Conserving the Sumatran Rhinoceros (*Dicerorhinus sumatrensis harrissoni*) on Borneo. What has been done and where it is heading?

BSc Thesis by Rasmus Gren Havmøller

In cooperation with WWF-Malaysia, Borneo Rhino Alliance and Sabah Wildlife Department.

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Supervisor. Prof. Dr. Neil David Burgess
Centre for Macroecology, Evolution and Climate.
Copenhagen University.

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1. Acknowledgement:

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2. Introduction:

The Sumatran Rhinoceros is the most critically endangered of all species of Rhinoceros; it is the smallest, the most illusive and also one of the least studied.

The inspiration to make the Sumatran Rhinoceros a Bachelor's Thesis was founded all ready as a child when I watched the mounted specimen at the Zoological Museum in Copenhagen and wondered how this small Rhinoceros went about in its rainforest habitat. The decision to make it my Bachelor's Thesis was made during my travels through Sabah Borneo in 2009, where I by chance came across several people who had either seen or worked with Sumatran Rhinoceros in the past. As I came home and started to do research on literature it became evident that the situation, both in Indonesia but especially in Borneo was extremely critical.

I felt compelled to act by the situation and decided I should do what I could to help the situation.

This project will hopefully shed light on the current status of conservation efforts on Borneo as well as provide a general insight to the biology of this little known species. Finally I hope my work can aid the good people on Borneo that work hard and every to save the Sumatran Rhinoceros there as aid to their own efforts.

This project is the result of many months literature research, long nights of computer simulations and a month of fieldwork with WWF-Malaysia and Borneo Rhino Alliance in Sabah, (Malaysia) - with approval of Sabah Wildlife department.
It is divided into three sections.

1). An assembled paper based on reviewed articles to create updated literature on the current scientific knowledge on the biology of the Sumatran Rhinoceros.

2). A timeline review of the past and present efforts to save the Sumatran Rhinoceros. Special emphasis is given to the situation on Borneo with a description of the current and future efforts based on the authors' fieldwork with WWF-Malaysia and Borneo Rhino Alliance in March 2010.

3). And finally a computer simulated population viability analysis based on the literature reviews, personal conversations with key figures within Sumatran Rhinoceros conservation on Borneo, a previous population viability analysis of the Javan Rhinoceros and personal experience.

Great thanks to everyone who have helped me with this project – I had an experience of a lifetime and would happily do it all over again.

Abstract:
The Sumatran Rhinoceros (*Dicerorhinus sumatrensis*) is currently one of the most critically endangered animals walking the planet. They have been studies on many occasions but mostly with a very specific topic. The last article that assembled all existing knowledge on the Sumatran Rhinoceros was made by Groves and Kurt in 1967. This paper is an attempt to update and add new scientific research to make a more complete impression of what is known about this shy and illusive species.

3. Scientific description:

Belonging to the order of Perissodactyla (Odd-toed Ungulates) there are currently 5 extant species in the Rhinocerotidae family – 2 species in Africa and 3 in Asia, easily recognized by the one or two horns on the muzzle, greyish coloured skin and distinct three toes on both front and hind foot (see figure 2) with a width of 18.5-23.5 cm for adult animals (Payne & Francis 2005) (see figure 1). First described by Fisher in 1814 on the Indonesian island of Sumatra, *Dicerorhinus sumatrensis* (*D.s.*) was named the "Double-horned Rhinoceros of Sumatra" and is the only Rhinoceros (Rhino) in Asia with two horns. It has later been referred to as the Asiatic Two-horned Rhino, the Hairy Rhino and the most commonly used - Sumatran Rhino (Fisher 1814).

Figure 1. Footprint by a Sumatran Rhino. Photo by RGH.

Figure 2. The characteristic footprint of a Sumatran Rhinoceros – front right foot. Note the old snare-wound. Photos by RGH.

3.1. Distribution:

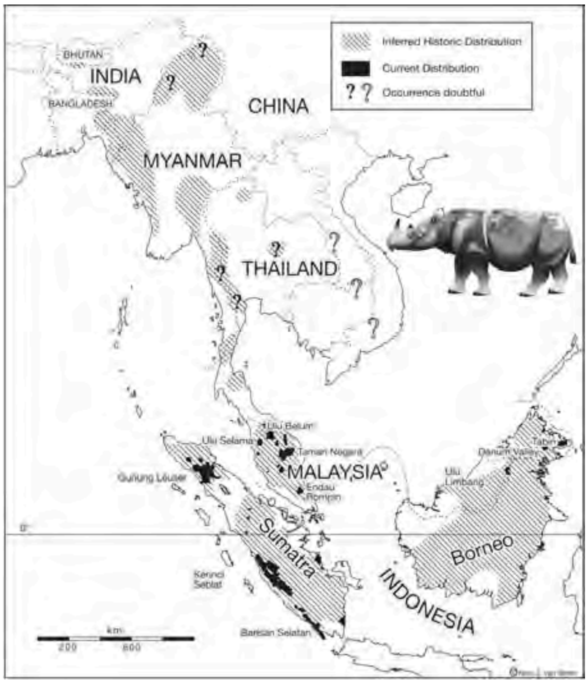


Figure 3. The map from Foose, T. J. & van Strien, N. 1997. Past and current distribution of the Sumatran Rhino in South East Asia marked as striped and black respectably.

Groves and Kurt (1972) investigated several papers in their article and found evidence of the Sumatran Rhino being distributed in the past, as far northwest as Lushai and Chittagong hills in India and Bangladesh, the distribution limit seems to have been the mountainous region of the Burma-China border, even though Delacour (1966) examined a skull of a two-horned Rhinoceros at Nonghet in what is today Laos. A specimen from Mong-Le, China, north of Laos was mentioned by Hubback (1939) (see figure 3). Groves and Kurt (1972) also confirm the occurrence of Sumatran Rhinos in Vietnam but the distribution range seemed fragmented and was primarily the range of the Javan Rhino (*Unicornis sondaicus annamiticus*), which today number only 3-5 animals (Talukdar 2009). SMART-patrol rangers at Huai Kha Khaeng Wildlife Sanctuary, Thailand, confirmed that in the past Sumatran Rhinos was once common in the Western Forest Complex of Thailand and south throughout the Malay Peninsula (Groves and Kurt 1972), but the current persistence on the Malay Peninsula is very much in doubt.

A 600km^2 survey of Malaysia's largest national park Taman Negara in 2003, gave no evidence of the Sumatran Rhino being present (Kawanishi et. al 2003; pers. comm. Dr. Carl Træholt). However the 2009 annual report from the Asian Rhino Specialist Group (AsRSG) estimates 52-69 Sumatran Rhinos still survive in the Taman Negara National Park and Royal Belum state park in Peninsula Malaysia (Talukdar et al. 2009).

On Sumatra, Indonesia, the Sumatran Rhino used to be widely dispersed over most of the island. Today the only viable populations are found in Bukit Barisan Selatan National Park, Way Kambas National Park, Kerinci Seblat National Park and Gunung Leuser National Park (Talukdar et al. 2009).

On Borneo the Sumatran Rhino used to be widely spread throughout the most of the island, but today they are only found with certainty in the northern state of Sabah, Malaysia, with their final strongholds in Danum Valley Conservation Area (DVCA) and Tabin Wildlife Reserve (TWR) (Talukdar et al. 2009). A survey in 2009 of Batu Lawi a 7.3km^2 inside the Ulu Limbang, Sarawak, revealed no presence of Sumatran Rhinos (Alfred et al. 2009).

3.2. Subspecies:

Three distinct subspecies has been recognized - *D. s. sumatrensis* or Western Sumatran Rhino, *D. s. harrissoni* or Eastern Sumatran Rhino and *D. s. lasiotis* or Northern Sumatran Rhino, the last presumed extinct (Groves & Kurt 1972, IUCN Red List). A survey in 1994 found no evidence in terms of sightings, faeces or footprints in what was believed to have been the last stronghold for the Northern Sumatran Rhino in Tamanthi Wildlife Sanctuary, Burma (Rabinowitz et. al 1995). The hybridization zone between the Northern and Western Sumatran Rhinos was believed to be in the border land of Thailand and Burma, where the Western Forest Complex is today (Groves & Kurt 1972). Groves (1965) classified *D. s. harrissoni* from Borneo as a distinct subspecies by comparing specimens and proved, that the individuals from Borneo was significantly smaller in size than the two other subspecies and the occipitonasal length did not extend with age as the occipital crest grew which was observed in the two other subspecies, along with the fact that the teeth was the smallest of the three subspecies Groves named the Bornean subspecies *harrissoni* after Tom Harrisson who did extensive work on zoology on Borneo in the 1960's (Groves 1965). It is locally known in Malay as "Badak" or the Bornean Rhino (pers. experience).

The decrease in body-size of *D. s. harrissoni* appears to have been recent as the 30.000 year fossil remains of prehistoric Rhinoceros from the Niah caves in Sarawak was significantly larger than the current animals (Payne & Francis 2005).

Several genetic studies have revealed the mitochondrial DNA variability in the Sumatran Rhino, kinship to the other four currently extant species of Rhinos and finally the evolutionary relationship to the prehistoric Woolly Rhino (*Coelodonta antiquitatis*).

The genetic study by Morales et al. (1997) of the mitochondrial DNA variability in 15 wild-born Sumatran

Rhinos from Sumatra (5), Peninsula Malaysia (4) and Borneo (6) supported the classification of the Rhinos from Borneo as a separate subspecies made by Groves in 1965. The purpose of this study was to survey the genetic heterogeneity in the 15 captive individuals by analyzing the rapidly evolving mitochondrial control region to gain knowledge and prospects on recovery for the Sumatran Rhinos. The DNA was obtained by the standard of the time, phenol/chloroform extraction method. The mtDNA was amplified with use of primers developed by Kocher et al. (1989). 22 restriction endonucleases were used to digest the amplified material and the resulting fragments in agarose gels and stained with ethidium. The result was 4 different halotypes within a 1550-bp segment. The divergence value range between the individuals from Peninsula Malaysia and Riau province on the east coast of Sumatran was only 0,3% (not significant), while the average difference from east Sumatra to west Sumatra and Borneo was 1,0% (parsimony tree figure 4). Furthermore 3 fixed differences, 2 of them synapmorphic, between individuals from Borneo and all the other regions was found and this gave the genetic background for recognizing the *harrissoni* subspecies as endemic and recommended that Bornean population should be considered as a separate conservation unit.

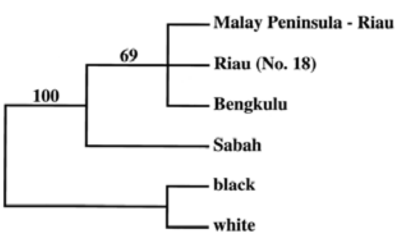


Figure 4. Parsimony tree from Morales et al. (1997).

The study by Amato et al. (1995) of 17 captive Sumatran Rhinoceros from Borneo (4), Sumatra (6) and Peninsula Malaysia (7) investigated the genetic diversity in the 12S and 16S ribosomal mtDNA for future management purposes, but concluded the same as Morales et al. (1997).

The individuals from Peninsula Malaysia and Sumatra are genetically more alike than either of them is to individuals from Borneo. However in the discussion of this article the question of whether the 3 populations should be considered, as separate conservation unit remains open, the argument was that all members of the Rhinocerotidae has a karyotype of 82 chromosomes (n=2) and thus reduces the concern of cytogenetic incompatibility.

The composition of this parsimony tree by Morales (1997) was supported by the study of genetic diversity in the Javan Rhino subspecies *annamiticus* from Vietnam and *sondaicus* from Java and included most subspecies of extant Rhinocerotidae family (Fernando et al. 2006) (parsimony tree figure 5).

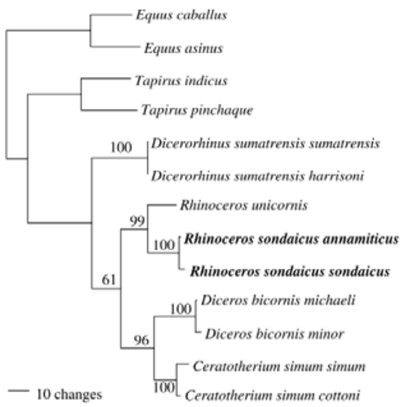


Figure 5. Parsimony tree from Fernando et al. (2006).

The relationship between the Sumatran Rhino and the other extant species of Rhinos had long puzzled science. Was the Sumatran Rhino a sister taxon to the African species based on the two horns and dental synapmorphies or a sister taxon to the Asian Rhinoceros species based on distribution – or where they of their own lineage?

Tougard et al. (2001) put the questions to the test by investigating mitochondrial cytocrome b and 12S rRNA in the five extant species in the

Rhinocerotidae family and created a parsimony tree (see figure 6).
The Sumatran Rhinoceros proved to form a sister taxon to the two other Asiatic Rhinos (Rhinocerotina), but test results were not 100% conclusive. *Dicerorhinus* genus clustered almost equally with the *Rhinocerotina* (Asian genus) and *Dicerotina* (African genus) and the decision to make the Sumatran Rhino a sister taxon was influenced by morphological similarities and paleontological evidence.

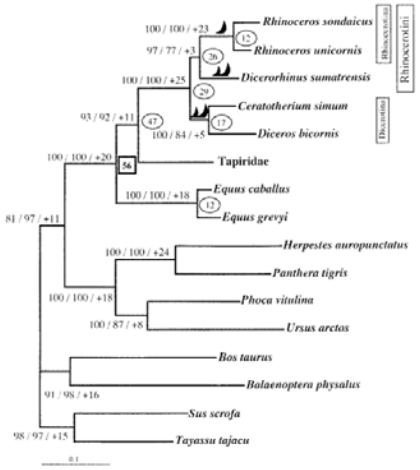


Figure 6. Parsimony tree from Tougard et al. (2001).

The two other Asian Rhino species is believed to have diverged 25,9±1,9 Mya while the African species is thought to have split between 23 and 16 Mya (Carroll 1988).
The evolutionary relationship of the extinct Woolly Rhino (*Coelodonta antiquitatis*) was revealed with ancient DNA technology by Orlando et al. (2003). The entire 12S rRNA and cytocrome b was sequenced from a 60-70.000-year-old sample, and a partial sequence was made on a 40-45.000-year-old sample of the 12S rRNA and cytocrome b. Based on two genetic markers and calculations on a molecular clock they found that the Sumatran Rhino is the Woolly Rhino most closely related extant species (parsimony tree figure 7). The study suggest that the lineage of *Dicerorhinus* diverged in the Oligocene, 21-26 Mya, which would explain the difficulties in the studies mentioned above that concludes the other Asian Rhino species diverged 25,9±1,9 Mya from the *Dicerorhinus*, very shortly after the *Dicerorhinus* themselves would have diverged from the Woolly Rhino.

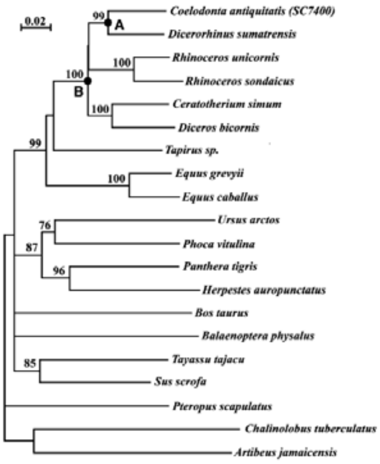


Figure 7. Parsimony tree from Orlando et al. (2003).

3.3. Morphology:

The Sumatran Rhino is the smallest of the currently extant Rhinocerotidae with a measured maximum shoulder height of 1,45m, body length of 2,36 to 3,175m and girth from 1,98 to 2,44m (Anderson 1872, Evans 1904, Peacock 1931, Hubback 1939) and weight between 800-2000kg (Skafte 1961; Ulrich 1955). However, weight records of all the Sumatran Rhinos currently in captivity span between 541-757kg. The author has proven that the Bornean subspecies is significantly smaller than the Sumatran subspecies - on average ~120kg (~17,5%) lighter (Mann-Whitney U) ($U_{8,8} = 6$; $P < 0,05$) (Annex I).

Figure 8. Bornean subspecies *harrissoni* – photo by Engelbert Dausip WWF-Malaysia 2008.

Dicerorhinus sumatrensis is the only Asiatic Rhino with two horns in contrast to the Greater One-horned Rhino (*Rhinoceros unicornis*) and Javan Rhino, which only have a single horn. The anterior horn protrudes above the nasal intake while the second posterior horn is situated over the eyes, both with broad rugose basal region, rapidly narrowing to short slender stem region exposing heavy keratinisation that makes up the horns (Cave 1964). Occasionally the second horn hardly protrudes and the Rhinos can appear single-horned (Groves & Kurt 1972) (see figure 8). Records of the length of the horns vary between 381mm and 800mm (Hubback 1939, Gray 1854). Two small dried anterior and posterior horns kept at Copenhagen Zoological Museum weighs 224g and 59g respectly.

Figure 9. The hair-covered skin of a Sumatran Rhino. Photo by RGH.

Figure 10. Characteristic wrinkles around the eye. Photo by RGH.

Figure 11. Note complete postcapular fold at forelimbs – incomplete at the hind limbs. Photo by RGH.

