CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Validation of body condition scoring systems for common eland (*Tragelaphus oryx*)

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled Validation of body condition scoring systems for Common eland (*Tragelaphus oryx*) independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 21st April 2023

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Sarah Thérèse Dearman

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Abstract

Body condition scoring (BCS) is a valuable tool used in both zoological and captive collections as well as in the field. It is a crucial tool for assessing an animal's general health status. Despite eland often being found in captive environments, there is yet to be a publication that outlines the most suitable way to assess the body condition of the common eland (*Tragelaphus oryx*). This thesis, therefore, occupies this gap in the existing literature and determines both the best method of assessing body condition as well as the optimal area of the body to do so in the common eland – the findings can then be utilised by zoological collections around the globe in addition to field researchers focusing on this species. Using a group of captive common eland, visual body condition scores were taken for each of the 56 individuals once a month for 30 months. To validate the visual body condition scoring system, the study then used inter-rater reliability and correlation with other parameters, including palpation body condition scores, tail base, and body weight. Our results show that we have validated a visual body condition scoring system since the output of the intraclass correlation (ICC) showed a significant degree of reliability between all scorers as each focus point gave an ICC value of above 0.7. Thus, the scoring matrix provided can be utilised by zoological and captive collections that house common eland. Additionally, the Spearman's rank correlations between visual and palpation BCS and the added variables were all statistically significant. The study also outlines the effect of age and sex of an individual on their body condition score, with there being a statistically significant difference between the average means of each age category and the post hoc testing finding a greater variance in younger age categories. We found that when testing for sex bias on the average visual BCS there showed to be no sex bias, however, when testing for sex bias for each focus area separately, the neck body condition scores showed to have sex bias.

Keywords: animal health; antelope; palpation body condition scoring; scoring matrix; visual body condition scoring

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List of the abbreviations used in the thesis

BCS – body condition score

BMI – body mass index

CZU – Ceska Zemedelska Universitá

ICC – Inter-class correlation

KFI – kidney fat index

1. Introduction and Literature Review

Whether an animal is living in the wild, in captivity, or in a semi-captive environment, it is important to easily be able to establish its level of health and body condition. In the wild, assessing this can help a researcher establish changes in environmental conditions and the quality of food available (Cook et al. 2010). In captive conditions, it can help evaluate whether a diet has been suitably adapted for the correct nutrient intake and allows for a change in activity budget, as it is common to find obese animals in zoos due to higher levels of sugar found in their feed (Morfeld et al. 2014). Optimising a quick, non-invasive method of assessing body condition will allow for more regular monitoring of an animal and its diet, allowing necessary adjustments to be made. This method needs to inform the body condition not only of the whole animal but also of varying focus areas. This is because different species accumulate fat reserves in different body areas. For example, buffalo (*Syncerus caffer*) accumulate the thickest degree of fat between their tailhead and pins (Alapati et al. 2010), whereas chimpanzees (*Pan troglodytes*) accumulate fat around the abdomen and neck (Reamer et al. 2020). Thus, when formulating a study, it is necessary to establish where on the focal species they accumulate fat.

1.1. Eland

Eland are the largest type of antelope in the world and are embedded in the genus *Tragelaphus*, in which two distinct species of eland can be identified: the common eland (*Tragelaphus oryx*) and the giant (derby) eland (*Tragelaphus derbianus*), both of which have identified subspecies; East (*T. o. oryx*), livingstone's (*T. o. livingstonii*) and southern (*T. o. pattersonianus*) common eland (Furstenburg 2007; Lorenzen et al. 2010) and western (*Tragelaphus derbianus derbianus*) and eastern (*Tragelaphus derbianus gigas*) derby eland (Kolackova et al. 2011; IUCN SSC Antelope Specialist group 2016; IUCN SSC Antelope Specialist group 2017). The focus of this study is the common eland (hereafter eland), which has a geographic range encompassing much of Southern Africa and has also been introduced into areas of semi-captivity in Western Africa in countries such as Senegal, where its sister species, the giant eland is naturally found (IUCN SSC Antelope Specialist group 2016; Kubatova et al. 2020).

Eland are ruminants commonly described as intermediate feeders: they fluctuate between browsing and grazing depending on season and food availability (Hoffman & Stewart 1972). Other studies, however, have shown them to primarily feed on browse in the wild, especially when living in shrubland where they most frequently consume woody species of plants (Watson & Owen-Smith 2000). Due to their captive environment, the eland involved in this study are fed a mixture of corn silage, lucerne and meadow hay, and straw, as well as a concentrate cattle feed (Musa et al. 2021). Diet has a large influence on, and is the basis of, an animal's body condition. Feeding of browsers has been deemed more difficult for captive institutions due to unattainable demand, which can potentially lead to the overfeeding of concentrate feed, resulting in the animals being overweight (Clavadetscher et al. 2021). On the contrary, if they are not supplied with high-sugar food to replace the inadequate quantity of browse, multiple other ruminants, including giraffes (*Giraffa camelopardalis*) and elk (*Alces alces*), have been recorded as underweight (Clavadetscher et al. 2021). This could also be applied to the eland in this study, as a large proportion of their diet is grass plant species rather than high-concentrate feed, which due to their natural history may lead to them being underweight. Thus, by studying different body condition scoring methods and establishing the most effective, we can then assess the impact and suitability of their diet in captivity as well as go even further and use body condition of eland to assess environmental changes and food quality in the wild.

1.2. Body condition

1.2.1. Significance of body condition scoring

Body condition is an important indicator of an animal's health and energy storage. It is an index of the nutritional resources in the animal's environment and how they are utilised (Viblanc et al. 2012). Body condition relates to the physical stature of an animal and mainly incorporates muscle and fat presence, with a higher body condition score referring to an animal's higher muscle and fat content (Mattiello et al. 2009). The body condition score can be obtained using a variety of different methods, some more accurate than others (table 1).

Table 1. Overview of different types of methods used to assess an animal's body condition.

Method classification	Method	Formula/ description	First use	Reference
Invasive	Ratio index	Body mass divided by a linear measure of body size	150+ years ago	Jakob et al. 1996
	Sloped-adjusted ratio index	slope of the regression of body mass against length of a body part		Jakob et al. 1996
	Residual index	Body mass is regressed on body size		Jakob et al. 1996
	Fulton's condition factor	Body mass divided by the cube of body length	1904	Stevenson & Wood 2006
	Body girth	G_b= circumference at iliac crests	2012	Viblanc et al. (2012)
	Blood biochemistry	Triglycerides (mg/dl) in blood	2002	Serrano et al. 2008b
	Pack cell volume	Red blood cell count		Gallivan et al. 1995
	Ultrasonography	Ultrasonic measurement of fat thickness	1998	Mattiello et al. 2009
	Palpation BCS	Manually estimating subcutaneous fat through touch		Audige et al. 1998
Non-invasive	Visual BCS	Visually estimating subcutaneous fat	1960	Robinson 1960
Post-mortem	Heart girth	Circumference of heart	1937	Lane et al. 2014 Brody et al. 1937
	Kidney fat index	Weight of fat around the kidneys/weight of kidneys without fat × 100	1937	Serrano et al. 2008a
	Kistner score	Visual assessment of quantity of fat found on a carcass at certain deposit sites	1980	Kistner et al. 1980

Body condition can also impact other biological functions, such as milk production and lactation in ungulates, which has been observed to be directly affected by an individual's body condition, with those with a lower body condition score yielding less milk (Landete-Castillejos et al. 2009). Body condition also influences social rank, but an individual's rank is not solely due to body condition (Landete-Castillejos et al. 2009). Furthermore, higher body condition scores can also lead to reproductive problems, including dystocia and ovarian cysts, and, as it can be common to find overweight animals in captive environments, it is necessary to ensure a suitable body condition scoring (BCS) method to be able to alter their diets accordingly (Audige et al. 1998; Morfeld et al. 2014). Additionally, since conservation is moving towards the One Plan Approach, whereby conservation management plans incorporate *in-situ* and *ex-situ* populations together, it is important that captive animals have an optimal body condition. It is therefore crucial to establish reliable methods to score body condition of captive animals before trying to assess the body condition of their counterparts in the wild.

1.2.2. Indices

In small animals, neither visual nor palpation BCS methods are feasible, so original methods of BCS come from measurements of body mass divided by body size. This is known as the **ratio index**, a method comparable to the body mass index used in humans for many years. Since the development of other methods, however, the ratio index method has been shown to be less reliable and should only be used for the initial indication of an animal's body condition (Jakob et al. 1996; Stevenson & Woods 2006). This is supported by more recent studies, which suggest that an overview – but not a detailed picture – of body condition can be provided by ratio indices (Labocha et al. 2014). It was found that, despite being more complicated, the **residual index** is a more accurate method. This uses the residuals of a regression of body mass on body size, and, as it is not biased by body size, it has been proven to be a more reliable method of BCS when compared to the ratio index and slope-adjusted ratio index methods (Jakob et al. 1996; Labocha et al. 2014). Contrary to this, Schulte-Hostedde et al. (2005) believe that calculating body condition by regressing body mass onto any chosen index of size is no longer accurate, as the body size still biases the calculation and the proportion of body mass associated with energy reserves, such as subcutaneous fat, is independent of the individual's size. Although for large mammals, the best body condition index is log body mass divided by log body length, a standard body mass index (BMI) calculation can be used in captive institutions for a quicker result – for example in zoo-housed giraffe (Clavadetscher et al. 2021, Stevenson & Wood 2006; Schulte-Hostedde et al. 2005). Similarly, the **Fulton's Condition Factor** takes the body mass and divides it by the cube of body length (Stevenson & Wood 2006). However, body mass as an independent measurement does have a positive correlation to the percentage of body fat, so it can give an initial indicator of body condition.

Sometimes, it is not possible to calculate the above indices because accurately measuring the body mass of an animal in the field can be unachievable or too expensive. Therefore, an alternative method has been developed to estimate body mass. This is done using the parameters of body length, which is far more easily measured as it involves carrying less equipment into the field, and **heart girth**, although this method does require the animal to be deceased (Lane et al. 2014).

