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Peer Commentary

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Abstract: The Sumatran Rhinoceros is approaching extinction. A few dozen animals remain, dispersed in dwindling Indonesian rainforest with only a few years of likely survival time. Eight rhinos belonging to two subspecies are in controlled breeding centres. The Sumatran Rhinoceros differs markedly from the other four species of Rhinocerotidae and requires management according to specific protocols. Several Sumatran Rhinoceros have died in zoos, owing to lack of knowledge concerning their particular dietary requirements and their high sensitivity to anthropogenic activities. Recently more positive results, including successful births, have been achieved with the aid of scientific research, which continues to examine factors required for successful conservation and accommodation efforts.

Keywords: Asiatic Two-horned Rhinoceros, behaviour, captivity, endangered species, ecology, forest protection, nutrition.

Abstrak: Badak Sumatera menuju kepunahan. Hanya beberapa lusin saja tersisa, tersebar di hutan hujan Indonesia yang semakin menipis dengan tinggal beberapa tahun waktu bertahan hidup. Delapan badak, satu milik subspesies, berada di pusat penangkaran terkendali. Badak Sumatera berbeda dari empat spesies lain dari Rhinocerotidae dan membutuhkan pengelolaan menurut protokol khusus. Beberapa Badak Sumatera mati di kebun binatang, karena kurangnya pengetahuan tentang persyaratan diet khusus dan sensitivitas mereka yang tinggi terhadap aktivitas antropogenik. Baru-baru ini hasil yang lebih positif, termasuk kelahiran yang berhasil, dicapai dengan bantuan penelitian ilmiah, yang terus memeriksa faktor-faktor yang diperlukan untuk upaya konservasi dan akomodasi yang berhasil.

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INTRODUCTION

The emergence of the Asiatic Two-horned Rhinoceros, popularly known as the Sumatran Rhinoceros *Dicerorhinus sumatrensis* (Fischer 1814), has been dated to the lower Miocene between 23 and 16 million years ago (Tougard et al. 2001). The species has shown little morphological change since then, leading some to refer to Sumatran Rhinos as "living fossils" (Groves 2017). Historically these rhinos have a large distribution area that once included northeastern India, Bangladesh, Myanmar, Thailand, southern China, Indochina, Malaysia, and Indonesia. Currently, only about 50 Sumatran Rhinos remain in small populations scattered in refuges in Sumatra and in Borneo.

Three subspecies have been described: the Sumatran or Southern Asiatic Two-horned Rhinoceros *Dicerorhinus sumatrensis sumatrensis* (Fischer, 1814) (Image 1). The range of this subspecies once extended from the southernmost parts of Myanmar and Thailand (Kra Isthmus) through peninsular Malaysia to the Indonesian island of Sumatra. Very small dispersed populations are still present in Sumatra. The Northern Asiatic Two-horned Rhinoceros *Dicerorhinus sumatrensis lasiotis* (Buckland, 1872) (Image 2), which is likely extinct, once ranged from the northeastern part of the Indian subcontinent to northern Myanmar and parts of Indochina; reports of occurrence from as far east as Sichuan are dated during the Song Dynasty (960–1279) (Rookmaaker 1980). The Bornean Two-horned Rhinoceros *Dicerorhinus sumatrensis harrissoni* (Groves, 1965) (Image 3) was historically present in much of Borneo; a few individuals survive in a small area in the heart of the island.

Sumatran Rhinos are by far the smallest of the five living species of rhino. On average, they weigh 600–950 kg, stand 1.0–1.5 m tall at the shoulder, and are about 2.0–3.0 m long (IRF 2019). The head is 70–80 cm long and the tail varies in length from 35 to 60 cm. This species has two horns, dark grey to black in colour, which in the wild are usually very smooth and form a slender cone that is curved backwards. A typical front horn of the Sumatran Rhinoceros is 15–25 cm long, although there is a horn 80cm long in the British Museum collection. The smaller second (posterior) horn is normally much smaller, seldom more than a few cm in length, and it is often not more than an irregular knob. *D. sumatrensis* has distinctive reddish-brown skin, which in the wild is variably covered with short bristly hair. In captivity the hair can grow out to a shaggy fur owing to less abrasion from vegetation. The ear edges have a prominent fringe of longer hairs, and the tail terminates with a tuft of thicker hairs. Two prominent folds in the skin circle the body behind the front legs and before the hind legs, and lesser folds occur on the neck and at the base of the legs.

The Sumatran Rhino is a solitary folivore of the southeastern Asian lowland and mountain (i.e., moss) rainforests. It is an induced ovulator, with females ovulating in response to external stimuli during or before mating rather than ovulating cyclically or spontaneously. This is the first example reported within the Perissodactyla (Roth et al. 2001). The gestation period lasts 16 months and females produce a single calf every 3–4 years. The typical low density of rhino populations is likely attributable to their dietary specialization for eating specific leaves that tend to be highly localized. Consequently, Sumatran Rhinos require large, undivided and undisturbed areas, which have all but vanished (Cannon et al. 2009). *Dicerorhinus sumatrensis* is listed as Critically Endangered by the IUCN Red List (van Strien et al. 2008). The biggest threats to Sumatran Rhinos are poaching for their horn, inbreeding depression, and loss of habitat due to anthropogenic development. The horn is used in Asia as a medicine against fever and pain, and trade in rhino horn between Borneo and other source areas in southeastern Asia and China likely began more than 2,000 years ago with the origin of traditional Chinese medicine. Use of rhino horn has recently reached a plateau as a "status symbol" among the rich populations of China, Viet Nam (Milliken 2012) and Thailand (pers. info.).

