Using BAD for good: how best available data facilitated a precautionary policy change to improve protection of the prey of the tiger *Panthera tigris* in Malaysia

Kae Kawanishi, Gopalasamy Reuben Clements, Melvin Gumal
Gareth Goldthorpe, Mohd Nawayai Yasak and
Dionysius Shankar Kumar Sharma

Abstract Tiger *Panthera tigris* populations are under threat from poaching and depletion of their prey populations. The National Tiger Action Plan for Malaysia contains several actions addressing the threat of legal and illegal hunting of tiger prey species. One action in this plan required an investigation of whether urgent policy changes were needed to improve the protection of the prey of tigers, based on existing data. As the lack of reliable baseline data prevented us from determining population trends accurately, we compiled camera-trapping data from 23 studies conducted between 1997 and 2008 on four principal tiger prey species (sambar *Rusa unicolor*, barking deer *Muntiacus muntjac*, wild boar *Sus scrofa* and bearded pig *S. barbatus*) and two potential prey species (gaur *Bos gaurus* and Malayan tapir *Tapirus indicus*) and compared their distributions and relative abundances. From 10,145 wildlife photographs spanning 40,303 trap-nights, sambar, bearded pig and gaur appeared to be most threatened given their restricted distribution and low relative abundance. Among these, the gaur has full legal protection and has received more conservation attention than the other two species. Following our assessment and advocacy a 6-year moratorium on hunting both sambar and barking deer was imposed by the Malaysian government and the highest protection status possible was afforded the bearded pig. This case study illustrates how best available data (BAD), in this case from camera-trapping studies, can be harnessed to effect precautionary policy changes to curb the impacts of hunting on threatened predator and prey populations that could crash well before resources would otherwise be available for rigorous scientific assessments.

Keywords Barking deer, bearded pig, camera trap, gaur, sambar, tapir, tiger, wild boar

This paper contains supplementary material that can be found online at http://journals.cambridge.org

Introduction

Although poaching has been shown to be the most serious short-term threat to the tiger *Panthera tigris* (Chapron et al., 2008), prey depletion may also be an extinction driver for this species (Karanth & Stith, 1999). In tiger range states such as Malaysia lobbying efforts have focused on amending outdated legislation to impose harsher penalties on poachers and consumers of tigers. However, improved protection of threatened ungulates to mitigate the threat of depletion of the tiger's prey has received comparatively less attention.

Across its range the tiger's prey base generally consists of various species of deer, wild pigs and wild cattle (Sunquist et al., 1999). Dietary studies on tigers in Peninsular Malaysia are lacking but the principal prey probably include large (> 20 kg) ungulates such as wild boar *Sus scrofa*, barking deer *Muntiacus muntjac* and sambar *Rusa unicolor* (DWNP, 2008). In southern Peninsular Malaysia the bearded pig *Sus barbatus* can be included in this list. However, it is uncertain whether the gaur *Bos gaurus* and Malayan tapir *Tapirus indicus* are preyed upon. Given the opportunity tigers may hunt tapirs, as indicated by a few records (Hislop, 1951; McClure, 1963). Adult male gaurs, which can weigh up to ten times more than adult tigers, are not ideal tiger prey but calves could conceivably be hunted.

In Malaysia tiger prey populations appear to be declining. Baseline figures for prey populations have been difficult to establish because of the challenges of estimating inherently low densities of ungulates in dense rainforests.

Kae Kawanishi (Corresponding author) Malaysian Conservation Alliance for Tigers Secretariat's Office, Unit 3, Ground Floor, Jln SS 23/11, Taman SEA, 47400 Petaling Jaya, Selangor, Malaysia. E-mail kae@malayantiger.net

Gopalasamy Reuben Clements* and Dionysius Shankar Kumar Sharma WWF–Malaysia, Selangor, Malaysia

Melvin Gumal Wildlife Conservation Society–Malaysia Programme, Selangor, Malaysia

Gareth Goldthorpe Fauna & Flora International, Cambridge, UK

Mohd Nawayai Yasak Department of Wildlife and National Parks Peninsular Malaysia, Kuala Lumpur, Malaysia

*Current address: Centre for Tropical Environmental and Sustainability Science and School of Marine and Tropical Biology, James Cook University, Cairns, Queensland, Australia, and Centre for Malaysian Indigenous Studies, University of Malaya, Kuala Lumpur, Malaysia

Received 7 October 2011. Revision requested 13 December 2011. Accepted 23 February 2012.