Viblanc et al. (2012) found that **body girth** had a firmly positive relation to **body mass** in all life stages of both sexes of king penguin. Other authors then narrowed this down to find that pelvic circumference at the iliac crests was the best girth measurement to assess body fat. Combining this with body mass and other possible biometric measurements, such as head length or zygomatic breadth, in a regression model is a reliable method that is non-fatal (Labocha et al. 2014). Larger animals that are unable to be handled would need to be habituated to human contact in order to employ this method. Other biometric measurements can be used, such as circumference measurement of either the neck or chest, however this only indicates subcutaneous fat and cannot be used alongside any other formula (Wemmer et al. 2006). Additionally, body condition can be assessed long-term by skeletal measurements – in large ungulates like elk. This includes head length and cranial breadth (Messier & Crete 1984).

In more recent times, many methods to assess an animal's body condition in real world settings have been developed. One of the most commonly used method is the **kidney fat index** (KFI), which was used in 82% of studies to monitor body condition in ungulates (Serrano et al. 2008a). KFI involves the assessment of fat stored on the kidney – this method can also be used on other vital organs to measure overall body condition but has been proven most accurate with the kidney (Serrano et al. 2008b). Since then, however, KFI has been found to be an unreliable method for BCS as it creates affected results due to inaccurate indices (Serrano et al. 2008a). Another method using the kidney and other organs – specifically the heart – was developed for use in the field: the **Kistner score** (Kistner et al. 1980; Cook et al. 2005). The Kistner score is a method used on carcasses, which gives a visual assessment of fat accumulation using five scoring categories (Kistner et al. 1980). An adaptation of Kistner scoring uses a 1-4 visual scoring scale on different fat reserves including the kidneys, stomach, and back (Stevenson & Woods 2006), and another alternative simply uses the weight of the heart or kidney (Messier & Crete 1984). However, KFI and the Kistner scoring methods can only be used on dead animals, so they are unsuitable for continuous studies or conservation purposes with a limited number of individuals.

In goats (*Capra pyrenaica*), nutritional status using **blood biochemistry** can be an accurate indicator of BC; it was found that total serum proteins and serum triglycerides gave an accurate assessment of the animals' body condition as they correlated with KFI (Serrano et al. 2008b). Blood composition can also be examined regarding blood sugar levels and the amount of uric acid (Stevenson & Wood 2006). Blood biochemistry can therefore be used as a continuous monitoring system of an animals BCS. For red deer (*Cervus elaphus*), however, a different study found blood serum to be ineffective at assessing its body condition, as it was not capable of measuring small fluctuations, in addition to being affected by seasonal changes (Cook et al. 2005). Another trialled method in red deer was urine indices, but this was found to be an unreliable method for assessing an animal's BCS, because the urine analysis did not correlate with the percentage of body fat (Cook et al. 2005). Other BCS methods include fur condition, femur fat assessment, parasite counts, skin fold measurements, haematocrit index, the insulin-like growth factor, and mandibular marrow fat percentage (Stevenson & Wood 2006; Ezenwa et al. 2009: Reamer et al. 2020).

Whilst there are limited BCS methods for live animals, this is a fast-developing area of science. As described above, invasive and fatal methods of determining BCS have previously been used in many zoological studies. However, when assessing threatened or endangered animals, the risk of losing valuable individuals is too high. Initially introduced for livestock such as cattle (*Bos taurus*), non-invasive BCS methods have been developed and refined for other wild ungulate species such as red deer, elk, and reindeer (*Rangifer tarandus*) (Cook et al. 2010). None of these, however, are African species, so it is imperative that more studies such as these ones are conducted (Gerhart et al. 1996; Audige et al. 1998; Cook et al. 2010). In many of these species found in colder climates – notably the deer – subcutaneous fat reserves of rump are used before marrow fat when starving, and therefore decreases of such fat reserves are the first indication of a decrease in condition (Wemmer et al. 2006). It is, therefore, necessary to find out whether the same focal areas should be studied to identify a declination of body condition in animals from more tropical climates.

1.2.3. Grades of body condition scoring

At least two methods of body condition scoring have grades, including the two used in this study: **visual body condition** and **BCS by palpation**. When doing a review, Serrano et al. (2008a) found that a mere 6% of papers assessed body condition through visual means, with more common assessments being animal weight and various fat depths due to many studies using deceased animals. This has left much space for further investigation into visual BCS. Some visual methods used to assess an animal's health and condition on live specimens include visual BCS, **ultrasonography** or dual-energy X-ray absorptiometry, however visual BCS is the quicker and easier method, which is also less stressful than ultrasonography to the animal as it is entirely non-invasive (Mattiello et al. 2009; Reamer et al. 2020). Visual BCS can be done in real-time by observing the animal or retroactively using photographs or videos (Stevenson & Wood 2006). Visual BCS is a reliable method, with a proven positive correlation between visual BCS and **packed cell volume** which is determining an individual's status of health though red blood cell count– another index that can be used as it is not fatal, albeit invasive so has the potential to be used only on animals habituated to handling (Gallivan et al. 1995).

Visual BCS is a simple way to assess subcutaneous fat and was first published by Robinson (1960) to assess body condition (Mattiello et al. 2009). This guideline for visual BCS used a scoring system of 1-10 and focused on the contours and vigour of the animal's body. A score of 10 indicated the best condition ("a prime, fat animal"), and a score of 1 the worst (Robinson 1960). In this system, a score of 7 was deemed the average score, whereby the animal is neither fat nor thin (Robinson 1960). Reamer et al.'s 2020 study of chimpanzees, however, also used a 10-point scoring system, but more expectantly, a score of five indicated a “normal” (healthy) condition (Reamer et al. 2020).

The scoring system with the narrowest range used for visual BCS is a 3-point system used in impala (*Aepyceros melampus*) (Gallivan et al. 1995), with a 4-point system being proven a reliable method when assessing reindeer (Stevenson & Wood 2006). It is the most common to use a 5-point scoring system, which has been employed for cheetahs (*Acinonyx jubatus*), greater one-horned rhinoceros (*Rhinoceros unicornis*), rhesus macaques (*Macaca mulatta*), and African elephants (*Loxodonta africana*) (Dierenfeld et al. 2005; Morfeld 2014; Heidegger et al. 2016). Scientists from the United States and Ireland have been found to favour such a 5-point scoring system, whereas those from Australia have endorsed an 8-point system (Roche et al. 2004). Akin to this, zoo-housed giraffes are assessed using an 8-point scoring system (Clavadetscher et al. 2021). Body condition of Asian elephants (*Elephas maximus*) is measured with the highest range of points, with an 11-point system with an average score of 7.3 (Wemmer et al. 2006; Morfeld 2014). A unique approach used to measure the body condition of giraffe uses a different scale for each body part, which means that some scores were out of four and some out of seven (Clavadetscher et al. 2021). One pitfall to this method is that – due to the differing scales – an average score for the entire body is less reliably calculated. However, not all studies use a numbered grading system – one study for red deer implemented a scoring system with only three categories: poor, medium, and good (Mattiello et al. 2009). On buffalo, a different form of visual BCS has also been used, which was purely based on coat quality, assessing thickness and shine on a five-point scoring system (Ezenwa et al. 2009).

Nowadays, a five-point system of visual BCS is the most common, with a score of three tending to denote healthy or ideal. However, in the greater one-horned rhino and red deer, for example, the ‘ideal’ body condition can range from 3 to 3.5 (Morfeld 2014; Heidegger et al. 2016; Clavadetscher et al. 2021). This shows that although the use of five-point scales is prevalent, they cannot all be interpreted in the same way. Therefore, each individual study must be considered within the terms of its specific scaling system in order to accurately assess the animals on which it focuses.

Whilst a ‘healthy’ score can be considered individually for each focus area, most often a mean of all the scores is used to give a total for the whole animal. This study uses both systems and will evaluate whether providing a total score for the entire animal effectively communicates accurate results of condition.

Different methods to this, however, are often used depending on the animal, including those within the same family. For the Baird's tapir (*Baird's tapir*), for example, six areas of the body are given a score between one and five, which are then totalled to give a maximum score of 30 (Perez-Flores et al. 2016). Whilst similar scales would yield an 'ideal' score of 15, the creators of this system propose that a score of 22-27 points represents a 'good' body condition (Perez-Flores et al. 2016). When using a five-point BCS scale, it has been found that each full unit increase equates to a 10% increase in body fat (Summers et al. 2012). Occasionally, however, the five-point scale has been used with the ability to measure body condition in each focus area in half increments, which helps to get a more precise score (Audige et al. 1998). Due to its increased accuracy, I have used such a scale in this study to enable the participants to more reliably evaluate each eland's body condition.

Palpation provides another common, non-invasive BCS method that uses a similar scale to visual BCS. Palpation BCS is a method whereby the assessor measures body condition by hand by pressing on different areas of the animal to feel how much fat has accumulated in that area. If the bone can be felt this tends to indicate poor body condition. The most common scale used for palpation BCS is a five-point scale (Audige et al. 1998; Ezenwa et al. 2009). Unlike in the visual BCS scale where a prime animal is often indicated by a score of three, in one palpation study using a five-point system, a score of five indicates very good – or perhaps optimal – condition, rather than obese (Landete-Castillejos et al. 2009).

Palpation BCS can be used extremely effectively alongside measuring **rump fat thickness**. However, authors have expressed the importance of sufficient training to provide consistent results – which has also been found to be the case with visual BCS (Cook et al. 2005). Both palpation and rump fat thickness methods have been determined to be reliable in all seasons on all ages of animals – in certain species with thicker coats; this cannot be said for visual BCS because hair thickness can prevent true assessment of body contours (Gerhart et al. 1996; Cook et al. 2005). Palpation BCS is therefore exclusively used instead of visual BCS for species such as reindeer and Iberian red deer, measured on either a four- or five-point scale (Gerhart et al. 1996; Roche et al. 2004; Landete-Castillejos et al. 2009).

