits and vegetables and recommended a diet of 60-75% grass hay and 25-40% pelleted feeds for grazing rhinos. They noted that the main reason to use a pelleted diet is the constant

provision of some nutrients (mainly minerals, some vitamins) that might be lacking in the hay, depending on the hay batch that is being used. Clauss & Hatt (2006) made similar recommendations for the feeding of rhinos, suggesting that the proportion of the pelleted feed in the diet could be reduced even further.

2.3.5 Diet formulation principles

Diets for herbivores should in theory be based solely on what they normally eat in the wild: whole plant material; in zoos, this represents fresh forages (such as freshly cut grass, browse) or preserved forages (hay, straw, silages). In theory, there is no reason to assume that large herbivores cannot subsist on such a diet.

However, in contrast to the wild where animals can choose among forages to a certain degree, feeding them from one batch of forage (e.g., one batch of hay) for a long time can incur the problem of a deficiency, if that particular batch of forage is deficient in a particular mineral or other nutrient.

In theory, therefore the ideal feeding regime in captivity would be to provide the animals a range of forage options, distributed spatially in such distances that they have to move a lot and cannot become obese by simply eating everything that is offered. Evidently, such a feeding regime is theoretical, but not realistic.

In reality, forage-based diets are supplemented with other feeds to ensure that a deficiency in a particular nutrient or mineral does not occur. Feeding an animal a ration of 100% pelleted diet will ensure that all its nutrient and mineral requirements are met all the time, but natural feeding behaviour as well as certain aspects of digestive physiology (chewing, gut peristalsis triggered by larger particles) will not be optimal. Feeding a ration of 50% forage and 50% pelleted diet represents a compromise that ensures constant provision of nutrients and minerals but also a certain amount of 'structure'.

However, thinking and talking like this leads to a certain conceptual approach: to consider forage only as a 'source of structure', and the pelleted diet only as a 'source of nutrients and minerals'. But only part of this concept is true: pelleted feeds really are only a source of nutrients and minerals – they do not provide any structure. Forages are a source of structure, but they are ***also*** a source of nutrients and minerals (that is the reason why wild animals survive without any pellets). If one wants to make sure that an animal receives a sufficient amount of nutrients and minerals, one must ask oneself whether one wants to provide these via pellets, or via forage. For example, if a diet requires a certain increase in protein – this can be achieved by feeding more protein-rich pellets, or by adding some alfalfa/lucerne hay to the diet. The second option is the one that automatically also delivers structure. As another example, diets that are mainly composed of forage will always have an appropriate calcium level – there is no rational need to add a calcium supplement.

Therefore, the diet design approach suggested here tries to account for the nutrients and minerals that one can assume to be present in forages, and to supplement only those minerals as a 'safety option' that might be limiting in the forages. In terms of mimicking natural diets, such an approach is closest to the forage-only diets in nature.

1. Exclude all commercial fruits, all commercial vegetables (except green leafy ones), all whole grains, bread, and grain-based pellets from the diet. These recommendations have become quite commonplace nowadays, although in practice, these diet items are still fed quite often. They all have in common that they are energy-dense (in their dry matter) and low in fibre, poor in calcium and other minerals (except formulated pellets), and have a fatty acid composition dissimilar to wild diets (Allen et al. 1996; Oftedal and Allen 1996; Clauss and Hatt 2006; Hummel et al. 2006; Clauss et al. 2007; Clauss and Dierenfeld 2008; Clauss et al. 2008a; Clauss et al. 2008b; Schwitzer et al. 2009).

2. Use fresh forage (freshly cut grass, browse) as much as possible during the season when it is available. Use branches as supplementary items as much as possible during any season. Fresh grass roughly contains

4-5 times more water than hay, which means that you should replace 1 kg of hay with 4-5 kg of fresh grass. When replacing hay with grass, use this factor in any of the subsequent diet designs.

3. For species such as the greater one-horned rhino, which accept hay and straw readily, there is probably no need to produce silages. Evidently, if logistics and finances are of little concern, then providing these animals with grass and browse silages during the winter season would be ideal, but there is little indication that it is crucial.

4. Base the diet on dried forages, and supplement only with a small proportion of pelleted feed that is high enough in mineral content to allow it being only a very small part of the diet while still providing a safe nutrient/mineral intake.

Using average values for hays from both North America (NRC 2001) and Europe (various sources) for alfalfa/lucerne hay, grass hay, and wheat straw, the following diets (Table 1) can be designed using one supplement (Supplement I, Table 2) at 10% of the overall diet.

Table 1. Diets (ingredients in % of total diet, as fed) which can be combined with Supplement I for the feeding at maintenance level for adequate nutrient/mineral supply as estimated using horse recommendations (Clauss and Hatt 2006; NRC 2007).

Ingredient	Alfalfa/lucerne hay	Grass hay	Wheat straw	Supplement I
% of total diet	-	90	-	10
	10	40	40	10
	20	35	35	10
	-	40	40	20

Table 2. Specifications for Supplement I (for forage compositions in Table 1)

Basic ingredient: alfalfa/lucerne meal	Additional ingredient: soy meal		
Nutrient/mineral	concentration in % (g/100g) dry matter	Nutrient/mineral	concentration in ppm (g/kg) dry matter
Crude protein	23	Cobalt Co	0.5
Calcium Ca	not important*	Copper Cu	50
Phosphorus P	1.0	Iodine I	3.5
Magnesium Mg	0.5	Iron Fe	not important*
Potassium K	not important*	Manganese Mn	20
Sodium Na	1.0	Selenium Se	1
Chloride Cl	not important*	Zinc Zn	230
Sulfur S	not important*	Vit E (IU / kg)	500

*with the combination of forages indicated in Table 1, these minerals need not be added specifically to the supplement

Specifications for the supplement can be used to have it produced by a local manufacturer, or to choose an existing product.

It is evident that part of the supplementation that is necessary can be compensated by feeding alfalfa/lucerne hay rather than a pelleted supplement.

It must be noted that the pelleted supplement contains minerals in such concentrations that feeding it at higher levels in the diet must be avoided.

Therefore, if for example the diet should be based on straw as the only forage, the composition of the supplement would have to change (Table 3).

Table 3. Specifications for Supplement II (for a diet consisting of wheat straw 70% and Supplement II 30%)

Basic ingredient: alfalfa/lucerne meal	Additional ingredient: soy meal		
Nutrient/mineral	concentration in % (g/100g) dry matter	Nutrient/mineral	concentration in ppm (g/kg) dry matter
Crude protein	23	Cobalt Co	0.2
Calcium Ca	0.5	Copper Cu	30
Phosphorus P	0.5	Iodine I	1.2
Magnesium Mg	0.1	Iron Fe	not important*
Potassium K	not important*	Manganese Mn	30
Sodium Na	0.05	Selenium Se	0.5
Chloride Cl	not important*	Zinc Zn	150
Sulfur S	0.25	Vit E (IU / kg)	250

*with the combination of wheat straw, these minerals need not be added specifically to the supplement

These data can be used to actually make a diet. E.g., Table 1, first diet, for every 9 kg of hay, 1 kg of Supplement I is fed.

If in this case fresh grass was to be used instead of hay for half the hay diet, this would mean that 4.5 kg of hay, 4.5 x 4.5 kg = 20.25 kg of fresh grass, and 1 kg of Supplement I is fed. (Remember: 1 kg of grass hay corresponds to 4-5 kg of fresh grass).

2.3.6 Forage choice

Fresh grass should not be chopped too short, because that might lead to constipation. Always use long-stem grass and grass hay.

All forages should always be of impeccable ***hygienic*** quality (no mould, not a lot of dust). However, the ***nutritional*** quality need not be high – actually, for greater one-horned rhinos, a long-stem hay with a high fibre content is desirable and adequate.

If a higher energy provision is intended for any particular reason, the first way to address this is to replace some straw (in a diet with straw) with grass hay, or to replace a high-fibre grass hay with a lower-fibre grass hay, or to replace grass hay with alfalfa/lucerne hay. Adding a grain-based pellet is not recommended for increased energy supplementation.

Clauss & Hatt (2006) state that in their experience, achieving a regular supply of fresh grass, and especially lucerne hay of acceptable quality, is sometimes a problem for European zoos and should probably be regarded as the major limiting factor for the optimization of the husbandry of large herbivores. The provision of high-quality hay is essential and personnel responsible for purchasing these products should be experienced in evaluating hay quality, and should be able to discuss the production and harvesting methods with farmers. The logical solution to the dilemma of limited availability of forage is to either contract farmers (rather than relying on forage dealers) or cultivate land owned by the zoo. Potentially several zoos could collaborate to contract a farmer if it is more economical to purchase a high tonnage. Such co-operation should be a long-term commitment with a mutual learning process that would eventually result in the production of forage of the highest quality, as specified by zoos and within the limitations of the land being cultivated. The hygiene problems associated with storage could partially be reduced by using fresh forage (grass, lucerne) during the growing season.

2.3.7 Feeding principles

When an adequate diet composition is achieved, the most important question is how much of that diet should be fed. Because the prevention of obesity is a major goal in the feeding of greater one-horned rhinos, offering the diets described above forages ad libitum may not be appropriate in many cases. It should be noted that the danger of becoming obese on an ad libitum diet is the lower the less energy-dense the diet items used are. A diet based on high-fibre grass hay and straw, for example, will less likely induce overfeeding and obesity than a diet based on low-fibre grass hay and grain-based pellets ad libitum.

