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Short Communication

Distance sampling reveals Cambodia's Eastern Plains Landscape supports the largest global population of the Endangered banteng *Bos javanicus*

THOMAS N. E. GRAY, SOVANNA PRUM, CHANRATTANA PIN and CHANNA PHAN

Abstract The banteng *Bos javanicus* is a globally threatened species of wild cattle restricted to South-East Asia. We report the first robust estimate of banteng density and population size from anywhere in the species' global range, using distance-based line transect sampling within two protected areas, Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary, which form part of the Eastern Plains Landscape, Cambodia. We surveyed 110 line transects multiple times during the dry seasons of 2009–2010 and 2010–2011. In a total survey effort of 1,310 km there were 63 encounters with banteng. The mean estimate of the population across the 3,406 km² study area is 3,200 (95% confidence interval 1,980–5,170). This suggests that the protected area complex of the Eastern Plains Landscape supports the majority of the global population of banteng. Stronger protection, both in the form of increased anti-hunting and poaching patrols and integrated land-use planning to prevent habitat loss within protected areas, is essential for securing wild cattle populations in the Eastern Plains Landscape.

Keywords Banteng, *Bos javanicus*, Cambodia, deciduous dipterocarp forest, density, line transects, population size, wild cattle

The banteng *Bos javanicus* is one of four sympatric wild cattle species indigenous to the Lower Mekong Dry Forests of Indochina (Tordoff et al., 2005). All four species, banteng, gaur *Bos gaurus*, kouprey *Bos sauveli* and wild water buffalo *Bubulus arnee*, were historically widespread and common throughout the deciduous dipterocarp dominated flatlands of northern and eastern Cambodia. The American naturalist Charles Wharton famously described the landscape as the 'Serengeti of Asia'

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(Wharton, 1957). Globally banteng has experienced extensive population declines and local extinctions throughout the ancestral range, from north-east India to Java and Borneo, and the species is currently categorized on the IUCN Red List as Endangered on the basis of an inferred decline of > 50% over three generations (24–30 years; criteria A2–4 c + d) across the species' range (Timmins et al., 2008).

Recent camera trapping in eastern Cambodia has indicated that substantial banteng populations may remain within protected areas of the Eastern Plains Landscape, Mondulkiri province (Phan & Gray, 2010). We report the first robust estimate of banteng density and population size from anywhere in the species' global range, using distance-based line transect sampling within two protected areas (Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary) in the heart of the Eastern Plains Landscape (Fig. 1). These lowland (100–300 m altitude) protected areas are dominated by deciduous dipterocarp forest, with smaller areas of mixed deciduous and semi-evergreen forest (Phan & Gray, 2010).

Distance-based line transect sampling is the standard method for estimating densities of the ungulate prey of tigers *Panthera tigris* in protected areas in the Indian subcontinent (Karanth & Nichols, 2002) and addresses two of the most problematic aspects of estimation of animal abundance: spatial sampling and detectability (Williams et al., 2002; Thomas et al., 2010). During the dry seasons of 2009–2010 and 2010–2011 we surveyed 110 1–4 km line transects within the 3,406 km² core areas of Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary (Fig. 1), with line transects demarcated using a stratified random sampling design (Gray et al., 2011). Surveys followed the protocols of Karanth et al. (2002) for line transect sampling of ungulates, with two observers slowly walking line transects at dawn (starting at 06.30–07.00) and dusk (finishing at 17.30–18.00). For each observation of banteng we recorded the number of animals (cluster size), distance between the animal or centre of a group of animals and the observers on the line (with a laser rangefinder), compass bearing to the animal or to the centre of a group of animals, and compass bearing of the transect line.

