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Body condition scoring of Bornean banteng in logged forests

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Abstract

Background: The Bornean banteng (*Bos javanicus lowi)* is an endangered subspecies that often inhabits logged forest; however very little is known about the effects of logging on their ecology, despite the differing effects this has on other ungulate species. A body condition scoring system was created for the Bornean banteng using camera trap photographs from five forests in Sabah, Malaysia, with various past and present management combinations to establish if banteng nutrition suffered as a result of forest disturbance.

Results: One hundred and eleven individuals were photographed over 38,009 camera trap nights from April 2011 to June 2014 in five forests. Banteng within forests that had a recent history of reduced-impact logging had higher body condition scores than banteng within conventionally logged forest. Conversely, when past logging was conducted using a conventional technique and the period of forest regeneration was relatively long; the banteng had higher body condition scores.

Conclusion: The body condition scoring system is appropriate for monitoring the long-term nutrition of the Bornean banteng and for evaluating the extent of the impact caused by present-day reduced-impact logging methods. Reduced-impact logging techniques give rise to individuals with the higher body condition scores in the shorter term, which then decline over time. In contrast the trend is opposite for conventional logging, which demonstrates the complex effects of logging on banteng body condition scores. This is likely to be due to differences in regeneration between forests that have been previously logged using differing methods.

Keywords: Body condition scoring, Camera trap, Habitat degradation, Reduced-impact logging, Sabah, Tropical forest

Background

Body condition scores (BCS) measure the amount of soft tissue an animal has relative to its size and are useful as a general guide to the health and fitness of an animal [1, 2]. Usually BCS systems allocate a number that is associated with condition, with lower scores given to animals in poorer condition [3]. Many BCS systems for domestic mammals use palpitation to more accurately assess the condition [1, 2], however this is not practical in wild animal studies as they would first have to be captured, which is both costly and stressful for the animal. There are BCS techniques developed for visual assessment of wild animals in the field; for example on Indian elephants (*Elephas maximus indicus*) by Ramesh et al. [4], and from photographs of mule deer (*Odocoileus hemionus eremicus*) by Marshal et al. [5] and Sri Lankan elephant (*Elephas maximus maximus*) by Fernando et al. [6]. Visual BCS systems are useful for animals that cannot be handled [7]. Non-invasive scoring of mammal body condition using camera traps furthers the scope for BCS applications in wildlife management and for assessing the health of highly elusive species such as the Bornean banteng (*Bos javanicus lowi*) that are not directly observable in the wild. BCS systems are straightforward to conduct, although variability can arise between observer [7, 8]. Clear and systematic BCS systems are beneficial because they can be implemented by wildlife managers [9] and because they are reliable in tracking changes in soft tissue carried by an animal over time (Edmonson et al. 1989 cited in [3]).

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BCS provide invaluable information on the health of the animal on an individual scale that can be related to the strength of their immune system (e.g. [10]), age at which they first breed (Carrion et al. 2007 cited in [8]), fertility [8] and mortality [11, 12]. Monitoring individual health allows the tracking of the health at the population scale [13] and BCS can be used to evaluate the factors limiting population growth [5]. If body condition is low, nutrition is likely to be the key limiting factor in population growth (Bowyer 2005 cited in [5]) but it may also indicate that the population has reached its carrying capacity [5, 8]. For these reasons it is possible that comparing results of BCS across different habitats may show optimal management techniques and be an indication of the longer term effects of different treatments.