TABLE 1 Summary of the protected status and information on hunting licences for the six large ungulate species in Peninsular Malaysia in 2008.

	IUCN Red List category[1]	CITES[2]	Protection of Wild Life Act 1972	Hunting season	Quota (no. of animals per licence)	Cost of licence (MYR)[3]
Sambar *Rusa unicolor*	VU	Unregulated	Protected game species	November	1	200
Gaur *Bos gaurus*	VU	Appendix 1	Totally protected	None		
Bearded pig *Sus barbatus*	VU	Unregulated	Protected game species	None		
Malayan Tapir *Tapirus indicus*	EN	Appendix 1	Totally protected	None		
Wild boar *Sus scrofa*	LC	Unregulated	Protected game species	Year-round	Unlimited	20, 50, 100, 200 for 1, 3, 6, or 12 months
Barking deer *Muntiacus muntjac*	LC	Unregulated	Protected game species	November	1	100

[1]LC, Least concern; VU, Vulnerable; EN, Endangered (IUCN, 2008)
[2]Trade in species on Appendix 1 of CITES (CITES, 2008) is permitted only in exceptional circumstances
[3]DWNP (2009); MYR 3=USD 1

Furthermore, the sampling effort and resources (i.e. manpower and funding) required to establish baselines for populations of large mammals in developing countries such as Malaysia often exceed the capacities of both governments and NGOs. Among large mammals in Peninsular Malaysia, scientifically defensible density estimates are only available for tigers (e.g. Kawanishi & Sunquist, 2004; Darmaraj & Shariff, 2009) and Asian elephants *Elephas maximus* (Hedges et al., 2008; Gumal et al., 2009).

Poaching has long been regarded as the major threat to ungulates in Peninsular Malaysia (Mohd Khan, 1968; Zaaba et al., 1991; DWNP, 1992; Misliah & Sahir, 1997; Abdul Kadir, 1998) and, along with habitat loss, is probably the main driver of declining tiger prey populations. Despite being considered totally protected or protected game species under the Protection of Wild Life Act 1972, some species can still be legally hunted (Table 1). Based on our recent camera-trapping data, however, certain tiger prey species such as sambar have become harder to detect outside protected areas. According to an interview-based survey to assess perceived changes in the abundance of wild ungulate populations (Goldthorpe & Neo, 2011) respondents from all survey areas admitted that sambar were hunted illegally throughout the year, despite an 11-month closed hunting season. In discussions with the Malaysian government the regulation of legal hunting has also proven difficult with respect to species such as bearded pig that, together with the more common wild boar, continues to be indiscriminately hunted despite no licences having been issued for the former. Thus the conservation status of tiger prey species requires an evaluation using the best available data (BAD).

In 2008 we carried out an assessment on 'the current status of the sambar deer, barking deer, bearded pig and wild boar based on existing information to justify the needs for better protection' (Action 2.2.2 of the National Tiger Action Plan, DWNP, 2008). This assessment (Kawanishi, 2008) was timely given increasing reports of poaching in Malaysia's forests (e.g. Murali, 2009; TRAFFIC South-east Asia, unpubl. data), and mounting evidence of significant range contractions of ungulates such as the bearded pig (Kawanishi et al., 2006).

Ideally, policy changes for tiger prey management should be based on sound population data. However, the potential for tiger prey populations to be completely depleted in a relatively short time was seen as sufficient reason to use best available data to help conserve the tiger and associated prey species. There is precedence in adopting such a precautionary approach in conservation: Principle 15 of the Rio Declaration at the 1992 Earth Summit states 'In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.' Since then, the need for applying the precautionary principle has been reiterated in numerous wildlife management scenarios (e.g. Olea et al., 2009; but see Jepson et al., 2001).

Here, we present the synthesis of best available data from camera-trapping studies, to elucidate whether any of the six prey or potential prey species of the tiger (gaur, sambar, barking deer, wild boar, bearded pig and Malayan tapir) warrant improved legal protection in Peninsular Malaysia. We also explain how the results of this assessment were used by conservation NGOs and the government to improve legal protection for tiger prey.