Any of the diets listed above should be used, with 1.5% of the estimated body mass as a rough guideline for the amount (for the whole diet) with which to start. A 1500 kg greater one-horned rhinos therefore should receive, as a starting guideline, 22.5 kg of any of the diets mentioned above. For the last diet in Table 1, for example, this would translate into 9 kg of grass hay, 9 kg of wheat straw, and 4.5 kg of Supplement II.

If this diet is ingested, and one feels that the animals need more food for enrichment (but not for energetic) reasons, then branches and more straw can be supplied.

Subsequently, the body mass development and the body condition of the animal must be observed. For greater one-horned rhinos, regular weighing with built-in scales should be part of the professional management of the species, similar to the widespread practice in elephants (Hatt and Clauss 2006).

Weighing should be performed regularly; it is the development of the body mass over time that should determine the decision of changing the amount of diet fed.

In addition to the recording of body masses, the body condition should be scored regularly. In those facilities where regular weighing is not an option, body condition scoring (BCS) must replace weighing completely. It is stressed that BCS is not an adequate replacement of weighing, but a second-rate surrogate solution.

The best body region to estimate the nutritional status of an greater one-horned rhinos is the spine along the hip (Fig. 1).

Fig. 1. A free-ranging (left) and a captive (right) greater one-horned rhino. Note the difference in the contour of the spine over the hip, indicating a higher nutritional status in the right animal. From Clauss & Hatt (2006; both photos by Nick Lindsay, ZSL, UK).

The most common mistake when applying a BCS to zoo animals is that scoring is performed by a person (often a keeper, or a curator) who sees the animal on a daily basis. Body condition scoring should be performed by a person familiar with the procedure, who does not see the animals on a frequent basis, but only after longer time intervals (e.g., 2 weeks) when the scoring is done. Constant exposure to the appearance of any animal numbs the senses against changes that come gradually. This is similar to the fact that the moment when one realizes how one's kids have grown is when one meets them again after they have spent two weeks with their grandparents. The ready availability of digital photo cameras should be used to document the body condition visually when scoring, to put the scoring on a more objective basis. In this way, all personnel involved can quickly klick through a series of photographs and better evaluate whether changes in the body condition have occurred.

Adjustments in terms of the energy provided to the animals should be either done by switching between higher and lower-fibre hays when keeping the total amount fed constant, or by increasing or decreasing the amount of the total diet (not only of one of its ingredients) as described in Table 1. Remember that the additional feeding of straw or branches is an enrichment option but should only be done after the diet as planned is consumed completely.

In order to avoid ingestion of sand, which can cause colic in these species (Miller 2003), and which can also lead to excessive tooth wear, rhinoceros should not be fed on sandy ground. Fresh drinking water and a salt lick should be available at all times.

2.3.8 Browse list

The following browse list, taken from the Best Practice Guidelines (Pilgrim 2013) for Black rhino, can also be offered to greater one-horned rhinos:

- Willow (*Salix spp*)
- Beech (*Fagus spp*)
- Hazel (*Corylus spp*)
- Ash (*Fraxinus*)
- Birch (*Betula spp*)
- Oak (*Quercus spp*)

- Hawthorn (*Crataegus spp*)
- Poplar (*Populus spp*)
- Apple (*Malus spp*)
- Cherry (*Prunus spp*)
- Prune (*Prunus spp*)
- Pear (*Pyrus spp*)
- Wild rose (*Rosa spp*)
- Blackberry (*Rubus spp*

2.4 Social structure

Data from wild populations describing the wild social structures can be read section 1.8.

2.4.1 Basic social structure

In zoos or smaller safari parks, adult greater one-horned rhinos are usually kept solitary. Two females (with or without their calves) can be kept together. In very large exhibits, more females can also tolerate each other. A male can become very aggressive towards a female. Therefore he is kept solitary, once he is sexually mature (usually at the age of eight).

2.4.2 Changing group structure

A zoo that is starting to keep GOHs will usually get two young animals of either the same sex or a male and a female. At the age of 2 -3, when they are normally send to other zoos, they appreciate the proximity of another and can easily be kept together, day at night. It should be considered that when keeping them together inside, enough space needs to be provided to allow each animal to move away and around the other. Very often, two young animals will feel more comfortable with the company of another young animal and will become upset / very excited when separated.

Keeping two young bulls is fun to have as they are really active and show a lot of play fighting, chasing each other, etc. It is very essential for them to be allowed to behave like this as they are learning the proper behaviour for the future. Sometimes the impression might arise that a play-fight can change into a serious fight but as long as no female is around, the likelihood is very low. Young rhinos will use their teeth in play-fight and they might inflict some wounds, but usually nothing serious is happening and it is not necessary to separate them. Of course the enclosure needs to be designed in a way that they can run without hurting themselves or being trapped.

A young female and a young male can also grow up together. Usually the female will start cycling (age 4) before the male reaches sexual maturity and this can startle some young bulls as they do not know what to do. Mating activities can start at the age of six in bulls but usually proper mating occurs a bit later. Very often, a male will not regard a young female he has been growing up with as a sexual partner. Even though he might be growing up with her until the age of eight, it can be possible that he will show no interest in her, despite her obvious cycling behaviour and despite the fact that he is sexually mature. Experiences in keeping young bulls with females have shown that it will become necessary to separate the bull visually from the female. If he is chosen to breed with her by the coordinator, he will need to be separated. If not, he or she needs to be translocated to another zoo.

Introducing a new female to another female needs time. As females are solitary by nature, but will tolerate other females, one has to do this process very slowly. In this case it has been useful to have a third outdoor exhibit where contact between the two females is possible. Good observation will show how much interest they have. In case the dominant (usually older female) starts snorting and attacking the gate / barrier, more time is needed. Older or dominant females will chase the younger female. But usually they stop chasing after a few rounds as they get tired. In those moments of introduction it is important that the dominant female is brought into the exhibit where the other animal is waiting. Before introduction the new animal has to get to know the introduction exhibit very well so that she knows where to go.

Separate feeding places will help to diminish stress but will later on not be needed. GOH are very tolerant feeders.

2.4.3 Sharing the enclosure with other species

Greater one-horned rhinoceroses are or have been kept with the following species:
Blackbucks, Nilgais, Axis deer, Antigone cranes, Himalayan geese, Chinese muntjac, short-clawed otters, Barasingha, Demoiselle cranes, Sarus cranes, bar-headed geese, ruddy shelducks, knob-billed ducks, pelicans, storks, Indian muntjac, Brow antlered deer, anoa, male takins, Vietnamese Sika deer.

Reported problems:

- Nilgai male is constantly challenging male GOH. Barasingha stags chasing other species (buffalos) and might not be scared to do so with GOH.
- Female rhino enjoyed running after other animals (deer and antelopes), but stopped it after a while.
- New male deer stands his ground with the rhino (seems to be a tough individual).
- Breeding bull sometimes chases deer.
- Banteng bull living in an enclosure next to the GOH, showed lots of display during the rhino female's oestrus. There are concerns that banteng are suitable enclosure mates for GOHs.
- Anoa and GOH didn't work. Several attempts were made with different procedures, the anoa finally suffered a horn fracture.
- Bull did not give up chasing deer.

But most exhibits that are built to keep more than one species and allow all species to retreat from each other, especially when chased, seem to work with GOHs. Space is an issue if larger deer species or antelope species are kept with GOH. Hygiene is also something to consider if many animals feed at the same areas.

Impressions of mixed species exhibits:

Sosto Zoo Archive

Chester Zoo (Sarah Beck)

Zoo Basel

2.5 Breeding

2.5.1 General considerations

Breeding greater one-horned rhinos is not really a difficult issue. But due to their rather aggressive nature a lot of zoos have struggled in the past and still do as they are too afraid to let them together. In order to avoid situations that do become dangerous either to staff or the animals, it is highly important to know the biology of this species and to translate this into adequate husbandry and management.

Regarding breeding, it is important to consider that some bulls can become so excited that they try to climb over fences. As in the wild the dominant bull will not locate a female in oestrus within a few minutes – due to the fact that tall grass up to 8m high is their prime habitat and due to the fact that other bulls will also target such a female, a bull will – while searching for the female – spend hours prior being able to attempt mating in a) searching for the female b) fighting off other bulls c) when finding the female, chasing her (some think that the female by running away will test the fitness of the male). In any case, the bull will have lost a lot of energy before even being able to mate. In zoos settings, especially in those settings where the enclosures of the bull and the female are designed in a way that the bull can see the female right away, the bull will focus all of his energy on the female. Bringing them together at the first behavioural oestrus signs of the female (whistling, urine spraying, restlessness, no appetite) will lead to strong confrontations. Those can become excessive and can result in serious injuries.

In order to avoid this, the following preparations should be considered:

1. Does the exhibit allow for fast chasing action, with no possibility of trapping an animal?
2. Are boundaries safe? A bull might lift a female up with his head moving underneath the hindquarters of the female. Observations where made of a bull who has even topped a female over. (So be careful in using sharp edges as borders or just wires unless your exhibit is really large).
3. Bulls will show signs of interest 2 – 7 days prior the onset of oestrus behaviour in the female. The bull will be restless; he will show a lack of appetite and might be difficult to manage. To allow him to lose a bit of his energy, allow him to go regularly on the female exhibit, where the female has been before.
4. On the day the female shows signs of oestrus, she will also be very eager to meet the bull. BUT do not let them together at once. The duration of oestrus is 24 – 48 h (in our experience the duration = interest of bull lasts 24 hours). It is important to alternate female and bull on the exhibit where mating should take place. This basically will imitate the 'wild experience': The bull will search for the cow… the cow will mark the places she has been… the bull will search. By doing so (rotate the animals every hour or two and do not let them see each other!), the bull will be very active.
5. Do not allow physical or visual contact in this time! Rotation is important and will wear off a bit the high energy level of the bull
6. Do not allow a female in with a male unless the behavioural signs in the female are evident! Even though the hormonal analysis might indicate the oestrus peak, be aware that the female – if not in heat – will be chased seriously by the male and will continuously run away. If she is not interested in the male herself and does not show any signs of interest, do not put them together!!!

