Scoring Body Condition in Wild Baird's Tapir (Tapirus bairdii) Using Camera Traps and Opportunistic Photographic Material

Authors: Pérez-Flores, Jonathan, Calmé, Sophie, and Reyna-Hurtado, Rafael

Source: Tropical Conservation Science, 9(4)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/1940082916676128

Scoring Body Condition in Wild Baird's Tapir (*Tapirus bairdii*) Using Camera Traps and Opportunistic Photographic Material

Tropical Conservation Science
October-December 2016: 1–12
© The Author(s) 2016
Reprints and permissions:
sagepub.com/journalsPermissions.nav
DOI: 10.1177/1940082916676128
trc.sagepub.com
SAGE

Jonathan Pérez-Flores[1], Sophie Calmé[1,2], and Rafael Reyna-Hurtado[1]

Abstract

Body condition score (BCS) systems have been used in wild animals as a technique for evaluating the health status of species that are difficult to capture but can be observed in their habitat. In this study, our goal was to enable scoring the BC of wild Baird's tapir (*Tapirus bairdii*) without the need for direct observation, using camera trap and opportunistic photographic records. First, we modified a BCS assessment that was created for other tapir species, using captive Baird's tapirs. Second, we applied it to a set of photographs of wild Baird's tapir that were obtained over six consecutive years in a protected area in southern Mexico. We compared morphometric measurements and muscle and fat deposited in several anatomical regions. We also evaluated changes in BC between seasons for individuals photographed on several occasions. We show that neck and thorax circumferences are significantly correlated with all BCSs associated with these anatomical regions, whereas abdominal circumference is correlated only with half of the BCS. BCS of captive tapirs that we evaluated averaged 24.93 ± 5.61, which was higher than that of wild tapirs (22.63 ± 3.68). No significant difference in BC was apparent between rainy and dry seasons in our study site; wild tapirs were able to maintain good BC throughout the year. Camera trap records and opportunistic photographs were a useful tool to track changes in BC over time.

Keywords

endangered species, health status, seasonality, conservation

Introduction

The body condition (BC) of wild animals is an important determinant of their ability to survive and reproduce. A low nutritional status may compromise the immune system, causing a weak host response to viral, bacterial, and parasitic infections (Katona & Katona-Apte, 2008). The ingestion of low-quality food may cause nutritional and metabolic disorders (e.g., hypovitaminosis, nutritional hyperparatiroidism, and mineral deficiencies), while triggering the depletion of energetic reserves, starting with the glycogen that is stored in liver and muscles, followed by fat deposits and, finally, by proteins (Colín, 2004). Animals with larger fat reserves usually have greater fasting endurance and higher survival than individuals with smaller reserves (Millar & Hickling, 1990). Indeed, a low body mass has been associated with decreased survival and fertility within species (Bassano, Perrone, & Von Hardenberg, 2003). For these reasons, wildlife researchers consider catabolism and mass loss as essential components of the life history strategies of many wild animals (Le Maho, 1977; Sherry, Mrosovsky, & Hogan, 1980; Stevenson & Woods, 2006). Festa-Bianchet, Jorgenson, Bérubé, Portier, and Wishart (1997) argued that individual mass plays an important role in the life history and population dynamics of ungulates.

BC is defined as a direct measurement of the nutritional status of an individual, especially the relative size of energy reserves such as fat and proteins (Peig & Green, 2009). BC assessment is of considerable importance in many ecological studies and as a wildlife management

[1]El Colegio de la Frontera Sur, Chetumal, Mexico
[2]Université de Sherbrooke, Sherbrooke, Canada

Received 8 August 2016; Revised 15 September 2016; Accepted 19 September 2016

Corresponding Author:
Jonathan Pérez-Flores, El Colegio de la Frontera Sur, Chetumal, Quintana Roo, Mexico.
Email: johnspf77@yahoo.com.mx

tool, which is the reason why noninvasive techniques have been developed to measure BC in livestock (Edmonson, Lean, Weaver, Farver, & Webster, 1989) and wild ungulates (Ezenwa, Jolles, & O'Brien, 2009). In this article, we use a previously described technique that was developed to assess BC in captive Malayan (*Tapirus indicus*) and lowland tapirs (*T. terrestris*) and which uses scores attributed to several body parts to construct a final score for BC (Clauss, Wilkins, Hartley, & Hatt, 2009). We have adapted it to assess the condition of Baird's tapir (*T. bairdii*).

Baird's tapir is a browsing and frugivorous perissodactyl species that is distributed from Southeastern Mexico to the Northwestern Andes (Hershkovitz, 1956). Several populations have been severely reduced through forest loss and hunting. Currently, Southern Mexico is estimated to hold 50% of the global population of Baird's tapir; however, in areas where forests and native vegetation have been severely fragmented, these animals have virtually disappeared (Naranjo, 2009). The isolation of small populations in fragmented areas makes the Baird's tapir susceptible to extinction when facing natural disturbances and epidemic diseases (Hernandez-Divers, Bailey, Aguilar, Loria, & Foerster, 2005). Efforts to protect the species would benefit from any information that can be related to the health and nutritional status of individuals.

Tapirs are predominantly nocturnal and crepuscular animals, and often inhabit areas that are difficult to access. Therefore, capturing tapirs in the field can be challenging, as exemplified by our 4-year effort that led to the capture of a single individual. Direct observations are equally difficult to carry out. For these reasons, the use of alternative surveillance techniques has become essential for monitoring the status of tapirs. One such technique is camera trapping, which has been used to record the presence of rare or secretive species (e.g., Olson et al., 2012), to estimate population densities (e.g., Karanth, Chundawat, Nichols, & Kumar, 2004; Rowcliffe, Field, Turvey, & Carbone, 2008), and to document activity patterns (e.g., Ridout & Linkie, 2009) and habitat use (Bowkett, Rovero, & Marshall, 2008).

Our aim is to provide a simple and reliable tool for evaluating the BC of free-ranging Baird's tapirs using the most readily available information, viz., photographs that were obtained from camera traps. We modified the technique that was developed by Clauss et al. (2009) and added a score for the head, using captive individuals that we were able to weigh and measure. Given that we had a number of individuals with poor BC, we were able to define better scoring criteria for these cases. We tested the correlation between morphometric measurements (neck, thorax, and abdomen circumferences) and the visual appearance of anatomical regions (head, neck, shoulder, ribs, spine and pelvis) in these captive Baird's tapirs. This aided us in scoring BC of wild tapirs, by comparing them with photographs of captive individuals with a defined BCS (Body Condition Score). The procedure was repeated with different observers to test its consistency. We also applied the technique to a set of Baird's tapir photographs that had been obtained with camera traps over 6 years in a protected area in southern Mexico to evaluate the BC of wild tapirs. Finally, we discuss how this technique could be an important conservation tool for improving the assessments of Baird's tapir populations.

