Landscape Characteristics of Sloth Bear Range in Sri Lanka

Authors: Ratnayeke, Shyamala, van Manen, Frank T., Pieris, Rohan, and Pragash, V. S. J.

Source: Ursus, 18(2) : 189-202

Published By: International Association for Bear Research and Management

URL: https://doi.org/10.2192/1537-6176(2007)18[189:LCOSBR]2.0.CO;2

Landscape characteristics of sloth bear range in Sri Lanka

Shyamala Ratnayeke[1,4], Frank T. van Manen[1,5], Rohan Pieris[2], and V.S.J. Pragash[3]

[1]University of Tennessee, Department of Forestry, Wildlife and Fisheries, 274 Ellington Plant Sciences Building, Knoxville, TN 37996, USA
[2]Department of Zoology, Open University of Sri Lanka, Nawala, Nugegoda, Sri Lanka
[3]Department of Biological Science, Faculty of Applied Science, Vavuniya Campus, University of Jaffna, Kurumankadu, Vavuniya, Sri Lanka

Abstract: Little is known about the biology, status, or distribution of sloth bears (*Melursus ursinus*) in Sri Lanka. To facilitate sloth bear conservation, information is needed about where bears occur and what landscapes support their populations. We overlaid a 5- x 5-km grid on 1:50,000-scale land-use maps covering historic sloth bear range in Sri Lanka. In 2004, we documented current (2002–04) sloth bear presence or absence in each 25-km^2 cell by interviewing knowledgeable forest users. We sought as respondents hunters, wildlife and security personnel, and others with experience in their local forests as most likely to supply reliable information regarding the presence or absence of sloth bears. We also assessed respondents' perceptions and attitudes toward sloth bears. Sloth bear range occupied <17% of Sri Lanka's land area with approximately 40% contained within national parks and strict nature reserves where hunting is banned and human access regulated. Except for a few small, isolated areas, sloth bear range was largely contiguous. However, large portions of sloth bear range in the north and east of the island were unprotected. Prevalence of monsoon forest was the strongest positive predictor of sloth bear presence. Elevation, road density, and human population density were significant negative predictors. Perceptions that sloth bear populations had increased were common among almost half (49%) the respondents. Although 70% of respondents regarded sloth bears as a threat, 66% supported legal protection. This positive attitude toward protection may facilitate conservation efforts. The establishment of additional protected areas in the north and east of the island and strict regulation of human activity in protected areas may enhance sloth bear conservation.

Key words: attitudes, distribution, landscape analysis, *Melursus ursinus inornatus*, perceptions, sloth bear, Sri Lanka, survey

Ursus 18(2):189–202 (2007)

The sloth bear (*Melursus ursinus*) is a termite-eating specialist found on the Indian subcontinent. A subspecies of sloth bear (*M. u. inornatus*) is found in Sri Lanka and is the island's only species of bear. Sloth bears once were abundant in forests of the dry zone lowlands of Sri Lanka (Phillips 1984). Increasing agricultural and human settlement in those areas have resulted in rapid loss of forest cover and fragmentation of sloth bear habitat (Santiapillai and Santiapillai 1990). Although sloth bears in Sri Lanka are legally protected, they have a reputation for aggressiveness and inflicting serious injury to humans (Rajpurohit and Krausman 2000). Thus, sloth bear populations are also vulnerable to decline from direct conflict with humans.

Developing effective conservation measures for the sloth bear requires detailed information regarding their status and distribution (Garshelis et al. 1999). Santiapillai and Santiapillai (1990) identified protected areas in Sri Lanka where sloth bear populations were known to occur, but very little is known regarding the presence of sloth bears outside protected areas. Mapping the distribution of sloth bears and identifying the natural and anthropogenic landscape factors associated with bear occurrence would be useful to establish a benchmark against which future changes in the distribution could be evaluated, to identify areas where sloth bears may be restored, and to establish new protected areas.

[4]sratnaye@utk.edu [5]vanmanen@utk.edu

Implementing conservation measures for sloth bears also requires an understanding of human–bear relationships and attitudes toward bears. Human densities in Sri Lanka exceed 300 people/km^2 with almost 80% of the population living in rural areas (United Nations Secretariat 2004). Subsistence living is common, and most rural families use forests to meet immediate needs (Forest Resources Assessment 2000), increasing the potential for forest degradation and human–bear encounters. The objectives of our study were to: (1) map the distribution of the sloth bear in Sri Lanka, (2) identify landscape characteristics associated with sloth bear distribution, and (3) assess the perceptions and attitudes of forest users toward sloth bears.

Study area

Sri Lanka lies to the south of India between 5°55′–9°50′N and 79°42′–81°52′E. The climate is tropical, marked by 2 monsoonal periods bringing rainfall, the majority of which is received by the southwest region of the island. Sri Lanka has 3 main ecological regions based on total annual rainfall (Fig. 1): the wettest region is in the southwest and receives >2,500 mm rainfall annually, the dry zone receives <1,900 mm, and the intermediate zone transitions between the 2 regions (Domrös 1974). The island's land area of 67,864 km^2 (United Nations Environment Program [UNEP] 2003) consists of 3 main physiographic regions: the coastal lowlands (0–250 m) cover the majority of the land area and surround 2 successively higher, greatly dissected plateaus occupying the central hill country of the island (Fig. 1). The majority of the human population lives in the wet zone; most of the land in this region is used for agriculture (UNEP 2003).

Agriculture is the mainstay of Sri Lanka's economy, accounting for >40% of total employment (World Bank 1995). Most of the rural population practice small-scale or subsistence-level farming (World Bank 2002) and are compelled to exploit forests for fuel, food, and other sources of income (e.g., bushmeat, honey). Sri Lanka's life expectancy (73 years) is high, as is literacy (91.6 percent), but >25% of the population live below the national poverty level (World Bank 2003). The poorest households are in areas directly affected by civil conflict in the north and east of the island (World Bank 2002).

Almost 50% of Sri Lanka's land area is used for agriculture, whereas dense forests comprise approximately 24–26% (Ratnayake et al. 2002, UNEP 2003). Much of the remaining land is comprised of lowland sparse forests (18%), consisting of low-stature vegetation, and grasslands (UNEP 2003). Lowland sparse forest occurs naturally due to local edaphic factors or as result of disturbance (e.g., logging, fire, abandoned agriculture; Perera 2001). The dense natural forests of the dry zone have been variously defined (dry evergreen forest [De Rosayro 1961], semi deciduous forest–woodland [Greller and Balasubramaniam 1980], monsoon forest–open forest [UNEP 2003]), but we follow the definition of Legg and Jewell (1995), who use the term dry monsoon forest. Dry monsoon forests may be further subcategorized based on canopy height and differences in community composition (e.g., Pabla et al. 1998), but are generally characterized by species such as *Drypetes sepiaria, Manilkara hexandra, Chloroxylon swietenia*, and *Diospyros* spp. (De Rosayro 1961, Greller and Balasubramaniam 1980). De Rosayro (1961) considered all dry monsoon forests in Sri Lanka to be secondary in origin, having been reestablished on abandoned agricultural lands that were irrigated 500–800 years ago.