2.5.2 Introducing the male to the female for breeding purpose

Be well prepared that you might need to separate the two animals in case an accident might happen. Strong water hoses, etc. might be good to have, but they will be by no means a 100% reliable tool to be used. It is extremely difficult to separate the two animals. The only option will be to allow the chased (usually female)

to run into another exhibit and close a gate before the bull arrives. Please bear in mind that this needs practice and can be highly dangerous. This is nothing one should do light-heartedly!!

When introducing the male to the female, keep in mind that you introduce the male to the female, with the female being already on the exhibit. In some cases the female might be eager and will walk towards the male, but she can be kept away by using a wip or something similar. When the two meet, they should preferably not meet in a corridor etc. but on open plains.

What will happen?

Very often, the two will great each other by snorting. The bull having 'finally' found the female will start head to head pushing. Both can utter sounds with open mouths which make you shiver ☺

In general there will be no aggression right away. The female – after some head to head pushing – will turn and run away. The bull, in the meantime hopefully a bit tired from hours of looking for her, will run behind her. This can take minutes**...** usually not too long as the physical fitness of zoo animals is not as good as the fitness of wild rhinos. If the bull stops chasing, the female will turn around, there will be head to head encounters, pushing each other. And more running. If the bull can corner the female, or will be too fit or the female too slow, he might lift her up in the hind quarters and will push her. This behaviour, running, pushing, etc. can go on for some time. It is normal though that the bull will also lie down and rest. The female will then lick him and will want him to get up. These are good signs as it shows that the stage of chasing and aggression has passed. If the bull does get up eventually, he might chase again, but the level of aggression is less. He might also just do nothing! A lot of zoos think that the bull has no interest**...** and separate them. Never do this. As long as the female shows interest, do not separate the animals. Be prepared to have strong lights available as a lot of matings happen when it is dark and this will enable you to observe them.

Courtship behaviour:

Biting

Licking each other

Flehmen

Female licking the male's genital area while squirt urinating

2.5.3 Mating

Mating takes place at the end of the 24hour cycle (observations from Zoo Basel). The 24h cycle is counted from the onset of oestrus behaviour of the female. In case the keeper comes into the stable early in the morning and the cow is already showing signs of oestrus, calculations need to be adapted. The timing is rather essential as this prevents high aggression in the bull toward the cow. So in case the keeper comes in the stable in the morning and the cow is in oestrus, calculate as if she started 8 hours ago. Then you will alternate the rhinos on the mating exhibit for another 10 hours. Basically at the end of the day, you can leave them together and mating will most likely take part at midnight.

Successful mating takes about one hour. Mating that takes only a few minutes might not be successful. During this hour the male will ejaculate frequently and will have moments of rest remaining on top of the female. The female will slowly move, most likely to be able to balance the male better. It is interesting to observe that usually the female will walk away after an hour.

After mating the two will be very relaxed and nice to each other. This will last for at least a day. Usually no further mating takes place. After some time the two can be separated. Usually they are exhausted and will sleep for the next day.

While mating, some females will stand on a small hill, with the front feet lower than the hind feet.

2.5.4 Pregnancy

Gestation length in captivity 479.1 days (425-496 days)

As a rule of thumb it can be said that if the female is not showing signs of oestrus for 100days after the last mating has occurred, she will be pregnant. This rule has nicely worked before the times of faecal analysis. Of course these can be done as well. Oestrous cycle and pregnancy in greater one-horned rhinoceroses can be monitored using faecal steroid analysis. Pregnane metabolites were reliable indicators of the corpus luteum and pregnancy, whereas faecal 17-oxo-androstanes and oestrogens were indicators of the follicular phase. Measuring progesterone levels will give indications of pregnancy or not (Schwarzenberger 2000).

2.5.5 Contraception possibilities

As for now, it has not been necessary to use contraceptives in greater one-horned rhinos. As the bull is not kept with the female, this is the easiest way to avoid a pregnancy if required.

At the current stage, breeding for many pairs is recommended, but one needs to keep in mind that young animals should be able to stay in the zoo for at least the age of 3years, especially in those cases where a new place has not been found.

Due to the high poaching incidents and the insecure situation in many rhino range countries, a reintroduction at the current state does not make sense. But it certainly can become an option in the future.

In the meantime, new holders are needed for this species, if breeding should occur regularly in every rhino.

2.5.6 Birth

Birth weight in captivity: 64.5kg (44 - 91kg)

The following preparations should be made prior to birth:

1. A female should be giving birth in a stable she is used to and comfortable with.
2. If the female is supposed to give birth in a different stable, one should transfer the female to the new surroundings at least 1 -2 months before birth, so that she feels comfortable with the new environment.
3. The same applies to all precautionary steps, such as horizontal bars to avoid that the calf can get out, lights at night for possible camera observations, or activities at unusual times by the keeper. The more they know, the easier the situation can be handled.
4. There should be sufficient bedding, so that the calf will not slip when trying to get up for the first time. A stable that contains wood chips needs no special additional material.
5. Depending on the drinking water basin, it might be better to cover it, to avoid that a new born might fall in, etc.
6. Installation of a video camera.

Some months / weeks before birth, the female can become quite aggressive towards other rhinos she is habituated to and even the keeper she knows well. This should be respected and the animal should not be kept with other rhinos. The udder will have developed by then but in some females it takes a long time and just before birth, the keeper might be able to detect some milk drops at the teats.

A few hours before birth (up to a day) the female will be restless. She will not eat properly (maybe stop at all), defecate a lot and will walk and rarely lay down. A lot of zoos move the females to the stable. If possible, allow the female access to an outdoor area and indoor area or manage her in and out as to her likes. The more she walks the better it seems to be for her. Confined in a stable, she might start banging her head etc.

The moment the female will want to lie down, take her in (especially if it is cold outside). In large safari parks, some allow the rhinos to give birth outside and it seems to be of no problem. The only problem that might arise is the fact that it can become quite difficult to monitor the female outside or to handle the calf if action is needed.

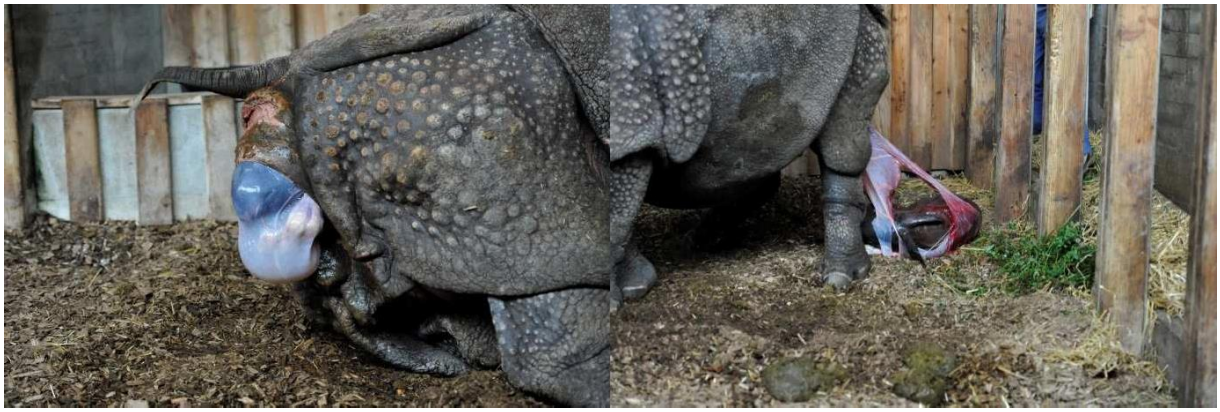
A female giving birth for the first time and a zoo that has not yet much experience with this species, is better off to keep the female inside.

Birth itself is rather straight forward but can last up to two / three hours (rupture of amniotic sac to delivery of calf).

Birth can take place with the female standing or lying. The preferred position of the calf is front legs first and less problems seem to occur when positioned this way.

Help is usually not needed.

Female Ellora giving birth at Zoo Basel:



Most GOH lie down when giving birth and will get up the moment the calf is delivered, which will lead to the rupture of the amniotic sack

They will turn an lick the calf dry, often 'helping' when the calf is trying to get up.

The preferred position of a calf is next to the mothers head when sleeping. The feeding place is an ideal place for it

Some females will tolerate the keeper checking the udder. In this case, milk was collected for analysis.

Some females will tolerate their former calf when giving birth to the next (all pictures Zoo Basel).

2.5.7 Development and care of the calf

The moment the calf is delivered the female will rise and / or turn and start cleaning / licking the calf. It takes up to 30-45min for the calf to get up, some are much quicker. It must be stressed here that a surface with a good grip will make it much easier for the calf to get up! Rubber mats alone will not help as the fluid from the amniotic sac is so slippery that a substrate is needed to suck up the fluid and to provide enough resistance. A calf that is trying to get up for too long will become hypoglycaemic and will lose the energy and finally the will to get up.