Banteng are classified as endangered by the IUCN Red List with the rate of their population decline being greater than 80 % in the last three generations in parts of their range [14]. The population size and structure in Sabah is unknown due to a lack of data [15]. The home range of banteng in Borneo is also unknown, however a bull has been observed travelling 23 km (P. Gardner unpublished observations cited in [15]) and herds of *Bos javanicus birmanicus* can occupy home ranges of up to 44.8 km^2 (Prayurasithi 1997 cited in [15]). The subpopulations studied here were not recaptured in any of the other forests studied. Banteng are crepuscular in their activities, spending more time on foraging and social activity at dawn and dusk, while the mid-part of the day is largely spent ruminating (P. Gardner unpublished observations cited in [15]). They feed on a wide variety of plant material, opting to graze in open areas and are more frequently found in open dipterocarp forests when available [15–17]. The Bornean subspecies is recorded as living in secondary forests and that logging, which opens up the forest floor, may benefit banteng due to the increased understory growth [14, 17, 18]. This suggestion is supported by Meijaard and Sheil [19] who observed that, with the exception of frugivores, ungulates are more successful in logged forests. Logging however removes timber and alters the habitat that may provide vital food sources for the banteng [18] and creates extensive disturbance [20]. Ancrenaz et al. [20] found it was possible to maintain populations of orangutans (*Pongo pygmaeus morio*) within commercial forests that adopt reduced-impact logging (RIL) techniques, whereas conventional logging was more damaging and resulted in localized extinctions. This pattern is also likely to be true for the Bornean banteng; Deramakot Forest Reserve in Sabah utilizes RIL techniques and observations suggest it may support a denser population of banteng [21]. It is possible that past and present logging techniques and management agendas will differ in their effect upon banteng populations, and that the most destructive types of management should result in reduced body condition.

The body condition of banteng in Sabah should reflect the habitat suitability of the forests and the health of the banteng populations (Adamczewski 1993 cited in [8]). Logging alters the vegetation composition of a forest [18], therefore it is important to know how logging practices affect banteng body condition. This information will be especially important as there is currently very little knowledge of the impact of logging on banteng [18]. At present there is very little unlogged forest remaining in Sabah [22] suggesting that it is likely that banteng will be confined to commercial forests in the very near future. Comparisons of banteng BCS from forests that differ in management may indicate the suitability of the management techniques and the most effective approach to conserve the banteng in commercially managed forest.

We conducted the first identification of individual banteng in Sabah using unique natural markings. We then created the first BCS system using non-invasive camera trap images to identify the impact of the implementation of conventional logging, RIL and protection from logging, both in the past and present, upon the health of banteng in Sabah. It was expected that banteng living in forests with longer post-logging regeneration times and which had been subjected to RIL instead of conventional techniques would have higher BCS.

Methods

Study sites

Camera trap surveys were conducted in five forests in Sabah, Malaysian Borneo: Tabin Wildlife Reserve, Malua Forest Reserve, the buffer zone of Maliau Basin Conservation Area, Sipitang Forest Reserve and Sapulut Forest Reserve, located in east, east-central, south-central, south and west of Sabah, respectively (Fig. 1). Within these locations the habitat that is inhabited by banteng is predominately lowland and hill dipterocarp forest and freshwater swamp forest. The forests experience uniform temperatures and very little variation in rainfall across the year [23], however extensive climatic data is not available. These forests have undergone different past and present logging management methods (Table 1).

Data collection

Camera trap images of banteng were obtained from the five forest reserves at differing time periods and camera trap stations were distributed in a grid format and/or on an ad-hoc basis (Table 2). The differing sampling schemes were due to two different prior studies of banteng with different objectives: a PhD project by Gardner [24] and a state-wide survey of the remnant banteng populations. With both sampling schemes the cameras

