Assessing sloth bears as surrogates for carnivore conservation in Sri Lanka

Shyamala Ratnayeke[1,3] and Frank T. van Manen[2,4]

[1]*University of Tennessee, Department of Forestry, Wildlife and Fisheries, 274 Ellington Plant Sciences Building, Knoxville, TN 37996, USA*
[2]*United States Geological Survey, Leetown Science Center, University of Tennessee, Department of Forestry, Wildlife and Fisheries, 274 Ellington Plant Sciences Building, Knoxville, TN 37996, USA*

Abstract: Bears are large, charismatic mammals whose presence often garners conservation attention. Because healthy bear populations typically require large, contiguous areas of habitat, land conservation actions often are assumed to benefit co-occurring species, including other mammalian carnivores. However, we are not aware of an empirical test of this assumption. We used remote camera data from 2 national parks in Sri Lanka to test the hypothesis that the frequency of detection of sloth bears (*Melursus ursinus*) is associated with greater richness of carnivore species. We focused on mammalian carnivores because they play a pivotal role in the stability of ecological communities and are among Sri Lanka's most endangered species. Seven of Sri Lanka's carnivores are listed as endangered, vulnerable, or near threatened, and little empirical information exists on their status and distribution. During 2002–03, we placed camera traps at 152 sites to document carnivore species presence. We used Poisson regression to develop predictive models for 3 categories of dependent variables: species richness of (1) all carnivores, (2) carnivores considered at risk, and (3) carnivores of least conservation concern. For each category, we analyzed 8 a priori models based on combinations of sloth bear detections, sample year, and study area and used Akaike's information criterion (AIC_c) to test our research hypothesis. We detected sloth bears at 55 camera sites and detected 13 of Sri Lanka's 14 Carnivora species. Species richness of all carnivores showed positive associations with the number of sloth bear detections, regardless of study area. Sloth bear detections were also positively associated with species richness of carnivores at risk across both study years and study areas, but not with species richness of common carnivores. Sloth bears may serve as a valuable surrogate species whose habitat protection would contribute to conservation of other carnivores in Sri Lanka.

Key words: Carnivora, conservation surrogate, *Melursus ursinus*, Poisson regression, remote camera, sloth bear, species richness, Sri Lanka

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Challenges associated with managing growing numbers of threatened and endangered species have prompted various approaches for prioritizing what species and ecosystems should be protected (Noss 1990, Lambeck 1997, Simberloff 1998). Certain species may serve as indicators of biodiversity, threatened habitats, or ecological processes (Caro and O'Doherty 1999), or are sufficiently charismatic that they can serve as flagships for conservation (Simberloff 1998). If species have area and resource requirements that would encompass those of other species, they could serve as conservation umbrellas (Frankel and Soulé 1981, Noss 1990, Ozaki et al. 2006). The umbrella species concept has been used to delineate protected areas (Caro 2003) and to identify or predict regions of high biodiversity (Cardoso et al. 2004, Thorne et al. 2006).

Sri Lanka is one such country where conservation challenges may be effectively addressed using the sloth bear (*Melursus ursinus*) as a surrogate for conservation. Fourteen species of Carnivora occur in Sri Lanka (Phillips 1984; Table 1). Mammalian

[3]Current address: School of Biology, The University of Dodoma, PO Box 338, Dodoma, Tanzania; sratnayeke@gmail.com
[4]Current address: US Geological Survey, Northern Rocky Mountain Science Center, Interagency Grizzly Bear Study Team, Bozeman, MT 59715, USA

Table 1. Carnivore species of Sri Lanka (Phillips 1984), International Union for Conservation of Nature/Species Survival Commission (IUCN/SSC) Red List 2011 status, and population trend based on entire geographic distribution.

Family	Common name	Scientific name	IUCN/SSC Red List	Population trend
Felidae	jungle cat	*Felis chaus*	least concern	declining
	fishing cat	*Prionailurus viverrinus*	endangered	declining
	rusty spotted cat	*Prionailurus rubiginosus*	vulnerable	declining
	leopard	*Panthera pardus*	near threatened	declining
Canidae	golden jackal	*Canis aureus*	least concern	increasing
Ursidae	sloth bear	*Melursus ursinus*	vulnerable	declining
Mustelidae	European otter	*Lutra lutra*	near threatened	declining
Viverridae	small Indian civet	*Viverricula indica*	least concern	stable
	common palm civet	*Paradoxurus hermaphroditus*	least concern	stable
	golden palm civet	*Paradoxurus zeylonensis*	vulnerable	declining
Herpestidae	Indian grey mongoose	*Herpestes edwardsi*	least concern	unknown
	Indian brown mongoose	*H. fuscus*	vulnerable	declining
	Indian ruddy mongoose	*H. smithii*	least concern	declining
	stripe-necked mongoose	*H. vitticollis*	least concern	stable