When the calf is up, it will start to search for the udder. This is something which can take some time with an inexperienced mother (3-4hours). If possible and safe for the keeper, one can assist by shovelling the calf into the right position. As the calf (normal, healthy) weighs about 60 - 70kg it is not as easy, as the calf will push automatically against anything pushing it forward and will start moaning. Most cows seem to be rather relaxed (or exhausted) but caution needs to be applied as every individual rhino reacts differently and they can be very protective mothers. It is advisable therefore to wait and observe before interfering too quickly.

The calf will suckle frequently and the suckling noises can be heard, as well as the swallowing seen by careful observation. When the calf is sleeping it usually seeks close proximity to the mother's head. If you observe that the calf is not near the mother and the mother not near the calf, this can be an indication that something is wrong with the calf. The mother should be separated and the calf should be examined.

If possible, the calf should be weight daily. On average a calf will gain 1-2-3kg per day. The meconium will be passed usually at day one / two.

At the age of 4 -6 weeks, the calf will start eating leaves. As they will also start eating pellets, one should be careful in observing the amount it will eat. It should be avoided that the calf will 'dig' into the mother's food!

Bull calves can become very playful and sometimes the mother is bothered by them, especially when the rhinos spend a lot of time inside during the winter time. Usually a calf should stay with the mother until the age of one and a half to two years, depending on the individual and the zoo situation. But every zoo should be prepared to look after a young rhino at least until they reach the age of three.

Some females allow the keeper to be inside the stable while controlling the calf drinking.

Historic picture Zoo Basel: Dr. Lang measuring the weight of a GOH calf.

At young age (eight weeks old), some calves will 'sit' when urinating.

2.5.8 Hand rearing

Hand-rearing a calf can become an option in greater one-horned rhinos if the mother has not enough milk or has rejected the calf. It should be stressed though that hand-rearing is only recommended when no other possibilities are available. In an ideal case, a hand-reared individual should still have contact to other rhinos. Hand-rearing should be done in protected contact as this is much safer for the person feeding. If possible, the EEP coordinator should be consulted prior to hand-rearing to see if hand-rearing is recommended and if another institution can assist.

The following hand-rearing protocol has been established at Zoo Basel.

Rhino-Milk (low fat) made by: Hokovit, Hofmann Nutrition AG, Industriestrasse 27, CH-4922 Bützberg, Switzerland, www.hokovit.ch email: info@hokovit.ch, Tel: +41 (0) 62 958 80 80 has been used.

(This product was developed specifically for the greater one-horned rhino calf at Zoo Basel and is now produced on request.)

Diarrhoea can be a common sign and to balance it Enteroferment® (5g - 3x daily) and Stullmisan® were added to the milk (these are standard products used to improve the gastrointestinal bacteria and are used commonly on horses and bovids as well). Further steps are to replace the water (partially so that the calf still drinks it) with electrolytes and / or fennel tea.

In the first week, 3 -4 litres are offered 6 times daily. The amount slowly increased according to the appetite of the young. At the age of 2 weeks the calf will drink 8 l, at the age of 3 weeks 11l. Monitor the weight gain, which should be 1 -2 kg daily at the beginning. At the age of 4 – 6 weeks the calf will start to feed on leaves, etc. At the age of 2,5 months, the molar teeth will erupt. Each of those events can have an influence on appetite and needs close monitoring. Keep all feeding devices clean and sterilise them before use with boiled water. A standard plastic bottle (1,5l) was used to feed the calf with, using a cow nipple. The milk should always be offered body warm.

At the age of about eight months, a calf does not 'need' milk any more, but will drink, if allowed for another year. This 'going for a drink' is often associated with moments of 'nothing else to do', moments of anxiety or when the calf feels insecure. The older the calf, the more strain on the mother will develop. It is important to observe the behaviour of the calf and the mother. Some females are really irritated by their calves –

especially if they have no companion to play with – and turn aggressive towards it. This will be the best time to wean. A pregnant female might chase away a calf, before birth. But a pregnant female, given the choice to chase away a calf and enough room might even tolerate a previous calf when giving birth to the next one.

2.5.9 Stillbirth and calf mortality

According to the data of the international studbook for greater one-horned rhinoceroses, the rate of stillbirth and neo-natal mortality is rather high (19%). The causes are not often communicated and thus unknown, but it seems that primiparous females have more problems than experienced mothers. One factor leading to such a case might be that primiparous females are often stressed or uneasy, restless and to some degree not kept in suitable environments. A sound management before birth is absolutely essential. It is also essential that rather nervous animals are desensitised by the keepers over the time and are used to them being around. Only known people should be around at the time of birth. Enough room needs to be provided as well as proper bedding for the calf to be able to get up.

More research needs to be performed to understand this issue in more detail.

2.5.10 Introducing a female with a calf to another female (with or without calf)

A female with a calf is usually kept for some weeks separate from other group members. At the age of 1 month some zoos have started to re-join a female with a calf to another cow. This is possible when the females have known each other before and stayed together. If not, it is not advisable to join the females at such a young age of the calf. Before joining group members it is important that all members know the exhibit very well.

The process to join a female with calf with another female without a calf is rather straight forward. As a preparation it is important to have two feeding spots which are out of sight of each other. Food is provided at both sides. The female with the calf is put on exhibit first. It helps if the female is moving towards the feeding spot that is out of sight for the animal entering the exhibit. When the other female is let out, usually she will go to the next visible feeding spot. Both females eat. What will happen – depending on the age of the calf – is that the calf will leave the mother and walk throughout the exhibit. Usually they do this when they are either very inquisitive by nature or at the age of around 3 months. The moment the other female will see the young, she will start approaching. This is also the time when the mother will go towards her calf and will move it with her head into her desired direction. The more inquisitive the other female is, the more the mother will start to attack the other. Usually this looks worse than it is. They will both be very vocal and might chase and run (again, important not to have any dead ends inside the exhibit). In all the years at Zoo Basel, there were over ten introductions and never anything has happened to the calf. Even though the calf might be separated from the mother, the other female will not intentionally hurt it. The mother will go after her calf until she has got it back.

When introducing a female with a calf to another female with a calf, the process of introduction is the same. But this time, the older calf will be the curious one and might molest the younger calf. Depending on age differences it might be useful not to introduce the young at an too early age (under one month of age) as it might be too stressed by the ongoing presence of the other young. Usually the mothers attack each other while the youngsters play.

It is important not to separate and to let them finish their discussion unless the young calf shows signs of distress or is too tired.

Food can be used to ease the temperament, especially if both females are let together when still a bit hungry.

Usually it takes some days and a bit of routine and they get used to the new situation. The calves highly enjoy the presence of another calf and love to play with each other. The older the mothers are the more one can get the impression that they are glad that their calf is playing with another calf and is not molesting them.

Introducing a female with a calf (five months) to another female with an older calf (1,5yr)

GOH can run fast, dead ends need to be avoided and islands / hills, etc. to run around have been used successfully to 'direct' the animals.

2.5.11 Population management

There is an EEP program for the greater one-horned rhinoceros. The target of the EEP is to raise the numbers of greater one-horned rhinoceroses and the number of zoos holding this species in the European continent. The aim is also to introduce new founders into the EEP population by exchanging animals with the SSP. Even though growth is anticipated, breeding recommendations are often regulated by the number of zoos able to keep this species in the future. As reintroductions to the wild are currently not discussed (the current poaching situation postpones such ideas at the moment) the EEP coordinator has chosen to use a sensible approach to breeding, so that the most wanted genes can be introduced into the current population and others might have to be slowed down in breeding.

The following details are taken from the EAZA Rhino TAG RCP 2012:

With a population increase to 66 animals, the rate of GD (gene diversity) loss will allow 78% of the genetic diversity to be retained for 100 years. In a 100 year time frame, 80% of the GD will be retained with 84 specimens, 83% with 147 animals. All of these strategies are based on a growth rate of 4% (lambda = 1.04), derived as a growth geometric mean from 1955 to 2010. A tested target population size of 250 animals was selected to allow freedom to grow without being impacted by a limit in upper population size. With these parameters, a target of 66 animals (to be attained within the next five years) has been selected.

Raising the EEP population to 66 animals within 5 years (until 2015) and maintaining GD of 78% is an ambitious, but realistic target, as well as with regard to the number of births that can be expected and with regard to the capacity increase from new holders.

2.6 Behavioural enrichment

2.6.1 General considerations

The design of the enclosure and the management of the animals should allow the rhinos to behave as naturally as possible. As it is neither the intention nor is it possible to 100 % copy the natural environment into a zoo setting, zoos and safari parks have the obligation to provide as good husbandry as possible. Next to the given structures a lot of temporarily available items can be offered, which will enable the animals to interact with them. The daily routine and the daily behaviour of the rhinos can be enriched mentally and physically. Enrichment should not act in a way that it causes mental or physical distress.

Behavioural enrichment can be done with and without food.

With food

Greater one-horned rhinos eat for many hours daily. In a zoo setting, each animal should have the opportunity to feed for as many hours per day as wanted. To avoid that the rhinos become obese, food needs to be chosen accordingly (see nutrition chapter). But the food can also be provided in a way which challenges the rhinos a bit more than just standing head down and eat. For example: branches can be hung up at different places. The rhinos need to 'fish' or search for them, using their upper lip and their senses. Branches can also be dispersed throughout the whole exhibit, allowing the animals to search for them, rather than stand and eat everything at one spot. GOH will enjoy chewing on branches. Therefore they can be thick (up to 10cm). This will keep them busy for a long time. Especially young rhinos enjoy this.