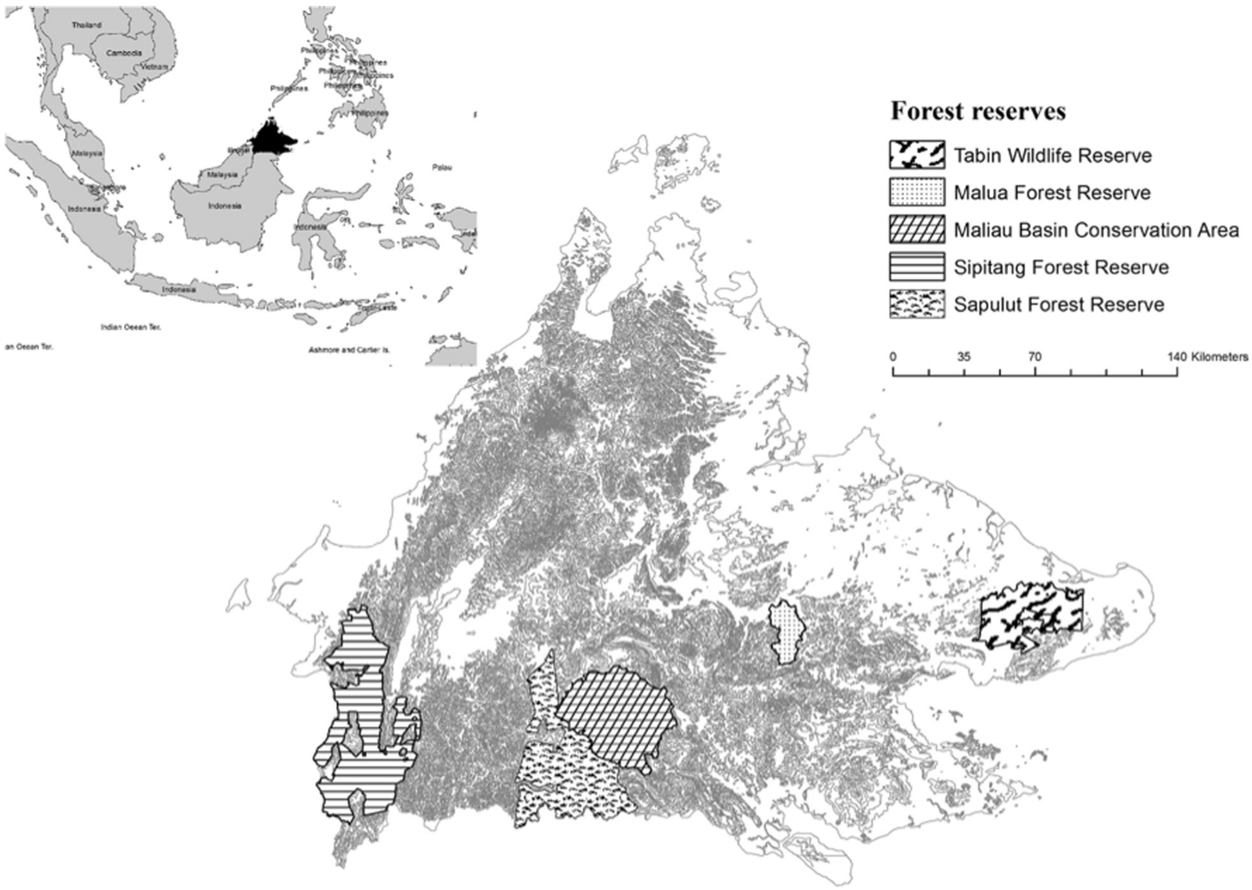

Fig. 1 A map with the position of Sabah, Malaysian Borneo in Southeast Asia (*inset*) and the positions of the five forests in Sabah used to survey Bornean banteng using remote camera traps. Photographs from the camera traps were used to score the body condition of banteng

were widely dispersed throughout the forest in question, making it reasonable to assume that the health of banteng individuals captured on camera are representative of the entire population. Cameras in a grid layout were positioned overlooking banteng or large mammal signs (or in the absence of these an animal trail) within a 50 m radius of a predetermined GPS position. Grid positions were determined primarily on access by vehicle, boat or on-foot, with a minimum distance of 500 m from the nearest unsealed road. Ad-hoc cameras were placed near or overlooking banteng signs (tracks or dung), direct sightings or in habitat suitable for banteng (*i.e.* internal openings or grassland). A camera trap station was comprised of two cameras facing each other, fixed to trees at approximately 10 m apart and 1 m high. Cameras were programmed to take three photographs at one-second intervals every time they were triggered. In low-light conditions images were taken in monochrome

Table 1 Logging categorisation scheme

Study Site	Past Logging Management	Present Logging Management	Year of Most Recent Logging
Tabin Wildlife Reserve	Conventional techniques [32]	Protected from logging	1989 [32]
Malua Forest Reserve	Conventional and RIL techniques [33]	Protected from logging for 50 years	2007 [33]
Buffer zone of Maliau Basin Conservation Area	RIL techniques [34]	Protected from logging during time of data collection, but logging has now recommenced.	1997 [34]
Sipitang Forest Reserve	Conventional techniques [35]	Areas logged with RIL techniques, managed as plantation or unlogged [35]	2010–2014 [35]
Sapulut Forest Reserve	Conventional techniques (Sabah Forestry Department staff, pers. obs.)	Logged using RIL techniques or managed as plantation (Sabah Forestry Department staff, pers. obs.)	2005–2014 (Sabah Forestry Department staff, pers. obs.)