1.2.4. Focus areas

When conducting visual or palpation BCS, it is uncommon for the person completing the assessment to give one overall score. There are often multiple focus areas that are individually assigned a score and, if desired, are usually averaged to give the animal's total BCS. This is not the case for all animals, however – studies involving the impala assess only the muscle around the lumbar vertebrae, making such an investigation have a total of one focus area. Aside from this, the smallest number of focus areas used on a species is three, which is the case for red deer in New Zealand, whereby the tuber coaxae, sacrum, and rump area are assessed (Audige et al. 1998; Lane et al. 2014). In European red deer, researchers also only study three focus areas: the backbone (spine), ilium (pelvis), and gluteal muscles (Mattiello et al. 2009). All these BCS systems focus on the rear of the animal, so it is possible that they do not give a complete representation of the animal's condition (Mattiello et al. 2009). In many other studie's of red deer BCS, there are also three focus areas: ribs, withers, and rump. By including a rib score, however, a more holistic representation of the animal's overall condition is obtained (Cook et al. 2005).

Increasing from this, measurements of buffalos' body conditions have used four focus areas: ribs, spine, hips, and tail base (Ezenwa et al. 2009). A comparative study of visual and palpation BCS in dairy cattle has also used the chest, back (spine), ribs, tuber sacral (hip bones), tuber ischii (pin bones), tailhead and thighs as focus areas (Roche et al. 2004). Additionally, African elephants are assessed similarly, measuring ribs, pelvic bone, vertebral ridge of backbone, and lumbar depression. Asian elephants, however, have six focus areas: head, scapula, thoracic region, flank, lumbar vertebrae, and pelvic bone, despite being in the same family. Between the two species, only two focus areas are the same (Wemmer et al. 2006; Morfeld et al. 2014). Like Asian elephants, BCS of Baird's tapirs also follows a system with six focus areas: head, neck, shoulders, spine, ribs, and pelvic bone (Perez-Flores et al. 2016). The largest number of focus areas found in published literature used on one animal's assessment was on the greater one-horned rhino with seven focus areas: neck, shoulder, ribs, spine, rump, abdomen, and tail base (Heidegger et al. 2016).

Aside from these two examples, the most common number of focus areas used in BCS is five, alongside the pre-described systems that use four focus areas. Animals with five areas assessed include, for example, rhesus macaques, whose five focus areas are hip, spine, pelvis, thorax, and abdomen (Clingerman & Summers 2012), as well as cheetahs (Dierenfeld et al. 2005).

As is most common in current zoological research, this study uses five focus areas for its assessment of visual BCS. Whilst at the time of writing there are no publications focusing on eland BCS, this study uses the scoring chart created by Disney's Animal Kingdom as a foundation, adapted to allow for greater precision. To assess palpation BCS, however, only four focus areas were used. This follows a method previously used on red deer (Audige et al. 1998), which was decided upon due to the lack of existing literature on using palpation on antelope species – proven BCS methods on an alternative wild animal kept in captive conditions of similar morphology was therefore chosen to be replicated in this study.

1.2.5. Age and sex bias

Although frequently mentioned, one factor that is not often considered when presenting a final body condition scoring matrix designed for a specific species is bias between animals of different ages. Younger animals generally receive lower body condition scores, as whilst they are growing, they tend to be leaner than adults (Mattiello et al. 2009; Clingerman & Summers 2012). Audige et al. (1998) found that when splitting red deer into two age groups: yearling or adult, there was a significant difference in palpation BCS between the two. Research on impala and greater one-horned rhinoceros further supports this, with higher scores attributed to adults over younger individuals (Gallivan et al. 1995; Heidegger et al. 2016).

An additional factor that can cause bias in results is the sex of the animal, which has been shown to occur in a variety of species regardless of sexual dimorphism. In giraffe, males generally have higher body condition scores in comparison to females (Clavadetscher et al. 2021), a trend also seen in horses (Cameron & Linklater 2007). Within a single sex, further characteristics also contribute to a variance in body condition scores, with more dominant males displaying increased scores and less dominant males showing no differentiation from females (Hohenbrink & Meinecke-Tillmann 2012). Some animals, conversely, appear to have no differentiation in scores between sexes, such as Asian elephants (Wemmer et al. 2006). In other cases, such as greater one-horned rhino, overall body condition scores have no significant variance between sexes, but individual focus areas do (Heidegger et al. 2016), with results showing bias between scores at the neck. So, thus this study will investigate whether any sex bias occurs between male and female eland body condition scores.

2. Aims of the Thesis

Each species found in the wild or kept in captivity is unique in morphology, biology and fat storage preventing there from being a standardised body condition assessment criteria for all animals. Up until now no scoring system has been validated for the species common eland (*Tragelaphus oryx*), so the objective is to finalise a visual body condition scoring method that can be used in zoological and captive collections, as well as in the field.

The aim of this thesis is to validate a visual body condition scoring system to be used on Common eland, by observing inter-rater reliability as well as looking for a relationship between visual BCS and other parameters including palpation BCS, tail base, body weight, average daily gains and age.

Specific objectives for this thesis are:

1. To compare visual body condition scores between different participant raters.
2. To validate the raters' scores by comparing them to palpation body condition and other parameters.
3. To assess whether there is any age and sex bias amongst the visual body condition scores.
4. To provide a visual body condition scoring matrix that zoological/ captive collections and field workers can utilise.
5. To provide a palpation body condition scoring matrix that zoological/ captive collections can utilise.

3. Methods

3.1. Study animals

The eland individuals studied for this thesis belong to the Ceska Zemedelska University (CZU) Common Eland Research Facilities in Lany, Czech Republic. It remains the first and only purpose-built eland farm in Europe, with a maximum capacity of 50 individuals. The herd is split into two groups, with an annual rotation of breeding between the two groups.

The first transfer of elands to the facilities occurred in 2006. However, this study only examines individuals born from 2019 onwards, when all the new-born individuals started to be routinely monitored and sampled on a monthly basis. These elands were deemed sufficiently habituated to enter the squeeze chute system (section E of figure 1) (Musa et al 2021), where monthly examinations – including palpation BCS – took place. The older individuals only pass through sections A-D of the runway system before exiting via an outlet in part D (see figure 1) and thus have not been included in this study.

Each eland at the farm can be identified via a unique number, which consists of the year an animal was born and their unique ID code, such as 19.248 (the oldest eland examined in this study). For visual BCS methods, elands were identified via an ear tag displaying this unique number. The eland could also be identified via a microchip that was scanned as they moved through the runway for weighing and palpation BCS (see figure 1).

As described in the methodology, a total of 56 eland were used in this study between 10 and 1337 days old, with a total of 761 assessments being completed over the 30-month period. A total of 419 of the assessments were completed on females and a further 342 assessments were completed on males. Furthermore, 334 of the assessments were completed on calves, 308 on juveniles and 119 on adults. For the visual BCS assessment, 78 participants observed the elands, with at least 4 participants observing each of the 761 assessments.

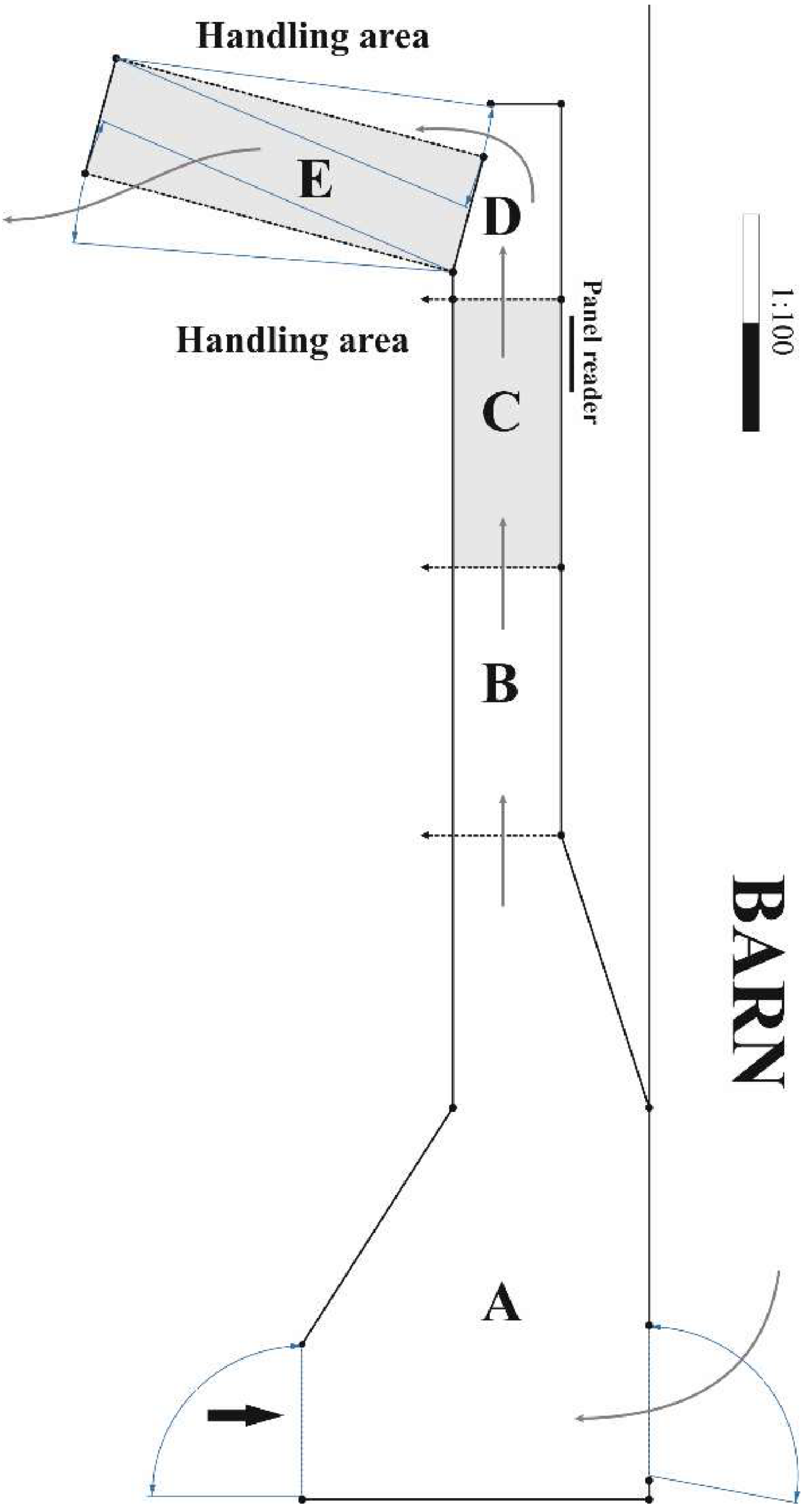


Figure 1: Layout of squeeze chute system at Common Eland Research Facilities.