The skin is gray-brown-reddish (see figure 9), 16mm at its thickest part, with characteristic wrinkles in the eye region (see figure 10) and a complete postscapular fold at the forelimbs, but incomplete fold at the posterior region at the hind limbs (Evans 1904, Cave 1964) (see figure 11). In contrast to other species of Rhinocerotidae the skin in *Dicerorhinus sumatrensis* can be describes as “strikingly soft and tender” (Krumbiegel 1965; pers. experience). Hairs cover the entire body of these Rhinos (figure 9 and figure 12), being most dense in juvenile individuals and seem to disappear with age due to natural changes rather than abrasion. The colour of the hairs is black when juvenile but appears more reddish in adult individuals.

Figure 12. Emi and Suci in Cincinnati Zoo & Botanical Garden. Note colouration differences. Source International Rhino Foundation website.

3.4. Ontogeny:

Pregnancy, reproductive cycles and mating behaviour has only been investigated within the last 20-odd years but captive breeding only had its first success with the birth of a Sumatran Rhinos calf in Cincinnati Zoo in 2001 (Roth 2010; Roth et al. 2001). Zoological gardens around the World have held Sumatran Rhinoceros in captivity for more than a century and ironically they were the first Rhino to have been recorded to breed in captivity (Reynolds 1960). Roth et al. (2001) conducted a 2-year study of the reproductive cycle prior to the successive pregnancy and following birth of a Sumatran Rhinos calf in Cincinnati Zoo. They found that the Sumatran Rhinos appear to be an induced ovulator, inferring that the female will only ovulate if allowed to engage breeding behaviours such as intromission or simply mounting. Not uncommon among mammals, Sumatran Rhinos are the only Perissodactyla known to be induced ovulators; none of the other known Rhinoceros species, that have been studied far more, has been observed being induced ovulators.

A 21-day reproductive cycle was observed by measuring levels of LH, progesterone and progestin in blood and faecal samples. Baseline values were set prior to mating and were found to increase 30-fold after mating and return to baseline within 22 hours. The ovulation would occur within 46 hours after copulation. Roth et al. (2001) also conducted ultrasound examination and found that when the ovulatory follicles reached 28-30mm in diameter, breeding attempts would fail because the oestrus would have passed at this point. When pregnancy occur a gestation period of 475 to 477 days have been observed in the successive captive breeding at Cincinnati Zoo & Botanical Gardens (Roth 2010). According to Groves and Kurt (1972) young way approximately 23 kg at birth and measure some 914mm in length and 610mm in height, however the calf Harapan born in Cincinnati Zoo & Botanical Garden in 2007 weighed 86lb (~39kg) at birth. The calf is weaned from its mother's milk around the age of 18 months, but will not be independent until the age of 2-3 years (Annex II). Females will give birth every third year at the most optimal exemplified by the Sumatran Rhino "Emi" in Cincinnati Zoo & Botanical Garden who had three calves with three-year intervals. Whether females in the wild give birth more frequently is not known, but Groves and Kurt (1972) reported that females had been seen in the wild with young of different ages.

Female individuals reach sexual maturity between the age of 5 to 6 year and males approximately at the age of 7-10 years (IRF website).

Articles and information about the male Sumatran Rhino genitalia has been difficult to obtain, but during the authors stay in TWR there was a very fortunate opportunity to observe, discuss and document general characteristics and behaviour of a captive male Rhino. The penis is situated below the anus and points backward in a relaxed state. Occasionally the penis will enlarge and the gland and two lateral projections become visible (see figure 13). A full erection is characterized by the penis turning forwards rather than backwards, which can be referred to as the normal position. During mating the two lateral projections act as locking devices under penetration and will go inside the female reproductive tract along with the gland and increase in size, insuring the penis will not slide out during copulation. The testes are retroperitoneal and can be seen under the skin between the anus and penis (pers. comm. Dr. Zainal Zahari Zainuddin; pers. experience).

Figure 13. Penis of a Sumatran Rhino. Note the lateral projections. Photo by RGH.

3.5. Ecology:

According to Groves and Kurt (1972) the Sumatran Rhinos inhabit the tropical rainforests and mountain moss forests of Borneo, Peninsula Malaysia and Sumatra, engaging in seasonal movements between low and highland up to 1500m. They suggested that the movements to highlands in March are attempts to avoid attacks of horseflies, although during the authors stay in TWR from March 13th to April 3rd only one horseflies was observed around Tam and the Rhinos of TWR seems to be in the lowlands during the dry periods simply due to the lack of water in the highlands (pers. comm. Dr. John Payne). In Borneo the Rhinos are also found in low coastal swamp areas as well as in lowland primary and secondary tropical rainforest (Pers. experience). In the past the Sumatran Rhinos were also found in the peat swamp forest of Sungai Dusun, Peninsula Malaysia (pers. comm. with Dr. Zainal Zahari Zainuddin and Mr. Palle Havmøller). In the past the Sumatran Rhinos seems to have been attracted by man-made secondary forest due to the abundance of food (Groves & Kurt 1972) – today they are still found in 30-year old secondary forest but human disturbance seems rather to force the Rhinos out of their habitat rather than attract them (pers. comm. Dr. Zainal Zahari Zainuddin and Dr. John Payne). Groves and Kurt (1972) described the male Sumatran Rhino as being more nomadic than females, possibly in the search of females to mate with. The female Sumatran Rhino was described as having a territory 500-700m in diameter centred on a wallow and with a home range of 2-3,5km in diameter with a dense network of tracks leading to and from the wallow. Van Strien (1986) described the male Sumatran Rhinos have a home-range of approximately $50km^2$ and the females of $10\text{-}15km^2$. The size of the female home-range is confirmed by the author after a review and calculation with Dr. John Payne of the home-range of a well monitored female Rhino in TWR. It is worth noting that numerous Rhino wallows are located within this home-range and the hypothesis that the entire home-range is centred on a single wallow made by Groves and Kurt (1972) can be put into question. The wallows are similar to those of Bearded Pigs (*Sus barbatus*) but can be distinguished by the deep clear and deep horn marks in the sides of the wallow. The wallow will at the most ideal be on the top of a small hill, at the root of a fallen tree, with only two tracks, one in and one out, giving the Rhino the option of a quick escape if disturbed. In Sabah the Bornean Pygmy Elephants (*Elephas maximus borneensis*) also create wallows but they are much larger, not of the characteristic kidney shape of Rhino wallows and will most often be surrounded by the unmistakable round footprints of Bornean Pygmy Elephants (Payne & Francis 2005; pers. comm. Dr. Zainal Zahari Zainuddin; pers. experience).

All records of Sumatran Rhinos in Sabah, Borneo, are within 14km of a mineral source which is frequently visited (Payne & Francis 2005) and there are no records of Rhinos on ultramafic rock that have a nutrient poor layer of top soil which can only support hardy plants i.e. nepenthes that are not the ideal Rhino diet (pers. comm. Dr. John Payne).

The Sumatran Rhino is a browser and have very varied diet of leaves, twigs, barks and fruits (Groves & Kurt 1972). A total of 31 different species of food plants from 13 different families has been described as being eaten frequently by Rhinos in DVCA (Lee et. al 1993), although the actual number of food plant might be close to 100 different species (pers. comm. Dr. Zainal Zahari Zainuddin) (List of food plants is in annex III). Interestingly one of the favourite food plants of the captive male Rhino is *Merrinia* sp. and *Caloponium mucinoides,* crawlers that are not found in primary tropical rainforest, but along roads and clearings and has not previously been described as Rhino food plants. This might be because Sumatran Rhinos normally never ventures out into open areas where these plants are found (pers. comm. Dr. John Payne). Sumatran Rhinos have a very characteristic way of incising the terminal 10-20cm of their food items, typically fresh shoots, leaving the plant with a straight cut when held together (see figure 14). Another characteristic feeding sign is a twist - where the Rhino uses its horn to twist down young trees and eat the top shoot (see figure 15).

3.6. Behaviour:

The Sumatran Rhinos are solitary animals. The male and female Rhino will only seek out each other for mating purposes and in captivity it is necessary to keep individuals separated as they will fight, bite and sometimes in-flick lethal trauma to each other (Foose T. J. 2006; Anonymous 2009).

Figure 14. Sumatran Rhino feeding sign. Photo by RGH.

Figure 15. A twist made by a Sumatran Rhino. Photo by RGH.

The Sumatran Rhino spends the hottest hours of the day in their wallows, becoming active in late afternoon till mid morning when they will go foraging and rarely venture out in open terrain - prefers to moving under forest cover and dense undergrowth where they create tunnels and sent mark frequently with urine along their trails (Groves & Kurt 1972; von Muggenthaler 2003; pers. experience). Despite their plump appearance these Rhinos are surprisingly agile and dexterous being able to climb nearly vertical cliffs and swims very well, even in the sea (Groves & Kurt 1972; Muggenthaler et al. 2003).

The Sumatran Rhinos have poor eyesight, but an excellent sense of smell and hearing (pers. comm. Dr. Zainal Zahari Zainuddin). Dr. Zainal Zahari Zainuddin told of an incident where a Sumatran Rhino escaped from the Sumatran Rhinoceros Conservation Centre (SRCC) in Sungai Dusun. They opened the gate into its outdoor enclosure and in the evening the Rhino returned and set of the remote movement sensor. As the Rhino had gone far back into the enclosure, they ran to close the gate behind it. But the Rhino heard them approaching and turned on the spot and ran back out of the gate before Dr. Zainal Zahari Zainuddin could make the gate – all in total darkness. They did manage to recapture the Rhino a couple of days later by closing the gate behind it. Dr. Zainal Zahari Zainuddin explained that their sense of smell is so accurate that it can guide them through the forest in full gallop and total darkness. In the wild Sumatran Rhinos are extremely shy and will take flight at the slightest suspicion of threat and are very sensitive to sent and sounds, this behaviour is very different from other Rhinoceros species as they are more likely to attack then flea when disturbed (Groves & Kurt 1972). Even the captive male Sumatran Rhino in TWR, which has been held captured for 1,5 years with daily physical contact to humans will be alarmed by the sound of branches breaking, but not very much from the noise of cars, horns, hammers or mechanical drills (pers. experience). There seems to have been a change in behaviour as they have in the past been described as "not seem to be so timorous and ready to take alarm…" and "have more than once strayed inside the suburban line of Sandakan itself; on one occasion one went into a garden in the outskirts of the town and ate some melons; on another, one managed to get into a chicken-house on the Beatrice estate, and when a man went with a light to see what it was, it rushed through the other side, carrying away part of the fencing with it…" (Clowes & Sons 1890). When disturbed the Sumatran Rhinos can give of a barking alarm sound while galloping through the jungle (pers. comm. BORA- & WWF-RPU; Groves & Kurt 1972). However for reasons unknown, the Sumatran Rhino tame very easily. In the case of male in TWR, he was first discovered in an oil palm plantation by a worker, which alarmed the Sabah Wildlife Department, WWF-Malaysia and BORA. The first couple of days the Rhino made skim-attacks on the RPU's that guarded him, but after just 10 days the staff could touch, hand feed and finally make him go into his transport crate voluntarily without the use of force or anaesthetics (WWF-video). Even so, on one occasion Dr. Zainal Zahari Zainuddin, Michael Ernst (Head zookeeper Leipzig zoo), Alvin Erut (Chief paddock) and the author disturbed male Rhino when he was lying in his outdoor wallow, and his response was a swift exit of the wallow and approached us snorting with a clear message - we were not welcome. Dr. Zainal Zahari Zainuddin however calmed Tam and proved with grace how experienced he is in handling Sumatran Rhinos. Defecation is on a daily basis and preferably in water, therefore dung in the wild is rarely found, as the water will wash it away (pers. comm. Dr. John Payne; Dr. Marshal Chuat). In captivity the Rhino will also defecate in water. If the Sumatran Rhino has no other option it will defecate in its wallow (Anonymous 1959). The Sumatran Rhinos are the most vocal of all the Rhinoceros species making a wide variety of low and high pitched squeaks called bleating, with short interval and often for very long periods of time. In the case of male Rhino in TWR his bleating could be related to begging behaviour, as he would stop when feed. But the squeaking was also observed during times when he was supposedly not hungry and when he was in his outdoor jungle enclosure without human contact, though they where shorter squeaks and not of the same amplitude as when thought to related to hunger and begging behaviour (pers. experience). Von Muggenthaler et al. (2003) conducted a study of the vocalization from Sumatran Rhinos (*D.s. sumatrensis*) in Bronx Zoo and Cincinnati Zoo & Botanical Garden. 3 different types of sounds was identified and named "eeps" (70Hz-4kHz; 57-92dB), "whales" (100Hz-3,2kHz; 87dB) and "whistle-blows" (17Hz-8kHz; 100dB). The final sound, a whistle follow by an immediate burst of air, containing a high level of infrasound which was suggested could be long distance communication between individuals in the forested habitat. "Whales" was named so because it resembles the sound made by Humpback Whales (*Megaptera novaeangliae*) and varies in duration between 4-7 seconds, while "eeps" only lasted about 1 second. The "whales" was only observed being produced by female Rhinos – interestingly the captive male in Borneo made sounds that could be interpreted as "whales" (pers. recordings).

The reproductive and courtship behaviour of Sumatran Rhinos have only been described from animals in captivity, though mating has been observed in the wild (Bartlett 1873). Under the breeding programs at the SRCC (Peninsula Malaysia) and Sepilok Rhino Breeding Centre (SRBC) Sabah, Borneo, Malaysia), the reproductive behaviour was studied. At the SRCC the study by Zainuddin et al. (2005) was to determine the signs for behavioural oestrus, which is recognized by the female taking stand to be mounted. A male and female Rhino was introduced on a daily basis for 1-2 hours and all behaviour, postures, frequency and duration were recorded. The behaviours were divided into precopulatory behaviour – vocalization, tail raising, urination, contact behaviour with the head and snout, involving the flanks, hind limbs, neck, head, perineum, external genitalia; and copulatory behaviour – penile exposure, erection, mounting and dismounting. When introduced the male Rhino would approach the female with open jaws and head raised, exposing the lower incisors (see figure 16). The male would sniff the female urine and rump, which resulted in the flehmen reflex and be repeated several times – also the male would show signs of flehmen while spraying small volumes of urine from the penis while protruding to an erection. Urine spraying by the male was frequent when placed in a new enclosure, during excitement and when the female was present. Frequent quivering of the hindquarters was observed from the male as well.

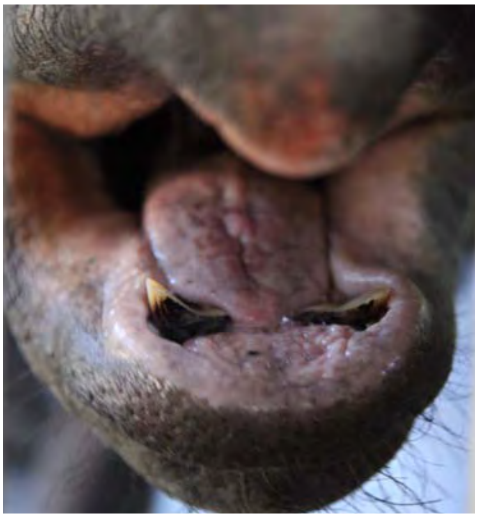
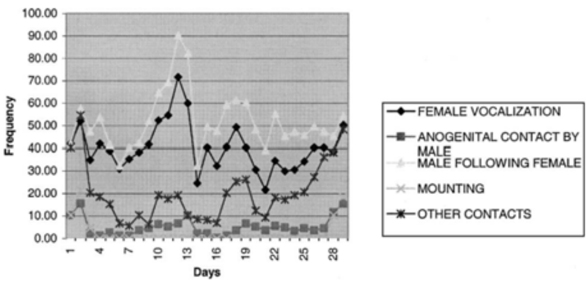


Figure 16. Lower incisors almost tusk-like with sharp edges. Photo by RGH

When the male and female was introduces a series of responses was noted. Physical contact snout to snout was the first observed followed by contact made by both the male and female to the head and neck region. Very little contact promoting behaviour (0,7%) by the male to the female perineum and hind limbs in the first week of introduction.



Graph 1. Intensity of behavioural observations. Source Zainuddin et al. (2005).

The female on the other hand made contact with the male anogenital region more often (4%) during the first week of introduction. The female was quite vocal and had several peaks in number of vocalizations during the When the male sniffed the rump of the female she would squeal and snort, and if the male made contact with the perineum the female would reverse. Rapid swinging of the tail was also frequently observed. During horn sparring behaviour the female would reverse and swing her head to the side, initiating the male to charge. Aggressive behaviour was displayed by both sexes and included biting, head butting, nuzzling nose to nose and horn clashes that resulted in severe lacerations on the female. When aggression became too severe the male and female would be separated by the staff.

A day before oestrus both sexes would display raising of the tail or swinging for a period of 5-10 minutes. The female would also squirt urine more often, but feeding and defecation behaviours were not altered. The male would chase the female over short distances in the paddock and an increasing contact with the female anogenital region as the female would reverse towards the male. The male would place its chin on the rump of the female, which would make her move forward initiating a driving reaction.

On the day of oestrus tail raising and swinging was frequent along rubbing of each other's flanks (see figure 17).

When the standing oestrus occurred, the male would sniff, lick and bite the perineum on either side of the vulva and there would be very little contact with the head or snout of the female. During oestrus the number of mountings would vary between 8-25.

Figure 17. Andalas and Ratu excerting mating behaviour. Source International Rhino Foundation Website.