Over the centuries, the Sumatran Rhinoceros has been exterminated over most of its range. In 2003 fewer than 300 Sumatran Rhinos were living in the wild. Most of these were in Bukit Barisan Selatan, Gunung Leuser and Way Kambas National Parks Sumatra, Indonesia, although a few were found in Borneo. By 2019 the situation had deteriorated considerably with no more than 80 rhinos left, for the most part in Gunung Leuser National Park (IRF 2019).

BACKGROUND

Sumatran Rhinos are rarely seen in the wild, confounding efforts to study them by direct observation (van Strien 1985) and limiting knowledge concerning their numbers, ecological aspects and management in controlled environments. In 1985 van Strien (1985) estimated that as many as 800 Sumatran Rhinos remained, while less than 30 years later, Nardelli (2014) estimated about 75 were still alive. Recently, some experts have estimated that as few as 30 animals survive

Image 1. Sumatran or Southern Asiatic Two-horned Rhinoceros *Dicerorhinus sumatrensis sumatrensis.* © Sumatran Rhino Sanctuary.

Image 2. Northern Asiatic Two-horned Rhinoceros *Dicerorhinus sumatrensis lasiotis* at the London Zoo, ca. 1890. © Zoological Society of London.

Image 3. Bornean Two-horned Rhinoceros *Dicerorhinus sumatrensis harrissoni* at BRS in Sabah. © Jeremy Hance.

(Hance 2017). From this apparent rate of decline, it would appear that the last wild populations of Sumatran Rhinos will soon be gone. This may be viewed as a total conservation failure. While all rhino habitats are strictly protected by legislation, in reality many areas are subject to large-scale human encroachment that the national park management has neither the means nor political support to prevent. Thus establishment of Sumatran Rhino populations in well managed conservation areas will be a vital component of future conservation strategy.

One of the conclusions reached at the Sumatran Rhinoceros Crisis Summit in Singapore (31 March–04 April 2013) (Lees 2013) was that ex situ facilities holding Sumatran Rhinos ought to participate in the following essential tasks: 1) form "insurance" populations to re-establish or genetically invigorate wild populations, granted that strong protection measures are in force; 2) undertake research to improve knowledge of rhino biology; 3) promote the Sumatran Rhino as a "flagship species" to draw attention to the biodiversity spots they inhabit and educate the local communities on the importance of conservation. Nevertheless, and despite problems in captivity such as high mortality and poor gestation mostly resolved (Roth 2003), these resolutions are redundant topics for discussions pro and contra diverging conservation strategies (Hance 2018a,b).

The existing ex situ population of the Sumatran Rhinoceros is not viable (Lees 2013; Putnam 2013). Hazardous inertia has left the tiny group concentrated at the Sumatran Rhino Sanctuary (SRS) on Sumatra Island in Indonesia on its own to sustain the survival of the species, perhaps for no more than a few decades, unless more rhinos are captured without delay and moved into controlled areas. Scientific research has proved useful at solving technical "how to" problems but not at working out precise "whether to" efforts. We cannot expect science to do any more than feed data into ethical or political decisions, which are lacking.

Unfortunately, conservation is not only scientific, it is multi-faceted and, according to anthropomorphic standards, aesthetically biased (e.g., "beautiful" tiger vs. "ugly" rhinoceros) even, requiring social science aspects as well as biological sciences to lead towards the proper solutions.

In April 2016, an attempt to capture a female rhino in Kalimantan, the Indonesian region of Borneo, ended with its loss (Meijaard 2016). In 2018 a decision was finally taken to capture isolated Sumatran Rhinos and scrupulous conservationists started to reunite those "lost-in-the-woods" rhinos (IRF 2018a); on 25 November 2018 a female Sumatran Rhinoceros, Pahu, was safely captured. On the same day and month in 1985, the male Torgamba was the first to be rescued by Save the Sumatran Rhino, a project of the Indonesian Directorate General of Forest Protection and Nature Conservation (PHPA) and the UK's Howletts & Port Lympne Wildlife Parks (H&PL) (King 2013; King and Beer 2018). Between 1985 and 1994, 16 rhinos from Sumatra followed Torgamba's safe arrival at H&PL, in the care of zoological institutions in Indonesia (Jakarta, Bogor, and Surabaya zoos), the UK (H&PL) and the USA (Cincinnati, Los Angeles, New York, and San Diego zoos, which had joined the project). Let us hope this coincidence of dates is a good sign that the ongoing capture and translocation will be as successful as the precedents.

OVERVIEW OF THE CURRENT STATUS OF THE SUMATRAN RHINOCEROS IN A CONTROLLED ENVIRONMENT

The situation at Borneo Rhino Sanctuary in Sabah

The Sumatran Rhinoceros is now officially extinct in Malaysia since Iman, a 25 year old female died in a sanctuary in Malaysia's Sabah state on 23 November 2019. Forced by circumstances, Malaysian scientists, with the help of the Leibnitz Institute for Zoo and Wildlife in Germany, were pursuing artificial reproduction technology options. ART has so far shown some degree of success in the White Rhinoceros *Ceratotherium simum* and the Greater One-horned Rhinoceros *Rhinoceros unicornis* (Roth 2006; Hildebrandt et al. 2018). So much is unknown about the Sumatran Rhinoceros' biology, fertility, and reproduction that these techniques seem less likely to succeed in the near future than natural conception, on time to propagate the rhinos. In any case and with the possible extinction of *D. sumatrensis*, it is important to preserve cryogenically as much genetic material as possible—starting with oocytes and gametes.