Seasonal food, such as water melons, etc. can be given whole. Preference should be given to food items that do not contain a lot of sugar, if they are given frequently.

Non food

The best enrichment for GOH is to keep them in a social set up and to have females with offspring. In the wild, females with calves pair up until the calf is about four years old. In a zoo setting, this can sometimes be too long for the female as the young animal is too playful and challenges – especially if the female is a bit older – the mother quite a bit. In order to provide more interaction possibilities, a second female with offspring is a very nice option. This setup requires good management and a really well constructed exhibit, but is the best enrichment for the animals.

As the bull is solitary and will only meet the females for mating, he needs something to play-fight with in his exhibit. Ideally these can be thick logs hanging from trees or the ceiling in the stable, trees to be pushed and lifted in the exhibit, etc. In order to keep him interested in those items, they should be changed and not left in the exhibit for years with no other alternatives.

Young bulls are really playful and the best to start with are two young animals. Playing can become wild, but is usually harmless.

There are no limits to enrichment as long as it is not harmful (poisonous or dangerous when eaten) or dangerous to the animal (head or feet get stuck, etc.). As rhinos will destroy a lot of things, this has to be kept in mind.

Enrichment: different seasons

branches to browse

Trees to rub and feed

keeping a group together (females with offspring)

Mixed species exhibits: small clawed otter (*Aonyx cinerea*) and Chines muntjak (*Muntiacus reevesi*)

2.6.2 Training

Training is a useful element to build up trust between the keeper and the animal and to ask for certain behaviour that enables medical check-ups.

A command should be trained until it is reliably executed before using it together with other commands. The animal can be rewarded with apples, carrots, bananas, pellets, etc., whenever it performs the desired behaviour 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 greater one-horned rhinos

love being stroked between the front legs, in the skin folds behind the shoulder or between rump and hind legs.)

Greater one-horned rhinos can become very tame. They are by nature very curious and lose their fear for humans if treated nicely. This rather positive attitude towards humans can be used when handling and training them. Training for foot work, drawing blood from the ears, chipping, crating, etc. can be done the standard way. One can use a target training model or one can train without a target and scratch the rhino between the folds. This will chill the animal to a degree that they will finally lay down. Once down, the keeper continues to scratch and the vet can check the feet, etc. This sort of training works really well, but needs time and there are days where the animal will not lay down. In addition care needs to be taken as the keeper as well as the person working on the rhino will be in direct contact. Usually a rhino will give 'notice' before it will get up: head up, snorting, front legs straightening for preparation to get up. This will give the keeper and vet enough time to go behind the bars. One should only do such training next to an area where one can escape easily. A rhino can be up on its feet VERY fast! For safety reason direct hands-on procedures should only be performed with two people.

When performing target training, one should keep in mind that each person training the animals uses the same commands and does it the same way. Using a whistle or a clicker has been done. A whistle can be difficult as it really depends on how it is used. Some have sounds that our ears cannot hear…as a rhino might leave the facility, use commands that are internationally known otherwise the animal will have to be trained again.

When scratching a rhino, one has to be aware that a rhino will not know how powerful it is so care needs to be taken when working with them (hands caught between the bars and the animals, etc.). A restraint chute is nice to have, but not really necessary. A lot of zoos can work with their rhinos in many different ways without using a chute.

In order to control the feet, the animals need to lie down on a rather clean surface.

Working like this with GOH implies to work not alone and to know where to retreat in case the animals get up.

2.7 Handling

2.7.1 Individual identification and sexing

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.

2.7.2 General handling

Greater one-horned rhinos can become much habituated to the keeper. But they all have their characters and if a rhino is upset, this can be highly dangerous. A rhino can turn around in a second, and can be up on its feet also very fast. Having more than one rhino in an exhibit, it becomes even more difficult. Therefore, the best way of handling such a large animal is by hands off.

The keeper should – for safety reasons – not be in the same area as the rhino. See exemptions: training.

2.7.3 Transportation

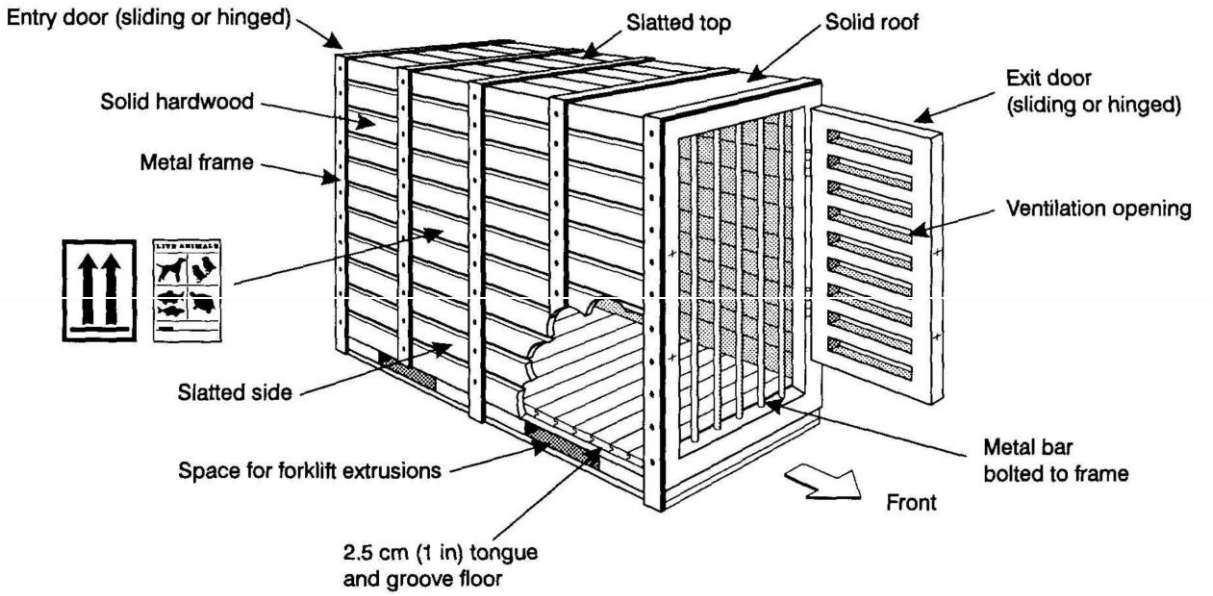
Adult greater one-horned rhinos are extremely powerful, with average males weighing over two tons. Do not attempt to force them into a crate. It is highly recommended to go through crate training of the animal before the procedure.

Pre-Shipment Legal and Medical Procedures

As an Appendix I species, greater one-horned 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.

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.

Materials

- Metal & hardwood

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 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
- The floor must be at least 2.5 cm thick 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.
- 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. Dimensions 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.

Recommended Modifications

Greater one-horned 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. 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. 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.

2.7.4 Crate training

Crating training should always be given preference to sedation / tranquilization. Greater one-horned 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, whenever the animal walks through. Later make it stop in the crate by offering preferred food items like browse, apples or bananas. It is paramount that only people known to the animal 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.

2.7.5 Transport

Discuss with the transport organization if a tranquilization is wanted / recommended in advance. Some GOH have travelled very well without any pre-medication (long-acting tranquillizer). GOHs can easily injure themselves; even break their horn, when banging their heads against the roof of the crate.

Adequate climatic conditions during transport are important since greater one-horned 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 aluminium 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, in case the animal gets annoyed or excited.

Greater one-horned rhinos will always accept titbits, even in a state of heavy agitation. Therefore, oral application of a tranquilizer, for instance in a banana, is simple.

Carry large amounts of carrots, apples, bananas, hay, etc., because you can always soothe even a very bad-tempered greater one-horned rhino with a considerable load of favourite 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.

Ideally the front side should have vertical bars and a door that opens easily so that the keeper and / or the vet have access to the animal when needed. Be careful not to allow the horn / head of the rhino to come below the lower part of the door.

2.7.6 Safety

Despite the fact that GOHs are very relaxed rhinos in human care, be careful when working with them. They are heavy and easily startled and will absolutely ignore any human being in such cases. Make sure never to be positioned between bars / walls and a rhino's head / body. A sudden movement might push you against the bar / wall.

2.8 Veterinary aspects

2.8.1 General

Greater one-horned rhinos (GOR) 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 still an issue in the captive GOR population.

The health chapter will concentrate on CFD and other diseases known specifically from GOR. For general health aspects and physiological normals of rhinos, reference is made to the 'health' chapter written by Eric Miller in the Rhinoceros Husbandry Resource Manual (Fouraker and Wagener, 1996). In Fowler & Miller (2003, 2008), the chapter Rhinoceridae provides very useful information regarding chemical restraint, haematology values and serum mineral values for GOHs.

2.8.2 Disease

2.8.2.1 Foot problems

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

1. Cracks between the sole and the pad

Description

These cracks form alongside the central sole and the adjacent pad. They rarely occur in young animals (under the age of 5). They tend 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 growth of granulation tissue leads to further irritation and prevents the tissue to fully regenerate.

Clinical signs

Clinical evidences of cracks between sole and pad are blood tracks on the floor and exuberant granulation tissue on the sides of the central hoof. The rhino has difficulties getting up and can show various degrees of lameness. Even rhinos whose feet look 'ok' will show small cracks in the horn of the pad after previous cleaning.

