

## Review

# Now or never: what will it take to save the Sumatran rhinoceros *Dicerorhinus sumatrensis* from extinction?

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**Abstract** In 1994 Alan Rabinowitz decried what he regarded as lackadaisical attempts by governments, NGOs and international funding agencies to conserve the Sumatran rhinoceros *Dicerorhinus sumatrensis*. Sixteen years on it is timely to evaluate whether his warnings were heeded. We review the current conservation status of *D. sumatrensis* throughout its range and the latest threats and challenges complicating efforts to conserve this species. Recent data from governments, NGOs and researchers indicate that the global population could be as low as 216, a decline from c. 320 estimated in 1995. Based on lessons learnt and expert opinions we call on decision makers to focus on two core strategies for conservation of *D. sumatrensis*: (1) the translocation of wild individuals from existing small, isolated or threatened forest patches into semi-in situ captive breeding programmes, and (2) a concomitant enhancement of protection and monitoring capacities in priority areas that have established these breeding facilities or have recorded relatively high population estimates and track encounter rates. At least USD 1.2 million is required to implement these strategies annually in four priority areas: Bukit Barisan Selatan and Way Kambas National Parks on Sumatra, and Danum Valley Conservation Area and Tabin Wildlife Re-

serve on Sabah. Given that conservation funds are rarely secure and *D. sumatrensis* is still in decline we call on potential donors to help secure and augment existing capacities of organizations in these four priority areas before committing resources to elucidate the status of the species in other areas such as Gunung Leuser and Taman Negara National Parks.

**Keywords** Borneo, captive breeding, *Dicerorhinus sumatrensis*, Indonesia, Malaysia, poaching, rhinoceros, Sumatra

## Introduction

Once distributed throughout South-east Asia to the foothills of the Himalayas (Corbett & Hill, 1992), the Sumatran rhinoceros *Dicerorhinus sumatrensis* is now confined to isolated parts of Indonesia and Malaysia: *D. sumatrensis sumatrensis* is confined to Sumatra and Peninsular Malaysia and *D. sumatrensis harrissoni* is endemic to Borneo. In 1995 the estimate of the total number of *D. sumatrensis* in these range states was c. 320 (Table 1). There may be < 250 mature individuals globally and the species is categorized as Critically Endangered on the IUCN Red List (IUCN, 2010). However, researchers and NGOs involved in monitoring and protection indicate there may only be c. 216 wild individuals remaining (Table 1). Even this estimate is contentious given the species' patchy distribution and secretive nature (Payne, 1990) coupled with the lack of reliable and comparable field data.

Sixteen years ago Rabinowitz (1994) claimed that much of the resources for the conservation of *D. sumatrensis* went into politically favourable initiatives that did not mitigate the real threats responsible for the species' decline: habitat loss and poaching. It is disconcerting that even after Rabinowitz (1994) chastised the international conservation community for not doing enough to address the species' plight, its population remains perilously low 16 years on. Here, we review the conservation status of *D. sumatrensis* across its range states and the threats facing the species. We call on conservation NGOs and governments of range states

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TABLE 1 Summary information for Sumatran rhinoceros *Dicerorhinus sumatrensis* populations from government agencies, researchers and NGOs in Sumatra, Peninsular Malaysia and Sabah.

