

Czech University of Life Sciences Prague

Faculty of Tropical AgriSciences

**Department of Animal Science and Food Processing in Tropics and
Subtropics**



Czech University of Life Sciences Prague

**Faculty of Tropical
AgriSciences**

**Coat pattern of Western Derby eland
(*Taurotragus derbianus derbianus*) – an
evidence for heritability?**

Diploma thesis

Prague 2013

Autor:	Bc. Zuzana Böhmová
Thesis supervisor:	Ing. Karolína Brandlová, Ph.D.
Thesis consultant:	RNDr. Jan Robovský, Ph.D.

Declaration

I honestly declare that this diploma thesis on the theme “Coat pattern of Western Derby eland (*Taurotragus derbianus derbianus*) – an evidence for heritability?” was elaborated independently and is based on my own knowledge, consultations with my supervisor and consultant, and literary resources cited in attached bibliography.

In Prague, dated 6th of April 2012

.....

Zuzana Böhmová

Acknowledgement

I owe my deepest gratitude to Ing. Karolína Brandlová, Ph.D., for guidance during writing my thesis, for the patience and for invaluable help with every single part of my thesis. I am also very thankful for giving me the unique chance to work in Senegal with the beautiful Western Derby elands.

I want to express my thanks also to RNDr. Jan Robovský, Ph.D. for the cooperation and professional assistance.

My thanks belong to Society for the Protection of Environment and Fauna in Senegal, namely to director managers Georges Rezk, and to managers of Bandia Reserve, namely Christian Dering and Souhel Fourzoli, as well as the reserve staff.

I am also very thankful to my colleagues, Kateřina Hozdecká, Magdalena Žáčková and Pavla Jůnková Vymyslická for the photographic documentation of elands in Senegal.

And finally I would like to thank my family. I am very grateful to my mother, Vendula Böhmová, and my younger brother, Jiří Böhm, for their financial and also moral support.

Abstract

This Diploma thesis deal with the coat pattern of Western Derby eland (*Taurotragus derbianus derbianus*). The body coloration and the coat pattern is a diagnostic tool for identifying animals, but even today we know about this subject very few. The object of this thesis was to describe the exterior of Derby eland (*Taurotragus derbianus*), to analyse the average stripe and colour characteristics of coat pattern in the Western Derby eland and compare it with the Eastern Giant eland (*Taurotragus derbianus gigas*), and to estimate the coefficient of heritability (h^2) for quantitative parameters in the captive breeding population of Western Derby eland, which was established in Senegal. For the description of Derby eland we used the photographs of both subspecies - we described the coloration, markings and stripe pattern. We found some differences between the subspecies - e.g. in the number of stripes, in the body coloration and also in the white markings on the head. Then we calculated the coefficient of the heritability, but from these results we could not confirm that there was a heritability of stripe characters from parents to offspring. All the details about the coat pattern could be very important for the precise description of these animals, for the recognition of the individuals and manipulation with them in the captive conditions and of course for the study of this species.

Key words: Coat pattern, heritability, *Taurotragus derbianus derbianus*, *Taurotragus derbianus gigas*

Abstrakt

Tato diplomová práce se zabývá vzorem srsti u západního poddruhu antilopy Derbyho (*Taurotragus derbianus derbianus*). Zbarvení těla a vzor srsti je diagnostický nástroj pro identifikaci zvířat, avšak i v dnešní době víme o tomto tématu velice málo. Cílem naší práce bylo popsat exteriér antilopy Derbyho (*Taurotragus derbianus*), analyzovat průměrný počet pruhů a barevné charakteristiky srsti u západního poddruhu antilopy Derbyho a porovnat je s východním poddruhem (*Taurotragus derbianus gigas*), a vypočítat koeficient dědivosti (h^2) pro kvantitativní parametry v populaci západního poddruhu antilopy Derbyho v lidské péči, která byla založena v Senegal. Pro popis antilopy Derbyho jsme použili fotografie obou poddruhů - popsali jsme zbarvení, znaky a vzor pruhů. Našli jsme několik rozdílů mezi poddruhy - např. v počtu pruhů, ve zbarvení těla a také v bílých znacích na hlavě. Pak jsme spočítali koeficient dědivosti, ale z těchto výsledků jsme nemohli potvrdit, že by zde byla nějaká dědičnost vzoru pruhů z rodičů na potomky. Všechny údaje o vzoru srsti by mohly být velmi důležité pro přesný popis těchto zvířat, pro rozpoznávání jednotlivců a manipulaci s nimi v zajetí a samozřejmě pro studium tohoto druhu.

Klíčová slova: vzor srsti, dědivost, *Taurotragus derbianus derbianus*, *Taurotragus derbianus gigas*

Contents

1. Introduction.....	9
2. Literature review	11
2.1 The mammalian coat pattern and its role.....	11
2.1.1 Evolution and coat pattern genes	12
2.1.2 Colours.....	13
2.1.3 Coat pattern.....	14
2.1.4 Seasonal and life cycle alterations to colours and patterns.....	15
2.1.5 The adaptive significance	15
2.2 The coat pattern of ungulates.....	17
2.2.1 The zebra stripes	18
2.2.2 The coat pattern of giraffes	21
2.2.3 The coat pattern of Tragelaphini.....	21
3. Objective.....	25
4. Materials and methodology	26
4.1 Locality and breeding management.....	26
4.2 Studied animals.....	26
4.3 Data collection and analysis	27
5. Results.....	29
6. Discussion.....	38
7. Conclusion	42
8. References.....	43
Annexes	49

List of graphs

Graph 1.	Dependence of the body coloration on the subspecies.....	34
Graph 2.	Dependence of neck coloration on the age in Western Derby eland.....	35
Graph 3.	Coefficient of the heritability counted for the number of stripes on the left flank.....	36
Graph 4.	Dependence of sum of the characters on the left flank on the maternal line, Western Derby eland.....	37

List of graphs in annexes

Graph 1.	Dependence of the number of stripes on the left flank on the subspecies...	51
Graph 2.	Dependence of the number of splits of the stripes on the back (the right flank) on the subspecies.....	51
Graph 3.	Dependence of neck coloration on the subspecies.....	52
Graph 4.	Dependence of the presence of tears under the eyes on the subspecies.....	52
Graph 5.	Dependence of the spot on left face on the subspecies.....	53
Graph 6.	Dependence of the spots on the right face on the subspecies.....	53
Graph 7.	Dependence of the presence of stripe with arc on the subspecies.....	54
Graph 8.	Dependence of the presence of back arc on the subspecies.....	54
Graph 9.	Dependence of the body coloration on the age in Western Derby eland....	55
Graph 10.	Dependence of body coloration on sex in Western Derby eland.....	55
Graph 11.	Dependence of the body coloration on the age in Eastern Giant eland.....	56
Graph 12.	Dependence of the neck coloration on the age in Eastern Giant eland.....	56
Graph 13.	Dependence of body coloration on the sex in Eastern Giant eland.....	57
Graph 14.	Dependence of the neck coloration on the sex in Eastern Giant eland.....	57
Graph 15.	Dependence of the presence of tears under the eyes on the sex in Eastern Giant eland.....	58
Graph 16.	Coefficient of the heritability counted for the sum of stripes on the left and right flank.....	58
Graph 17.	Dependence of sum of the characters on the left flank on the maternal line, Western Derby eland.....	59

List of figures

Figure 1.	Typical coloration of <i>Taurotragus derbianus derbianus</i> , adult male.....	24
Figure 2.	Adult male of <i>Taurotragus derbianus gigas</i> in Cincinnati Zoo, USA.....	24
Figure 3.	Characteristic of stripes in Derby eland.....	30
Figure 4.	Pre-stripe in Western Derby eland.....	31
Figure 5.	Split of the stripe on the back, Western Derby eland.....	31
Figure 6.	Back arc, Western Derby eland.....	32
Figure 7.	Stripe anomaly, Western Derby eland.....	32
Figure 8.	Markings on the head of Western Derby eland – tears and spot on the cheek, adult female.....	33

List of figures in annexes

Figure 1.	Split of the pre-stripe on the back, Western Derby eland.....	49
Figure 2.	Split of the stripe on belly, one-year male of Western Derby eland.....	49
Figure 3.	Markings on the head of Eastern Giant eland – tears and spot on the cheek, adult male in Cincinnati Zoo, USA.....	50
Figure 4.	Adult females of Eastern Giant eland in Cincinnati Zoo, USA.....	50

1. Introduction

The body coloration and coat pattern play an important role in the animal life - it varies within species, subspecies and even between individuals. Their coloration and markings can help us to recognize individuals (especially in the significantly colored species) and thus contribute to the study of these animals. Each animal can have its own characteristic pattern, which allows us to identify individuals in groups and herds and so study the behaviour between the individuals, the ability to adapt, the relations and evolution between the species and subspecies - it can help us to answer many questions. In this work, we deal with the exterior of Derby eland (*Taurotragus derbianus*) which has quite pronounced coat pattern - it has markings on various parts of the body and the individuals of this species have a very conspicuous banding on both flanks.

The Derby eland is divided into two subspecies. The Western Derby eland, *Taurotragus derbianus derbianus* (Gray, 1847), was first mentioned in the 40's of the 19th century - Dr. E. J. Gray described it on the basis of 2 skins and the horns of a male and female from Senegambia (Gray, 1847). The Eastern Giant eland, *Taurotragus derbianus gigas* (Heuglin, 1863), was described by Dr. Martin Theodore von Heuglin, who organised an expedition to the area of the White Nile (today's Sudan), where he found the horns of this eastern subspecies (Heuglin, 1864). The subspecies differ in the area of distribution and conservation status – Eastern Giant eland is classified as "least concern" and it inhabits Central Africa, Western Derby eland is classified as "critically endangered" and it lives in Senegal (IUCN, 2008). The number of individuals of western subspecies in the nature is estimated to be less than 200 animals (Renaud *et al.*, 2006) - so it is very close to the extinction. Number of individuals of the eastern subspecies is much larger and nowadays it has become very popular for trophy hunters.

In both subspecies of Derby eland we have described the coloration and coat pattern. In Western Derby eland the number of stripes and characteristics is same throughout the life of the animal (Akakpo *et al.*, 2004). We have counted the number of the stripes on both flanks. Then we have described 7 categories of the stripe characteristics in both subspecies: pre-stripe, split on the back, split on the belly, fork on the back, fork on the belly, arc on the back and stripe with arc (any other differences were described as visible anomaly). In the case of coloration we have examined the colour of the body and of

the neck. We have also described the markings on the head - tears under the eyes and spots on the cheeks. Based on those descriptions of exterior we have tested the differences between subspecies and counted the coefficient of heritability.

Finally, we would like to mention that all the taxonomy used in this diploma thesis is according to Wilson and Reeder (2005).

2. Literature review

2.1 The mammalian coat pattern and its role

In vertebrates, pigmentation and coloration vary widely from black and white stripes of zebra to the reticulated giraffe, where its reddish-brown coat is divided by a network of fine white lines into large geometric shapes, up to bright colours and bold patterns of some birds. In many species of animals the coat pattern plays a big role in their behaviour, in their social bonds and relations and in the antipredatory behaviour, camouflage or warning coloration (Caro, 2005). While the diverse patterns of domestic animals have mainly aesthetic value, the coat patterns of wild animals are of great importance to their fitness (Mills and Patterson, 2009).

In mammals, pigmentation can vary across the entire body or across individual hairs. By varying the type of melanin produced in different regions of the body a wide range of patterns may be achieved (Mills and Patterson, 2009). Coloration is a diagnostic tool for identifying mammals, but despite its important function it was not elaborated many studies on this subject. Animals display diverse colors and patterns that vary within and between species and subspecies. Similar phenotypes appear in both closely related and widely divergent taxa. In the scientific world they are recognized three classic hypotheses for the function of coloration in mammals: concealment, communication, and regulation of physiological processes (Caro, 2005). Camouflage may be the single most important evolutionary force in explaining overall coloration in mammals (Caro, 2005). In the case of communication the patches of colored fur may be used for intraspecific signaling - for example to signal danger to conspecifics (Alvarez *et al.*, 1976). The role of coat pattern in sexual selection in mammals is not so strong (opposed to birds) - it can be observed only in a minority of primates and other restricted mammalian taxa (Caro, 2005). Finally, the coloration of pelage may also influence the thermoregulation with either dark and white hairs increasing or decreasing heat gain depending on hair structure, density, aspect and wind velocity (Walsberg, 1983).