According to Agil et al. (2008), Sumatran Rhinos have a low sperm concentration (oligozoospermia) and a small volume of ejaculate. This may be one more *sumatrensis'* peculiarity or a cause of the Allee effect—e.g., anthropogenic alteration of population size leading to lack of genetic diversity and demise. Recent scientific research attempting to resurrect extinct species from cells has not been considered here because it is still remote from guarantees and may be a possible diversion to the present efforts to save the Sumatran Rhinoceros via experimented methodologies.

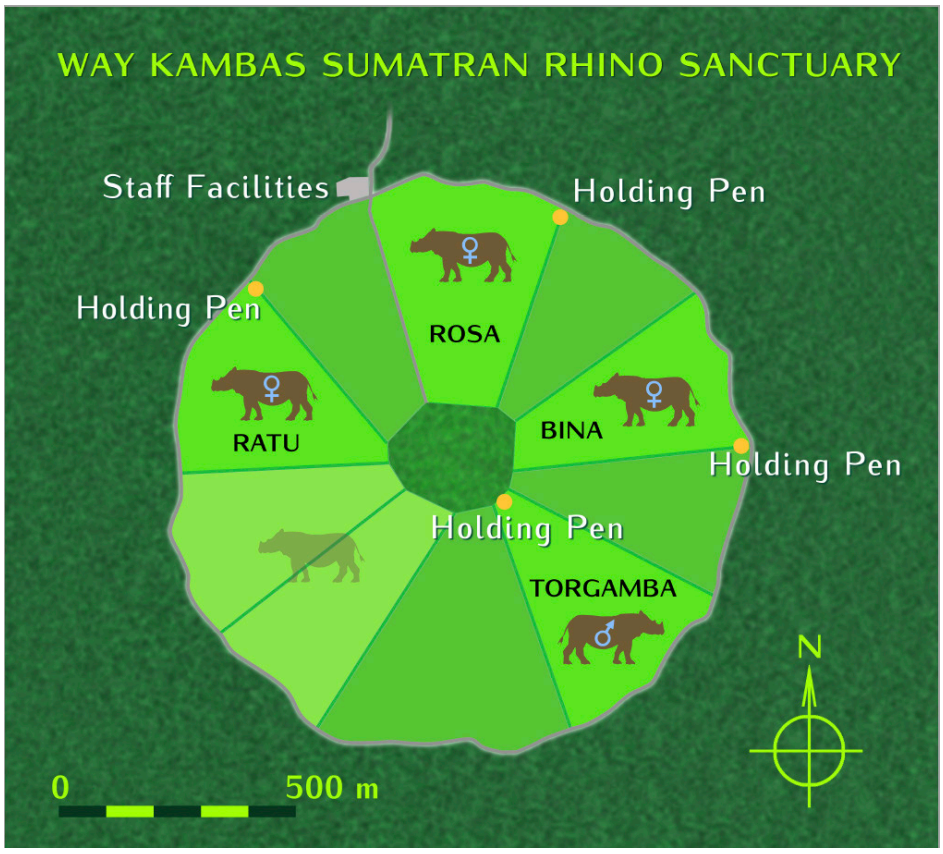

Image 4. An early map of the Sumatran Rhino Sanctuary. Reproduced by Tomasz Cofta.

The situation at Sumatran Rhino Sanctuary in Indonesia

The few remaining Sumatran Rhinos (three males and four females), are presently at SRS in order to breed them under the best possible conditions with the potential for reintroduction of offspring to the wild. At SRS they are carefully monitored and kept under scientific protocols in a semi-wild condition. SRS is within Way Kambas National Park and covers an area of about 100ha between Way Kanan and Way Negarabatin, within an area of approximately 10,000ha.

Rhinos are kept in individual areas of 10–20 ha, connected at the center to permit mating (Image 4). Every 20–25 days, the male is introduced to the female (YABI 2019).

Harapan was born in Cincinnati Zoo on 29 April 2007 to female Emi and male Ipuh, and was their third and last calf. Harapan spent time in three US zoos during his first eight years of life: Cincinnati Zoo, White Oak Conservation Center in Florida, and Los Angeles Zoo. He was moved to the Sumatran Rhino Sanctuary (SRS) on 01 November 2015.

Bina, estimated to have been born around 1985, was one of the last Sumatran Rhinos to be captured and relocated within Indonesia. She, who was about 18 years old at capture, lived in an area of southern Sumatra called Bina Samakta, in Bengkulu province. The region was home to a significant population of Sumatran Rhinos, but the construction of several villages, large oil palm plantations and a logging concession and consequent rampant poaching, left the province with few rhinos.

Rosa, in late 2003, was rescued and brought to the sanctuary. Rhino Protection Units working in Bukit Barisan Selatan National Park received reports from local villagers that a young female Sumatran Rhino had

Breaking news: Two Northern White rhino (*Ceretotherium simum cottoni*) in-vitro embryos were successfully created at Avantea Laboratories in Cremona, Italy. "*Researchers from Kenya, Italy, the Czech Republic, United States and Germany are still fine-tuning the implantation procedure before the embryos are transferred into a surrogate mother, but are hopeful a Northern White rhino calf can be born via surrogacy within the next three years*" (Wingard 2019).

