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Assessing large mammal and bird richness from camera-trap records in the Hukaung Valley of Northern Myanmar

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Abstract. Myanmar is regarded as a last frontier of biodiversity in Asia. We used results from camera-traps set for tigers (*Panthera tigris*) during 2001–2011 in the Hukaung Valley Wildlife Sanctuary of northern Myanmar to assess overall species richness of large mammals and birds, and to identify differences in species detection rates spatially and temporally. We deployed 403 camera stations during the dry seasons, October–July, of 2001–2011, placing 260 in the Core area (~1,800 km²) and 143 in the Extension area (~15,500 km²). From 10,750 trap-nights we obtained 2,077 independent photographs of wildlife species and 645 of humans. Wildlife included 35 species of mammals (19 carnivores, four primates, one elephant, six even-toed ungulates, one pangolin, and four rodents) and 16 species of birds. Of these, one is considered Critically Endangered, seven are Endangered, 11 are Vulnerable, and 5 are Near Threatened. Some species that probably occur in the Sanctuary (e.g., arboreal or semi-aquatic mammals) were not recorded, likely because of camera placement or rarity. In total, 48 species of wildlife were recorded in the Core area, while only 33 species were detected in the Extension area. Roughly half of the photographs were of poachers, villagers, and park rangers. The greater diversity of wildlife in the Core area may be partly due to increased patrol efforts, but is most likely due to differences in elevation, slope, density of streams, trails, and roads, and vegetation, all of which influence access to poachers. The decline in detection of tigers in the Core area, and several of their prey species, during this decade-long study suggests a need for increased management of human activities in order to conserve wildlife diversity in the Hukaung Valley Wildlife Sanctuary.

Key words. abundance, anthropogenic, biodiversity, distribution, Southeast Asia, wildlife

INTRODUCTION

Biodiversity is thought to play a key role in the functioning of ecosystems, and thus current high rates of species extinction may have dramatic effects on environmental health. Globally, one-third of wild vertebrate species declined between 1970 and 2006, especially in freshwater ecosystems (41% decline) and the tropics (59% decline; United Nations, 2010). Myers et al. (2000) identified 25 global eco-region hotspots, based on species richness and endemism, and four of those are in Southeast Asia (Indo-Burma, Sundaland, Philippines, and Wallacea). Importantly, Southeast Asian tropical forests have seen the highest rates of deforestation, and it is projected that 75% of the original forest, and 41% of its biodiversity, will be lost by the end of this century (Sodhi et al., 2004).

Myanmar (formerly known as Burma) encompasses a major hotspot area and is regarded as the last country in Southeast Asia containing large areas that have not been surveyed for biodiversity, and could harbor ~5% of mammal species (Corbett & Hill, 1992) and ~10% of bird species of the world (Avibase, 2015). Because Myanmar has been largely unavailable for survey and exploration for the last four decades, unusual natural diversities may have been preserved that are yet to be discovered. In addition, baseline information on species occurrence and distribution is urgently needed to update conservation and protected area management plans. Economic expansion, climate change, poaching, and social reform are all factors potentially affecting biodiversity in Myanmar (Rao et al., 2013; Nijman & Shepherd, 2015; Donald et al., 2015).

The aim of our study was to collate the records from camera trap surveys conducted over the last decade to assess species diversity, distribution, and relative abundance (cf., Stein et al., 2008; McCarthy et al., 2010; Coudrat et al., 2014) for large mammals and birds in a protected area in northern Myanmar. We hypothesised that species richness/diversity and abundance of large mammals and birds would be highest in the most actively protected portion of the Sanctuary, but

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even so, the abundance of some species may have declined due to increasing pressures from humans.

MATERIAL AND METHODS

Study area. The 17,373 km² Hukaung Valley Wildlife Sanctuary (HKVWS; Fig. 1), established in 2001 and expanded in 2004, is one of the largest of 43 protected areas in Myanmar (total = 49,456 km²; NCEA, 2009). The HKVWS is in the country's northernmost state (~25°23'–27°23'N and 95°33'–97°18'E) and ranges in elevation from 94 to 3,440 m (Lynam et al., 2009). The Hukaung Valley is surrounded by steep mountain ranges in the north, east, and west, and the streams and rivers flowing toward the central plain form a major catchment basin of the Chindwin River. The plain contains a mosaic of broadleaf forest and grassland habitats, the hilly slopes are covered with broadleaf forest, and the mountains consist of temperate broadleaf forest, coniferous forest, and shrubland (Lynam et al., 2009). The study area is in the humid subtropical climate zone, having a mean annual rainfall of approximately 2,340 mm, and mean annual minimum and maximum temperatures of 18.8°C and 30.0°C, respectively. The climate is greatly influenced by monsoons, which help define three distinct seasons. Generally, the hot season runs from mid-February to mid-May, the monsoon or rainy season from mid-May to mid-October, and the cool season from mid-October to mid-February.

Indigenous people of the Hukaung Valley are primarily Naga, Kachin, and Shan tribes relying primarily on shifting cultivation, non-wood forest product collection, and subsistence hunting. Compared to other areas in Myanmar, the growth of the indigenous population had been relatively low, but during the course of the camera trapping surveys, and especially after 2004 when the Sanctuary was officially established, the number of temporary migrants entering the Hukaung Valley increased significantly. Many of these migrants were employed in gold and jade mining, rattan harvesting, and agricultural businesses, especially south of Ledo Road which passes through the valley and floodplain of the Chindwin River. When HKVWS was established, the need for coexistence of humans and nature was recognised, and in order to avoid undesirable conflicts, park management was designed to allow resource use in many areas.

Camera-trapping was conducted both inside the ~1,800 km² Core area of the reserve (Fig. 1), where there are no human settlements, and also outside of the Core area. It should be noted, that villages occur along the southern boundary of the Core area adjacent to the historic Ledo Road, built by the U.S. Army during World War II. Forest trails, which are primarily mule tracks and footpaths along ridges and rivers, connect remote villages, and waterways are used as a secondary transportation option. Regular patrols by Sanctuary rangers were done in the Core area during 2005–2010, in

