Habitat destruction and poaching threaten the Sumatran tiger in Kerinci Seblat National Park, Sumatra

Matthew Linkie, Deborah J. Martyr, Jeremy Holden, Achmad Yanuar, Alip T. Hartana, Jito Sugardjito and Nigel Leader-Williams

Abstract The Sumatran tiger, categorized as Critically Endangered on the 2002 IUCN Red List, is threatened by poaching for domestic and international markets, by prey depletion from human hunting and by habitat loss from illegal and commercial logging, oil palm production, pioneer farming, mining operations and forest fires. Kerinci Seblat National Park (KSNP) in west-central Sumatra still has large blocks of forest that support tiger populations. In this paper we present information on photo-trapping and tiger distribution in KSNP and adjoining forest. Tigers were found to be present in all habitat types across KSNP. The poaching pressures on tigers and their prey species were evaluated from confiscations of snare traps by Tiger Protection and Conservation Units (TPCU). Poaching pressures were found to be highest for muntjac, then sambar, tiger, and serow and mouse deer. We determined the effectiveness of TPCU patrol size from the number of arrests, and chainsaw and snare trap confiscations per patrol. The success of forest patrols increased with the number of TPCU staff per patrol. We looked at general law enforcement for KSNP, which appeared to be inadequate. To reduce the threat posed by poaching and illegal logging extra TPCU staff are required for patrols, and extra patrol units are required for the northern and southern sections of the Park. In KSNP it is necessary to monitor habitat loss, establish an unambiguous scheme to mitigate human-tiger conflict, and develop a photo-trapping programme to monitor the tiger population.

Keywords Deforestation, human-tiger conflict, Kerinci Seblat National Park, *Panthera tigris sumatrae*, poaching, Sumatran tiger.

Introduction

Large carnivore species occur at naturally low densities, and this makes them particularly susceptible to extirpation and extinction (Lande, 1988; Caughley, 1994). To maintain viable populations they need large areas with adequate prey densities, and are therefore threatened by habitat loss and fragmentation (Woodroffe & Ginsberg, 1998). Large carnivores are generally unpopular with the people that share their range, as they are blamed for loss of life and livestock (Schaller & Crawshaw, 1980). Furthermore, the body parts of some carnivores can provide considerable financial gains (Nowell, 2000). These factors have lead to the death of many large carnivores, further reducing their population densities (Ginsberg & Macdonald, 1990; Nowell & Jackson, 1996) and increasing their dependency on protected areas for survival.

The size of these protected areas is particularly important because 'edge effects' are pronounced for large carnivores (Woodroffe & Ginsberg, 1998). However, large protected areas are also more costly to maintain and many are under-funded (Leader-Williams & Albon, 1988; James *et al*., 1999). This means that poaching and habitat degradation within protected areas still affect their resident large predators and the predators' prey. In Indonesia, the losses of the Bali tiger *Panthera tigris balica* in the 1940s and the Java tiger *P. t. sondaica* in the 1980s was largely attributed to human-induced habitat loss and a decline in ungulate prey (Seidensticker, 1986). Sumatra is now home to the last populations of tiger *P. t. sumatrae* in Indonesia, yet these are facing similar threats.

Deforestation rates on Sumatra have been at their highest in Indonesia during the last 15 years (Holmes, 2001). The *c*. 500 remaining tigers (Faust & Tilson, 1994),

Matthew Linkie (Corresponding author) and **Nigel Leader-Williams** The Durrell Institute of Conservation and Ecology, University of Kent at Canterbury, Kent, CT2 7NS, United Kingdom. E-mail: ml33@ukc.ac.uk

Deborah J. Martyr, Jeremy Holden, Achmad Yanuar Fauna & Flora International, PO Box 42, Sungai Penuh, Kerinci, Jambi, Sumatra, Indonesia.

Alip T. Hartana Kerinci Seblat Tiger Protection Programme, c/o KSNP, Sungai Penuh, Kerinci, Jambi, Sumatra, Indonesia.

Jito Sugardjito Fauna & Flora International-Indonesia Programme, Bantarjati, Bogor, Indonesia.

Received 6 September 2001. Revision requested 27 February 2002. Accepted 26 September 2002.

have been consequently fragmented into smaller populations, and the subspecies is categorized as Critically Endangered on the 2002 IUCN Red List (IUCN, 2002). Deforestation has been caused by the unsustainable demand for natural resources created by a human population that has the highest rate of growth in Indonesia. Sumatra has been the recipient of both Government sponsored and spontaneous transmigrations from other Indonesian islands. Deforestation has also been caused by a government initiative to increase tree crop plantations and high intensity commercial logging that has led to forest fires and encroachment. Within Sumatra there is also a substantial domestic trade in tiger parts (Plowden & Bowles, 1997), and Indonesia has been a long-term source for the international trade in such parts. Between 1970 and 1993 South Korean customs recorded 3,994 kg of tiger bone, or 44.5 per cent of total imports, as coming from Indonesia (Mills & Jackson, 1994).