Methods

To make crude comparisons of the abundance and distribution of our focal species, data from long-term

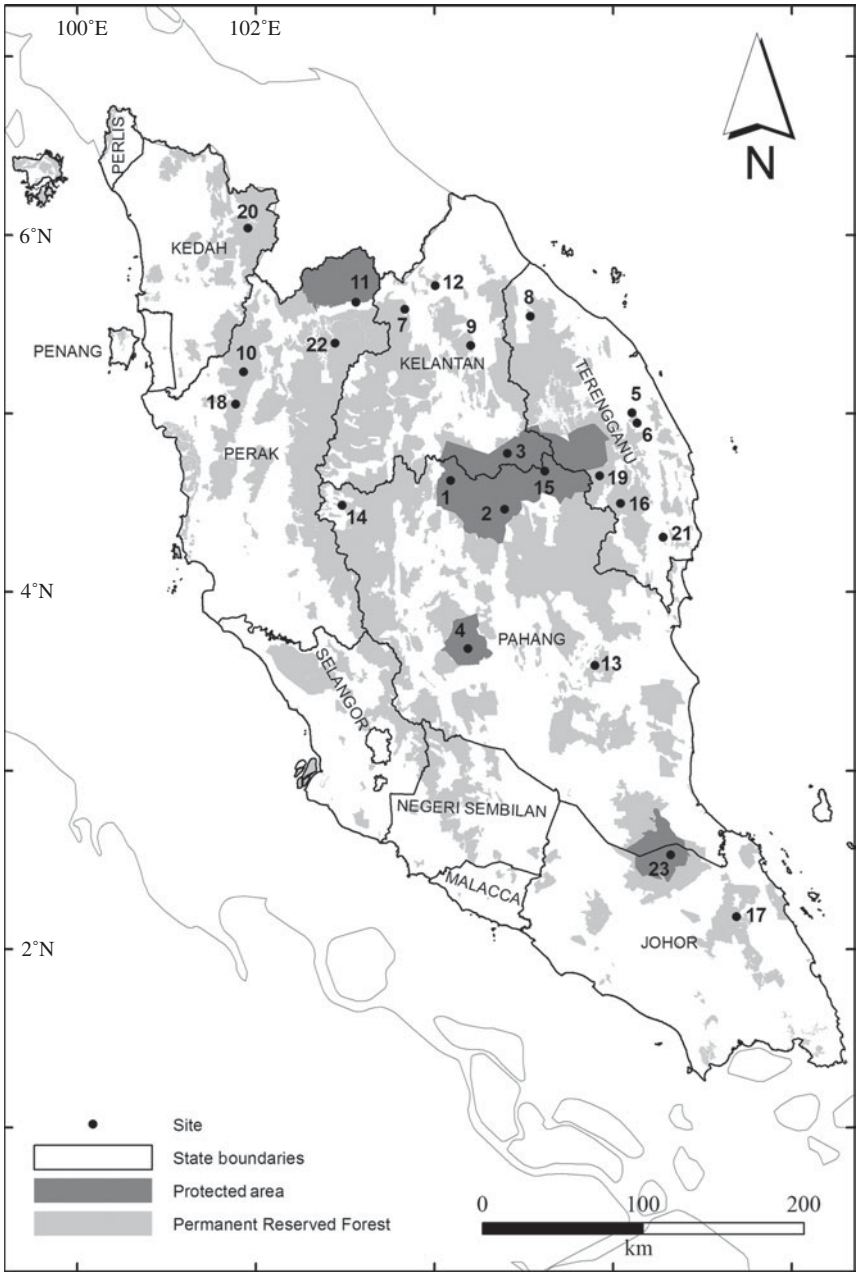

FIG. 1 The 23 camera-trapping study sites (see Supplementary Table S1 for locality names) within protected areas and forest reserves across Peninsular Malaysia.

and rapid assessment camera-trapping studies conducted at 23 sites in Peninsular Malaysia (Fig. 1) between 1997 and 2008 were compiled from published (Laidlaw et al., 2000; DWNP/DANCED, 2001; Kawanishi & Sunquist, 2004; Sharma & Ahmad Zafir, 2005, 2007; Ahmad Zafir et al., 2006; Ahmad Zafir & Sharma, 2006; Darmaraj, 2007; Lynam et al., 2007; Shariff et al., 2010) and unpublished sources (WWF–Malaysia and Wildlife Conservation Society–Malaysia Programme/Johor National Parks Corporation). Most of these studies targeted tigers, with cameras set on active game trails to maximize detection probability, and so biases towards detection of tigers were expected. For the purposes of our assessment, however, detection probabilities were assumed to be constant temporally and spatially for our focal ungulate species. Detection (i.e. locations of confirmed presence) and non-detection (i.e. locality sampled but target species not detected) data were used to generate a distribution map for the six species. Non-detection either means (1) true absence of the species, or (2) false absence (i.e. failure to detect the species when present). Our assessment did not attempt to differentiate between the two, and thus the results were interpreted with caution and emphasis was placed on the pattern of sites with confirmed presence. For comparing relative abundance we assumed that true abundance has a positive and constant relationship with the rate of photographs taken (the detection rate; see Supplementary Information 1 for supporting information).