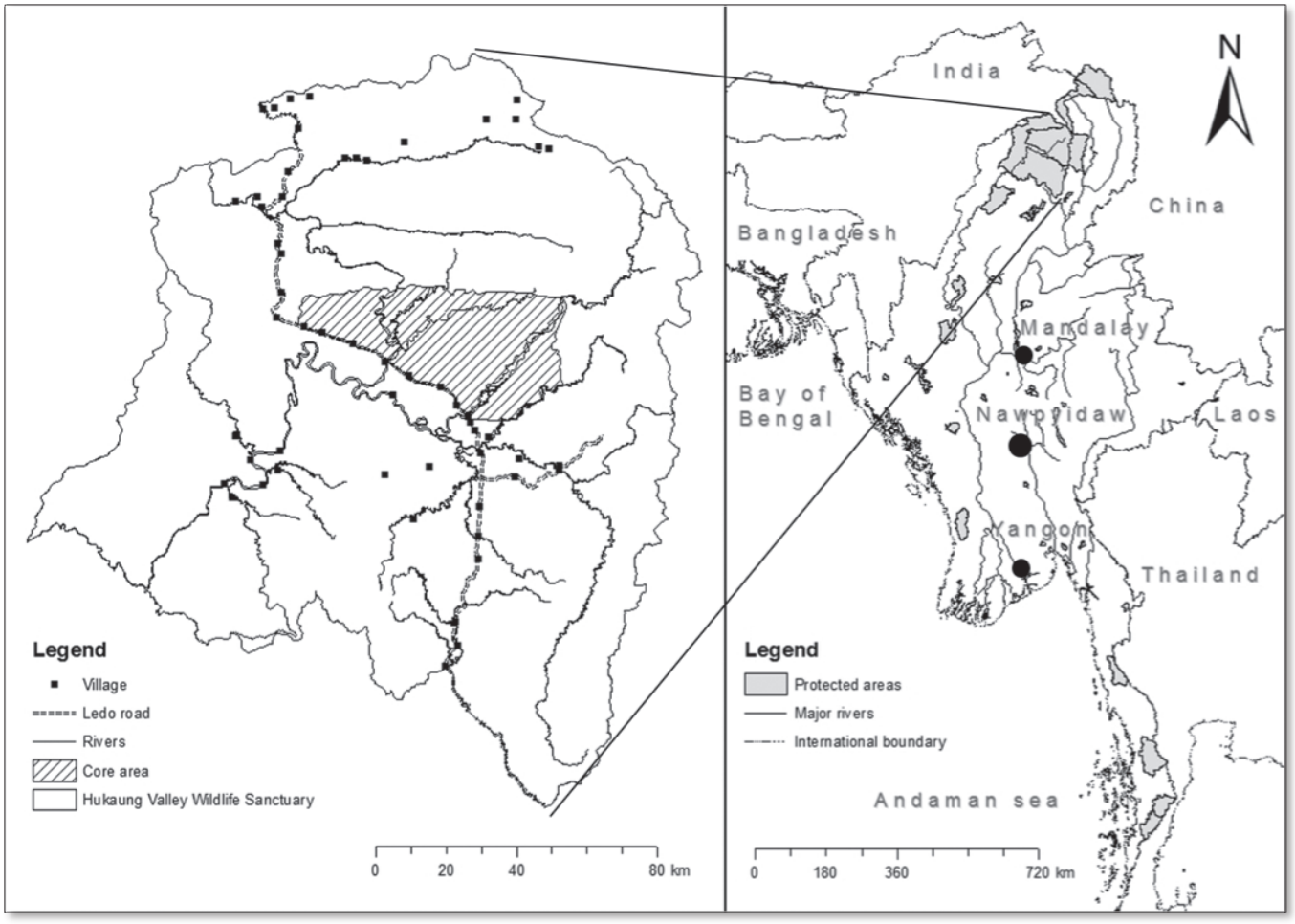

Fig. 1. Location of Hukaung Valley Wildlife Sanctuary and Core study area (hatched) in Northern Myanmar.

contrast to other areas of the HKVWS (i.e., Extension area) where patrols were infrequent, or absent, due to remoteness, insufficient staff and general lack of resources for law enforcement monitoring.

We characterised the major differences in camera trapping sites between the Core area and Outside the Core area by assessing the area within 3 km of camera trapping sites (Fig. 2), and identifying the mean elevation, slope, and density of streams, trails, roads, and villages, as well as the total percentage of 13 land cover features over the cumulative area covered by trap sites. Relative to the Core area, sites Outside the Core area were at higher elevations, had steeper slopes, fewer streams and trails, more roads (Table 1), more Hill Forest, and less Evergreen Open Forest (Table 2).

Camera-trap surveys. Camera-trapping in the HKVWS initially was carried out to investigate tiger (*Panthera tigris*; scientific names of all species are identified in Table 3) distribution and relative abundance (Lynam et al., 2009) in a variety of areas in the Sanctuary (Naing, 2015). Before beginning surveys, researchers and rangers conducted rapid assessments of potential camera trap locations and identified natural animal trails, historical wildlife corridors, streambeds, mountain ridges, saddles, mineral saltlicks, animal wallows, access routes, areas of thick vegetation such as bamboo and rattan brakes, deep rivers, and seasonally flooded wetlands. Potential trap locations and old trail networks were recorded, and logistical constraints regarding accessibility were considered. Due to the complicated and sensitive political climate, surveys were limited to specific areas, especially during the last two survey seasons (2009–2010 and 2010–2011).

After suitable sites were identified, a sub-set of those locations was selected and trapping stations were set up, usually at least 2 km from the next nearest station in order to increase independence among traps. At each station, a passive infrared camera unit (CamtrakkerTM, Camtrak South Inc., Watkinsville, GA, and/or DeerCam with DC-300 film, Non-Typical, Park Falls, WI, USA) was attached to a tree on the side of the trail and at a distance of 3.0–3.5 m from the probable location of animal detection. This arrangement was used throughout the study to allow for comparison and pooling among years. Each camera trap was operated continuously (24 hours day^{-1}) in order to detect both nocturnal and diurnal species, and was programmed to take photos at 15-second intervals when triggered. Camera traps were checked periodically (every three to six weeks) to replace batteries and rolls of film. Camera traps were left in the field for at least two weeks at the same location, and were operational during portions of the cool and hot seasons each