The majority of Sumatran tigers are currently dispersed between the National Parks of Berbak, Bukit Barisan Selatan, Gunung Leuser, Way Kambas, and Kerinci Seblat (Tilson *et al.*, 1994). In this paper we map the distribution of tigers in Kerinci Seblat National Park (KSNP) and adjacent logging concessions. We investigate the poaching pressures facing tigers and their prey species, evaluate the effectiveness of forest patrols and law enforcement within the park, and the threat posed by habitat loss. The future for tiger conservation in KSNP is discussed in the light of these threats.

Study area

The *c.* 13,300 km^2 of KSNP contains large patches of continuous forest that are capable of supporting a healthy tiger population (Wikramanayake *et al.*, 1998). KSNP is in west-central Sumatra, spanning the provinces of Jambi, West Sumatra, Bengkulu and South Sumatra. The altitude of KSNP ranges from the lowland hill forests in Bengkulu at 200 m to the montane forests of Mount Kerinci at 3,805 m, the highest point in Sumatra (Fig. 1). The park lies within a warm perhumid bioclimate (Whitmore, 1984). It has a dry hot period, from July to October, when average temperatures are 24–30°C, with daily fluctuations of 2°C. The temperature falls after October when the rainy season begins, typically from November through to May. Average annual rainfall is 2,300 mm (Departemen Kehutanan, 1995).

Methods

From January 1996 to August 2001 field surveys were conducted in KSNP and in nine of the 14 adjoining logging concessions to record the occurrence of tiger signs (pugmarks, scats and sightings). From July 1996 to July 1999 photo-trapping was conducted in four different forest types within the Park: Tapan Valley (lowland hill), Tandai (hill), Sipurak (hill/submontane), and Mount Tujuh (submontane/montane). Photo-trap placements (for further details see Holden *et al.*, 2003) were not set specifically for tiger, but for forest mammals in general, such as small cats (Holden, 2001; Martyr, 1997) and Asian tapirs *Tapirus indicus* (Holden *et al.*, 2003). It was not possible to estimate tiger density directly (Karanth & Nichols, 1998), and therefore encounter rates (trap days per tiger photograph) were calculated for each forest type.

From June to August 2000 two Tiger Protection and Conservation Units (TPCU), each consisting of between 2 and 13 staff (mean = 5.0, SD = 3.2), conducted law enforcement forest patrols for a duration of between 3 and 12 days (mean = 4.5, SD = 3.0). The objective was to arrest illegal loggers and wildlife poachers, confiscate chainsaws, and dismantle snare traps. When a snare trap was encountered a sweep search radiating 1 km outwards from the trap was conducted along ridge and animal trails, because traps are usually concentrated in small areas to maximize their success. The purpose of a snare trap was determined by its weight, construction and location. A snare set for mouse deer *Tragulus napu* and *T. javanicus* uses a narrower diameter rope (2 mm) than the larger ones set for muntjac *Muntiacus muntjac* (4–6 mm) and for sambar *Cervus unicolor* (8 mm). A snare trap set for a serow *Naemorhedus sumatrensis* (4–6 mm) is similar in diameter to that set for muntjac but is located at higher altitudes on mountain ridge trails. A snare trap set for tiger or rhino *Dicerorhinus sumatrensis* uses a wire cable (Borner, 1979). For tiger a double loop mechanism or a 'two room' pit or cage trap baited with a dog is also used.

The effectiveness of having different numbers of TPCU staff on a patrol was tested by dividing the number of patrol results (arrests, chainsaws confiscated, and snare traps disabled) by the number of patrol days to give mean results per day for the different patrol sizes. Staff density for KSNP was then calculated by dividing the number of KSNP staff by the total area of the park. This method was repeated for TPCU staff only and for KSNP and TPCU staff combined.

Results

Of 141 locations surveyed, tiger signs were found in 126, 43 of which were outside KSNP (Fig. 1). Tiger signs were found in seven out of the nine logging concessions surveyed. Tigers were recorded at altitudes of 50–2,440 m, and across all the major habitat types. From a total of 5,500 photo-trapping days in four locations in

https://doi.org/10.1017/S0030605303000103 Published online by Cambridge University Press