3.2. Body condition indices

3.2.1. Visual BCS

Materials:

- Video recorder
- Adaptation of Disney's Animal Kingdom (2015) scoring system.

This study used a five-score system with five focus points, with a score of 1 being the lowest (skinniest) and 5 being the highest (fattest). This study focuses on neck/shoulder, withers, loin/back, tailhead/hips, and ribs (figure 2), as advised by Disney's Animal Kingdom 2015. Table 2 displays the protocols used to evaluate the score of each focus point by each assessor, which was adapted from a scoring system created by Disney's Animal Kingdom in 2015.

For the visual BCS data, a video of each eland studied was recorded once a month. Video lengths varied from 20 seconds to two minutes to ensure that all five focus points were clearly visible. The videos also showed different angles of each focus point to reduce bias due to lighting and perspective. The videos were then uploaded to the video database and labelled in the following format: '*year.month.day identification number*', for example: *2019.10.11 19.248*. The videos were then distributed to the selected viewers, either current students or graduates of zoological management-related degrees, via email or an in-person session. Seventy-eight volunteers watched the videos and completed a visual BCS assessment, with a minimum of four volunteers assessing each video. The volunteers were selected using a range of non-random sampling methods; primarily purposeful sampling, as it was desired that all participants had a background in animal studies to provide an educated BCS evaluation. Purposeful sampling also accounted for the participants' capacity, as those with more time to participate in the study were given more videos to watch.

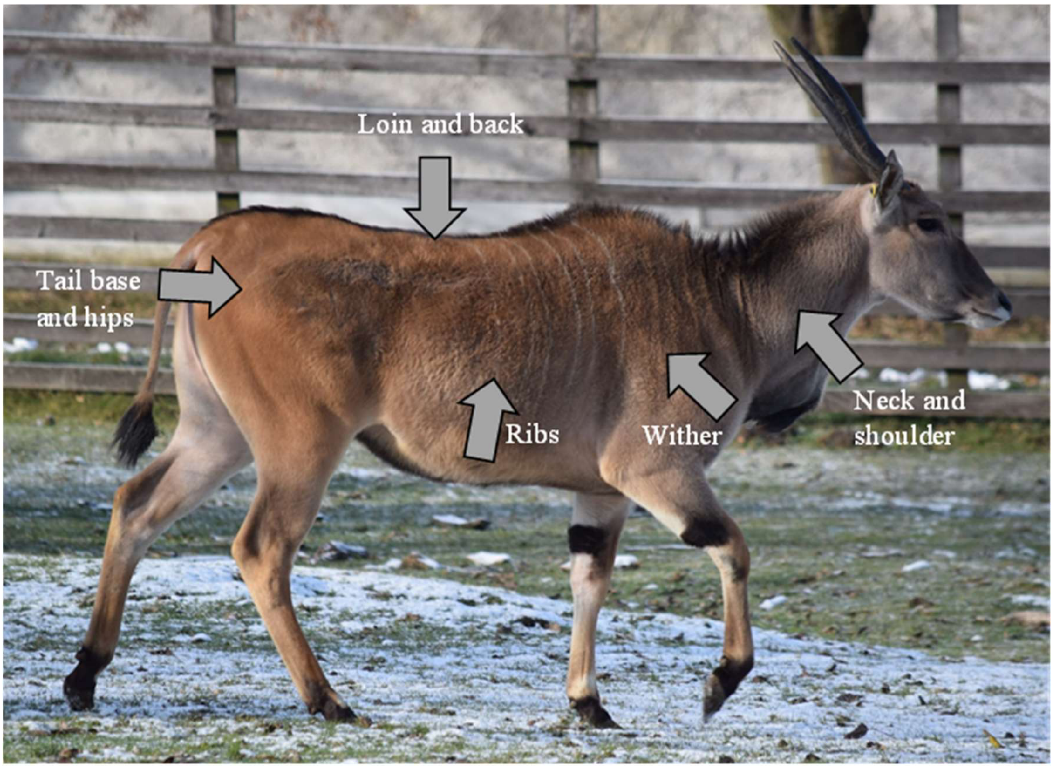


Figure 2: Focus areas used for visual BCS. Arrows indicate location of focus areas used.

Table 2: Guidelines to follow when completing a visual body condition score for Common Eland (*Tragelaphus oryx*) (adapted from a scoring system created by Disney's animal kingdom (2015).

Visual Body condition scoring matrix for common

Score	**1**	**2**	**3**	**4**	**5**
					
Neck and shoulders	Neck very thin and bones very visible	Neck is thin	Neck has some thickness and brachiocephalicus muscle is prominent. No visible bone protrusions.	Neck is thick and shoulders are beginning to look rounded	Neck is very thick; muscles are not visible due to fat. Shoulders quite rounded.
Withers	Bones and scapula very visible, top of withers is very pointy	Bones still visible, scapula not as prominent. Withers a bit pointy but some muscle shows	Withers are rounded over spinous structure so no visibility of bone	Fat visibly situated on withers	Large fat deposits n withers
Loin and back	Spine very visible/prominent and raised above muscles. Visible processes	Spine still visible but not as prominent and processes may no longer be as visible	Back is flat and in line with spine	Back muscle/ fat starting to rise above spine	Back muscle/ fat is raised above spine
Tailhead and hips	Iliac crest very prominent, area generally skinny	Iliac crests still slightly visible but more muscle in the rump area	Bones no longer visible but no evidence of fat deposits	Rump area and hips are beginning to look rounded; muscle is very defined	Rump area very rounded
Ribs	Very thin, ribs and latissimus dorsi are visible	Base of ribs visible and ribs may still be a bit visible	Ribs are not visible, but the area is quite flat	Ribs not visible and started to look rounded due to slight fat deposits	Sides starting to look very rounded.

3.2.2. Palpation BCS

Materials:

- Squeeze chute
- Adaptation of Audige et al. (1998) scoring system for red deer (*Cervus elaphus*).

The studied eland underwent a monthly handling and data collection process at the farm. All handling and data collection was performed by a well-trained member of the CZU Animal Physiology and Behaviour research team. Animals were moved through the runway shown in figure 1, stage E of a squeeze chute where a physical examination took place on each of four focus points, performed by pressing to feel the fat levels. Most frequently, the palpation examination was undertaken after the other procedures – including faecal and blood sampling used for parasitology analysis and biometrics – as this was the quickest and least stressful procedure for the elands. For all procedures in the squeeze chute, a blindfold was placed over the eland's face to reduce stress levels.

The focus points (figure 3) were pin bones, sacrum, *Longissimus thoracis et lumborum* (*longissimus dorsi*) muscle, and the rump region. Each palpation focus point was given an individual score between 1 and 5, with a lower score indicating a poorer condition. Using a scoring system on a scale of five allowed for accurate comparison and analysis against the visual body condition scores as it was in the same scale and range. Table 3 shows the criteria followed at each focus point when performing the palpation BCS. This is adapted from the 1998 scoring system for red deer by Audige et al., as deer are another close comparison example of a wild animal habituated to human presence, unlike domestic cattle species.

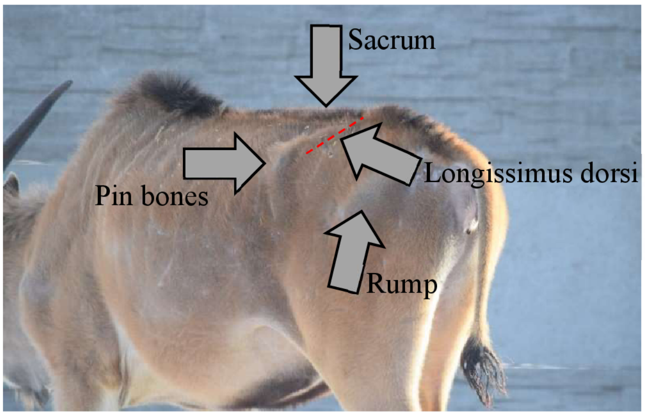
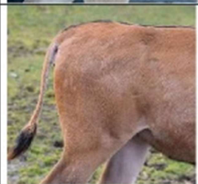
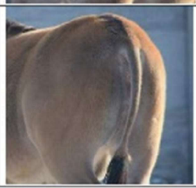
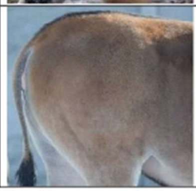


Figure 3: Focus areas used for visual BCS. Arrows indicate location of manual palpation.

Table 3: Guidelines to follow when completing palpation body condition scores for Common Eland (*Tragelaphus oryx*), adapted from of Audige et al. (1998) BSC for red deer scoring system.