Early accounts of the distribution of the sloth bear in Sri Lanka indicate that it was almost exclusively confined to the dry zone in the early 20th century (Phillips 1984), when forests covered up to 80% of the island (Legg and Jewell 1995). We confirmed that the wet zone and central hill country had historically not supported sloth bears by interviewing individuals whose families had hunted in those areas for several generations. Phillips (1984) noted exceptional reports of bears in the hills (up to 1,200 m) during severe droughts. Thus, we limited our study to the dry zone and forests of the intermediate zone up to 1,500 m to fully represent the historic range of the sloth bear (Fig. 1).

Methods

Field surveys

Sloth bear distribution. We used a list of questions related to the perceptions and attitudes of people toward sloth bears, presence or absence of sloth bears, and demographic information of the interviewee. We administered the questionnaire orally as semi-structured interviews (Feuerstein 1986, Byers 1996) from February 25 to December 3

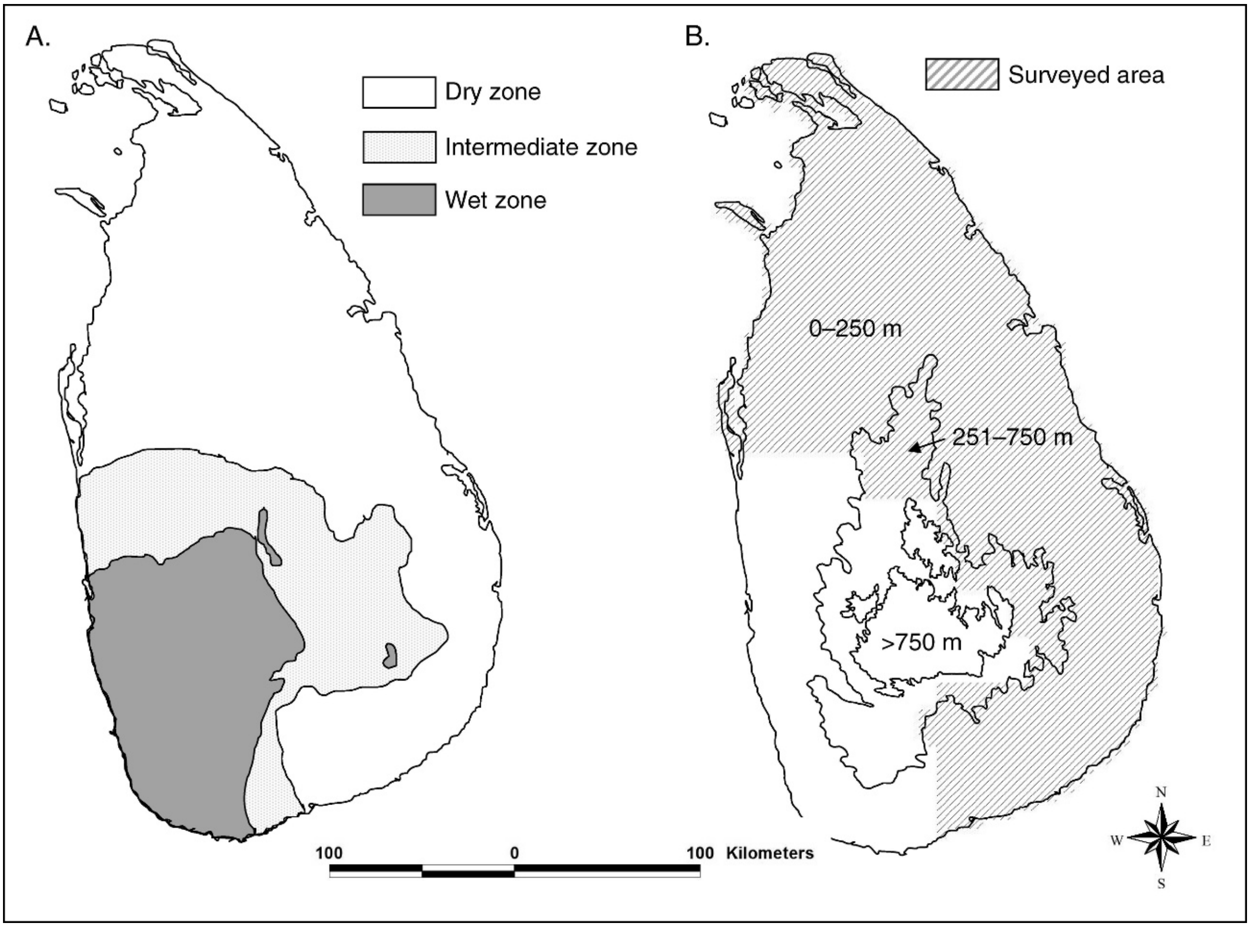

Fig. 1. Study area to determine the distribution of sloth bears in Sri Lanka showing (A) climatic zones based on mean annual rainfall (Cooray 1984) and (B) topographical regions of the island (UNEP 2003) consisting of the coastal lowlands (≤250 m), upland plateau (251–750 m), and highland plateau (>750 m). Boundaries of the surveyed area were subjectively determined based on sloth bear reportings in forests of the dry zone (Phillips 1984). Study area included the historic range of the sloth bear in Sri Lanka.

2004. We field tested and edited the questionnaires to clarify the phrasing and order of questions prior to the surveys (Nov and Dec 2003). Because the primary purpose of the survey was to provide information to map sloth bear distribution, sampling of respondents was purposive (Babbie 2001). Interviewees were almost exclusively individuals with first-hand knowledge of the forests in the area and were the most likely to reliably report on the presence or absence of sloth bears. Interviewees who lived in areas where sloth bears no longer occurred had few or no opinions in response to questions that related to their attitudes and perceptions of sloth bears so we excluded them from those analyses.

The study area was systematically inventoried using a 5- x 5-km grid overlaid on 1:50,000-scale maps (Sri Lanka Survey Department 1985–1996). Through inquiry of villagers, we sought out and interviewed individuals who regularly used nearby forests. We began the interview by asking respondents whether sloth bears were present locally and to indicate where they had made those observations. Except for wildlife staff who patrolled sites up to 20 km from their headquarters, almost all respondents provided information for areas within 10 km of their residence. We independently confirmed bear presence for each grid cell by interviewing at least 2 individuals or 2 groups of people. If those 2 or more independent respondents provided observations of sloth bears at a particular landmark within the preceding 2 years, we recorded sloth bears as present for the grid cell containing that landmark. We treated direct sightings of bears and detection of sloth bear sign (tracks, scats, and vocalizations) as observations of presence. Many respondents had independent observations of bears for more than one grid cell and were usually able to provide information for 4–6 contiguous grid cells. We marked a grid cell as absent for sloth bears if 2 or more independent respondents claimed familiarity with the area, had not seen sign of sloth bears in the previous 2 years, and did not believe they were present. We classified the occupancy of a grid cell with 2 conflicting reports of bear presence as uncertain. On the few occasions of conflicting reports from >2 interviewees, we classified a cell as occupied if we had at least 2 independent confirmations of bear presence for that grid cell, even if $\geq$1 interviewees reported absence. Although many interviews were conducted in the presence other people, information was collected from the individual identified as a forest "expert." In 12 instances we conducted group interviews with wildlife staff of protected areas; for these, we used one questionnaire per group to assess sloth bear distribution within protected areas. The senior staff person was identified as the respondent, although information usually was gathered from several staff members. In addition to the interviews, we used direct evidence of sloth bear presence within Wilpattu, Yala, Wasgomuwa, and Maduru Oya national parks from our own observations of bears, bear sign, and remote camera data (S. Ratnayeke unpublished data). Although a peace agreement was in effect during our surveys, a few areas (10–12 grid cells) had ongoing civil conflict and respondents had last visited those areas prior to the mid 1990s. Given little habitat change in those areas, we assumed that presence or absence of bears had not changed since those observations. We classified grid cells that consisted entirely of long-established towns and settlements as unoccupied by sloth bears, without use of questionnaires.