carnivores tend to occur at low densities and in small populations, which makes them particularly vulnerable to habitat loss, poaching, and local extinction (Woodruffe and Ginsberg 1998, Woodruffe 2001, Cardillo et al. 2004). Indeed, 5 Carnivora species in Sri Lanka are listed as Endangered or Vulnerable and 2 as Near Threatened (International Union for Conservation of Nature [IUCN] 2011; Table 1), but little empirical data exist on past or recent distributions of these species. All forms of sport hunting were banned in Sri Lanka in 1956, but conservation measures for carnivores have been mostly incidental through in-situ conservation of habitat reserves to protect and facilitate the movement of Asian elephants (*Elephas maximus*). The presence of intact carnivore assemblages is important because carnivores play an important role in structuring ecological communities (Eisenberg 1989, Prugh et al. 2009). However, biological knowledge of the habitat requirements, current distribution, and population status of Sri Lanka's carnivores is poor, the sloth bear being a notable exception (Santiapillai and Santiapillai 1990; Ratnayeke et al. 2006, 2007a,b).

Our objective was to determine whether the sloth bear could serve as a conservation surrogate for other mammalian carnivores in Sri Lanka. The sloth bear, found on the Indian subcontinent and Sri Lanka, occurs in a global region with high human densities, widespread poverty, and few resources for conservation planning (Garshelis et al. 1999). For example, human densities in Sri Lanka exceed 300 people/km^2 with almost 80% of the population living in rural areas (United Nations Secretariat 2011). Subsistence farming is the most widespread means of livelihood for rural families, who also exploit forests to supplement incomes (Forest Resources Assessment 2000), increasing the potential for forest degradation and loss of wildlife habitat. This trend is expected to accelerate in the aftermath of a 30-year civil war that ended in 2008, with subsequent resettlement of displaced families in the north and east. Sloth bears are still distributed widely in remaining forests of Sri Lanka's dry lowlands, where human densities and disturbance are low (Ratnayeke et al. 2007a,b), and thus could be a potentially useful species to identify, prioritize, and manage areas for biodiversity protection (Fleishman et al. 2004). Areas occupied by sloth bears in the north and east of Sri Lanka contain the largest extents of unprotected, contiguous forest on the island (Ratnayeke et al. 2006). Establishing protected areas for bears in this region might also serve to protect habitat for numerous carnivore species. Detection of sloth bears with remote cameras, for example, may provide an effective tool to identify priority areas for carnivore conservation. Therefore, we tested the research hypothesis that carnivore richness is associated with the frequency of detection of sloth bears. We tested this hypothesis for all carnivores, carnivores at risk (IUCN categories Endangered, Vulnerable, and Near Threatened), and common carnivores in Sri Lanka.

Study area

The national parks of Yala (126,781 ha) and Wasgomuwa (39,385 ha) are in the dry zone lowlands of Sri Lanka and represent 2 different landscapes typical of sloth bear range (Panwar and Wickramasinghe 1997, Pabla et al. 1998, Ratnayeke et al. 2007b). Both parks are composed of a mosaic of vegetation types ranging from dense forest to open grassland. Yala National Park is situated along the southeastern coastline (81°20′E, 6°33′N) and Wasgomuwa National Park is in the central lowlands (80°55′E, 7°45′N; Fig. 1). The climate is classified as Tropical Dry Zone (Domrös 1974), with an extended dry period from June through mid October, although the southernmost region of Yala receives much less rainfall (<50 cm annually) than Wasgomuwa (>180 cm annually). Most precipitation occurs from November through January.

At Wasgomuwa, elevations range from 60 to 200 m of undulating terrain separated by a long ridge (300–1,000 m) extending north–south. In contrast, Yala's topography is mostly flat undulating plain (30–100 m) interspersed with rock outcrops (Panwar and Wickramasinghe 1997). Temperatures are uniformly high throughout the year, with an annual mean of 32°C.