Materials and Methods

Tapir Specimens

Captive tapirs. Five zoos in Mexico and one in Belize allowed us to take photographs and measurements of the tapirs in their collection. A total of 15 tapirs (nine adult and two juvenile males, and four adult females) were photographed in captivity, of which 8 were also measured (five adult males and three adult females).

Wild tapirs. As part of ongoing studies on wildlife species in the Calakmul region, we obtained 81 records of tapirs between 2008 and 2013. This region encompasses the Calakmul Biosphere Reserve (CBR), which is located in Southeastern Campeche, Mexico (17°45'–19°15'N, 89°15'–90°10'W). The climate is tropical with a marked dry season, an annual average temperature of 25°C, and average annual precipitation ranging from 950 to 1200 mm, according to location (Márdero et al., 2012). The dominant vegetation types are seasonal tropical forests that differ according to their topographical position, canopy height, species relative abundance, and degree of deciduousness (Vester et al., 2007).

The photographic records were obtained from two studies employing camera traps on the use of waterholes by large fauna and documenting the presence of four tapirs with low BC in villages surrounding the Calakmul Biosphere Reserve. The first study on waterholes ran from 2008 to 2010. The NGO Pronatura Peninsula de Yucatán, A.C., placed 45 camera traps at 15 waterholes (three per waterhole) within the CBR. They used four camera models: WildView Xtreme (Stealth Cam LLC, Grande Prairie, TX, USA), $n = 19$; Deer Cam DC-100 (Non Typical Inc., De Pere, WI, USA; www.deercam.com), $n = 17$; Stealth Cam 300 (Stealth Cam LLC; www.epicstealthcam.com), $n = 7$; and CamTrakker MK-10 (CamTrakker South, Watkinsville, GA, USA; www.trailcam.com), $n = 2$. The second study took place in 2012–2013, using 18 camera traps of three different models: PC800 Hyperfire professional (Reconyx Inc., Holmen, WI, USA; www.reconyx.com), $n = 6$; Moultrie Game Spy I-65 (EBSCO Industries Inc., Birmingham, AL, USA; www.moultriefeeders.com), $n = 6$; and

Cuddeback Capture IR digital scouting camera (Cuddeback Inc., De Pere, WI, USA; www.cuddeback.com), $n = 6$. These cameras were placed at nine waterholes (two per waterhole) of the Calakmul region. In both studies, the cameras remained active 24 hours per day and were checked every 15 to 30 days, to change batteries and empty memory cards. The cameras remained installed and active from April to August, to encompass both the rainy and dry seasons.

Of the 81 photographic records from camera traps, 16 were excluded, either because they corresponded to a same individual in a photographic sequence or because the body was not in full view. Therefore, we used a total of 65 independent records (61 from camera traps and 4 from villages), of which 27 were males, 9 were females, and 29 were from individuals of indeterminate sex (Baird's tapir does not exhibit obvious sexual dimorphism, even when genitalia are visible). In some cases, photos of the same tapir were obtained on different dates, allowing us to score BC over time. These individuals were identified using distinguishable marks. Two tapirs could be clearly identified with such marks: an adult male with a large cut in his right ear; and a young male, which we had equipped with a telemetry collar.

Assessing BC

Clauss et al. (2009) developed a technique for scoring BC in the Malayan and lowland tapirs that were in zoos in the United Kingdom. We used their technique, which we slightly modified by adding one criterion, the head. A BCS was assigned to each animal based on the visual assessment of the appearance of fat and muscles associated with skeletal structures (head, neck, shoulders, ribs, spine, and pelvic bones; Figure 1; Table 1). These body regions have been used previously to visually estimate BC in African buffalo (*Syncerus caffer*), Asian elephant (*Elephas maximus*), impala (*Aepyceros melampus*), black rhinoceros (*Diceros bicornis*), caribou (*Rangifer tarandus caribou*), elk (*Cervus canadensis*), and mule deer (*Odocoileus hemionus*; Ezenwa et al., 2009; Wemmer et al., 2006; Gallivan, Culverwell, & Girdwood, 1995; Reuter & Adcock, 1998; Gerhart, White, Cameron, & Russell, 1996; Cook et al., 2001; Cook, Stephenson, Myers, Cook, & Shipley, 2007).

Scores were assigned to each of the six body regions using three or four criteria for each region (Table 1). The six scores were then totaled to obtain the BCS. The total score ranged from a minimum value of 6 up to 30 points. We established subjectively the following ranges: obese (28–30 points); good (22–27 points); fair (16–21 points); thin (10–15 points); and emaciated (6–9 points; Figures 2 to 6).

We then assessed the relationship between the scores that were assigned to those six body regions where fat reserves accumulate or exhibit large muscular masses and measurements of the neck, thorax, and abdomen circumferences. Neck circumference was measured at the base of the neck; thorax circumference was measured between ribs #8 and #10; and abdominal circumference was measured at the widest part of the abdomen. Eight captive and three wild Baird's tapirs were fully measured and scored for BC. Pregnant females were not measured to avoid bias that would be incurred by their condition. Otherwise, the same protocol was intentionally performed on individuals of both sexes. Captive tapirs were measured during training sessions, allowing us to measure them standing up. In the case of the wild tapirs, one was measured during its necropsy, another was captured during a field study and then measured in lateral decubitus position during the chemical immobilization, and the last one was measured during physical

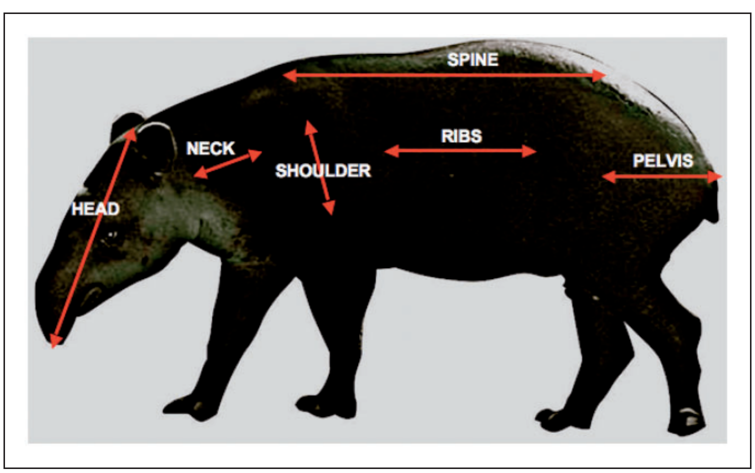

Figure 1. Anatomical regions selected for the assessment of body condition in Baird's tapir.