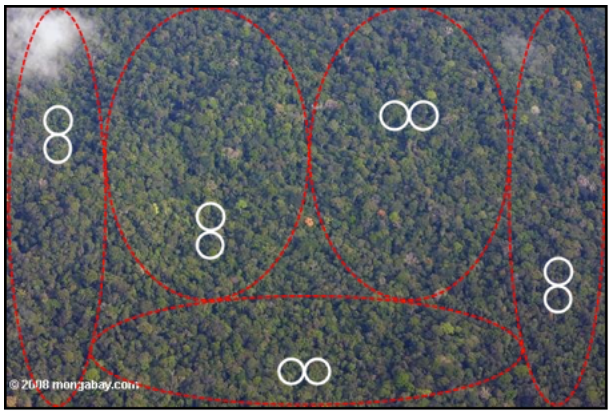

Image 5. An example of possible layout of double breeding units (white) with potential protected forest areas (red). Arial photo credit: Mongabay.com

frequently been observed walking along one of the main roads, crisscrossing the park and browsing vegetation in villages around the park boundaries. She exhibits none of the shy, solitary behaviour associated with her species.

Ratu, was born around 2000 in Way Kambas NP, the protected area where the sanctuary is located. On 20 September 2005, rangers received reports that this female Sumatran Rhinoceros had been spotted in Braja Asri Village at about 04.00h. They rescued her and brought her to SRS.

Andalas, the Sumatran Rhino conceived and born at Cincinnati Zoo, the first one produced in captivity in 112 years, is the result of ground-breaking researches undertaken by American zoos, the Indonesian Government and the Sumatran Rhino Sanctuary. A worldwide news sensation, he was sent to Los Angeles Zoo when he was two years old and then brought to SRS four years later.

Andatu was born in the early morning of Saturday, 23 June 2012 at the Sumatran Rhino Sanctuary in Way Kambas National Park. His father is Andalas and his mother is Ratu.

Delilah was born in the early morning hours of Thursday, 12 May 2016 at the Sumatran Rhino Sanctuary. Her father was also Andalas and mother, Ratu (IRF 2018b).

Pahu, the female recently captured (25 November 2018) in Kalimantan, is presently kept in a new facility on the island. Husbandry experts and veterinarians are monitoring her health and assessing her breeding viability. They indicated she was in good health, fit for transport to a designated sanctuary located less than 160km from capture site, where she arrived safely.

Sumatran Rhinos conceived and born in controlled environments

Only one Sumatran Rhinoceros had been conceived and born ex situ before 13 September 2001, a hybrid between *D. s. sumatrensis* and *D. s. lasiotis*, at the time considered full species. The event took place at the zoo of Alipore, Calcutta, on 30 January 1889 (Sanyal 1889 in Rookmaaker et al. 1998). Cincinnati Zoo & Botanical Gardens was the first facility to repeatedly breed *D. s. sumatrensis* using a planned and managed reproduction protocol. In the nineties, scientists using endocrinology analysis and ultrasonography set off research on the reproductive physiology of the species (Schaffer et al. 1994; Roth et al. 1997). The major scientific breakthrough in the discovery of induced ovulation in female Sumatran Rhinos, at the Center for Conservation and Research of Endangered Wildlife in Cincinnati (Roth et al. 1998), produced the male Sumatran Rhinoceros Andalas (Roth et al. 2001; Roth 2002). Cincinnati Zoo's breeding techniques subsequently led to the birth of a female, Suci, on 30 July 2004 and another male, Harapan, on 29 April 2007.

The Cincinnati Zoo's breeding pair was rescued from the wild during the Indonesian-American Save the Sumatran Rhino project: Ipuh, the male, was captured on 23 July 1990, in Ipuh, Bengkulu, in southwestern Sumatra. He was transferred to San Diego Zoo on 10 April 1991, then to Cincinnati Zoo on 24 October 1991. Emi, the female, was captured as a subadult on 6 March 1991 also in Ipuh. She was moved to Los Angeles Zoo on 23 November 1991, then to Cincinnati Zoo on 5 August 1995.

Success followed success and at the SRS two rhinos were born: on 23 June 2012 the female Ratu gave birth to the male Andatu, the first Sumatran Rhinoceros conceived and born ex situ in southeastern Asia. Ratu mated with Andalas in March 2011 and took a 16-month pregnancy to term. Andalas, born at Cincinnati Zoo, had been brought to Indonesia from Los Angeles Zoo when he was six years old.

Ratu mated again with Andalas on 22 January 2015 and took a 16-month pregnancy to term. On 12 May 2016, a female, Delilah (Image 6), was born to the same pair (Arsan 2016) at the Sumatran Rhino Sanctuary. She weighed approximately 20kg at birth, markedly less than her brother, Andatu, who weighed 27kg.

Considerations

Due to the extreme urgency to mitigate extinction of the Sumatran Rhinoceros, ex situ management is a critical component in the conservation of this critically

Image 6. Dr. Zulfi Arsan checking baby Delilah's health. Photo credit: Sumatran Rhino Sanctuary

endangered species.

Natural reproduction in a controlled environment can be achieved through: a) optimum ex situ facilities, b) sorting out the reproduction conundrum, c) best operated feeding protocol, and d) a deep understanding of the species' behavioural ecology.

When compared with other endangered species in controlled environments, some aspects of the ecology and biology of the Sumatran Rhinoceros are still poorly known. Several essential elements of their ecology are based on scientific and methodical evidence: the most outstanding finding was that the female is an induced ovulator. The Sumatran Rhino's reproductive physiology is no longer a mystery. Know-how, skills and means have been difficult to acquire and marked with deep sorrows before this extraordinary mammal prospered and its complete reproduction cycles succeeded, resulting in five healthy calves growing to adults. These successes demonstrate the impact scientific research can have on breeding endangered species. Even so, no rhino species breeding has been consistent in controlled conditions so far, and their propagation continues to be further investigated to identify the reasons for below optimal reproduction (Roth et al. 2018).