Area	Population estimates provided by range states in 1995 (Foose & van Strien, 1997)	Latest population [occupancy <sup>1</sup> ] estimates (source)	Latest no. of tracks per 100 km [SE if known]; survey distance (km); survey dates (source)
<b>Sumatra</b>			
Gunung Leuser National Park	60	60–80 (MOF, 2007)	
Bukit Barisan Selatan National Park	22	50–70 [0.32] (WCS, YABI and BBSNP in Talukdar et al., 2009)	4.62; 2,532; 2005–2006 (Isnan et al., 2006)
Way Kambas National Park	16	27–33 [0.43] (PKHS, WCS, YABI and WKNP in Talukdar et al., 2009)	4.46; 2,756; 2006 (Isnan et al., 2006)
Kerinci Seblat National Park	28	Extinct (MOF, 2007)	
Others	25	10–15 (MOF, 2007)	
<i>Subtotal</i>	151	147–198	
<b>Peninsular Malaysia</b>			
Taman Negara National Park	44	21–34 (DWNP, 2005)	0.42 [0.24]; 718; 1999–2001 (Kawanishi & Sunquist, 2004) <sup>2</sup>
Royal Belum State Park	10	12–13 (DWNP, 2005)	0.14 [0.14]; 710; 2007–2010 (WWF-Malaysia, unpubl. data) <sup>2</sup>
Endau Rompin National Park	9	1–2 (DWNP, 2005)	0; 2,500; 2008–2010 (WCS, Malaysia Program) <sup>2</sup>
Others	36	35–45 (DWNP, 2005)	
<i>Subtotal</i>	99	69–94	
<b>Sabah</b>			
Danum Valley Conservation Area	11	13–15 (Alfred & Payne, 2005; Talukdar et al., 2009)	4.99; 621; 2005–2010 (WWF-Malaysia, unpubl. data)
Tabin Wildlife Reserve	20	15 (BORA & SOS Rhino in Talukdar et al., 2009)	
Others	39	7 (Talukdar et al., 2009)	
<i>Subtotal</i>	70	37	
<i>Total</i>	320	216–284	

<sup>1</sup>Occupancy refers to the proportion of an area that is occupied by *D. sumatrensis*

<sup>2</sup>Extremely low track encounter rates do not appear concordant with latest population estimates

to focus on two core strategies, for which we provide estimates of the annual implementation cost. This turns out to be a relatively small price to pay for saving a Critically Endangered species.

## Conservation status

### Sumatra

*D. sumatrensis* formerly occurred in all eight provinces of the Indonesian island of Sumatra (van Strien, 1974) but now remains in only three (Aceh, Lampung and South Sumatra). Eight populations have been extirpated over the last 15 years including that in Kerinci Seblat National Park (Uryu et al., 2010; Fig. 1), which once comprised 28 individuals (Foose & van Strien, 1997). According to the Ministry of Forestry (MOF, 2007) current island-wide population estimates are 145–200 and the species mainly persists in

three protected areas: Gunung Leuser, Bukit Barisan Selatan and Way Kambas National Parks (Fig. 1, Table 1). However, reports suggest that the Gunung Leuser population, which was the best studied in Sumatra (van Strien, 1985), could now be much lower, although there is little information on its status (W.S. Ramono, pers. obs.). The species persists in Bukit Barisan Selatan and Way Kambas National Parks, with reasonably high track encounter rates and photo-captures. Kinnaird et al. (2003) obtained 10 photo-captures of *D. sumatrensis* from 4,967 trap days in 140 km<sup>2</sup> in Bukit Barisan Selatan National Park even though their surveys were not targeting the species. Despite habitat loss from fires and expanding coffee plantations in and around this Park (Kinnaird et al., 2003), monitoring and enforcement efforts by government-backed Rhino Protection Units have helped maintain what is one of Sumatra's largest populations of *D. sumatrensis*. In Way Kambas, where a relatively smaller population is being