The descriptions of the past and present logging managements of each of the five study forests in Sabah, Malaysia, showing the categories that were used in the data analysis

Table 2 Camera trap sampling scheme

Location	Study Period	No. of Stations	Camera make/model	Sampling scheme
Tabin Wildlife Reserve	April 2011–October 2012	130	Reconyx H500	2 grids: 4 km^2 (500 m between each station)
				2 grids: 6.25 km^2 (500 m between each station)
				8 ad-hoc stations placed in areas of banteng signs
Malua Forest Reserve	April 2011–June 2014	118	Reconyx H500 & PC800	3 grids: 6.25 km^2 (500 m between each station) 10 ad-hoc stations placed in areas of banteng signs
Maliau Basin Conservation Area	June 2013–June 2014	21	Reconyx H500, PC800 & PC850	Cameras in areas of banteng signs
Sipitang Forest Reserve	September 2013–March 2014	30	Reconyx PC800	Cameras in areas of banteng signs
Sapulut Forest Reserve	November 2013–April 2014	30	Reconyx H500 & PC800	Cameras in areas of banteng signs

The camera trapping methods used to capture banteng in each forest reserve studied in Sabah, Malaysia

using an in-built infrared light with the exception of one camera in the buffer zone of Maliau Basin Conservation Area (Reconyx PC850), which operated with a white flash for colour pictures. Cameras were checked every 4 weeks for tampering and functionality, and to change the batteries and SD cards. Surveys were conducted for a minimum of 90 days in each forest. This study only utilized non-invasive remote camera trapping for data collection in order to minimize the disturbance caused to this shy and nervous large bovid. No experimental work and no direct handling of banteng individuals in the wild or in captivity was conducted. This study was executed in compliance with the Sabah Wildlife Department: no ethics statement was required and no ethics committee exists for wildlife studies within Sabah, Malaysia. Research permits were granted by the Sabah Biodiversity Council, reference numbers: JKM/MBS.1000-2/12(156) and JKM/MBS.1000-2/2 JLD.3 (18).

Body condition scoring

Individual profile cards of each banteng were created using camera trap images of the head, rear and both sides of the animal to create a reference allowing the banteng to be identified in the future if recapture occurred. Each individual was given a score for every day that it appeared in the camera traps using the five-point pictorial scoring system developed specifically for the Bornean banteng (Additional file 1). All the scores given to each banteng were included in the analysis and in cases where not all of the scored parts of the banteng were visible; the parts that were in sight were used to create the score. The five-score pictorial BCS system covers the full range of conditions observed in banteng captured on camera within the research period. Individuals were assigned a score of 1, 2, 3, 4 or 5, with high values corresponding to more soft tissue; a score of 1 was given to animals with prominent skeletal features such as the ribs, 2 when the hips protruded but the ribs were not obvious, 3 when there was some rounding to the body and the most prominent skeletal features such as the hooks and pins were covered by some soft tissue, 4 when there was a relatively high degree of soft tissue covering the prominent skeletal features and the body was quite rounded, and 5 when all skeletal features on the body were covered in soft tissue giving a very rounded appearance. It is possible that body conditions both above and below this range exist in individuals not captured during this study and future users of this method could extend the scale to 0 or 6 if necessary, as with the elephant BCS system developed by Fernando et al. [6]. Predominantly only colour images were used in the profiling and for scoring the body condition. In exceptional circumstances, monochrome photographs were included when the light levels shifted and caused the camera to change from colour to monochrome photographs (or vice versa) while the herd was still present. These images retained sufficient light to permit individual recognition and scoring. Images where it was not possible to allocate an accurate score were not included in the dataset for analysis.