The overall coloration of the coat can be classified as patterned or uniform. The markings are usually on the specific body parts - ears, tails and legs. Markings are defined as an area of color contrasting with the rest of the body or with the nearest area of the

body. Thus, a white tail tip on a white animal would not be recorded as such, but a white tail tip on a black animal or one with a black tail would constitute a marking (Ortolani and Caro, 1996).

2.1.1 Evolution and coat pattern genes

Pigmentation patterning has long captured the interest of biologists, largely because of the tremendous diversity in color pattern among animals. The colours of organisms are produced by molecular pigments or by the physical interactions of light waves with biological nanostructures (Prum and Torres, 2004). Structural colours, produced by the latter mechanism, are an important component of the phenotype of many animals (Parker, 1999). Many of the most striking pigment patterns found in nature are the result of regional differences in pigmentation, such as stripes of a zebra or the white head and tail of a bald eagle (*Haliaeetus leucocephalus*). Understanding the genetic and developmental basis of variation in form and structure of the animal coloration is of central importance to developmental biology. Pigment patterns present an ideal system in which to study how developmental changes generate differences in form both within and between species (Mills and Patterson, 2009). But there is very little information about the molecular or cellular processes that generate complex patterns such as stripes and spots, or how alterations in those processes might produce different phenotypes. It is difficult to explore these issues, because the closely related species may show highly divergent patterns, while distantly related species can appear strikingly similar (Mills and Patterson, 2009).

In vertebrates, several mechanisms may contribute to regional variation in melanin type and density. During embryogenesis, neural crest cells arise along the dorsal neural tube, and some differentiate into melanoblasts (precursors of melanocytes), which migrate ventrally along the body. Melanoblasts typically enter the epidermis, where some remain, while others localize to the hair follicles and differentiate into melanocytes (Hoekstra, 2006). Melanocytes synthesize melanin pigment, package it into melanosomes and then transfer those melanosomes to keratinocytes for deposition into developing hairs (Mills and Patterson, 2009). Though mammals have only one pigment cell type, the melanocyte, these cells can produce either eumelanin (black/brown) or pheomelanin (yellow/red) and can switch rapidly between the synthesis of these two pigment types (Mills and Patterson, 2009).

In mammals, increased production of eumelanin and a corresponding reduction in pheomelanin synthesis generates a melanic phenotype, which may be dark brown or entirely black. This switch is primarily controlled by the interaction of two genes: the melanocortin receptor 1 (Mc1r) and agouti (Mills and Patterson, 2009). Like black phenotypes, changes in a variety of genes can cause yellow, orange, or red coloration in vertebrates, but unlike black, these colours can be produced by a wide range of pigments. The loss of function mutations in Mc1r or dominant mutations in agouti cause increased pheomelanin synthesis, generating a yellow or red coat (Mills and Patterson, 2009). The blue-coloured skin is caused by thick arrays of collagen fibers in the dermis. The precise colour produced is dependent on the diameter of fibers in the array, with smaller-diameter fibers reflecting shorter-wavelength light. The colours produced can therefore range from ultraviolet to (rarely) yellow or orange, although blue is most common (Mills and Patterson, 2009).

2.1.2 Colours

Across the mammalian species there are at least five different coat colours (white, pale, red, grey, dark) to match the typical background (Caro, 2005). Species that are white or become white in winter are found in arctic and tundra biomes. White fur might scatter solar radiation toward the skin and so it can be expected in cold climes - the best example is a polar bear (*Ursus maritimus*) which has a white body colour all year round, and arctic fox (*Vulpes lagopus*) with arctic hare (*Lepus arcticus*) that both turn white in winter (Caro, 2009). Pale species are found in very hot environments such as deserts and open environments, because the pale fur reflects light. Red and grey species can be found in rocky habitats. These findings can occur also within one species, for example in oldfield mice (*Peromyscus polionotus*) - individual desert rodents with paler coats are found on pale soils, and those with darker coats are found on blackened lava beds (Belk and Smith, 1996). The dark species are found in closed environments and in dense or tropical forests, because dark fur enhances water evaporation more readily than cool surfaces. But the problem is that these robust associations do not make a clear-cut case for concealment, because coats of different colour have differing thermoregulatory properties (Caro, 2005).

Another type of the coloration is albinism. It is characterized by reduced melanin in the skin, hair and eyes. Albinism has evolved repeatedly in widely divergent taxa and is

caused by a single genetic mutation that is thought to have no adaptive significance (albinos are removed from populations rapidly) (Caro, 2005). The opposite of albinism is melanism (black or very dark brown pelage), may be found in 20% of individuals in some populations. The functional advantages of melanism are unclear, maybe it could be important for temperature regulation in humid habitats, such as tropical forests (Caro, 2005). For example it can be seen in some predators living in tropical forests, such as black panther - in fact melanistic jaguar (*Panthera onca*), and jaguarundi (*Puma yaguarondi*) (Majerus and Mundy, 2003).

2.1.3 Coat pattern

Changing the type of pigment can lead to the differences in coloration over the entire body of an animal - result is the coat pattern which has a different structure in each animal species (Caro, 2005). The stripes can be found only in some areas of the body - like the rings on the tail of a ring-tailed lemur (*Lemur catta*), or may be repeated across the body, like those of a zebra. Spots can be regular and repeated, like those found on a leopard (*Panthera pardus*), or broad and irregular, like the black and white pattern of dairy cows.

A coat with the appearance of dappled light, for example, might be expected in a diurnal, solitary species that live in forests, where crypsis is a likely mechanism by which an animal could escape notice. This has been confirmed in artiodactyls; in particular, there is a very tight association between young having spotted coats and young being sequestered during the first week after birth (hider species). Among carnivores, spotted species tend to be arboreal and to live in closed habitats, whereas striped species are found in grasslands (Caro, 2005).

The importance of banding is not clear. It is difficult to find some evidence about disruptive coloration in mammals. Numerous artiodactyls have remarkable black or white bands on the flanks and leg markings that could function to break up the body's outline; but although these markings are found in species that are diurnal and live in open country and in desert habitats, few associations between potentially disruptive coloration and these behavioral and ecological variables stand after controlling for phylogeny (Stoner *et al.*, 2003). Patches of color and coat pattern, rather than overall coloration, may also be used as intraspecific signals - the placement of these patches on the body often hints at their

function. For example, badges of dominance are likely to be at the front of the animal whereas indicators of body condition that signal an ability to avoid predators or a readiness to mate are likely to be at the rear (Caro, 2009).

2.1.4 Seasonal and life cycle alterations to colours and patterns

Changing ecological pressures throughout the ontogeny of an organism can necessitate corresponding changes in the organism's appearance. Animals, that live in seasonal ecosystem, change their pigmentation to match (for example arctic fox). Some animals can exhibit specific coloration during the mating season. Permanent changes in colour or patterning can be very common. In a number of mammals this change is a relatively simple one: cubs of puma (*Puma concolor*) and fawns of white-tailed deer (*Odocoileus virginianus*) have spots, while older individuals of their species do not (Mills and Patterson, 2009). On the other hand, some of the structure and colors can remain the same throughout the life. For example, in Western Derby eland (*Taurotragus derbianus derbianus*) the number and shape of white stripes on the flanks does not change during the life (Akakpo *et al.*, 2004).

2.1.5 The adaptive significance

Camouflage or concealment may be the most important reason for the coat pattern of many species. Animals can remain concealed when their overall coloration resembles or matches the natural background of their environment (Endler, 1978). Concealment may be achieved through disruptive coloration - by contrasting colors or irregular marks that break up the body's outline (Merilaita, 1998). A type of the camouflage can be also crypsis, in which overall body colour resembles the general colour of the habitat, or pattern blending, in which colour patterns on the body match patterns of light and dark in the environment (Caro, 2005). Animals may also attain concealment if they have a lighter ventral surface and dark dorsum, because this may counteract the sun's effects - lightening the dorsum and shading the ventrum - when it shines from above (Kiltie, 1988). This arrangement is one of the most common pigment patterns found among vertebrates. For most taxa, it is difficult to relate coloration or markings to crypsis or conspicuousness, because animals that are

easy to notice close up may be difficult to see a long way off (zebras are highly conspicuous nearby but difficult to see at a distance) (Caro, 2005).

The contrast between an animal and its background depends also on ambient illumination and spectral reflectance to the background - an animal may be cryptic at one time of day but not later on (Burt, 1981), or against one background but not another (Endler, 1990). There can be also a problem that an animal may be conspicuous to humans but not to nonprimate animals. Primates have three types of colour-sensitive retinal cones, whereas carnivore predators possess only two. Or they may be cryptic to humans but conspicuous to birds, which have four types of cones, the additional one of which is sensitive to ultraviolet light (Caro, 2005).

The second major evolutionary force thought to be responsible for coloration of particular body parts may be the communication between conspecifics. The systematic proofs from artiodactyls and carnivores show, that the markings on the face, ears, legs, tail, and rump serve to the intraspecific signaling - these markings are associated with conditions in which they are most visible (diurnal activity and open habitats) and are seen in gregarious species (Caro, 2005). White or dark faces are seen in social ungulates, white patches on the ears in forest-living carnivores and conspicuous legs in diurnal desert and grassland ungulates. Conspicuous tail coloration in ungulates is strongly associated with being diurnal and living in groups, whereas some carnivores exhibit black tail tips in grassland habitats (Caro, 2005). Coloration as communication has been advanced most thoroughly in primates. The patterns and colours can also serve for the interspecific communication. Artiodactyls use colour patches to enhance pursuit-deterrent signals aimed at predators. These signals may inform an approaching predator that it has been detected. They may also inform the predator of the prey's condition and hence its probability of escaping (Caro, 1995). For instance, when pursued by wild dogs, Thomson's gazelles (*Eudorcas thomsonii*) stot vigorously and lift their tails, perhaps to flaunt their white rump patch (FitzGibbon and Fanshawe, 1988).

The coat pattern may also signal reproductive condition, dominance, health, or even genetic quality to potential mates (Pagel, 1994). The adaptive significance of sexual coloration can be observed in some species with polygynous mating systems (Caro, 2005). Male lions carry manes, some of which are black whereas others are sandy-coloured like the rest of the coat. Black mane coloration is associated with higher food intake, with age, with testosterone concentrations, and with cooler environments. The dark-maned males

have longer reproductive life spans and higher offspring survival. The lionesses prefer to mate with the darkest-maned male in their coalition (West and Packer, 2002).

The final hypothesis for the coloration in mammals deals with physiological and physical functions that are involved in regulating body temperature (by reflecting or absorbing radiation, or by providing a surface that enhances or reduces evaporation) and reducing glare from the sun, although predictions regarding these functions vary according to whether skin or hair colour is under discussion, and depend on physical properties of hair follicles (Walsberg, 1983). Some findings suggest that white face markings in ungulates, and possibly white rump patches, are instrumental in reducing heat load in open desert or grassland habitats because they reflect heat (Caro, 2005).

2.2 The coat pattern of ungulates

The even-toed ungulates exhibit a range of hues from black through grey and red to pale (Caro, 2009). The predation pressure is seen to be key selective force acting on coloration in this order of mammals. Many aspects of coloration in ungulates are related to concealment – it appears the principal force driving the evolution of coloration in ungulates with communication, and then thermoregulation, playing less of a role (Stoner *et al.*, 2003). And also the role of coloration in mate choice is minor, because there is a small number of ungulate species that are sexually dichromatic. In even-toed ungulates, there is no evidence for spotted or striped coats being involved in intraspecific communication because they are not associated with gregariousness (Stoner *et al.*, 2003).

The striped coats in adults of artiodactyl species are found in light forests groups, while spotted young across all artiodactyls are tied to dense forests. The striped and spotted young are associated with hiding species (mothers leave their neonates alone, when they forage) - it supports strongly a concealment hypothesis (Stoner *et al.*, 2003). On the other hand, spotted pattern of adults might provide a mechanism to reduce intraspecific aggression - spotted coats resemble those of young in many species and might therefore act as a signal of subordination (Stoner *et al.*, 2003).

All 6 species of Hippotraginae (for example gemsbok - *Oryx gazella*) have light or white coloured bodies and faces with black wigs, cheek patches and patches between eyes and nostrils that may be joined depending on subspecies and individual (Caro, 2009).

Artiodactyls with both black and white facial markings are diurnal and live in intermediate-sized groups, and species with conspicuous faces live in grassland or bushland habitats suggesting communication (Stoner *et al.*, 2003). Artiodactyls with white faces are found in open environments, however, suggestive of thermoregulation (Geist, 1987). Blackbuck (*Antilope cervicapra*) have a white chin and eye rings contrasting with black or dark brown upperparts - many artiodactyls have black or white eye rings (e.g. dik-dik *Madoqua kirkii*) or spots on their face (e.g. sao la *Pseudoryx nghetinhensis*) that probably draw attention to pre-orbital glands with which they scent and mark their territories (Caro, 2009).