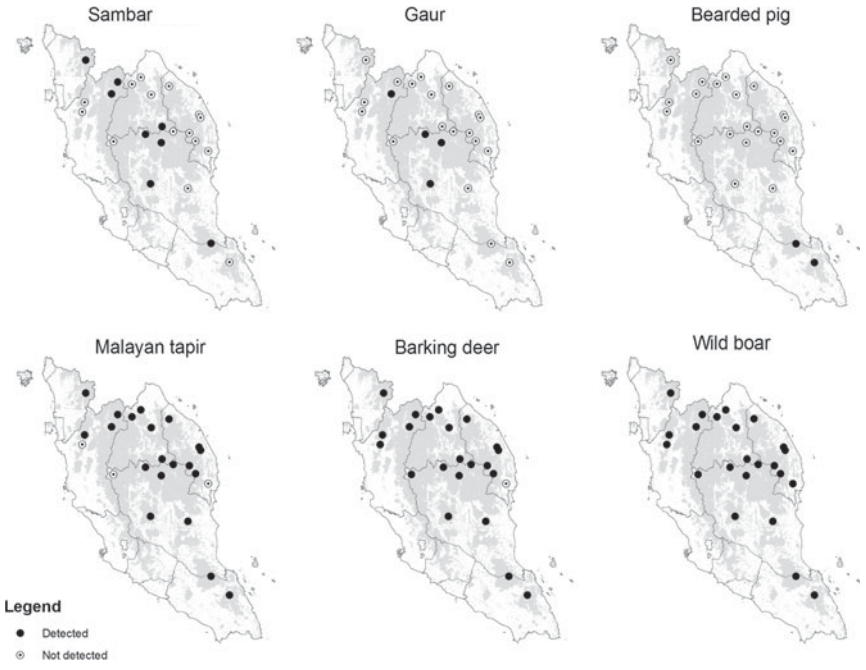

FIG. 2 Detection/non-detection of six tiger prey species between 1997 and 2008 in 23 camera-trapping study sites across Peninsular Malaysia (see Fig. 1 for numbered locations).

Results

The combined sampling effort of 23 camera-trapping studies spanned 40,303 trap-nights and gave a total of 10,145 photographs of species of wild mammals. Six of the studies were in protected areas where c. half of the trapping effort (n = 20,651) was spent. The areas sampled ranged from 6.3 to 400 km^2 and total trap-nights per site were 120–5,970 nights. We used the collated data to construct a detection/non-detection map of ungulates from sampled sites in Peninsular Malaysia (Fig. 2). The details of our assessment are given in Supplementary Table S1.

The three most commonly detected ungulate species (in order of increasing mean detection rates) were Malayan tapir, barking deer and wild boar (Fig. 3). However, the relative abundance of wild boar should be considered conservative as it is a gregarious species. These three species were also the most widely detected species based on the number of sites (i.e. 20, 22 and 23 sites, respectively; Fig. 2).

The three least detected ungulate species (in order of decreasing mean detection rates) were sambar, bearded pig and gaur (Fig. 3). These three species were also detected in the least number of sites (i.e. 8, 2 and 4 sites respectively; Fig. 2). Of 414 photos of sambar, 346 (84%) were from protected areas; this was higher than expected when the proportion of the sampling efforts in protected areas and non-protected areas were accounted for ($X^2 = 41.9$, df = 1, $P < 0.001$). This indicates their relative rarity in unprotected forests. Bearded pigs were only detected in the southern half of the Peninsula, whereas detections of gaur were restricted to two protected areas and none were detected in the southern peninsula (Fig. 2).

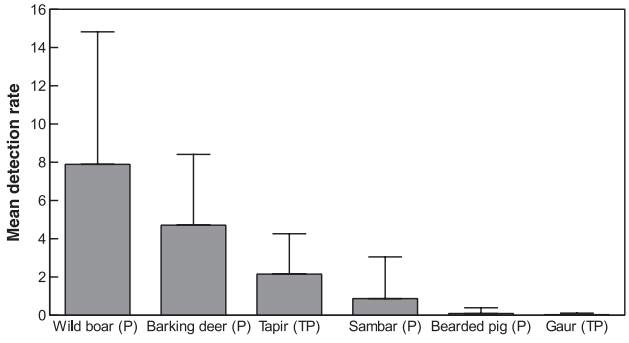

FIG. 3 Mean detection rates (number of photographs per 100 trap-nights), based on 23 camera-trapping studies conducted in Peninsular Malaysia between 1997 and 2008 (see Fig. 1 for numbered locations), of six tiger prey species, with their protected status (P, protected; TP, totally protected). The error bars represent one standard deviation.