The mounting it self would occur when the female stood for the male, the male would rest his chin on the rump of the female and slowly rotate it from left to right while moving forwards, using the chin as a pivot and subsequently push forward and lift his forelimbs onto the hindquarter of the female "row forwards" to the lumbar region and securing at the shoulder fold. Erection took from 5-100 seconds followed by expansion of the two lateral projections 1-2 min later. Though it is not mentioned in any of the studies, the lateral projections has to go inside the female reproductive tract, expand and act as locking device. As mentioned in the discussion of the study, if the lateral projections are expanded before mounting, the intromission will fail due to the simple fact that the lateral projections will block for penetration and the male will become very agitated and aggressive (pers. comm. Dr. Zainal Zahari Zainuddin). In the study made by Bosi (1996) at the SRBC of two female Sumatran Rhinos on Borneo were observed for mucoid discharge and swelling of the vulva as well as behaviour on a day to day basis as indicators of oestrus. The presence of mucous was proven by manually manipulating the vulva of the Rhinos when they where lying down, while restless pacing along the walls and looking for the males on the other side of the fence was interpreted as a sign of oestrus. Two male Rhinos were also included in this study. On a weekly rotary basis each of them was let into a breeding enclosure with one of the females at the time. Much the same behaviour as observed at the SRCC in Peninsula Malaysia was made in the study by Bosi (1996), although not described in the same detail and some behaviour were interpreted differently. The shivering or quivering of the hind limbs of one of the male Rhinos was interpreted as "apprehensive" behaviour and the oestrus cycle was determined to be 28-30 days rather than a 21-day cycle (Bosi 1996; Roth et al. 2001). The SRBC had success with full intromission with both female Rhinos, but none of them became pregnant for reasons unknown until an ultrasonic examination in 2004 was conducted on the only remaining female Rhino, which revealed that there was no follicular development and the uterus had shrunken compared to the 1998 record (Kretzschmar 2008).

3.7. Threats:

The single largest threat to the survival of the Sumatran Rhino is poaching for it horns, that might sell for as much as $45.000 on the black marked used in traditional Chinese medicine (WWF-Malaysia website). Loss of habitat in the term of destruction of forests either for timber or convention into plantation is the second largest threat to the continued existence of the Sumatran Rhinos (IUCN Red List website). It is also a growing concern that the remaining populations might be of to few individuals that rarely meet and therefore have become inbreed resulting in lower fecundity (IUCN Red List website).

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Abstract: Efforts to save the Sumatran Rhino from extinction in South-Asia have been a long process with high stakes. But to fully understand why the current efforts are being managed, as they are it is important to understand what came before them. Although it is a very sensitive subject to rip up in the past the intention is not to point the blame at any one but to take past lessons learned into account when creating new strategy plans for conserving the Sumatran Rhino. This chapter will present a time line of past actions taken to save the Sumatran Rhino followed by a description of current efforts on Borneo observed by the author.

4. What has been done? – A review of the past efforts.

The Sumatran Rhino was first declared an ”endangered” species in 1986 and was re-evaluated to ”critically endangered” ten years later in 1996. The reason was that the worldwide population of Sumatran Rhino had declined with more than 80% over three generations and that there was no subpopulation with more than 50 individuals left anywhere. Today the Sumatran Rhinos are the only species of Rhinoceros with a declining trend; all others are either stable or increasing in numbers. According to the IUCN 2008 Red List the current total World population of Sumatran Rhinos is less than 250 adult individual with an expected decline of at least 25% per generation (IUCN Red List website). However in 2009 the International Rhino Foundation (IRF) revised the number of Sumatran Rhinos to be only around 200 individuals (Fleischer 2009).

The main threat to the Sumatran Rhino is poaching for its horn that is used in traditional Chinese medicine, loss of habitat due to logging concessions and the creation of plantations (IUCN Red List website). With the number of Sumatran Rhinos still decreasing inbreeding in small and scattered population is also a threat that concerns their survival.

4.1. Past efforts:

Early concerns on the decline in Sumatran, Greater One-Horned and Javan Rhino numbers lead to the creation of the Asian Rhino Specialist Group (AsRSG) under IUCN’s Species Survival Commission (SSC), who held their first meeting in Thailand in 1979. They concluded that data on collection, research, monitoring, protection of Rhino habitat, reduction of poaching and strict control on trade in Rhino products was needed. In 1982 the AsRSG met in Malaysia and analyzed distribution patterns, population estimates and put forward conservation requirements. In 1984 the AsRSG met in Singapore and launched a campaign to capture “doomed” Sumatran Rhinos for captive breeding efforts. The definition of “doomed” Sumatran Rhinos was very loosely formulated as animals in areas in immediate danger due to conversion of forest to other use or clearing was included as “doomed”. The Sumatran Rhino Trust (SRT) was founded under the American Association of Zoological Parks and Aquariums and attempted to produce agreements with Malaysia to export Sumatran Rhinos to the United States as part of the establishment of a captive breeding programme (Emslie et al. 2009; Rabinowitz 1995). But political protests in Malaysia obstructed the agreements and lead to the creation of the Sumatran Rhinoceros Conservation Centre (SRCC) in Sungai Dusun, Malaysia. Further political differences between Peninsula Malaysia and the Malaysian state of Sabah on Borneo lead to the creation of Sepilok Rhino Breeding Centre (SRBC). Complication in cooperation between the involved countries resulted in the design of a comprehensible conservation action plan for all Asian Rhino species during meetings in Malaysia (1986) and Indonesia (1987). The captive breeding programmes where deemed a important component subsequent to the action plan, although recognition of *in situ* protection and management of wild population also held high priority the *ex situ* management of Sumatran Rhinos was underlined. In 1987 the SRT made agreements with the Indonesian government on export of Sumatran Rhinos. But the agreement also acknowledge that *in situ* conservation had top priority and that the newly formed Indonesia Rhino Foundation (YABI) would receive a donation of US$ 60.000 for every Sumatran Rhino received at a SRT facility, in the case of death during transport or in the following year of a Sumatran Rhino the YABI would receive US$ 25.000 per animal from the SRT, in the event of death of an animal during capture the YABI would receive US$ 5.000 form the SRT, all expense of surveys, captures and transports would be paid by the SRT and finally the SRT would contribute with US$ 25.000 annually for the duration of the agreement to improve protection and management of Sumatran Rhinos in Indonesian national parks.

Five years and US$ 2.5 million later the SRT was dissolved. Between 1984 and 1993 a total of 35 Sumatran Rhinos had been caught in Malaysia and Indonesia and 12 of these had died by 1993. The remaining 23 (9 males; 14 females) were separated by 10 different locations in the United Kingdom, the United States, Indonesia, Sabah and Peninsula Malaysia. Only the SRCC in Peninsula Malaysia held 5 individuals at once while the Cincinnati Zoo & Botanical Garden held 3 animals and except for a female that was pregnant went caught, no offspring had been produced in captivity by 1993 (Foose & Zainuddin 1993).

The SRCC in Sungai Dusun was a facility designed to house up to 8 animals with individual outdoor enclosures but only held 2 males and 3 females. The first male proved to have very low sperm quality and was thus not suited for breeding purposes. The second male was originally from Indonesia, but was in very poor health conditions due to snare wounds and infection when caught and received long term treatment for his injuries. He was then returned to the SRCC but was unable to complete intromission with the females as a result of his injuries being unable to heal completely – he was simply unable to hold the stand for any longer period of time (pers. comm. Dr. Zainal Zahari Zainuddin). Nine years of intense research and breeding attempts came to an abrupt stop in 2003 when all 5 Sumatran Rhinos at the SRCC died within 18 days. The cause of death was determined to be trypanosomiasis - an infection of blood parasites (Foose 2006). However the validity of the official post mortem examination can be put into question as trypanosomiasis is not a common cause of death in Sumatran Rhino and the fact that all 5 animals died within 18 days seems to be quite a coincidence.

The Department of Wildlife and National Parks (DWNP) has had a Rhino Protection Unit (RPU) operating in Peninsula Malaysia and has fought a hard uphill battle against poaching. Many animals has been found snared and shot with their horns sawed of and the current existence of Sumatran Rhinos in Peninsula Malaysia is very much in doubt (Kawanishi et. al 2003).

Even so the AsRSG still stated in 2009 that 52-69 Sumatran Rhino still exists within the Taman Negara National Park and Royal Belum State Park.

In total 7 Sumatran Rhinos were captured in Sumatra and sent to the US between 1988 and 1992. 4 where sent to the San Diego Zoo and 3 to the Los Angeles Zoo. In the end by 1995 all but 3 of the animals (1 male; 2 females) were alive. They were all moved to the Cincinnati Zoo & Botanical Garden in a final effort to get them to breed. Several failed pregnancies and 6 years later the effort resulted in the female Emi gave birth to the first captive breed Sumatran Rhino in 112 year - the male calf named Andalas was born on the 13th of September 2001. Not even 3 years later in July 2004 Emi once again gave birth to a female calf that was named Suci and then again in April 2007 she gave birth to another male named Harapan. Sadly Emi died in 2009 from liver failure caused by hemochromatosis, an iron storage disease (Roth 2010).
Currently Suci is in Cincinnati Zoo & Botanical Garden where she is monitored for puberty (ultrasound and faecal hormones), Harapan is the White Oak Conservation Centre and in 2007 Andalas was translocated to the Sumatran Rhino Sanctuary (SRS) in Way Kambas National Park, Sumatra, Indonesia (anonymos[2]).

4.2. Current efforts:

The SRS was created in 1998 inside the Way Kambas National Park as a part of YABI's Indonesian Rhino Conservation Program (IRCP), which is supported by the IRF financially. SRS is a 100ha facility that currently holds 5 Sumatran Rhinos (2 males, 3 females) in enclosures designed in as a spider-web with a central paddock.

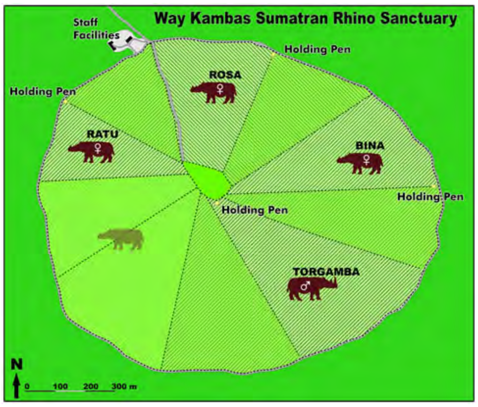


Figure 1. Diagram of SRS. Source IRF website.

Only one Rhino has died at the SRS since it was first set into operation and after the arrival of Andalas the SRS has had it first confirmed pregnancy in 2009 with the young female Ratu. However the faetus was lost in April 2010 (IRF website). Since 1997 until date the YABI and IRF has been operating 5 anti-poaching units (RPU) within Way Kambas National Park along with a public awareness programme. The RPU's consists of 4-6 armed rangers and has the objective to prevent encroachment and poaching, removing traps and snares set up by poaches as well as record data on Sumatran Rhinos signs, dung, footprints and direct sightings. Since the RPU was set into operation there has been no record of poaching of large mammals within Way Kambas National Park (IRF website).

4.3. Past efforts on Borneo:

All ready in 1982 the population of Sumatran Rhinos in Sabah was estimated to be between 15-30 individuals (Davies & Payne 1982) and the AsRSG initiative of capturing of "doomed" and isolated Sumatran Rhinos was carried out from the start of 1987 by the newly formed Sabah Wildlife Department (SWD). Under SWD the Sabah Rhino and Wildlife Conservation Committee (SRWCC) got the task of capturing "doomed" and isolated Rhinos. A total of 10 Sumatran Rhinos (8 males; 2 females) were caught until 1995, 7 of them were moved to SRBC, 2 died in the pit-fall trap during capture and 1 was released into TWR (Bosi 1996). Although the SRBC had success with full intromission and made the first study of Sumatran Rhino breeding behaviour in captivity, they never had success with pregnancy. The reason for the failure in SRBC is not fully clear. The facility struggled with very small individual pens (see plan of SRBC annex IV), an outdoor enclosure that was shared between all the animals, lack of experienced keepers, infertile animals, a skewed sex-ratio in the captured Rhinos and high mortality rate - and by 2006 only one male and one female was still alive at SRBC but tragically in the end of 2006 the male was killed by a fallen tree branch (Tan 2007).

In year 2000 a local NGO named SOS Rhino started operating a RPU in TWR in cooperation with SWD and an awareness programme aimed at the local communities was launched. The RPU recorded data on encroachment, removed snares and traps and destroyed camps made by poachers. They also recorded all signs of Rhinos in terms of footprints, dung, feeding signs and direct sightings. In July 2008 SOS Rhino stopped operation and the work was taken over by another newly formed local NGO named Borneo Rhino Alliance (BORA). In August 2008 a worker close to the Kretam Forest Reserve spotted a Rhino wondering about inside an oil palm plantation. The manager of the plantation alerted the SWD, BORA and WWF-Malaysia who in a coordinated operation over 10 days feed, supplied water, protected and eventually translocated the Rhino to TWR where he was released into a paddock with a outdoor enclosure. The Rhino was named Kretam, but is referred to Tam throughout this paper.

4.4. Current efforts on Borneo:

Borneo Species Programme (BSP) includes monitoring and protection of Borneo's Pygmy Elephants, Orangutans (*Pongo pygmaeus*) and Sumatran Rhinos. The objective of BSP is to locate all isolated Sumatran Rhinos in Sabah and bring them together to increase the overall probability for the species survival and also to create public awareness on the species in BSP (pers. comm. Dr. Marshal Chuat).

5. Fieldwork.

During the stay the author got a unique opportunity to learn conservation methods by hand, acquire information on much unpublished data, freely discuss the political, financial, personal and human issues facing the conservation of Sumatran Rhinos with the professionals having many years of experience in the field and get directly involved in conserving the Sumatran Rhino on Borneo for the future generations. Much of the knowledge obtained during this stay has been used to create the population viability analysis in the next chapter of this project.

5.1. Fieldwork with WWF.

WWF-Malaysia has operated a RPU under BSP since 2005 supported by Honda Malaysia, WWF-Netherlands, WWF-Germany and the United States Fisheries and Wildlife Service. The RPU consists of 13-16 men ranging from 19 to 45 of age with many years experience in wildlife and most of them have been working with the WWF-Malaysia for many years. The RPU does not cover one particular area in Sabah, but changes between mainly 3 localities every 2nd month.

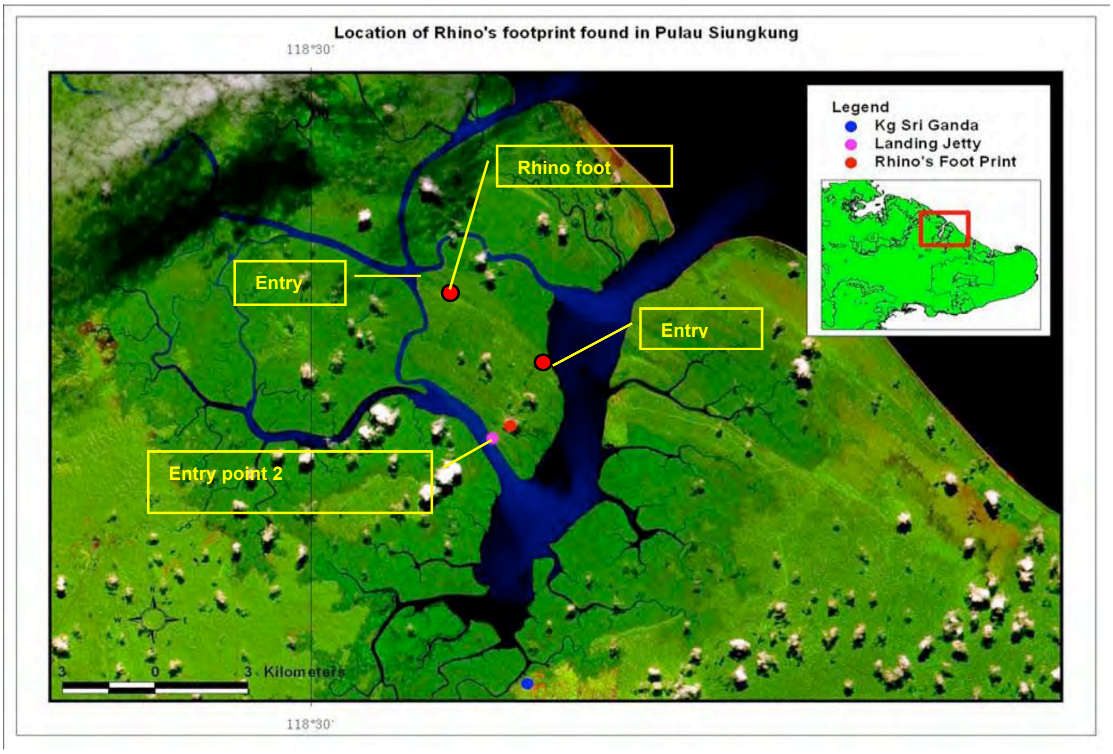


Figure 5. Satellite photo of Siungkung Island. Note the Kulamba Forest Reserve (unmarked) opposite and the island Lawa-Lawa (unmarked) right of Siungkung Island. Satellite photo from Bili (2008).

During the authors stay from March to April 2010 the RPU went to the Lower Kinabatangan, more specifically the island of Siungkung, which holds a base camp and from here daily patrols of 3-5 men went to the nearby islands of Lawa-Lawa, Malbumi and the Kulamba Forest Reserve on the other side of the river as well as daily patrols into the island of Siungkung it self. The patrol lasted 23 days and consisted of searching for signs of the Sumatran Rhino, which included feeding signs, dung, footprint as well as direct sightings, setting up new camera traps, change batteries and memory cards on existing camera traps and a general wildlife survey.