Palpation body condition scoring matrix for common eland

			Iliac crest (pin bones/wings of pelvis)	**Lumbar/sacral vertebrae**	**Longissimus dorsi**	**Rump**
Score 1			Pins bones are very easy to touch as they feel sharp, no muscle around them.	Spinous processes very easily felt and sharp, raised above any other tissue.	The longissimus dorsi muscle feels concave.	Rump area also feels concaved.
Score 2			Pin bones still easily touched without much pressure, some muscle present around them.	Spinous processes still easily touched, not as sharp.	The longissimus dorsi muscle still slightly concave, to almost flat.	Rump is slightly concave, almost flat.
Score 3			Pin bones can be touched but are surrounded by muscle/fat.	Spinous processes can be touched but muscle is level with processes.	Longissimus dorsi is flat.	Rump is flat, to almost curved.
Score 4			Pin bones are hard to distinguish as they are under a layer of surrounding muscle/fat.	Spinous processes can be felt but muscle/fat rises above them slightly.	Longissimus dorsi is slightly raised/rounded.	rump area is slightly raised/rounded.
Score 5			Pin bones under a deep layer of muscle and fat, they cannot be felt.	Spinous processes are under a layer of muscle and fat, which rises significantly above processes at the side.	Longissimus dorsi is very rounded	rump is very rounded.

3.2.3. Weighing of eland

During the monthly handling, the eland passed through stage C of the runway (see Figure 1), where a weighing scale was installed on the floor, recording the weight in kilograms (±100 g) as they pass through. Weight measurements of the studied eland ranged from 30.5 to 434 kg.

3.3. Data collection

For both visual and palpation BCS methods, data were collected monthly for 30 months between April 2019 and October 2022. A total of 56 individual elands were included in the study. Data was then collected from all participants and collated in Microsoft Excel.

3.4. Data analysis

All data was compiled in Microsoft Excel and analysed using IBM SPSS statistics for Windows, Version 28.0. (Armonk, NY: IBM Corp). The level of significance for all statistical tests was set at 0.05.

3.4.1. Inter-rater reliability

Inter-rater reliability tests were used to analyse whether multiple individual observers have a statistically significant extent of agreement between their scores. An intra-class correlation with the model set as two-way mixed and the type as absolute agreement was used to analyse the inter-rater reliability of visual body condition scores. For the test we had a total sample size of 763. The test was then run seven times, with the first of seven analyses assessing all raters and all focus points. Next, the same test model was run for each focus point and the average score. The intraclass correlation coefficient has three levels of significance: 0.7 or above denotes an acceptable degree of agreement, 0.8 or above a good degree of agreement, and 0.9 or above an excellent degree of agreement.

3.4.2. Visual BCS and Palpation BCS correlations

Multiple correlations were run to assess the relationship between all the variables. Starting with a test for normality, each variable was run separately in a Kolmogorov-Smirnov test, chosen to account for the large sample size. The results from the test for normality showed that the data were not normally distributed, thus, could be classified as a non-parametric data set. Therefore, a Spearman's rank correlation coefficient was run to assess the relationship between the individual palpation body condition scores and the relationship between the palpation body condition scores, with the added variables of the tail base, body weight, average daily gains, and age in days. A Spearman's rank correlation coefficient was then used again to determine the relationship between the individual visual body condition scores and the relationship between the visual body condition scores and the aforementioned added variables. Lastly, Spearman's rank correlation coefficient was used to assess the relationship between all palpation and visual body condition scores.

3.4.3. Age and sex bias

All eland used in this study were grouped at each assessment into three age categories: calf (1), juvenile (2) and adult (3). The calf category was for individuals of both sexes up to the age of one year – the period between birth and weaning. Juveniles are described as young animals after weaning, so in males this is up to three years of age and up to two years in females. It is older in males because of stages of physical development, hormonal and musculature changes, and functional sperm development occurring later in males. Accordingly, eland in the adult category included males older than three years and females older than two years. The presence of age bias within the visual BCS was analysed using ANOVA. When significant differences were derived from the ANOVA, a Tukey's HSD post hoc test was completed to ascertain between which groups there was variance. Following this, an ANCOVA was used to analyse age bias, adding a covariate and controlling for body weight.

When measuring for sex bias among the body condition scores, two defined categories were used: male and female. Due to there being only two independent groups a Mann Whitney U test was performed to assess if there was a difference in mean score between males and females. The test was run six times to independently test the visual body condition scores for each focus area and the average visual body condition score. Then for focus areas with a statistically significant difference the mean rank output was used to evaluate where the variance in score was located.

4. Results

4.1. Inter-rater reliability

The first analysis that took place was inter-rater reliability. Table 4 displays the intraclass coefficient results, which tell us that overall, there is a degree of agreement between the raters with an average measure intraclass correlation coefficient of 0.961 and a 95% confidence interval of 0.955 to 0.966 ($F_{445,10235} = 26.335$, $p < 0.001$).

Table 4: Output of intraclass correlation coefficient

Intraclass Correlation Coefficient							
	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Average Measures	0.961[c]	0.955	0.966	26.335	445	10235	0.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

After having determined that there was a degree of agreement overall, an intraclass coefficient was performed on each individual focus point, along with the final average, which allowed us to see which focus points were the most reliable. Table 5 shows the intraclass correlation coefficient average measures for each focus point and indicates that all focus points display a degree of reliability (ICC = 0.710 - 0.763) and when running all the focus points together in the ICC there was a degree of reliability (ICC = 0.802).

Table 5: Intraclass correlation values for each focus area.

Focus point	Intraclass correlation coefficient	95% confidence interval – lower bound	95% confidence interval– upper bound	Value	Df1	Df2	Significance
Neck and shoulder	0.758	0.719	0.792	4.151	463	1389	<0.001
Withers	0.762	0.725	0.796	4.244	463	1389	<0.001
Loin and back	0.710	0.664	0.750	3.462	467	1401	<0.001
Tailhead and hips	0.763	0.724	0.796	4.300	461	1383	<0.001
Ribs	0.736	0.693	0.774	3.865	461	1383	<0.001
Average	0.802	0.770	0.830	5.095	446	1338	<0.001

4.2. Palpation correlations

All the palpation focus areas were significantly positively correlated with one another (see table 6), and also had a significant positive correlation with other variables measured within the study. Tail base, body weight, average daily gains, and age of eland in days all showed a *p*-value of <0.001 when correlated with all four palpation focus areas and the average palpation body condition score (appendix 1).

Table 6: Spearman's rank correlation between palpation BCS focus areas.

	Palpation Sacrum	Palpation longissimus dorsi	Palpation rump	Palpation Average
Palpation Pin bones	0.861^{***}	0.846^{***}	0.836^{***}	0.933^{***}
Palpation Sacrum		0.853^{***}	0.860^{***}	0.941^{***}
Palpation longissimus dorsi			0.860^{***}	0.935^{***}
Palpation rump				0.935^{***}

*** indicates significance at <0.001 level.

4.3. Visual correlations

Each visual BCS focus point and average visual body condition score had a significant positive correlation between them (see table 7). Additionally, all the visual body condition scores had a significant positive correlation with tail base, body weight, average daily gains and age in days ($p < 0.001$) (appendix 2).

Table 7: Spearman's rank correlation between visual BCS for all focus areas.

	Visual withers	Visual loin and back	Visual tailhead and hips	Visual ribs	Visual average
Visual neck and shoulders	0.851***	0.796***	0.827***	0.798***	0.912***
Visual withers		0.857***	0.857***	0.868***	0.945***
Visual loin and back			0.871***	0.841***	0.933***
Visual tailhead and hips				0.825***	0.937***
Visual ribs					0.919***

***** indicates significance at <0.001 level**

4.4. Palpation vs visual correlations

A statistical analysis of both the visual and palpation body condition scores was conducted to determine whether there was a correlation between the different forms of BCS. The alternative hypothesis is that there is a correlation between the visual and palpation body condition scores. Each visual and palpation focus point had a statistically significant positive correlation with its counterpart (appendix 3), therefore rejecting the null hypothesis.

4.5. Age bias

This study analysed three age categories, with the average visual body condition score analysed to determine whether there was any bias between age categories. There was a statistically significant difference between the mean score of the age categories (F(2,758)=37.000, p = 0.001, η^2 = 0.089) (figure 4). With a partial eta squared of 0.089 this tells us that 8.9% of the variability can be accounted for by age category. Due to the statistical level of significance, post hoc testing was performed and, as can be seen in table 8, the Tukey's HSD concludes that there is a significant difference in the mean of all three age categories. The mean results in Category 3 (adult) have a small variance and higher average visual body condition score mean of 3.2, than the categories 1 and 2, which encompass the younger Elands. The BCS measurements of Category 2 (juvenile) exhibited the largest variance (figure 5).

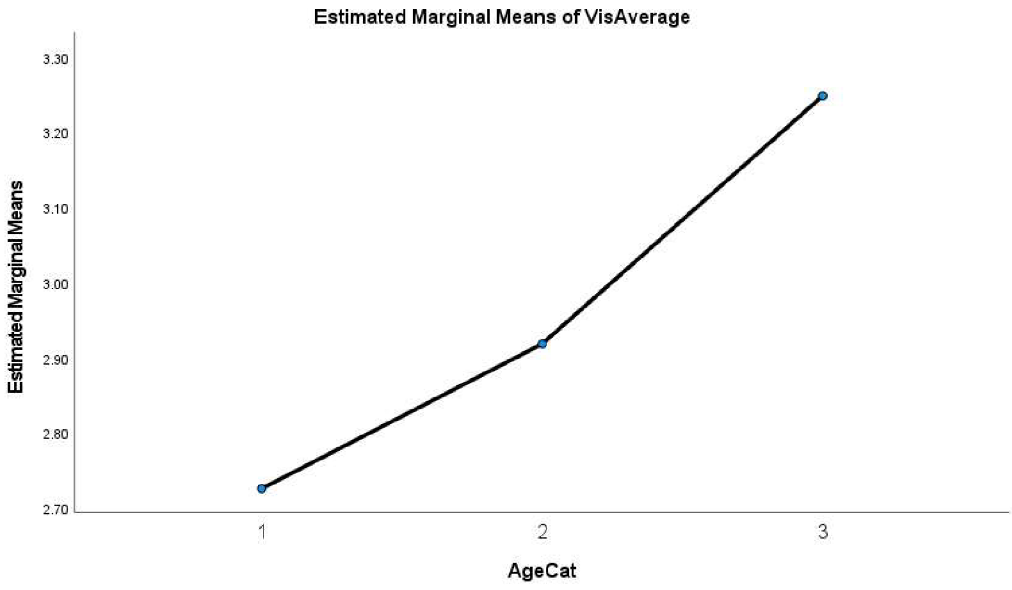


Figure 4: Line graph showing difference in means of average visual body condition score.