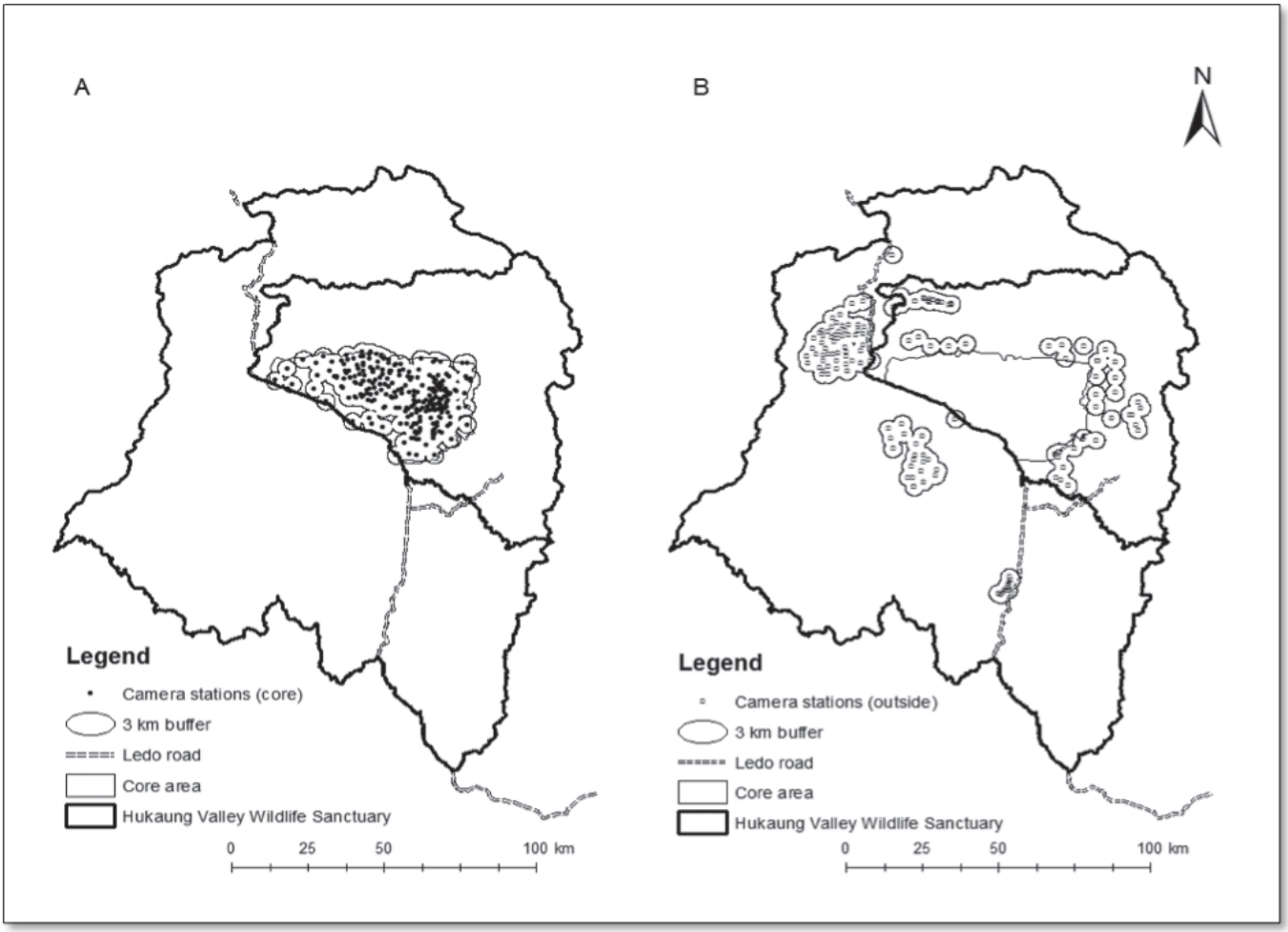

Fig. 2. Camera stations, and the composite areas within 3 km of each station, in the Core study area (A) and Outside of the Core area (B) in the Hukaung Valley Wildlife Sanctuary of Myanmar

Table 1. Characteristics of landscapes within a 3 km radius (28.3 km^2 plot) of camera trap locations in the Core study area (n = 260) and Outside the Core study area (n = 143) in the Hukaung Valley of northern Myanmar during 2001–2011. Significant differences (P<0.05) are indicated with an asterisk.

	Core (1695 km^2)			**Outside (1950 km^2)**			
	Mean	**Median**	**Range**	**Mean**	**Median**	**Range**	**P-Value**
Elevation (m)	272	260	208–542	712	687	208–1737	<0.0001*
Slope (degrees)	2.9	1.4	0.5–18.6	14.6	16.6	1.1–25.6	<0.0001*
Density							
Stream (km/km^2)	0.74	0.75	0.01–1.40	0.36	0.3	0–0.94	<0.0001*
Trail (km/km^2)	0.26	0.24	0–0.84	0.2	0.15	0–0.79	0.004*
Road (km/km^2)	0.01	0	0–0.22	0.02	0	0–0.27	0.02*
Village (no./100 km^2)	0.19	0	0–7.07	0.07	0	0–3.54	0.14

Table 2. Percent of land cover types in the cumulative areas (Fig. 2) within 3 km of each camera trapping site in the Core area and Outside of the Core area in the Hukaung Valley Wildlife Sanctuary.

Cover Type	**Core**	**Outside**
Evergreen closed forest	63.1	62.3
Bamboo	12.3	13.4
Evergreen open forest	11.1	6.3
Rattan	5.0	0.0
Stream bed	2.3	0.7
Hill Forest	1.9	14.1
Scrub land	1.9	0.6
Water	1.1	0.6
Kaing grass	0.9	0.7
Agricuture	0.4	0.2
Rock	0.1	1.2
Shifting cultivation	0.0	0.1

Table 3. Comparison of cumulative photo detection rates (no. of independent photos/100 trap nights; total no. of trapnights per comparison in parentheses) between the Core study area and Outside the Core area, and between time periods in the Core Area for wild mammal and bird species, domestic animal species, and humans in the Hukaung Valley of northern Myanmar during 2001–2011. Significant differences (P<0.001) indicated in bold.

Common name	**Scientific name**	**Status**	**2001–2011**		**Core**	
			Outside	**Core**	**2001–2004**	**2005–2010**
			(3,298)	**(7,452)**	**(3,005)**	**(4,395)**
tiger	*Panthera tigris*	E	0.06	0.21	**0.5**	**0.02**
leopard	*Panthera pardus*	NT	0	0.01	0	0.02
clouded leopard	*Neofelis nebulosa*	V	0.36	0.51	0.40	0.59
Asian golden cat	*Pardofelis temminckii*	NT	**0.64**	**0.03**	0.07	0
marbled cat	*Pardofelis marmorata*	V	0.18	0.11	0.23	0.02
leopard cat	*Prionailurus bengalensis*	LC	0.46	0.79	**1.30**	**0.46**
dhole	*Cuon alpinus*	E	0.30	0.44	0.60	0.34
Asiatic black bear	*Ursus thibetanus*	V	0.12	0.11	0.03	0.16
Malayan sun bear	*Helarctos malayanus*	V	0.82	0.42	0.37	0.46
binturong	*Arctictis binturong*	V	0.15	0.07	0.10	0.05
large Indian civet	*Viverra zibetha*	NT	**0**	**0.34**	**0.63**	**0.14**
small Indian civet	*Viverricula indica*	LC	0	0.15	0.17	0.14
common palm civet	*Paradoxurus hermaphroditus*	LC	0.55	0.52	0.27	0.71
large-spotted civet	*Viverra megaspila*	V	0	0.01	0.03	0