Logging management analysis

Past logging was defined as the logging that took place before the current logging management and present logging was defined as the logging being practiced at the time the images were captured. The logging history of each forest was classified into four categories that best describe the past and present logging methods: (1) RIL [25]; (2) industrial tree plantation: the area is clear felled and replanted; (3) conventional: traditional logging without RIL techniques; and (4) none: no logging. The time since logging in years was calculated from the year that that part of the forest was last harvested. When the exact date of logging cessation for the compartment was unknown, the last harvesting activity for the entire forest was used. When an individual was recaptured in different areas of the study forest that had had differing logging treatments on the same day, the photos were discounted. However every instance where an individual was only captured in an area of the same logging treatment in a day was included in the analysis.

R statistical software version 3.0.2 [26] and the package Ordinal [27] was used in the data analysis. Only the first BCS given to each individual was used in the analysis to remove bias for those individuals who were scored multiple times. The independent variables were Past Logging Type (categorical), Present Logging Type (categorical) and Years Since Logging (continuous) and these were included in a cumulative link model (CLM) to explain the dependent categorical variable, BCS. Density was not included in the analysis, as the nature of the camera trap deployment did not allow this to be estimated. An initial CLM of BCS explained by Past Logging, Present Logging, Years Since Logging and all possible two-way interactions was created and run with every possible link. Akaike information criterion (AIC) comparison was used to choose the best link. In order to remove insignificant terms and arrive at the most efficient model the initial CLM was reduced by AIC comparison by automatic stepwise refinement.

Results

Profiling

There was a differential surveying effort in each forest due to the nature of the primary objectives for the data collection and this is laid out in Table 3. Out of the total 681 daytime banteng captures there were 100 instances where the individual could not be reliably assigned a profile (Table 3). In total 111 individuals were identified and scored from the five forests (Additional file 2). Individuals were captured during the first 46 survey days. Two individuals were excluded from the analysis because no reliable scores could be allocated for any of the occasions they appeared on the camera. In Tabin Wildlife Reserve eight bulls, six cows and two juveniles were studied whereas 16 bulls, 17 cows and seven juveniles were studied for Malua Forest Reserve, seven bulls, 10 cows and one juvenile for Maliau Basin Conservation Area, seven bulls, 12 cows and five juveniles for Sipitang Forest Reserve and six bulls, five cows and two juveniles for Sapulut Forest Reserve. The main natural features used to identify individuals were the shape of the horns, tears in the ears, the pattern at the edges of the stockings and scars. Occasionally other features that were used in identification were the length of tail, ear hairiness and pairing up of cows and calves (Gardner PC: Individual recognition and profiling of Bornean banteng, in preparation).

Forest management

The most efficient link in the initial model was a loglog link and after automatic stepwise deletion the final most efficient model was BCS explained by Years Since Logging in interaction with Past Logging. The interaction between years since logging and past logging type was significant ($p = 0.0192$), meaning that the relationship between the timing of logging and the BCS of the banteng differs depending on which logging method (RIL or conventional) was previously used in the area (Table 4; Fig. 2). BCS also differed significantly between past logging types ($p = 0.0238$) however time since logging did not significantly affect BCS ($p = 0.9907$) (Table 4). The BCS of banteng living in forest previously logged by RIL was significantly higher by 1.07 ± 0.47 than those living in forest that was previously logged using conventional methods. The BCS of banteng living in previously logged forests using the RIL method had declined over time, whereas banteng in the conventionally logged forests now have a higher BCS, after a longer regeneration time (Fig. 2). In the short term banteng have higher body condition in areas where RIL was used in the past, however after approximately 11 years of regeneration banteng BCS are higher in areas that have had conventional logging techniques in the past (Fig. 2).