Both national parks supported high faunal diversity including large herbivores such as Asian elephants, buffalo (*Bubalus bubalis*), sambar (*Rusa unicolor*), and spotted deer (*Axis axis*). Vegetation at Wasgomua and Yala was broadly classified as dry monsoonal forest (Jayasingham et al. 1992, Jayasingham and Vivekanantharajah 1994, Panwar and Wickramasinghe 1997) dominated by *Drypetes sepiaria* and *Manilkara hexandra* trees. Owing to its coastal proximity, Yala had greater habitat heterogeneity, including mangrove and sand dune communities, and greater expanses of short grasslands interspersed with thorn scrub and *Salvadora persica* trees. Wasgomuwa National Park's southern region consisted of a patchwork of grassland, scrub, and secondary forest, reflecting various stages of ecological succession resulting from human occupation before establishment of the national park in the early 1980s. Legal entry into both national parks required permits and a Department of Wildlife Conservation (DWLC) guide.

Methods

Field sampling

We used remote cameras (Trailmaster®, Lenexa, Kansas, USA; Kucera and Barrett 1993) triggered by active infrared sensors to detect sloth bears and other carnivores. Remote cameras are effective for sampling species that are secretive and difficult to capture (Karanth 1995, Wemmer et al. 1996, Karanth and Nichols 1998, Kelly et al. 2008). We overlaid the national parks with a 1-km^2 grid, and demarcated regions that covered a range of habitat types and could be accessed by road or by foot. We numbered those grid cells and randomly selected 98 cells at Wasgomuwa and 90 at Yala for field sampling. The size of the grid cells was appropriate for our analysis because sloth bear home ranges we documented in Wasgomuwa National Park are some of the smallest reported for any bear species (Ratnayeke et al. 2007a). We sampled during the dry season (Jun–Sep). We sampled 49 sites at Wasgomuwa and 50 sites at Yala in 2002. In 2003, we sampled an additional 49 sites at Wasgomuwa and 40 sites at Yala. We deployed 3–5 cameras/session; not all sites were sampled concurrently. In a few instances, we placed cameras in adjacent grid cells if recent illegal activity (e.g., poaching, logging) at the original site was evident. This resulted in 6 grid cells being sampled twice, although the site of camera placement and time that the cell was sampled differed. We recorded the locations of camera sites with a global positioning system (GPS) receiver. We placed 1 camera within a grid cell along an animal trail for 4 consecutive nights and programmed all cameras using a 1-minute delay between pictures. We placed sensors to maximize detection of sloth bears and small and medium-sized carnivores by positioning the infrared beam at a height of 12–15 cm above ground level across animal trails. Camera systems recorded an event when the infrared beam was intercepted for >0.15 seconds.

We calculated carnivore species richness at each camera site as the number of detected mammalian carnivore species, excluding sloth bears. For each camera site, we used activity data from the Trailmaster receiver to determine detection (presence of 1 or more bears) or nondetection of sloth bears for 4 consecutive sampling occasions of 24 hr.

Thus, the maximum number of detections of sloth bears at a camera site was 4. We used the number of sloth bear detections at camera sites rather than sloth bear presence or absence because detections contained more information, not only measuring presence of bear habitat but also the relative importance of habitat.

Analysis

We used Poisson regression (Jones et al. 2002) to determine if carnivore species richness (the dependent