Table 3...Continued

Common name	Scientific name	Status	2001–2011		Core	
			Outside	Core	2001–2004	2005–2010
			(3,298)	(7,452)	(3,005)	(4,395)
masked palm civet	*Paguma larvata*	LC	0	0.08	0.07	0.09
crab-eating mongoose	*Herpestes urva*	LC	0.15	0.59	**1.20**	**0.18**
yellow-throated marten	*Martes flavigula*	LC	0.27	0.3	0.37	0.25
hog badger	*Arctonyx collaris*	LC	0.06	0	0	0
banded linsang	*Prionodon linsang*	LC	0.03	0.03	0.07	0
stump-tailed macaque	*Macaca arctoides*	V	**1.79**	**0.42**	0.27	0.52
northern pig-tailed macaque	*Macaca leonina*	V	**0.03**	**0.44**	0.37	0.50
Rhesus macaque	*Macaca mulatta*	LC	**1.06**	**0.27**	0.40	0.18
capped-leaf monkey	*Trachypithecus pileatus*	V	0.06	0.03	0.07	0
Asian elephant	*Elephas maximus*	E	0	0.13	0.27	0.05
gaur	*Capricornis rubidus*	V	0.64	0.56	**0.27**	**0.77**
red serow	*Capricornis rubidus*	NT	**0.33**	**0.01**	0.03	0
sambar	*Cervus unicolor*	V	**2.82**	**1.60**	**2.60**	**0.93**
hog deer	*Hyelaphus porcinus*	E	0	0.19	na	na
barking deer	*Muntiacus muntjak*	LC	5.31	4.98	**6.76**	**3.78**
wild pig	*Sus scrofa*	LC	0.94	0.98	1.33	0.75
Chinese pangolin	*Manis pentadactyla*	E	0	0.01	0.03	0
Malayan porcupine	*Hystrix brachyura*	LC	**0.79**	**1.64**	2.06	1.37
Asiatic brush-tailed porcupine	*Atherurus macrourus*	LC	0.49	0.6	0.57	0.64
Edward's rat	*Leopoldamys edwardsi*	LC	0	0.03	0.03	0.02
Asian red-cheeked squirrel	*Dremomys rufigenis*	LC	0.03	0.04	0.10	0
white-winged duck	*Cairina scutulata*	E	0	0.04	0.03	0.05
imperial heron	*Ardea insignis*	CE	0	0.01	0.03	0
black stork	*Ciconia nigra*	LC	0.03	0.24	**0.57**	**0.02**
woolly-necked stork	*Ciconia episcopus*	LC	0.06	0	0	0
green imperial pigeon	*Ducula aenea*	LC	0	0.03	0	0.05
Oriental pied hornbill	*Anthracoceros albirostris*	LC	0	0.03	0	0.05
greater coucal	*Centropusz sinensis*	LC	0	0.03	0	0.05
green peafowl	*Pavo muticus*	E	0	0.05	0	0.09
grey peacock pheasant	*Polyplectron bicalcaratum*	LC	0.67	0.54	0.63	0.48
Kalij pheasant	*Lophura leucomelanos*	LC	0.58	0.51	**0.83**	**0.30**
red jungle fowl	*Gallus gallus*	LC	**0.15**	**0.81**	0.90	0.75
rufous-throated partridge	*Arborophila rufogularis*	LC	0.03	0	0	0
green magpie	*Cissa chinensis*	LC	0	0.01	0.03	0
blue whistling thrush	*Myophonus caeruleus*	LC	0.06	0.04	0.10	0
brown fish owl	*Ketupa zeylonensis*	LC	0	0.03	0	0.05
eastern marsh-harrier	*Circus spilonotus*	LC	0	0.01	0.03	0
poacher[b]			**0.42**	**1.81**	**3.49**	**0.68**
villager[c]			**1.15**	**4.79**	**2.60**	**6.05**
peace group member[d]			**0.58**	**0**	0	0
park ranger[e]			**0.21**	**1.14**	1.20	1.11

[a]IUCN (2015) status categories: CE = Critically Endangered, E = Endangered, NT = Near Threatened, V = Vulnerable, LC = Least Concern
[b]Person carrying hunting/fishing gear (e.g., gun snare, snare, spear, single-action rifle, shotgun, homemade gun, blanket or cloth for making a hide, fishing net, ring net, fishing rod, electro-fishing equipment, poison, bow and arrow), or wild plants and/or parts of or whole animals.
[c]Person without hunting/fishing gear, or wild plants and/or parts of or whole animals, in the vicinity of villages and farmland.
[d]Person in non-state military uniform.
[e]Person in ranger uniform or otherwise known to be part of a management or research team.

year. As the setups were intended to maximise detection probability for tigers and their prey, all other records should be considered by-catch and interpreted accordingly (sensu Zaw et al., 2008).

Sampling effort at a station was calculated as the number of days a camera trap was operational at that location (Burton et al., 2012). Locations of camera traps were different for each year, and are thus considered independent. Detections of wild mammals and birds, as well as humans, were tallied for each station for each day. In addition, photos obtained of humans divided into 4 categories (including peace group members that were only photographed Outside of the Core area; see more below). To avoid pseudo-replication, we considered photographs to be independent when: 1) consecutive photographs were of different individuals of the same species (for those that could be identified individually, e.g., tigers); 2) consecutive photographs of a species were separated by more than 30 min; or 3) non-consecutive photos of individuals of the same species (O'Brien et al., 2003).

We compared cumulative photo rates of individual species (number of independent photos per 100 trapnights; 1 trapnight = 1 camera functioning for 1 night) between areas and time periods using Chi-square statistics at $\alpha = 0.001$ (to account for multiple tests). Species richness/diversity was simply calculated by tallying the numbers of species recorded by area and time period. Species accumulation curves were generated from annual survey results (Naing, 2015) in both the Core area and Outside of the Core area.

RESULTS

In total, 403 camera stations were deployed during October–July (but usually December–June;) in the dry seasons of 2001–2011 (Appendix 1). Overall, 260 stations were established in the Core area and 143 Outside of the Core area (Fig. 2, Appendix 2A–D), resulting in 7,452 trap-nights in the Core area and 3,298 trap nights Outside of the Core area (average no. trap-nights per station = 30.9; Appendix 3). We obtained 2,077 independent photos of wildlife species and 645 of humans.

In terms of species richness, we captured 35 species of wild mammals and 16 species of wild birds (Table 3). In total, 48 wild species were photographed in the Core area vs. 33 Outside of the Core area (Table 3). The lower number of species recorded Outside of the Core area was also reflected in species accumulation curves in both the Core area, (r^2 = 0.844), and Outside of the Core area (r^2 = 0.608; Fig. 3).

The 35 mammal species (U Tun Yin, 1967a, b) included 19 carnivorans, four primates, one elephant, six even-toed ungulates, one pangolin, and four rodents. Only 16 of more than 430 bird species likely occurring in the Hukaung Valley (Robson, 2000) were recorded. By conservation status (Table 3), recorded species included one Critically Endangered, seven Endangered, 11 Vulnerable, five Near Threatened, and 27 Of Least Concern (IUCN, 2015).