Dark leg markings, which may serve as another form of disruptive coloration, is associated with open environments - dark legs are seen in desert living species and those in large social groups (Stoner *et al.*, 2003). Species with white leg markings are associated with diurnality and live in grassland or bushland habitats (Stoner *et al.*, 2003). The contrasting leg coloration is very common in Bovidae - here, members of some genera have white legs (*Capra* sp., *Pseudovis* sp.), or white stockings (bontebok - *Damaliscus pygargus pygargus*, goral - *Naemorhedus goral* or gemsbok); or white spots on the fetlocks (nilgai - *Boselaphus tragocamelus*, Derby eland and sao la) or elsewhere on the shank (e.g. tahr - *Hemitragus hylocrius*) (Caro, 2009). Other species show black frontal surfaces on the forelegs (*Kobus* sp., *Capra* sp., *Pseudovis* sp., chiru - *Pantholops hodgsonii*); or black upper legs (e.g. hartebeest - *Alcelaphus buselaphus*, gemsbok, blackbuck); or black stockings (a few *Cephalophus* sp.); or black spots on the fetlocks (nilgai, Derby eland, impala - *Aepyceros melampus*) or elsewhere on the leg (e.g. common eland - *Taurotragus oryx*) (Caro, 2009).

2.2.1 The zebra stripes

The bold black and white striped patterns are shown by the three living species of zebra – plains zebra (*Equus burchelli*), mountain zebra (*Equus zebra*) and Grevy's zebra (*Equus grevyi*). The stripes in plains zebra are highly variable according to regions and individuals (Kingdon, 2004). The northernmost race (*E. b. boehmi*) is most completely and boldly striped, decreasing southward. The coat of young is longer and softer with brown stripes (Estes, 1991). The mountain zebra has vertical stripes regularly spaced on the neck and body, on the rear there are 3 or 4 very marked horizontal stripes, legs are thinly

horizontally striped (Kingdon, 2004). These animals have white belly without stripes (Estes, 1991). Black stripes of the face change to orange-brown on the nose and around the mouth and nostrils (Kingdon, 2004). Stripes continue in the mane and the dewlap – to increase the impression of thickness of the neck, especially in adult males (Kingdon, 2004). The Grevy's zebra has close narrow stripes, bolder on the neck and chest extending through mane, belly is unstriped (Estes, 1991). The stripes are regular on the body, head and limbs, but the width varies (Kingdon, 2004). There are some hypotheses about reasons for the striped patterns of zebra coats: protection from predators, social functions, thermoregulation, and protection from tsetse flies (*Glossina* sp.) (Ruxton, 2002).

One of the most established hypothesis suggests that zebra stripes have perplexing effect on predators, thus making it difficult for predators to distinguish a single individual from a herd. Morris (1990) suggests that the stripes of even a single individual, when viewed up close, are enough to dazzle and confuse a predator. There is also a theory that stripes make a zebra look bigger. According to this theory, as propounded by Cott (1966), Vaughan (1986) and Morris (1990), the stripes create an optical illusion that increases the apparent size of the animal. This illusion may occasionally cause predators to misjudge the range when leaping for the zebra. The theory that stripes provide camouflage in tall grass was not approved. But another theory say, that while stripes make zebra very visible in full daylight, they break up the animal's outline when viewed from a distance in poor lighting conditions near dusk and dawn (McLeod, 1987) - lions and hyenas commonly hunt at these times.

There is the theory, that the stripes can have also the social functions. Morris (1990) suggests that variations in striping between individuals could be used as a means of individuals identifying each other. But he also says, that a herd of wild horses (lacking in the striping pattern) also has accurate individual identification and every member of the herd is known individually to other members. It is therefore hard to say that the individual identifying is the reason of the black and white pattern.

The black and white coloration of the zebras has also led to the theory that stripes serve as a mechanism of thermoregulation. Morris (1990) suggests that rotary breezes could be created by differential cooling of the black and white zones. He suggests that this might explain why the quagga (*Equus quagga*), from the cool south of Africa, had less distinct striping.

The last theory of the origin of stripes deals with the protection from tsetse flies. Waage (1981) compared the number of flies that were attracted to black, white and striped model animals. The striped model attracted smallest number of flies. Gibson (1992) used targets that were either monochrome white, black or grey, or had horizontal or vertical black and white stripes. These targets were exposed singly and in combinations. It was observed that tsetse were generally less attracted to stripes than to solid colours, they appear to avoid horizontally striped objects; significantly fewer tsetse were caught on a horizontally striped target than on a nearby transparent target, even with host odour present and no other conspicuous targets near the odour source. The important knowledge is that zebras spend a big amount of their time in close proximity to other mammals (De Boer and Prins, 1990). Thus, even if odour attracts flies from a distance, striping could still be effective by protecting the zebra when other more visible targets are nearby.

The extinct quagga was morphologically divergent in coat colour from all extant equids (horses, zebras and asses). The interesting feature of the quagga is that the front half of the animal had brown zebra-like stripes, whereas the rear looked more like a horse - brown in colour. It was formerly abundant in South Africa and it became extinct around 100 years ago. Until very recently, the quagga was considered to be a separate species from the three extant types of zebra. However, DNA analysis of preserved skins (Higuchi *et al.*, 1987) has shown that it was not a distinct species but a subspecies of the plains zebra. But the morphological analyses of the quagga and other zebra species have different conclusions. In a study based on cranial measurements, the quagga was found to be as different from plains zebra as the plains zebra is from the mountain zebra (Klein and Cruz-Uribe, 1999). Another study, based on pelage as well as cranial characters, found the quagga and the plains zebra to be highly similar and argued for subspecific status of the quagga (Groves and Bell, 2004). The question is why the quagga had fewer stripes than the plains zebra, or the mountain zebra, with which it had an overlapping range?

The theory that zebra stripes provide an effective cryptic defence against tsetse flies appears to be backed by the strongest evidence. However, the evidence is not yet conclusive, and evidence needed to test critically some other theories will be difficult to obtain.

2.2.2 The coat pattern of giraffes

The skin pigmentation of giraffes is uniformly dark grey, but the coat markings are highly labile (Mitchell and Skinner, 2003). The ground colour of is brown to dark chestnut (sometimes black - males darken with age), and it is broken up into patches and blotches by a network of light-coloured hair, the pattern is individually unique (Estes, 1991).

The markings of giraffes can be adapted to local conditions by natural selection and contribute to camouflage (Mitchell and Skinner, 2003). Their coat markings break up the body outline especially when sunlight filters through trees and scrub, and they are difficult to see even when they are no more than a few metres away (Mitchell and Skinner, 2003). Coat patches also seem to have another function apart from camouflage that may contribute to survival - the patches can act as thermal windows through which giraffes dissipate heat (Skinner and Smithers, 1990). It is possible, that the complicated body coloration of giraffes serves as a thermoregulatory system. So in giraffes the mechanism seems to combine camouflage and temperature regulation.

Among giraffes, the detailed geometric configurations of the darkened pelage areas differs across subspecies, but in all types of giraffes, the blotches darken with age, especially among males (Berry, 1973; Estes, 1991). The blotches in the torso area change gradually from a brownish to black colour, while the facial area of older males becomes grey (Berry, 1973). The age of initial transition of the blotches from brown to black in males is not very well known, as is the duration of time required for full colour transformation. Berry and Bercovitch (2012) found that the change of pelage coloration in males of Thornicroft's giraffe (*Giraffa camelopardalis thornicroftii*) takes an average 1.8 years and that males are completely covered with coal-black blotches at an average age of 9.4 years.

2.2.3 The coat pattern of Tragelaphini

The tribe Tragelaphini include the medium-sized to very large antelopes: bushbuck (*Tragelaphus scriptus*), sitatunga (*T. spekii*), nyala (*T. angasii*), mountain nyala (*T. buxtoni*), greater kudu (*T. strepsiceros*), lesser kudu (*T. imberbis*), bongo (*T. eurycerus*), common eland (*Taurotragus oryx*), and Derby eland (*Taurotragus derbianus*) (Wilson and Reeder, 2005).

The coloration in this tribe is quite similar - fawn to dark brown or black, females tan to red-brown. Animals have vertical stripes on both flanks, white chevron or bar between eyes, cheek spots, white throat patch and chest crescent (except greater kudu and nyala), upper forelegs with garters. They have pronounced sexual dimorphism - males have bulky spiral horns (females are hornless - except bongo and elands), and they darken with age. The markings are concealing rather than revealing, serving to break up the animal's form (disruptive coloration) and enabling it to blend into the background. However, some markings are clearly important for social communication, notably the dorsal crest and white scut (Estes, 1991).

The coloration of the bushbuck is highly variable geographically and individually - there are recognized 27 subspecies (Kingdon, 2004). The northern and western forms are reddest with best-developed markings, including harness-like diagonal lines on shoulder in *T. s. scriptus* (Estes, 1991) The southern and eastern forms are more yellow (Estes, 1991) and they have fewer markings - sometimes almost without markings or lightly marked with spots and stripes on the legs (Kingdon, 2004). Both sexes darken with age, but males far more than females (Estes, 1991). Coloration of sitatunga is also geographically and individually variable. The adult males are grey-brown to chocolate-brown, females brown to bright chestnut. Calves are bright rufous-red, woolly-coated, spotted, and striped (Estes, 1991). They have 8-10 dorsal stripes (Kingdon, 2004). Adults (especially males) are long-coated and markings therefore less distinct than the bushbuck's. They have white neck patches, dorsal crest is often brown. Females and young of nyala are bright chestnut, smooth-coated, They have 8-13 contrasting white stripes (Estes, 1991), no more than 18 (Kingdon, 2004). They have also spots on the chest and nose chevron (Estes, 1991). Males are charcoal grey (except tan lower legs) and hairy, with fringe of dark hair from throat to hindquarters and white dorsal crest (longest in tribe) (Estes, 1991). The body colour of males darkens with age and vertical stripes fade and may almost disappear (Kingdon, 2004). In mountain nyala, females are without horns and they look like a doe. Adult males have a deep chest, dorsal mane and the body coloration is sepia brown which darkens with age. They have white spots on the ears, face, throat and chest (Kingdon, 2004). Males of the lesser kudu are blue-grey and they darken with age, females and young are bright red-brown (Estes, 1991). These animals have 11-15 well-defined vertical white stripes (Kingdon, 2004). The nose chevron is incomplete and they have 2 cheek spots, tail is bushy with black tip and white underside, legs are tawny with black and white patches

(Estes, 1991). The throat and chest are marked with geometrical white spots (Kingdon, 2004). Males have short white dorsal crest but no throat beard (Estes, 1991). The greater kudu is reddish brown to blue-gray (darkest in South Africa), males darken with age (Estes, 1991). It has 4-12 vertical white stripes on the flanks (Kingdon, 2004). These animals have prominent nose chevron and small cheek spots, there are no throat or chest patches (Estes, 1991). Both sexes have dark leg garters, black-tipped tail with white underside and dorsal crest, beard is only in males (Estes, 1991). Bongo is bright chestnut (darker on head, neck, chest, belly, and legs). Males darken with age - old individuals are nearly black (Kingdon, 2004). Markings are clearly defined - animals have 12-14 stripes continuing into black-and-white dorsal crest, large white chest crescent and cheek patches, ears edged with white, a broad nose chevron, legs banded black and white. Calves are similar to adults, but they have lighter colour with reduced dark areas and bushy tail (Estes, 1991). The coloration of common eland is individually and geographically variable. General colour is tawny, young are reddish brown. Common eland has 10-16 white stripes, a dark dorsal crest, white markings on legs, and black garters on upper forelegs and around hooves (Estes, 1991). Adult males develop a tuft of dark hair on the forehead and nose, a massive neck, an enlarged dewlap, and a short, curly neck mane. Males turn blue-grey with age (Estes, 1991) and the neck and shoulders darken with the age (Kingdon, 2004). There are three recognized subspecies : *T. o. oryx* is tawny and the adult animals lose their stripes, *T. o. livingstonei* has brown body coloration with 12 and more stripes on the flank, *T. o. pattersonianus* is more reddish with 12 and more stripes (Kingdon, 2004). The Derby eland is richer in colour than the common eland and has more pronounced markings (Estes, 1991). It has 8-12 vertical white stripes on the flanks (Kingdon, 2004). Coloration of body is grey sandy or reddish, the belly has a black stripe from front to back (Wilson and Mittermeier, 2011). Adult males have a black neck (Kingdon, 2004) and they tend to turn grey as they age (Wilson and Mittermeier, 2011). These antelopes have a prominent neck ruff and large rounded ears which are clearly marked (Estes, 1991). Both sexes have a short brown to black spinal mane from the neck to the middle of the back (Wilson and Mittermeier, 2011). They have a dewlap between the chin and chest, it begins on the chin instead of at the throat like in common eland (Estes, 1991). All four legs have two separate garters of white and black just about the hooves and the upper forelegs have a posterior black spot (Wilson and Mittermeier, 2011). There are two recognized subspecies: *Taurotragus derbianus derbianus* is reddish with on average 15 stripes on the flank

(Fig. 1), *Taurotragus derbianus gigas* is grey sandy with 12 stripes on average (Fig. 2) (Kingdon, 2004).