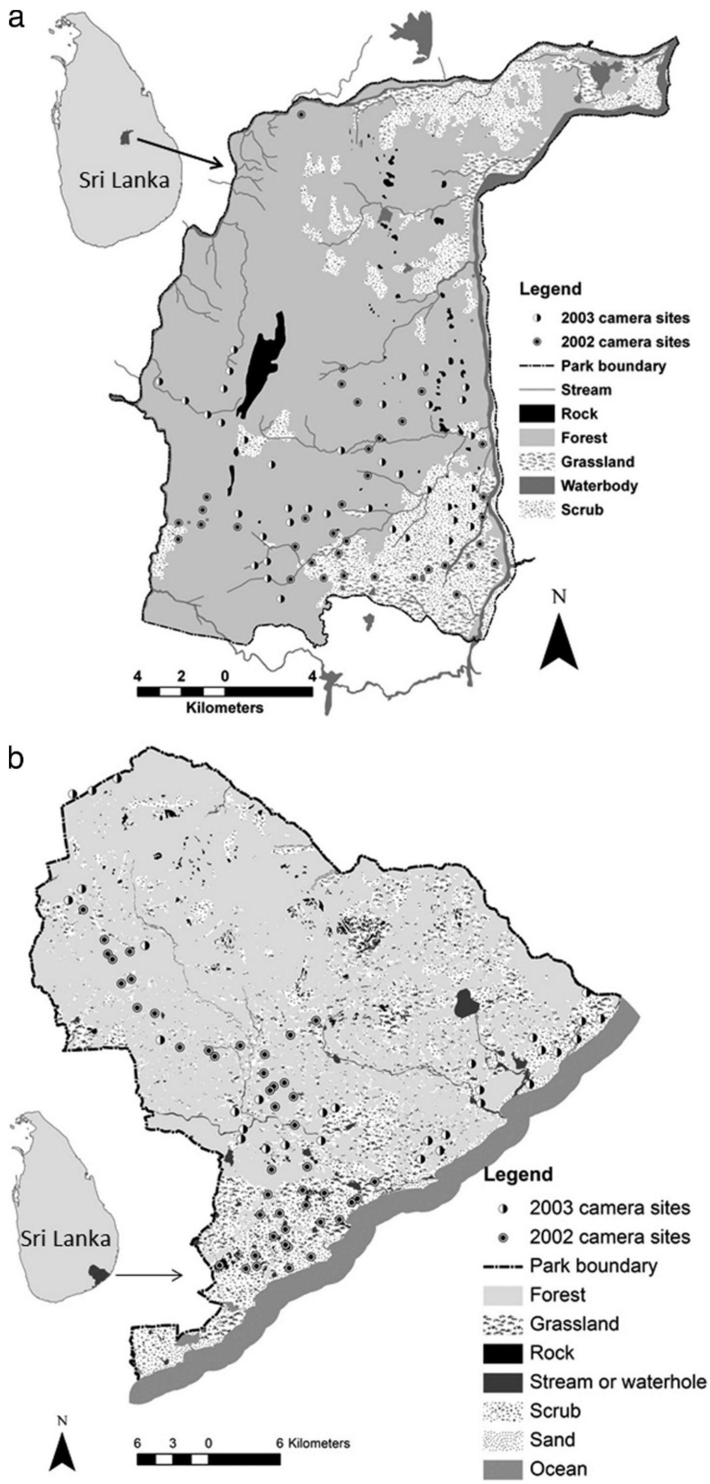

Fig. 1. Location of (a) Wasgomuwa National Park and (b) Yala National Park, Sri Lanka, displaying sampling sites to assess carnivore species distributions in 2002–03. Original habitat classes were derived from Pabla et al. (1998) and Panwar and Wickramasinghe (1997).

variable) can be predicted by the frequency of sloth bear detections, study year, and study area. Poisson regression is particularly suited for data from faunal or floral surveys, which often involve count data that tend to have skewed frequency distributions. We conducted separate analyses for 3 different groupings of carnivores, excluding bears: (1) all carnivore species reported from Sri Lanka (Table 1), (2) carnivores considered at risk (species listed as Endangered, Vulnerable, or Near Threatened by IUCN; Table 1), and (3) carnivores that were common. We used IUCN rankings to designate species to these categories, but there were a few exceptions for common carnivores based on data from Sri Lanka. For common carnivores, we considered 4 species whose conservation status was listed as Least Concern by the IUCN (2011): small Indian civet, common palm civet, golden jackal, and grey mongoose. These 4 species were common outside protected areas and in areas occupied by humans (Phillips 1984, Duckworth et al. 2008a,b), and population trends were thought to be stable or increasing, with the exception of the grey mongoose whose population trends were "unknown" (IUCN 2011). Three other species were listed by the IUCN as Least Concern (jungle cat, stripe-necked mongoose, ruddy mongoose; Table 1) but we disagreed with this status for Sri Lanka. The ruddy mongoose is not common outside protected areas in Sri Lanka (S. Ratnayeke, personal observation), nor near human settlements (Shekhar [2003], cited in Choudhury et al. 2008). The jungle cat and stripe-necked mongoose are uncommon within and outside protected areas in Sri Lanka (Phillips 1984; S. Ratnayeke, personal observation). Finally, populations of the jungle cat and ruddy mongoose are perceived as declining (Choudhury et al. 2008, IUCN 2011). Therefore, we did not include these 3 species in the category of common carnivores.

For each of the 3 categories of carnivore species richness, we fitted 8 a priori models using combinations of the 3 independent variables (number of sloth bear detections, study area, study year). Our main question was whether carnivore species richness can be predicted by the number of sloth bear detections. Because the relationship between carnivore species richness and sloth bear detections may vary with study year and study area, we also examined the influence of year and study area on carnivore species richness and their 2-way interactions with the number of sloth bear detections (Table 2). In using study area as a covariate, we implicitly tested the hypothesis that relationships between carnivore richness and sloth bear detections varied according to the coarse-scale habitat differences between the 2 study areas. We used Akaike's information criterion adjusted for small sample size (AIC_c: Hurvich and Tsai 1989, Burnham and Anderson 2002) to examine the evidence for competing models. We based inference on the entire set of models and used 95% confidence intervals of model-averaged parameter estimates to identify informative variables (Anderson 2008). We used residual plots to examine if Poisson regression assumptions were met. We used R (version 2.14.1; R Development Core Team 2007) statistical software to perform the Poisson regressions.