Table 1. Criteria and Point Scores Used to Assess Body Condition in Baird's Tapir.

Body region	Criteria	BCS	General
Head	Head bone structures (mandibular angle, zygomatic bone, and nuchal crestal) covered, abundant fat, rounded proboscis	5	Obese
	Slightly visible head bone structures, rounded proboscis	4	Good
	Visible head bone structures, moderate amount of fat, proboscis moderately rounded	3	Fair
	Prominent head bone structures, small amount of fat, broad proboscis	2	Thin
	Very prominent head bone structures, proboscis wide and without fat	1	Emaciated
Neck	Thick neck, plenty of fat, rounded, vertebrae not observed	5	Obese
	Thick neck, lower in fat than the previous, well muscled, inconspicuous vertebrae	4	Good
	Neck median diameter, moderate amount of fat deposits, more apparent vertebrae	3	Fair
	"Ewe neck", narrow and slack at base, little fat deposits and more apparent vertebrae	2	Thin
	Marked "ewe" neck, narrow and slack at base, decreased fat deposits and very apparent vertebrae	1	Emaciated
Shoulder	Scapula not visible, rounded shoulders, deposits behind the shoulder filled with fat	5	Obese
	Scapula covered, fat beginning to be deposited	4	Good
	Shoulder bone structures (scapular cranial and caudal angles) are visible	3	Fair
	Shoulder bone structures obvious	2	Thin
	Shoulder bone structures extremely visible	1	Emaciated
Ribs	Not visible, fatty layer on and between ribs	5	Obese
	Not visible, few fatty layer on and between ribs	4	Good
	Few ribs visible toward abdomen	3	Fair
	Visible throughout	2	Thin
	Ribs prominent with deep depressions between them	1	Emaciated
Spine	Spinous processes (dorsal and transverse) covered, backbone rounded	5	Obese
	Spinous processes slightly visible, backbone slightly angular	4	Good
	Spinous processes visible, groove along backbone visible	3	Fair
	Spinous processes prominent, deep groove along backbone obvious	2	Thin
	Spinous processes very prominent, groove along backbone very obvious	1	Emaciated
Pelvis	Pelvic bones covered and rounded, tail base rounded (bulging), skin distended, rump well rounded	5	Obese
	Pelvic bones slightly visible, tail base rounded, rump flattened	4	Good
	Pelvic bones visible, tail base narrow, rump slightly concave	3	Fair
	Prominent pelvic bones, tail base slightly bony, rump concave	2	Thin
	Very prominent pelvic bones, tail base very thin and bony, obvious depression in the rump	1	Emaciated

BCS = Body condition score.

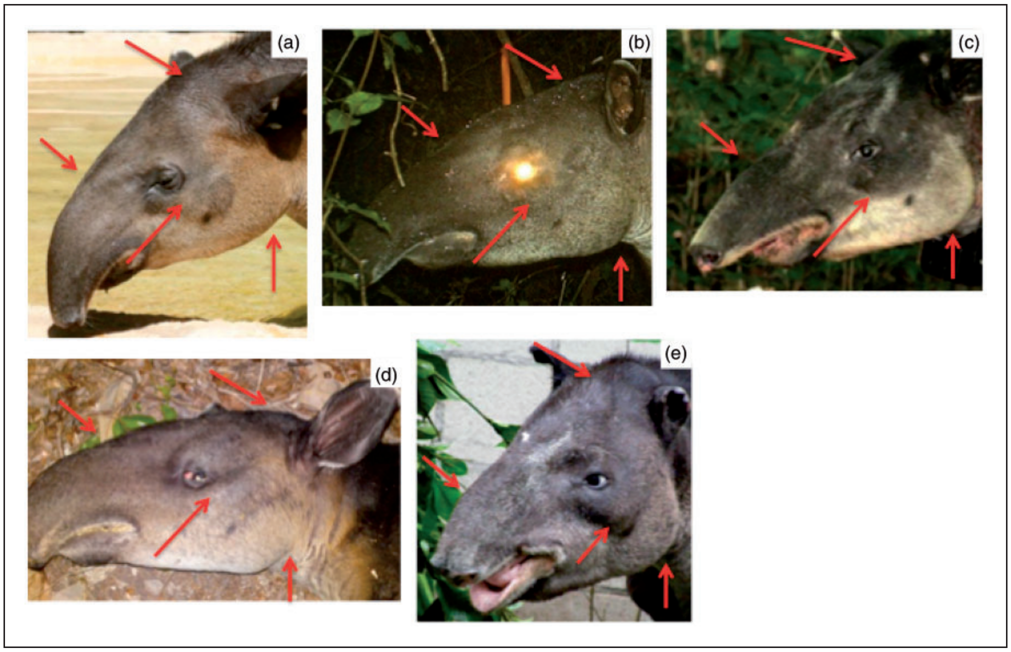

Figure 2. Head of Baird's tapir showing skull structures and shape of the proboscis, from an obese (a) to an emaciated (e) animal. Following Table 1 scores as follows: A = 5, B = 4, C = 3, D = 2, and E = 1.