Human perceptions and attitudes. Although our survey was designed primarily to determine sloth bear range, we also asked respondents 4 questions regarding their perceptions and attitudes toward sloth bears. Men in rural communities of Sri Lanka are more likely than women to hunt, trap, and gather honey, thus venturing further into forests on trips lasting several days. Consequently, we were invariably directed to males when we sought individuals who were the most familiar with the local forests. Therefore, the perceptions and attitudes reflected in our survey essentially represent those of rural males who supplemented their livelihoods with resources from forests, and not the general public. Because rural hunters and honey-gatherers are most likely to encounter and come into conflict with sloth bears, their attitude toward bears is an important consideration for conservation planning. The only other groups of forest users that frequently encounter sloth bears are security and wildlife personnel, so we included them in this portion of the study as well, representing about 9% of all interviews. We asked respondents whether they considered bear populations to have increased, decreased, or remained stable during the preceding decade (1993–2004). We also asked whether they believed that sloth bears were a threat to humans, whether the absence of sloth bears was preferable, and whether sloth bears should be legally protected.

One of the advantages of administering the questionnaire as a semi-structured interview was that it allowed us to minimize errors of interpretation by probing issues with related questions (Byers 1996). However, this method may lead interviewees to a particular answer. Feuerstein (1986) cautioned that respondents may be less likely to answer honestly if questionnaires address sensitive issues. Because respondents were not anonymous in our survey, and because many interviews also included several bystanders, it is possible that respondents may have been less forthright with providing certain kinds of information. For example, when asked about their main activities in the forest, respondents may be more likely to state socially acceptable forest use (e.g., honey-gathering rather than hunting). Because bear distribution mapping was central to our study, we considered the order of questions. We started interviews by introducing ourselves as university students conducting a survey on bear distribution. We attempted to minimize bias to an interviewee by using standard wording for each question. The first questions addressed the respondent's knowledge of bear presence locally, followed by questions on perceptions and attitudes toward sloth bears, and, lastly, potentially sensitive information regarding the respondent's occupation and forest activities.

Distribution model

We used logistic regression (PROC LOGISTIC; SAS Institute, Inc. 2000) to identify landscape characteristics associated with grid cells where sloth bears were present versus those where sloth bears were absent. We used Akaike's Information Criterion (AIC) to select the set of independent variables that best predicted sloth bear occupancy (Bozdogan 1987). Based on literature and field observations (Ratnayeke et al. 2007), we hypothesized that sloth bear distribution was associated with several key landscape features. First, sloth bears in Sri Lanka typically are observed in forested habitats (Phillips 1984, Ratnayeke et al. 2007). Monsoon forests in particular provide ample cover and represent some of the least disturbed areas of the dry zone. Second, although many species of ursids occupy mountainous terrain, sloth bears in Sri Lanka are essentially a lowland species (Phillips 1984, Santiapillai and Santiapillai 1990). Therefore, we hypothesized that elevation may be negatively correlated with sloth bear distribution. Third, sloth bears often react aggressively to humans (Phillips 1984, Santiapillai and Santiapillai 1990, Rajpurohit and Krausman 2000) and avoid areas where human activity is high (Garshelis et al. 1999, Ratnayeke et al. 2007). Thus, we used 2 variables to measure human activity: human population density and road density.

We included percent monsoon forest, human density, road density, elevation in all the models we evaluated. In addition to those 4 variables, we considered 2 additional variables that we believed could improve our prediction of sloth bear occurrence. First, we examined whether the addition of lowland forest improved model fit. Although lowland sparse forests have sparse vertical cover and usually are associated with homesteads or recent disturbance, sloth bears occasionally are observed in this forest type. Finally, water is a critical resource for wild animals in many portions of Sri Lanka and we hypothesized that sloth bear populations may be associated with water sources such as rivers and streams.

We used ArcView® 3.2 (Environmental Systems Research Institute [ESRI], Redlands, California, USA) to calculate each landscape variable for each grid cell. We calculated the percent of monsoon or lowland sparse forest from land-cover data delineated from a 2001 satellite image (UNEP 2003). Our field observations indicated that land-cover types corresponded well with the map data, except for some regions of monsoon forest that were misclassified as mixed plantations. We calculated human population density using 2001 divisional secretariat (DS division) data from the Sri Lanka Department of Census and Statistics (2001). DS divisions correspond to 323 administrative zones that were composed of 25 larger districts. Thirty-one DS divisions (11.8% of Sri Lanka's land area) in 7 districts were in conflict areas in the north and the east and were not surveyed during the 2001 census; district population estimates for those areas were based on the registrations of births and deaths in 2001. We used the district population estimates to determine population density of the 31 sectors. For each grid cell, we determined road density (km/km^2) from digital road maps (1:50,000-scale, 1985–2001 data, Sri Lanka Survey Department, Colombo, Sri Lanka). We calculated mean elevation for each grid cell from Shuttle Radar Topography Mission data from 2000 (90-m resolution; Consultative Group for International Agriculture Research [CGIAR] 2005). We calculated stream density (m/km^2) from 1:160,000 Sri Lanka Survey Department 1985 hydrology maps (International Water Management Resources Institute 2006).

Upon selecting the best model, we calculated the Hosmer-Lemeshow goodness-of-fit statistic (Hosmer and Lemeshow 1989). Our analysis was based on observations from grid cells covering the entire historic range of sloth bears in Sri Lanka, so neighboring grid cells tend to have similar conditions. Therefore, we tested whether spatial autocorrelation could have influenced the results of our analysis. For each grid cell, we calculated the residual of the fitted model. We used those residuals to calculate Moran's I using ArcGIS 9.1 (ESRI). Moran's I is an index of spatial dependence with values ranging from -1 to 1 indicating maximum negative and positive autocorrelation, respectively; values near 0 indicate random patterns. We calculated the global Moran's I statistic using inverse distance weighting and standardization based on all weight values.

We evaluated the distribution of predicted probabilities of sloth bear occupancy (P_o) and selected a cut-off value to classify grid cells as occupied or unoccupied. We chose a cut-off value for P_o that maximized sensitivity (proportion of grid cells correctly predicted as areas where sloth bears occur) and specificity (proportion of grid cells correctly predicted as areas without sloth bears) while minimizing false positive and false negative rates (Hosmer and Lemeshow 1989).