Because they have poor eyesight, rhinos communicate primarily by vocal and olfactory signals. The Sumatran Rhinoceros is the most creative vocalizer among the extant rhino species, and its vocalization has a number of similarities with that of the Humpback Whale *Megaptera novaeangliae* (Muggenthaler et al. 1993, 2003). Several characteristics of whales were probably in place 25 million years ago at the latest and these traits have not changed over millions of years (Slater et al. 2010). The many conversation expressions combined with olfactory and auditory clues including infrasounds—extreme frequencies that fall outside the normal response curve for the human ear—trigger a variety of mental states (Wiseman 2014), some of which may interfere with the rhino's breeding activity. For example, a male may subdue others sending "specific messages".

Psychosomatic weakness resulting from emotional stress can be a cause of severe disorders such as digestive and breeding complications. These conditions should also be investigated using the techniques available for the Black Rhinoceros *Diceros bicornis* and the White Rhinoceros *Ceratotherium simum* (Carlstead et al. 2005), and new research carried out.

In future, an animal's psycho-physical condition and consciousness (Griffin 2001; Andrews 2015) will undoubtedly have a much broader application in the management of several species for their relevant influence over the animals' welfare. The Sumatran Rhinoceros has proved to be an extremely sensitive species, one of the most difficult to adapt to controlled environment.

Nutrition

Nutritional aspects are of particular significance for health and, perhaps, for the reproductive difficulties of Sumatran Rhinos in captivity (Dierenfeld et al. 2000). Paul Reinhart, the Cincinnati Zoo's Sumatran Rhinos' keeper at the time of the breeding successes says: "*We didn't know much about the Sumatran Rhino, not many people did. We assumed you could keep them like Indian rhino and like black [rhinos], feed [them] high-quality alfalfa grain, browse… and that was not the case, not even remotely the case… The animals didn't thrive in captivity until we logged on to feeding them large amounts of browse, which we got from San Diego and Florida."* (Hance 2018b).

The Sumatran Rhinoceros belongs to the leaf-eating taxa, a relatively small number of species that depend strictly on the forest as selectors of specific foliage on which their diet is based. These unusual animals are better identified as folivores because a large number of species—the Black Rhinoceros included—among ungulates, primates and other orders are recognized as browsers: generalist vegetation eaters. Most folivores have specialized stomachs, with their own kind of bacterial flora, to digest leaves, which are abundant yet all-but-void of nutrition but very rich in leaf fibre (also known as insoluble or long fibre) content. These rhinos consume foliage from a wide range of rainforest tree species but at different intensities, indicating that the Sumatran Rhinoceros is a selective folivore.

Knowledge of general and seasonal food preferences of this megafolivorous mammal allows a better prediction of animal movements and therefore can assist in conservation efforts in situ.

If the folivore's extreme nutritional feeding pattern is ignored, or confused with the browser's habit, the risk of malnutrition in folivores within controlled facilities will persist (Nardelli 2013). Most tropical wild leaves are low in iron content, on the contrary of those from temperate arboreal species, mainly broad-leaved deciduous and usually sourced to feed browsers in temperate ex situ facilities; iron causes the deadly iron storage disease (ISD) or hemochromatosis, a disorder resulting from deposition of excess iron into insoluble iron clusters in soft tissue (Watanabe et al. 2016). Deciduous temperate forests also have a higher leaf concentration of sodium, potassium, and calcium, hence the consumption of saltlicks above all as source of sodium by several rainforest mammals. Some Sumatran Rhinos died of ISD in zoos, proving that presently this species is only safe feeding on its native foliage. These high adaptations lock folivores into their own world and make them vulnerable to changes.

The Sumatran Rhinoceros is an opportunistic feeder, taking a mouthful here and there rather than feeding intensively and systematically from one source. This species' cheek teeth are brachydont, adapted to retain a branch and pluck just the leaves, nodding-turning its head. The long-term supply of fresh leaves in large quantities and variety is a priority in managing this species. These rhinos prefer fast-growing, sun-loving plants found in forest openings created by fallen trees, although the rhinos are also found in higher density in primary forests.

From 1975 to 1980, Van Strien (1985) sampled 150 plants, mainly dicotyledonous species, and established that the Sumatran Rhinoceros does not eat fruit and monocotyledons (grasses and sedges) including the wild banana (*Musa* sp.), a very tall "grass" common in some areas. In 2016 Candra et al. (2016) listed 211 species of plants consumed by Sumatran Rhinos and research by Awaliah et al. (2018) found that the Sumatran Rhinos in the SRS area feed on 61 plant species; leaves constitute 75–85 percent of total food intake. The rhino keepers supply 51 types (Image 7). At SRS each rhino consumes daily 36–47 kg (x 7 = 252–329 kg), a massive burden for the surrounding forest. Data on the type, amount and proportion of the Sumatran Rhino's favourite leaves are still lacking or are not known with certainty, thus specific research activities need to be persistent. It is however known that leaves in tropical forests are defended by having low nutritional quality, great toughness, and a wide variety of secondary metabolites (Coley & Barone 1996) and because of the poor nutritional quality of mature leaves, Sumatran Rhinos consume the more nutritious young leaves when possible.

Image 7. Keeper at the Sumatran Rhino Sanctuary carrying a "mouthful" of leaves and saplings. © Sumatran Rhino Sanctuary.

Controlled environment

The quality of ex situ environments is fundamental for successful conservation breeding. As custodians of the last Sumatran Rhinos, we are responsible for ensuring their limited habitats are safe and healthy for them to prosper.