Figure 1. Typical coloration of *Taurotragus derbianus derbianus*, adult male (Bandia reserve in Senegal, 2013).



Figure 2. Adult male of *Taurotragus derbianus gigas* in Cincinnati Zoo, USA. © Jeff Whitlock, 2006. Source: www.theonlinezoo.com

3. Objective

The object of this thesis is firstly to describe the exterior of Derby eland. All the information about the coat pattern are very important for the following work and study of these animals - especially in the case of the western subspecies, because when you know the coat pattern of each animal, you can distinguish the individuals in the herd very well.

Then we would like to analyse the average stripe and colour characteristics of coat pattern in Western Derby eland (WDE) and compare them with Eastern Giant eland (EGE). All designated stripe characteristics are found in both subspecies and we would like to know if the subspecies differ in their number and ratio. With the help of these results we would like to find the difference in the exterior of the subspecies. So our first hypothesis is that the differences between the subspecies would be primarily in the number and characteristics of the stripes.

In the end we would like to estimate the coefficient of heritability (h^2) for quantitative parameters in contrast with environmental variation for the population of Western Derby eland. Our second hypothesis is that the number of stripes and their characteristics would be heritable from the parents to the offspring.

4. Materials and methodology

4.1 Locality and breeding management

In 2000, the first semi-captive Western Derby eland population was established in western Senegal with an objective to establish a viable population in semi-captivity (Nežerková *et al.*, 2004). The conservation programme was launched and has been running till present. The animals are held under shepherd breeding management in two nature reserves - the Bandia and Fathala Reserve (Koláčková *et al.*, 2012).

The Bandia Reserve is a fenced area situated 65 km south-east of Dakar, on the south-western border of the classified forest Bandia (Forêt classée de Bandia) (Nežerková *et al.*, 2004). The Bandia Reserve was the first site where the wild-captured Western Derby elands were placed after the capture operation in 2000. The Fathala Reserve is the fenced area of the Fathala Forest (Forêt de Fathala) situated on the west coast of Senegal, near the northern border of the Gambia (Nežerková *et al.*, 2004). The Fathala Reserve is the second reserve with Western Derby eland semi-captive population, with two breeding herds and one bachelor herd (Koláčková *et al.*, 2012).

The original breeding herd of Western Derby eland consisted of 6 founders (one male and five females), which were captured in the Niokolo Koba National Park in May 2000 and transported to the Bandia Reserve (Antonínová *et al.*, 2004). The reproduction of animals started in 2002 in the Bandia Reserve with 2 female calves born, and in June 2012 the Western Derby eland in semi-captivity formed a population of 83 living individuals (Koláčková *et al.*, 2012).

4.2 Studied animals

The present population of Western Derby eland is divided in 5 breeding herds: three in the Bandia Reserve (Bandia 1: 5 males and 14 females, Bandia 2: 4 males and 9 females, Bandia 3: 3 males and 8 females) and two in the Fathala Reserve (Fathala 1: 2 males and 5 females, Fathala 3: 1 male, 2 females); and two bachelor herds (Bandia 4: 17 males, Fathala 2: 15 males) (Koláčková *et al.*, 2012). Among these are 57 adults (30 males

- four breeding males, 27 females), 14 sub-adults (11 males, 3 females) and 12 calves (6 males, 6 females). A total of 100 offspring were born from 2000 to 2012 (Koláčková *et al.*, 2012).

In the case of Western Derby eland we used the data from African Studbook (published since 2008 by Czech University of Life Sciences Prague and Prague Zoo), where each individual from the captive population in Senegal is photographed from both sides (data from 115 individuals). For a description of EGE we used photographs from various sources with identified locality of origin (92 individuals).

4.3 Data collection and analysis

For description of the coat pattern of Derby eland we used the photographs of both subspecies to determine the pattern characteristics and the colour variations. We counted the number of stripes, number of anomalies in the stripes and we determined coloration of each individual. From analyses of these photographs we designated stripe characteristics for description of each individual.

To distinguish the subspecies, we used the coefficient of difference - CD, (based on the rule of 75% difference between the subspecies, Mayr *et al.*, 1953) for quantitative data: number of stripes on the right and left flank, number of splits of the stripes on back and on belly, number of forks on the stripes on back and on belly, sum of all characters on the left and on the right flank. Then, in programme STATISTICA 10, all the quantitative data were analyzed by using Mann-Whitney U test. And by using Pearson's chi-squared test we analyzed the qualitative data: body coloration, neck coloration, presence of tears under the eyes, shape of spot on the left and right cheek, presence of stripes with arc, visible anomalies, presence of back arc, presence of pre-stripe on the left and right flank. With the use of same test we have also analyzed the dependence of the qualitative data on sex and age.

To determine the coefficient of heritability in population of Western Derby eland it is necessary to know the data of quantitative characters in the parental generation and offspring. To identify the individual animals and the maternity we focused on each animal in particular - using photos from both sides from studbook. Every year the identification of new born calves takes place in both reserves in Senegal. The maternity is confirmed by the mother-calf relationship and by the suckling of a certain calf from a certain female. To

count the coefficient of heritability between parents and offspring, we used linear regression in STATISTICA 10. We performed the linear regression analysis between the diameter of parents and offspring. We also examined the relationship of number of stripes and their characteristics across the maternal lines. In programme STATISTICA 10 we used Kruskal-Wallis test - we counted with five maternal lines named from the initials of founding females: Dalaba, Salémata, Bambou, Malapa and Tamba.

5. Results

Our studied sample had 206 individuals of two subspecies of Derby eland (115 of Western Derby eland and 92 of Eastern Giant eland) and in some characteristics we observed both flanks separately (e.g. number of stripes). In the sample of WDE we had photographs of both flanks in all individuals, while in the animals of eastern subspecies we had available only photographs of one flank. So we had a total of 322 photographs - 164 of the left flank and 158 of the right flank, both subspecies together.

In the studied sample of Derby eland we described 7 possible stripe characteristics - pre-stripe, split on the back, split on the belly, fork on the back, fork on the belly, arc on the back and stripe with arc (Fig. 3). These characteristics were found in both subspecies. Pre-stripe is the first stripe from head, which begins before or on the shoulder blade and ends at the elbow (Fig. 4). Pre-stripe can be separated from other stripes on the chest by a visible gap. The split of the stripe can occur on the back or on the belly of the animal. It is a gradual breakdown of the stripe into two branches (Fig. 5). On the back and belly of the animal the fork on the stripe can also occur - it is a stripe division into three branches, thus creating a kind of fork. Arc on the back is a connection of two stripes (mostly the last stripes on the stern of the animal) into the arc on the upper part (Fig. 6). Stripe with arc does not go straight down from the back to the belly, but there is a clearly visible arc on it. Any differences in banding, which did not fall under these seven categories were described as visible anomaly (Fig. 7). With regard the animal coloration, we described four colour variations: light beige, beige, light red and light brown. We have also defined three colour variants of neck: light brown, brown and black. On the head of the animals we have described two pattern characteristics: tears and spots on the faces (Fig. 8). Tears are small white stripes that start just under the inner corner of the eye and continue until the nasal bone. Regarding the spots on faces - each animal has a small white spots of various shape on both cheeks, we described four options: rounded spot, strip, double spot, ellipsoidal spot.

In the studied sample, the mean number of stripes for WDE on the left flank was 13.79 ± 1.22 SD and on the right flank 13.8 ± 1.15 SD (range 10-17), for EGE on the left flank 13.29 ± 1.35 SD and on the right flank 13.44 ± 1.74 SD (range 10-18). The coefficient of difference (CD), calculated for quantitative data, did not demonstrate a difference

between the subspecies within the studied sample - all the results were below the subspecies border 1.28 (Mayr *et al.*, 1953), therefore the subspecies did not differ in observed characteristics. The quantitative data were also analyzed by using Mann-Whitney U test. There was found a difference between the subspecies in the number of stripes on the left flank (Graph 1 in annexes) - the animals of western subspecies had more stripes (median=14) than the individuals of eastern subspecies (median=13). And there was also found a difference in the number of splits of the stripes on the right flank (Graph 2 in annexes) - bigger number of this characteristic was in the eastern subspecies.

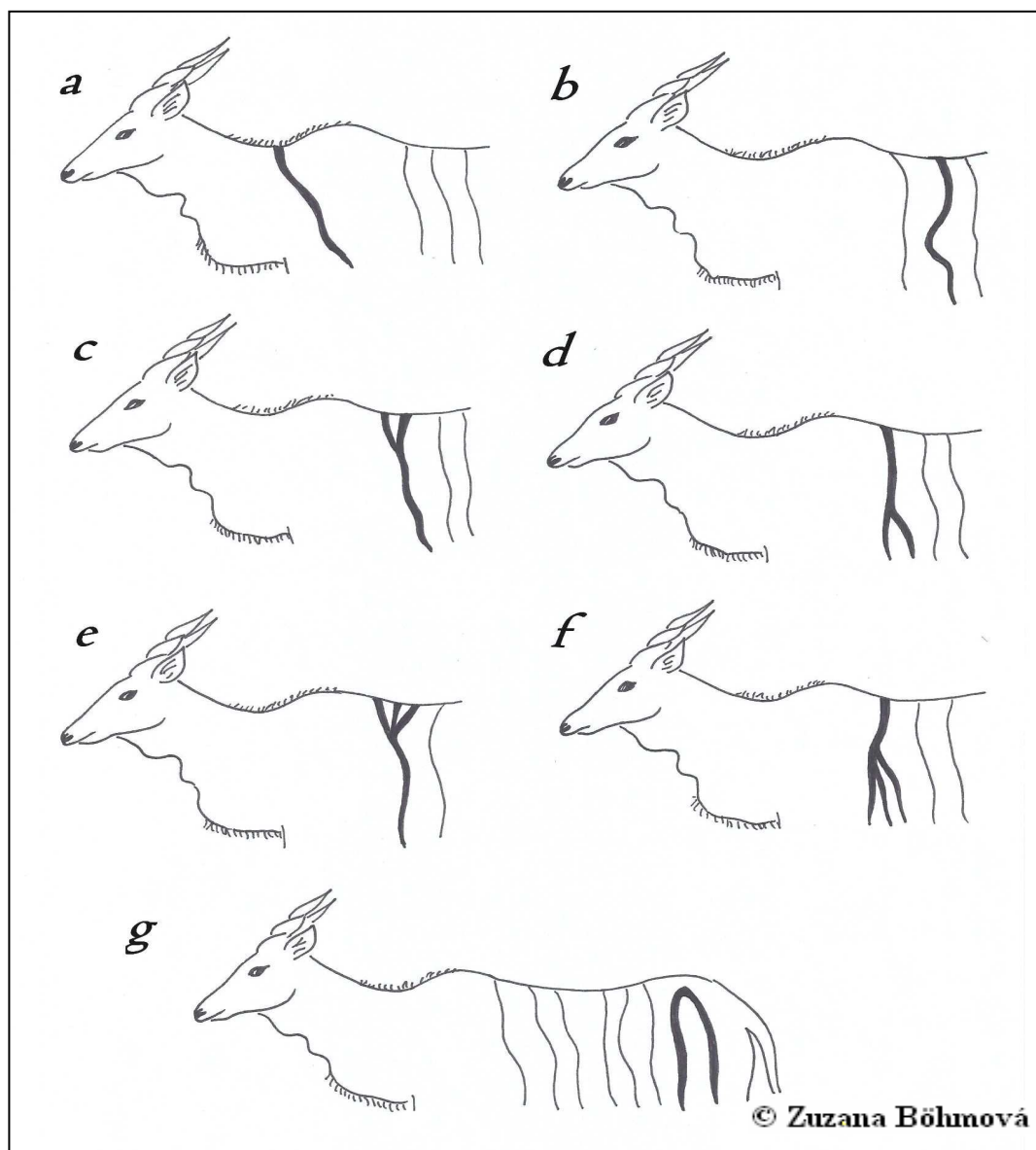


Figure 3. Characteristic of stripes in Derby eland: a – pre-stripe, b – stripe with arc, c – split on the back, d – split on the belly, e – fork on the back, f – fork on the belly, g – arc on the back.