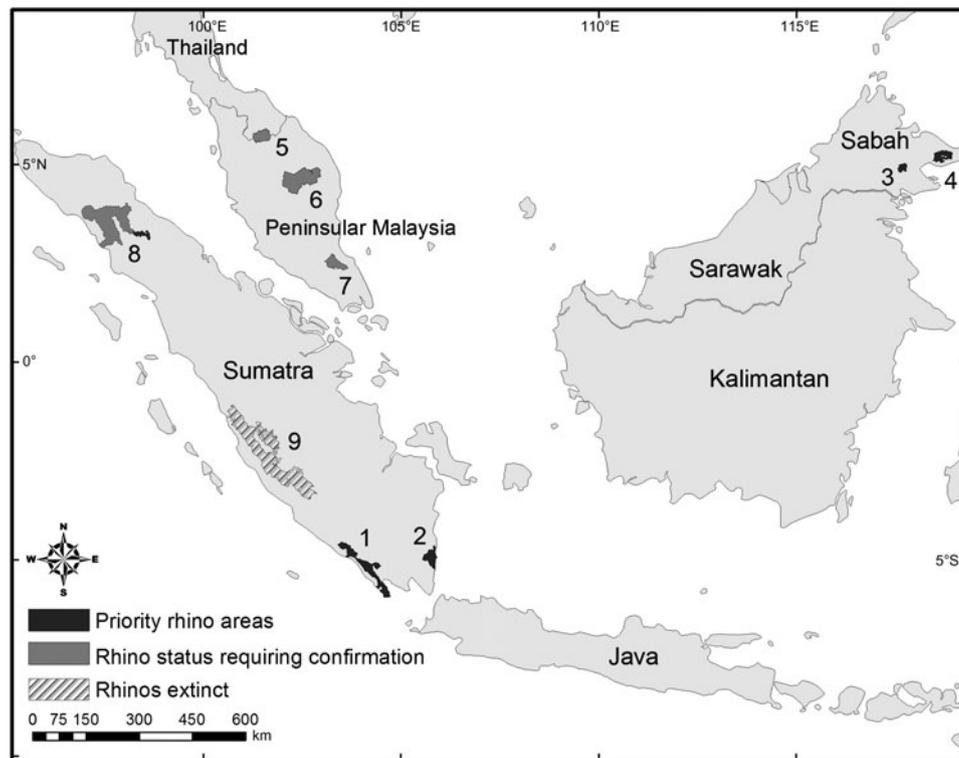


FIG. 1 Priority Sumatran rhinoceros *Dicerorhinus sumatrensis* areas: 1, Bukit Barisan Selatan National Park; 2, Way Kambas National Park; 3, Danum Valley Conservation Area; 4, Tabin Wildlife Reserve. Areas identified by the IUCN Asian Rhino Specialist Group (AsRSG) as requiring scientifically defensible population estimates to confirm conservation status: 5, Royal Belum State Park; 6, Taman Negara National Park; 7, Endau Rompin National Park; 8, Gunung Leuser National Park. Area identified by the AsRSG where *D. sumatrensis* has been extirpated: 9, Kerinci Seblat National Park.

protected, a semi-in situ breeding centre for *D. sumatrensis* was established in 1998 as a last-ditch attempt to save the Indonesian population from extinction.

#### Peninsular Malaysia

The Malay Peninsula probably provides the last hope for *D. sumatrensis* on mainland South-east Asia in terms of habitat availability, yet the species' viability and conservation status remains uncertain because of extremely low densities and a paucity of reliable population estimates (Clements et al., 2010). Low numbers and declining population trends have been reported since the 1930s (Hubback, 1939) and, up to 1994, estimates of the population have varied between 10 and 130 (Metcalf, 1961; Stevens, 1968; Mohd. Khan et al., 1982; Mohd. Khan, 1987, 1989). Subsequently, Zainal Zahari (1995) reported a drastic decline from 77–130 individuals in 1993 to c. 28–30. Since then population estimates from the Department of Wildlife and National Parks (DWNP) have continued to fluctuate, with the latest published figure being 69–94 (Table 1). However, the survey techniques used to derive these estimates are unknown and since 1994 no further individuals have been physically captured and no sightings have been documented (Tan, 2003).