Model testing

For the selected model, we conducted a 10-fold cross validation (Verbyla and Litvaitis 1989). We divided observations into 10 random subsamples of similar size. We used 9 subsamples to develop the logistic regression model and used the other subsample to calculate predicted probability of bear occurrence. We repeated this 10 times so that each subsample was excluded once and calculated the average correct prediction rates.

We also conducted a second test with independent data by determining the percent of locations of sloth bear attacks within areas where the habitat model predicted sloth bear occurrence. Attack locations were obtained from interviews we conducted with bear victims during an assessment of human–sloth bear conflict concurrent with the distribution survey. Sloth bear victims were not survey respondents. During the distribution survey, we consistently inquired about individuals attacked by sloth bears from villagers and survey respondents. We attempted to locate and interview all sloth bear victims or eyewitnesses of the attack. Not all victims could be interviewed because some had died or moved away since the incident. Because some victims had been attacked many decades ago and landscapes had presumably changed since then, we only used attacks that occurred within the 10 years preceding the distribution survey. Although the precise coordinates of attacks could not always be determined, sloth bear victims were able to provide sufficient detail to place the location of the encounter within a 25-km^2 grid cell.

Model simulations

To assess the potential effects of future landscape changes on sloth bear distribution, we used model predictions to determine the relative importance of variables. We changed the values of the landscape variables, both singly and in combination, across all grid cells by 20%. We then determined the percent of cells whose occupancy changed from sloth bear presence to absence.

Results

Field surveys

We conducted 266 interviews, of which 12 were group interviews. All respondents were males between 20 and 89 years of age (median age = 45 years), of whom 67% identified themselves as rural farmers who used forests for swidden agriculture or to supplement their households, usually with bushmeat, honey, or wood. A small proportion (9%) of interviews consisted of security personnel and wildlife staff who patrolled forested areas in conflict zones or protected areas (e.g., national parks, nature sanctuaries). The remaining 24% included fishermen, boutique owners, priests residing in forests, and contract workers involved in logging, reservoir maintenance, or stone quarry work. Many respondents used forests for hunting or collecting forest products; the most commonly sought item was honey from wild bees (Fig. 2).

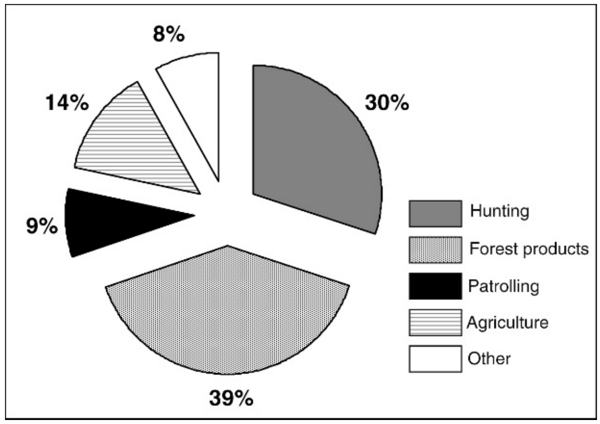

Fig. 2. Predominant activity (%) of survey respondents ($n = 247$) when using forests in their locality in Sri Lanka, 2004.

Sloth bears were reported as being present in 828 of 1,874 grid cells (46% of the surveyed area). The remaining grid cells were either classified as absent (n = 989) or uncertain (n = 57). Grid cells classified as uncertain were omitted from further analysis.

Distribution model

The best model (model 1) included 4 variables: monsoon forest, road density, elevation, and human population density (Table 1). Because AIC values for models including sparse forest and stream density did not greatly differ from that model ($\Delta AIC < 2.0$; Table 1), we examined whether model averaging (Burnham and Anderson 2002) would improve model performance. We used a threshold value of $P_o = 0.42$ to classify grid cells as occupied by sloth bears and compared those with actual occupancy based on the survey data. The correct prediction rate (88.4%), sensitivity (88.8%), and specificity (88.2%) for model 1 were high and were almost identical to those based on model-averaged parameter estimates (88.7%, 89.0%, and 88.6%, respectively).

Table 1. Comparison and ranking of logistic regression models to relate landscape variables to the presence or absence of sloth bears in 5- x 5-km grid cells within their historic range in Sri Lanka, 2004.

(Model no.) Model parameters	AIC	ΔAIC	K^a
(1) Monsoon forest, elevation, human density, road density	999.8	0	5
(2) Monsoon forest, elevation, human density, road density, sparse forest	1,000.6	0.8	6
(3) Monsoon forest, elevation, human density, road density, stream density	1,001.7	1.9	6
(4) Monsoon forest, elevation, human density, road density, stream density, sparse forest	1,002.5	2.7	7

[a] K = number of parameters in the model.

Furthermore, because the parameter estimates for stream density and sparse lowland forest were not different from zero, we used model 1 as our operating model. That model did not demonstrate a lack of fit to the data (Hosmer and Lemeshow χ^2 = 9.76, 8 df, P = 0.282) and had a high maximum rescaled R^2 for binomial error of 0.76. Because we did not detect strong spatial autocorrelation among model residuals (Moran's I = 0.0318, Z = 1.26, P = 0.104), we felt justified in using this model that did not account for autocorrelation.

The presence of monsoon forest was most strongly associated with sloth bear occupancy (Table 2). Road density, elevation, and human population density were negatively associated with sloth bear occupancy (Table 2). Sloth bear presence was predicted for 48% of the surveyed cells, which was slightly greater than the 46% of cells based on the survey. Thus, the predicted distribution corresponded well with the observed distribution of sloth bears as determined by the survey (Fig. 3).

The cross-validation indicated high correct classification rates of sloth bear occurrence (84.6–91.8%, n = 10, $\bar{x}$ = 88.6%, SE = 0.023). Our independent test based on locations of sloth bear attacks from 1993 to 2004 indicated that 146 of 150 (97.3%) attacks occurred within our predicted distribution (Fig. 4).

Given no change in other variables, predicted sloth bear range was most sensitive to changes in road density. A 20% increase in road density was associated with a 6.2% decrease in predicted sloth bear range. We predicted that a similar increase in human population density would reduce bear range by 2.6%, whereas a 20% decrease in forested habitat would reduce the range by 3.5%. The combined effects of these 3 variables produced the greatest decline in predicted range: a 20% change in all 3 parameters resulted in a 14.6% decrease in predicted sloth bear range.

Human perceptions

Although most respondents perceived sloth bears as a threat (70%), only 35% thought that the absence of bears was preferable (Fig. 5). That attitude varied by locality; for example, 66% of respondents from the northernmost portion of sloth bear range (also know as the Vanni region) felt that the absence of sloth bears was preferable. However, 66% of respondents throughout sloth bear range, including 88% of Vanni residents, agreed that the legal protection of sloth bears was warranted. Almost half of the respondents (49%) believed that local sloth bear populations had increased in the preceding decade. That perception varied locally, with respondents in the Vanni region more inclined to state that bear populations had increased. None of the respondents reported any nuisance activity by sloth bears.

Discussion

Sloth bear range in Sri Lanka remains primarily in dry zone lowlands with substantial monsoon forest, where human population density and activity are

Table 2. Parameter estimates of a logistic regression model to relate landscape variables to the presence or absence of sloth bears in 5- x 5-km grid cells covering their historic range in Sri Lanka, 2004.