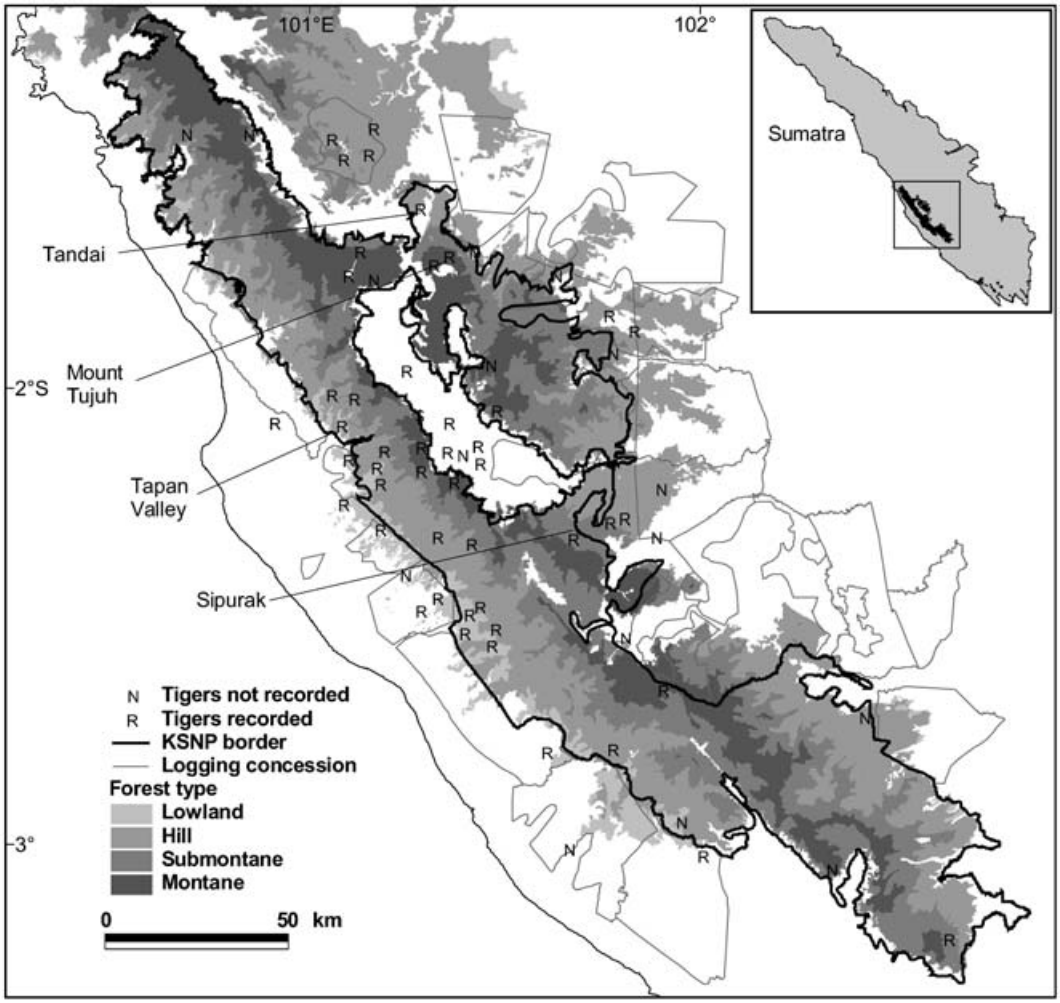

Fig. 1 Locations in which tigers were or were not recorded in Kerinci Seblat National Park and adjoining logging concessions, with the distribution of the four forest types of lowland, hill, submontane and montane (distribution of forest types after Smith & Linkie, 2001). The inset map indicates the position of the Park in Sumatra.

KSNP 13 adult tigers (seven males and six females) and three cubs were recorded (Plate 1). Encounter rates of the photo-traps were higher at lower elevations (125–1,000) than at higher elevations (1,800–2,400 m) (Table 1).

From 184 patrol days, a total of 172 snare traps were found and disabled in and around KSNP. The poaching pressure was greatest for muntjac and lowest for serow and mouse deer (Fig. 2).

Table 1 Number of individual tigers 'caught' by a photo-traps and the encounter rates of the traps at four locations in Kerinci Seblat National Park.

Location	Date	Total trap hours	Forest type	Altitude (m)	Total no. tigers (adult males, adult females, cubs)	Encounter rate (no. days per tiger photo)
Tapan Valley	11/1996-05/1997	31,000	Lowland	125–400	10 (3,4,3)	38
Tandai	07/1996-09/1996	50,000	Degraded/hill	500–900	2 (1,1,0)	74
Sipurak	09/1998-05/1999	28,000	Hill/submontane	600–1,000	3 (2,1,0)	97
Mount Tujuh	04/1997-10/1997	23,000	Submontane/montane	1,800–2,400	1 (1,0,0)	479

https://doi.org/10.1017/S0030605303000103 Published online by Cambridge University Press

Plate 1 Self portrait of an adult male tiger photo-trapped walking along a ridge trail in Tapan Valley (*Jeremy Holden*).