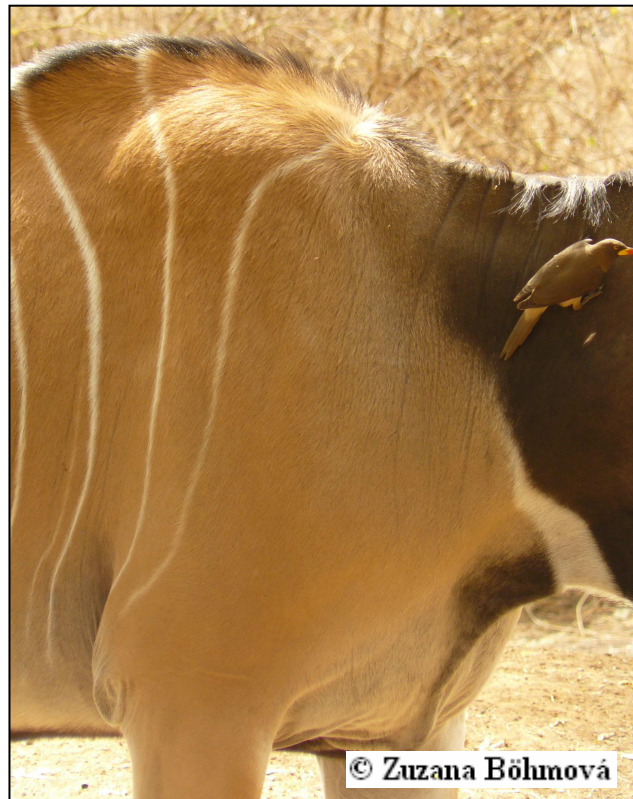


Figure 4. Pre-stripe in Western Derby eland (Bandia reserve in Senegal, 2013).



Figure 5. Split of the stripe on the back, Western Derby eland (Bandia reserve in Senegal, 2013).



Figure 6. Back arc, Western Derby eland (Bandia reserve in Senegal, 2013).



Figure 7. Stripe anomaly, Western Derby eland (Bandia reserve in Senegal, 2013).

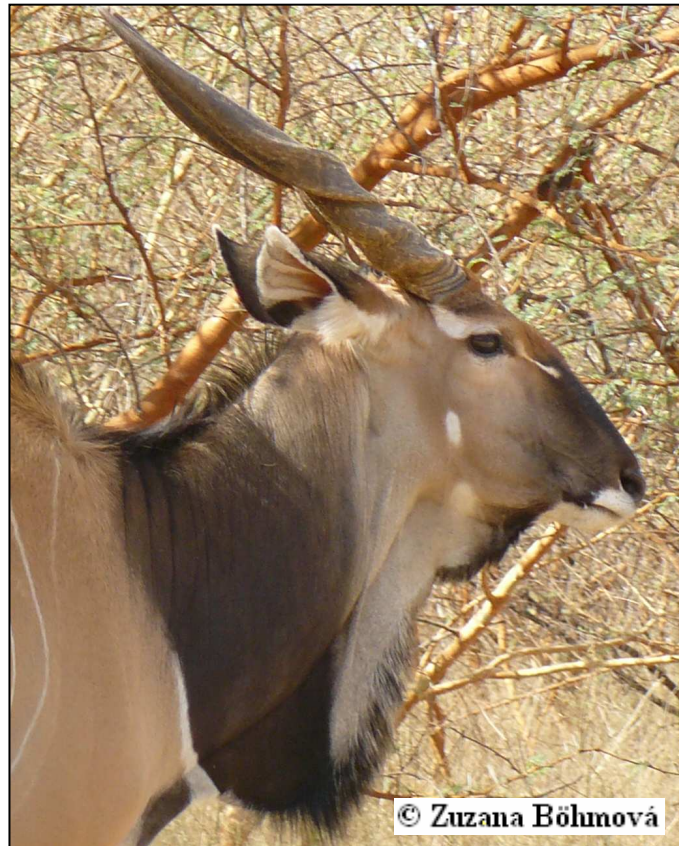
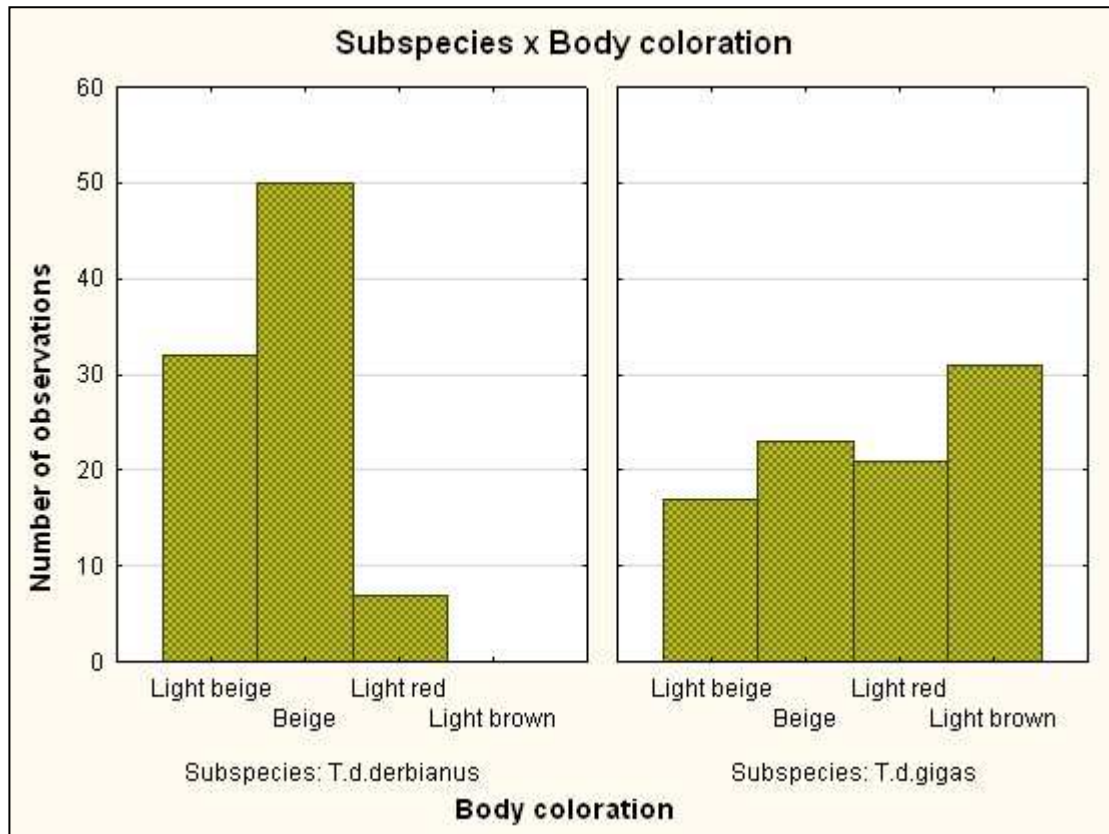


Figure 8. Markings on the head of Western Derby eland – tears and spot on the cheek, adult female (Bandia reserve in Senegal, 2013).

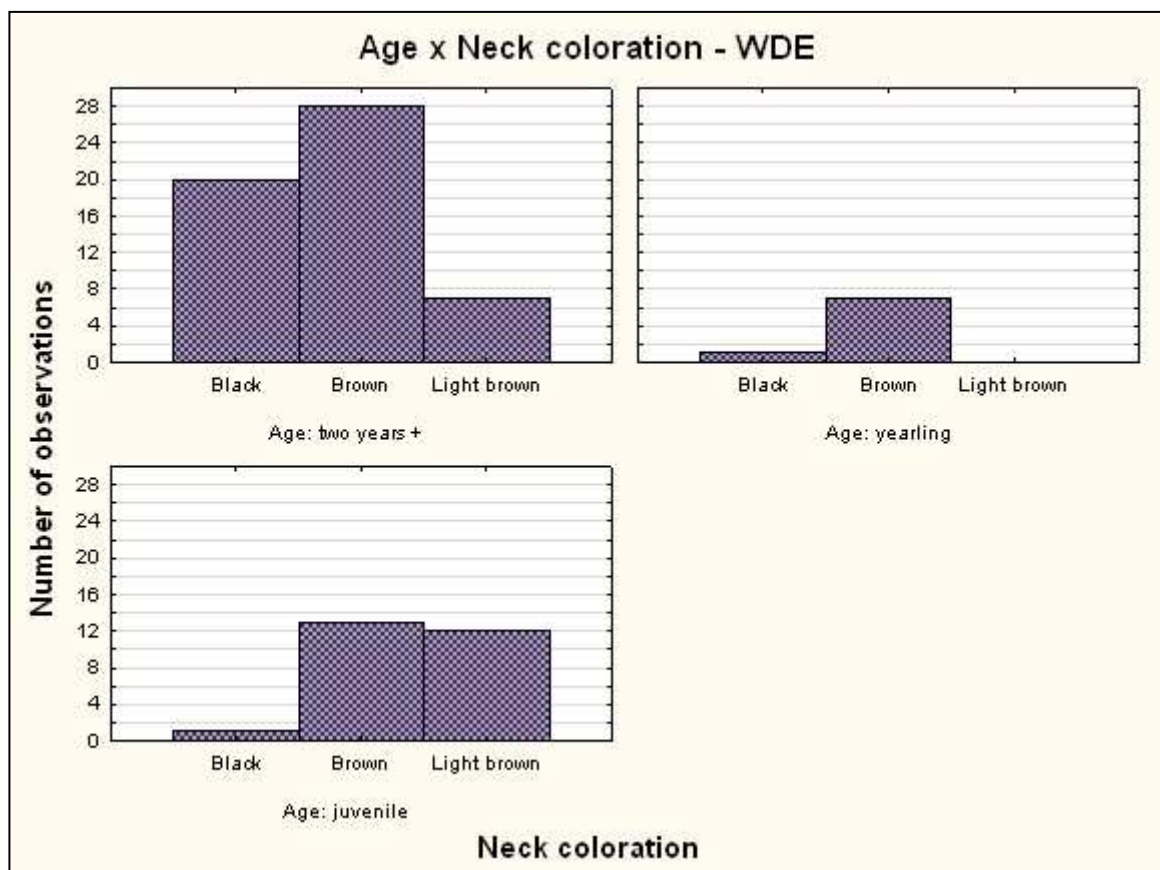
In the results of the descriptive statistics, there were significant differences between the subspecies in the body coloration ($p < 0.001$) (Graph 1). The dominant body colour in WDE was beige, while in EGE the dominant colour was light brown which was not observed in WDE. The individuals of western subspecies had more brown neck than the animals of eastern subspecies which had more often black or light brown neck ($p = 0.0035$) (Graph 3 in annexes). In the EGE there were some individuals without tears under the eyes, while in WDE all the individuals from studied sample had the tears ($p < 0.001$) (Graph 4 in annexes). Regarding the spots on the face, WDE had these spots more ellipsoidal and elongated while EGE more rounded - shape of spot on the left cheek ($p = 0.0017$) (Graph 5 in annexes) and on the right cheek ($p = 0.0001$) (Graph 6 in annexes). In EGE there were not common the stripes with arc ($p = 0.0001$) (Graph 7 in annexes) and also the back arc ($p < 0.001$) (Graph 8 in annexes), in WDE these characteristics were represented more frequently.



Graph 1. Dependence of the body coloration on the subspecies, Pearson's chi-squared test, $p < 0.001$.