Results

Data loss at several sites was caused by stolen cameras, camera malfunction, or cameras being dislodged by animals, thus yielding <4 nights of data. Because it was logistically difficult to resample those sites, we excluded them from analysis. At Wasgomuwa, we obtained adequate camera data from 36 sites in 2002 and 39 different sites in 2003, resulting in 300 camera nights (Fig. 1a). At Yala we obtained usable data from 46 camera sites in 2002 and 31 in 2003, totaling 308 camera nights (Fig. 1b). We detected all of Sri Lanka's 14 carnivora species (Fig. 2), except for the endangered fishing cat (*Prionailurus viverrinus*). We recorded the small Indian civet and ruddy mongoose most frequently at Yala (Fig. 2). At Wasgomuwa, we photographed the small Indian civet and the sloth bear most frequently (Fig. 2). We detected 12 carnivore species, excluding bears, at 128 of 152 remote camera sites, carnivores at risk (n = 5) at 70 sites, and common carnivores (n = 4) at 89 sites (Fig. 3). More camera sites were visited by carnivore species in Yala (87%) than at Wasgomuwa (76%), but the proportion of sites visited at Yala (46%) and Wasgomuwa (47%) was similar for carnivores at risk. We detected a mean overall carnivore species richness of 1.73 (SD = 1.45, range = 0–6) per site at Wasgomuwa and 1.79 (SD = 1.22, range = 0–5) at Yala. Species richness of carnivores at risk ($\bar{x}$ = 0.65, SD = 0.83, range = 0–3) and common carnivores ($\bar{x}$ = 0.67, SD = 0.64, range = 0–2) at Wasgomuwa were similar. At Yala, species richness of common carnivores ($\bar{x}$ = 0.75, SD = 0.71, range = 0–2) was greater than that of carnivores at risk ($\bar{x}$ = 0.51, SD = 0.60, range =

Table 2. Model selection results of Poisson regressions to predict 3 dependent variables of carnivore species richness (all carnivores, carnivores at risk, common carnivores) from the number of sloth bear detections (bear) at camera sites, year of study (year), study area (area), and their 2-way interactions (bear x year, bear x area), Yala and Wasgomuwa National Parks, Sri Lanka, 2002–03.

Model	AIC_c [a]	ΔAIC_c [b]	AIC_c weight	*K* [c]
All carnivores				
bear, year	482.03	0	0.45	3
bear, year, bear x year	483.42	1.39	0.23	4
bear, area	484.74	2.71	0.12	3
bear	485.33	3.30	0.09	2
bear, year, area, bear x year, bear x area	485.87	3.84	0.07	6
bear, area, bear x area	486.47	4.44	0.05	4
year	492.30	10.27	0.00	2
area	502.09	20.06	0.00	2
Carnivores at risk				
bear	292.76	0	0.39	2
bear, year	293.56	0.80	0.26	3
bear, area	294.82	2.05	0.14	3
bear, year, bear x year	295.34	2.58	0.11	4
bear, year, area, bear x bear, bear x area	296.36	3.59	0.07	6
bear, area, bear x area	298.86	6.09	0.02	4
year	300.28	7.51	0.01	2
area	302.24	9.48	0.00	2
Common carnivores				
bear, year	313.69	0	0.31	3
area	315.00	1.31	0.16	2
bear	315.05	1.35	0.16	2
bear, area	315.13	1.44	0.15	3
bear, year, bear x year	315.41	1.71	0.13	4
bear, area, bear x area	317.19	3.50	0.05	4
bear, year, area, bear x year, bear x area	318.51	4.81	0.03	6
area	319.84	6.14	0.01	2

[a]Akaike's information criterion adjusted for small *n*.
[b]Difference in AIC_c compared with lowest AIC_c model.
[c]Number of model parameters.

0–2; $t = 2.33$, 148 df, $P = 0.020$). For Wasgomuwa, frequencies of grid cells with 0, 1, 2, 3, and 4 sloth bear detections were 39, 22, 9, 3, and 2, respectively. For Yala, these frequencies were 58, 16, 3, 0, and 0, respectively.