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, the weight is shifted to the palmar / plantar part (hind part) of the pad, leading eventually to a change in conformation of the hoof (becomes very long) and the associated joints.

Diagnostics

Close observation is the most effective diagnostic tool.

Swabs taken for microbiology reveal in general 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.

2. Vertical cracks in the horn wall

Description

Cracks of the horn wall can reach from the coronary band to the sole or can run horizontally across the horn wall. Vertical cracks are occasionally found inside the 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

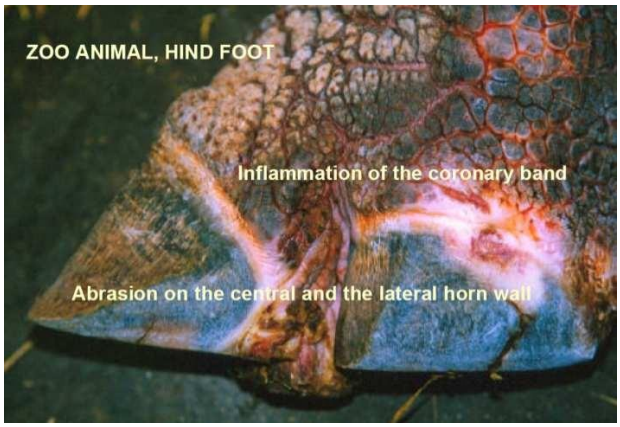
During ambulation, the cracks open and close due to the weight shift. An infected horn wall can lead to complications such as sole abscesses, 'loose wall' ('break down' between the horn and the living tissue), and abscesses along the coronary band.

Vertical crack in the central hoof (front foot)

3. Abraded horn wall

Description

Abrasions are visible mainly on the hind and occasionally on the fore feet. The medial hooves are less affected. The coronary band is reddened and sometimes infected. The horn wall shows signs of abrasion, the shape of the lateral hoof can be rectangular instead of oval. Highly abraded side hoof walls will show the underlying white horn layer, which is highly sensible. Cracks, as mentioned above, are often seen in association with highly abraded horn walls.



Both feet show abrasion on the lateral hoof as well as to some degree on the lateral side of the central hoof. The hoof wall is partially white, this is the inner horn layer. The coronary band of both feet is inflammed. Cracks have developed in the white horn of both lateral hooves.

Clinical signs

Signs include inflammation and reddening of the coronary band. In general the animal shows no direct sign of discomfort, unless the inflammatory process will continue and an infection will settle. It is important to know that the horn is built in the coronary band. If this area is infected, no horn of good quality will be built.

4. Ulcers and lesions of the pad

Description

The lesions can reach deep into the sub-cutis of the pad.

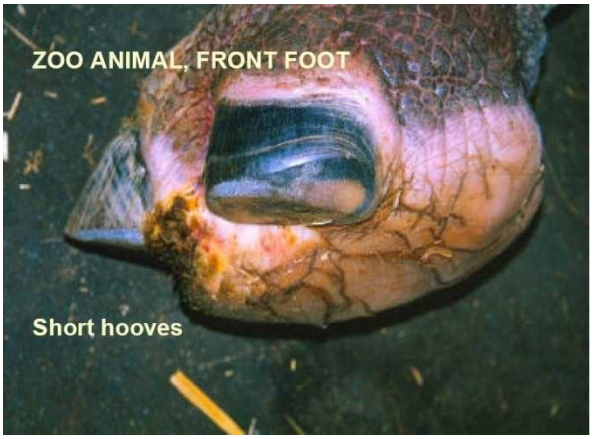
The pad of this rhino looks very soft and has a thin horn layer. Two areas show lesions.

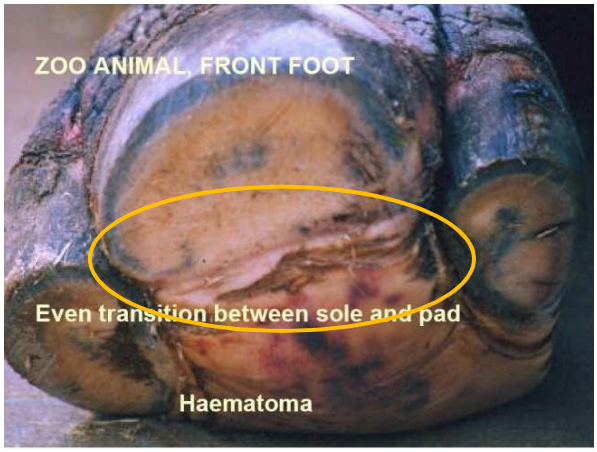
Causes of foot problems in greater one-horned rhinos

Studies of the anatomical structures of captive and wild greater one-horned rhinoceros feet have helped to recognize the high prevalence of foot problems and to understand the causes for the occurrence of the different types of chronic foot disease in greater one-horned rhinos.

Clinical picture associated with chronic foot disease (CFD)

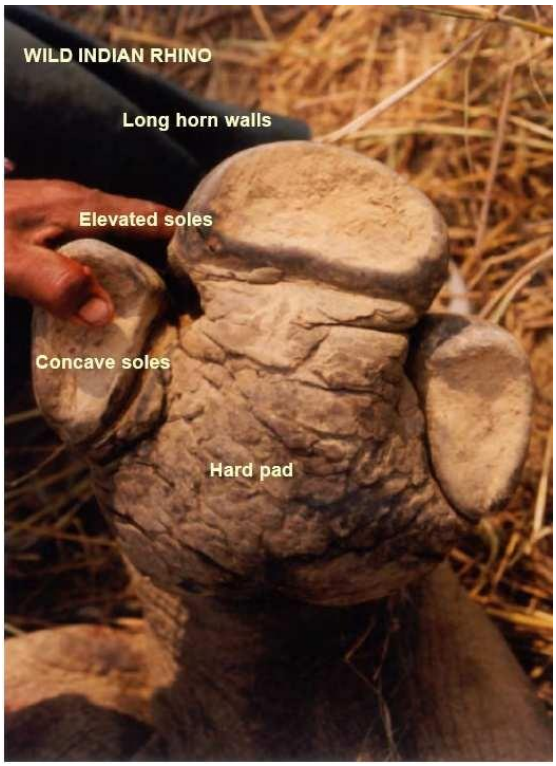
1. Whitish, flat and thin foot pads (often affected by haematoma).
2. The horn walls are short.
3. The soles are short, flat, and adjoin the adjacent pad at an even level.
4. The side parts of the hooves (in particular the lateral hooves) are abraded and show white, thin, and flattened horn walls.

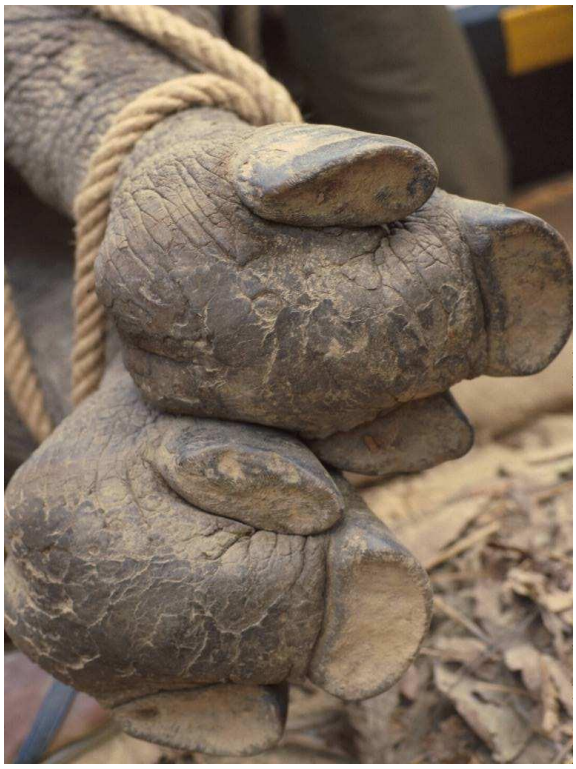




Feet of wild greater one-horned rhinos

1. The foot pad is grey, appears strong and shows minor, superficial cracks.
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 is 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 neither on the side or front hooves nor on the pads themselves. The horn of the horn wall had a shiny appearance.





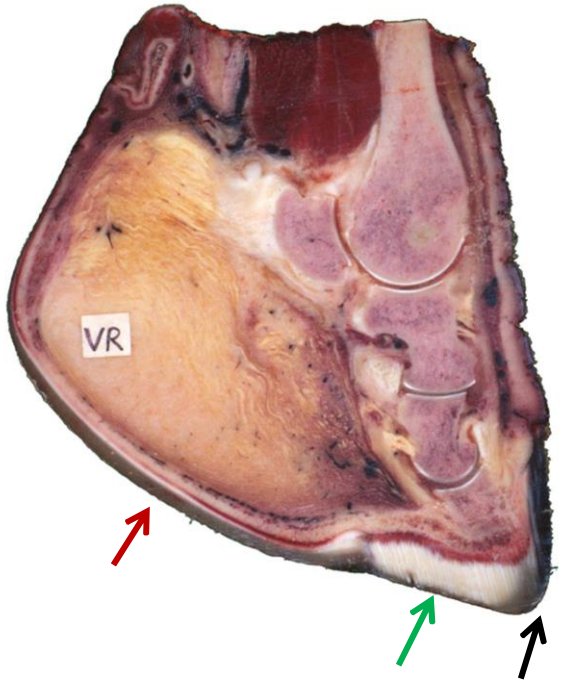
Front feet of wild GOH

Hind feet of wild GOH

Histology performed on GOH feet 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.