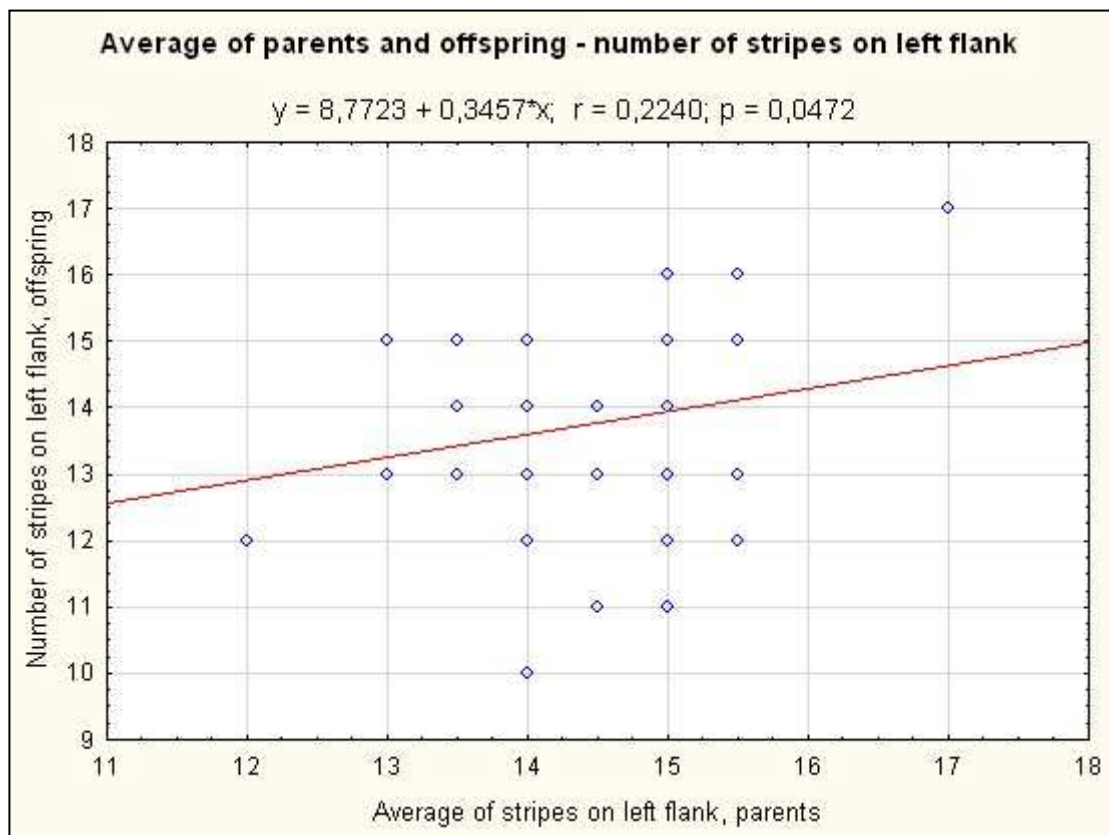
In some characteristics we have confirmed a dependence on sex and age. In subspecies WDE the correlation between age and body coloration ($p = 0.026$) (Graph 9 in annexes), age and neck coloration ($p = 0.0003$) (Graph 2), and between sex and body coloration ($p = 0.0001$) (Graph 10 in annexes) was confirmed. In adults, the ratio between beige and light beige was balanced, while the juveniles had more individuals with beige body coloration and the light beige was minor. On the contrary, in yearlings the predominant colour was light beige. Darker neck coloration was more frequent in older than in young individuals. Black neck was minor in the juveniles and yearlings, while in the adult animals was very common. There was also the correlation between the sex and body coloration - beige was the main body colour in females, while in males the dominant colour was light beige closely followed by beige. In subspecies EGE the correlation between age and body coloration ($p = 0.037$) (Graph 11 in annexes), age and neck coloration ($p = 0.003$) (Graph 12 in annexes), sex and body coloration ($p = 0.006$) (Graph 13 in annexes), sex and neck coloration ($p < 0.001$) (Graph 14 in annexes) and between sex and

the occurrence of tears under the eyes ($p=0.022$) (Graph 15 in annexes) was confirmed. In adults the most common body coloration was light brown and light red, while in juveniles it was beige and in yearlings it was light beige. So we could say that the adults were darker than the young animals. In the case of the correlation between the age and neck coloration the result was clear - in the young individuals the main colour was light brown, while in the adult animals the dominant colour was black and then brown. So darker neck coloration was more frequent in older than in young individuals like in WDE. There was also the correlation between sex and body coloration - females were mostly light red, while males were light brown. Opposed to WDE, at subspecies EGE there was confirmed a correlation between sex and neck coloration and also between sex and the occurrence of the tears under the eyes. Dominant colour of the neck in males was black, while females had mostly light brown neck. And in the case of tears, males had more individuals without tears than females.



Graph 2. Dependence of neck coloration on the age in Western Derby eland, Pearson's chi-squared test , $p=0.000311$.

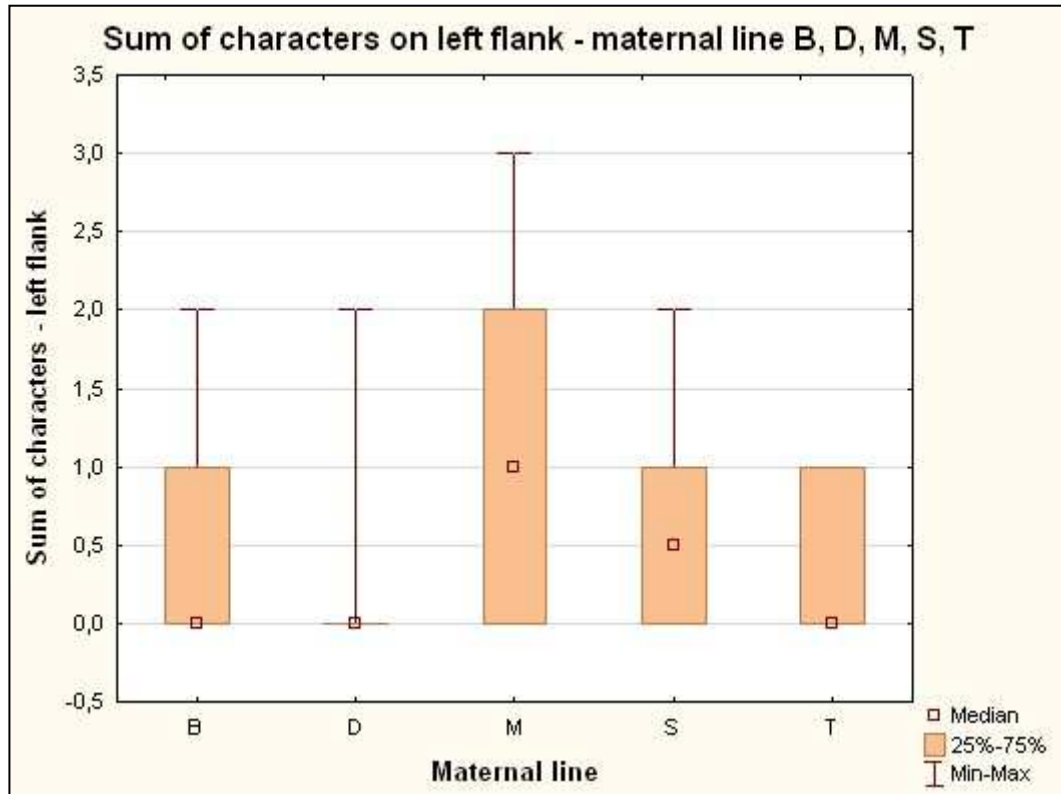
In the case of counting the coefficient of heritability we used the quantitative data from captive population of Western Derby eland. We performed the analysis between the diameter of parents and their offspring - the significant correlation was confirmed in the number of stripes on the left flank ($p=0.0472$) (Graph 3) and in the sum of the stripes on both flanks ($p=0.0279$) (Graph 16 in annexes). But in both cases the coefficient of heritability was very low (in the number of stripes on the left flank $\rightarrow h^2=0.35$ and in the sum of the stripes on both flanks $\rightarrow h^2=0.40$). Thus, the results indicate that we can not confirm that there is a heritability of stripe characters from parents to offspring.



Graph 3. Coefficient of the heritability counted for the number of stripes on the left flank, linear regression, $p=0.0472$.

In the end, we examined the relationship of quantitative data across the five maternal lines – D, S, B, T, M. The significant difference between the maternal lines was confirmed in the number of the splits of stripes on the back ($p=0.0227$) (Graph 4) and in the sum of the stripe characters on the left flank ($p=0.0454$) (Graph 17 in annexes). In both cases, the greatest abundance of these characteristics was found in the maternal line M - so

the biggest number of the splits on the back and of the stripe characteristics on the left flank can be found in animals from the maternal line after the female Malapa.



Graph 4. Dependence of sum of the characters on the left flank on the maternal line, Western Derby eland, Kruskal-Wallis test, $p = 0.0454$.

6. Discussion

The description of Derby eland in the scientific literature is not unified. Some characteristics are consistent, but we can find some descriptions with pronounced differences. The description of the body coloration is mostly identical - from tawny (Akakpo *et al.*, 2004) and reddish to grey sandy (Kingdon, 2004). It is problematic to observe the body coloration in Derby eland, because it can be affected by the subspecies, age and sex as we described in our results but also by the condition of the animal and by the season and climatic conditions, which can be affected also by the different area of distribution. For example according to Kingdon (2004) the adult males have black neck - this contention can be confirmed by our results that the neck coloration darkens with the age.

In Western Derby eland the number of stripes remains the same since the birth of the animal, and by the age does not change (Akakpo *et al.*, 2004), so it can be possible that the same principle can be found also in the eastern subspecies. In both subspecies of Derby eland we described the stripe pattern and the stripe characteristics. Thanks to these features it could be easier to observe the animals which live in large herds and at the first glance they appear to be very similar. The recognition of the individuals can be very important especially in the case of critically endangered western subspecies. It can be used in the manipulation with the animals - in the creation and management of the breeding herds, in the transfers of animals and veterinary procedures (Koláčková *et al.*, 2011).

Then we counted the number of stripes of Derby eland and our results do not match with the number of stripes indicated in the scientific literature. According to Wagner (1855) both subspecies have the bright white stripes, which are in EGE brighter in front of the body than in the rear, while in WDE they are clear anywhere. But he determined the number of stripes together for the *Taurotragus* sp. (*oryx* and *derbianus*). He described 2-15 white stripes on the flank and he claimed that the northern subspecies had more and clearer stripes than the southern subspecies. According to Kingdon (2004) the Derby eland has 8-12 vertical white stripes on the flanks. But according to our results the minimum number of the stripes was 10 and the maximum was 18 (this extreme was observed on the right flank of one animal of the eastern subspecies). So the normal range of the number of stripes in our studied sample was 10-17. We can also find the differences in the number of stripes

between the subspecies. Kingdon (2004) states that the Western Derby eland has on average 15 stripes on the flank and the Eastern Giant eland has 12 stripes on average. According to Wilson and Mittermeier (2011) the individuals of western population tend to be richer in colour and they have 14-15 stripes, while the individuals of eastern population have only 12 stripes. Gray (1847) also claimed that the western subspecies has 14 or 15 narrow perpendicular white stripes on each side of the body. But in other article dealing with the western subspecies (Akakpo *et al.*,2004) we can find that the number of stripes of this subspecies is 11-16 and the most common range is between 13 and 15. Our results can confirm the assertion of Kingdon (2004) and Wilson and Mittermeier (2011) that the western subspecies has more stripes than the eastern. In our studied sample the mean number of stripes was 14 on flank in WDE and in the case of EGE the mean number was 13 stripes on flank.

According to Groves and Grubb (2011) there were no morphometric differences among the subspecies (they compared the samples from Sudan, Central Africa and West Africa) and their inspection of photos showed no consistent external differences. Thus they assumed that all giant elands, from Gambia to the Nile, would be taxonomically the same. In our results the coefficient of difference did not demonstrate a significant difference between the subspecies. However, the next results showed the differences not only in the number of stripes on the left flank and in the number of splits of the stripes on the right flank but also in some other coat patterns. Regarding the stripe pattern in EGE there were not common the stripes with arc and also the back arc was not very frequent. While in WDE the back arc is very frequent in the observed population. So can we say that the stripe anomalies are more common in WDE? Not so quite. There was found one difference where the eastern subspecies dominated - it was in the number of splits of the stripes on the right flank (bigger number of this characteristic was found in EGE).

In WDE all the individuals from our studied sample had the tears, while in the EGE there were some individuals without tears under the eyes. In our studied sample of EGE we observed a lot of old males which were killed as trophy animals. The absence of tears under the eyes was described mainly in the photographs of these older males, so it is possible that the darkening of the coloration affected by the age can be reflected also by the loss of white tears under the eyes in this subspecies. In the case of spots on the face we have also found a difference between the subspecies. Wagner (1855) mentioned the spots on the cheeks in both subspecies and the shape of these spots described as rounded in EGE

and oblong in WDE. We can confirm this assertion by our results, where the WDE had these spots more ellipsoidal and elongated while EGE more rounded. In summary, we could say that the differences between the subspecies are visible also in the coloration of the head.