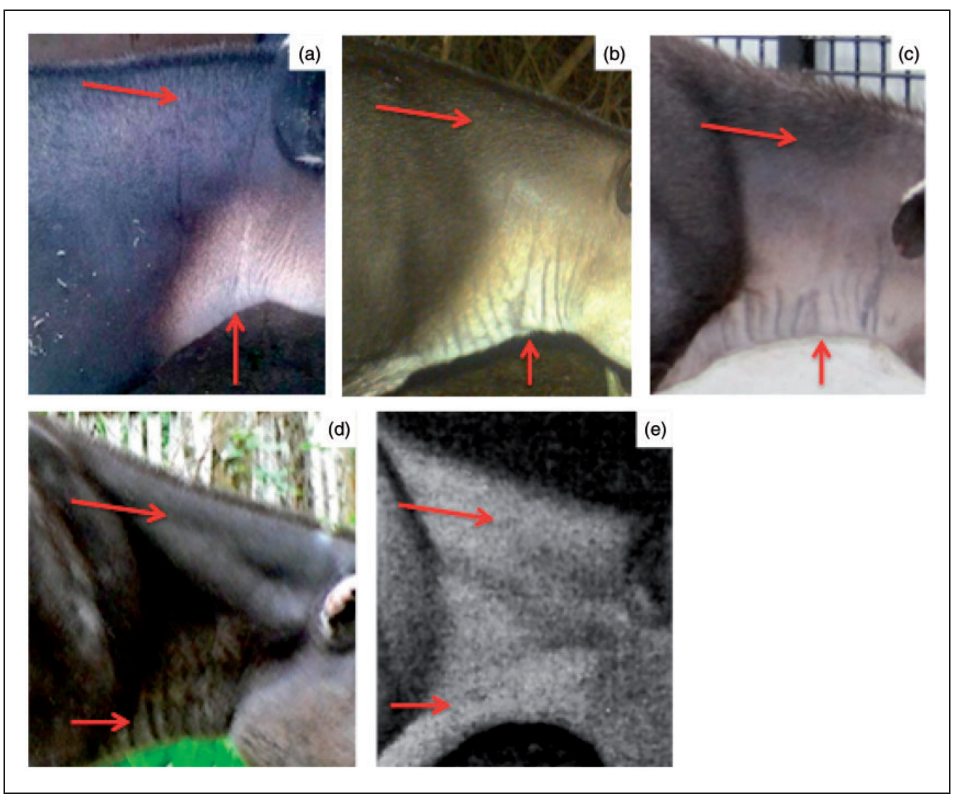

Figure 3. Visibility of the muscles of the neck of Baird's tapir, from an obese (a) to an emaciated (e) animal. Following Table 1 scores as follows: A = 5, B = 4, C = 3, D = 2, and E = 1.

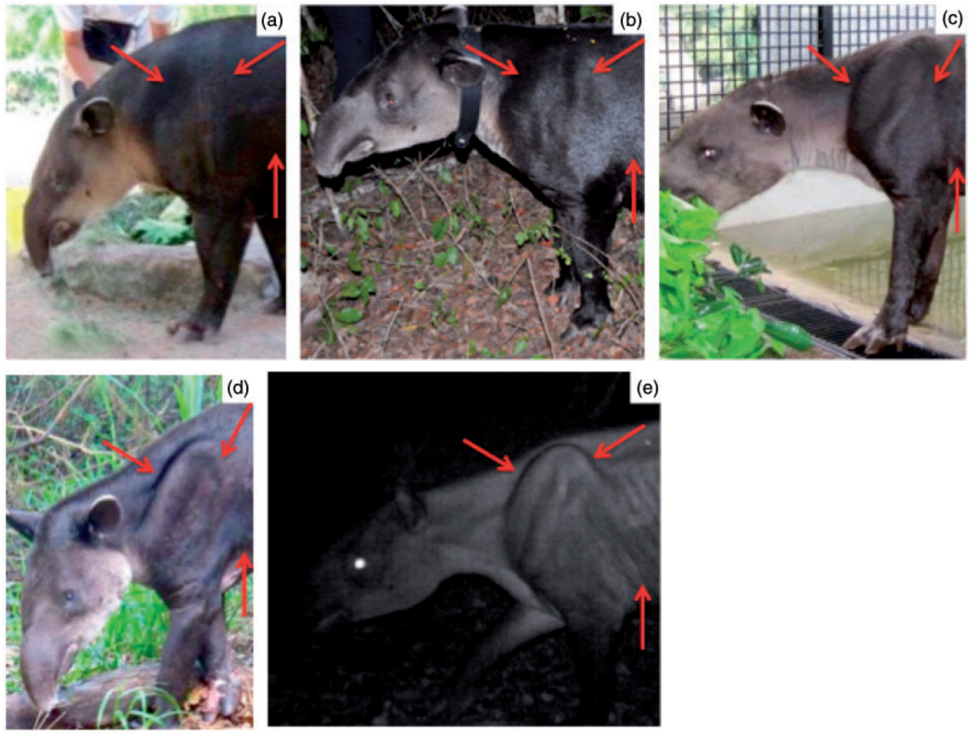

Figure 4. Visibility of the bone structures and muscles of the shoulder, from an obese (a) to an emaciated (e) animal. Following Table 1 scores as follows: A = 5, B = 4, C = 3, D = 2, and E = 1.

confinement when being transferred to a zoo. All measures were taken with a flexible tape to the closest centimetre (Table 2).

To improve accuracy and reduce subjectivity, anyone assessing BC must be familiar with the anatomy and range of conditions that a Baird's tapir may present. We therefore tested the ease of use and consistency of the evaluation criteria during the meeting of the Mexican Tapir Specialist Group, which was held in Zoh Laguna, Campeche in November 2013. We showed three pictures of three tapirs (wild and captive) that ranged from obese to fair BC to each of nine of the participants. Participants were either veterinarians or biologists, but all had experienced physical contact with tapirs. Based on the established criteria (Table 1), each participant then scored the BC of the three tapirs.

Only one of the authors (JPF) scored the BC of the wild tapirs from the 65 photographs that had been obtained in the Calakmul region. The scoring sessions were done over the course of one month.

Data Analyses

We assessed relationships between body measures and the corresponding BCSs for each anatomical region using Pearson's product–moment correlations (r). We assessed the degree of agreement among the six body scores assigned to each of the 11 tapirs fully measured and scored, using Kendall's test of concordance (Legendre, 2005) with 4,999 permutations. We did not correct for ties. After we scored the animals, we ordered all pictures of tapirs that had been photographed in the CBR according to the month in which the pictures were taken to test for differences in BC between the dry (December to May) and the rainy (June to November) seasons. We compared BC scores during the dry versus rainy season and within CBR versus zoos using a Mann–Whitney U-test, because data were not normally distributed. All tests with a p-value $\leq .05$ were considered significant.