Variable	Parameter estimate	Standard error	Wald χ^2	P
Intercept	1.9072	0.2262	71.0760	<0.0001
Monsoon forest (%)	0.0869	0.0058	224.7183	<0.0001
Road density (km/km^2)	−1.9126	0.1585	145.6763	<0.0001
Elevation (m)	−0.0103	0.0012	77.8567	<0.0001
Human density (people/km^2)	−0.0084	0.0015	31.2384	<0.0001

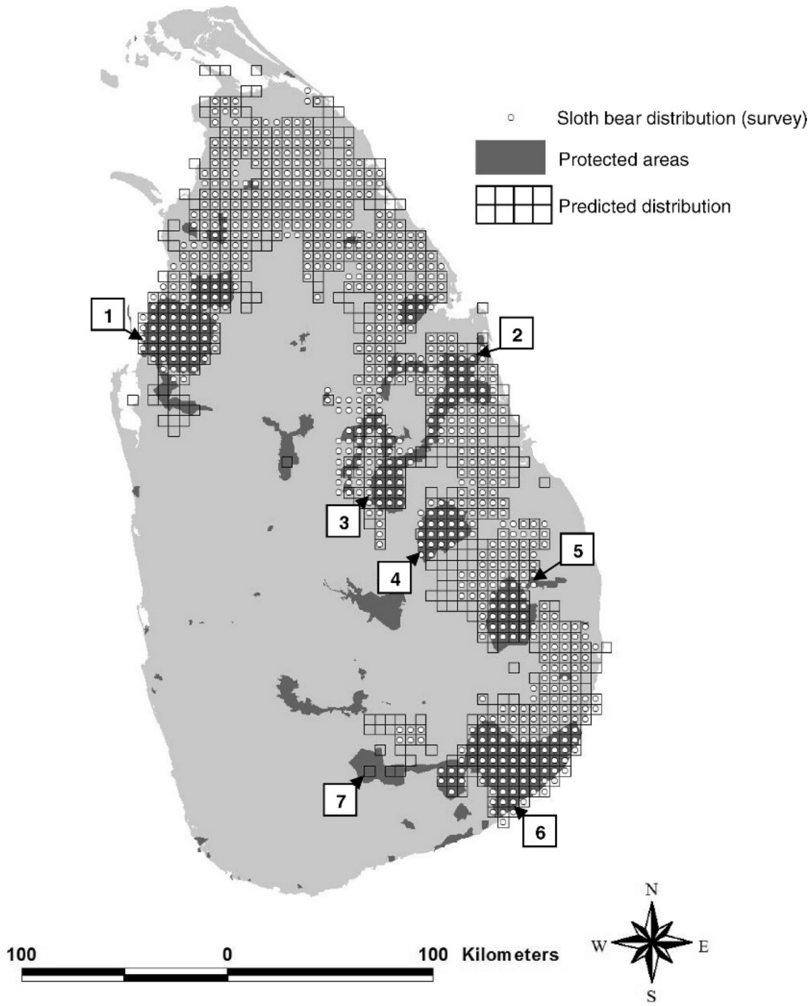

Fig. 3. Distribution of sloth bears in Sri Lanka based on 2004 survey data for 5- x 5-km grid cells compared with the predicted distribution based on a logistic regression model of landscape variables, and protected area complexes (national parks, strict nature reserves, nature reserves, and sanctuaries): (1) Wilpattu National Park, (2) Somawathie protected area complex (PC), (3) Wasgomuwa National Park, (4) Maduru Oya National Park, (5) Gal Oya PC, (6) Yala PC, and (7) Udawalawe National Park.

relatively low. Our survey suggests that sloth bear range constitutes about 17% of Sri Lanka's total land area. That estimate probably exceeds actual sloth bear range, because some grid cells classified as occupied contained only a small area of sloth bear habitat. Furthermore, we had no reliable data on bear abundance, and some portions of the distribution may represent marginal habitat or consist of relict bear populations on the verge of extirpation. One example is an isolated area at the extreme southwestern portion of bear range, northeast of Udawalawe National Park, which is the proposed site for Bogahapitiya sanctuary (Fig. 3). Respondents reported that much of this region was former sloth bear range, including Udawalawe National Park, but it is now uncertain whether any bears remain within the national park.

The 4 variables that we identified as important correlates of sloth bear range (monsoon forest, road density, elevation, and human population density) were consistent with observations of radiotracked sloth bears at Wasgomuwa National Park, where bears used forested habitats with plenty of vertical cover but were rarely observed in areas where human

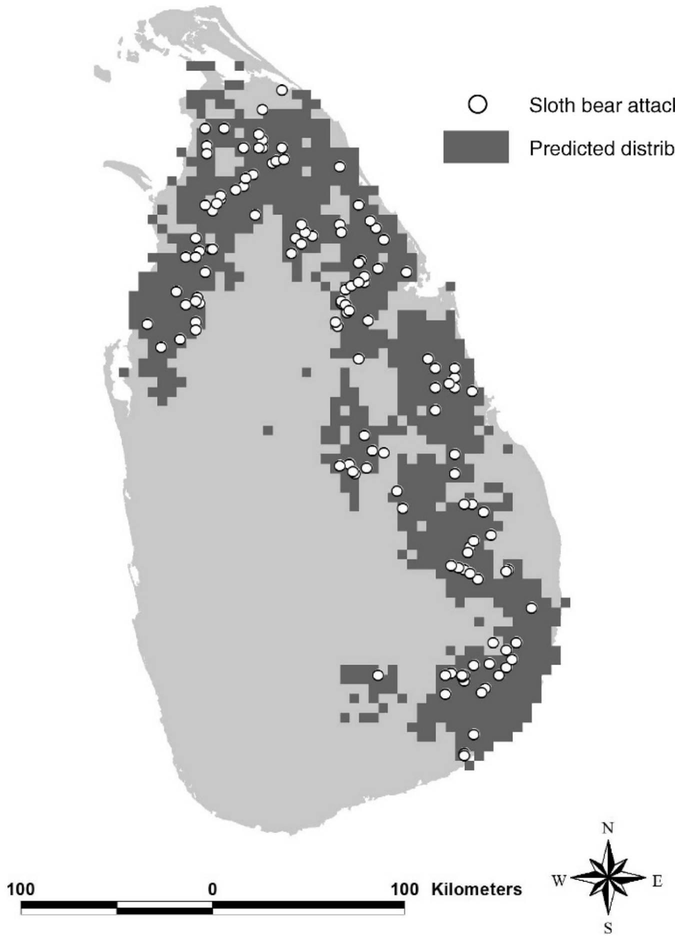

Fig. 4. Locations of sloth bear attacks in Sri Lanka between 1993 and 2004 (S. Ratnayeke unpublished data) and predicted distribution of sloth bears in 2004 for 5- x 5-km grid cells.

activity was high and vegetative cover sparse (Ratnayeke et al. 2007). Lowland sparse forest was not a good predictor of sloth bear occupancy because it was not consistently associated with either bear presence or absence. Lowland sparse forests with little human activity, such as those in protected areas, are used by sloth bears, particularly if they contain thickets of scrub that provide cover and shade. However, without protection, human activities (e.g., swidden agriculture) are a common feature of lowland sparse forests and bears tend to be absent. Possibly the most important category of monsoon forest for sloth bears is high forest, locally called 'mukalana,' which many survey respondents considered prime sloth bear habitat. High monsoon forest is characterized by old, large trees and relatively moist soil conditions (Pabla et al. 1998), and is presumably more productive in fruit and provides more den cavities. Furthermore, relatively moist soil conditions could facilitate foraging for termites, an important source of food for sloth bears (Laurie and Seidensticker 1977, Gokula et al. 1995, Joshi et al. 1997, Bargali et al. 2004, Ratnayeke et al. 2007), because sloth bears cannot readily break into hard, dry mounds (Davidar 1983).