Of course the data and results can be affected by many factors. The body and neck coloration and some markings like the tears under the eyes and spots on the cheeks can depend on the animal's age, sex or condition and also on the climatic period. All the data were taken from the photographs so there is also possibility that the data (especially the body and neck coloration) are affected by the quality of the photographs and the conditions in which they were taken. And in the case of the back arc, there is a possibility, that the data in EGE are undervalued - it can be affected by the poor quality of some photographs and because there was not optimal visibility on the back of the animal in some photographs of this subspecies.

In the captive population of Western Derby eland we counted the coefficient of heritability. By this method we wanted to ascertain if the number of stripes and their characteristics is inherited from the parents to the offspring. For example in some breeds of horses the primitive markings (so-called zebra markings) are very common, characteristic for the primitive horses like Norwegian Fjords, Icelandic horses, Hutzul horses or Przewalsky horses but they also occur in low frequencies among warm- and cold-blooded breeds, such as Quarter horses (Stachurska, 1999). And according to the study of Stachurska (1999) the markings on front legs in the horses seem to be inherited in a dominant way. But the inheritance of other forms of the markings (e.g. the dorsal stripe) is not clear. Several genes may produce the stripes on the neck and shoulder, as well as on the forehead. In the case of Western Derby eland there would be also the possibility to determine the parents of the calves by the stripe characters which are inherited - so the exterior of calf would be similar to that of the mother or sire. The related individuals often have similar phenotypes, however Kruuk and Hadfield (2007) alleged that these similarities may be due to the effects of shared environments as much as to the effects of shared genes. And from our results of the coefficient of heritability in the population of Western Derby eland we can not confirm that there is a heritability of stripe characters from parents to offspring.

Our calculations did not confirm any relation between the parents and offspring in exterior. Can we say that the coat pattern in Western Derby eland is not heritable? We have

examined the relationship of stripe characteristics across the maternal lines. We thought, that these results could also tell something about the inheritance of coat pattern. From the five maternal lines (D, S, B, T, M) the greatest abundance of the number of the splits of stripes on the back and of the sum of the stripe characters on the left flank was found in the maternal line M (after the female Malapa) even though this founder female had only one split on the belly. From this result we can say that some stripe characteristics are inherited from the mother to the offspring and there can be also a possibility that these characters are inherited from the sire.

The results of the external difference between the subspecies can be also affected by the genetic factors. We have detected that there is a possibility that the stripe characteristics and their number are inherited from the parents to the offspring in WDE. But in the founding of this captive population there were only 6 animals (Antonínová *et al.*, 2004). So there is a problem, that these six founders could bring into the present population some characteristics which are not typical for the whole population of Western Derby eland. Based on this fact, we can speculate if the data are not affected by the low genetic variation in the western subspecies, and if there is a possibility that we compared the eastern subspecies only with a small cutout of western population that may not be a typical and representative.

7. Conclusion

We described the exterior of Derby eland in both subspecies and we analysed the average stripe and colour characteristics of coat pattern in WDE and compared it with EGE. But our first hypothesis that the differences between the subspecies would be primarily in the number and characteristics of the stripes was not confirmed. The results showed that the differences in the quantitative data were only in the number of stripes on the left flank and in the number of splits of the stripes on the right flank. The difference between the subspecies was predominantly found in the qualitative data. We found significant differences in the body coloration, neck coloration, presence of the tears under the eyes, the shape of the spots on the cheeks, the presence of the arc on the stripes and in the presence of the back arc.

Then we calculated the coefficient of heritability (h^2) for quantitative parameters in the population of Western Derby eland. Our second hypothesis was that the number of stripes and their characteristics would be heritable from the parents to the offspring in this population. The significant correlation was confirmed in the number of stripes on the left flank and in the sum of the stripes on both flanks. But in both cases the coefficient of heritability was very low so from these results we cannot confirm that the stripe characteristics are inherited from parents to offspring. We also examined the relationship of quantitative data across five maternal lines. The significant difference was confirmed in the number of the splits of stripes on the back and in the sum of the stripe characters on the left flank. The greatest abundance of these characteristics was found in the maternal line M - after the female Malapa. These results support our hypothesis, so there could be a possibility, that some stripe characteristics are inherited from the parents to offspring.

8. References

Akakpo A J, Al Ogoumrabe N, Bakou S, Bada-Alambéji R, Ndiaye S. 2004. Essai d'élevage de l'Eland de Derby (*Taurotragus derbianus derbianus*) à la Réserve de faune de Bandia: Prélude à une opération de sauvegarde de cette espèce au Sénégal. *Revue Africaine de Santé et de Productions Animales*, 2 (3-4): 257-261.

Alvarez F, Braza F, Norzagaray A. 1976. The use of the rump patch in the fallow deer (*D. dama*). *Behaviour*, 56: 298–308.

Barsh G S. 2006. Regulation of pigment type switching by Agouti, melanocortin signaling, Attractin and Mahoganoid. In: Nordlund J, Boissy R, Hearing V (eds). *The pigmentary system: physiology and pathophysiology*. Malden, USA. Blackwell Publishing Inc., 2: 395 pp.

Belk M C, Smith M H. 1996. Pelage coloration in oldfield mice (*Peromyscus polionotus*): Antipredator adaptation? *Journal of Mammalogy*, 77: 882–890.

Berry P S M. 1973. The Luangwa Valley giraffe. *Puku*, 7: 71–92.

Burt E H Jr. 1981. The adaptiveness of colors. *BioScience*, 31: 723–729.

Caro T M. 1995. Pursuit-deterrence revisited. *Trends in Ecology and Evolution*, 10: 500–503.

Caro T M. 2005. The Adaptive Significance of Coloration in Mammals. *BioScience*, 55 (2): 125-136.

Caro T M. 2009. Contrasting coloration in terrestrial mammals. *Phil. Trans. R. Soc. B*, 364: 537–548.

Cott H B. 1966. *Colouration in Animals*. Methuen, London, UK.

De Boer W F, Prins H H T. 1990. Large herbivores that strive mightily but eat and drink as friends. *Oecologia*, 82: 264–274.

Eizirik E, David V A, Buckley-Beason V, Roelke M E, Schaffer A A, Hannah S S, Narfström K, O'Brien S J, Menotti-Raymond M. 2010. Defining and mapping mammalian coat pattern genes: multiple genomic regions implicated in domestic cat stripes and spots. *Genetics*, 184: 267-275.

Endler J A. 1978. A predator's view of animal colour patterns. *Evolutionary Biology*, 11: 319–364.

Endler J A. 1990. On the measurement and classification of colour in studies of animal colour patterns. *Biological Journal of the Linnean Society*, 41: 315–352.

Estes R D. 1991. The behaviour guide to African mammals including hoofed mammals, carnivores, primates. University of California Press, California, 611 pp.

FitzGibbon C D, Fanshawe J. 1988. Stotting in Thomson's gazelles: An honest signal of condition. *Behavioral Ecology and Sociobiology*, 23: 69–74.

Geist V. 1987. On the evolution of optical signals in deer: a preliminary analysis. In: Wemmer C M (ed.). *Biology and management of the Cervidae*. Washington, DC. Smithsonian Institution Press, pp 235–255.

Gibson G. 1992. Do tsetse flies 'see' zebras? A field study of the visual response of tsetse to striped targets. *Physiological Entomology*, 17: 141–147.

Graván C P, Lahoz-Beltra R. 2004. Evolving morphogenetic fields in the zebra skin pattern based on Turing's morphogen hypothesis. *Int. J. Appl. Math. Comput. Sci.*, 14 (3): 351-361.

Gray J E. 1847. Description of a new species of Antelope from West Africa. In: Jardine W, Selby P J, Johnston G, Babington C C, Balfour J H, Taylor R. The Annals and Magazine of Natural History. London, 2 (20): 286.

Groves C P, Bell C H. 2004. New investigations on the taxonomy of the zebras genus *Equus*, subgenus *Hippotigris*. *Mamm. Biol.*, 69: 182–196.

Groves C, Grubb P. 2011. *Ungulate Taxonomy*. Baltimore, Maryland. Johns Hopkins University Press, pp 142–143.

Heuglin M T. 1864. Über die Antilopes und Büffel Nordost Africa's, und Beiträge zur Zoologie Africa's. *Novorum Actorum Academiae Caesareae Leopoldino-Carolinae germanicae Naturae Curiosorum*, 30 (2): 1–32.

Higuchi R G, Wrischnik L A, Oakes E, George M, Tong B, Wilson A C. 1987. Mitochondrial DNA of the extinct quagga: relatedness and extent of postmortem change. *Journal of Molecular Evolution*, 25: 283–287.

Hoekstra H E. 2006. Genetics, development and evolution of adaptive pigmentation in vertebrates. *Heredity*, 97: 222–234.

Kiltie R A. 1988. Countershading: Universally deceptive or deceptively universal? *Trends in Ecology and Evolution*, 3: 21–23.

Klein R G, Cruz-Uribe K. 1999. Craniometry of the genus *Equus* and the taxonomic affinities of the extinct South African quagga. *S. Afr. J. Sci.*, 95: 81–86.

Koláčková K, Hejčmanová P, Antonínová M, Brandl P. 2011. Population management as a tool in the recovery of the critically endangered Western Derby eland *Taurotragus derbianus* in Senegal, Africa. *Wildlife Biology*, 17(3): 299- 310.

Koláčková K, Haberová T, Vymyslická P, Žáčková M, Hejzmanová P, Brandl P. 2012. African Studbook. Western Derby Eland, *Taurotragus derbianus derbianus* (Gray, 1847). Czech University of Life Sciences Prague, 5: 103 pp.

Kruuk L E B, Hadfield J D. 2007. How to separate genetic and environmental causes of similarity between relatives. *J. Evol. Biol.*, 20: 1890–1903.

Leonard J A, Rohland N, Glaberman S, Fleischer R C, Caccone A, Michael Hofreiter M. 2005. A rapid loss of stripes: the evolutionary history of the extinct quagga. *Biology Letters*, 1: 291-295.

Ljetoff M, Folstad I, Skarstein F, Yoccoz N G. 2007. Zebra stripes as an amplifier of individual quality? *Ann. Zool. Fennici*, 44: 368-376.

Majerus M E N, Mundy N I. 2003. Mammalian melanism: natural selection in black and white. *Trends in Genetics*, 19 (11): 585-588.

Mayr E, Lynsey G E, Usinger R L. 1953. *Methods and Principles of Systematic Zoology*. New York – London. McGraw-Hill Book Company, pp 328.

McLeod D N K. 1987. Zebra stripes. *New Scientist*, 115: 68.

Merilaita S. 1998. Crypsis through disruptive coloration in an isopod. *Proceedings. Biological Sciences*, 265: 1059–1064.

Mills M G, Patterson L B. 2009. Not just black and white: Pigment pattern development and evolution in vertebrates. *Semin Cell Dev Biol.*, 1-10.

Mitchell G, Skinner J D. 2003. On the origin, evolution and phylogeny of giraffes *Giraffa camelopardalis*. *Transactions of the Royal Society of South Africa*, 58 (1): 51–73.

Morris D. 1990. *A Field Guide to Animal Behaviour*. Animal Watching. Jonathan Cape, London, UK.

- Ortolani A, Caro T M. 1996. The adaptive significance of color patterns in carnivores: Phylogenetic tests of classic hypotheses. *Carnivore Behavior, Ecology, and Evolution*, Ithaca (NY): Comstock Press, 132–188
- Pagel M. 1994. The evolution of conspicuous oestrous advertisement in Old World monkeys. *Animal Behaviour*, 47: 1333–1341.
- Prum R O, Torres R H. 2004. Structural colouration of mammalian skin: convergent evolution of coherently scattering dermal collagen arrays. *The Journal of Experimental Biology*, 207: 2157-2172.
- Renaud P C, Gueye M B, Hejcmanová P, Antonínová M, Samb M. 2006. Inventaire aérien et terrestre de la faune et relevé des pressions au Parc National du Niokolo Koba. Plan d'Urgence, Rapport Annexe A. Dakar, APF, DPNS, Senegal.
- Vaughan T A. 1986. *Mammology*. North Arizona University, Flagstaff. 3rd edn.
- Ruxton G D. 2002. The possible fitness benefits of striped coat coloration for zebra. *Mammal Review*, 32 (4): 237–244.
- Skinner J D, Smithers R H N. 1990. *The mammals of the Southern African Sub-region*. University of Pretoria, 2: 604–607.
- Stachurska A M. 1999. Inheritance of primitive markings in horses. *J. Anim. Breed. Genet.*, 116: 29–38.
- Stankowich T, Coss R G. 2007. The re-emergence of felid camouflage with the decay of predator recognition in deer under relaxed selection. *Proc. R. Soc. B*, 274: 175-182.
- Stoner C J, Caro T M, Graham C M. 2003. Ecological and behavioral correlates of coloration in artiodactyls: Systematic analyses of conventional hypotheses. *Behavioral Ecology*, 14 (6): 823–840.