Discussion

Sambar and bearded pig require better legal protection

Based on the best available data, tiger prey species such as sambar and bearded pig appear to be as threatened as the totally protected gaur, with all three species having low relative abundance across Peninsular Malaysia. There is a paucity of detections and reliable information on sambar from sites outside protected areas. In two prolonged (> 9 months) camera-trapping studies (Ahmad Zafir et al., 2006; Darmaraj, 2007) in two forest reserves (also known as selectively logged forests), sambar were not detected despite high sampling effort (7,631 and 2,664 trap-nights, respectively). An ongoing study in the largest forest reserve (1,948 km^2),

adjacent to the country's largest protected area (Taman Negara), has yet to detect this species (Kawanishi et al., 2011). Even within Taman Negara, sambar were not as abundant or widespread as other ungulates; an estimate of sambar density in a 200 km^2 area was c. 0.16 individuals per km^2, one order of magnitude lower than estimates of wild boar and barking deer densities (Kawanishi & Sunquist, 2004). These conclusions are corroborated by local resource users. An interview-based survey conducted in 18 villages around the country found a general consensus amongst hunters and wildlife dealers (n = 61) that both sambar and barking deer populations are either reduced or locally extinct, with many indicating overhunting as the primary cause (Goldthorpe & Neo, 2011). It is surprising that the sambar appears to be becoming scarcer than the tapir, despite the latter's greater body mass, energetic needs and hence lower intrinsic rate of increase (Caughley & Krebs, 1983). The implication is that external factors such as overhunting are probably responsible. Tapirs are relatively more abundant, probably because they are not highly prized as game animals (Kawanishi et al., 2002). However, the contraction of the range of the sambar in Peninsular Malaysia cannot be demonstrated conclusively as its historical distribution has never been assessed. Nevertheless, its sparse distribution and low numbers in Malaysia have been documented in the country report for the IUCN Red List (IUCN, 2008).

Our results also corroborate the suspected extirpation of bearded pig populations in the northern half of Peninsular Malaysia. The bearded pig is known to be a migratory species, following mast fruiting of dipterocarp trees. This species used to be fairly abundant and widespread but has suffered severe population declines because of hunting (Caldecott et al., 1993) and habitat loss over the past 60 years (Kawanishi et al., 2006). Prior to the 1950s bearded pigs were widely reported from the northern, central and southern areas of Peninsular Malaysia (i.e. southern Perak, southern and eastern Pahang, Negri Sembilan and Johor; Allen, 1948; Kempe, 1948; Hislop, 1949). This species now appears restricted to Endau Rompin State Park and neighbouring forest reserves from southern Pahang to eastern Johor. The impacts of hunting on bearded pigs remain difficult to quantify because of the lack of long-term data but hunters licensed to take wild boar are probably killing them, incidentally or intentionally, year-round.

The discussion and lobbying process

At the time of this study (Kawanishi, 2008) the Protection of Wild Life Act 1972 was considered by civil society to be outdated and its penalties were deemed ineffective in deterring illegal hunting (e.g. Damis, 2009). The Tiger Action Plan addressed these faults to some degree but there was insufficient justification to effect changes in this law prior to our study. At the end of 2008 we presented our recommendations (Supplementary Information 2) for improved legal and regulatory protection of tiger prey species (except for gaur and tapir as they already had the highest legal protection status) to the local wildlife authority, the Department of Wildlife and National Parks. Subsequently the Department, with technical support from the Wildlife Conservation Society–Malaysia Programme, carried out a second assessment focusing on wildlife inventory and camera-trapping data for Taman Negara, and the results supported our findings. Concurrently, three of the country's main conservation NGOs (TRAFFIC South-east Asia, WWF–Malaysia and the Malaysian Nature Society) launched media campaigns designed to raise public awareness of the need to change the status of the sambar and bearded pig in Malaysia's wildlife legislation. Local and international pressure to amend the laws were also instrumental in the lobbying process and a petition, circulated by the three NGOs and signed by c. 56,000 people globally, was handed to the government.