Discussion

Profiling

Banteng can be reliably identified using differences in their coat colour, size and shape of horns, differences in the edges of the stockings, cuts and scars and any other

Table 3 Camera trap sampling results

	Camera Trap Nights	Daytime Captures	Unscored captures	Number of Individuals	Elevation of Captures (m) above sea level
Tabin Wildlife Reserve	14784	26	4	16	22–164
Malua Forest Reserve	12400	486	113	40	29–293
Maliau Basin Conservation Area	4971	77	18	18	267–398
Sipitang Forest Reserve	3714	56	11	24	781–1143
Sapulut Forest Reserve	2140	36	5	13	407–482
Total	38009	681	151	111	22–1143

The camera trapping survey and profiling results for the Bornean banteng in Sabah, Malaysia, showing how long cameras were left up, at what elevations, how many times individual banteng appeared on camera and how many captures could not be reliably given a score

Table 4 The results of the final CLM

Term	Coefficient	SE	Test Statistic	*p*-value
Past Logging * Years Since Logging	−0.09	0.040	−2.341	0.9907
Past Logging (RIL)	1.06	0.473	2.260	0.0238
Years Since Logging	−0.0001	0.017	−0.012	0.9907

The statistical results of the cumulative link model (CLM) of Banteng BCS ~ Past Logging*Years Since Logging for banteng in Sabah, Malaysia

permanent or semi-permanent distinguishing feature (Gardner PC: Individual recognition and profiling of Bornean banteng, in preparation). Profiling juveniles was more difficult, particularly the very young calves that had neither horns nor stockings and rapidly developed between photographic recaptures that were often infrequent. Furthermore, recognition was difficult when multiple calves in the same herd were born over the same time. It was necessary to be very flexible with the features used to recognize the individuals, as different lights and angles showed different features. When profiling it is important to keep in mind the changes that occur over time: new scars may be acquired, horns will curve more and the coat may change colour slightly. For forests where camera trapping was carried out over multiple years, instances of all stages of an individual's growth were included in their profile to allow their recognition at all ages. Although individuals would change in many ways; for example horn development and shape, number of scars and colour; features such as the pattern at the edge of their stockings would not change, allowing an individual to be successfully identified a number of years after it was last captured.

Body condition scoring

As body condition scoring has been successfully applied to elephants using only visual observations [4, 6, 9] it was expected that a scoring system for banteng using photos would be straightforward to implement. Camera trap captures are often limited in their photographic aspect and do not always permit the animal to be viewed from all angles to assess the condition, however this technique does allow a much closer observation of a wild animal than would normally be possible. Occasionally the camera functionality or weather conditions gave rise to poorer quality photos, which were more difficult to score. As stated by Wemmer et al. [9], the skeletal features are much more visible when an animal is stretched out mid-stride whereas they are much less visible when bunched up, each of which decreases or increases the perceived body condition respectively. This would be less of a problem with live observations. Fernando et al. [6] found that lighting and posture might cause a different score to be assigned to an animal, but the error is usually only small (equating to ± 0.5 BCS in this case). It was suggested that the use of a series of photographs would be beneficial to obtain more reliable scores of an animal [6]. As the camera traps used in this study provided a short series of photographs of each individual, we maximized the potential for capturing the features used for scoring. For these reasons, we believe our scores of each banteng are accurate given the harsh environmental conditions and the inability to conduct direct observations.

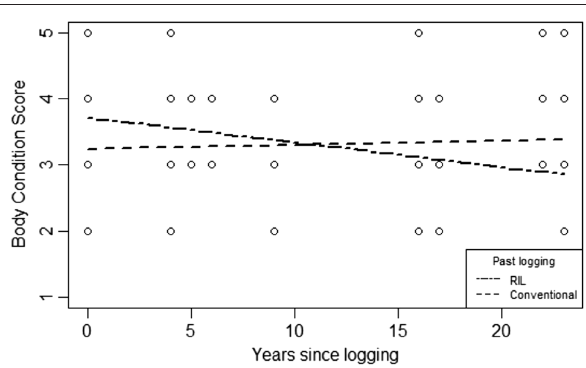

Fig. 2 The body condition scores (BCS) of banteng inhabiting forests in Sabah, Malaysia, with increasing time since the forest was last logged by either reduced-impact logging (RIL) or conventional techniques for an ordinal regression model with the raw data (circles) and predicted values (dashed lines). The body condition scores were obtained from camera trap images

Forest logging effects

It was expected that the BCS would be higher in forests that have been marginally opened up by recent and small amounts of logging. This is because it would promote the growth of pioneer grasses, which are suitable forage for banteng, but that extensive logging would remove some of the important feeding habitats and therefore the banteng would be in poorer condition there. We found evidence in this study that supports this theory.