Table 8: Tukey's HSD post hoc testing for age bias ANCOVA

Multiple comparisons						
Dependent variable: visual BCS average						
Tukey HSD						
Age category (a)	Age category (b)	Mean difference (a-b)	Std. error	Significance	95% confidence intervals	
					Lower bound	Upper bound
1	2	-0.1924	0.04545	<0.001	-0.2992	-0.0857
	3	-0.5223	0.06142	<0.001	-0.6665	-0.3781
2	1	0.1924	0.04545	<0.001	0.0857	0.2992
	3	-0.3299	0.06210	<0.001	-0.4757	-0.1840
3	1	0.5223	0.06142	<0.001	0.3781	0.6665
	2	0.3299	0.06210	<0.001	0.1840	0.4757
Based on observed means.						

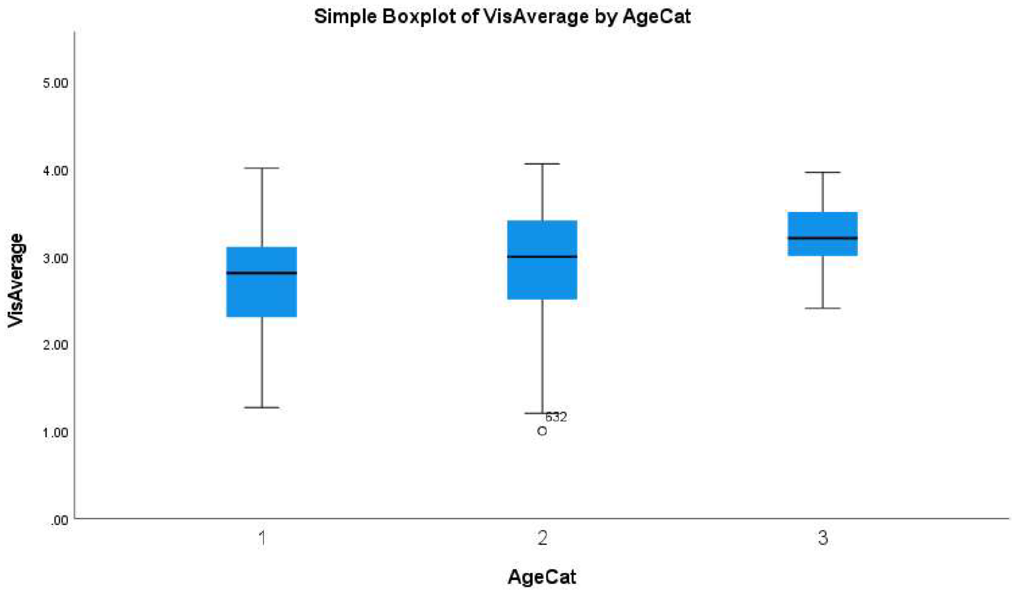


Figure 5: Boxplots showing the variance and mean score for each category for average visual body condition score.

The above results indicated a significant difference between each age category. To allow the test to control for body weight, an ANCOVA was then performed, with the results showing that there was still a statistically significant difference between average visual body condition scores in different age categories, ($F_{2,730} = 15.211$, $p = <0.001$, $\eta^2 = 0.089$). Figure 6 displays that the visual body condition scores of the two younger age categories – calf and juvenile – have a steady increase as body weight increases, however although the adult age category shows a statistically significant difference in average visual BCS when controlling for body weight, the average visual body condition score was not influenced by this.

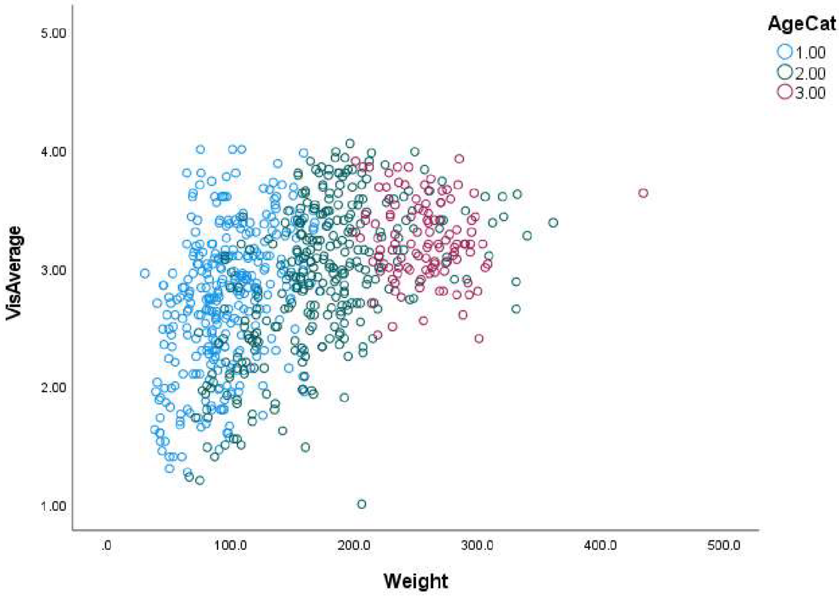


Figure 6: Scatterplot showing comparisons of average visual body condition score and body weight for the three different age categories: calf (1), juvenile (2) and adult (3).

4.6. Sex bias

A Mann Whitney U test was performed to determine whether average visual body condition score differed between the two sexes, and indicated that there was no significant contrast between them ($U = 69670$, $p = 0.512$). Following this, a Mann Whitney U test was carried out on each individual visual body condition score focus area (neck/shoulder, withers, loin/back, tailhead/hips, ribs). Only the neck showed a statistically significant result ($U = 62761$, $p = 0.003$), with the mean rank indicating that males had higher average neck visual body condition scores than females (table 9). All other focus areas had no sex bias (table 9), from which we can discern that there is minimal differentiation between the two sexes when it comes to a visual BCS method.

Table 9: Mann-Whitney U test output for sex bias in all visual BCS focus areas.

	Mann-Whitney U test	Asymp Significance (2-tailed)	Mean rank males (0)	Mean rank females (1)
Visual neck/ shoulders	62751	0.003	407.02	359.76
Visual withers	70793	0.776	383.50	378.96
Visual loin/ back	69612	0.499	375.04	385.86
Visual tailhead/ hips	79828	0.785	378.60	382.96
Visual ribs	69842	0.549	378.60	382.96
Visual average	69670	0.512	386.79	376.28

5. Discussion

Using captive individuals, this study has provided a visual BCS system for eland that has been validated and is ready for application. The final visual BCS system includes all five focus areas tested: neck, withers, loin/back, hips and ribs, and calculating an average score, which was determined to be a good overview of all focus areas. The system was validated by successful inter-rater reliability and correlating visual body condition scores with other parameters. The results showed there is no sex bias, and therefore the provided scoring matrix is suitable for application on both female and male eland. There are, however, some limitations of the study, with the results showing age bias within the visual body condition scores.

5.1. Significance of BCS

Establishing an animal's body condition is extremely important as it can indicate of many factors, such as appropriate diet and the presence of disease. Weight problems such as obesity or being emaciated can lead to the animal being at higher risk for infection (Reamer et al. 2020). In zoos or captivity, this is notably more common than in the wild (Morfeld et al. 2014); thus, having a validated system for individual species is essential. Over the years, the techniques for BCS have evolved, with the basic principle to develop a method that can easily be learnt and, therefore, easily applied (Kistner et al. 1980).

5.2. Inter-rater reliability

Audige et al. (1998) trialled assessing inter-rater reliability, but only used two raters, leading to variability in the results. The authors propose that this variability could have been removed if they had implemented training for the assessors. Therefore, for this study, each participant was trained and given a reference sheet for this study prior to completing their assessment. Furthermore, more raters were used to improve the integrity of the inter-rater reliability assessment. Our study used four raters for each scoring point – deemed a suitable number of raters as this mirrors a study by Clingerman and Summers' (2012), which validated visual BCS inter-rater reliability.

When testing the inter-rater reliability, we initially analysed all focus areas and the average, for which an intraclass correlation coefficient of 0.961 was produced. This is an excellent degree of reliability of scores as the intraclass correlation coefficient has three levels of significance: 0.7 - 0.799 is an acceptable degree of agreement, 0.8 - 0.899 is a good and 0.9 – 1.0 is excellent. Because of the high overall intraclass correlation coefficient, I decided to analyse each focus area to determine which focus areas had the highest reliability and to establish whether any individual focus area had an intraclass correlation coefficient lower than 0.7.

Running the analysis on the average score of the five focus areas, the intraclass correlation coefficient showed a good degree of agreement, meaning that we have a reliable overview of the whole animal's body condition. All five focus areas showed an acceptable significant level of agreement between raters. Neck/shoulder, withers and tailhead/ hips had the highest degree of agreement when inter-rater reliability was assessed individually. Loin/back and ribs had lower intraclass correlation coefficients, but their value was still significant, although their lower bound 95% confidence intervals were below 0.7. Clavadetscher et al. (2021) deduced that in giraffes, specifically, the visual BCS for hips was significantly correlated with BMI. However visual BCS for the shoulder was slightly less effective because of the visibility and thickness of muscle and skin. Therefore, in certain species, different focus areas have different levels of reliability. We can assume that these focus areas are less reliable for visual BCS. However they remain in the scoring matrix because when combined with the other focus areas, the average score produces a reasonable agreement.