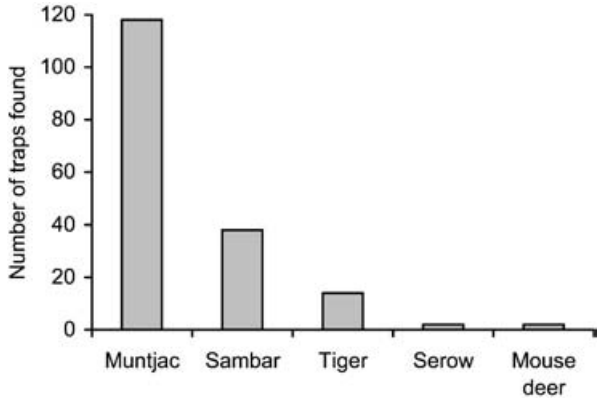

Fig. 2 Poaching pressure on tiger prey species within Kerinci Seblat National Park, as indicated by the number of traps found set for five species.

From 28 TPCU forest patrols conducted during 2000 there were 66 arrests, 10 chainsaw seizures, and 179 confiscations of sawn logs, of which 166 were destroyed and 13 were held as legal evidence. The detection of illicit activities within KSNP generally increased as patrol units contained a greater number of staff (Fig. 3).

The 167 permanent staff of KSNP, comprising 62 office-based personnel and 105 forest police, gives an effective field staff density for the 13,300 km^2 of KSNP of *c*. one staff member per 127 km^2. The 11 members of the TPCU have a staff density of one guard per 1,209 km^2 or, when combined across all law enforcement effort in KSNP, a density of one staff member per 114 km^2.

Discussion

Kerinci Seblat National Park is important for the existence of wild Sumatran tigers because it has large blocks of forest habitat. The inadequate number of staff has, however, resulted in protection being focused in the centre of the Park. This neglects the northern and southern sections that contain lowland hill forest, an important habitat for tigers. Even in the centre of the Park, patrol units could benefit from more staff per unit because poaching pressure on tigers and their prey is high. It is often more difficult for smaller TPCUs to seize chainsaws or make arrests, especially if forest police staff are not present and if confiscations are from large gangs. However, because resources are limited and because of the elongate shape of KSNP, which results in a border of 2,550 km, two units often need to be operational at once, even though single larger units may be more successful in habitat protection.

The staff density for KSNP is clearly insufficient to protect a large area (Leader-Williams *et al.*, 1990). In Luangwa Valley, Zambia, detection of poachers through frequent foot patrols was the greatest disincentive to poaching of black rhino (Milner-Gulland & Leader-Williams, 1992), and the full protection of such vulnerable target species required one guard per 20 km^2 of protected area. To achieve such a staff density in KSNP would require a total of 665 staff. However, in Chitwan National Park, Nepal, where a well-established infrastructure is in place, 80% of rhino poaching between 1990 and 1997 was found to occur in only two locations (Dinerstein *et al.*, 1999). If a similar situation is occurring in KSNP, concentrating TPCU patrols in key areas 'with a mandate to detect and destroy all traps and deter poachers with force if appropriate' (Duckworth & Hedges, 1998) may circumvent the need to protect the whole area, thereby requiring fewer staff.

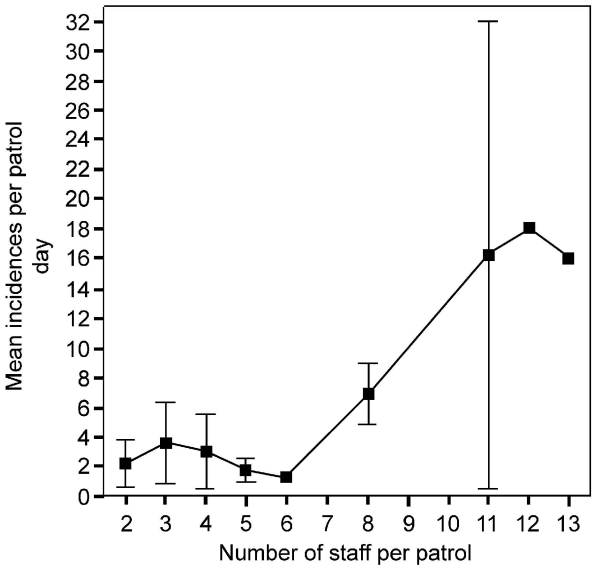

Fig. 3 Mean successful number of arrests (± SD), chainsaw confiscations, and snare traps (both for tigers and prey species) dismantled per day for Tiger Protection and Conservation Unit patrols of different sizes.

https://doi.org/10.1017/S0030605303000103 Published online by Cambridge University Press

Tigers were recorded in all habitat types but most frequently within lowland hill forest. This emphasizes the need to protect this habitat, which occurs at the borders of KSNP (Linkie & Holden, 2002). However, these lower elevation forests experience the greatest human population pressure, with oil palm production, forest fires, commercial and illegal logging, mining operations and pioneer farming all resulting in loss of tiger habitat.