We focus our summary on three of Peninsula Malaysia's largest protected areas, which are considered priority areas for conservation of *D. sumatrensis* (Foose & van Strien, 1997): Taman Negara, Endau Rompin National Park and Royal Belum State Park (Fig. 1, Table 1). Taman Negara, which is the country's largest protected area, was regarded as one of Malaysia's strongholds for *D. sumatrensis* (Flynn & Abdullah, 1984). Surveys by Kawanishi & Sunquist (2004), which were the most scientifically robust large mammal surveys in this Park so far, covered c. 15% (600 km<sup>2</sup>) of the Park and yielded 4,533 wildlife photos from 14,054 trap nights across forests overlapping the species' known altitudinal range. However, there were no photo-captures of *D. sumatrensis*. Track encounter rates were also relatively low (Table 1) compared to six other large ungulate species recorded in the same study. Although not targeting *D. sumatrensis* specifically, these surveys suggest an extremely small population in Taman Negara (Kawanishi et al., 2003) inconsistent with it purportedly having the largest *D. sumatrensis* population in Peninsular Malaysia (Foose & van Strien, 1997). In Endau Rompin National Park 20–25 individuals were estimated to be present in the 1980s (Flynn & Abdullah, 1984) but surveys in the 1990s failed to detect fresh tracks and found numerous signs of poaching (M.T. Abdullah, pers. comm.). Since 2008 tiger prey occupancy

surveys conducted by the Wildlife Conservation Society (Malaysia) in this Park have yet to detect signs of *D. sumatrensis* along transects totalling more than 2,500 km (M. Gumal, pers. comm.).

Royal Belum State Park, which was identified as another protected area with viable populations (IUCN, 1997), has yielded similar results. Since February 2007 extensive surveys have been conducted in suitable habitats (e.g. major rivers, valleys, salt licks, old wallows and ridges) and localities where indigenous people claimed to have seen *D. sumatrensis* recently but only one possible footprint has been detected. To date, camera-trapping surveys have not photo-captured *D. sumatrensis* despite yielding 2,124 wildlife photos over 844 trap nights and track encounter rates are extremely low (Table 1). In interviews with 297 people frequently entering forests (indigenous communities, hunters, loggers and villagers extracting forest products) only 2% of interviewees claimed to have seen *D. sumatrensis* within the last 5 years. In addition, no active rhinoceros wallows have been recorded in the Park since intensive surveys began in 2007.

## Sabah

When the distribution of *D. sumatrensis* in Sabah was reviewed in the 1990s (Payne, 1990; Boonratana, 1997; Foose & van Strien, 1997) the population was estimated to be c. 40–70 (Table 1). Danum Valley Conservation Area (438 km<sup>2</sup>) and Tabin Wildlife Reserve (1,225 km<sup>2</sup>) now support the State's largest *D. sumatrensis* populations (Fig. 1, Table 1). Track encounter rates in monitoring surveys in Danum have been comparable to those of protected areas in Sumatra with sizeable *D. sumatrensis* populations (Table 1). In Tabin surveys over the past 3 decades involved simultaneous sweeps to estimate the size of the population (which is similar to Danum's) but systematic surveys have been difficult to implement because of the rugged terrain, frequent heavy rain and insufficient field capacity (J. Payne, pers. obs.). Apart from these strongholds, other sites across Sabah (whose localities remain undisclosed for security reasons) still support isolated individuals. One of these isolated individuals was spotted in an oil palm plantation adjacent to a forest patch and was subsequently rescued and translocated to Tabin (NST, 2008). Although populations in Sabah have not shown any signs of increase (c. 37 individuals; Table 1), evidence of breeding in the form of fresh footprints of immature individuals was recorded in both Danum and Tabin in 2006.

## Threats and challenges

Prior to 1950 numbers of *D. sumatrensis* were probably already low as there were major gaps in the species' distribution in apparently suitable habitats (Hubback,

1939). The species is now probably confined to protected lowland forests or high-altitude forests that are largely inaccessible to conversion. Therefore, habitat loss, especially in the lowlands, is no longer the most significant threat to the conservation of the species in Sumatra (Uryu et al., 2010) and Malaysia.