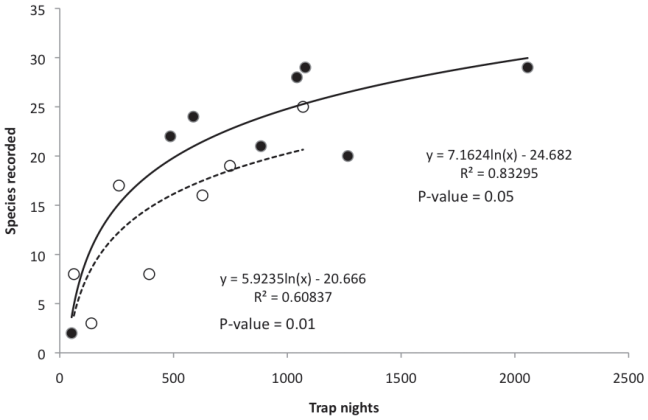

Fig. 3. Trend lines, correlations and p-values for the relationship between number of camera trap nights per season per area (effort) versus number of species photographed (diversity) in the Core study area (solid line & solid circle) and at and near camera trap locations Outside the Core area (dash line & hollow circle) in the Hukaung Valley, Myanmar (season [= year] data from Naing 2015).

There were statistically significant differences ($P<0.001$) between the overall photo detection rates in the Core area vs. Outside the Core area for nine mammals and one bird species (Table 2). Large Indian civet, crab eating mongoose, northern pig-tailed macaque, sambar deer, Malayan porcupine, and red jungle fowl were photographed more often within the Core area, and Asian golden cat, stump-tailed macaque, rhesus macaque, and red serow were photographed more often Outside of the core area. In addition, no leopards, small Indian civets, large-spotted civets, masked palm civets, Asian elephants, hog deer (recorded only in the Core area in 2010–2011 because during that year the few traps deployed were specifically set in hog-deer habitat), Chinese pangolins, or Edward's rats were photographed outside of the Core area, and no hog badgers were photographed in the Core area. Nine species of birds were only photographed inside the Core area, two species were photographed only Outside of the Core area, and no more than four photos were obtained of any of these species. Many more photos of poachers and villagers, but also park rangers, were obtained inside the Core area compared to Outside, and photos of peace group members were obtained only Outside of the Core area.

Statistical differences ($P<0.001$) of overall photo rates of individual wildlife species in the Core area in early (2001–2004) vs. later (2004–2011) years were identified for seven mammals and two birds (Table 3). Over time, photo rates of tigers, leopard cats, large Indian civet, crab-eating mongoose, sambar, barking deer, black stork, and Kalij pheasant declined, while photo rates of gaur increased.

DISCUSSION

During the course of our tiger-focused camera trap surveys, 34 other species of mammals (33 ≥ 1 kg) were also recorded, and thus confirmed to occur in the Hukaung Valley Wildlife Sanctuary. Some species that probably occur in the Sanctuary were not recorded, most likely because camera placement did not include habitats likely to be used by the missing species (Chutipong et al., 2014). For example, we did not record

the presence of hog deer during camera trapping from 2001 to 2010; however, in 2011, this species was photographed in traps specifically set in swampy grassland habitat that is more typically used by hog deer and where traps had not been previously set. Large-sized (≥ 1 kg) mammals of at least 58 species have been recorded or are presumed to occur throughout northern Myanmar (Appendix 4; Corbett & Hill, 1992). Many of these have specific habitat niches that were unlikely to be detected by camera-traps set in this study due to arboreal behavior (e.g., gibbons) or affinity to water (e.g., otters), or high elevation (e.g., red pandas). Others are extremely rare (e.g., leaf deer) or likely were rare occurrences recorded outside of their normal range (e.g., red foxes). Nevertheless, we did document a substantial number of species, and the relative frequency of their occurrence gives us a sense of their abundance (Rovero & Marshall, 2009), recognising that reliability is an issue for these indices (Carbone et al., 2001; Jennele et al., 2002). Capture frequency is likely dependent on camera location and spacing, species-specific body mass, home range size, and behavior (e.g., Trolle & Kery, 2005).

Differences in species-specific photo rates inside and outside of the Core area may be due in part to higher patrol efforts and thus a greater chance that illegal activities such as poaching are detected, in the core area. Jenks et al. (2010) found that abundance of photographed species was higher nearer ranger stations in a national park in Thailand and recommended more patrol efforts in areas away from stations to help reduce poaching. However, differences in photo rates between areas were likely influenced by habitat differences in elevation, slope, density of streams, trails, and roads, and perhaps vegetative cover type, causing natural variation in species distribution. Moreover, due to political instability in the region since 2006, it was observed that patrol efforts were inconsistent at best, and since 2012 patrol efforts were completely precluded from taking place.

With respect to the relatively higher photo rates of villagers and poachers in the Core area, we note that this likely is due to placement of a small number of camera traps in proximity to human settlements along the Ledo Road or along river access routes through the Core area that detected high rate of human traffic. In contrast, camera placements outside of the Core area were in more remote settings albeit less accessible to ranger patrol teams. Local hill tribes from the northern most part of the country's remote area migrate seasonally to the southern part of the Hukaung Valley through the Core area, in order to look for new jobs in agriculture and the mining industry. Still, photo rates of poachers inside the Core area declined over time, more likely due to the higher patrol effort rather than reduced detection rate of poachers by camera traps.

Declines in photo rates of some species, particularly tigers and several of their major prey species (especially sambar deer, barking dear, and wild pig), are an important finding of this study and a cause for conservation concern. When the Sanctuary was extended in 2004, the priority activities for the protected area were to increase staffing of the reserve, settle land claim issues of the local people, properly delineate reserve boundaries, build a headquarters and guard stations, build an education center and local education kiosks at key settlements, and provide an extensive community outreach program. Despite efforts made under a very modest protected area budget, interviews of local hunters by Kywe (2012) in 2010, along with auxiliary data collected by others, indicated that human activities, and intrusions such as logging, gold mining, dynamite fishing, non-timber forest product collections, and hunting continued to occur in the Core area (Kywe 2012: 46,125). Hunting, in particular, is likely a major factor affecting biodiversity in Myanmar protected areas (Rao et al., 2010, 2011), and the viability of tiger populations is affected by tiger poaching (Kenney et al., 1995; Chapron et al., 2008; Rao et al., 2013) and other human impacts (Mondal & Nagendra, 2011). Still, after the gazettement of the protected area, the number of temporary migrants entering the Hukaung Valley increased significantly and our results subsequently documented wildlife declines in the core area and to a lesser extent the outside core area. Establishing the protected area while simultaneously planning for monitoring or mitigating potential human population growth seems a sensible step that must be considered in the future.

Overall, our camera surveys, though not originally intended to serve as a long-term monitoring survey for wildlife diversity, provide important insights into wildlife distribution and abundance trends, especially for an area where few data have been gathered (Zaw et al., 2008). One of the bird species we photographed, the White-bellied, or Imperial, Heron, is classified as one of the world's 100 most threatened species, with a world population of only 70–400 individuals (Baillie & Butcher, 2012). Our documentation of a probable decline in the tiger population, the focal species for the protected area, may be sufficient justification for supporting conservation efforts to recover the species and re-establish a source population (Walston et al., 2010) in the Hukaung Valley landscape.