The hill forests of Sipurak, located *c*. 7 km from any human habitation, are an important area for tigers in KSNP (Anon, 2001). The main tiger prey species have been photo-trapped there, in localised patches at the 10 open salt licks in the area (J. Holden, unpub. data). The forest adjoining Sipurak outside KSNP is part of an active logging concession. Selective logging, as in this area, can be more benign than single cycle logging, but its regulation needs to be more stringent (Bennett, 1998). Collateral damage from logging operations at an intensity of 15 trees per ha can be as much as 60% of non-harvested trees (Crome *et al*., 1992). When a concession finishes in Indonesia, or is inadequately policed, illegal sawmills often emerge to remove all commercially viable timber that remains (Jepson *et al*., 2001). Around KSNP illegal logging is now competing directly with legal logging.

In certain circumstances logging and tiger conservation can be compatible (Miquelle *et al*., 1999). Tandai was such an area. Selective logging during the 1980s left a mosaic of primary and secondary, logged forest. This would have increased the plant biomass available to terrestrial herbivores, and created a favourable edge environment in which tigers could hunt, by providing both cover and greater visibility. Photo-trapping in the Tandai area (Table 1), before its clearance, frequently recorded two individuals, an adult male and a female, and the pugmarks of a juvenile tiger were found. Both adult tigers made extensive use of old logging trails. Further forest clearance in Tandai, however, makes compatibility between tigers and logging unlikely in this area.

In Tapan Valley, where tigers were photo-trapped in 1996–1997 (Table 1), forest clearance for farmland that began during commercial logging activities did not, however, create a favourable edge environment for the tiger. During a 6-week field survey in 1999 we did not record any signs of tigers. Semi-structured interviews with 20 local farmers produced a consensus that the once frequently encountered tiger population had decreased over the past 5 years and that tigers had rarely been encountered during the past 2 years. The high level of human activity would not have created a suitable habitat for tigers (Griffith & van Schaik, 1993). The construction of logging roads into the forest increased access, and tiger habitat was converted to farmland (Linkie, 1999). The construction of roads also increases access for poachers (Wilke *et al*., 2000).

On Mount Tujuh extensive photo-trapping in primary rainforest along ridge trails recorded two muntjac, one young sambar, and one porcupine. The high altitude (1,800–2,400 m) may, in part, explain this low occurrence of tiger prey, but a large serow photographed with two snare traps around its neck, and the discovery of eight snare traps set for small to medium sized animals, suggests that this otherwise intact habitat had experienced heavy poaching. Poaching pressure on muntjac was high in KSNP. In an area of forest of 1 km^2 a total of 51 snare traps, mainly set for muntjac, were dismantled on one occasion by a TPCU. Snare traps, however, are relatively selective because they are placed on animal trails. Asian tapir have been discovered in traps set for tiger, two masked palm civets *Paguma larvata* were caught in muntjac snare traps, and a Malay sun bear *Helarctos malayanus* was caught in a wild boar snare trap (Hartana & Martyr, 2001). Four tigers were reported to have died as a result of being accidentally snared in pig and sambar traps (Hartana & Martyr, 2001).

Depletion of tiger prey by hunting and by competition from livestock for land is rapidly becoming the most serious threat to the tiger over large parts of its range (Karanth & Stith, 1999). This may be less of a problem in KSNP because the predominantly Muslim population around the park does not hunt wild boar for meat (Blouch, 1984). However, wild boar are hunted by local communities for sport and trapped by farmers trying to protect their crops. Any concentration of prey species, such as at the farmland-forest edge, attracts tigers, which are also vulnerable to the traps set for these crop pests. The more serious threat, however, comes from direct poaching of tigers, the incentive for which is great.

A tiger skin from Sumatra might have cost US $1,000 during the late 1970s, and the shop price charged by the middlemen increased to *c*. US $3,000 during the mid 1980s (Santiapillai & Widodo, 1985). However, the current price paid for a tiger skin in villages around KSNP is US $400–500, and US $600–700 in provincial capitals. In their first year of operation, the TPCUs have been gathering information on the trade in tigers around KSNP and establishing intelligence networks. These led to the confiscation of one female tiger skin and 4.5 kg of bones from the same tiger, resulting in the poacher's arrest and the first successful prosecution for a tiger-related incident. The 18 month prison sentence for the offender was later reduced on appeal to 9 months because this was a first known offence (Hartana & Martyr, 2001). A recent suggestion that only two tigers were poached from KSNP between 1998 and 1999 (Nowell, 2000) greatly

underestimates the level of poaching. A monitoring program operated by a local non-governmental organization, Fauna & Flora International and WWF indicates that at least 14 tigers were poached from KSNP during this period.