Total survey effort was 1,310 km, stratified between Phnom Prich Wildlife Sanctuary core area (1,670 km²; 34 transects; total transect length surveyed 622 km),

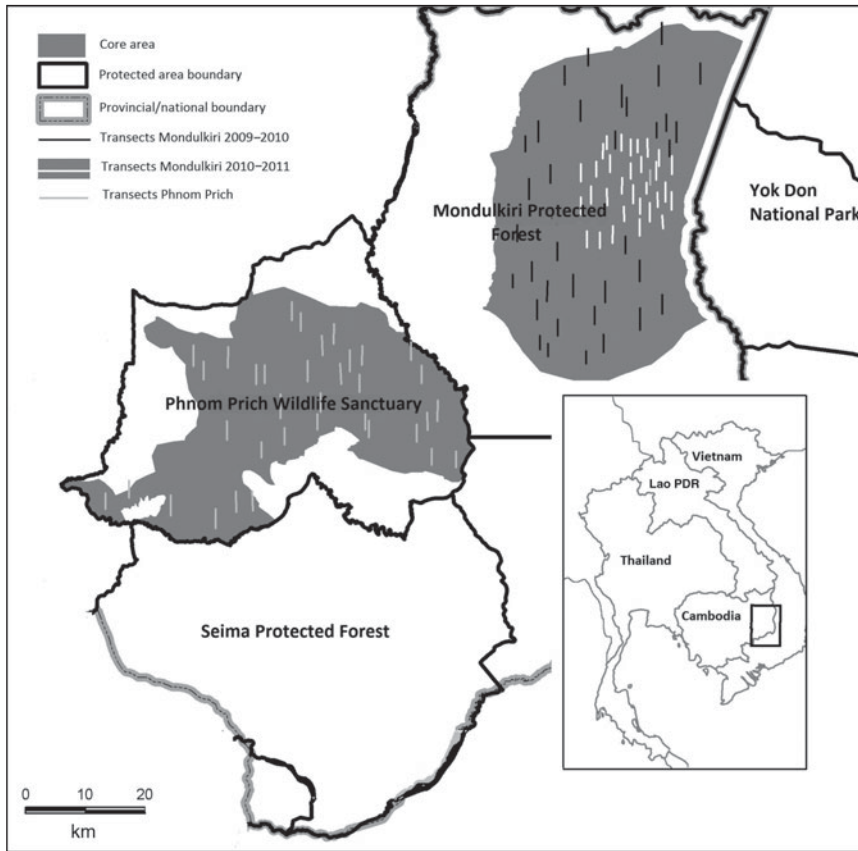


FIG. 1 Location of Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary and other protected areas of the Eastern Plains Landscape, Cambodia, showing the core zones of the two study areas and locations of all line transects. The inset indicates the location of the main map in South-East Asia.

Mondulkiri Protected Forest-outer core (1,276 km²; 38 transects; total transect length surveyed 273 km) and Mondulkiri Protected Forest inner core (460 km²; 38 transects; total transect length surveyed 415 km). The latter area approximately corresponds to the area identified by the Cambodian government as a proposed inviolate tiger recovery zone. We used the conventional distance sampling engine in *Distance v. 6.0* (Thomas et al., 2010) to estimate banteng density. Prior to modelling data was right truncated to prevent the inclusion of additional adjustment terms that fit a long tail to the detection function but reduce precision for little gain (Thomas et al., 2010). The model that best described the detection process was selected on the basis of Akaike Information Criteria values corrected for small sample size (AICc). Because of the limited number of encounters with banteng in each stratum a single global detection function was fitted and this was used to calculate stratum-specific estimates of banteng density. Using the selected model estimates of group density, cluster size and individual density were derived. Checking for size-bias in detection of animal clusters (Drummer & McDonald, 1987) led to a non-significant regression equation at $\alpha = 0.10$, and therefore the mean observed cluster size ($5.1 \pm \text{SE } 0.6$) was used for analysis. Overall density, and hence estimated population size, across the 3,406 km² study area was estimated as the mean of the three stratum-specific density estimates weighted by stratum area.