Results

Assessing BC

Neck and thorax circumferences were significantly correlated with all body scores associated with the six anatomical regions that were deemed to be important for fat deposition or muscle masses (Table 3). Abdomen circumference was significantly correlated with half of the body scores (i.e., neck, spine, and pelvis scores) and marginally correlated with the remaining half (Table 3). The degree

Figure 5. Visibility of the ribs from an obese (a) to an emaciated (e) animal. Following Table 1 scores are as follows: A = 5, B = 4, C = 3, D = 2, and E = 1.

of concordance among the ratings assigned to the six body scores for each of the 11 tapirs fully evaluated was strong (Kendall's $W = 0.752$, $df = 10$, $p < .001$).

The evaluation performed at the Mexican Tapir Specialist Group showed that some anatomical regions may be easier to score than others. In the first individual (a fair animal), most anatomical regions were scored as 2 to 3, with the shoulder exhibiting the greatest ranges (Figure 7). The second individual (obese) was scored between 3 and 5, with 5 being the most common score for all anatomical regions. For the third individual, scores ranged between 3 and 5, with 4 being the most common score for most anatomical regions.

Body Score of Captive Tapirs

Of the 15 tapirs that had been evaluated in captivity (11 males and four females), 40.0% were scored as obese (n = 6), 26.7% good ($n = 4$), 26.7% fair ($n = 4$), 6.6% thin ($n = 1$), and none as emaciated (Figure 8). The BCS of the captive tapirs averaged 24.93 ± 5.61 (*SD*). A tapir that had been confiscated by wildlife authorities at the end of the dry season of 2011 had a total BC score of 15 points at that time. It reached the highest score (30) after 6 months in captivity at a zoo.

Body Score of Wild Tapirs

Overall, the BCSs of captive and wild tapirs differed (U = 399, $p = .042$). None of the wild tapirs was scored as obese, 77.0% as good ($n = 50$), 18.4% as fair ($n = 12$), 1.5% as thin ($n = 1$), and 3.1% as emaciated ($n = 2$; Figure 8). The BCS of wild tapirs averaged 22.63 ± 3.68 (*SD*). One tapir captured in a village during the rainy season that showed a BC score of only 6 at that time reached a score of 26, 7 months after having been translocated to a wildlife rescue centre in Bacalar, Quintana Roo.

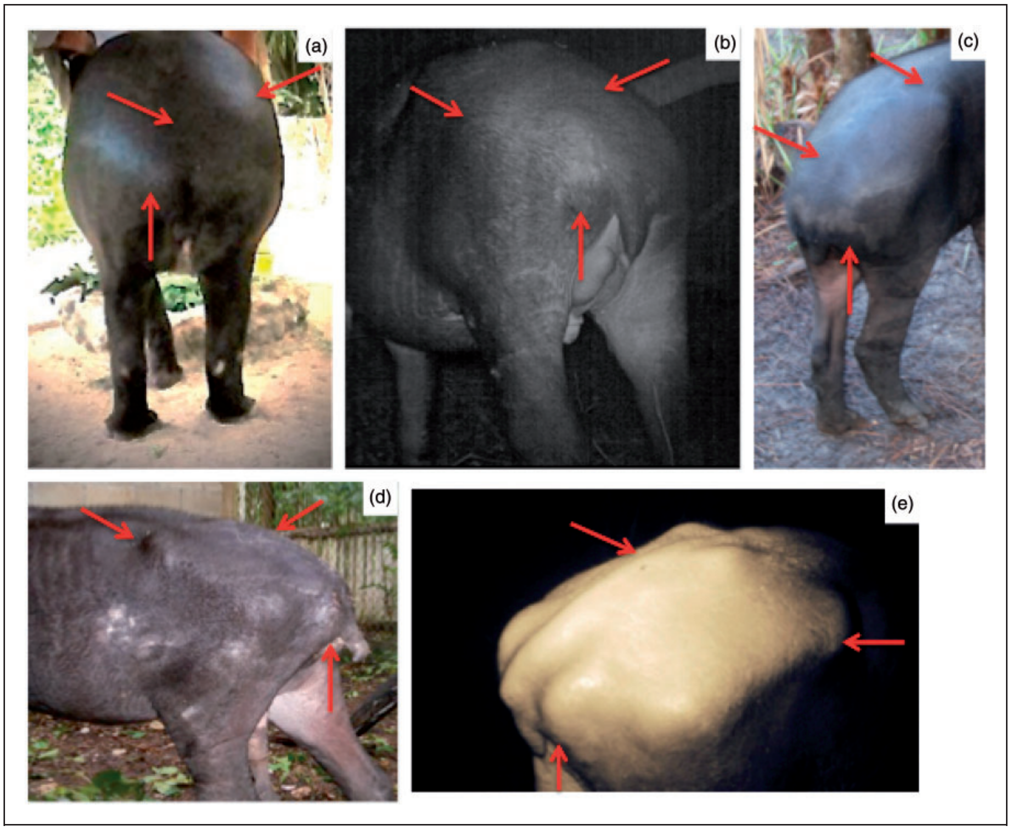

Figure 6. Visibility of the pelvic bones, tail, and the spines of the vertebrae, from an obese (a) to an emaciated (e) animal. Following Table 1 scores are as follows: A = 5, B = 4, C = 3, D = 2, and E = 1.

Table 2. Body Measurements and Body Condition Scores of 11 Baird's Tapirs.

	Body measurements			Body condition scores						
Individual	NC	TC	AC	Head	Neck	Shoulder	Ribs	Spine	Pelvis	Total
CM1	96	152	166	4	4	5	5	5	5	28
CM2	77	135	164	5	5	5	5	5	5	30
CM3	84	150	140	4	4	5	5	4	4	27
CM4	92	153	151	5	5	5	5	5	5	30
CM5	98	164	177	5	5	5	5	5	5	30
CF1	83	169	172	4	5	5	5	5	5	29
CF2	85	139	150	5	5	5	5	5	5	30
CF3	95	150	173	4	4	4	4	4	4	24
WM1	70	106	141	3	3	2	3	2	2	15
WM2	75	120	146	3	3	4	4	3	3	20
WM3	62	115	132	2	2	2	2	2	2	12

Note. NC = Neck circumference; TC = Thorax circumference; AC = Abdomen circumference; all measures in cm. Codes for individuals are as follows: C = captive, W = wild, M = male, F = female; hence, CM1 is a captive male.