The removal of a few individual tigers from a healthy population may not necessarily affect population growth, because transient tigers may fill any vacant territories (McDougal, 1977), but it does not send out a good message for law enforcement. In KSNP the population of tigers has already been decreased by a variety of other threats, and therefore the poaching of a few individuals may dramatically increase the probability of extinction (Kenney *et al.*, 1994). Although the forest areas patrolled by TPCUs were those identified as a high priority, which could have exaggerated the occurrence of poaching, it was found to be a problem in most of the areas surveyed during this study. This makes effective protection difficult because of the limited number of TPCU staff.

Information collected on human-tiger conflict by KSNP staff during the 1990s documented 34 incidents, comprising both attacks on humans and livestock depredation. In Tapan Valley alone there were seven reported tiger attacks on humans. These reports probably underestimate the problem because information is available only from a small number of villages surrounding KSNP. In addition, tiger attacks are not normally reported to KSNP staff because of a lack of response in the past and because there is no compensation scheme to mitigate human-tiger conflict. Traditional (*adat*) law is often preferred to national law for any resolution or retribution against attacks on humans by tigers. The police or army will often intervene in incidents of human-tiger conflict, and legitimize the killing of a problem animal. This type of removal may be valid as a last resort but it should be tightly regulated by KSNP and TPCU staff, and only considered as part of a decision process that takes all factors into account (including whether it is possible to translocate the problem animal to an area away from human habitation or send it to a captive breeding centre).

Based on our surveys within KSNP and our observations of the operation of the TPCUs, we conclude that future research and management needs to focus on:

- monitoring tiger and prey species using reliable methodologies such as photo-trapping (Karanth & Nichols, 1998) and transect sampling to determine population trends and to allow management strategies to be evaluated,
- determining the rate, location, and factors causing tiger habitat loss, and using this information to identify tiger habitat most at risk and locations where human-tiger conflict will probably be high,
- involvement of KSNP forest police staff with TPCUs through training and coordination of patrol activities, thus allowing the northern and southern sections of the park to be patrolled, conflict areas to be patrolled more frequently, and the provision of cover for TPCUs when they need to pursue wildlife traders outside KSNP and are therefore not able to patrol,
- investigating the possibility of setting up a compensation scheme for villagers that suffer loss, such as of livestock, from living with wild tigers,
- producing guidelines for villagers on how to minimize conflict with tigers through modification of human behaviour and livestock management practices,
- developing an unambiguous protocol that allows problem tigers and complaints about problem tigers to be dealt with promptly and appropriately.

Acknowledgements

We thank Fauna & Flora International, 21st Century Tiger, IUCN/WWF, and the Exxon Mobil Save The Tiger Fund for providing support for the TPCUs. ML is funded by the University of Kent's Alumni Postgraduate Research Scholarship, 21st Century Tiger and the Mammal Conservation Trust. DM, JH, AY and JS thank Fauna & Flora International for continued support of biological diversity studies. We are grateful to the management and staff of KSNP, especially Ir. Listya, Ir. Wandojo and Ir. Anwar, the Indonesian Academy of Sciences and the Department of Forestry and Nature Protection for assisting us in our research. We have a debt of gratitude to the unwavering commitment and diligence of the TPCU staff. Kurt Woofner provided encouragement and provisions. Dr Frank Lambert, Dr Bob Smith and Sarah Christie are thanked for reviewing and making useful comments on an earlier manuscript. Dr Frank Lambert and Habib Subagio (Kerinci Seblat-Integrated Conservation and Development Programme Component C) kindly provided logging concession data.

References

Anon. (2001) *Biodiversity Hotspots of the Kerinci-seblat Ecosystem: the Sipurak Hook, Kabupaten Merangin, Jambi. Justification for its Conservation and Options for Protection Strategy*. KS-ICDP Component C1, Technical Report 1, Jaakko Pöyry, Jakarta, Indonesia.

Bennett, C.P.A. (1998) *Logging for Conservation: Forest Concession as Contributors to Conservation in Kerinci Seblat National Park and its Buffer Zone*. KS-ICDP Component D, Technical Report, Agriconsulting SPA, Jakarta, Indonesia.

Blouch, R.A. (1984) *Current Status of the Sumatran Rhino and Other Large Mammals in Southern Sumatra*. Project 3033 Final Report, IUCN/WWF Indonesia Programme, Bogor, Indonesia.

Borner, M. (1979) *A field study of the Sumatran rhinoceros (*Dicerorhinus sumatrensis *Fischer 1814)*. PhD thesis, Universität Basel, Basle, Switzerland.