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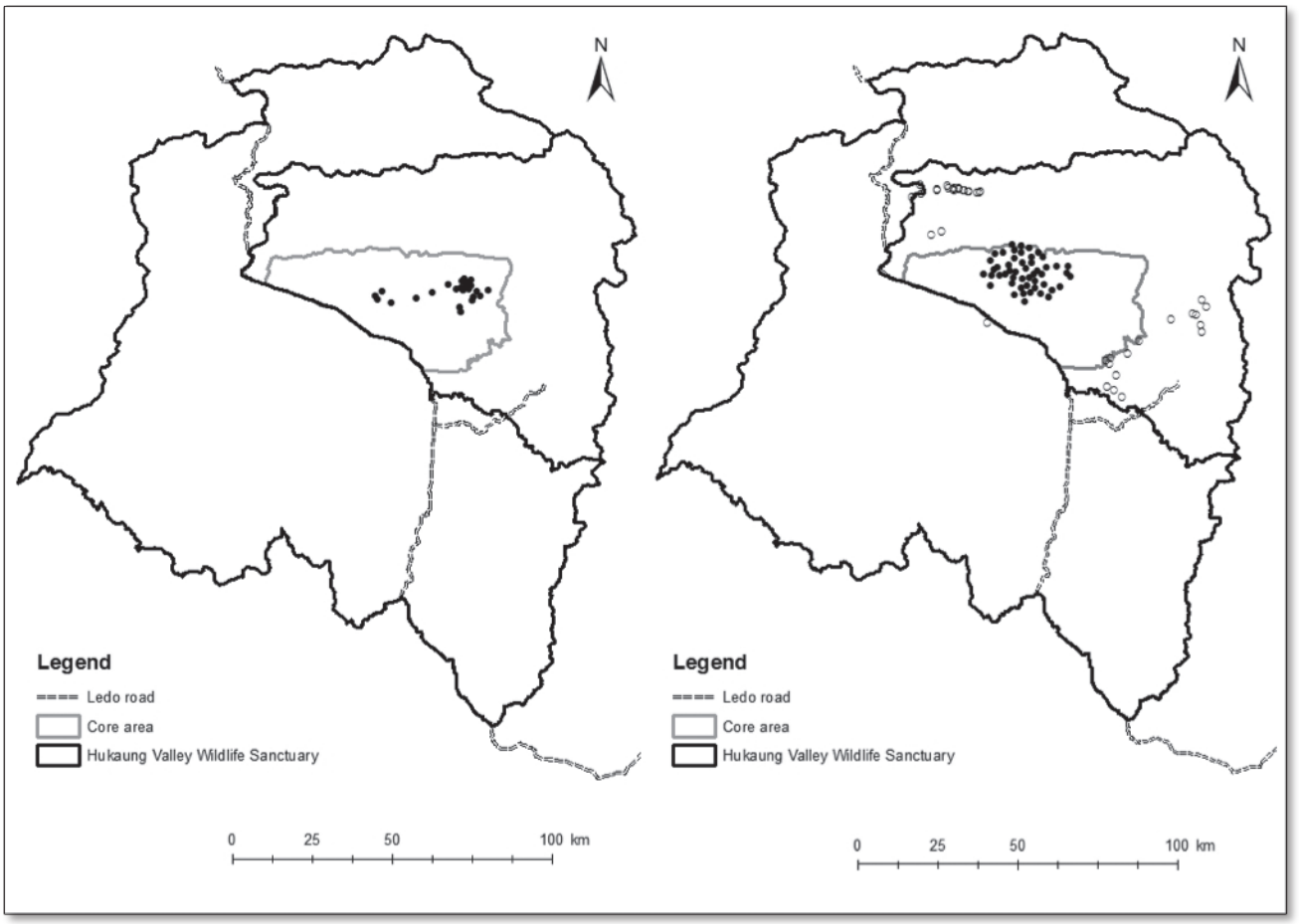
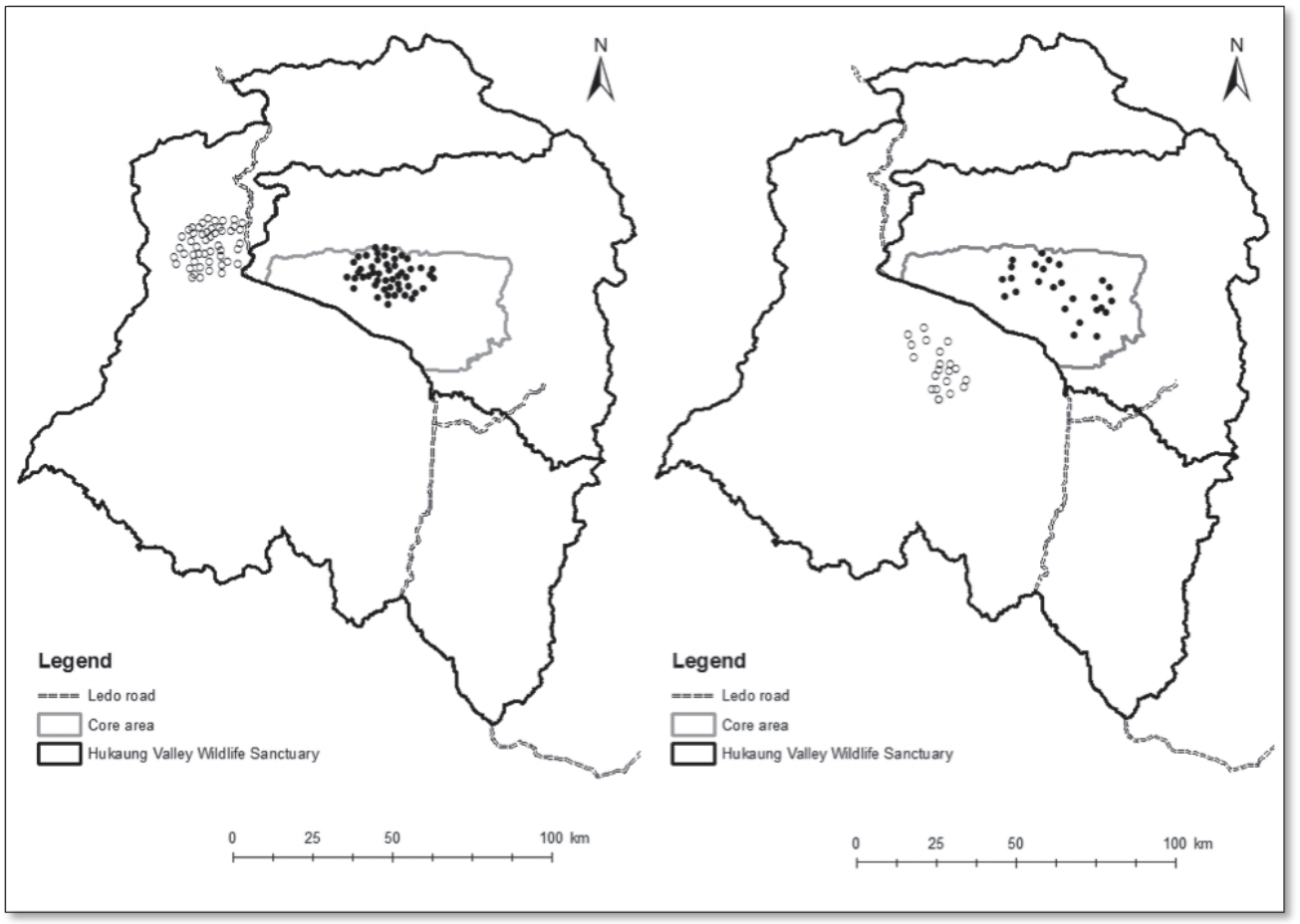
Appendix 1. Distribution of camera trapping survey efforts in the Core study area (circles) and Outside of the Core area (triangles) in the Hukaung Valley of northern Myanmar during 2001–2011.