Sloth bear distribution in India and Nepal also is closely tied to forest cover (Garshelis et al. 1999), but the range of habitats in which they occur seems to be broader than in Sri Lanka. An unusual aspect of sloth bear distribution in Sri Lanka is its historic absence from the relatively wet regions of the southwest and hill country. On the Indian mainland, sloth bears occur in semi-arid forested habitats comparable with dry monsoon forests of Sri Lanka (Johnsingh 2003, Akhtar et al. 2004); moreover, they also occur in the montane forests of the Western

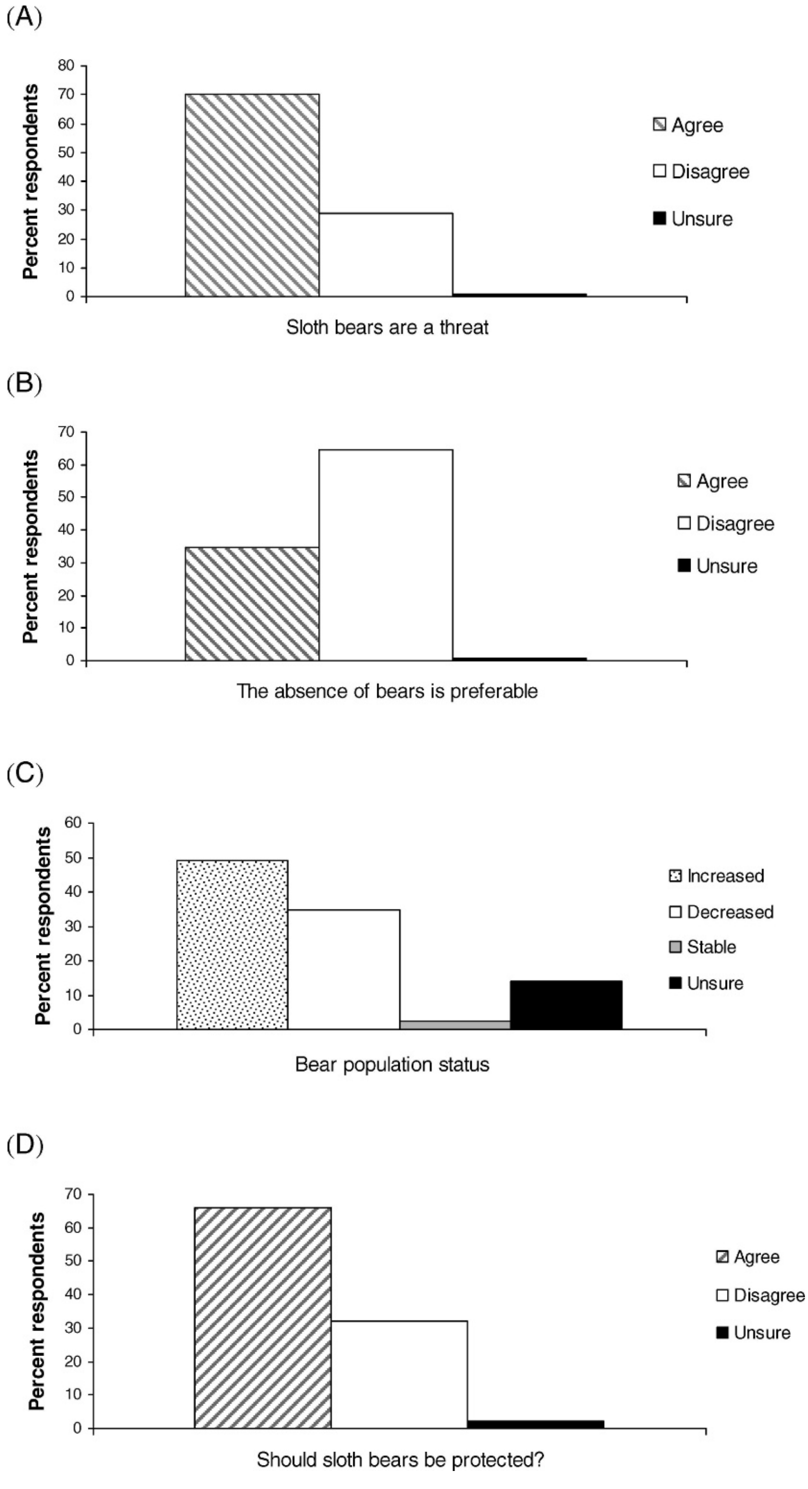

Fig. 5. Respondents in Sri Lanka (*n* = 247) who agreed, disagreed, or were uncertain about statements that (A) sloth bears were a threat to humans, (B) the absence of sloth bears would be preferable, and who provided opinions (C) about changes in sloth bear numbers during the preceding decade, and (D) whether sloth bears should be protected.

Ghats (Johnsingh 2003), moist evergreen and deciduous forests of southwestern India (Sreekumar and Balakrishnan 2002), and tall grasslands (Joshi et al. 1995, Desai et al. 1997).

Sloth bears seem to be primarily a lowland species throughout their range, usually occurring in habitats below 1,000 m in India (Johnsingh 2003) and Nepal (Garshelis et al. 1999). We documented sloth bears at elevations ranging from 0–1,376 m, but 98% of the range was below 300 m. Respondents living in the upland and highland regions contiguous with sloth bear range unequivocally confirmed the absence of sloth bears in their area. We speculate that the climate at higher elevations may not have adequate foods favored by sloth bears. Our surveys indicated that sloth bears occasionally use isolated hills and mountain ridges (>670 m) of coastal lowlands. Many of these rocky ridges, which are unsuitable for agriculture, constituted the only remaining forest in some areas.

Although hunting on protected or unprotected government land is prohibited, 30% of respondents stated that they used forests mainly for hunting. Our surveys were frequently observed by numerous bystanders, so it is possible that many respondents were unwilling to admit they hunted. Thus, hunting activity likely was underreported. The perception that sloth bear populations were increasing was particularly widespread in the north, where, due to the military conflicts, less forest has been cleared than in other portions of Sri Lanka. Elsewhere, respondents were less likely to report that sloth bear populations had increased. Almost all respondents who perceived a reduction in sloth bear numbers associated it with the decline of forest cover.