Bowles, I.A., Rice, R.E., Mittermeier, R.A. & da Fonseca, G.A.B. (1998) Logging and tropical forest conservation. *Science*, **280,** 1899–1900.

Caughley, G. (1994) Directions in conservation biology. *Journal of Animal Ecology*, **63,** 215–244.

Crome, F.H.J., More, L.A. & Richards, G.C. (1992) A study of logging damage in upland rainforest in north Queensland. *Forest Ecology and Management*, **49,** 1–29.

Departemen Kehutanan (1995) *Rencana Pengelolaan Taman Nasional Kerinci Seblat 1995–2019*. Data, Proyeski, Dan Analisis book II, Indonesia. [Foresty Department, Kerinci Seblat National Park Management Programme. Data Projection and Analysis].

Dinerstein, E., Rijal, A., Bookbinder, M., Kattel, B. & Rajuria, A. (1999) Tigers as neighbours: efforts to promote local guardianship of endangered species in lowland Nepal. In *Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes*, (eds J. Seidensticker, S. Christie, & P. Jackson), pp. 316–333, Cambridge University Press, Cambridge, UK.

Duckworth, J.W. & Hedges, S. (1998) *Tracking Tigers: a Review of the Status of Tiger, Asian Elephant, Gaur and Banteng in Vietnam, Lao, Cambodia and Yunnan (China), with Recommendations for Future Conservation Action*. WWF Indochina programme, Hanoi, Viet Nam.

Faust, T. & Tilson, R. (1994) Estimating how many tigers are in Sumatra: a beginning, In *Sumatran Tiger Population and Habitat Viability Report* (eds R.L. Tilson, K. Soemarna, W. Ramono, S. Lusli, K. Traylor-Holzer & U.S. Seal), pp. 11–38. Indonesian Directorate of Forest Protection and Nature Conservation and IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, USA.

Ginsberg, J.R. & Macdonald, D.W. (1990) *Canid Action Plan*. IUCN, Gland, Switzerland.

Griffith, M. & van Schaik, C.P. (1993) The impact of human traffic on the abundance and activity periods of Sumatran rain forest wildlife. *Conservation Biology*, **7,** 623–626.

Hartana, A.T. & Martyr, D. (2001) *Pelestarian Harimau Sumatera Kerinci-Seblat [Kerinci Seblat Sumatran Tiger Protection Programme]*. Unpublished report, Kerinci Seblat National Park and Fauna & Flora International, Sungai Penuh, Indonesia.

Holden, J. (2001) Small cats in Kerinci Seblat National Park, Sumatra, Indonesia. *Cat News*, **35,** 11–14.

Holden, J., Yanuar, A. & Martyr, D. (2003) Asian tapir in Kerinci Seblat National Park, Sumatra: evidence collected through photo-trapping. *Oryx*, **37,** 34–40.

Holmes, D. (2001) *Deforestation in Indonesia: A Review of the Situation in Sumatra, Kalimantan, and Sulawesi*. World Bank, Jakarta, Indonesia.

IUCN (2002) *2002 IUCN Red List of Threatened Species*. http://www.redlist.org [accessed 29 October 2002].

James, A.N., Gaston, K.J. & Balmford, A. (1999) Balancing the Earth's accounts. *Nature*, **401,** 323–324.

Jepson, P., Jarvie, J.K., MacKinnon, K. & Monk, K. (2001) The end for Indonesia's lowland forests? *Science*, **292,** 859–861.

Karanth, K.S. & Nichols, J.D. (1998) Estimation of tiger densities in India using photographic captures and recaptures. *Ecology*, **79,** 2852–2862.

Karanth, K.S. & Stith, B.M. (1999) Prey depletion and tiger population viability. In *Riding The Tiger: Tiger Conservation in Human-Dominated Landscapes*, (eds J. Seidensticker, S. Christie, & P. Jackson), pp. 100–113, Cambridge University Press, Cambridge, UK.

Kenney, J.S., Smith, J.L.D., Starfield, A.M. & McDougal, C.W. (1994) The long-term effects of tiger poaching on population viability. *Conservation Biology*, **9,** 1127–1133.

Lande, R. (1988) Genetics and demography in biological conservation. *Science*, **241,** 1455–1460.

Leader-Williams, N. & Albon, S.D. (1988) Allocation of resources for conservation. *Nature*, **336,** 533–535.

Leader-Williams, N., Albon, S.D. & Berry, P.S.M. (1990) Illegal exploitation of black rhinos and elephant populations: patterns of decline, law enforcement and patrol effort in Luangwa Valley, Zambia. *Journal of Applied Ecology*, **27,** 1055–1087.

Linkie, M. & Holden, J. (2002) The enigma of tigers in Kerinci Seblat National Park, Indonesia. *Cat News*, **36,** 2–3.