This study only validated the inter-rater reliability, so future studies could further measure consistency by assessing intra-rater reliability for common eland visual BCS. Some studies on different species measured intra-rater reliability by having the same observer score the same animals twice with an interval of two weeks (Morfeld et al. 2014; Clavadetscher et al. 2021), which could be done using this study's visual BCS method.

5.3. Correlations between both BCS methods and other variables

When comparing visual and palpation BCS, Roche et al. (2004) found that whilst palpation BCS is more precise, visual still gives a good gauge of assessment, confirming the validity of visual BCS. Additionally, palpation BCS is more successful at identifying minor changes in body condition than visual BCS (Audige et al. 1998). This is why this study used palpation body condition scores to validate visual body condition scores. There was a significantly strong correlation between all palpation and visual body condition scores in this study, with the highest correlation being between the average visual body condition score and the average palpation body condition score. This is likely because both scores give a representation of the whole animal. Two other scores with higher correlation are visual tailhead/hips and palpation pin bones; we can infer that this is because the two focus areas are on the same body area. The lowest, but still strong, correlation was between visual ribs and palpation pine bones and palpation sacrum, presumably because they two very different parts of the body. One concern reported by Gerhart et al. (1996) was that when completing visual BCS instead of palpation BCS, it is hard to get an accurate assessment around the spine due to hair thickness. Still, this study'd visual loin body condition score had a strong positive correlation with the palpation body condition score the other focus areas assessed in the visual BCS.

When validating a visual body condition scoring system for giraffes, it was determined that the rib BCS score was ineffective due to skin folds around the rib area (Clavadetscher et al. 2021). We predicted this could be a potential restriction in the eland as they have white strip markings following the shape of the ribs. Still, the results showed that not only did the intraclass correlation coefficient have a significant degree of agreement between the raters' scores, but the visual rib body condition scores were also positively correlated with all other visual and palpation body condition scores, as well as with other biometric parameters (tail base, body weight, average daily gains and age).

Ezenwa et al. (2009) also found that, in African buffalo, visual and palpation BCS had a significantly strong correlation when compared to intrusive methods, including KFI and haematocrit, showing that these non-invasive methods can be used reliably. Visual BCS also significantly positively correlated with BMI in greater one-horned rhinoceros and body weight in chimpanzees (Heidegger et al. 2016; Reamer et al. 2020). However, for the focus species of this study, body weight and BMI alone are not considered reliable assessments of an animal's health, as this does not cater for animal morphology such as horn and dewlap size and weight (Reamer et al. 2020). Furthermore, Reamer et al. (2020) reported visual BCS as more reliable because some animals with the same weight have different body condition scores, showing that visual BCS is more precise at assessing fat accumulation. It also has more implementation abilities due to being completely non-invasive, so it can also be applied to animals in the wild. Visual BCS and other variables in this study also had a strong correlation, with the strongest being between all visual body condition scores and body weight (strongest between visual neck and body weight). Although this study showed a positive correlation between body weight and all the body condition scores, this alone cannot be used to assess body condition as it is biased to the animal's height (Roche et al. 2004). There was also a similarly high correlation between all visual body condition scores and tail base – similarly it has been shown that fat build up in North American deer species (*Odocoileus hemionus heminonus*) first appears in the rump showing at the tail base (Kistner et al. 1980). Although Kinster et al. (1980) state that subtropical and tropical ruminants have different fat reserves than ruminants found in colder areas, the data presented in this study shows that the common eland, a subtropical species, also has the tail base as a fat reserve. The two other variables tested: body weight and average daily gains, still had positive correlation. However, the weakest was between the visual body condition scores, especially visual ribs and average daily gains. This is because elands have fat storage in their tail base, so average daily gains are less likely to show appearance on the rib area.

Other biometric variables that were not included in this study included horn length, coat condition and circumference of the pelvis, neck, and chest. In some species such as red deer (*Cervus elaphus*), antler length was used to indicate body condition. However, this is not reliable on its own due to the influence of genetics and antlers being an honest signal (Mattiello et al. 2009), so this study did not consider using horn length as a variable to test. Likewise, it was decided that participants would not assess the coat condition visual score because when tested, the visual coat condition in African buffalo did not correlate with other body condition indices (Ezenwa et al. 2009). Finally, one method that could have been used, but was not investigated in this study, is pelvic circumference, a method proven to predict body fat in mice (*Mus musculus*) (Labocha et al. 2014). Although this would have been possible to have been assessed on the eland in this study as they are habituated to handling, this would not contribute to a method applicable for wider usage, so it was chosen not to be included here. Additionally, neck and chest circumference has been reported to correlate to body condition score, but this may not be suitable for common eland as they have a dewlap (Perez-Flores et al. 2016).

Some researchers believe visual scoring systems can produce subjective scores (Mattiello et al. 2009). However, these results show that a standardised training session or instruction sheet provides inter-rater reliability within the visual scoring system. Therefore, visual assessment of live animals by experienced or trained assessors is a viable BCS system (Kistner et al. 1980) and is a far more practical method for animals not habituated to routine handling. Mattiello et al. (2009) provided illustrations to their study participants when completing the visual body condition scoring, also included in this study as a proven standardisation method. Originally using the illustrations provided by Disney's Animal Kingdom (2005), these were adapted for this study to create a more detailed validated assessment criterion.

Other studies used photographs for visual body condition scoring assessment. However, it was decided in this study to use videos to ensure that assessors had an overview of the whole animal (Stevenson et al. 2006; Wemmer et al. 2006; Morfeld et al. 2014; Clavadetscher et al. 2021). In a single photograph, an animal will only sometimes be standing facing the right direction or maybe standing in lighting that would cause shadows affecting the score, which would not necessarily lead to accurate results. An additional benefit of using videos is the ability for the viewer to see multiple angles of the individuals, allowing all focus areas to be easily and clearly seen. According to Heidegger et al. (2016), in three different species of rhinoceros, it was important to have a view of the rhinoceros with its head up and head down to ascertain a correct body condition score successfully. This method requires multiple photos for one animal, thus validating the effectiveness of completing visual BCS using videos. However, one limitation of the videos was that sometimes the video would only capture the view of the neck from the front and sometimes only from the side. Therefore, the visual neck BCS was sometimes performed based on neck width and neck length. Despite this, the neck score still showed inter-rater reliability, meaning it can still be included within the body condition scoring matrix for eland.

5.4. Age and sex bias

Due to the subjectivity of visual BCS, it is thought that the animal's body size affects the scores due to bias (Mattiello et al. 2009). It is seen that younger animals have a higher percentage of lower scores due to being particularly lean in periods of growth, and adult males have a very high percentage of high scores that could be attributed to bias overestimation due to their body size (Mattiello et al. 2009; Clingerman & Summers 2012). This is supported by the fact that body condition scores in impala were significantly higher in adults than young (Gallivan et al. 1995). On the contrary, a different study found that in the giraffe, juveniles had higher BCS (Clavadetscher et al. 2021), which could be due to factors such as overcompensation by raters or no development of skin folds due to age. Additionally, it was found that visual BCS methods were most effective in greater one-horned rhinoceros above the age of four (Heidegger et al. 2016). When testing for age bias, the results of this study support most results that other authors found. This study showed a difference in average visual BCS mean between the three age categories used, with the biggest difference being in adults compared to both juveniles and calves. This is likely because both juveniles and calves are still growing, accounting for the larger score variability.

Although the matrix provided has been validated with inter-rater reliability for all age categories, it indicates that an adult eland in ideal condition should score between three and four. This follows guidelines presented for other animals, such as greater one-horned rhinos and red deer (Morfeld 2014; Heidegger et al. 2016). The mean average score for adult eland in this study is 3.2, a score that has been validated by inter-rater reliability. Younger animals, however, received far fewer scores of three and four, which implies that their body condition is less than ideal based on the parameters of this study. Therefore, going forward, it would be ideal to create a scoring system based on young animals, with an emphasis on determining the prime score for a calf or juvenile.

In addition to age bias within species, discrimination has been found between scores of different sexes. Clavadetscher et al. (2021) found that males had higher scores than females on average, probably because females had to expend more energy due to reproduction costs. However, this was only found in wild individuals, not zoo-housed animals. The results of this study also show that the average visual BCS score is not affected by the sex of the animal, which could be due to the amount of food available in captivity throughout different seasons. Wemmer et al. (2006) also reported no differences in Asian elephants' body condition scores between sexes despite some sexually dimorphic features. However, in greater one-horned rhinoceros – which are not sexually dimorphic – it was found that average visual BCS scores were not significantly different but the scores of certain focus areas such as the neck were, with males having larger necks and therefore higher scores in this area (Heidegger et al. 2016). This study, therefore, also examined whether there was any sex bias for individual focus areas in visual BCS, with findings comparable to those of Heidegger et al. (2016). The results showed that there was a sex bias in the visual body condition score for the neck in eland, with males having a higher mean score. This is likely because male eland use their necks in certain fighting styles, and therefore dominant males possess thicker necks, and larger dewlaps (Bro-Jorgensen & Daelsteen 2008). This was the only focus area with any statistically significant difference between the two sexes, with all others showing no variation. Social rank could be a factor that influences this sex bias so future studies should investigate the relationship between sex bias is body condition scoring and social rank.

5.5. Future perspectives

Going forward, a way to build on this study would be to validate visual and palpation BCS with ultrasound of subcutaneous fat or dual-energy x-ray absorptiometry. This would provide a more precise assessment of an animal's health. These methods, however, can be expensive and time-consuming and thus would not apply to most zoos as a standard method for monitoring body condition (Clingerman & Summer 2012; Morfeld et al. 2014; Heidegger et al. 2016; Reamer et al. 2020).