The small population size is now the most significant threat to the species. Various factors associated with very low numbers (e.g. narrow genetic base, difficulty in finding a fertile mate) are likely to drive populations to the point where death rates will exceed birth rates even with suitable habitat and zero offtake (Courchamp et al., 2008). Rhinoceroses have a long inter-birth interval and small increases in juvenile mortality can suppress recruitment rates below levels needed to replace breeding adults (Johnson, 2006; Cranbrook, 2009). The only information on the inter-birth interval of *D. sumatrensis* comes from Cincinnati Zoo where calves have been born at 34-month intervals (Foose, 2006; T. Roth, pers. comm.). In the wild birth intervals are likely to have grown further apart, especially as the probability of males meeting receptive females decreased. If Danum and Tabin protected areas are each assumed to contain 15 individuals, that c. 50% are females, and that some of these are too old or too young to reproduce, only three or four individuals are likely to be reproductively active in each site. With a birth interval of 3 years under optimum wild conditions, a maximum of only one *D. sumatrensis* will be born into each population annually. Furthermore, at least half of all the females caught between 1984 and 1995 in Sumatra, Peninsular Malaysia and Sabah had reproductive tract pathology (Schaffer et al., 2001), a phenomenon associated with no pregnancies, which reflects a lack of breeding opportunities. Another consequence of low population sizes is an increased likelihood of skewed sex ratios, a phenomenon revealed during trapping operations in the 1980s and 1990s. Of 10 *D. sumatrensis* captured in Sabah between March 1987 and November 1995 eight were mature males; because females are potentially easier to locate than males because of their smaller home ranges, the females may have been selectively taken by poachers.

Poaching is the second significant risk to the survival of *D. sumatrensis*, although it was the primary threat in the early 20th century (Hubback, 1939; Medway, 1977). Rabinowitz (1994) similarly identified poaching (for horns, hooves and other body parts for traditional Chinese medicine) and habitat loss as the two main drivers of the species' decline. In Sumatra the government reported that poaching was brought under control after 1997 (MOF, 2007). In Bukit Barisan Selatan and Way Kambas National Parks, however, anti-poaching data revealed that *D. sumatrensis* was still being targeted during 2002–2009 (Table 2). Eight populations went extinct during 1997–2007 (Uryu et al., 2010). In Peninsular Malaysia, DWNP (2006) estimated that c. 30 individuals were poached during 1975–2005; horns from at

TABLE 2 Anti-poaching statistics from the Rhino Protection Unit in Bukit Barisan Selatan (BBS) and Way Kambas (WK) National Parks, Sumatra, Indonesia, for 2002–2009.

Year	Poachers arrested in BBS	Poachers arrested in WK	Snares/traps removed in BBS	Snares/traps removed in WK
2002	5*			
2003	14*			
2004	11*	4		
2005	1	11	10	
2006	4	4	22	
2007	5	2	1*	
2008	0	3	3*	322*
2009	4	4	6	62*

\*Indicates some targeted rhinoceroses (source: Yayasan Badak Indonesia, unpubl. data)

least eight individuals and a piece of skin were discovered in pharmacies in the states of Penang and Johor, respectively (DWNP, 2005). The world's largest wildlife trader was still trading horns of *D. sumatrensis* after 1995 (Christy, 2010). Interviews with hunters during 2007–2008 in Peninsular Malaysia indicated that there was still a demand for rhinoceros horns (TRAFFIC, unpubl. data), which can fetch up to USD 45,000 kg<sup>-1</sup>. Dinerstein (2003) reported that Asian rhinoceros horn could be sold for USD 30,000 kg<sup>-1</sup>, triple the mean price for that of the African rhinoceros *Diceros bicornis* (USD 10,000 kg<sup>-1</sup>).