Linkie, M. (1999) *Using a Geographic Information System to assess the importance of lowland rainforest habitat in Tapan Valley, Kerinci Seblat National Park: the tiger as a case study*. MSc thesis, University of Kent, Canterbury, UK.

Martyr, D. (1997) Important findings by FFI team in Kerinci Seblat, Sumatra, Indonesia. *Oryx*, **31,** 80–82.

McDougal, C. (1977) *The Face of the Tiger*. Rivington Books, London, UK.

Mills, J.A. & Jackson, P. (1994) *Killed for A Cure: A Review of the World-wide Trade in Tiger Bone*. TRAFFIC International, Cambridge, UK.

Milner-Gulland, E.J. & Leader-Williams, N. (1992) A model of incentives for the illegal exploitation of black rhinos and elephants: poaching pays in Luangwa Valley, Zambia. *Journal of Applied Ecology*, **29,** 388–401.

Miquelle, D.G., Merrill, T.W., Dunishenko, Y.M., Smirnov, E.N., Quigley, H.B., Pikunov, D.G. & Hornocker, M.G. (1999) A habitat protection plan for the Amur tiger: developing political and ecological criteria for a viable land use plan. In *Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes*, (eds J. Seidensticker, S. Christie & P. Jackson), pp. 273–295. Cambridge University Press, Cambridge, UK.

Nowell, K. & Jackson, P. (1996) *Wild Cats: Status Survey and Conservation Action Plan*. IUCN, Gland, Switzerland.

Nowell, K. (2000) *Far From A Cure: the Tiger Trade Revisited*. TRAFFIC International Cambridge, UK.

Plowden, C. & Bowles, D. (1997) The illegal market in tiger parts in northern Sumatra, Indonesia. *Oryx*, **31,** 59–66.

Santiapillai, C. & Widodo, R.S. (1985) On the Status of the Tiger (*Panthera tigris sumatrae* Pocock, 1829) in Sumatra. *Tigerpaper*, **12,** 23–29.

Schaller, G.B. & Crawshaw, P. (1980) Movement patterns of a jaguar. *Biotropica*, **12,** 161–168.

Seidensticker, J. (1986) Large carnivores and consequences of habitat insularization: ecology and conservation of tigers in Indonesia and Bangladesh. In *Cats of the World: Biology, Conservation and Management* (eds S.D. Miller & D.D. Everett), pp. 1–41. National Wildlife Foundation, Washington, D.C., USA.

Smith, R. & Linkie, M. (2001) *Measuring and Predicting Forest Loss in the Kerinci Seblat ICDP Project Area*. US-ICDP Component D, Technical Report, Agriconsulting SPA, Jakarta, Indonesia.

Tilson, R.L., Soemarna, K., Ramono, W., Lusli, S., Traylor-Holzer, K. & Seal, U.S. (eds) (1994) *Sumatran Tiger Population and Habitat Viability Report*. Indonesian Directorate of Forest Protection and Nature Conservation and IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, USA.

Whitmore, T.C. (1984) A new vegetation map of Malesia at scale 1:5 million. *Journal of Biogeography*, **11,** 461–471.

Wikramanayake, E.D., Dinerstein, E., Robinson, G., Karanth, U.K., Rabinowitz, A., Olson, D., Matthew, T., Hedao, P., Connor, M., Hemley, G. & Bolze, D. (1998) An ecology-based method of defining priorities for large mammal conservation: the tiger as a case study. *Conservation Biology*, **12,** 865–878.

Wilke, D., Shaw, E., Rotberg, F., Morelli, G. & Auzel, P. (2000) Roads, development, and conservation in the Congo Basin. *Conservation Biology*, **14,** 1614–1622.

Woodroffe, R. & Ginsberg, J.R. (1998) Edge effects and the extinction of populations inside protected areas. *Science*, **280,** 2126–2128.

Biographical sketches

Matthew Linkie is investigating the impact of edge effects caused by farmland encroachment on tiger and their prey species in Kerinci Seblat National Park, where he previously studied local level deforestation caused by pioneer farming, logging and coal mining activities.

Dr Jito Sugardjito has worked on the ecological constraints and grouping behaviour of orang-utans in Gunung Leuser National Park in northern Sumatra. He formerly directed the WWF-US Indonesian Program, and is now Chairman of the Borneo Orang-utan Society Foundation's scientific advisory board, and coordinator for the Fauna & Flora International-Indonesia Programme.

Professor Nigel Leader-Williams currently holds the Ibnu Sutowo chair of Biodiversity Management at the University of Kent, and is Director of the Durrell Institute of Conservation and Ecology. He has studied the ecology of introduced reindeer on South Georgia, the ecology and conservation of black rhinos, and was an Advisor to the government of Tanzania on wildlife policy.

https://doi.org/10.1017/S0030605303000103 Published online by Cambridge University Press