Year	Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
2001–2002	Core					●	●				
2002–2003	Core			●	●	●	●				
	Outside					Δ	Δ				
2003–2004	Core			●	●	●					
	Outside							Δ	Δ	Δ	
2004–2005	Core						●	●			
	Outside								Δ	Δ	Δ
2005–2006	Core						●	●	●	●	
	Outside						Δ	Δ	Δ	Δ	
2006–2007	Core						●	●	●	●	
	Outside						Δ	Δ	Δ		
2009–2010	Core	●	●	●		●	●	●	●	●	●
	Outside			Δ		Δ	Δ	Δ			
2010–2011	Core						●	●			
	Outside								Δ	Δ	

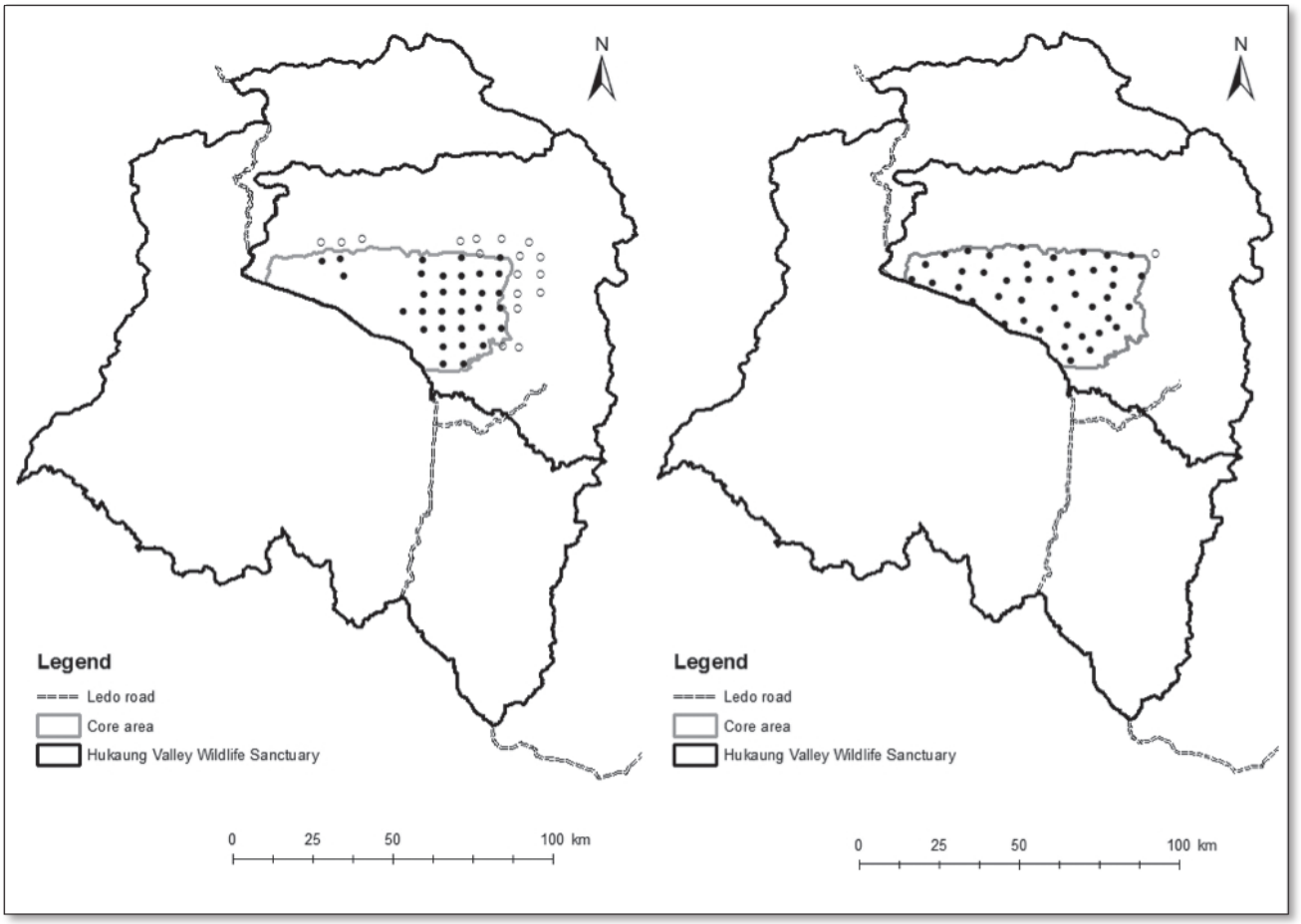
Appendix 2A. Locations of camera stations in 2001–2002 (left) and 2002–2003 (right) in the Hukaung Valley Wildlife Sanctuary of Myanmar.