Another factor that could be analysed in the future, would be the assessment of seasonal changes when evaluating body condition scores. Although this is less of a concern in captive animals, if our validated system were used on wild animals, we would need to determine how accurate it would be between varying times of the year. Seasonal changes have been shown to naturally affect some body condition indices; for example, KFI is lower in the dry season as food contains a less nutritious value (Lane et al. 2014). Gallivan et al. (1995) also found that visual BCS was significantly affected by seasonal changes, and whether the animal was occupying a managed or unmanaged area, with animals in unmanaged areas having poor body condition scores. Therefore, it is recommended that future studies research seasonal changes in both captive and wild eland to assess their change in body condition so that these methods can accurately be applied to animals at all levels of management.

Whilst this visual BCS system is a validated method for common eland, the field would benefit from further investigation into its suitability for subspecies of common eland and other eland species, such as the giant (derby) eland. Cook et al. (2010) reported that, when performing BCS assessments on elk, there was an underscoring bias when the same scale was used on two subspecies: rocky mountain elk and Roosevelt elk, which could well be the case for common eland subspecies. Researching whether such a bias is present in the assessment of giant (derby) eland, or if a new system would need to be created for their BCS is therefore beneficial. This investigation would be particulary important due to their declining population and the critically endangered status of their western subspecies and additionally would potentially enable the utilisation of a universal scoring system in the wild.

6. Conclusions

Suitable and validated body condition scoring systems are an important resource required for zoological and captive collections, and landowners with wild counterparts. Whilst using a singular criterion to assess an animal's body condition does not provide a full representation of health (Kistner et al. 1980), performing a quick primary assessment such as visual BCS can inform whether an individual animal needs further evaluation or treatment, indicating many factors such as appropriateness of diet, presence of disease, and general health. This study presents a validated visual BCS system for captive eland using five focus areas on the animal's body and a five-point scale with a prime animal scoring between three and four. Its application can be used by captive collections with minimal training and without needing resources. Due to the higher variability in validated scores of young animals, however, further research is required to establish the prime score in this age group. It thus should be used in conjunction with other body condition scoring systems. Additionally, future studies should also focus on assessing differences in visual BCS of both captive and wild individuals, as well as seasonal differences for the latter.

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Appendices

List of the Appendices:

Appendix 1: Palpation BCS and other variables correlations

		Tail base	Body weight	Average daily gains	Age in days	Palpation pin bones	Palpation Sacrum	Palpation Longissimus	Palpation rump	Palpation average
Tail base	Correlation coefficient		0.785	0.065	0.650	0.522	0.536	0.536	0.556	0.558
	Significance (2-tailed)		<0.001	0.152	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N		707	491	708	695	696	696	696	696
Body weight	Correlation coefficient	0.785		0.066	0.901	0.533	0.537	0.528	0.570	0.568
	Significance (2-tailed)	<0.001		0.137	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N	707		511	734	717	718	718	718	718
Average daily gains	Correlation coefficient	0.065	0.066		-0.142	0.210	0.245	0.253	0.242	0.244
	Significance (2-tailed)	0.152	0.137		0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N	491	511		512	507	508	508	508	508
Age in days	Correlation coefficient	0.605	0.901	-0.142		0.387	0.369	0.354	0.403	0.397
	Significance (2-tailed)	<0.001	<0.001	0.001		<0.001	<0.001	<0.001	<0.001	<0.001
	N	708	734	512		719	720	720	720	720
Palpation pin bones	Correlation coefficient	0.522	0.533	0.210	0.387		0.861	0.846	0.836	0.933
	Significance (2-tailed)	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	0.000
	N	695	717	507	719		719	719	719	719
Palpation Sacrum	Correlation coefficient	0.536	0.537	0.245	0.369	0.861		0.853	0.860	0.941
	Significance (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	0.000
	N	696	718	508	720	719		720	720	720
Palpation Longissimus	Correlation coefficient	0.536	0.528	0.253	0.354	0.846	0.853		0.860	0.935
	Significance (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	0.000
	N	696	718	508	720	719	720		720	720
Palpation rump	Correlation coefficient	0.556	0.570	0.242	0.403	0.836	0.860	0.860		0.935
	Significance (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001
	N	696	718	508	720	719	720	720		720
Palpation average	Correlation coefficient	0.558	0.568	0.244	0.397	0.933	0.941	0.935	0.935	
	Significance (2-tailed)	<0.001	<0.001	<0.001	<0.001	0.000	0.000	0.000	0.000	
	N	696	718	508	720	719	720	720	720	

Appendix 2: Visual BCS and other variables correlations

		Tail base	Body weight	Average daily gains	Age in days	Visual neck	Visual withers	Visual loin	Visual tailhead/ hips	Visual ribs	Visual average
Tail base	Correlation coefficient		0.785	0.065	0.650	0.489	0.461	0.456	0.456	0.454	0.487
	Significance (2-tailed)		<0.001	0.152	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N		707	491	708	708	708	708	708	708	708
Body weight	Correlation coefficient	0.785		0.006	0.901	0.515	0.470	0.445	0.432	0.459	0.490
	Significance (2-tailed)	<0.001		0.137	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N	707		511	734	734	734	734	734	734	734
Average daily gains	Correlation coefficient	0.065	0.066		-0.142	0.213	0.189	0.202	0.210	0.172	0.202
	Significance (2-tailed)	0.152	0.137		0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N	491	511		512	512	512	512	512	512	512
Age in days	Correlation coefficient	0.650	0.901	-0.142		0.364	0.339	0.313	0.285	0.334	0.346
	Significance (2-tailed)	<0.001	<0.001	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N	708	734	512		761	761	761	761	761	761
Visual neck	Correlation coefficient	0.489	0.515	0.213	0.364		0.851	0.796	0.827	0.798	0.912
	Significance (2-tailed)	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001
	N	708	734	512	761		761	761	761	761	761
Visual withers	Correlation coefficient	0.461	0.470	0.189	0.339	0.851		0.857	0.857	0.868	0.945
	Significance (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	0.000
	N	708	734	512	761	761		761	761	761	761
Visual loin	Correlation coefficient	0.456	0.445	0.202	0.313	0.796	0.857		0.871	0.841	0.933
	Significance (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	0.000
	N	708	734	512	761	761	761		761	761	761
Visual tailhead/ hips	Correlation coefficient	0.456	0.432	0.210	0.285	0.827	0.857	0.871		0.825	0.937
	Significance (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	0.000
	N	708	734	512	761	761	761	761		761	761
Visual ribs	Correlation coefficient	0.454	0.459	0.172	0.334	0.798	0.868	0.841	0.825		0.919
	Significance (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001
	N	708	734	512	761	761	761	761	761		761

Visual average	Correlation coefficient	0.487	0.490	0.202	0.346	0.912	0.945	0.933	0.937	0.919
	Significance (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	0.000	0.000	0.000	0.000
	N	708	734	512	761	761	761	761	761	761

Appendix 3: Visual vs palpation BCS correlations

		Visual neck	Visual withers	Visual loin/back	Visual hips	Visual ribs	Visual average	Palpation pin bones	Palpation sacrum	Palpation longissimus	Palpation rump	Palpation average
Visual neck	Correlation coefficient		0.851	0.796	0.827	0.798	0.912	0.539	0.523	0.536	0.539	0.561
	Significant (2-tailed)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N		761	761	761	761	761	719	720	720	720	720
Visual withers	Correlation coefficient	0.851		0.857	0.857	0.868	0.945	0.553	0.530	0.542	0.552	0.571
	Significant (2-tailed)	<0.001		<0.001	<0.001	<0.001	0.000	<0.001	<0.001	<0.001	<0.001	<0.001
	N	761		761	761	761	761	719	720	720	720	720
Visual loin/back	Correlation coefficient	0.796	0.857		0.871	0.841	0.933	0.503	0.503	0.522	0.532	0.538
	Significant (2-tailed)	<0.001	<0.001		<0.001	<0.001	0.000	<0.001	<0.001	<0.001	<0.001	<0.001
	N	761	761		761	761	761	719	720	720	720	720
Visual hips	Correlation coefficient	0.827	0.857	0.871		0.825	0.937	0.559	0.537	0.540	0.544	0.570
	Significant (2-tailed)	<0.001	<0.001	<0.001		<0.001	0.000	<0.001	<0.001	<0.001	<0.001	<0.001
	N	761	761	761		761	761	719	720	720	720	720
Visual ribs	Correlation coefficient	0.798	0.868	0.841	0.825		0.919	0.500	0.500	0.501	0.532	0.533
	Significant (2-tailed)	<0.001	<0.001	<0.001	<0.001		0.000	<0.001	<0.001	<0.001	<0.001	<0.001
	N	761	761	761	761		761	719	720	720	720	720
Visual average	Correlation coefficient	0.912	0.945	0.933	0.937	0.919		0.569	0.553	0.565	0.577	0.594
	Significant (2-tailed)	<0.001	0.000	0.000	0.000	0.000		<0.001	<0.001	<0.001	<0.001	<0.001
	N	761	761	761	761	761		719	720	720	720	720
Palpation pin bones	Correlation coefficient	0.539	0.553	0.503	0.559	0.500	0.569		0.861	0.846	0.836	0.933
	Significant (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	0.000
	N	719	719	719	719	719	719		719	719	719	719
Palpation sacrum	Correlation coefficient	0.523	0.530	0.503	0.537	0.500	0.553	0.861		0.853	0.860	0.941
	Significant (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	0.000
	N	720	720	720	720	720	720	719		720	720	720
Palpation longissi.	Correlation coefficient	0.536	0.542	0.522	0.540	0.501	0.565	0.846	0.853		0.860	0.935
	Significant (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	0.000
	N	720	720	720	720	720	720	719	720		720	720

Palpation rump	Correlation coefficient	0.539	0.552	0.532	0.544	0.532	0.577	0.836	0.860	0.860		0.935
	Significant (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		0.000
	N	720	720	720	720	720	720	719	720	720		720
Palpation average	Correlation coefficient	0.561	0.571	0.538	0.570	0.533	0.594	0.933	0.941	0.935	0.935	
	Significant (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.000	0.000	0.000	0.000	
	N	720	720	720	720	720	720	719	720	720	720	