There was no significant difference in BCS between the rainy ($n = 19$; BCS ± $SD = 22.26 \pm 4.26$) and dry ($n = 46$; BCS ± $SD = 22.78 \pm 3.46$) seasons (U = 416.0, $p = .75$). The BC of the two males with distinctive marks indicated that scores remained stable over more than 2 years (2011–2013), ranging between 22 and 25 points for the older male, and between 21 and 25 points for the younger radio-collared male.

Table 3. Pearson Correlations Between Body Measurements and Body Scores of 11 Baird's Tapirs, and Associated *p*-Values (Within Parentheses).

Body measure	Body condition score					
	Head	Neck	Ribs	Shoulder	Spine	Pelvis
NC	0.717 (0.013)	0.683 (0.020)	0.737 (0.010)	0.732 (0.010)	0.769 (0.006)	0.769 (0.006)
TC	0.665 (0.026)	0.768 (0.006)	0.774 (0.005)	0.813 (0.002)	0.842 (0.001)	0.842 (0.001)
AC	0.592 (0.055)	0.668 (0.025)	0585 (0.059)	0.585 (0.059)	0.705 (0.015)	0.705 (0.015)

Note. NC = Neck circumference, TC = Thorax circumference, AC = Abdomen circumference.

Discussion

Assessing BC

Several researchers have considered the relationship between BC, body mass, and body measurements in domestic (Machebe & Ezekwe, 2010; Nesamvuni, Mulaudzi, Ramanyimi, & Taylor, 2000; Nicholson & Sayers, 1987; Ozkaya & Bozkurt, 2008) and nondomestic animals (Amaral, da Silva, & Rosas, 2010; Hile, Hintz, & Erb, 1997), as a useful indicator of a population's general health. For Baird's tapirs, we found that BC scores were positively correlated with their corresponding body measurements. The high and significant correlations between body measurements and scores (Table 3) indicate that scores are appropriate estimators of BC in Baird's tapirs.

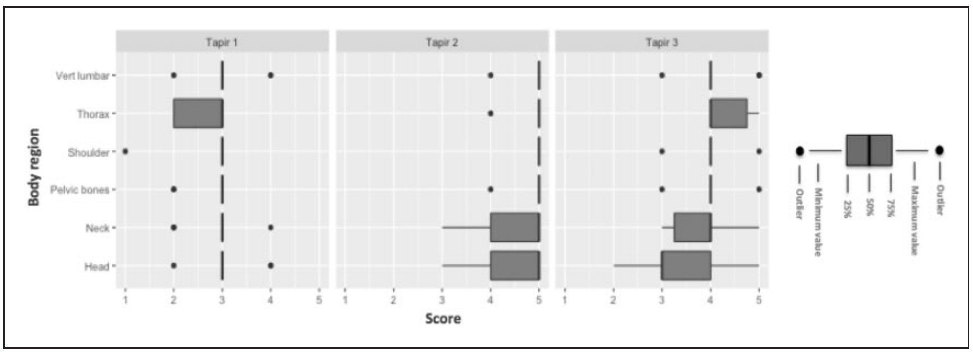

Figure 7. Boxplots of body condition scores of three Baird's tapir, results of the exercise performed by nine members of the Mexican Tapir Specialist Group. Six body regions were evaluated. Scores range from 1 to 5.

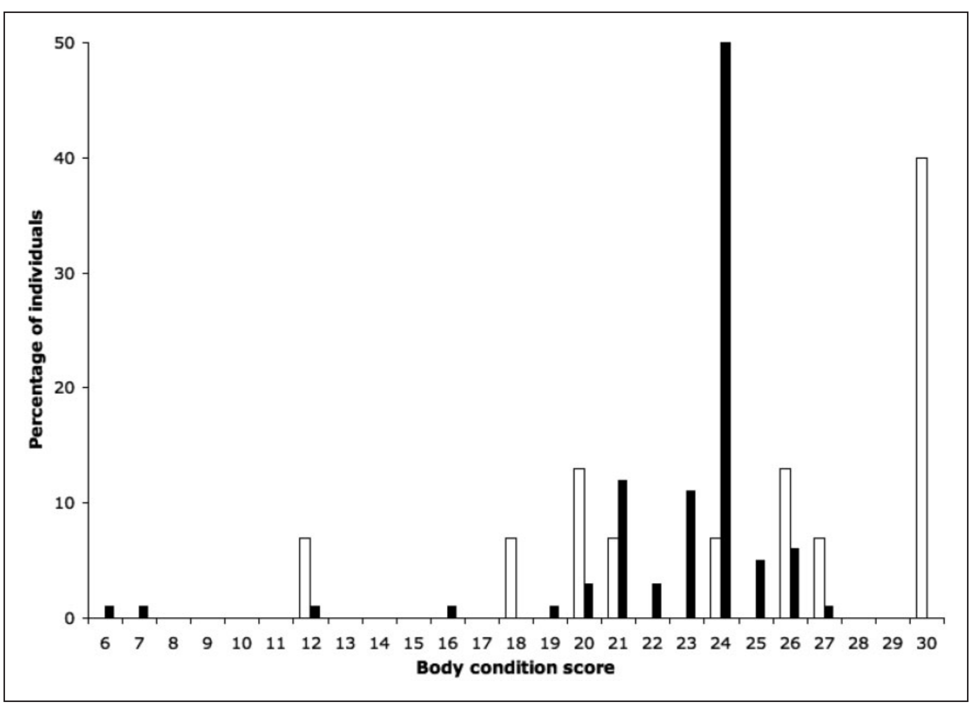

Figure 8. Body condition scores (BCS) of wild (black; $n = 65$) and captive (white; $n = 15$) Baird's tapirs. BCS can range from 6 to 30.

Clauss et al. (2009) study was the only previous work where the BC of tapirs had been estimated. However, these authors scored captive and mostly obese animals, which prevented them from defining scores that could assess animals in poor physical condition. In our study, 40% of the captive animals were obese (from slightly to extremely obese), due to either inadequate high-energy diets (Association of Zoos and Aquariums, 2013; Clauss et al., 2009) or a lack of space in which to move (Association of Zoos and Aquariums, 2013). In the wild, 4.6% ($n = 3$) of the individuals were thin or even emaciated (compared with only one thin, old individual in captivity), allowing for a wider range of BC in our study. The significant difference between the BCS of captive and wild tapirs was likely caused by wild tapirs having never reached the maximum score (BCS = 30), as had happened with captive animals, while the latter never reached the lowest score (BCS = 6). This allowed us to provide a method for scoring BC in Baird's tapir regardless of their condition, from emaciated (BCS = 6) to obese (BCS = 30).