## Two core conservation strategies

Maguire et al. (1987) suggested several measures to save *D. sumatrensis* from extinction (anti-poaching efforts, fencing, translocation and captive breeding). These mitigation measures have been implemented with varying degrees of success and failure over the last 16 years in Indonesia, Malaysia and the USA. We believe only two of these measures are relevant to ensure the survival of the species.

Translocate isolated individuals into semi-in situ captive breeding programmes

Mohd. Khan (1989) suggested that c. 50 individuals could sustain 5–10 generations of the the Sumatran rhinoceros, whereas a recent meta-analysis showed that any mammal species generally requires a minimum of 3,876 individuals to maintain population viability (Traill et al., 2007). Current Sumatran rhinoceros populations number less than these thresholds and in some areas only isolated individuals remain. While in situ captive breeding programmes could theoretically help augment wild populations via reintroductions, Rabinowitz (1994) was critical of

the magnitude of resources invested in these programmes and labelled them expensive failures; 42 *D. sumatrensis* were caught for this purpose and 34 died during 1984–2006 (Foose, 2006). Captive breeding programmes have suffered significantly more setbacks than successes but we argue that some form of captive breeding is still necessary. Without specific actions to bring Sumatran rhinoceroses together to boost production it is likely that the species will go extinct even if protection of suitable habitat increases. Only 10 individuals remain in captivity (AP, 2009) and successful births have only occurred in the Cincinnati Zoo. A female named Emi produced three calves at the zoo, the youngest of which was the first Sumatran rhinoceros bred and born in captivity since 1889. However, Emi died in 2009 at c. 21 years; her eggs were rescued for possible in-vitro fertilization (AP, 2009).

Captive *D. sumatrensis* held in their range states require forest habitats and natural conditions to improve chances of breeding, and carefully managed captive breeding centres in native habitats (semi-in situ captive breeding) were deemed necessary almost a decade ago (van Strien, 2001). We still concur with van Strien's recommendation despite the absence of reproductive success so far. Three breeding facilities were created to receive translocated *D. sumatrensis*: Way Kambas (Sumatra), Sungai Dusun (Peninsular Malaysia) and Sepilok (Sabah) but all three failed to breed the species. The latter two facilities no longer hold any living *D. sumatrensis* (Tan, 2003); an old female from Sepilok which was recently transferred to Tabin. The semi-in situ Sumatran Rhino Sanctuary in Way Kambas, however, is the most promising model for captive management. This sanctuary currently supports five *D. sumatrensis* and only one death, of an unproductive old female, has occurred. Constructed within the 1,250 km<sup>2</sup> Way Kambas National Park in 1997 this sanctuary comprises 100 ha of forest habitat surrounded by an electrified fence. Circa 20 ha of forest habitat is provided for each individual (monitored continuously during daylight hours and breeding periods) and the design of the paddocks allows mixing and separation when necessary (Agil et al., 2002). *D. sumatrensis* were repatriated to this facility from zoos in January 1998 and they have adapted well (Anon., 2000). In 2007 the Sumatran Rhino Sanctuary received Andalas (the calf borne from Emi) to be paired with the resident females, two of which are young mature individuals brought to the Sanctuary after 2000. Andalas recently impregnated another female, Ratu, in the sanctuary (Hance, 2010a). This success is attributable not only to the natural settings of the sanctuary but also to the use of monitoring techniques (e.g. hormonal assays and ultrasound techniques) initially introduced from Cincinnati Zoo to determine the optimal time for introducing males and females (IRF, 2010). Although Ratu lost her pregnancy a few months later, there is optimism for a successful birth as it was her first

pregnancy; Emi had five failed pregnancies before she gave birth to Andalas (Hance, 2010b). Annual operating costs for the Sumatran Rhino Sanctuary are at least USD 184,724 (YABI, 2009).