The island of Siungkung and surrounding islands consist totally of secondary peat swamp and mangrove forest that had almost been completely logged of 30 years ago. It is surrounded by salt water and entrance to the island is difficult due to the Nipa palms (*Nypa fruticans sp.*) that cover the banks (see figure 2). The interior of the island is dense regenerated secondary peat swamp forest with the floor covered in dead leaves in the dry season and has very little fresh water present (see figure 3). The WWF-Malaysia was first notified of the presence of Sumatran Rhinos on Siungkung Island in 2008 by 2 locals from the village of Sri Ganda, who today work along with the RPU (see figure 4).

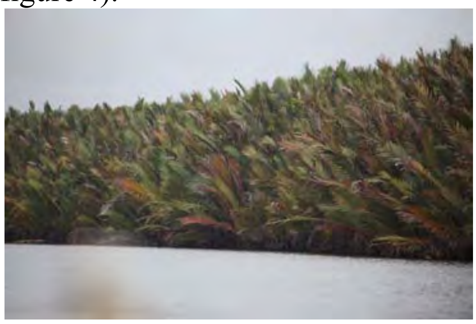


Figure 2. Nipa Palm (*Nypa fructicans sp.*) surrounding the island of Siungkung. Photo by RGH.

Figure 3. The forest floor at the interior of Siungkung. Photo by RGH.

Figure 4. Amran who first alerted the WWF-Malaysia on the presence of Sumatran Rhinos in the area setting up a "cudde back" camera trap. Photo by RGH.

After 2 years of survey on Siungkung Island and the surrounding area the RPU have found footprints of at least 3 different individuals (2 adults and 1 sub-adult) determined by the different sizes of 18.3, 21 and 23.5cm in width (Bili 2008; pers. comm. Dr. Marshal Chuat) (see figure 5). Other signs such as dung, scrape marks and feeding signs has also been found but there has been no luck with getting a photo of a Sumatran Rhino from a camera trap.

The WWF-Malaysia also operates in the Greater Danum Valley area as well as within the DVCA in central Sabah.
A survey lead by the WWF-Malaysia in 2007 in cooperation with University Malaysia Sabah (UMS), Sabah Forestry Department (SFD) and Sabah SWD found evidence of 15 adult Sumatran Rhinos within the 438km^2 conservation area (pers. comm. Dr. Raymond Alfred). The RPU has also set up camera and video traps in Greater Danum Valley area since 2006 and the efforts has resulted in 8 photos of at least 4 different individuals (see next page) – 3 of them different females and one of them is presumed to be pregnant (see figures 13 and 14)(WWF-Malaysia press release) - also track of at least 2 infant Sumatran Rhinos have been found in the last 3 years (WWF-Malaysia press release).
The RPU also operate in the more rural areas of central Sabah around Imbak Canyon Conservation Area and Maliau Basin Conservation Area where a female Sumatran was poached in March 2001 – the poachers was never caught and the head and horns where never found.

Figure 6. The poached female found south-east of Maliau Basin Conservation Area. Photo by Raymond Alfred.

Very little is known about the presence of Sumatran Rhinos in these areas, but a survey in April 2010 let to the finding of new tracks close to Imbak Canyon Conservation Area (pers. comm. Edward Addjuhe). Finally the WWF has been authorised to set up road-blocks in areas suspected to be under poaching. They can inspect vehicles under suspicion and gather personal information on the person they encounter. If the violation is of a serious degree they can arrest them and hand them over to the authorities, which will take care of the prosecution. The penalties of killing a female or young Sumatran Rhino is being raised in 2011 to 100.000 Malaysian ringgit or $US 31.00 and 5 years in prison, if the poacher is found to have killed a male the fine drops to 50.000 Malaysian ringgit or $US 15.500 (Hance 2010). '

Figure 7. 1st photo (4/15/2006) ©WWF-Malaysia

Figure 8. 2nd photo (18/7/2008) ©WWF-Malaysia

Figure 9. 3rd photo (18/7/2008) ©WWF-Malaysia

Figure 10. 4th photo (8/6/2009) ©WWF-Malaysia

Figure 11. 6th photo (20/6/2009) ©WWF-Malaysia

Figure 12. 5th photo (20/6/2009) ©WWF-Malaysia

Figure 13. 7th photo (25/2/2010) ©WWF-Malaysia

Figure 14. 8th photo (25/2/2010) ©WWF-Malaysia

5.2.WWF fieldwork results:

The island of Siungkung has been under surveillance for 2 years and the RPU have during this time identified 3 different footprints (Bili 2008, pers. comm. Dr. Marshal Chuat), which is presumed to be a male, a female and a young calf all ready weaned from the female. It appears that the animals move around in the area as footprints and feeding signs have been found in the surrounding island of Lawa-Lawa and Malbumi as well as in feeding signs in the Kulamba Forest Reserve. Therefore it was uncertain if the Rhinos were still present at Siungkung Island when the RPU and author arrived in the beginning of March 2010. The objective was to change the batteries and memory cards of the 10 camera traps on Siungkung Island and set up 10 new camera traps using a transects method. In the past camera traps was set up on location where there had been found either foot prints, dung or feeding signs based on the assumption that Sumatran Rhinos are creatures of habits and would frequently return to their feeding and defecation sites. However the method had for reasons unknown been unsuccessful and to date there are no camera trap photos of Rhinos on Siungkung Island. Dr. Marshal Chuat and Dr. Raymond Alfred had therefore changed the strategy and implemented the used of a transect strategy. The theory is that at some give time, but by simple chance a Rhino would pass a given point and in this way be caught by the camera traps. The RPU made a straight transect from Simpang Empat, the entry point on the north-western shore, going southeast for 3km setting up camera traps every 500m. As faith would have it, at the 3km mark, fresh scrape marks made by the Sumatran Rhino when sharpening its horn on a tree was found at the point where a new camera trap was suppose to be set up. The scrape was still moist, started about 75cm over ground and was 5-7mm deep (see figure15).

Figure 15. Horn scrape by Sumatran Rhino. Photo by RGH.

Though Samba Deer (*Rusa javanicus*) also make horn scrapes the depth and straight lines in the tree made them unmistakable signs of a Sumatran Rhino (pers. comm. RPU team leader Patrick Jonnes Sading). On the way back toward the kilometre 2 mark a feeding sign was found at an open area. Folding the bits bitten off together the shoot has been cut of straight. This sign is harder to distinguish as a Rhino sign as both the Tembadau (*Bos javanicus*) and Samba Deer also eats the fresh shoots from plants and tree, however when they are held together, they do not appear to have been cut of straight (see figure 16). The reason is that the Tembadau and Samba Deer bites each shoot of individually, while the Sumatran Rhino takes in a lot of fresh shoots, huddle them together with its tongue and bites them of with it molars, rather than its incisors as the Tembadau and Samba Deer does.

Figure 16. Recognising a Sumatran Rhino feeding sign is done by holding the twigs together a see if it form a straight cut. Photo by RGH.

At the 2km mark a twist was found, a textbook example of signs for the presence of Sumatran Rhinos (see figure 17). The Rhinos twist a sampling using its horn and brings the tree to the ground eating the fresh shoot at the top of the tree. The twist was several weeks old and right next to it another feeding sign was found.

Figure 17. The young sapling forced to the ground by being twisted around the horn of a Sumatran Rhino. Photo by RGH.

The RPU was growing increasingly frustrated after 2 years of survey but with no camera trap photos of Sumatran Rhinos so far. During a discussion one evening the author suggested making an artificial waterhole with a heavy-duty plastic canvas – as the lack of fresh water on Siungkung Island might attract the Rhinos during the dry season.

5.3. Fieldwork with BORA:

The board of BORA consists of Executive Director Dr. John Payne, Chairman and Director of Tropical Biology and Conservation (UMS) Dr. Abdul Hamid Ahmad, Chairman Cynthia Ong and Chairman Dr. Isabelle Lackman. It is a small NGO funded partly by the Sabah state government, several private organisations and is working closely together with WWF-Malaysia and SWD. BORA operates only within TWR a 1200km^2 of protected area on the east coast of Sabah, outside the WWF proposed "Heart of Borneo". Apart from TWR 36km^2 core area of virgin jungle TWR is all secondary tropical rainforest that has re-grown since the 1980's when the TWR was first gazetted but is currently under dual administration by the SWD an SFD (pers. comm. Mr. Rashid Saburi). Though the highest point in TWR is not more than 800m above sea level the terrain is in general very rugged – a map of TWR is listed in annex V. Except for a proposed corridor to the Kulamba Forest Reserve in the north, TWR is completely surrounded by plantations (see figure 18).

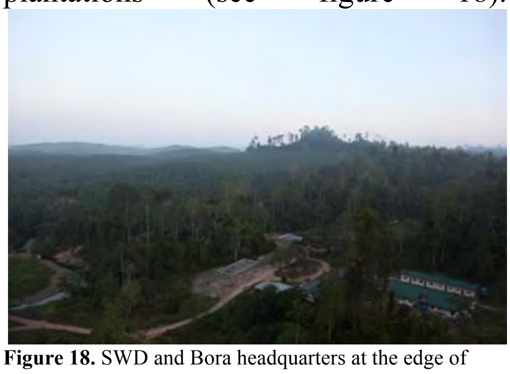


Figure 18. SWD and Bora headquarters at the edge of TWR. Oil palm plantation borders the reserve. Photo by RGH.

BORA has a 7-point mission:

1. To engage in and facilitate collaboration between government, NGOs, industry and public.
2. To provide leadership in management and operational capacity building.
3. To ensure that all rhinos in at Tabin Wildlife Reserve are protected from deliberate and accidental harm and killing
4. To plan and construct the Borneo Rhino Sanctuary infrastructure.
5. To locate, capture and translocate isolated rhinos into the Borneo Rhino Sanctuary.
6. Operation of Borneo Rhino Sanctuary.
7. To establish funding needs and build sustainable funding mechanisms.

BORA operates a RPU, which consists of 3 groups with 4-6 men in each. Working closely together with the SWD the RPU is frequently a mixed group of BORA staff and rangers from SWD typically spending about 3 weeks in the jungle at the time. The primary objective for the RPU is to deter and if possible apprehend poaches. Poaches will be arrested and transferred to the SWD that will prosecute them for their violations. The RPU operate mainly in the south-eastern part of TWR, the reason being that the most encroachment comes from this region. The main route into TWR for poaches seems to be via the rivers. The RPU also survey the rest of TWR frequently and records all signs of Sumatran Rhinos be it dung, footprint, feeding signs, wallows and scrape marks. Direct sightings are very rare – in the past 10 years a Rhino has only been seen thrice (pers. comm. Markarius John).

Not mentioned in the mission of BORA, the NGO also cares for the captive male Sumatran Rhino Tam that was translocated to TWR after wondering into a plantation near the Kretam Forest Reserve in 2008. Under Sabah state law all wildlife is owned by the government and managed by the SWD. Thus BORA was hired and partially funded by the government to care for Tam, create the Borneo Rhino Sanctuary (BRS) and ensure the protection of the Sumatran Rhinos within TWR. Tam is currently held in a paddock that was refurbished as he was caught in 2008. The paddock staff consists of 6 people, who on a 12 hour rotation system, changing 8am and 8pm, have Tam under supervision 24 hours a day. The people on the daily watch clean the inside paddock and supply Tam with fresh water and food plants. 2 people gather the food plants every afternoon and the location of the collection of food plants is rarely the same within a week. In the evening the daily team is replaced and the night is spends ensuring that there are no intrusions to the paddock area.

The idea of a sanctuary to gather the remaining Sumatran Rhino in was originally derived during a SOS Rhino workshop in 2007. In 2008 TWR was chosen as site for sanctuary on the background that is has until date had a breeding population of Sumatran Rhinos and its remoteness to villages which is considered the largest threat due to poaching activities originating from the villagers. As BORA took over operations the plan of a sanctuary evolved. An African Rhino specialist was hired as a consultant and the advice was to make a 4500ha electrically fenced sanctuary within TWR following 33km of 1970s-80s logging road (Talukdar 2009). However after careful considerations and a cost benefit analysis BORA decided that the sanctuary BRS would have to be much smaller as the costs of building, maintaining and guarding a 33km fence in the terrain of TWR would be of great practical difficulties as well very costly even long term – however a the design and plan of BRS still includes an option to expand as the objective is to breed and release Sumatran Rhinos to supplement the population in TWR. The design of BRS is meant to be of the same principles as the SRS on Sumatra (pers. comm. Dr. John Payne). BORA has hired Dr. Vet. Zainal Zahari Zainuddin who has extensive knowledge from SRCC to manage the captive breeding programme.

5.4. BORA fieldwork results:

Director of BORA Dr. John Payne had prior to the arrival of the author located an area suited for constructing the BRS. Most of TWR consist of undulating terrain with very few flat areas needed for a breeding centre.

2 members of the RPU and the author got the task of making a thorough survey of the area, making 100m transects every 50m following a old 1970's logging road. The transects of the first 500m was at a 220^{o} angles as the road was heading northwest and every start and end point was recorded by GPS. At the 500m mark the road turned southwest and transects were made at a 40^{o} angle. The result was that the area about 121 ha with very little variation in terrain. A sketch with GSP coordinates is in annex VI.

In the southeastern corner of TWR a female Sumatran Rhino named Puntong has been under close monitoring the last couple of years. This part of TWR is the area with the most frequent encroachment and poaching activities and there are growing concerns that the animals here are under threat. The first record of Rhinos here was in 2006 of an adult and a calf. For reasons unknown all signs of the adult disappeared but footprints of the calf were still present. However the footprint changed – the adolescent calf had supposedly stepped in a poachers snare but managed to get out of it, unfortunately in the process lost the 3 toes on its left front foot. The adolescent survived the ordeal and today makes easily recognisable round footprints – hereby the name Puntong "the three-legged one". Furthermore the RPU has made direct sightings of Puntong on several occasions and can confirm that she is limping and that she is a female (pers. com. Dr. John Payne). With a current footprint being 19cm across the estimated age of Puntong is 4-6 years old (Dr. Zainal Zahari Zainuddin).

Figure 19. The unmistakeable footprints of Puntong – one normal with three toes and one round with no toes. Photo by RGH.

Finally two photos from the Bornean Wild Cat & Clouded Leopard Project captured by a camera trap of a female Sumatran Rhino within the home-range of Puntong (see figure 20 and figure 21).

Figure 20. Camera trap photo of a Sumatran Rhino presumed to be Puntong. Source Bornean Wild Cat & Clouded Leopard Project.

Figure 21. The photos do not verify the animal as Puntong since the right front foot is not visible. There is however no doubt that it is a female Sumatran Rhino. Source Bornean Wild Cat & Clouded Leopard Project.

The decision to capture Puntong for the breeding programme was made on the basis that there has been no records of Rhinos in the part of TWR for many years, she is under serious threat from poaching and it is certain that it is a female (pers. comm. Dr. John Payne).
SWD has an officer (Mr. Herman Bert) employed at TWR only to take care of issues concerning Rhinos in cooperation with BORA. The field manager of the BORA RPU Mr. Markarius John has been working with Herman Bert for many years and the two of them caught several of the doomed and isolated Rhinos in the 1980-1990's (pers. comm. Herman Bert, Markarius John, Dr. John Payne). The method used to capture Sumatran Rhinos is with a pitfall trap modified from the original design by Dr. Carl Træholt to capture Tapirs (*Tapirus indicus*). As the method has proven successful in capturing Sumatran Rhinos in the past both in Peninsula Malaysia, Indonesia and Borneo there seems little reason to develop a new strategy to capture at the current stage. Therefore the construction of a new pitfall trap and boma was constructed during the authors stay. Photos of the pitfall trap and boma are listed in annex VII.
Last but not least the author joined the BORA paddock team to learn of the daily husbandry of captive male Tam. The Head Zookeeper Michael Ernst from Leipzig Zoo was in TWR as a part of an exchange programme between Leipzig Zoo and the SWD managed Lok Kawi Wildlife Park in Kota Kinabalu.

Figure 22. Head Zoo-keeper Mr. Michael Ernst discussing issues of husbandry with BORA's Chief Paddock Mr. Alvin Erut. Photo by RGH.

Sharing accommodation Michael Ernst enlightened the author on a great deal in regards to husbandry of large animal and together a list of suggestion was composed as several issues regarding the husbandry became apparent over the time spent there. It has to mentioned that Dr. Zainal Zahari Zainuddin had not started his work with BORA when the list of suggestions was composed – and it was clear from the first moment that these issues were visible and of concern to Dr. Zainal Zahari Zainuddin as well. The concerns were regarding the general level of knowledge of the paddock staff in handling large mammals and preventing stereotypic behaviour, enrichment as well as target training the animals, which will be essential for the breeding programme, where frequent ultrasound scans will be necessary for monitoring the female Rhino for oestrus.

As the BRS at the current time is not ready several safety issues at the current facility was discussed. The problem being that the door into the paddock could open both ways and had horizontal bars blocking for a quick exit in case of emergency. A second issue was the electrical fence sat right at the entrance to the outdoor enclosure where Tam has created a wallow. In case Tam slips in the mud from the wallow he might accidently fall into the electrical fence. The full list of suggestion composed by Michael Ernst and the author is found in annex VIII.

The author was very kindly invited to TWR by the SWD officer in charge of TWR Mr. Rashid Saburi and was on several occasions with the SWD on nightly anti-poaching patrol – though this work was strictly as an observer.