The Sumatran Rhino Sanctuary located in Way Kambas National Park is home to the only Sumatran Rhinos breeding in controlled environment in the world. This tiny population is pivotal in the managed breeding program for the species' recovery and for research. Built in 1996–1998 by the International Rhino Foundation (IRF) and the Indonesian Rhino Foundation (YABI), the original SRS facility was constructed within a vast, circular, single element split into a number of enclosures

to obtain triangular sections, bordering each other on two sides—according to the standards of that time. Each rhino resides in one subdivision of approximately 20ha of fenced forest. The seven Sumatran Rhinos at the SRS prosper in these large territories and receive state-of-the-art veterinary care and nutrition (IRF 2018b). In addition, SRS staff provide optimal care by physically checking the rhinos regularly (Image 6); however, they have to be moved around (evidently some paddocks are kept empty in turns) to allow the plants to re-grow (Bittel 2018).

Knowledge of the Sumatran Rhino's consciousness is lacking. Their conditioned responses to stimuli should be researched and analyzed, as these factors could assist in increasing survival and reproduction rates. From a series of photographs, videos and personal observations, the presence of and interactions with human contacts apparently are not causing visible stress on Sumatran Rhinos in the controlled environment. What may not be possible to recognize without specific studies could be the mutual stress induced by other rhino(s) in adjacent enclosure(s), or other reasons. If animals are calm or seem to be calm, it doesn't mean that underlying tensions are not present. Zulfi Arsan, SRS head veterinarian, reports: "*Sumatran Rhinos are solitary animals that become violent when housed together.*" (Bittel 2018). In a former controlled breeding centre, it was recommended to introduce only one female into a male enclosure because of their solitary habit, to avoid serious injuries being inflicted on the female (Zainuddin et al. 2005). Nevertheless, a short-term skirmish between male and female is usual at the time of introducing the two for mating; in fact such an event is widespread among a number of solitary species.

The SRS enclosures built in 1996 are adjacent to each other; the animals likely consider these environments "confined", considering the views in this article, and thus these conditions can be causes of undetected stress. With new and up-to-date knowledge of the ecology of this species, new structures should be located in separate areas, designed and created to meet the unique requirements of the Sumatran Rhinoceros. New controlled field centres for Sumatran Rhinos are likely better positioned when they are separate and at distant locations, and with newly developed fenced areas. At the same time, all known rhinos, whether in situ or in controlled breeding centres, must be managed as one population (Ellis 2013).

Keeping any animal species in a single location is an unsafe, if not hazardous, practice (Nardelli 2016). Where a species' population has been reduced to isolated individuals or a segregated group, the need is critical to establish at least a new, viable population, either in situ or ex situ or, better, both, without procrastinating, to avoid the risk of spreading pathogens over whole areas, or to prevent catastrophic events that can decimate the remaining animals. The first concern when planning is the health and safety of the rhinos. Disasters—whether close to the SRS such as in 2003 at the Sungai Dusun Conservation Centre in Malaysia, where a bacterial infection wiped out all rhinos in two weeks (Vellayan et al. 2004), or far away in the Democratic Republic of Congo in central Africa, where in June 2012 armed rebels led by a poacher attacked the Okapi Wildlife Reserve Epulu Station headquarters and killed seven people and all 14 Okapi *Okapia johnstoni* (Hance 2013)—represent hard experiences that justify the construction of new facilities in distant areas, as suggested by the Indonesian delegates at the Sumatran Rhinoceros Crisis Summit in Singapore in 2013. The news that pathogenic bacteria have been detected in Borneo Rhino Sanctuary and Sumatran Rhino Sanctuary (Borneo Rhino Sanctuary Programme 2018; Wahyuni et al. 2018), is a sign that innovative SRS logistic solutions are necessary to increase safety standards.

Desiderata

Nutrition

The assessment of leaf nutritional status can bring important and essential information for direct actions in the conservation breeding of the Sumatran Rhinoceros. Thus, in view of the recent decision by the Indonesian government to count the remaining Sumatran Rhinos throughout the present distribution areas, a comprehensive quantitative and qualitative vegetation

Image 8. SRS senior staff (L–R): Inov, Sumadi Hasmaran (Facilities Manager), Yohadi, Rois and Dr. Andriansyah (Veterianian) at the Sumatran Rhino Sanctuary, Indonesia. © Cathy Dean.

survey and analysis of the rhinos' feeding leaves is highly recommended.

Sumatran Rhinos are believed to experience little feeding competition but field studies so far lack sufficient examination of competition from other taxa, except humans (e.g., Asiatic Elephant *Elephas maximus* ssp., Asiatic Tapir *Tapirus indicus*, other large and medium-sized terrestrial rainforest mammals). Terrestrial existence, large body size, and folivory are correlated (Palo & Robbins 1991). Van Strien (1985) reported: "*From the total amount of undergrowth (about ½ to 1½ kg per square meter) the leaves and stems suitable as rhino food weighed between 260 and 520 grammes (fresh weight) per square metre. Re-growth of leaves and stems varied from 0.7 (in the forest) to 3.8 (near the river) grams per day per square metre. It seems from these figures that the average production of browse suitable for the rhino is probably not more than 1 gram per day per square metre. There are a few hundreds of grams of browse standing on each square metre, but it takes a long time, up to a year or so, for replacement*".

To better assess the consequences, future investigations should include other connections to feeding competition such as modification of ranging patterns, changes in activity, and decreased fecundity. Information gained from such studies may advance our current knowledge of Sumatran Rhinoceros ecology and better define their conservation plans. Best possible feeding in controlled environment, hopefully of an increasing number of Sumatran Rhinos, may possibly become a handicap for the optimum care of animals eating about 50kg daily of both specific and varied kinds of foliage (Candra et al. 2016). Suitable leaves may start to run out from the surroundings of a congregate, highly populated breeding centre, their re-growth could be too slow to fill the demand, or they may grow too high to be reached by the gatherers, not to mention the ever-present logging predation. Furthermore, because folivores depend on such an ephemeral food source and plant phenologies, this may select for more elaborate life history traits. Isolating new enclosures and allowing large distances between them will allow a larger quantity and variety of leaves to be harvested for a much longer time, with ease and with less damage to the vegetation that will re-grow in good health.