We recognize that scoring systems include a certain degree of subjectivity; however, the observer error regarding some criteria will not substantially bias the results. Results have been often shown to be repeatable, independent of observer experience. Further, variation between observers has been found to be minimal (Edmonson et al., 1989). In our study, we estimate that the head, neck, thoracic, and pelvic areas can be scored reliably, given the consistency among participants in the scores assigned to these anatomical regions. However, the spinal vertebrae and shoulder required that observers were sufficiently familiar with tapir anatomy to be able to differentiate the structures that compose them. Therefore, we recommend caution in the use of these regions to score BC.

Applying BCS to Wild Tapirs of Calakmul

In 6 years of intensive monitoring of tapirs by camera trap, 95.4% of photographic records showed animals with a fair or good BC (i.e., 16–27 points). Tapirs in Calakmul are apparently healthy, similar to the wild populations of lowland tapir that had been evaluated by Medici, Mangini, and Fernandes-Santos (2014) in the Atlantic forest (93% of individuals with good or regular BC, and 7% poor BC) and in the Pantanal (98% of individuals with good or regular BC, and 2% poor BC) regions of Brazil. These Brazilian evaluations were based on captured individuals; therefore, their similarity with our results increases our confidence in the reliability of photographic material to score BC in tapirs.

Despite the strong contrast in vegetation physiognomy between the rainy (June to November) and the dry (December to May) seasons in the region of Calakmul (Vester et al., 2007), no difference was found in the BC of wild tapirs between the two seasons. The harsh dry season would suggest that tapirs, like other herbivores, suffer a decrease in BC during that season due to the lack of both water and high-quality food (Moss & Croft, 1999). In the Calakmul region, tapirs probably have large home ranges (e.g., 18.82 km^2 for one male tapir over a period of 2 months in the dry season; Carrillo et al., unpublished data), indicating that they may have to travel extensively to track resources (O'Farrill, Galetti, & Campos-Arceiz, 2013). Travelling such large home ranges might cause variation in fat reserves, especially since males expend a great amount of energy in agonistic interactions related to territoriality (Medici et al., 2014). However, the two males that we were able to follow over more than 2 years maintained good BCSs throughout the year.

Implications for Conservation

Noninvasive techniques can help researchers to obtain information about tapir health. In many parts of their distribution, tapirs live in areas that are difficult to access (Naranjo & Cruz-Aldán, 1998), which may complicate the safe capture of individuals to obtain direct information about the health of tapirs in the wild. Tapirs are also difficult to observe in the wild, preventing the use of direct observations to estimate BC. We suggest that visual estimation of BC using photos can be a very valuable tool for wildlife managers in assessing BC in wild populations of tapirs. Detecting changes in BC of wild, secretive, and endangered species, such as tapirs, may allow signalling the early emergence of diseases or very strong seasonal changes (e.g., droughts) that may affect populations. We also expect this tool to help us to better understand the ecological conditions that influence the BC of wild tapirs.

Acknowledgments

We thank the personnel of Africam Safari, Aluxes Ecopark, Xcaret, Chapultepec zoo, Payo Obispo Zoo, and Belize Zoo for permitting our BC evaluations of the tapirs in their care. For their invaluable help in the field, we are very grateful to the capture team: Mauro Sanvicente, Nicolas Arias, Natalia Carrillo, Antonio Jasso, and Marcos Briseño. This manuscript benefited from comments by David Gonzalez, Gerardo Suzan, and William Parsons. We thank Michelle Guerra, Francisco Pérez, and Pronatura Peninsula de Yucatán, A.C., for sharing materials. Special thanks are due to the authorities of the Calakmul Biosphere Reserve for their support in this research.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: JPF was supported by a scholarship (332977/269696) granted by the Mexican government through CONACYT. The project was funded by grant C01-108348 (CONACYT & SEMARNAT) to SC and RR-H.

References

Amaral, R. S., da Silva, V. M. F., & Rosas, F. C. W. (2010). Body weight/length relationship and mass estimation using morphometric measurements in Amazonian manatees *Trichechus inunguis* (Mammalia: Sirenia). *Marine Biodiversity Records*, *3*, 1–4.

Association of Zoos and Aquariums (2013) *Tapir (Tapiridae) Care Manual*. Silver Spring, MD: AZA Tapir TAG.

Bassano, B., Perrone, A., & Von Hardenberg, A. (2003). Body weight and horn development in Alpine chamois, Rupicapra rupicapra (Bovidae, Caprinae). *Mammalia*, *67*, 65–73.

Bowkett, A. E., Rovero, F., & Marshall, A. R. (2008). The use of camera-trap data to model habitat use by antelope species in the Udzungwa Mountain forests, Tanzania. *African Journal of Ecology*, *46*, 479–487.

Clauss, M., Wilkins, T., Hartley, A., & Hatt, J.-M. (2009). Diet composition, food intake, body condition, and fecal consistency in captive tapirs (*Tapirus* spp.) in UK collections. *Zoo Biology*, *28*, 279–291.

Colín, R (2004). Interaction between host-agent-environment. In F. Trigo, & G. Valero (Eds.). *General pathology veterinary* (pp. 387–431). México, DF: Universidad Nacional Autonoma de México.

Cook, R. C., Cook, J. G., Murray, D. L., Zager, P., Johnson, B. K., & Gratson, M. W. (2001). Development of predictive models of nutritional condition for Rocky mountain elk. *Journal of Wildlife Management*, *65*, 973–987.

Cook, R. C., Stephenson, T. R., Myers, W. L., Cook, J. G., & Shipley, L. A. (2007). Validating predictive models of nutritional condition for mule deer. *Journal of Wildlife Management*, *71*, 1934–1943.

Edmonson, A. J., Lean, I. J., Weaver, L. D., Farver, T., & Webster, G. (1989). A body condition scoring chart for Holstein dairy cows. *Journal of Dairy Science*, *72*, 68–78.

Ezenwa, V. O., Jolles, A. E., & O'Brien, M. P. (2009). A reliable body condition scoring technique for estimating condition in African buffalo. *African Journal of Ecology*, *47*, 476–481.

Festa-Bianchet, M., Jorgenson, J. T., Bérubé, C. H., Portier, C., & Wishart, W. D. (1997). Body mass and survival of bighorn sheep. *Canadian Journal of Zoology*, *75*, 1372–1379.