At different levels of covariates, variances were similar to or slightly smaller than the means for all 3 categories of carnivore species richness. Thus, we found no evidence of overdispersion. Residual plots of fitted values indicated constant variances. Considering all carnivores, models that received the most support suggested carnivore species richness was positively associated with the number of bear detections and varied by year (Table 2). Confidence intervals for model-averaged parameter estimates excluded zero for bear detections and study year but not for the bear x year interaction, suggesting the relationship between carnivore richness and bear detections did not vary by year (Table 3). On average, 1.46 carnivore species occurred at camera sites if sloth bears were not present; with sloth bear detections mean carnivore species richness increased from 1.91 for 1 detection to 4.29 for 4 detections. Carnivore species richness was greater in 2002 ($\bar{x} = 2.07$) than 2003 ($\bar{x} = 1.40$). Models for carnivores at risk also suggested that species richness was positively associated with bear detections and was greater during 2002 ($\bar{x} = 0.68$) than 2003 ($\bar{x} = 0.46$; Table 2); unlike models based on all carnivores, the frequency of bear detections was the most important correlate of carnivore species richness (Table 3). An average of 0.46 at-risk carnivores were observed at camera sites without sloth bear presence, which increased to 0.64 for 1 sloth bear detection and to 1.79 for 4 detections. A variety of models for common carnivores indicated broad support (Table 2). Greater species richness of common carnivores was associated with the number of bear

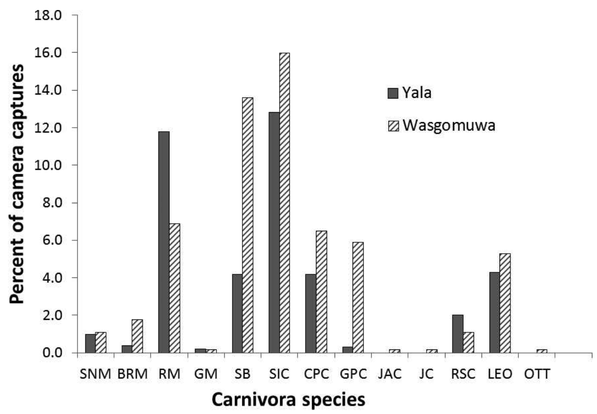

Fig. 2. Relative frequency expressed as a percentage of all camera captures ($n = 713$) of Carnivora at Yala and Wasgomuwa national parks, Sri Lanka, 2002–03, for stripe-necked mongoose (SNM), brown mongoose (BRM), ruddy mongoose (RM), grey mongoose (GM), sloth bear (SB), small Indian civet (SIC), common palm civet (CPC), golden palm civet (GPC), golden jackal (JAC), jungle cat (JC), rusty spotted cat (RSC), leopard (LEO), and European otter (OTT).

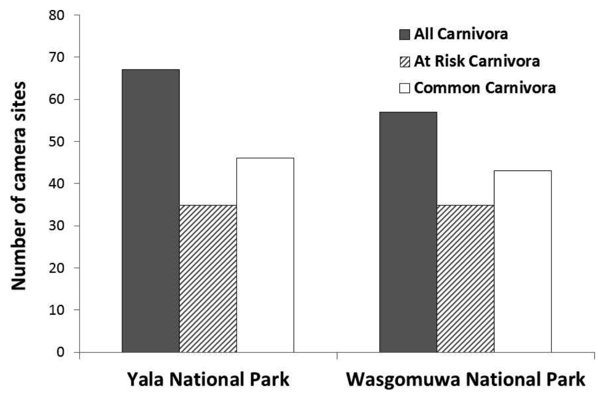

Fig. 3. Number of camera sites at Yala National Park (total $n = 77$) and Wasgomuwa National Park (total $n = 75$), Sri Lanka, 2002–03, where we recorded species of Carnivora, excluding bears.

detections, study year, study area, and bear x year interaction. However, confidence intervals for model-averaged parameter estimates overlapped zero for all parameters (Table 3), suggesting no association between species richness of common carnivores and sloth bear detections.

Discussion

Our study provides the first empirical data on carnivore species occurrence and distribution in 2 protected areas in the low country dry zone of Sri Lanka. Carnivore guilds that include 10 or more species are rare (Schaller 1996). Our documentation of 13 of the island's 14 carnivore species indicates the global significance of Yala and Wasgomuwa National Parks. Our measures of carnivore richness and frequency of sloth bear detections varied substantially among camera sites, thus providing a suitable data set to test our research hypothesis. Sloth bears were detected at a lower proportion of sites at Yala than at Wasgomuwa, but species richness of all carnivores, and at-risk carnivores in particular, was positively associated with the frequency of bear detections regardless of study area. Because we used the study area covariate as a coarse-scale measure of sloth bear habitat conditions, this finding suggests the relationship between carnivore species richness and sloth bear detections was similar for both landscapes. Our models indicated species richness of carnivores was greater at camera sites in 2002 than in 2003, which corresponded with our expectations. Precipitation during the second study year was greater, which may have resulted in more dispersed movements and consequently less reliance on heavily used animal trails that often form the shortest route between sources of water for many species, including carnivores. Although bear detections were fewer during the second year of the study, the lack of a distinct interaction effect with study year indicated the relationship with species richness of all carnivores or carnivores at risk was similar both years. These results suggest that the sloth bear may serve as a useful indicator of areas that are also occupied by other carnivores in Sri Lanka, particularly carnivores of conservation concern. Furthermore, large carnivores such as sloth bears can garner substantial conservation attention, and because they leave conspicuous sign or are easily observed, their populations are more effectively monitored than small species.