Fear of sloth bears was widespread, with 65% percent of respondents acknowledging that sloth bears were killed in their locality (Ratnayeke et al. 2006). Respondents cited self-defense as the principal reason that people killed sloth bears, although merely encountering a bear was sufficient reason in some instances. Although respondents feared sloth bears, there was broad support for their legal protection. Even most northern respondents, who stated they would rather not have sloth bears in their forests, supported legal protection. These seemingly contradictory responses may be a consequence of economic necessity. Although Buddhist and Hindu traditions of Sri Lanka favor the protection of wild animals, the northern region of the country is one of the poorest regions of Sri Lanka (World Bank 2002), where reliance on forests for additional means of subsistence is greatest. It is also possible that, because of the civil conflict, respondents were less tolerant of factors that threatened their livelihood.

Conservation implications

Large mammalian carnivores that are perceived as dangerous historically have had a tenuous relationship with humans, and some species have been hunted to the brink of extinction (Eisenberg 1989). A key question facing wildlife managers in Sri Lanka is how conflicts between sloth bears and humans may be minimized and whether people will tolerate the presence of sloth bears in the forests they use. Approximately 41% of the sloth bear range we documented was within national parks and nature reserves, where hunting is prohibited and human access is regulated (Fig. 3). Another 10% of bear range is within sanctuaries and nature reserves that are less restrictive and permit free access and traditional human activities. The largest contiguous forests in Sri Lanka are found in the northern and eastern regions of the island, which are also areas directly affected by the island's 20-year civil conflict. These forests historically supported healthy populations of sloth bear (Phillips 1984), but approximately 75% of this area is unprotected. Although the civil war may have inadvertently benefited sloth bears by keeping people, including poachers, out of conflict areas (Santiapillai and Wijeyamohan 2003), some protected areas have effectively remained unprotected for extended periods. Ultimately, extending the protected area network into the north and east will benefit sloth bear conservation.

With few exceptions, the distribution of sloth bears in Sri Lanka still exhibits high connectivity. Thus, opportunities exist to protect existing habitat linkages and maintain connectivity among sloth bear populations. A network of corridors is proposed for elephants, *Elephas maximus* (De Silva 1998), but these corridors might lack vertical cover, have high levels of human activity, and be unsuitable for sloth bears. Establishing such a network for sloth bears must consider maintaining forest cover and restricting human disturbance.

Despite the extent and connectivity of remaining sloth bear range, future reductions in bear range may result from the combined effects of forest habitat loss and increasing density of humans and roads. Although forest decline in Sri Lanka has been limited in recent years (10% decline during 1983–1992 and little apparent change during 1992–2001; Legg and Jewell 1995, UNEP 2003), human density increased from 232 to 316 individuals/km^2 between 1992 and 2001 (United Nations Secretariat 2004). Thus, it seems inevitable that human activity in forests will increase, as will encounters with sloth bears. Furthermore, political instability in the north and east leaves some of the largest contiguous areas of sloth bear habitat at risk.

Sloth bear populations in Sri Lanka do not seem to be highly vulnerable to direct exploitation; Ratnayeke et al. (2006) found that sloth bears were rarely hunted specifically for meat or body parts. The most severe threat to sloth bears in Sri Lanka is habitat loss and mortality resulting from human–bear conflicts. It is crucial that laws restricting human use of protected areas be enforced. Because the use of forests still remains a fundamental aspect of rural life in Sri Lanka, conservation efforts should focus on reducing human pressure on forests through rural development projects helping families generate alternate sources of income. Furthermore, education programs that promote conservation goals and provide recommendations to reduce human–sloth bear encounters will be beneficial. For example, our surveys on sloth bear attacks show that humans traveling in groups experience less injury from sloth bear attacks than do single travelers (S. Ratnayeke unpublished data). Techniques to avoid bear attacks suggested for other bear species (e.g., Herrero 2002) may be similarly effective for sloth bears and should be investigated. It is encouraging that most respondents agreed that sloth bears were an integral part of the forests and warranted protection. That attitude provides an important basis for enhancing conservation efforts (Bath 1998) and future coexistence among humans and sloth bears in Sri Lanka.

Acknowledgments

We thank the International Association for Bear Research and Management, the Swedish Large Carnivore Center, Örsa, Gronklitt, the National Science Foundation, Chicago Zoological Society, and the American Institute for Sri Lankan Studies for supporting the fieldwork for the survey. We thank the Sri Lankan Army, in particular retired General S. Jayasundera and Lt. Col. P. Rodrigo for facilitating access to several areas in the north, and the Liberation Tigers of Tamil Eelam for permitting us to work in the northern and eastern provinces. D. Garshelis helped with identifying sources of funding, C. Santiapillai and L. Soundranayagam assisted with designing the questionnaire, and Y. Ratnayeke assisted with field work. We thank numerous individuals, in particular the staff of Sri Lanka Sumitrayo, who assisted with locating hunters and victims of sloth bear attacks. Field staff and wardens of protected areas generously shared information with us. K. Kotta, UNEP, Sri Lanka, provided the land-cover data. C. Thatcher and L. Thompson assisted with GIS data preparation and various aspects of data analysis. We thank J.E. Clark, D. Hamer, and 2 anonymous reviewers for providing critical comments to improve the manuscript.

Literature cited

Akhtar, N., H.S. Bargali, and N.P.S. Chauhan. 2004. Sloth bear habitat use in disturbed and unprotected areas of Madhya Pradesh, India. Ursus 15:203–211.

Babbie, E. 2001. The practice of social research. Ninth edition. Wadsworth Thompson Learning, Belmont, California, USA.

Bargali, H.S., N. Akhtar, and N.P.S. Chauhan. 2004. Feeding ecology of sloth bears in a disturbed area in central India. Ursus 15:212–217.

Bath, A.J. 1998. The role of human dimensions in wildlife resource research in wildlife management. Ursus 10:349–355.

Bozdogan, H. 1987. Model selection and Akaike's Information Criterion (AIC): the general theory and its analytical extensions. Psychometrika 52:345–370.

Burnham, K.P., and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information theoretic approach. Springer-Verlag, New York, New York, USA.

Byers, B.A. 1996. Understanding and influencing behaviors in conservation and natural resources management. Biodiversity Support Program, African Biodiversity Series 4. Washington, DC, USA.

Consultative Group for International Agriculture Research (CGIAR). 2004. Ruhuna Basin/Sri Lanka Shuttle Radar Terrain Mission (SRTM elevation mosaic data). http://www.srtm.csi.cgiar.org, accessed 25 May 2005.

Cooray, P.G. 1984. Geology, with special reference to the Precambrian. Pages 1–34 in C.H. Fernando, editor. Ecology and biogeography of Sri Lanka. Martinus Nijhoff Publishers, The Hague, The Netherlands.

Davidar, E.C.R. 1983. Sloth bear's method for hunting for termite nests. Journal of the Bombay Natural History Society 80:637.

DE ROSAYRO, R.A. 1961. The nature and origin of secondary vegetational communities in Ceylon. Ceylon Forester 5:23–49.

DESAI, A.A., N. BHASKARAN, AND S. VENKATESH. 1997. Behavioural ecology of the sloth bear in Mudumalai Wildlife Sanctuary and National Park, Tamil Nadu. Bombay Natural History Society and Tamil Nadu Forest Department. Bombay Natural History Society, Mumbai, India.