In the line transect surveys there were a total of 63 encounters with banteng, with the species the second most frequently recorded large ungulate along the transects after red muntjac *Muntiacus muntjak* (198 encounters). Banteng were recorded from 40 of the line transects (mean 0.6 banteng encounters per transect; range 0–4). Based on AICc scores the best fitting model was the uniform key model with cosine adjustments and right truncation at 112 m from the transect line. Modelled densities varied from $0.7 \pm \text{SE } 0.2$ individuals km⁻² in Phnom Prich Wildlife Sanctuary core to $1.9 \pm \text{SE } 0.4$ km⁻² in Mondulkiri Protected Forest inner core (Table 1). The overall density estimate of $0.9 \pm \text{SE } 0.1$ km⁻² gives an estimated banteng population of 3,201 (95% confidence interval, CI, 1,982–5,170) within the 3,406 km² study area (Table 1).

On the IUCN Red List it is estimated that the global banteng population is 5,000–8,000 and that no subpopulation exceeds 500 individuals (Timmins et al., 2008). In addition to the populations in Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary banteng are present in the adjacent Seima Protected Forest (c. 250 individuals; O'Kelly & Nut, 2010), Yok Don National Park, Vietnam (c. 30–44; Pedrono et al., 2009), Lumphat Wildlife Sanctuary and O'Yadao protected forest. Therefore, although the global estimate (Timmins et al., 2008) may be accurate the contiguous banteng subpopulation of the Eastern Plains Landscape clearly exceeds 500 and the area probably

TABLE 1 Densities of banteng in Phnom Prich Wildlife Sanctuary core, Mondulkiri Protected Forest outer and inner cores and the entire study area (Fig 1) estimated using distance-based line transect surveys (N, number of observations included in models; D_g , density of groups; D_i , density of individuals; population size, with 95% CI).

	N	$D_g \pm SE$ (km ⁻²)	$D_i \pm SE$ (km ⁻²)	Population size \pm SE	Population size 95% CI
Phnom Prich Wildlife Sanctuary core	12	0.13 \pm 0.04	0.66 \pm 0.20	1102 \pm 341	602–2018
Mondulkiri Protected Forest outer core	8	0.16 \pm 0.06	0.81 \pm 0.31	1039 \pm 399	493–2190
Mondulkiri Protected Forest inner core	31	0.37 \pm 0.06	1.90 \pm 0.37	872 \pm 169	596–1276
Entire area	51	0.17 \pm 0.03	0.94 \pm 0.14	3201 \pm 703	1982–5170

supports the majority of the global population of this species. The landscape is therefore irreplaceable for the conservation of wild cattle.

This study is the first to estimate the density of wild cattle in South-East Asia using robust sampling methodologies that account for imperfect detection. We therefore believe there is little reason to doubt the accuracy of our estimates, particularly as the assumptions of distance sampling were largely met (Gray et al., 2011). However, our estimates of the banteng population in Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary are much higher than previous expert opinions based on limited previous fieldwork within the area (e.g. Olivier & Woodford, 1994; Desai & Lic, 1996). Whilst our higher population estimates may represent recent population and/or behavioural changes in response to law enforcement and conservation programmes we believe our work highlights the importance of rigorous baseline surveys, using standardized, peer-reviewed methodologies, for accurately assessing the conservation value of a landscape.

Despite our revised population estimates for eastern Cambodia we believe that categorization on the IUCN Red List as Endangered is still appropriate given the large-scale hunting and habitat loss occurring throughout tropical dry forest in South-East Asia, including within Cambodia, over the last 10–30 years. There are also extensive threats to lowland forest across Cambodia from the escalation of the awarding of agricultural and social land concessions both outside and within protected areas. Hunting for wild meat and trophy horns also remains a problem for wild cattle in eastern Cambodia (Kelly & Nut, 2010). Therefore stronger protection, both in the form of increased anti-hunting and poaching patrols and integrated land-use planning to prevent habitat destruction within protected areas, is essential for securing the wild cattle populations of the Eastern Plains Landscape. Our results have been presented to the government management agencies for both Mondulkiri Protected Forest and Phnom Prich Wildlife Sanctuary, and banteng conservation will be highlighted as an essential component of protected area management in the management plans currently being developed for the two protected areas.

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Biographical sketches

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