We considered 3 caveats interpreting the results of our analyses: (1) factors that may bias species richness estimates, (2) application of the observed relationship between sloth bear detections and carnivore richness outside protected areas of Sri Lanka, and (3) measuring species richness may diminish the important role of rare species to conservation. Behavioral differences among species or between sexes of the same species likely influenced

Table 3. Model-averaged parameter estimates and their standard errors and confidence intervals for Poisson regression parameters to determine relationships of 3 dependent variables of carnivore species richness (all carnivores, carnivores at risk, common carnivores) with number of sloth bear detections (bear) at camera sites, year of study (year), study area (area), and their interactions (bear x year, bear x area), Yala and Wasgomuwa National Parks, Sri Lanka, 2002–03.

Parameter	Model-averaged parameter estimate	Standard error	95% lower CI	95% upper CI
All carnivores				
intercept	0.29 [a]	0.14	0.01	0.58
bear	0.27 [a]	0.11	0.06	0.48
year	0.24 [a]	0.12	0.00	0.49
area	−0.05	0.05	−0.16	0.05
bear x year	−0.04	0.06	−0.15	0.07
bear x area	0.01	0.02	−0.03	0.05
Carnivores at risk				
intercept	−0.84 [a]	0.18	−1.20	−0.48
bear	0.34 [a]	0.14	0.06	0.61
year	0.12	0.12	−0.12	0.35
area	0.00	0.06	−0.11	0.11
bear x year	−0.02	0.04	−0.09	0.06
bear x area	0.02	0.03	−0.04	0.08
Common carnivores				
intercept	−0.57 [a]	0.21	−0.98	−0.17
bear	0.20	0.12	−0.04	0.45
year	0.26	0.17	−0.06	0.59
area	−0.07	0.08	−0.22	0.08
bear x year	−0.03	0.05	−0.12	0.07
bear x area	0.00	0.02	−0.04	0.05

[a]Confidence interval excludes zero

capture probabilities. We placed cameras along animal trails and across dry or partially dry stream beds. Species such as the common palm civet and golden palm civet (*Paradoxurus zeylonensis*) are semi-arboreal (Phillips 1984) and are possibly underrepresented in our camera data. Several species, including the grey mongoose, jungle cat, and golden jackal, frequent open habitats and may have little need for trails. Season and camera placement may have reduced the probability of obtaining photos of fishing cats and otters. Each of these factors would result in potential underestimation of carnivore richness, but this bias is not likely to vary with the number of sloth bear detections. Therefore, the relationships we observed between sloth bear detections and carnivore species richness would not be affected.

The second caution is that carnivore species distributions at Yala and Wasgomuwa may not represent the status of carnivore species in other parts of the low country dry zone, particularly unprotected areas. Richness and population sizes of at-risk carnivores are likely larger in protected areas. Thus, the relationship we observed between sloth bear detections and carnivore species richness may not be the same outside protected areas where anthropogenic influences are greater.

Thirdly, although species that are rare (and thus of greatest conservation concern) may not be well represented by measures of species richness, our data indicate this may not be a major concern. We used the IUCN Red List to determine the conservation status of carnivores. We recorded almost all species that were considered at risk at Yala and Wasgomuwa and many with greater frequency (e.g., the sloth bear, leopard, golden palm civet, rusty spotted cat, brown mongoose; Fig. 2) than species of Least Concern (e.g., grey mongoose, stripe-necked mongoose, golden jackal; Fig. 2). We recognize, however, this may not be the case for the otter (1 detection) and the endangered fishing cat (no detections). Although poor detection likely was a function of their rarity, narrow niche requirements may have played a role as well. Thus, it is important to document which species are represented when using surrogate species for conservation.