Based on this model the Sabah government launched a rescue programme for *D. sumatrensis* in 2009 that endorses the establishment of a semi-in situ captive breeding facility within Tabin similar to the Way Kambas model of individual small paddocks within a large fenced forest area. This facility, the Borneo Rhino Sanctuary (Cheang, 2009), will function as a breeding area for reproductively isolated *D. sumatrensis* translocated from other sites. Borneo Rhino Alliance (BORA, 2010), a non-profit company, will continue the role of the now defunct SOS-Rhino Borneo to assist the Sabah government in the development and management of this sanctuary. The annual operating costs of this sanctuary, once fully established, could be at least USD 334,000, excluding costs of capture and translocation.

#### Secure priority areas with enhanced monitoring capacities

Rabinowitz (1994) lambasted the international conservation community for not providing enough resources to protect rhinoceroses in the wild. Anti-poaching patrols, which increase the chances of poachers being caught, are the greatest disincentive to hunting of *D. bicornis* in Africa (Milner-Gulland & Leader-Williams, 1992), the full protection of which required one guard per 20 km<sup>2</sup> of protected area. In April 1995 an anti-poaching initiative known as Conservation Strategy for Rhinos in South-east Asia (Indonesia and Malaysia) was organized. It received funding from the Global Environment Facility through the UN Development Programme. The Asian Rhino Specialist Group and International Rhino Foundation, which operated as the financial and administrative agent, jointly coordinated and facilitated this initiative (van Strien, 2001). The main objective was to establish units to protect and monitor *D. sumatrensis* populations, destroy snares and traps and arrest poachers in core *D. sumatrensis* areas (van Strien, 2001). In Peninsular Malaysia protection units have been in operation in key *D. sumatrensis* habitats since 1995 (Abdul Kadir, 2009). In Sumatra, eight and five protection units operate in Bukit Barisan Selatan and Way Kambas, respectively (Isnan et al., 2006).

Key features that set *D. sumatrensis* protection units in Indonesia apart from those in other regions include an intelligence and law enforcement unit to gather information on poacher identities, and that rangers from the Ministry of Forestry are seconded to the units to facilitate the arrest of suspected poachers. While the persistence of *D. sumatrensis* in Bukit Barisan Selatan and Way Kambas has been credited to intensive anti-poaching work by the protection units (MOF, 2007), their effectiveness has been

difficult to evaluate. For example, the protection units in both areas reported an absence of poachers targeting *D. sumatrensis* since 2004 (Table 2) but this could be part of a trend associated with decreasing numbers of *D. sumatrensis*. Protection units were unable to prevent the extirpation of *D. sumatrensis* from Kerinci Seblat (Table 1). Additional data (e.g. number of snares removed each year in relation to law enforcement effort and occupancy estimates of *D. sumatrensis*, number of poaching cases detected by patrol- and intelligence-based efforts) need to be obtained to evaluate the effectiveness of enforcement interventions (Linkie et al. 2010). Nevertheless, more resources must be provided to improve existing law enforcement coverage and monitoring capacities if we want to determine the conservation status of *D. sumatrensis* in priority areas (Fig. 1). In Sumatra annual support for protection units and intelligence and law enforcement units operating in Bukit Barisan Selatan and Way Kambas (i.e. operational costs excluding technical, administrative and communication support; YABI, 2009) amounts to at least USD 397,423.