Controlled field conservation centres and units

From his experience as former curator of H&PL and director of the Save the Sumatran Rhino project in Indonesia, the author suggests that several vast forested areas measuring 20–50 ha apiece be fenced, in the region of one percent of the natural home ranges of female–male Sumatran Rhinos.

Two enclosures should be adjacent to each other [shaped e.g., ∞], to keep rhinos apart and to offer each animal sufficient and secluded space. Such double units should be sited several kilometres away (an expert veterinary team will assess the safest distance) from each other, to avoid any physical and perceptive interference between the rhinos.

The small portion where the two enclosures connect will be the pair's "meeting point", which can be opened when managers decide to allow male and female to mate, or closed to allow gestation, birth and the young's growth under natural physical and mental conditions. In a 2008 study, Terry Roth asserts: "*... a scientific method for accurately predicting when the female would be receptive to the male was developed so that animals could be paired safely. Stimuli causing induced ovulation include the physical act of coitus or mechanical stimulation simulating this, sperm and pheromones. Sumatran females exhibit unusual progesterone patterns when not mated*". SRS veterinarians monitor the female's ovarian follicular development via ultrasound examination before the animals mate. When follicles reach 20–22 mm in diameter, the time is right to put the two rhinos together (Terry Roth pers. comm. April 2013).

Habitat protection

This new concept of *controlled field conservation centres* should be considered because it contributes to preserving not only the forest areas occupied by the enclosures but also of much larger portions of habitat. The forest surrounding the 'controlled field units' will have to be preserved for: a) the rhino's safety and welfare, b) the food reservoirs and buffer zones, and c) the activity of the keepers, the food gatherers and the Rhino Protection Units' guards. As a result, a whole, much larger area can be saved once several controlled field units become operational, ultimately making use of the entire forest allocated to a new Sumatran Rhino sanctuary (Image 5). Such controlled and managed field conservation centres could become central to the future protection of this rhino as well as other species in need of human intervention.

Animal welfare

Hutchins & Kreger (2006) stated in 2006: "*Perceiving, retaining and replicating the species best conditions for their behaviour performances are essential for their welfare, and this is particularly important if conservation centres hope to reintroduce animals to the wild in the*

future". Animal welfare is a fundamental consideration in curatorial management, and although animal wellbeing can be measured systematically only to a certain degree (Hill & Broom 2009), behavioural habits can be lost if the specific taxon's natural ecology is not comprehensively studied and properly applied. It is noteworthy that much of their welfare depends on some people's inborn endowment to interpret their needs (Aspinall 1976). Accordingly, ex situ wildlife management and breeding is not a subject of university teaching.

"The welfare of any sentient animal is determined by its individual perception of its own physical and emotional state" (Webster 2016). How do Sumatran Rhinos obtain, process and exercise information if those states and processes are not directly assessable? Behavioural ecology can shed light on issues of cognition and on an ecological approach to cognition—environment information, then cognitive planning, leading to behaviour—should provide the evidence.

For the purpose of biological conservation, several aspects of management are important and poor quarters and environments are responsible for permanent changes in behaviour and physiology (Hofer & East 1998).

Housing Sumatran Rhinos in a species-appropriate area where they are able to perform normal activities and make independent choices should be considered fundamental for their well-being. To that end, managers could go to greater lengths to provide their animals items (e.g., mud wallows and saltlicks) that encourage exploration of a greater diversity of behaviours and that encourage maximal use of space. A further possibility is corridors that allow animals to move from one space to another. Not only does this provide the option for animals to choose one location over another, but it also increases the space available for them to roam, and it enlarges the diversity of stimuli that the animal can possibly experience in each of the different settings.

Behavioural ecology

Several animal species communicate through all their senses including by means humans do not have. In recent years, the study of animal communication has expanded rapidly as has information on their consciousness (Bekoff et al. 2002) and has allowed the discovery of mesmerizing phenomena. For example, the Sumatran Rhinoceros emits an infrasound whistle followed by a sharp burst of air that can travel for kilometres (Muggenthaler 2003). Such complex communication, infrasounds included, in addition to the known capacity of the sensory organs to influence cognitive activities result in behaviour remarkably similar to what humans define as social behaviour, although the Sumatran Rhinoceros is solitary and generally avoids contact with other rhinos in nature.

Reproductive competition occurs when an individual's capacity to conceive has diminished due to the presence of a conspecific. Most animal species resolve this problem by living solitarily (Emlen 1982): one more reason to manage the Sumatran Rhinos separately in several controlled field centres. Another aspect to consider is the behaviour of adult breeding males in the presence of sub-adult and/or adult non-breeding males; a psychological submission may develop, under controlled conditions, which could inhibit the non-breeding males. In fact, dominant male rhinos were present in situ during Borner (1979) and van Strien (1985) field studies, as reported by the authors. Furthermore, in spite of "social" designates to do with more than one individual (Waal & Tyack 2003)—the behaviour of a pair of animals may even be called social—socialising induces stress.

Stress in this context means the effects resulting from causes of various origins in rhinos, which interrupt homeostasis and cause harm because they diminish biological functions and ultimately result in reduced health conditions and a negative factor that favours the action of glucocorticoids, which cause infertility in mammals (Broom & Johnson 1993). Measuring faecal glucocorticoids, or their metabolites, may be useful for well-being studies in controlled environments—especially in assessing short-term responses to stressors e.g. capture, transportation and translocation are important stressors—and can contribute non-invasively to the work of biologists (Metrione & Harder 2011).