We also note that carnivores rarely encountered in protected areas might not necessarily be rare outside national parks. Camera records and direct observations of grey mongoose, stripe-necked mongoose, and jungle cat were infrequent during this study. It is possible that these species do better in areas occupied by humans, or experience ecological release where top predators or competitors they would encounter in protected areas are absent. These 3 species are listed as Least Concern (IUCN 2011) and have a wide geographic distribution, but their apparent rarity in the 2 national parks we surveyed suggests their distribution and status in Sri Lanka need to be assessed in more detail.

Our objective was to assess the potential for sloth bears to serve as a focal or surrogate species that would provide the incentive to protect other carnivores in Sri Lanka. Simberloff (1999) specifically addressed the role of bears as potential umbrella species whose protection would also safeguard species that coexist with bears. The umbrella species concept represents a hypothesis that has not been thoroughly tested (Simberloff 1998, 1999) and thus has received substantial criticism. For example, there is debate whether the requirements of a single species can effectively meet those of many co-occurring species (Berger 1997, Linnell et al. 2000, Caro 2003), particularly species from different orders and classes (Roberge and Angelstam 2004, Seddon and Leech 2008). Fleishman et al. (2004) suggested that a species could serve as an effective umbrella for conservation if its distribution overlapped with a relatively large percentage of its close taxonomic relatives or species of conservation interest (see Seddon and Leech 2008). Our analysis supports the notion that sites where sloth bears occur tend to have greater richness of carnivores, particularly those of greatest concern for conservation. Sloth bear detections were associated with 4 threatened carnivore species (leopard, rusty spotted cat, brown mongoose, and golden palm civet). Large portions of sloth bear range in the north and east of the island remain unprotected and currently experience heavy exploitation with the recent end of a 30-year civil war and the establishment and resettlement of human communities. About 800,000 ha in Sri Lanka exist in the form of sanctuaries, nature reserves, and national parks (Sri Lanka Department of Wildlife Conservation, Colombo, unpublished data), the majority of which function as protected areas for Sri Lanka's conservation flagship species, the Asian elephant. Although elephants have large area requirements, their primary habitats are associated with shifting agriculture (Fernando et al. 2006), which is unlikely to be optimal for threatened carnivore populations. Home ranges of sloth bears are small and despite its small size, Wasgomuwa National Park supports an abundance of sloth bears and other carnivores of conservation concern (Ratnayeke et al. 2007a). Even establishing small protected areas (e.g., similar in size to Wasgomuwa National Park) within sloth bear range in northern and eastern Sri Lanka would likely protect habitat for most carnivores of conservation concern.

Bears are generally viewed as a charismatic, flagship species whose presence contributes positively to conservation efforts (Simberloff 1998). That characteristic is also important if the sloth bear is to serve as a conservation surrogate or umbrella species. However, sloth bears frequently attack humans, often resulting in serious injuries or even death (Santiapillai and Santiapillai 1990, Rajpurohit and Krausman 2000, Bargali et al. 2005, Ratnayeke et al. 2006). Consequently, people who live in sloth bear habitat greatly fear bears (Ratnayeke et al. 2007b), posing considerable challenges to sloth bear conservation. Effective umbrellas, however, need not exclude species that are not good conservation flagships. Species associated with endangered biological communities can be effective umbrellas if their protection automatically extends protection to other species (Ozaki et al. 2006). Thus, if the sloth bear were to be used as a conservation surrogate for the dry lowlands of Sri Lanka, where most of the island's threatened carnivores remain, the significance of carnivores in ecological communities and the sloth bear's role as an indicator of healthy carnivore communities would need to be emphasized. Such an approach may be effective within the cultural framework of rural Sri Lanka where peasant traditions and livelihoods are closely linked with healthy, diverse ecosystems. The 1974 Chipko movement and 1995 Jungle Jeevan Bachao Yatra (Save the Forests, Save our Lives) march are examples in which rural communities have successfully championed the conservation of natural forests (Rangarajan 1996).

Finally, beyond the relationships we observed between sloth bears and other carnivores, we hypothesize that sloth bears may play a significant ecological role in tropical dry forests. Most regions inhabited by sloth bears experience long, dry periods where waterholes and streambeds dry out. Sloth bears dig deep holes in dry streambeds, some of which exceed 2–3 m in depth, to reach water (Phillips 1984; S. Ratnayeke, personal observation). The powerful forelimbs and long claws, adapted for breaking into termite mounds, undoubtedly help sloth bears with this ability. These watering sites are also used by a multitude of vertebrates and invertebrates. Six camera sites were near such waterholes, resulting in 21 photos of sloth bears, 35 photos of threatened carnivores, and 86 photos of other mammals, birds, and reptiles. This potential keystone function should be explored to elucidate the role of this unique species of bear in tropical dry forests.

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