Gallivan, G. J., Culverwell, J., & Girdwood, R. (1995). Body condition indices of impala, Aepyceros melampus: Effect of age class, sex, season and management. *South African Journal of Wildlife Research*, *25*, 23–31.

Gerhart, K. L., White, R. G., Cameron, R. D., & Russell, D. E. (1996). Estimating fat content of caribou from body condition scores. *Journal of Wildlife Management*, *60*, 713–718.

Hernández-Divers, S., Bailey, J. A., Aguilar, R., Loria, D. L., & Foerster, C. R. (2005). Health evaluation of a radiocollared population of free-ranging Baird's tapirs (*Tapirus bairdii*) in Costa Rica. *Journal of Zoo and Wildlife Medicine*, *36*, 176–187.

Hershkovitz, P. (1956). Mammals of Northern Colombia, preliminary report No. 7: Tapirs (Genus *Tapirus*), with a systematic review of American species. *Proceedings of the United States National Museum*, *103*, 465–496.

Hile, M. E., Hintz, H. F., & Erb, H. N. (1997). Predicting body weight from body measurements in Asian elephants (*Elephas maximus*). *Journal of Zoo and Wildlife Medicine*, *28*, 424–427.

Karanth, U. K., Chundawat, R. S., Nichols, D. J., & Kumar, S. N. (2004). Estimation of tiger densities in the tropical dry forests of Panna, Central India, using photographic capture-recapture sampling. *Animal Conservation*, *7*, 285–290.

Katona, P., & Katona-Apte, J. (2008). The interaction between nutrition and infection. *Clinical Infectious Diseases*, *46*, 1582–1588.

Le Maho, Y. (1977). The emperor penguin: A strategy to leave and breed in the cold. *American Scientist*, *65*, 680–693.

Legendre, P. (2005). Species associations: The Kendall coefficient of concordance revisited. *Journal of Agricultural Biological, and Environmental Statistics*, *10*, 226–245.

Machebe, N. S., & Ezekwe, A. G. (2010). Predicting body weight of growing-finishing gilts raised in the tropics using linear body measurements. *Asian Journal of Experimental Biological Sciences*, *1*, 162–165.

Márdero, S., Nickl, E., Schmook, B., Schneider, L., Rogan, J., Christman, Z., . . . Lawrence, D. (2012). Droughts in the south of the Yucatán Península: Analysis of annual and seasonal variability of precipitation. *Investigaciones Geográficas*, *78*, 19–33.

Medici, E. P., Mangini, P. R., & Fernandes-Santos, R. C. (2014). Health assessment of wild lowland tapir (*Tapirus Terrestris*) populations in the Atlantic forest and Pantanal biomes, Brazil (1996–2012). *Journal of Wildlife Diseases*, *50*, 817–828.

Millar, J. S., & Hickling, G. J. (1990). Fasting endurance and the evolution of mammalian body size. *Functional Ecology*, *4*, 5–12.

Moss, G. L., & Croft, D. B. (1999). Body condition of the red kangaroo (*Macropus rufus*) in arid Australia: The effect of environmental condition, sex and reproduction. *Australian Journal of Ecology*, *24*, 97–109.

Naranjo, E. J., & Cruz-Aldán, E. (1998). Ecology of the tapir in the Biosphere Reserve La Sepultura. *Acta Zoológica Mexicana*, *73*, 111–125.

Naranjo, E. J. (2009). Ecology and conservation of Baird's tapir in Mexico. *Tropical Conservation Science*, *2*, 140–158.

Nesamvuni, A. E., Mulaudzi, J., Ramanyimi, N. D., & Taylor, G. J. (2000). Estimation of body weight in Nguni-type cattle under communal management conditions. *South African Journal of Animal Science*, *30*, 97–98.

Nicholson, M. J., & Sayers, A. R. (1987). Relationships between body weights, condition score and heart girth changes in Boran cattle. *Tropical Animal Health and Production*, *19*, 115–120.

O'Farrill, G., Galetti, M., & Campos-Arceiz, A. (2013). Frugivory and seed dispersal by tapirs: An insight on their ecological role. *Integrative Zoology*, *8*, 4–17.

Olson, E. R., Marsh, R. A., Bovard, B. N., Randrianarimanana, H. L. L., Ravaloharimanitra, M., Ratsimbazafy, J. H., . . . King, T. (2012). Arboreal camera trapping for the critically endangered greater bamboo lemur *Prolemur simus*. *Oryx*, *46*, 593–597.

Ozkaya, S., & Bozkurt, Y. (2008). The relationship of parameters of body measures and body weight by using digital image analysis in pre-slaughter cattle. *Archiv für Tierzucht*, *51*, 120–128.

Peig, J., & Green, A. J. (2009). New perspectives for estimating body condition from mass/length data: The scaled mass index as an alternative method. *Oikos*, *118*, 1883–1891.

Reuter, H. O., & Adcock, K. (1998). Standardised body condition scoring system for black rhinoceros (*Diceros bicornis*). *Pachyderm*, *26*, 116–121.
Ridout, M. S., & Linkie, M. (2009). Estimating overlap of daily activity patterns from camera trap data. *Journal of Agricultural, Biological, and Environmental Statistics*, *14*, 322–327.
Rowcliffe, J. M., Field, J., Turvey, S. T., & Carbone, C. (2008). Estimating animal density using camera traps without the need for individual recognition. *Journal of Applied Ecology*, *45*, 1228–1236.
Sherry, D. F., Mrosovsky, N., & Hogan, J. (1980). Weight loss and anorexia during incubation in birds. *Journal of Comparative and Physiological Psychology*, *94*, 89–98.
Stevenson, R. D., & Woods, W. A. (2006). Condition indices for conservation: new uses for evolving tools. *Integrative and Comparative Biology*, *46*, 1169–1190.
Vester, H., Lawrence, D., Eastman, J., Turner, R., Calmé, S., Dickson, R., . . . Sangermano, F. (2007). Land change in the southern Yucatán and Calakmul Biosphere Reserve: effects on habitat and biodiversity. *Ecological Applications*, *17*, 989–1003.
Wemmer, C., Krishnamurthy, V., Shrestha, S., Hayek, L. A., Thant, M., & Nanjappa, K. A. (2006). Assessment of body condition in Asian elephants (*Elephas maximus*). *Zoo Biology*, *25*, 187–200.