Abstract: Population viability analysis is a tool of alternative logical and repeatable evaluations for communicating alternate management plans to others so they can be persuaded to endorse or admen currently existing plans. Create specifically for simulating scenarios of critically endangered species with a very low population this analysis is the first of its kind for the Bornean population of Sumatran Rhino. The data and knowledge used in this simulation has been gathered from key figures within Sumatran Rhino conservation on Borneo, a previous population viability analysis of the Javan Rhino and publicly available information on Sumatran Rhinos. The hypothesis is that the current two populations have become to small to the next century due to inbreeding, a skewed sex ratio, animals that rarely or never meet and occasional poaching.

The results of the analysis revealed that with the current known population size of Sumatran Rhinos on Borneo the probability of survival is low on a 100-year time scale if no actions are taken. If a successful breeding programme results in supplementation of just one female every sixth year the probability of survival is significantly higher and the simulation results indicates a good probability of the population to increase. Careful considerations about genetic management must be taken into account as well for the long-term survival of the Sumatran Rhino on Borneo.

6. Introduction to Population Viability Analysis:

This population viability analysis has been created with the software Vortex produced by Bob Lacy from the Chicago Zoological Society in 2001.

The software has been tested and used by organisations such as IUCN, several universities including the authors own for as a scientific tool for research for many years and works as guidelines in a decision making process regarding conservation matters. The AsRSG created a population viability analysis in 1996 for the Sumatran Rhino on Sumatra that indicated unless strict measure where taken the populations on Sumatra could be extinct by 2020 (WWF International). The entire analysis is not available and was therefore regrettably not used as background knowledge in this analysis. The latest 9.99 version was used in this study.

The analysis has been based on intimate knowledge from publications, conversations with key figures within Sumatran Rhino conservation and a previous population viability analysis of the Javan Rhinoceros by Rafferty (2008).

As stated in the AsRSG report from 2009 very little is known about the growth rates of Sumatran Rhinos and several assumptions have been made due to lack of scientific research on these secretive animals (Talukdar 2009). The AsRSG aims at a 3% annual growth rate for the Indonesian populations and no more can be expected from the populations on Borneo. The low numbers in Borneo gives concern that the fecundity is affected by inbreeding (Talukdar 2009).

Several sensitivity tests have been made to assess the significance of the different parameters used in the simulation. A scenario where individuals are supplemented to the populations was create to simulate the product of the upcoming breeding programme and asses the effects on probability of survival for the population of Sumatran Rhinos on Borneo.

6.1. Simulation input:

Two scenarios have been created on the background that these locations are protected areas, the final strongholds of the Sumatran Rhinos in Sabah and have registered births within the last five years. At least 3 individuals, possibly 7 (Talukdar 2009), occur outside these areas but they are not included in the analysis as they are currently not contributing to the survival of the total population and are not considered as viable long term.

Several simulation inputs are identical for both scenarios and all are listed in annex IX. Inputs based on the population viability analysis of the Javan Rhino by Rafferty (2008) includes the 20% infant mortality and inbreeding depression with a high and conservative lethal equivalent of 5. Ralls et al. (1988) estimated the lethal equivalents in mammals and found that they ranges from 1,4 to 30,3 with a mean of 4,6 and median of 3,1, a sensitivity test of lethal equivalent has been created within this range to reveal the effect of inbreeding.

The animals in the simulations are also ticked of as monogamous. Not because the Sumatran Rhinos are proven to be monogamous, but because the program will then not assume that the females will deliberately find a new male to mate with each time. The background knowledge for this choice is not backed up by recent scientific research, but a Danish expedition lead by Dyhrberg and Skafte that set out to catch Sumatran Rhinos in the Riau province on Sumatra in 1959 caught 1 male and 9 females in one area, which deductively leads to the assumption that normally a male would have a home-range that overlaps the home-range of several females, thus for a number of years while the male has dominance in its territory, the females overlapping within it will probably not mate with any other males (Rookmaaker 1998). Also with the low number of individuals the number of males available will limit the possible combination of pairs.

The age of first offspring has been set to 5 years for females and 7 years for males based on the data of the captive juvenile Sumatran Rhinos at Cincinatti Zoo & Botanical Garden (Anonymos[2] 2009). As the gestation period has been recorded to be approximately 476 days and the fact that the young is not weaned before the age of 2-3, 20% of females in the population have been set to breed annually, as a mean of an precautionary conservative approach rather than an optimistic approach (Roth 2010). Even so the birth frequency of a female in a wild population of Sumatran Rhinos has never been studied and it is theoretically possible that they give birth more frequently than every 3rd year under good natural conditions as the two other Asian Rhino species does (IRF). Groves and Kurt (1972) also reported that females with offspring of different age groups had been observed.

The Vortex program also allows for a catastrophe to occur. In this simulation poaching is designated as a harvest of 1 female at a 10-year interval. In the past females have been poached more often than males. The reason is not clear, but it is believed that they are easier to locate due to their smaller home-range (pers. comm. Dr. John Payne).

6.2. Scenario “Tabin 10”.

The first scenario created is called “Tabin 10” and is simulates the situation in TWR, where there are currently 10 individual Rhinos identified (pers. comm. Mr. Markarius John). The potential carrying capacity for TWR has been calculated to 120 individuals and has been set as the maximum carrying capacity in the "Tabin 10" scenario with standard deviation of 5% (Foose & Strien 1997). There is no information on the sex of the 10 Rhinos, but there are concerns that the proportion of males is much higher than found in the past on Sumatra and Peninsula Malaysia. The reason for this concern is based on the capture of "isolated doomed" Sumatran Rhinos in the 1980's and 1990's, where only two of ten animals where females and the rest males (Bosi 1996). As these past captures was within the vicinity of TWR the proportion of males in TWR has been set to 60% even though the actual sex-ratio could theoretically be completely different.

6.3. Scenario "Danum 15".

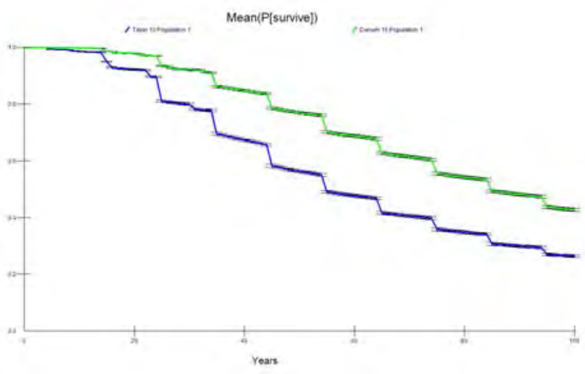
The second scenario is called "Danum 15" and is simulating the situation in DVCA, a 438 km^2 protected area within the Sabah Foundation 100-year logging concession. A survey in 2007 identified 15 adult Sumatran Rhinos within DVCA; however there have been records of 2 births in the last 3 years (WWF-Malaysia press release). These births have not been included in the simulation as their current status is unknown. The proportion of males has been set to 40%. The only scientific background for this is that so far have 3 of 4 camera trapped animals been different females, which deductively leads to the assumption that there are fewer males. But again the true composition of population remains unknown. The potential carrying capacity in the "Danum 15" has been estimated to 80 individuals with a 5% standard deviation (Foose & Strien 1997).

In both scenarios the age distribution in both sexes has been set to random, as there is no available data on the age of the animals nor birth sex-ratio, which has been set to 50/50. The programme also incorporates the maximum age as the maximum reproductive age of 35 years. Every simulation has been set to the maximum 10.000 iterations.

7. Simulation results:

This population viability analysis included far more simulations and sensitivity tests then presented in this chapter - but after considerations these results where not considered as important as the ones presented in this project to reveal the overall tendency and most usable arguments for a decision making process. All other simulations and sensitivity test have been listed with comments in annex X.

7.1. Initial simulation – no action taken.

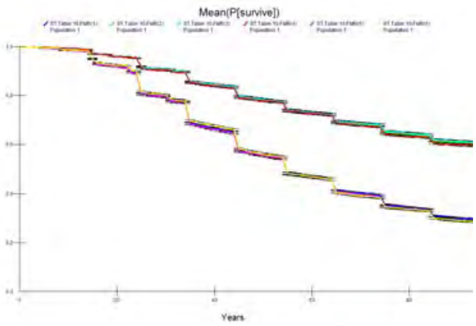


Graph 1. The initial result of the simulation. Years (X) against probability of survival (Y).

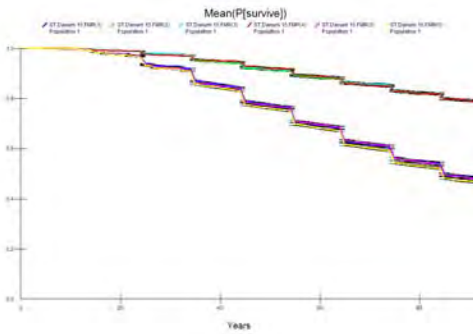
The results of the first simulation (graph 1) where no actions are taking and the occasional poaching of one female individual per 10 year. The probability of survival for the Sumatran Rhinos in the next 100 year is 30% for TWR (blue) and 43% for DVCA (green).

7.2. Sensitivity test on infant mortality rates.

A sensitivity test on the infant mortality rates for TWR (graph 2) and DVCA (graph 3) was conducted and revealed no significant difference between the probability of survival of ~60% and ~30% for TWR when mortality rates are 5, 10 and 15% in contrast to 20, 25 and 30%. The results of the sensitivity test of infant mortality reveals that the population in DVCA (graph 3) will have a significantly higher probability of survival of ~80% and ~50% when mortality rates are 5, 10 and 15% in contrast to 20, 25 and 30%. There is no data available on infant mortality rates for Sumatran Rhinos and therefore it is difficult to create an analysis of good quality before further research has revealed the true mortality rate and thereby a corrected population viability analysis could be created that might differ from the initial result presented in graph 1.



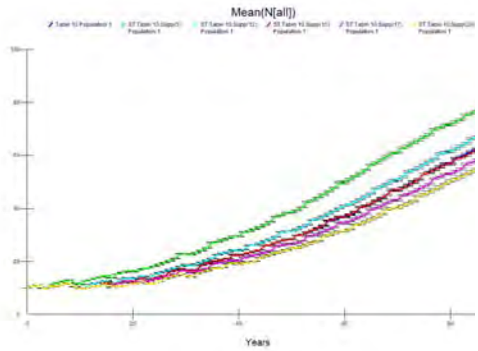
Graph 2. Result of sensitivity test on infant mortality rates for females in TWR. Years (X) against probability of survival (Y).



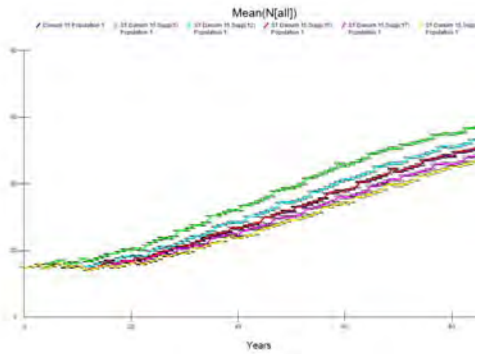
Graph 3. Result of sensitivity test on infant mortality rates for females in DVCA. Years (X) against probability of survival (Y).

7.3. Sensitivity test of supplementation.

This sensitivity test was created to simulate and analyse the effect of the BRS breeding and releasing females into the wild populations and thus supplementing it. The results are presented as the population development in numbers against a 100-year time scale. For "Tabin 10 population 1" (graph 4) supplementation start from year 10 following every 6th year. For the remaining graphs 1st year of supplementation is indicated by the number in (#). The results show that even with the first supplementation starting 20 years from now the populations in both TWR (graph 4) and DVCA (graph 5) will recover.



Graph 4. Result of the sensitivity test for TWR where one female is added as product of the upcoming breeding programme and with continued poaching of 1 female every 10 years. Years (X) against number of individuals (Y).



Graph 5. Result of the sensitivity test for DVCA where one female is added as product of the upcoming breeding programme and with continued poaching of 1 female every 10 years. Years (X) against number of individuals (Y).

8. Discussion:

In this simulation much of the biology of the Sumatran Rhino is simply not known to science and a lot of scientific research on this species is still needed to understand their biology and thus design appropriate guidelines for their conservation. Because of this lack in science a lot of the input becomes "guestimations" rather than a qualified guesses. Even so a trend is visible. Judging from the current data available and with poaching still occurring a continued decline seems inevitable, however the probability of survival varies significantly within each of the sensitivity tests.

One element in the simulation that should not be left out at any time and is the threat of poaching. With a 15-year high surge in Rhino poaching worldwide in 2009 it would be decadent to leave it out of the simulations as a real threat to the Bornean population of Sumatran Rhinos (BBC website). Unfortunately a "glitch" occurred in the Vortex programme making the catastrophe occurrence unusable. If a catastrophe was implemented in the simulations the populations would do better if poaching occurred than if did not. Even with the help of Dr. David Richard Nash who is familiar with this programme could this "glitch" be corrected. Therefore it was decided to add poaching to the simulation as a harvest.

Taking the results from the top the infant mortality rates are highly debatable. With only 3 captive births in the last century, all of them without infant death it is a matter of theoretical speculations versus common patterns of infant mortality in other species of Rhinos. It can be questioned if the used reproductive rates are correct. Groves and Kurt (1972) wrote that females with two calves of different ages have been observed, which would indicate a reproduction more frequent than every third year as seen with the two other Asian Rhino species.

Another point to the case of the Sumatran Rhinos on Borneo is that there are no natural threats in the form of predators as Sumatran Tiger (*Panthera tigris sumatrensis*) which infant Rhinos could fall prey to. Neither is there much competition as Malay Tapirs, Gaurs (*Bos gaurus*) or other species of Rhino does not exists on Borneo - and with the small number of Rhinos on Borneo intra-specific competition will also presumably be low. Therefore infant mortality rates might be lower than 20% assumed by Rafferty (2007). It is worth noting that there is no significant difference between the probability of survival (~60% for TWR and ~75% for DVCA) when the mortality rates are 5, 10 and 15% - nor is there any significant difference in the probability of survival (~30% for TWR and ~40% for DVCA) when the mortality rates are 20, 25 and 30%. One way of lowering the infant mortality rates directly is by removing all snares made by poacher, which is a direct threat to both adult but especially young Sumatran Rhinos as they to not have the strength to break of the snares as seen done by both Tam and Puntong. Mortality rates might also depend on the severity of inbreeding. This leads to the results of the sensitivity test on the lethal equivalents as a parameter on the level of inbreeding. The results of this sensitivity test are based on pure speculations. The have been no research what so ever on the magnitude of inbreeding in Sumatran Rhinos neither on Borneo nor on Sumatra – the result have therefore been listed in annex X as they cannot be considered anything more than speculations. In both scenarios an increased level of the lethal equivalent

results in lowered probabilities of survival long term.
Even though the sensitivity test is speculations, the concerns of inbreeding are real as mentioned by Talukdar (2009). Exchanging animals between Sumatra and Borneo would be a way of avoiding inbreeding, but the findings of distinct synapmorphic genetic markers in the mtDNA in the research by Morales et al. (1997) and the fact that the Bornean subspecies are no average 17,5% lighter than the Sumatran subspecies might lead to an outbreeding depression or even partially genetic incompatibility resulting in infertile offspring. The study by Zschokke and Baur (2002) revealed partially genetic incompatibility in captive breed Greater One-Horned Rhinos from two different populations that have only been separated since the beginning of the twentieth century. Having undergone severe inbreeding depression they have purged deleterious alleles through bottlenecking and today breeding individuals from the two populations result in higher infant mortality than seen in inbreed infants. With the population on Borneo having been isolated geographically for at least 30.000 years and the intensive hunting during the last century the possibility of the Bornean subspecies has undergone inbreeding, several bottlenecks and purging of deleterious alleles is very likely. The fact that they where all ready scares in numbers by the time Tom Harrisson worked with them in the 1960's (Groves 1965) and Payne (1990) estimated their numbers to be below 50 in the 1980's but with the current population still breeding today the theory that the Rhinos on Borneo have been purged could be supported.
An indicator of a passed inbreeding depression and bottleneck could be their decrease body size – but a serious studies of the genome of the Sumatran Rhinos both on Borneo and Sumatra is needed to determine the level of inbreeding and the differences between the Bornean and Sumatran animals. A founder effect could also be possible with the low number of individuals being recorded in the last 50 years, which in terms could lead to speciation and the possibility that the Bornean Rhinos in reality is a species on its own species rather than a subspecies. On this note Groves et al. (2010) made a re-assessment of the two subspecies of White Rhinos, Northern White Rhino (*Ceratotherium simum cottoni*) and Southern White Rhino (*Ceratotherium simum simum*) in Africa and found that difference in dental morphology, cranial anatomy and in nuclear and mitochondrial DNA was so significant that they were recognized as two distinct species: The Northern White Rhino (*Ceratotherium cottoni*) and the Southern White Rhino (*Ceratotherium simum*).
Finally the results of the sensitivity test where a female Rhino is released every 6th year, but with difference in the year of the first release all showed a high probability of survival for both populations on a 100-year timeframe but more interestingly both populations increase in numbers after the first release but with a flattening tendency towards the end of the timeframe where the populations have grown towards the carrying capacity. This result is in contrast to the other simulations that indicate a decline in probability of survival regardless of changes in parameters. The fact that supplementing the populations with just 1 female every 6th year underlines the effects of captive breeding efforts. Strict protection and careful managed captive breeding effort has lead to remarkable recoveries for the Black, White and Greater One-Horned Rhino.