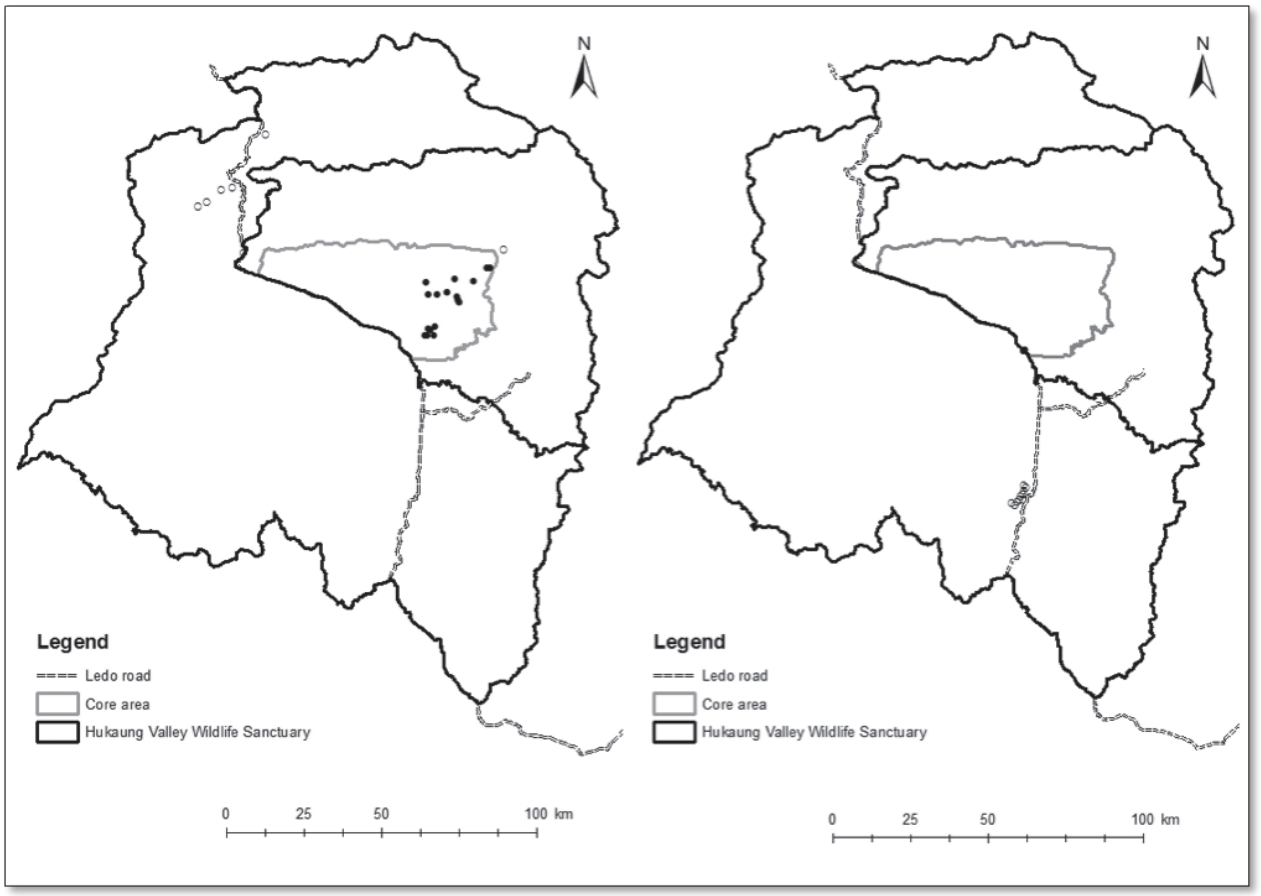
Appendix 2B. Locations of camera stations in 2003–2004 (left) and 2004–2005 (right) in the Hukaung Valley Wildlife Sanctuary of Myanmar.



Appendix 2C. Locations of camera stations in 2005–2006 (left) and 2006–2007 (right) in the Hukaung Valley Wildlife Sanctuary of Myanmar.



Appendix 2D. Locations of camera stations in 2009–2010 (left) and 2010–2011 (right) in the Hukaung Valley Wildlife Sanctuary of Myanmar.



Appendix 3. Annual camera trapping survey efforts and overall data accumulation for wildlife species in the Core study area, and Outside of the Core area, in the Hukaung Valley of northern Myanmar during 2001–2011.

Year	Zone	No. of Camera Stations	No. of Trap Nights	Mean No. of Trap Nights per Station	Wildlife		
					Total No. of Photos	Total No. of Independent Photos[a]	Total No. of Species Detected
2001–2002	Core	25	884	35.4	215	192	21
2002–2003	Core	63	1079	17.1	536	329	29
	Outside	38	748	19.7	163	143	19
2003–2004	Core	50	1042	20.8	344	221	28
	Outside	49	1069	21.8	441	299	25
2004–2005	Core	26	587	22.6	154	120	24
	Outside	21	627	29.9	83	66	16
2005–2006	Core	32	486	15.2	204	134	22
	Outside	17	260	15.3	100	71	17
2006–2007	Core	42	2056	49.0	415	269	29
	Outside	1	62	62.0	18	15	8
2009–2010	Core	17	1266	74.5	188	136	20
	Outside	7	393	56.1	63	51	8
2010–2011	Core	5	52	10.4	23	16	2
	Outside	10	139	13.9	22	15	3
Total	Core	260	7452	30.6	2079	1417	48
	Outside	143	3298	31.2	890	660	33
Grand Total		403	10750	30.9	2969	2077	51

[a]Independent photo = (1) consecutive photographs of different individuals of the same or different species, (2) consecutive photographs of individuals of the same species when separated by more than 30 min, or (3) non-consecutive photos of individuals of the same species (O'Brien et al 2003).

Appendix 4. Large (≥1 kg) mammals believed to occur in northern Myanmar (U Tun Yin, 1967a, b; Rabinowitz et. al, 1999) but were not photographed from 2001–2011 in the Hukaung Valley Wildlife Sanctuary.

Common Name	Scientific Name	Presumed Distribution
jungle cat	*Felis chaus*	Myanmar border in Kachin
fishing cat	*Prionailurus viverrinus*	Myanmar
Asiatic jackal	*Canis aureus*	Myanmar and Assam, India
Indian wolf	*Canis lupus pallipes*	Northern Myanmar
red fox	*Vulpes bengalensis*	Myitkyina, Kachin
red panda	*Ailurus fulgens*	Northern Myanmar
Bengal slow loris	*Nycticebus bengalensis*	Myanmar
small-toothed palm civet	*Arctogalidia trivirgata*	Myanmar border with Assam, India (Upper Chindwin R.)
Chinese ferret-badger	*Melogale moschata*	Northern Myanmar, Naga Hills, Myitkyina
Myanmar ferret-badger	*Melogale personata*	Myanmar, Assam and Manipur (India)
spotted linsang	*Prionodon pardicolor*	Northern Myanmar, Assam (India
common otter	*Lutra lutra*	Upper Myanmar, Myitkyina
Oriental small-clawed otter	*Aonyx cinerea*	Myanmar
Hoolock gibbon	*Hylobates hoolock*	Upper Myanmar
Phayre's leaf monkey	*Trachypithecus phayrei*	As far north as Bhamo
Assamese macaque	*Macaca assamensis*	Northern Myanmar, Naga Hills
greater one-horned rhinoceros	*Rhinoceros unicornis*	Bumpha Bum, Myitkyina
Sumatran rhinoceros	*Dicerorhinus sumatrensis*	Myanmar, Shwe-U-Daung Wildlife Sanctuary
mythun	*Bos frontalis*	Naga hill, Kachin hills, Kachin
banteng	*Bos javanicus*	Kachin, Myanmar
wild buffalo	*Bubalus arnee*	Assam, India; Bhamo and East Katha, Myanmar
tufted deer	*Elaphodus cephalophus*	Northern Myanmar, Lisu
musk deer	*Moschus moschiferus*	Northern Myanmar
leaf deer	*Muntiacus putaoensis*	Northern Myanmar
Myanmar goral	*Naemorhedus goral*	Myanmar Jinghpaw (Bum-ya)