Policy change and implementation of the Tiger Action Plan

In the face of overwhelming public concern the Department of Wildlife and National Parks initiated a 2-year moratorium in 2009 on the issuance of hunting licences for sambar and barking deer. Following our recommendation for a hunting ban of 5–8 years (Supplementary Information 2) the 2-year moratorium was extended to 6 years, which effectively implemented Action 2.2.1 of the National Tiger Action Plan for Malaysia (DWNP, 2008). Since then, NGOs and various researchers have commenced studies at various sites to establish scientifically defensible baselines for tiger prey species, to facilitate long-term monitoring of population trends and to assess the impact of the moratorium (Action 2.2.3, Tiger Action Plan; DWNP, 2008). The method involves sign surveys within an occupancy framework to account for imperfect detections (McKenzie et al., 2002).

Meanwhile, local and international pressure to improve the 30-year old Protection of Wild Life Act 1972 escalated in the millennium's first Year of the Tiger. A new and improved Wildlife Conservation Act 2010 was finally passed by the Cabinet in August 2010 and became fully enforced by December 2010 (Action 2.1.2, Tiger Action Plan; DWNP, 2008). Under this new law the bearded pig was afforded the highest protection status. Subsequently, the government and NGO partners publicized these changes in wildlife legislation and hunting regulation through the media, talks and community outreach programmes (Action 2.1.3 and 2.2.6, Tiger Action Plan; DWNP, 2008).

We have demonstrated that best available data can sometimes be used to improve legal protection of threatened mammals when baselines are absent. Furthermore, we have shown that it was such data that facilitated the implementation of certain actions in the Tiger Action Plan, the best blueprint for tiger conservation in Malaysia. Scientists should, of course, strive to collect data from peer-reviewed, long-term monitoring programmes, to improve conservation policies, but the precautionary principle should be invoked when there is new evidence suggesting the decline of populations of threatened species. Despite the shortcomings of our assessment, a combination of long-term biological information, cooperation, public awareness and determination eventually led to changes in the legal and regulatory framework to improve protection of threatened ungulates and, by association, the country's apex predator, the Malayan tiger. The greater long-term challenge, however, lies in the stringent enforcement of this new and improved legal framework, as well as in monitoring the recovery of tiger prey species that have been granted a reprieve from licensed hunting pressure.

Acknowledgements

We thank three anonymous reviewers, Arun Venkataraman, Loretta Ann Shepherd and Mark Ryan Darmaraj for useful discussions on this subject and for reviewing earlier drafts of this article, and Ahmad Zafir, Mark Rayan Darmaraj and Shariff Wan Mohamad of WWF–Malaysia and the Johor National Parks Corporation for making unpublished data available. The preparation of the original report was made possible with financial support from the National Fish and Wildlife Foundation's Save the Tiger Fund.

References

Abdul Kadir, A.H. (1998) Potential threats to Sumatran rhinoceros population in Belum Valley. *Journal of Wildlife and Parks*, 16, 156–157.

Ahmad Zafir, A.W., Lee, B., Sharma, D.S.K. & Jayasilan, M.A. (2006) *Tiger Ecology Study in FELDA Jerangau Barat, Peninsular Malaysia*. WWF–Malaysia, Petaling Jaya, Malaysia.

Ahmad Zafir, A.W. & Sharma, D.S.K. (2006) Rapid Assessment of terrestrial mammals in Gunung Mandi Angin. In *Gunung Mandi Angin Terengganu, Pengurusan, Persekitaran Fizikal, Kepelbagaian Biologi dan Pelancongan Ekologi (Volume 7)* (eds A. Muda, N. Jaafar, R. Sabran, J. Md Som, M.S. Nizam & A. Latiff), pp. 475–480. Jabatan Perhutanan Semenanjung Malaysia, Kuala Lumpur, Malaysia.

Allen, E. E. (1948) The bearded pig. *Malayan Nature Journal*, 13, 31.

Caldecott, J.O., Blouch, R.A. & MacDonald, A.A. (1993) The bearded pig (*Sus barbatus*). In *Pigs, Peccaries, and Hippos: Status Survey and Conservation Action Plan* (ed. W.L.R. Oliver), pp. 136–145. IUCN, Gland, Switzerland.

Caughley, G. & Krebs, C. J. (1983) Are big mammals simply little mammals writ large? *Oecologia*, 59, 7–17.

Chapron, G., Miquelle, D.G., Lambert, A., Goodrich, J.M., Legendre, S. & Clobert, J. (2008) The impact on tigers of poaching versus prey depletion. *Journal of Applied Ecology*, 45, 1667–1674.

CITES (2008) Http://www.cites.org [accessed 8 October 2008].