The Southern White Rhino was reduced to no more than 20 individual by the turn of the nineteenth century but in 2007 the estimated number was 17.480 and increasing (IUCN Red List website; Emslie et al. 2009; Rookmaaker 2000). Only 200 Greater One-Horned Rhino was left in the year 1900 but due to strict protection from wildlife authorities and breeding programs the number today is around 2.850 individuals (Emslie et al. 2009; IRF website). The Black Rhino population was reduced by 96% between 1970 and 1993 from 65.000 to 2.300 individuals. Since 1996 the Black Rhino has been recovering and nearly doubled its population in just 12 years to 4.240 individuals in 2008 (Emslie et al. 2009; IRF website). However while the recovery of the Black, White and Greater One-Horned Rhinos are real, the results of this population viability analysis for the recovery for the Sumatran Rhino on Borneo is still only a simulation and should not be regarded as more than a guideline.

The current plan for the BRS is to start with 2 animals (Tam and Puntong), but with the options to expand and increase the number of animals (pers. comm. Dr. Abdul Hamid Ahmad; Dr. John Payne). If the breeding programme is successful but not expanded all animals released will be of the same genetic profile originating from one sire and one dam, and the risk of genetic drift in the wild population will rise. Therefore it will be crucial to capture the remaining isolated animals in Sabah and add them to the breeding programme and manage it carefully so as much genetic diversity will be supplemented to the wild population and lower the risk off inbreeding and genetic drift. For the same reason it would be worth considering an exchange of animals between TWR and DVCA every 10th year or so as another method to reduce the risk of inbreeding and genetic drift. It is worth empathising that the population of Sumatran Rhinos in DVCA in every scenario have higher probabilities of survival than TWR and for that reason it would be worth considering intensifying the RPU patrolling in DVCA and possibly setting up a permanent RPU with its base in DVCA as it has been done in Peninsula Malaysia, Sumatra and TWR. However how the AsRSG has calculated the carrying capacity for DVCA to 80 animals in a protected area of only 438km^2 is a bit of a riddle. A quick calculation reveals that DVCA with a population at it carrying capacity of 80 would have 1 individual per 5,5km^2, while TWR is almost 3 times the size of DVCA but the carrying capacity has been estimated only to be a third more (K=120). This mean that TWR with a population at its carrying capacity would have 1 individual per 10km^2 – much closer to what is the reported to be the home-range size of a female Sumatran Rhino (Van Strien 1986). As TWR and DVCA are two different habitat types further research into what the home-range sizes are in these two areas will be needed if the Sumatran Rhino starts to recover. One obvious way of conducting this research would be by trapping Sumatran Rhinos in TWR and DVCA and fit them with satellite tracking collars, it will however all ways be controversial to capture critically endangered species and if something went wrong it would be very hard to excuse. Having said that, the researcher from WWF-Malaysia and SWD has had good experience with satellite tracking Bornean Pygmy Elephants (Alfred et al. 2007)

If the population of Sumatran Rhinos on Borneo increase in the future it can be suspected that poaching will increase as well. Hopefully the

presence of the RPU will deter poachers if the upcoming enforcement of the wildlife law with high penalties does not. It should be considered to use the knowledge of poachers apprehended or former poachers as source of information on the methods they use for hunting and possible buyers of Rhino horns. Their knowledge could very well result in more efficient protection of the Sumatran Rhino.
The validity of the data used in the analysis can be set into question. As Dr. John Payne explained, the main focus of the RPU in TWR is to deter poaching activities and secondly note all signs of Sumatran Rhinos. When the RPU are on patrol the pace is high and Rhino signs could easily be overlooked, also the RPU tends to walk the same trails and this makes the recordings of Rhinos bias as an animal would have had to cross the path of the RPU and leave signs to be registered. Therefore the number of Sumatran Rhinos in TWR could be higher. Dr. John Payne, Dr. Zainal Zahari Zainuddin and the author experience first hand how a single days rainfall can erase footprints that where clear and fresh just days before. Another issue in estimating the number of Sumatran Rhinos is the quality of the surveys conducted. Normally survey consists of a large number of teams trotting through the jungle at the same time from various directions, but the people involved in such a grand operation do not necessarily have the skill and experience needed to conduct an efficient survey.
A new action plan for the conservation of Sumatran Rhinos is currently being finish by the SWD, WWF and BORA.

9. Conclusion:

In a world where instant success is demanded working with Sumatran Rhinos is one of the most difficult tasks to obtain success with. Very few if any other critically endangered species has witnessed such devastating failures as the captive breeding programmes of Sumatran Rhinos. Being browsers the animals are hard to care for in regards to food plants needed, but monitoring females for oestrus, finding fertile males, paring a couple at the right time to avoid injuries and ensuring that a pregnancy is not lost has been a major challenge with a steep learning curve and high costs. Never the less the future is looking brighter with the information flowing freely between all parties involved in *ex situ* conservation of the Sumatran Rhinos. However education of staff is essential for success, but with the exchange programme being settled with Leipzig Zoo there is reason for optimism.
The RPU’s in all of Southeast Asia must be underlined as *the* most important measure for *in situ* conservation, without them the future of Sumatran Rhinos is looking bleak. Poaching is and will probably be for many years to come the largest threat to the survival of the Sumatran Rhino. Long-term however the loss of habitat will be just as great a threat and a concern of inbreeding has to be taken into account when making management plans. However the recovery of the White, Black and Greater One-Horned Rhino who in the past was as much on the edge of extinction as the Sumatran Rhino is currently gives hope and proof that saving this species from extinction is possible. It will require many years of hard work but judging from past knowledge and with the results of this population viability analysis as a

guideline there is a potential chance for the Sumatran Rhino on Borneo to recover. But actions will have to be made soon as this is the absolutely final call for Rhinos of Borneo.

The recommendations for the future management within Sumatran Rhino conservation on Borneo would be:

A) Continue and enhance the RPU's with increasing efforts in protecting the Rhinos in DVCA. Possibly establishing a permanent RPU based in DVCA.
B) Capture the isolated individuals as soon as possible and include them in the BRS breeding programme.
C) Education of RPU and paddock staff to improve the chances of success in protection and breeding programme.
D) Expansion of the breeding programme to several males and females from both DVCA and TWR to maximise the genetic diversity and lower the odds of genetic drift by releasing individuals with different genetic background.
E) Continue and expand the public awareness programme and create political debates to gain further support and enforce legislation on encroachment and poaching.
F) Study of the genetics of Sumatran Rhinos from Borneo and Sumatra to evaluate conservation units and reveal if the Bornean subspecies should be considered its own species – thus re-evaluating the conservation status and priority.
G) Identify additional Rhino habitat in Sabah, possibly also in Sarawak and Kalimantan.

One can only conclude so much with the amount of knowledge available – however one thing is certain, the continued existence of a heritage species as the Sumatran Rhinos on Borneo will require a great deal of hard work and management in many years to come.

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Persons cited and supplied unpublished data:

Project Manager of Borneo Species programme: **Dr. Raymond Alfred.**
Tel. +6088262420 ext 30
Mobile private: +60138866277
Email: ralfred@wwf.org.my
Email private: raymond_alfred@yahoo.com

Senior Programme Officer (Rhinoceros Conservation Project): **Dr. Marshal Mathews Chuat** (D.V.M.)
Tel. +6088262420 ext 46
Mobile private: +60198977754
Email: MChuat@wwf.org.my
Email private: mcc_vet@yahoo.com

Executive Director of Borneo Rhino Alliance: **Dr. Scient. John Payne.**
Tel. +6088488080
Mobile private: +60198602040
Email private: jpayne@pd.jaring.my

Chief Vetenarian of BORA: **Dr. Vet. Med. Zainal Zahari Zainuddin.**
Mobile private: +60183532325
Email private: zzainalzahari@yahoo.com

IZW manager of Sabah Rhino Project: **Dr. Vet. Med. Petra Kretzchmar.**
Email private: petra.kretzschmar@gmx.de

Dr. Carl Træholt
Private email: ctraeholt@pd.jaring.my

MSc. Silv. Palle Havmøller
Private email: palle_havmoller@yahoo.com

BORA Field Manager **Mr. Markarius John**
Mobile private. +60198078541

BORA Chief Paddock **Mr. Alvin Erut**
Mobile private. +60198639902

WWF-Malaysia RPU **Mr. Edward Addjuhe**
Private email: add_juhe@yahoo.com.my

WWF-Malaysia RPU Team Leader **Mr. Patrick Jonnes Sading.**
Please refer to **Dr. Marshal Mathews Chuat.**

Sabah Wildlife Officer in charge of Tabin Wildlife Reserve **MSc. Scient. Rashid Saburi.**
Mobile private: +60138560657

Head Zoo-keeper Leipzig Zoo **Mr. Michael Ernst.**
Mobile: +491605327153
Email: mernst@zoo-leipzig.de

Annex I

Name	Weight (kg)	Age	Sub. Species
Torgamba	718	28	*sumatrensis*
Bina	726	25+	*sumatrensis*
Ratu	546	7	*sumatrensis*
Rosa	606	6	*sumatrensis*
Andalas	757	7	*sumatrensis*
Emi	710	18†	*sumatrensis*
Suci	702	4.5	*sumatrensis*
Ipuh	716	30+	*sumatrensis*
Harapan		1.5	*sumatrensis*
Total	5481		
Average weight	685.125		
Tam	611	18+	*harrissoni*
Tanjung	541	†	*harrissoni*
Gelogob	544	28	*harrissoni*
Teneggang	650	†	*harrissoni*
Lun Parai	575	†	*harrissoni*
Sidom	540	†	*harrissoni*
Malbumi	492	†	*harrissoni*
Takala	571	†	*harrissoni*
Total	4524		
Average weight (kg)	565.5		
Average weight (kg) diff.	119.625	-17.46031746	

Mann-Whitney U-test   0-hypothesis: no difference

Sample 1	718	726	546	606	757	710	702	716								
Sample 2	611	541	544	650	575	540	492	571								
Observations	492	540	541	544	546	571	575	606	611	650	702	710	716	718	726	757
Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Value of underlined (R1)	94
Value of not underlined (R2)	42
U1	58
U2	6
U1+U2=n1n2	64
Appendix 6 8x8	13

0-hypothesis rejected - there is a significant difference

Annex II
Info plate at Lok Kawi Wildlife Park.

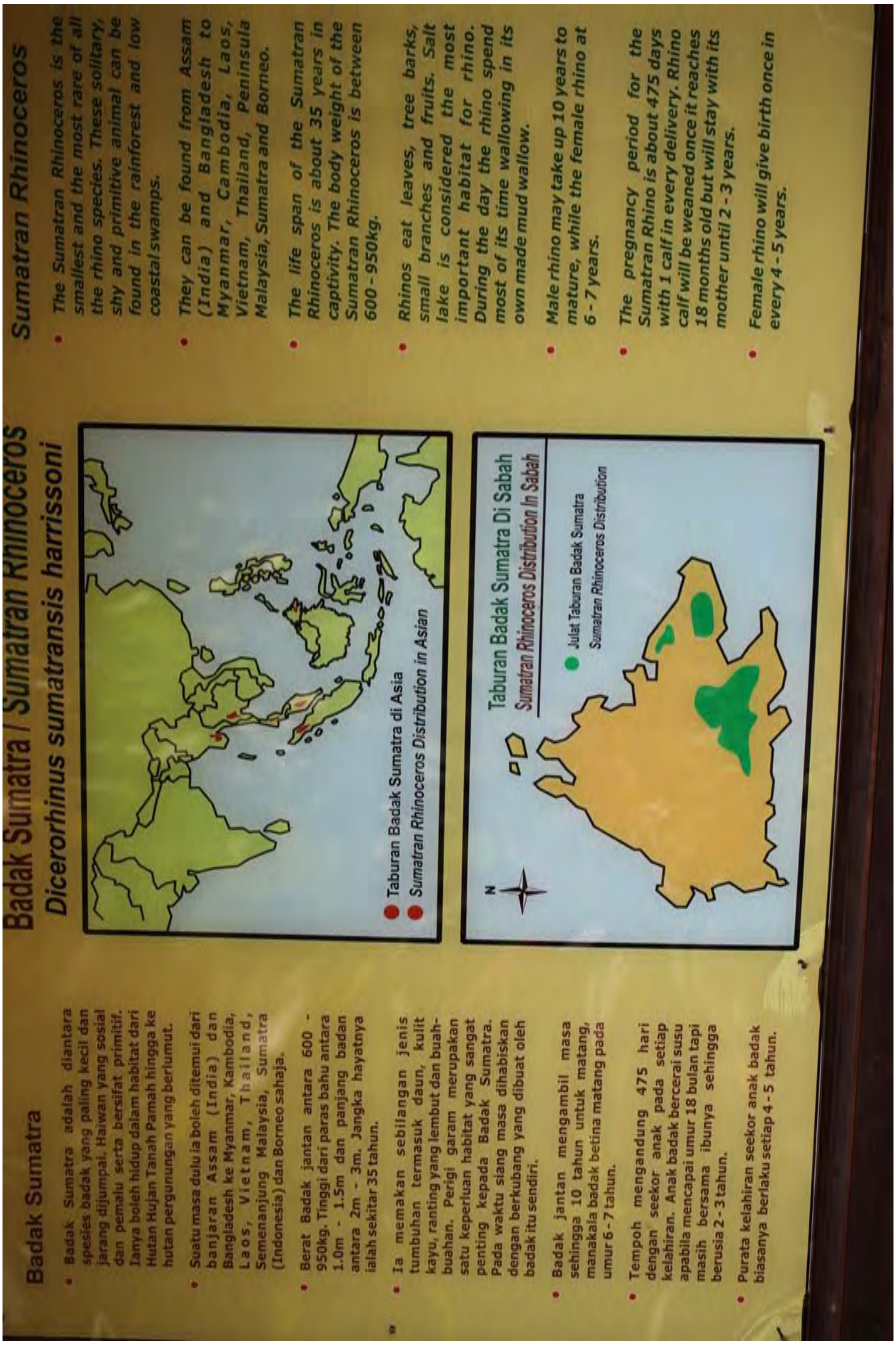


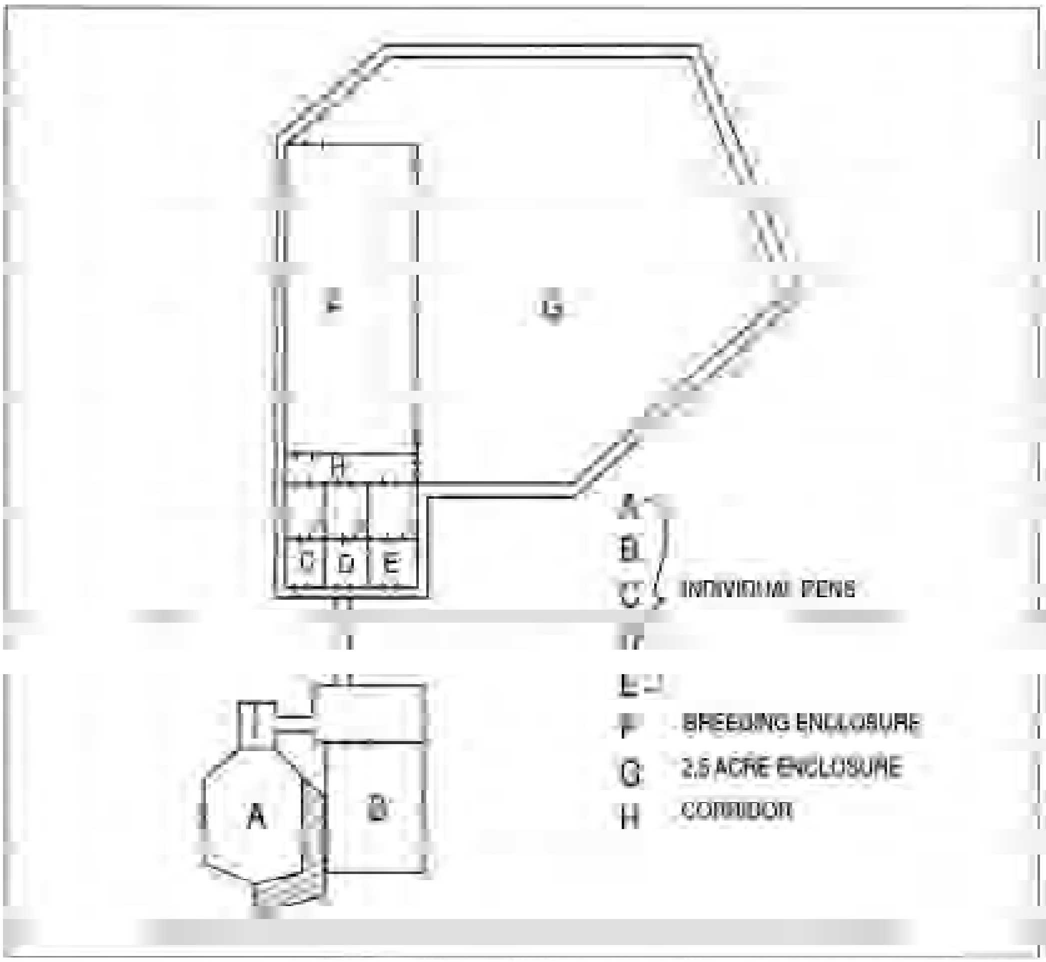
Photo by RGH

Annex III

List of Sumatran Rhino food plants.