Carlstead & Brown (2005) presented evidence showing that social tension may cause chronic stress in the Black Rhinoceros and the White Rhinoceros, and established that non-cycling female rhinoceroses had more variable corticoid concentrations and higher rates of stereotypic pacing, an indicator of high stress levels. This factor gives the managed population a sustainability struggle that is observed in each species. Psychosomatic weaknesses, a probable cause of severe disorders, should also be investigated using the techniques available for the Black Rhinoceros and the White Rhinoceros (Carlstead & Brown 2005), and new research carried out.

Ex situ conservation centres with more than one female Black Rhinoceros have a lower reproductive rate and a later age of first birth. Probably, there is a density-dependent restraining effect on breeding function among females in confined environments

(Carlstead et al. 1999a,b). A physiological evaluation of welfare in managed animals can be obtained non-invasively through analysis of adrenal hormones in saliva. Adrenalin hormones measure activity in the sympathetic–adrenal medullary system and in the hypothalamic–pituitary–adrenocortical system (Palme 2012). Salivary corticosterone concentrations can determine stress in White rhinos (Schmidt & Sachser 2000).

A survey study conducted on Black rhinos ex situ surprisingly found that more aggression and assertiveness contributed positively to a female's chances of breeding (Carlstead et al. 1999a,b). The reproductive rates of Black Rhinoceros and White Rhinoceros in controlled environments are unsustainably low. Evidence shows that to a large extent social signals may cause chronic stress in rhinos, and this element contributes to the sustainability problems observed in each species of managed populations (Carlstead & Brown 2005; Metrione et al. 2007). The concentration of glucocorticoids (or their metabolites) can be measured in various body fluids or excreta. Above all, faecal samples offer the advantage that they can be easily collected and this procedure is feedback free. Thus, such methods are a valuable tool in a variety of research fields such as animal welfare in handling, housing and transport and also in ethological and environmental studies.

Scientific research on the behaviour of the Sumatran Rhinoceros should be expanded to include cognitive ethology—the comparative study of mental phenomena—including both conscious and unconscious mental states. A lot of effort is expended on the care of animals but only rarely is the inner world of those sentient beings well thought-out in strategic planning.

CONCLUSIONS

There is reason to believe that the Sumatran Rhinoceros can continue to exist, providing that animals will still be around for a sufficient time to be rescued, or survivors that have lost contact with each other are not all genetically or reproductively ruined. Populations lose genetic diversity at a rate proportional to the inverse of their effective population size (Frankhman 1996), thus the surviving, small, *D. sumatrensis* populations are rapidly losing genetic diversity through drift (random loss of alleles across generations). To re-establish viable populations in numbers sufficient to maintain genetic diversity, it is imperative not only to capture the few remaining individuals, wherever they may be, but to induce them to breed under the best conditions as a matter of urgency.

Food preferences of Sumatran Rhinoceros probably trigger short-term movements of individuals outside their home ranges, conservation actions should therefore aim at enlargements and connectivity of its habitats utilizing controlled field centres. The species' selective feeding habits may result in individuals moving into areas with highly preferred food resources, which can be areas of high mortality risks, once known to poachers. Habitat connectivity projects should pinpoint areas that allow these rhinos to access higher elevated areas, secluded and less accessible to humans.

With the rapid destruction of tropical forests and the threat of global climate change, a greater understanding of the importance of what has worked and what would work, is essential to the preservation of the megafolivorous Sumatran Rhinoceros.

In controlled environments, animal species which are difficult to observe in the wild can increase our knowledge of ecologic aspects that influence their habitat utilization within fragmented landscapes and can assist in animal husbandry and the planning of current and future conservation efforts. It is essential and urgent to match ongoing efforts for in situ protection with ex situ breeding, and to optimize this species' peculiar requirements inside strictly protected areas and in controlled field centres. The critically endangered Sumatran Rhino is a perfect example of the need for conservation measures that follow a One Plan Approach paradigm. The One Plan Approach, initially proposed by the IUCN SSC Conservation Planning Specialist Group (CPSG), considers all populations of the species, in situ and ex situ, under different conditions of management, engaging all responsible parties and all available resources from the very start of any species conservation planning initiative, as per Byers et al. (2013): "*The One Plan approach aims to establish new partnerships, ensure that intensively managed populations are as useful as possible to species conservation, increase the level of trust and understanding among conservationists across all conditions of management of a species and accelerate the evolution of species planning tools. Integrated species planning is not a new concept. Such holistic conservation efforts have led to several well-known conservation successes, from Golden lion tamarins in Brazil to Puerto Rican Crested toads in the Caribbean to Arabian oryx in the Middle East*".

The Sumatran Rhinoceros is of special interest because, with the Javan Rhinoceros *Rhinoceros sondaicus*, it is one of the largest mammal species that

depends on undisturbed rainforest and for that reason can be regarded as an important indicator species. Despite the vigorous attempts by a handful of people to protect it, time is running out for the Sumatran Rhinoceros: a foremost phylum-genetic diversity loss (Davis et al. 2018). In the present status of wildlife, it is difficult to reconcile the actions of leaving a species to become extinct or allowing individuals to solely survive in ex situ breeding centres, albeit with unavoidable negative experiences. The Sumatran Rhinoceros represents the emblematic example of such a perplexing state of affairs.

Is saving the Sumatran Rhino mission possible? Yes! It will require a collaborative effort, following hard-and-fast rules, and optimal management conditions.

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