The results of this study indicated that forests that were logged using RIL in the recent past contained banteng with higher BCS than forests that were logged using only conventional logging methods. RIL techniques minimize the impact on the forest by removing timber using helicopter and/or long-distance cranes to avoid non-target stem destruction, soil erosion and compaction [21], however all logging activity still causes much disturbance and habitat degradation [28].

Most of Sabah's forests have been logged previously [29], therefore it is necessary to conserve banteng in logged areas. All logging in Sabah must now follow RIL techniques if the forest is not going to be converted into plantation [25], which will be less detrimental to banteng habitat than old-style conventional logging. The higher BCS in forests that have been logged recently using RIL may be due to the short-term benefits of increased understory growth of pioneer species in the first few years after logging [29]. This is due to the increased light intensity on this layer [30]. Pioneer species such as grasses were found in greater abundance when logging had occurred within the last ten years (S. Ridge, pers. obs.) making banteng forage more abundant. The nature of RIL techniques is less damaging than conventional techniques [25] because they allow the vegetation to recover more quickly [31]. Past logging was found to significantly influence banteng BCS but our results show that current disturbance or present logging does not manifest in different BCS. It is therefore possible that a negative lag effect exists and that banteng BCS may decline in the future. For this reason, it is important to minimize the impact of logging. Long-term monitoring of banteng BCS in an area undergoing changes in management will be required in order to assess the full consequences. The effects of past conventional logging techniques are evident today as low BCS, with the more recent the conventional logging the lower the BCS (Fig. 2). It was not possible to document banteng BCS prior to logging but we believe the lower scores to be due to conventional logging techniques decreasing the rate of vegetation regeneration [31]. We observed a gradual increase in BCS with time in forests that were regenerating from conventional logging; however we observed the opposite trend for RIL whereby BCS decreased at a steep gradient over time following RIL activity.

How recently a forest is logged and the type of logging undertaken significantly affect BCS and these factors are indicative of forest regeneration; forests logged using RIL will vary in the extent and speed of regeneration compared with conventional logging, which may take significantly longer. It is likely that the effects of logging on banteng are actually very complex with many more facets that were not covered in this study. A note of caution however regarding the interpretation of the significance of time since logging; although there was overlap in the time since logging between the three most recently logged forests (Malua Forest Reserve, Sipitang Forest Reserve and Sapulut Forest Reserve), the time of the two most distantly logged forests (Tabin Wildlife Reserve and the buffer zone of Maliau Basin Conservation Area) do not overlap with any other forest, therefore the increase in BCS with recent logging could actually be due to other factors not measured in this study within these latter two forests.

Conclusions

The BCS system is appropriate for monitoring the long-term nutrition of the Bornean banteng and for evaluating the extent of the impact caused by present-day RIL methods. RIL techniques give rise to individuals with higher BCS in the shorter term, which then decline over time. In contrast the trend is opposite for conventional logging, demonstrating the complex effects of logging on banteng BCS. This is likely to be due to differences in regeneration between forests that have been previously logged using differing methods. This study highlights the lack of information there is into the effects of logging on the Bornean banteng and provides new methods for allowing research into this elusive mammal. It is imperative that this knowledge gap is closed and corrective measures are implemented to facilitate the persistence of this endangered species.

Additional files

Additional file 1: Body Condition Score (BCS) system for the Bornean Banteng from camera trap images. (DOCX 6024 kb)

Additional file 2: Body Condition Score data file. (CSV 3 kb)

Abbreviations

AIC, Akaike Information Criterion; BCS, Body Condition Score; CLM, Cumulative Link Model; RIL, Reduced-Impact Logging

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Availability of data and material

The data can be found as an additional supporting file.

Authors' contributions

NP carried out the background research, formulated the methods including creating the body condition scoring system for banteng, identifying the individuals and carrying out the statistical analysis. PG facilitated research and conducted surveys and data acquisition, provided advice and ideas on the methodology and carried out extensive editing of the manuscript. JS provided much assistance with the data analysis and editing of the results section. JG conducted surveys and data acquisition. LA was a local counterpart, provided research permits and facilitated research. BG facilitated research and gave extensive advice and edits on the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Not applicable.

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