Damis, A. (2009) Wildlife to bite back. *New Straits Times*. 19 July.

Darmaraj, M. R. (2007) *Tiger Monitoring Study in Gunung Basor Forest Reserve, Jeli, Kelantan*. WWF–Malaysia, Petaling Jaya, Malaysia.

Darmaraj, M.R. & Shariff, W.M. (2009) The importance of selectively logged forests for tiger conservation: a population density estimate of tigers *Panthera tigris* in Peninsular Malaysia. *Oryx*, 43, 1–4.

DWNP (Department of Wildlife and National Parks) (1992) *Wildlife Plan for Peninsular Malaysia*. DWNP, Kuala Lumpur, Malaysia.

DWNP (Department of Wildlife and National Parks) (2008) *National Tiger Action Plan*. DWNP, Kuala Lumpur, Malaysia.

DWNP (Department of Wildlife and National Parks) (2009) Types and fees of license of DWNP. Http://www.wildlife.gov.my/webpagev4_en/bhg_ukkPenguatkuasaan_JenisLesen&Fi.html [accessed 7 June 2009].

DWNP/DANCED (Department of Wildlife and National Parks/Danish Cooperation for Environment and Development) (2001) *Krau Wildlife Reserve Management Plan*. Unpublished document. Department of Wildlife and National Parks, Kuala Lumpur, Malaysia.

Goldthorpe, G. & Neo, S.H. (2011) A preliminary investigation into the effects of hunting on three large ungulate species in Peninsular Malaysia, with implications for tiger conservation. *Malayan Nature Journal* 63, 549–560.

Gumal, M., Oziar, A., Wong, E. P., Chin, C., Ng, S. & Hedges, S. (2009) *WCS/GoM Peninsular Malaysia Elephant Project, Year 2: Asian Elephant Surveys and Capacity-building in Endau Rompin National Park, Peninsular Malaysia. Final Report to the U.S. Fish & Wildlife Service, March 2009*. Wildlife Conservation Society, Bronx, USA.

Hedges, S., Gumal, M. & Ng, S. (2008) *WCS/GoM West Malaysian Elephant Project: Year 1, Elephant surveys and training in Taman Negara National Park, Malaysia. Final Report to the U.S. Fish and Wildlife Service, December 2008*. Wildlife Conservation Society, Bronx, USA.

Hislop, J.A. (1949) Field notes on the bearded pig. *Malayan Nature Journal*, 4, 62–64.

Hislop, J.A. (1951) The story of a tapir. *Malayan Nature Journal*, 5, 92–95.

IUCN (2008) *IUCN Red List of Threatened Species*. Http://www.iucnredlist.org [accessed 8 October 2008].

Jepson, P., Brickle, N. & Chayadin, Y. (2001) The conservation status of Tanimbar corella and blue-streaked lory on the Tanimbar Islands, Indonesia: results of a rapid contextual survey. *Oryx*, 35, 224–233.

Karanth, K.U. & Stith, B.M. (1999) Prey depletion as a critical determinant of 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.

Kawanishi, K. (2008) *Questioning the Sustainability of Legal Hunting of Deer and Pig in Peninsular Malaysia*. Unpublished report submitted to the Department of Wildlife and National Parks, Kuala Lumpur, Malaysia.

Kawanishi, K., Aik, Y.P., John, E., Gumal, M. & Sukor, S. (2011) Malaysia, a leading country for green infrastructure. *Cat News*, 55, 38–40.

Kawanishi, K. & Sunquist, M. (2004) Conservation status of tigers in a primary rainforest of Peninsular Malaysia. *Biological Conservation*, 120, 329–344.

Kawanishi, K., Sunquist, M. & Sahir, O. (2002) Malayan Tapir (*Tapirus indicus*), far from extinction in a Malaysian rainforest. *Tapir Conservation (IUCN/SSC Tapir Specialist Group)*, 11, 23–27.

Kawanishi, K., Richardson, D. & Lazarus, K. (2006) Contraction of bearded pig *Sus barbatus* distribution in Peninsular Malaysia. *Suiform Soundings (IUCN/SSC Pigs, Peccaries, and Hippos Specialist Newsletter)*, 6, 13–16.

Kempe, J. E. (1948) The riddle of the bearded pig. *Malayan Nature Journal*, 3, 36–43.

Laidlaw, R.K., Rahman, M.T.A. & Zainal, Z. (2000) Large mammals. *Journal of Wildlife and Parks*, 18, 75–106.

Leslie, D. M. Jr. (2010) *Rusa unicolor* (Artiodactyla: Cervidae). *Mammalian Species*, 43, 1–30.