In Peninsular Malaysia protection units initiated by the federal government have focused their daily patrols in *D. sumatrensis* habitat within Taman Negara and have arrested 72 encroachers up to 2009 (Abdul Kadir, 2009). To our knowledge, however, only one person has ever been prosecuted for rhinoceros poaching in Peninsular Malaysia, in 1985 (Abdullah et al., 1989). However, the Malaysian government recently passed a new wildlife conservation law to be enforced in December 2010 (Kuppusamy, 2010); at least 13 new provisions are being suggested, including a significant enhancement of penalties for wildlife crimes involving protected species such as *D. sumatrensis* (e.g. fines of USD 30,000–150,000 coupled with mandatory prison sentences of up to 5 years). To complement the government's enforcement work NGOs initiated anti-poaching units that patrol together with government agencies in *D. sumatrensis* habitat within Peninsular Malaysia and Sabah. In the former, WWF–Malaysia formed a wildlife protection unit to patrol in and around Royal Belum, a priority area identified by the Asian Rhino Specialist Group (Foose & van Strien, 1997). In conjunction with government enforcement authorities the wildlife protection unit has removed 141 snares and apprehended 11 poachers since January 2009 (WWF–Malaysia, unpubl. data). However, no evidence of *D. sumatrensis* or poaching of the species was recorded by active patrols and intelligence networks during that period.

In Sabah both WWF–Malaysia and Borneo Rhino Alliance operate protection units for the populations in Danum, Tabin and other areas in the lower Segama-Kinabatangan landscape. The Sabah State government granted the status of honorary wardens to some members of these protection units, who have powers of investigation and arrest. Given these enabling conditions, more resources

need to be allocated to protect the two priority areas in Sabah by augmenting existing law enforcement coverage and the capacity to monitor effectiveness. Currently in Sabah annual financial support for protection units amounts to a total of USD 332,221: USD 111,221 at Danum (according to WWF–Malaysia) and USD 216,000 at Tabin (according to Borneo Rhino Alliance), with protection unit staff also involved in care of captive *D. sumatrensis* and rescue work.

## Conclusions

Some of Rabinowitz's (1994) warnings were heeded: protection of wild *D. sumatrensis* in some areas did increase and the removal of wild individuals into ex situ captive conditions soon ceased. Yet, since 1995, the population of *D. sumatrensis* appears to have declined by c. 32% to a lower bound estimate of c. 216 wild individuals. The prognosis for the survival of the species is not good and the situation will worsen unless there is more political support, better enforcement of wildlife laws, improved cooperation among stakeholders, and funds available to implement the two best available conservation strategies: (1) translocation of isolated wild *D. sumatrensis* into existing semi-in situ captive breeding programmes, to maximize reproductive success, and (2) securing priority areas (Bukit Barisan Selatan, Way Kambas, Danum and Tabin) with improved law enforcement coverage and monitoring capacities.

If decision makers in Indonesian and Malaysian governments do not commit to this approach we may never have another chance to reverse the decline of this species. Given that the remaining wild *D. sumatrensis* populations have not shown signs of recovery under the current funding scenario, potential donors could help strengthen the capacities of conservation agencies in the four priority areas, as well as support efforts to obtain scientifically defensible population estimates for other areas (e.g. Gunung Leuser and Taman Negara). The annual amount that is currently spent to sustain the bulk of conservation efforts for *D. sumatrensis* in the four priority areas is at least USD 1,245,368, similar to the price of a 1939-edition Batman comic book auctioned off at Heritage Auctions of Dallas, Texas, USA in February 2010. Surely the future of the world's remaining Sumatran rhinoceroses is worth more than a piece of historical paraphernalia?

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### Biographical sketches

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WWF–Malaysia’s rhinoceros monitoring and protection in Royal Belum, Peninsular Malaysia, and RAYMOND ALFRED and JUNAIDI PAYNE currently lead the conservation efforts of WWF–Malaysia and BORA for *D. sumatrensis*, respectively, in Sabah. DIONYSIUS SHANKAR KUMAR SHARMA is the Chief Executive Officer of WWF–Malaysia and AMIRTHARAJ CHRISTY WILLIAMS is in charge of WWF’s Asian Rhino conservation strategies. SENTHIVAL NATHAN oversees the husbandry of captive *D. sumatrensis* in Sabah on behalf of the Government of Sabah through the Sabah Wildlife Department. WIDODO S. RAMONO leads Indonesian conservation efforts for *D. sumatrensis* as executive director of Yayasan Badak Indonesia in Sumatra.