Medial cut through a front foot of a GOH. Notice the thin horn structures of the pad (red arrow) and the short horn layer of the sole of the hoof (green arrow) and the abraded horn wall of the hoof (black arrow).

When comparing wild and captive greater one-horned rhinos it becomes evident that **wild** greater one-horned rhinos have naturally very strong pads, elevated soles, and long horn walls. They are **'solewalkers'** 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** greater one-horned rhinoceroses the situation looks different. Their footing surface is flat and abraded. They have turned – if not kept properly - 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.

Therapy

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 debridement. 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 is 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 managed 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. 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).

Quite a few zoo GOHs have 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 wall needs 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 is very long, the weight-bearing border does not touch the footing surface anymore after cutting. The white material underneath the hoof is the horn of the sole. This is rather weak material. 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.

Wooden blocks have been applied underneath the soles to functionally raise the hoof, in order to take the strain away from the crack when walking. This is a difficult procedure and often not feasible in practice. When using blocks, one has to make sure that all three blocks remain on a foot. As soon as one block drops off, it either has to be replaced immediately or the others need to be taken off. Otherwise the animal will walk not in balance and will put the weight on the pad, adding in the formation of cracks. Applying blocks might be done without anaesthesia but the animal has to be well trained and there is always the risk that the animal will get up before the treatment is completed.

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.

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.

Ulcers and Lesions of the Pad

These need debridement, cleaning with antiseptical lotions and application of antibacterial and antifungal crèmes. In general those localized 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.

Prevention

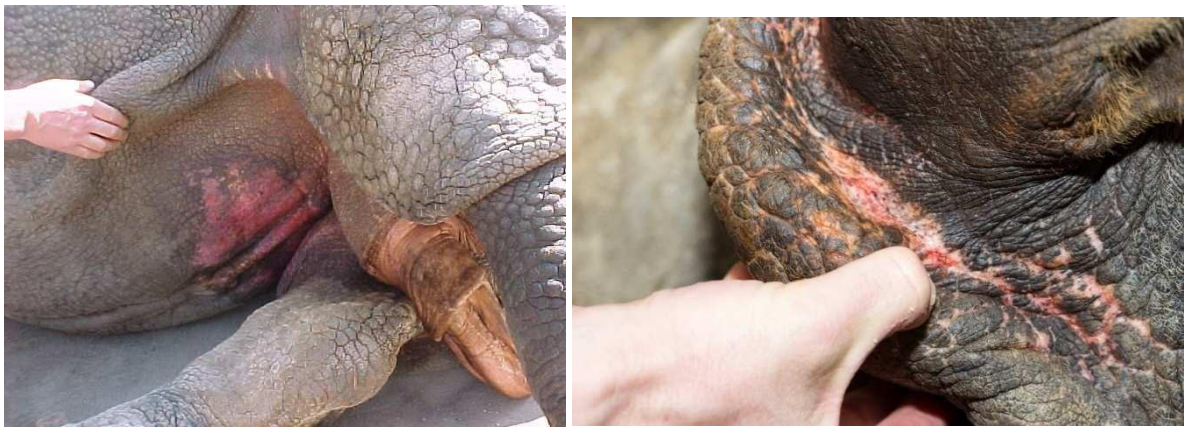
Above mentioned alterations appear due to highly abraded horn structures of the pad, sole, and horn wall. As mentioned, treatment schemes are only palliative and in order to prevent foot problems in greater one-horned rhinos, serious thoughts need to be given to the husbandry conditions in zoological gardens. Greater one-horned rhinos are by nature not made to live on hard floor. This has become evident when keeping them in zoos and with CFD appearing. Keeping GOH on non-abrasive flooring substrates outdoors and indoors will prevent this major problem to occur (see chapter 2).

2.8.2.2 Skin disease

1. Exudative 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.



Dermatitis at various regions seen in a male GOH

Diagnostic

In several cases microbiology revealed a wide 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). A study performed by L. Blatter (2014) revealed that exudative dermatitis is a common problem in the captive European GOH population (ten zoos out of 12 reported to have this problem in one or more of their rhinos). Histology of the affected areas defined two types of dermatitis: an interstitial eosinophilic dermatitis and a multifocal erosive dermatitis. Allergy tests

gave hints that the dermatitis was associated with certain allergens (pollens, mites) but it was difficult to detect the 'true' agent. Therapy with a combination of zinc ointment used as an adhesive for Locoid® 0,1% (=Hydrocortison-17-butyrat) applied over a few days proved to be very successful. In milder cases, phytotherapeutic ointments containing Calendula and Echinacea can be applied to calm and cool irritated skin.

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 pustules are located to certain areas and the general state of health is not affected.

Pustular dermatitis seen in a female GOH

2.8.2.3 Horn Problems

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 needs to be evaluated and whenever possible to be stopped by using behavioural enrichment programs, changing of husbandry and / or management plans. Sometimes this behaviour is only seen temporarily – when the female is in oestrus. The best start of all is 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 rounded timbers along the wall.

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.

2.8.2.4 Other health problems

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

Joints / Bones

Arthritis seems to affect greater one-horned 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.

Digestive Tract

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.

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).

Stomach

Greater one-horned rhinos may easily be stressed by minor events, undetected things, noise, 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.

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).

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 investigation. Moistening also prevents spores from spreading (Rüedi & Müller, 1975).

Cardiovascular

Sarcoma in the heart and lungs resulted in a sudden death of a greater one-horned 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). Another animal became recumbent due to severe foot lesions and was not able to get up. He died of cardiovascular shock.

Urinary Tract

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

2.8.3 Bacterial infection

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.

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.

Tuberculosis

Greater one-horned rhinos are susceptible to *Mycobacterium bovis* and *tuberculosis* (Silbermann & Fulton, 1979). Local or systemic infection with atypical mycobacteria also do occur (Hoby, S. pers. com. 2015).

Leptospirosis

Leptospirosis, although primarily a health problem in Black rhinos, usually presents with depression and anorexia. Other signs may include hemolytic anemia (not present in all cases), hemoglobinuria, colic, and development of skin ulcers. Abortion was reported linked to infection with leptospirosis in an Indian rhino (Fowler, 2003). Successful treatment of black rhinos with trimethoprim-sulfamethoxaxole and ceftiofur was reported in black rhinos.

2.8.4 Viral infections

Herpes

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

Equine herpesvirus type 1 (EHV-1) was detected in a greater one-horned rhinoceros (*Rhinoceros unicornis*), which was euthanized because of severe neurological disease. Encephalitis was suspected and EHV-1 DNA was detected in brain, lung, and spleen tissues (Abdelgawad A, et al. 2013)

2.8.5 Endoparasites

Anoplocephala gigantea seems to occur quite often in this species. Proglottids in the faeces are easily diagnosed. Oxyuridae (*Oxyuris vermicularis)* are also a common finding.

2.8.6. Ectoparasites

GOH are frequently molested by flies, wasps, and other flying insects. Especially the summer months can be rather stressful. It has been observed that wasps rasp off / cut off edges of the skin near small wounds. This seems to be a painful procedure by the insects (even though no dramatic damage occurs) to the rhino. The rhino can start being nervous and will run around.

Standard pour-on repellents used for horses can be used and applied pour-on along the back of the rhino.

2.8.7 Medical aspects of reproduction

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

2.8.7.1 Female Reproductive Disorders

Female greater one-horned 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 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.

Leiomyoma

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; Stoops, 2004, Hermes, 2014). 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 a 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.

Endometritis

Endometritis has occurred in greater one-horned 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).

Ovary cysts

Ovary cysts have been reported to occur in greater one-horned rhinos (Stoops, 2004). The causes for their occurrence remain still presumptive and it is likely that they stand in close correlation with a hormonal imbalance.

2.8.7.2 Male reproductive disorders

Males tend to have fewer organic disorders than females. 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 is caused by husbandry and breeding aspects.

2.8.7.3 Dystocia / Malformation of calf

Two cases are reported:
At Berlin, a 20 years old pregnant female GOH showed - after one day with several uterine contractions and on the next day parts of the gestational sac hanging outside the vagina - indications that the fetal membranes have been ruptured. With the diagnosis of dystocia she was immobilized (30 mg Butorphanol + 30 mg Detomidin i.m.). Obstetric examination and manual extraction revealed a malposition of a dead female fetus showing the malformation cyclopia. This fatally malformation is characterized in a single enlarged eye and a shortened upper jaw (Brachygnathia superior) and was described for the first time in a GOH (Ochs 2009).
The second case occurred in a 17 year old female. 31 h after the rupture of the foetal membranes no part of the foetus had yet been observed and a dystocia was assumed. The dead foetus presented with a forelimb flexed at the shoulder joint, with all other joints extended. The foetus was dissected into five parts and extracted during two anaesthesia on two consecutive days. The dam recovered fully and came into oestrous 31 days after surgery. Post-mortem and CT examination of the malformed foetal head revealed cranioschisis with cerebral aplasia and cerebellar hypoplasia. The female had given birth to three calves prior to this, and all were sired by the same male. They were born alive but died within a few hours after birth, or at the age of 2 and 2.5 months, respectively. Necropsy of the animal that lived 2 months revealed an ocular dermoid, and the animal that lived 2.5 months a gastric ulcer was noted. Hereditary or nutritional causes were suspected (Schaftenaar 2011).