DE SILVA, M. 1998. Status and conservation of the elephant and the alleviation of man–elephant conflict in Sri Lanka. Gajah 19:1–24.

DOMRÖS, M. 1974. The agroclimate of Ceylon. Franz Steiner Verlag, Wiesbaden, Germany.

EISENBERG, J.F. 1989. An introduction to the Carnivora. Pages 1–9 in J.L. Gittleman, editor. Carnivore behavior, ecology and evolution. Cornell University Press, Ithaca, New York, USA.

FEUERSTEIN, M. 1986. Partners in evaluation: evaluating development and community programmes with participants. McMillan Publishers Ltd, London, UK.

FOREST RESOURCES ASSESSMENT. 2000. Forest resources of Sri Lanka: Country report. Forest Resources Assessment Program, Working paper 17, Rome, Italy.

GARSHELIS, D.L., A.R. JOSHI, J.L.D. SMITH, AND C.D. RICE. 1999. Sloth bear Conservation Action Plan (*Melursus ursinus*). Pages 225–240 in C. Servheen, S. Herrero, and B. Peyton, editors. Bears: Status survey and conservation action plan. IUCN/SSC Bear and Polar Bear Specialist Groups, IUCN, Gland, Switzerland.

GOKULA, V., N. SIVANAGESAN, AND M. VARADARAJAN. 1995. Food of the sloth bear (*Melursus ursinus*) in Mundanthurai plateau, Tamil Nadu. Journal of the Bombay Natural History Society 92:408–410.

GRELLER, A.M., AND S. BALASUBRAMANIAM. 1980. A preliminary floristic-climatic classification of the forests of Sri Lanka. Sri Lanka Forester 14:163–169.

HERRERO, S. 2002. Bear attacks: their causes and avoidance. Revised edition. Lyons Press, Guilford, Connecticut, USA.

HOSMER, D.W., JR., AND S. LEMESHOW. 1989. Applied logistic regression. John Wiley and Sons, New York, New York, USA.

INTERNATIONAL WATER MANAGEMENT RESOURCES INSTITUTE. 2006. Vector layer. Vector rivers in Sri Lanka. http://www.iwmidsp.org/iwmi/SearchData/preview.asp?xPath=/dsp/rs-gis-data/National/Sri-Lanka/03-vector-basin-streams/ReadMe, accessed 24 May 2005.

JOHNSINGH, A.J.T. 2003. Bear conservation in India. The Journal of the Bombay Natural History Society 100:190–201.

JOSHI, A.R., D.L. GARSHELIS, AND J.L.D. SMITH. 1995. Home ranges of sloth bears in Nepal: Implications for conservation. Journal of Wildlife Management 59: 204–213.

———, ———, AND ———. 1997. Seasonal and habitat-related diets of sloth bears in Nepal. Journal of Mammalogy 78:584–597.

LAURIE, A., AND J. SEIDENSTICKER. 1977. Behavioral ecology of the sloth bear (*Melursus ursinus*). Journal of Zoology (London) 182:187–204.

LEGG, C., AND N. JEWELL. 1995. A 1:50,000 forest map of Sri Lanka: the basis for a National Forest Geographic Information System. The Sri Lanka Forester Special Issue:3–24.

PABLA, H.S., V.B. MATHUR, AND W.R.M.S. WICKRAMASINGHE. 1998. Management Plan Wasgomuwa National Park and Riverine Nature Reserve: Volume 1. Project UNO/SRL/001/GEF-SRL/92/G3, Department of Wildlife Conservation, Sri Lanka.

PERERA, G.A.D. 2001. The secondary forest situation in Sri Lanka: a review. Journal of Tropical Forest Science 13:768–785.

PHILLIPS, W.W.A. 1984. The sloth bear. Pages 290–296 in Wildlife and Nature Protection Society of Sri Lanka, Manual of mammals of Sri Lanka. Colombo, Sri Lanka.

RAJPUROHIT, K.S., AND P.R. KRAUSMAN. 2000. Human–sloth bear conflicts in Madhya Pradesh, India. Wildlife Society Bulletin 28:393–399.

RATNAYAKE, J., M. ABEYKOON, AND Y. CHEMIN. 2002. District-wise forest area variation in Sri Lanka from 1992 to 2001 for supporting the National Physical Planning Policy. http:/www.gisdevelopment.net/aars/acrs/2002/for/015.pdf, accessed 5 July 2006.

RATNAYEKE, S., S. WIJEYAMOHAN, AND C. SANTIAPILLAI. 2006. The status of the sloth bear in Sri Lanka. Pages 35–40 in T. Oi, T. Mano, K. Yamazaki, T. Aoi, M. Carr, M. Durnin, C.B. Imaki, A. Takayanagi, and T. Tsubota, editors. Understanding bears to secure their future. Japan Bear Network, Gifu, Japan.

———, F.T. VAN MANEN, AND U.K.G.K. PADMALAL. 2007. Home ranges and habitat use of the sloth bear (*Melursus ursinus inornatus*) at Wasgomuwa National Park, Sri Lanka. Wildlife Biology 13: in press.

SANTIAPILLAI, A., AND C. SANTIAPILLAI. 1990. Status, distribution and conservation of the sloth bear (*Melursus ursinus*) in Sri Lanka. Tiger Paper 1:13–15.

SANTIAPILLAI, C., AND S. WIJEYAMOHAN. 2003. The impact of civil war on wildlife in Sri Lanka. Current Science (Bombay) 84:1182–1183.

SAS INSTITUTE, INC. 2000. User's guide, version 8.2. SAS Institute Inc., Cary, North Carolina, USA.

SREEKUMAR, P.G., AND M. BALAKRISHNAN. 2002. Seed dispersal by the sloth bear *(Melursus ursinus)* in India. Biotropica 34:474–477.

SRI LANKA DEPARTMENT OF CENSUS AND STATISTICS. 2001. Census of population and housing 2001. District sector division data. http://www.iwmidsp.org/iwmi/info/main.asp, accessed 28 June 2006.

United Nations Environment Program. 2003. Land cover assessment and monitoring, Sri Lanka. Environmental Assessment Technical Reports, Volume 12-A. United Nations Environment Program Regional Resource Center for Asia and the Pacific, Bangkok, Thailand.

United Nations Secretariat. 2004. World population prospects: the 2004 revision and world urbanization prospects. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. http://esa.un.org/unpp, accessed 13 June 2006.

Verbyla, D.L., and J.A. Litvaitis. 1989. Resampling methods for evaluating classification accuracy of wildlife habitat models. Environmental Management 13:783–787.

World Bank. 1995. Sri Lanka poverty assessment. World Bank Report No. 13431-CE. Washington, DC, USA.

———. 2002. Sri Lanka poverty assessment. World Bank Report No. 22535-CE. Washington, DC, USA.

———. 2003. Sri Lanka: South Asia Region Country Brief. http://lnweb18.worldbank.org/sar/sa.nsf/Attachments/LKCountryBrFY04/$File/Sri+Lanka+Country+Brief+FY04pdf.pdf, accessed 17 July 2006.

Received: 28 August 2006
Accepted: 5 February 2007
Associate Editor: D. Hamer