Family	Species
Euphorbiaceae	*Mallotus wrayi*
	Mallotu sp
	Koilodepas cf. *longifolium*
	Koilodepas sp.
	Macaranga sp
	Macaranga beccariana
	Blumeodendron sp.
Dipterocarpaceae	*Shorea*
Ebenaceae	*Diospyros* sp.
Rubiaceae	*Psychotria woodii* Merr.
	Pavetta cf. Axillaris
	Pavetta sp.
	Croton oblongifolius Burm.
	Uncaria cf. borneensis
	Uncaria sp.
	Ixora eliptica
	Piper cf. retrotracum Vahl
	Piper
Lauraceae	*Litsea* sp.
Meliaceae	*Aglaia odoratisima* Bl.
	Kibbesia cf. Kortbalsiana
	Kibbesia sp.
	Memecylon cf. peniculatum Jack
	Memecylon sp.
Apocynaceae	*Kopsia dasyrachis* Ridl.
Annonaceae	*Friesodielsia* sp.
	Popowia tomentosa
Anisophylleaceae	*Anosphyllea* sp.
Styraceae	*Styrax* sp.
Zingiberaceae	*Zingiber* sp.
Myrtaceae	*Eugenia* sp.
	Merrinia sp.*
	*Caloponium mucinoides**

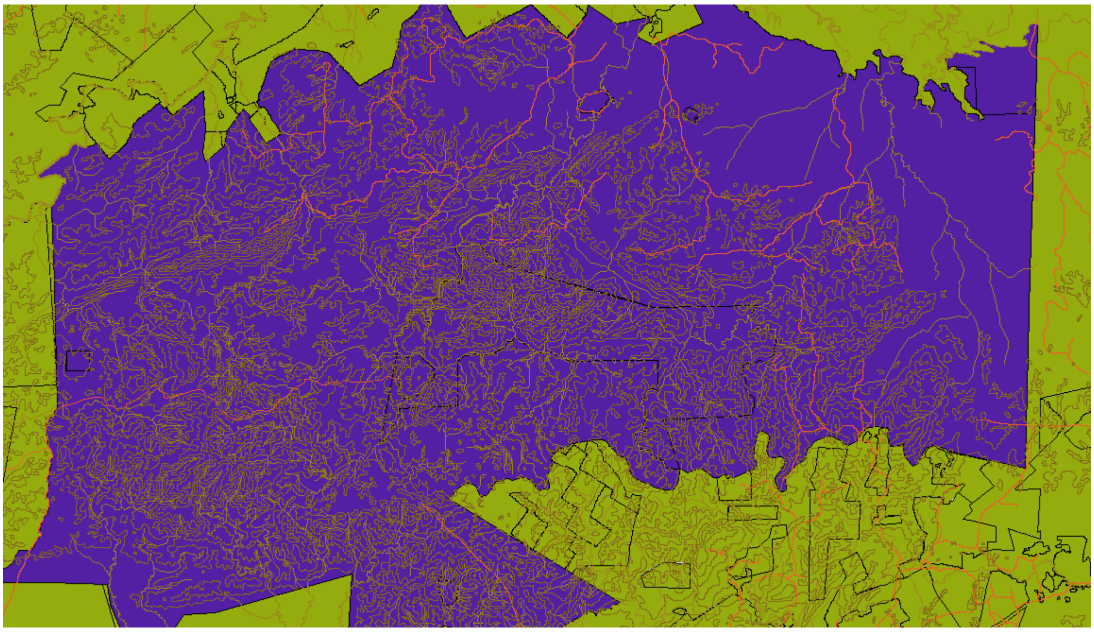
* witnessed by the author and confirmed by Dr. John Payne.



Fiure. A diagram of the rhino stockade at the Rhino Breeding Centre, Sepilok.

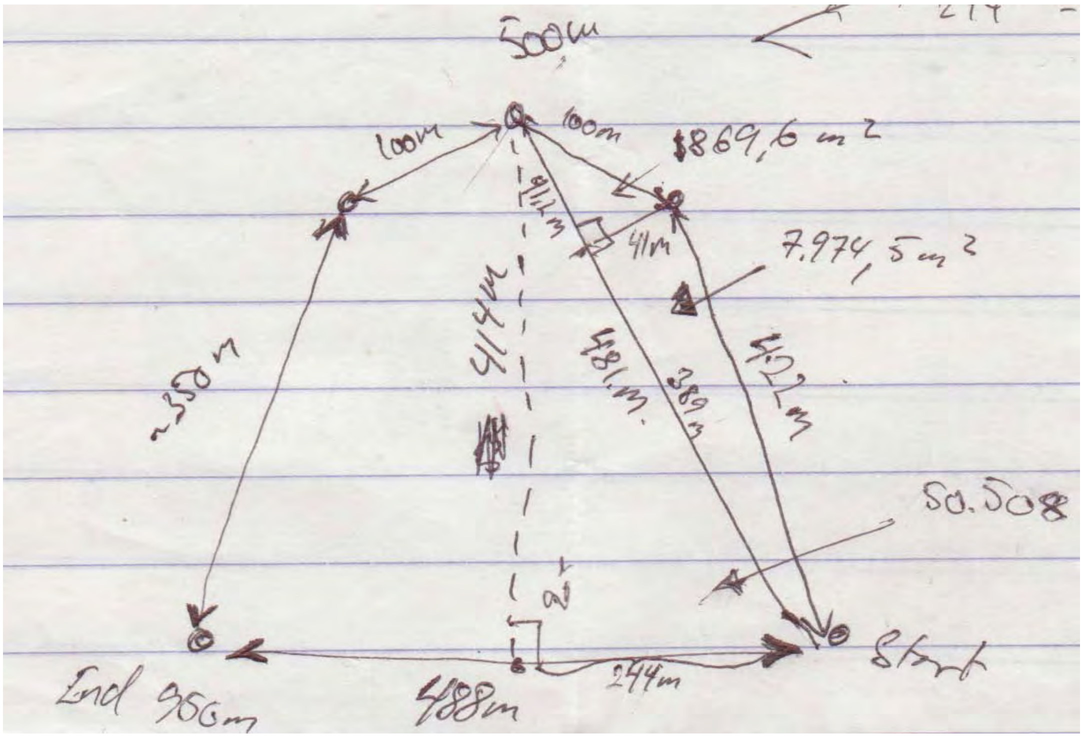
Figure from Bosi (1996).

Annex V



The purple colour indicates Tabin Wildlife Reserve, the light green colour indicates the surrounding plantations. Red stripes indicates roads, terrain is measured in 200ft intervals and waterways are a light yellow colour. Map created with arc soft 3.3 by RGH.

Annex VI



Sketch of BRS

Starting point	N05°12'24.4" - E118°31'11.4"
500m mark	N05°12'37.8" - E118°31'03.5"
Ending point	N05°12'26.0" - E118°30'55.6"

Annex VI
Photos of modified pit-fall trap and boma for trapping Sumatran Rhinos.

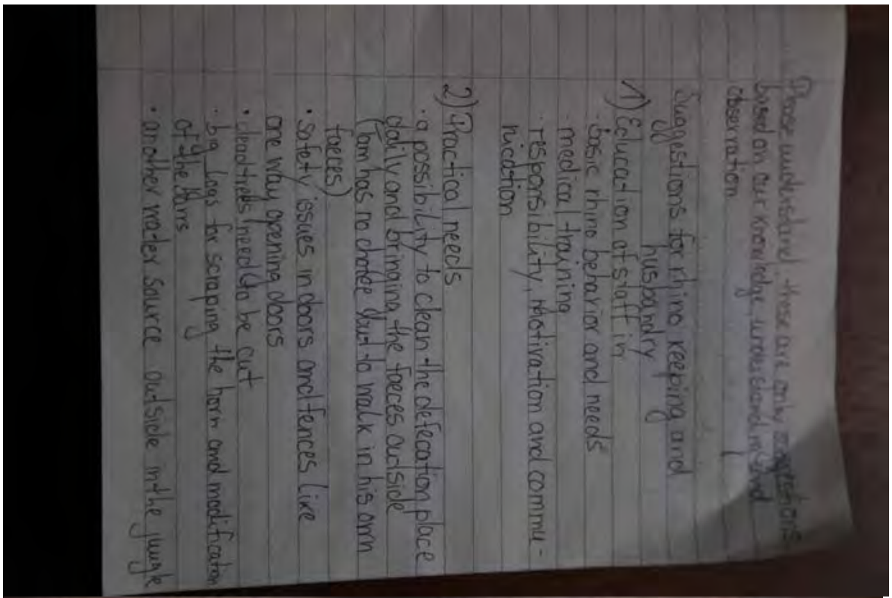
Side view. 7,5 feet long – 8 ft high. The frame in both end consists of three 2x4 in posts. The three posts in the middle are 2x3 in. The bottom post is 2x6.

Front view. Door consists entirely of 1x4 planks.

Front quarter view of trap. The top five posts are removed when the trap is installed.

Rear quarter view of trap with boma attached. The lower part of the posts will be dug into the ground.

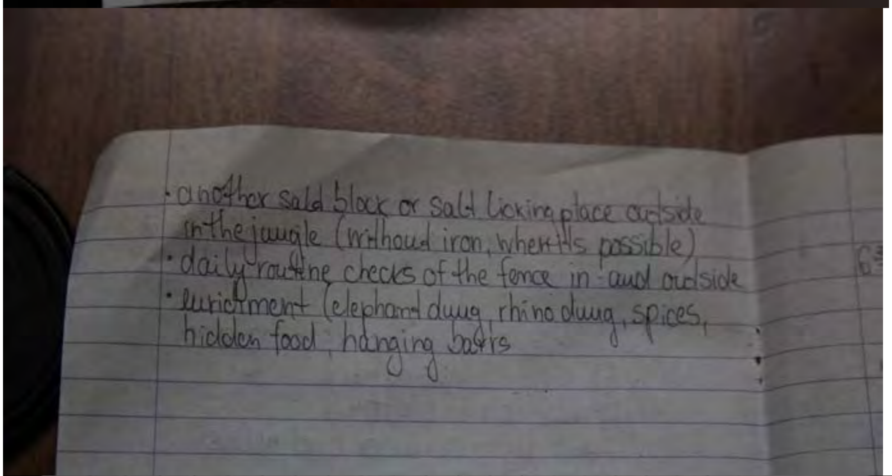
Annex 8
List of suggestions created with chief zookeeper Michael Ernst from Leipzig Zoo, Germany.

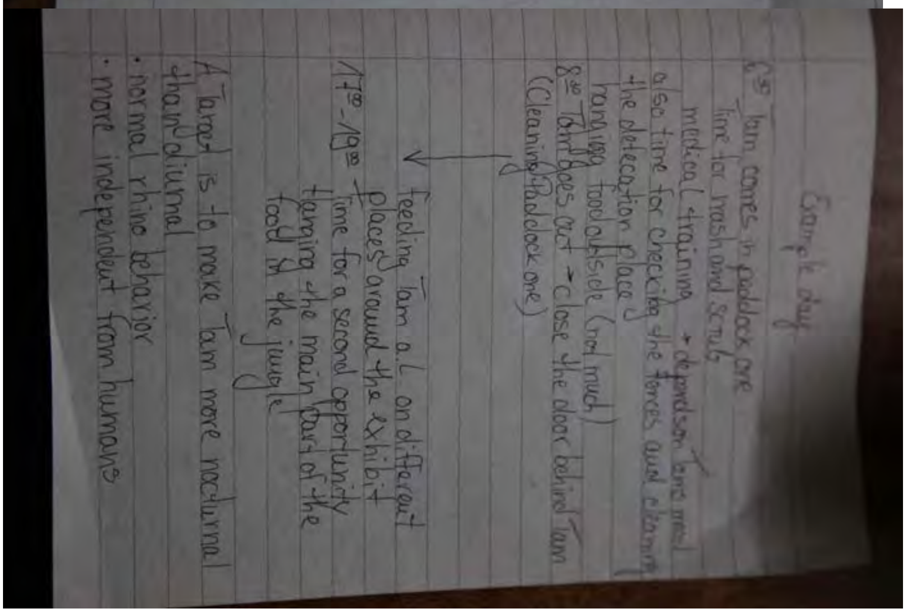

Please understand, these are only suggestions based on our knowledge, [illegible] and observation

Suggestions for rhino keeping and husbandry

1) Education of staff in
- basic rhino behavior and needs
- medical training
- responsibility, motivation and communication

2) Practical needs
- a possibility to clean the defecation place daily and bringing the feces outside (Tam has no chance but to walk in his own feces)
- Safety issues in doors and fences like one way opening doors
- dead trees need to be cut
- big logs for scraping the horn and modification of the doors
- another water source outside in the jungle


- another salt block or salt licking place outside in the jungle (without iron, when it's possible)
- daily routine checks of the fence in- and outside
- enrichment (elephant dung, rhino dung, spices, hidden food, hanging balls


Sample day

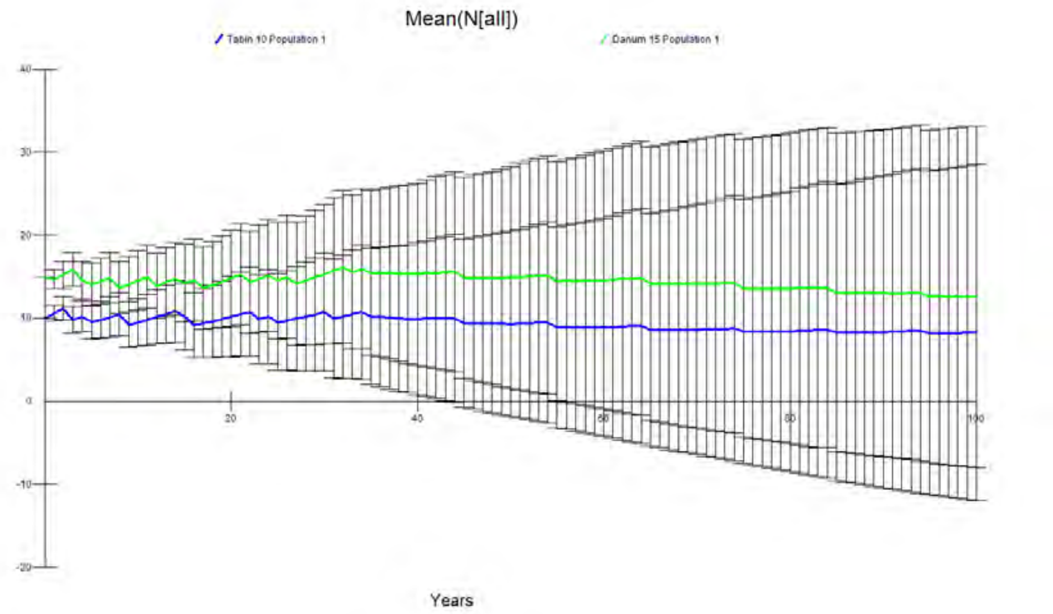
6⁰⁰ Tam comes in paddock one
time for trash and scrub
medical training + dependent Tam's meal
also time for checking the fences and cleaning the defecation place
hanging food outside (not much)
8⁰⁰ Tam goes out → close the door behind Tam
(Cleaning Paddock one)
↓
feeding Tam a.l. on different places around the exhibit
17⁰⁰-19⁰⁰ time for a second opportunity
hanging the main part of the food in the jungle

A target is to make Tam more nocturnal than diurnal
- normal rhino behavior
- more independent from humans

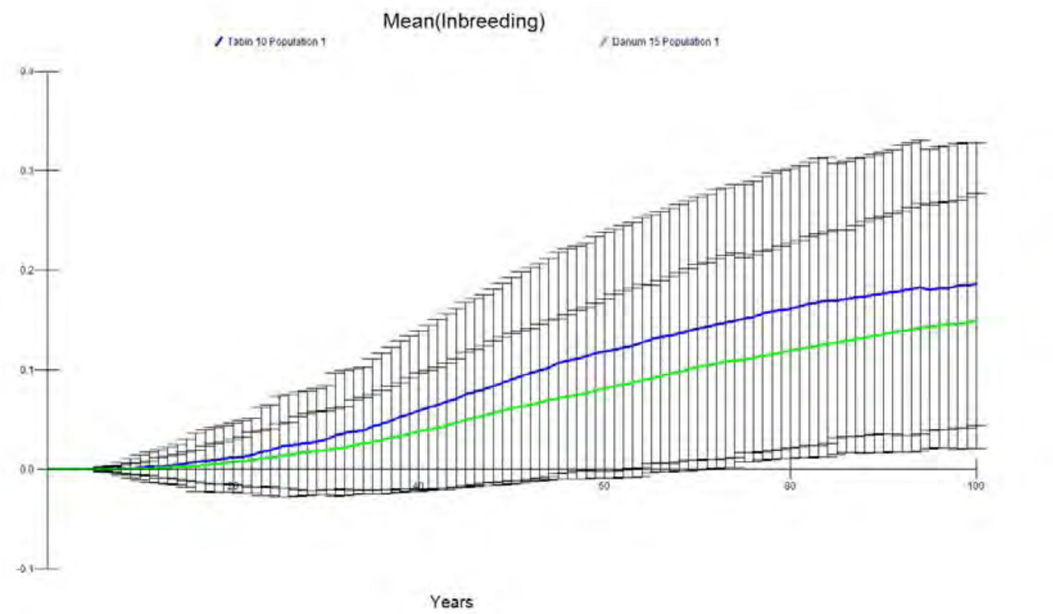
Annex 9

Table name	Setting name	#
Scenario Settings	Iterations	10.000
-	Number of Years	100
Species Description	Inbreeding Depression	Checked
-	Lethal Equivalents	5
-	Percent Due to Recessive Lethal	50
Reproductive System	Monogamous	Checked
-	Age of First Offspring for Females	5
-	Age of First Offspring for Males	7
-	Maximum Age of Reproduction	35
-	Maximum Number of Broods per Year	1
-	Maximum Number of Progeny per Year	1
-	Sex Ratio at Birth – in % Males	50
Reproductive Rates	% Adult Female Breeding	20
-	EV in % Breeding	10
- Distribution of broods per year	0 Broods	75
-	1 Broods	25
- Specify the distribution of number of offspring per female per brood	Specify exact distribution	Checked
Mortality Rates	Mortality of Females as %	-
-	Mortality from age 0 to 1	20
-	SD in 0 to 1 Mortality Due to EV	5
-	Mortality from age 1 to 2	10
-	SD in 1 to 2 Mortality Due to EV	5
-	Mortality from age 2 to 3	10
-	SD in 2 to 3 Mortality Due to EV	5
-	Mortality from age 3 to 4 (and onwards to “Annual Mortality After Age 6”)	5
-	SD Mortality Due to EV from Year 4 to 6	5
-	SD in Mortality After Age 6	2
-	Mortality of Males as %	-
-	Copied from Females	Checked
-	Frequency %	10
-	Reproduction	80
-	Survival	90
Initial Population Size	Specified Age Distribution - random	Checked
Harvest	1 female harvested every 10th year	