Lynam, A.J., Laidlaw, R., Wan Shaharuddin, W.N., Elagupillay, S. & Bennett, E. (2007) Assessing the conservation status of the tiger *Panthera tigris* at priority sites in Peninsular Malaysia. *Oryx*, 41, 454–462.

MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Royle, J. A. & Langtimm, C. A. (2002) Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, 83, 2248–2255.

McClure, H.E.A. (1963) Wounded tapir. *Malayan Nature Journal*, 17, 266–267.

Misliah, M.B. & Sahir, O. (1997) Wildlife protection and management in Peninsular Malaysia. In *State of the Environment in Malaysia: a Compilation of Selected Papers Presented at the CAP-SAM National Conference State of the Malaysian Environment 5 –9 January 1996* (ed. O.B. Gaik), pp. 154–159, Consumer's Association of Penang Press, Penang, Malaysia.

Mohd Khan, M.K. (1968) Deer biology data. *Malay Nature Journal*, 21, 159–164.

Murali, R.S.N. (2009) Duo nabbed for poaching. *The Star*. 15 May. Kuala Lumpur, Malaysia.

Olea, P.P., Sanchez-Barbudo, I., Vinuela, J., Barja, I., Mateo-Thomas, P., Pineiro, A. et al. (2009) Lack of scientific evidence and precautionary principle in massive release of rodenticides threatens biodiversity: old lessons need new reflections. *Environmental Conservation*, 36, 1–4.

Shariff, W.M., Darmaraj, M.R., Ahmad Zafir, A.W., Murray, J.P. & Fong, A.L.M. (2010) A rapid camera-trapping survey revealing information on diversity and abundance of several mammals in Bintang Hijau Forest Reserve. In *Biodiversity Expedition in Bintang Hijau Forest Reserve (Volume 12)* (eds U. Razani, H.L. Koh, N.M. Nik Mohd. Shah, A. Damanhuri & A. Latiff), pp. 100–110. Jabatan Perhutanan Semenanjung Malaysia, Kuala Lumpur, Malaysia.

Sharma, D.S.K. & Ahmad Zafir, A.W. (2005) A note on camera trapping of terrestrial vertebrates in peat swamps around Sungai Bebar, Pekan Forest Reserve, Pahang. In *Biodiversity Expedition Sungai Bebar, Pekan, Pahang: Summary Findings* (ed. A. Latiff), pp. 167–169. PSF Technical Series No. 4. Forest Research Institute Malaysia, Kuala Lumpur, Malaysia.

Sharma, D.S.K. & Ahmad Zafir, A.W. (2007) Rapid assessment and preliminary list of terrestrial mammals at Bukit Labohan Forest Reserve, Terengganu, Peninsular Malaysia. In *Biodiversity Expedition in Bukit Labohan, Ma' Dearah, Terengganu*. (eds D.S.K. Sharma, A.W. Ahmad Zafir, B. Nadzirah & A.A.B. Dayang Norwana), pp. 86–91. WWF–Malaysia, Selangor, Malaysia.

Sunquist, M., Karanth, K. U. & Sunquist, F. (1999) Ecology, behaviour and resilience of the tiger and its conservation needs. In *Riding the Tiger: Tiger Conservation in Human-dominated Landscapes* (eds J. Seidensticker, S. Christie & P. Jackson), pp. 5–18. Cambridge University Press, Cambridge, UK.

Zaaba, Z.A., Mohd Tajuddin, A., Mustafa,, A.R. & Ebil, Y. (1991) Large Mammals in Peninsular Malaysia. In *The Status of Nature Conservation in Malaysia*. (ed. R. Kiew), pp. 173–176. Malayan Nature Society, Petaling Jaya, Malaysia.

Biographical sketches

Kae Kawanishi is a wildlife biologist interested in carnivore ecology and conservation. Reuben Clements worked for WWF–Malaysia at the time of the study and is currently studying the impacts of roads on large mammals and indigenous peoples. Melvin Gumal's research interests include tigers, elephants, orang-utans and effects of land use change on wildlife. Gareth Goldthorpe previously worked for WWF–Malaysia. His research interests include carnivore conservation, human–wildlife conflict and protected area management. Mohd Nawayai Yasak was the Director of the Biodiversity and Conservation Division in the Department of Wildlife and National Parks Peninsular Malaysia at the time of the study. Dionysius S.K. Sharma has worked for over 20 years on a variety of mammals and reptiles in Peninsular Malaysia and Borneo.