2.8.8 Medical procedures

As mentioned in the training chapter, GOH are very easily trained for standard procedures such as allowing foot care, blood sampling, rectal examination, etc. .

Performing foot care on a rhino without sedation has to be done in a cautious way. The crack, especially the granulation tissue, is heavily supplied with blood vessels. Bleeding will occur easily. The deeper layer is sensitive and as a reaction to pain, the rhino can kick with the foot / leg.

Blood is collected from the ear vein. This can be done on a standing or lying rhino. It helps to desensitize the rhino before and to apply a local anaesthetic crème a few minutes before the procedure.

When working in a restraint chute, blood has been drawn also from the medial leg vein. But in GOHs this vein is not easily seen and therefore often the ear vein is preferred.

Intramuscular injections are best given in the rather soft area of the upper neck behind the ears. This spot is also a good place for darting.

As GOHs like fruits, medicine can be given orally when hidden in bananas, etc.

The gastrointestinal tract (GI) of rhinos is very similar to the GI tract of horses. A lot of medicines available for horses have been used with success in rhinos.

2.8.9. Care of offspring

In the past years, it has been noticed that 2 – 9 days old calves suddenly show listlessness, sleep a lot, will not suckle, and have a warm surface. A causative agent has so far not been found as it is difficult to obtain blood from the calf and difficult to separate the offspring for a longer time from the mother. Some calves have had fever 38.0 – 40.2C. The heart rate was 80 – 120 beats per minute, and the respiratory rate 25 – 48/ minute. At Zoo Basel, two clinically affected calves (72 – 75 kg) were empirically treated with:

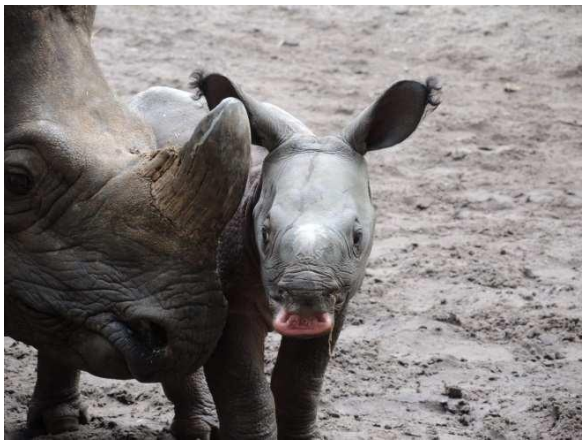
5 mg/kg enrofloxacin i.m. (Baytril) and

1.1 mg/kg flunixine i.m. (Finadyne)

For three to five days. The clinical signs of the calves resigned within a few hours and handling became difficult. All calves recovered within 2 days. The navel was disinfected as well.

It has also been notice that some calves have red eyes (conjunctivitis bilateral). It was never treated and disappeared after a few days.

Some calves also drop the lower lip. They do that at early age and it will also go away after some days / week.



Dropped lower lip in a young GOH (10 days old)

2.8.10 Anaesthesia

(For details, reference is made to Fowler's Zoo and Wild Animal Medicine. Vol. 8, 2015.)

Important considerations before and during anaesthesia

- Keep stress-level as low as possible, nervous animal should be sedated or the procedure should be postponed for another day. The risk of fractured bones, pulled tendons or broken horns is high. Procedures should be planned for the coolest time of the day, preferably early mornings.
- Stressed animals also need a higher dosage for full anaesthesia. The risks associated with this drug increase. (Flach, pers. com., 2000).
- Rhinos tend to push their head between bars when Immobilon® is used. 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. Wood chips are ideal. Rubber mattresses, which cover the whole ground prove helpful as well. Straw bales should be available to cover hard edges etc.
- Food and water should be withheld at least overnight (esp. hay, straw) to minimize the risk of regurgitation (although rare in rhinos).
- 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 lies 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
- Use oxygen applied via nasal insufflation (essential in order to ensure adequate supply, especially if the head lies in an awkward position), prepare emergency drugs (Doxapram®, 10 mg Nalorphine, naloxon, antidote); pulsoxymetry (clip on the tongue, the ear, vulva) is the absolute minimum equipment for monitoring.
- Make sure you have the human antidote naloxon (Narcanti®) ready **before** drawing up etorphine.
- Injection site: muscles of the neck behind the ear. Use adequate needle length, at least 40-60 mm x 2 mm.
- Ensure intravenous access (ear veins). Eye ointment should be applied before covering the eyes with a blanket.
- Close monitoring of heart and respiratory rate. Average parameter under anaesthesia are:
  - Heart rate: (50) 65-90 /min
  - Respiratory rate: 6-10 /min
  - Rectal body temperature can be slightly elevated in anesthetized rhinos: 37 – 39 C. Hyperthermia > 40 C: requires immediate reversal of the anesthesia
- For surgical work on the feet, straw bales should be available to put the legs on. Rhinos are prone to developing myopathy and neuropathy after prolonged recumbency. Adequate padding (inflated truck

inner tubes, heavy mats, straw, etc.) should be used to prevent radial nerve paralysis and other neuropathies. In lateral recumbency the lower foreleg should be pulled forward as much as possible.

- Positioning of the animal is still being debated and depends on the procedure. Lateral recumbency provides better circulation to the limbs, sternal recumbency may allow better ventilation.
- Duration of anaesthesia should not exceed 1 ½ hours but this is not a general rule! Decision should always be based on monitoring! The first 20 minutes seem to be the most critical ones.

Size and weight

Male:	front: 166 - 187 cm; hindquarter: 175 - 194 cm
Weight adult:	1900 - 2400 kg
Female:	front: 154 - 166 cm; hindquarter: 159 - 170 cm
Weight adult:	1600 - 2200 kg

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.

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

Drugs to use

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®).

The most common approach:

Dosages

The combination of etorphine, detomidine, and ketamine had been used successfully in over 24 anaesthetic episodes of an adult male greater one-horned rhino (6-8 weeks interval) by 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®) and atipamezole (Antisedan ®) are used to reverse etorphine and detomidine, respectively.

It is a pure Opioid antagonist, which avoids the problems associated with 'renarcotization' (150-300 mg divided IV / IM).

At Zoo Basel, the following protocol is used in females (approx.. 1900kg)

Detomidin 14mg plus butorphanol 14mg, mixed in one syringe, injected with Daninject – Dart gun, using 4bar, IM in the neck muscles behind the ear.

After 15min, reliable standing sedation should be achieved and a second dart with 1,5ml Immobilon LA ® is injected IM.

After further 18min, the animal should go down and can be approached.

In case the muscle tone remains high, 100mg Ketamin ® can be given IV.

Anaesthesia was good.

Reversal: 50mg Atipamezol (5mg/ml) half IM half IV

128mg Naltrexon (40mg/ml) half IM half IV

Usually the animal is on its feet 2min after giving the antidote.

Do not let the animal go outside or close to waterpools before the animal is fully awake.

2.8.11 Post-mortem protocol

The plan of action concerning pathological procedures depends very often on the situation itself. In case of accident in the outdoor enclosure one has to work much faster and is not as well prepared than in the case of euthanasia.

The following thoughts will give an idea of how to proceed in case of euthanasia. Some of them can well be incorporated in other cases.

Before euthanasia a well prepared plan should be established. Two – three pathologists should be informed to be on place before the animal is dead. Prior to death the animals should be weighed (in case a scale is incorporated in the stable/gangway). In case this is not possible it would be ideal to weigh the animal by using a crane or other device. The 'standard procedures' of pathology should be followed. It is advisable to establish an own protocol of how to proceed once the animal is dead, of what to think prior to euthanasia, and who is in charge of what.

Blood samples should be obtained and stored (deep frozen) as whole blood and serum for further research.

It is advisable to weigh and measure all organs. So far there are only little data available regarding weight and size of organs. It would be helpful to collect as many data as possible.

Commonly affected organs in rhinos:

The stomach can be affected by ulcers. This seems to stand in close correlation with prior stressful situations and can serve as an indicator to assess husbandry aspects. Liver, gall bladder and gastrointestinal (GI) tract are often affected by parasites, especially in import animals and very likely in those animals that live in larger enclosures.

The lungs may be affected by fungus ('Farmers lung').

The uterus and ovaries can have leiomyoma respectively cystic degenerations. They should be looked at in all cases. If this is not possible, due to autolytic processes, this should at least be mentioned in the protocol.

The feet should be controlled as well as the joints.

For histology and further research parts of the GI should be conserved in 4% Formalin, precisely labelled and stored.

2.8.12 Dosage calculation (Dr. Christian Wenker)

Pharmacological studies in rhinos are rare. Therefore, it is recommended to use allometric dosage calculation for therapeutics using the formula:

Horse dose (mg/kg) x horse metabolic rate = rhino dose (mg/kg) x rhino metabolic rate e.g.

Horse metabolic rate (horse body weight = 500 kg) = $500^{0.75}$ = 106

Rhino metabolic rate (rhino body weight = 1900 kg) = $1900^{0.75}$ = 288

Horse dose for flunixine (a non-steroidal anti-inflammatory drug): 1.1 mg/kg

1.1 x 106 = rhino dose x 288

1.1 x 106 / 288 = allometric rhino dose for flunixin = 0.4 mg/kg

2.9 Recommended research

The high rate of stillbirth / infant mortality still leaves many questions open and more research is required.

Greater one-horned rhinos are prone to skin disease in European collections. A study performed by Blatter in 2014 revealed a high prevalence of dermatitis. More research into this subject is needed to improve the wellbeing of the GOH in captivity.

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