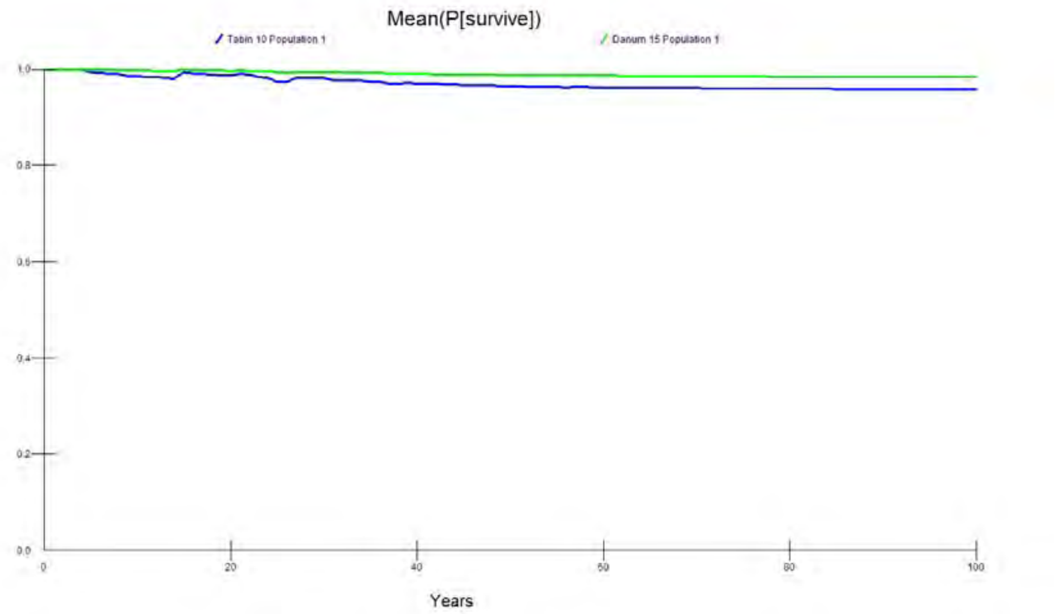
Annex 10



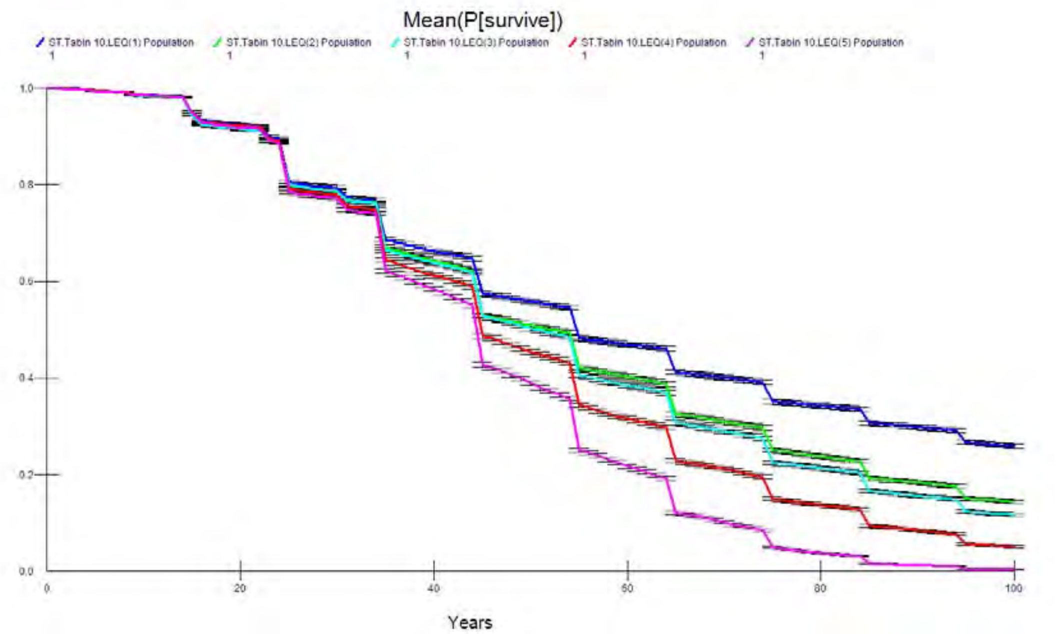
Graph A. Estimated population development for TWR (blue) and DVCA (green) in a simulation where no action is being taken. The bars indicate standard error, which prove that both populations could go extinct between 40 and 50 years.



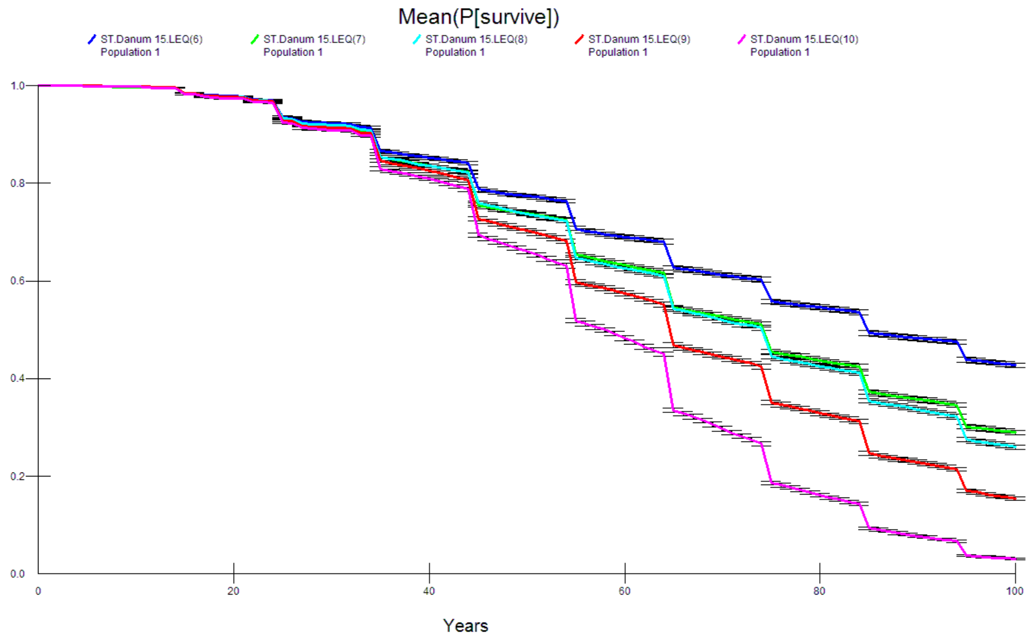
Graph B. This graph is a sensitivity test of the mean inbreeding for the TWR (blue) and DVCA (green) in a simulation where no action is being taken. The increase in inbreeding is dramatic.



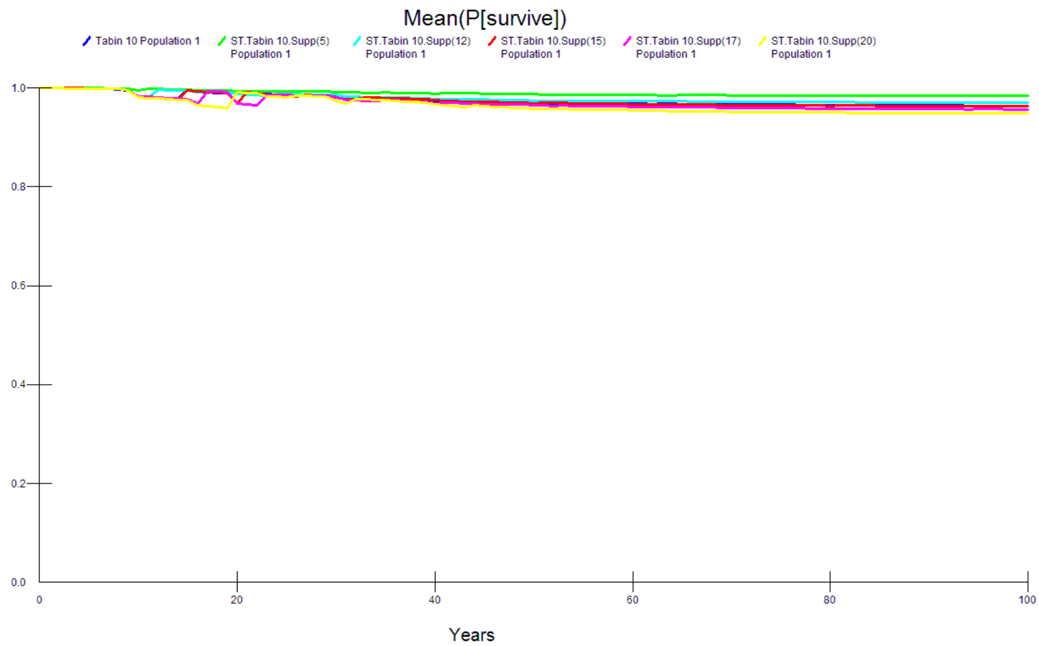
Graph C. This simulation incorporates the supplementation of 1 adult female every 6th year from year 15. A surprisingly high probability of survival for both populations.



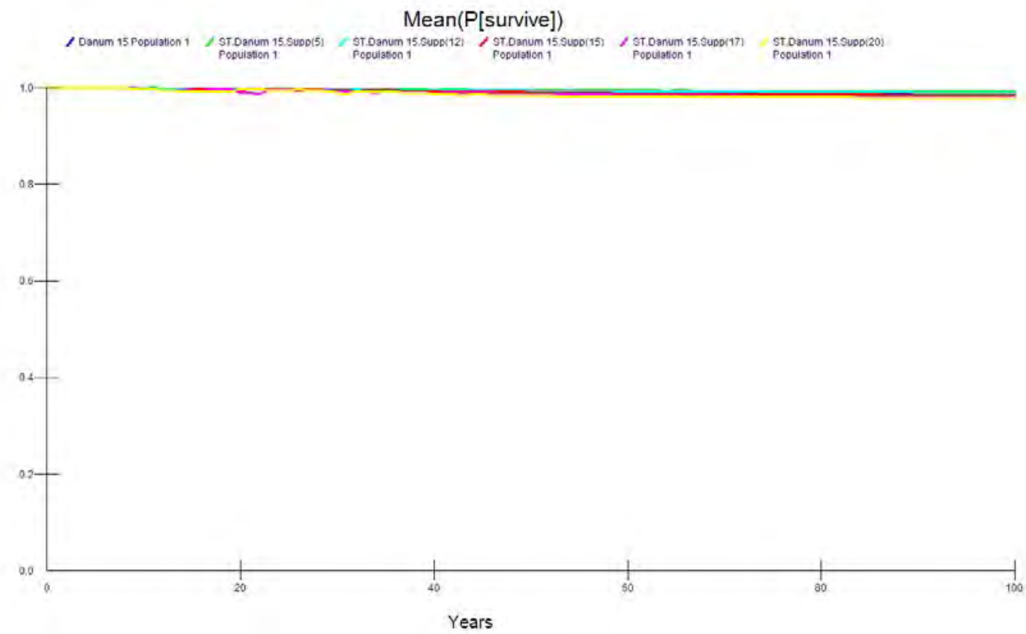
Graph D. Lethal equivalent sensitivity test TWR - no supplement.
STT(1) = 5 (Baseline)
STT(2) = 9
STT(3) = 10
STT(4) = 15
STT(5) = 30



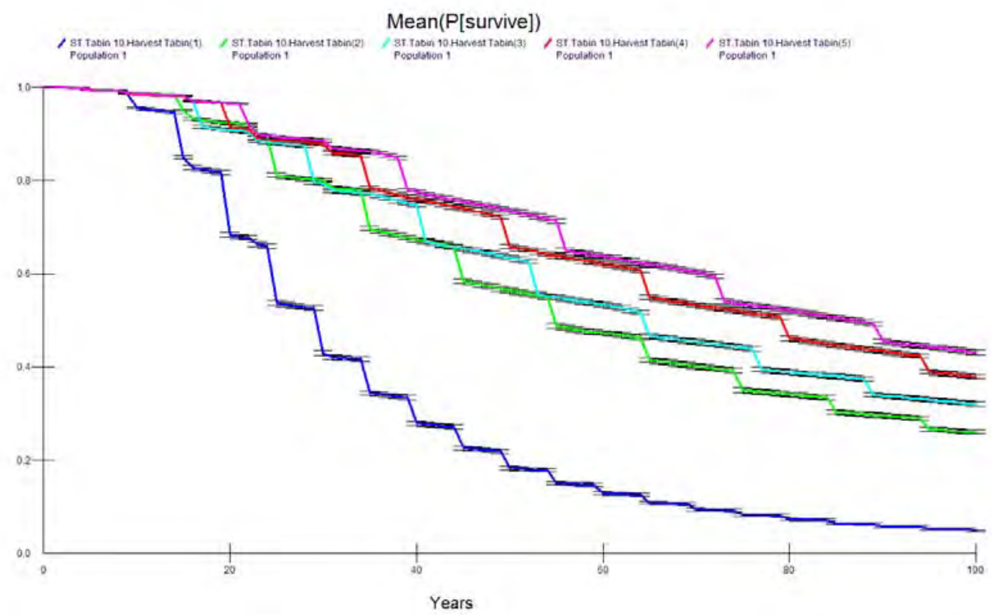
Graph E. Lethal equivalent sensitivity test DVCA - no supplement.
STD(6) = 5 (Baseline)
STD(7) = 9
STD(8) = 10
STD(9) = 15
STD(10) = 30



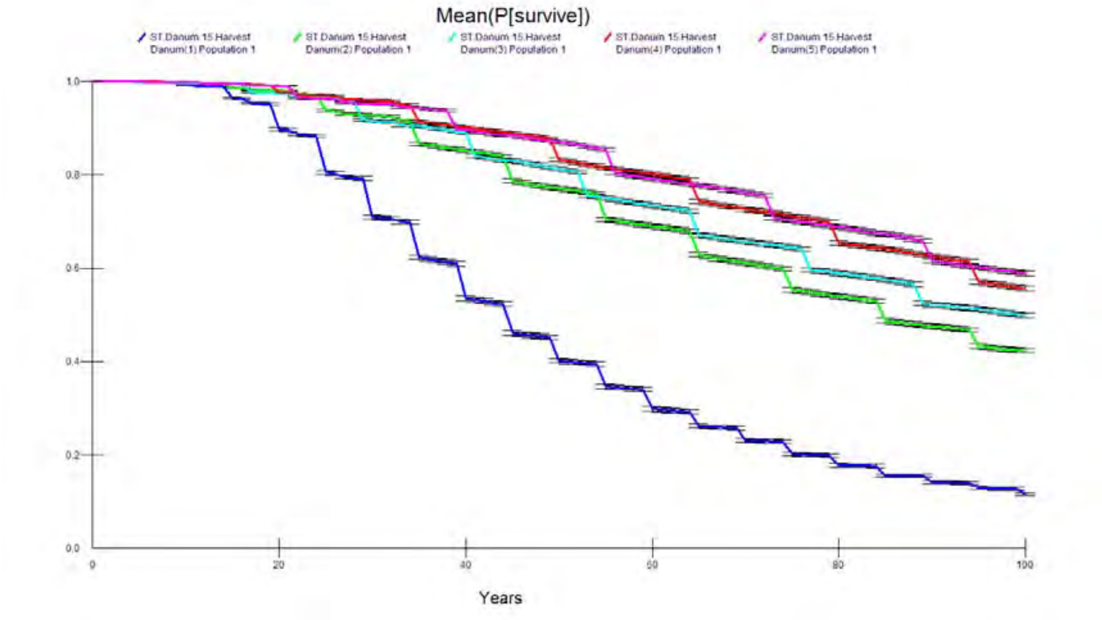
Graph F. In this sensitivity test for TWR poaching of 1 female occurs every 10 years. “Tabin 10 population 1” supplements first time from year 10 and following every 6th year. The first release year is indicated by the number in (#) and following every 6th year.



Graph G. In this sensitivity test for TWR poaching of 1 female occurs every 10 years. "Danum 15 population 1" supplements first time from year 10 and following every 6th year. The first release year is indicated by the number in (#) and following every 6th year.



Graph H. This sensitivity test simulates different intervals of "harvest" (poaching) for TWR.
1 = 5 years
2 = 10 years
3 = 12 years
4 = 15 years
5 = 17 years



Graph I. This sensitivity test simulates different intervals of ”harvest” (poaching) for DVCA.
1 = 5 years
2 = 10 years
3 = 12 years
4 = 15 years
5 = 17 years