Waage J K. 1981. How the zebra got its stripes – biting flies as selective agents in the evolution of zebra colouration. *Journal of the Society of Southern Africa*, 44: 351–358.

Wagner J A. 1855. Untergattung – *Taurotragus*. In: Helmcke J G, Von Lengerken H, Starck D, Wermuth H. 1963. *Handbuch der Zoologie – eine Naturgeschichte der Stämme des Tierreiches*. Berlin, Walter de Gruyter and co., 167 pp.

Walsberg G E. 1983. Coat color and solar heat gain in animals. *BioScience*, 33: 88–91.

West P M, Packer C. 2002. Sexual selection, temperature, and the lion's mane. *Science*, 297: 1339–1343.

Wilson D E, Mittermeier, R A (eds). 2011. *Handbook of the Mammals of the World*. Vol. 2. Hoofed Mammals. Barcelona. Lynx Edicions, pp 617-618.

Wilson D E, Reeder D M (eds). 2005. *Mammals species of the world: A taxonomic and geographic reference*. Baltimore (Maryland), USA. The Johns Hopkins University Press, 2142 pp.

Internet sources:

IUCN SSC Antelope Specialist Group 2008. *Tragelaphus derbianus*. [online] In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2. <www.iucnredlist.org>. Downloaded 20 November 2012.

Annexes



Figure 1. Split of the pre-stripe on the back, Western Derby eland (Bandia reserve in Senegal, 2013).



Figure 2. Split of the stripe on belly, one-year male of Western Derby eland (Bandia reserve in Senegal, 2013).

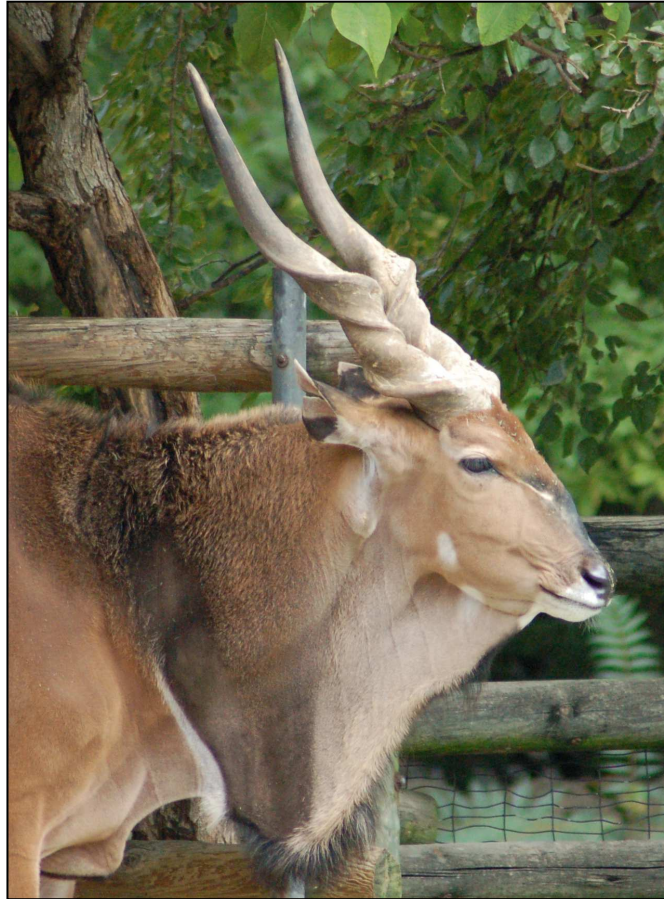
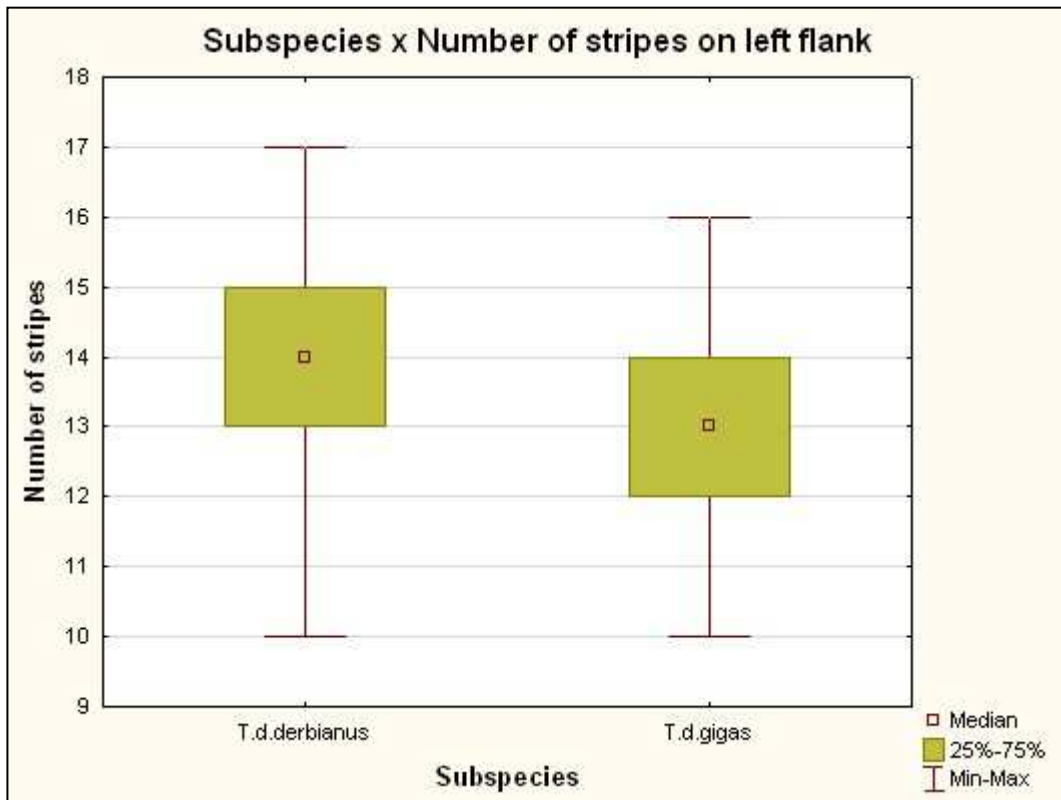


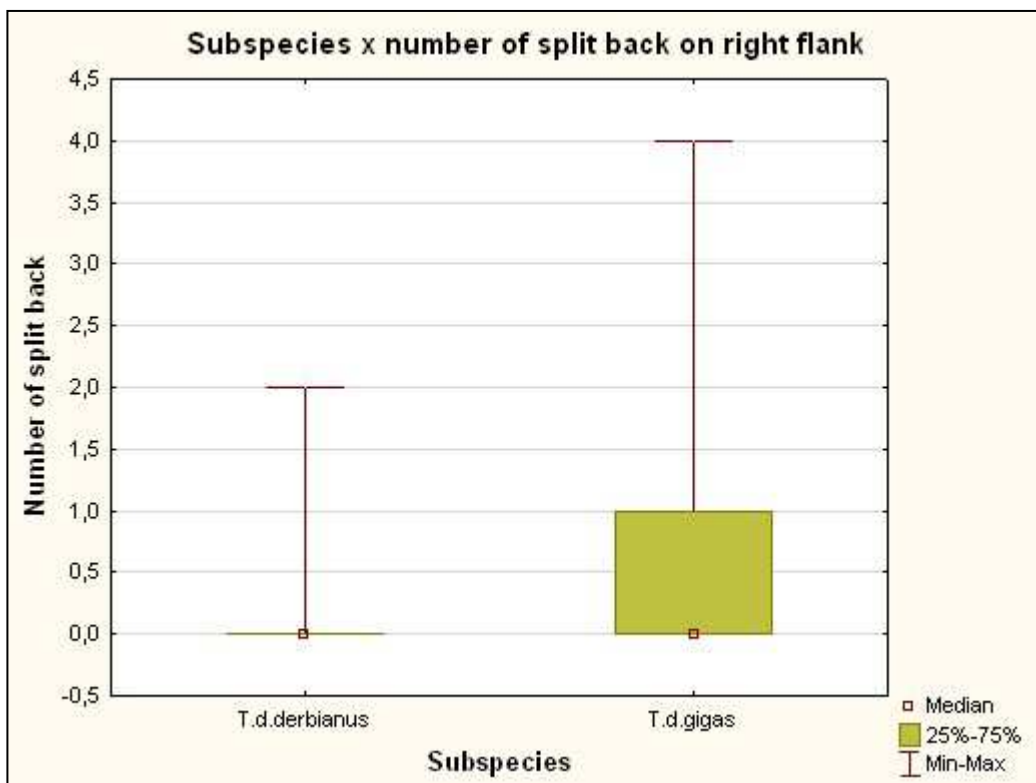
Figure 3. Markings on the head of Eastern Giant eland – tears and spot on the cheek, adult male in Cincinnati Zoo, USA. © Jeff Whitlock, 2006. Source: www.theonlinezoo.com



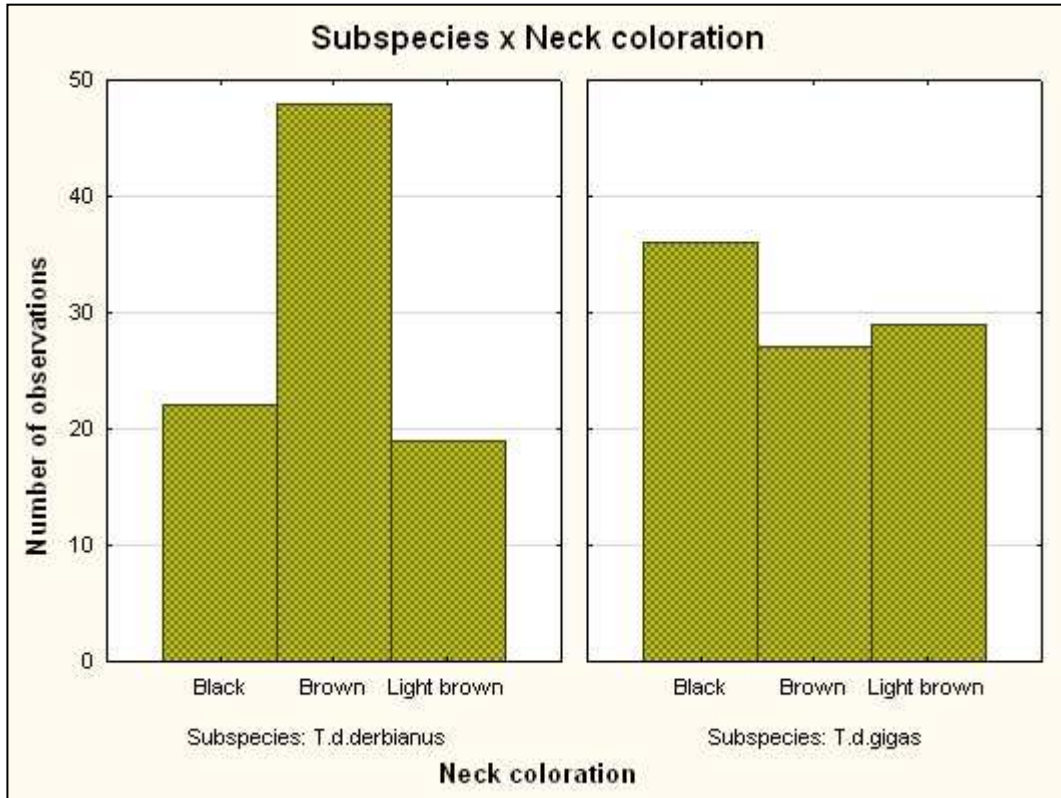
Figure 4. Adult females of Eastern Giant eland in Cincinnati Zoo, USA. © Jeff Whitlock, 2006. Source: www.theonlinezoo.com



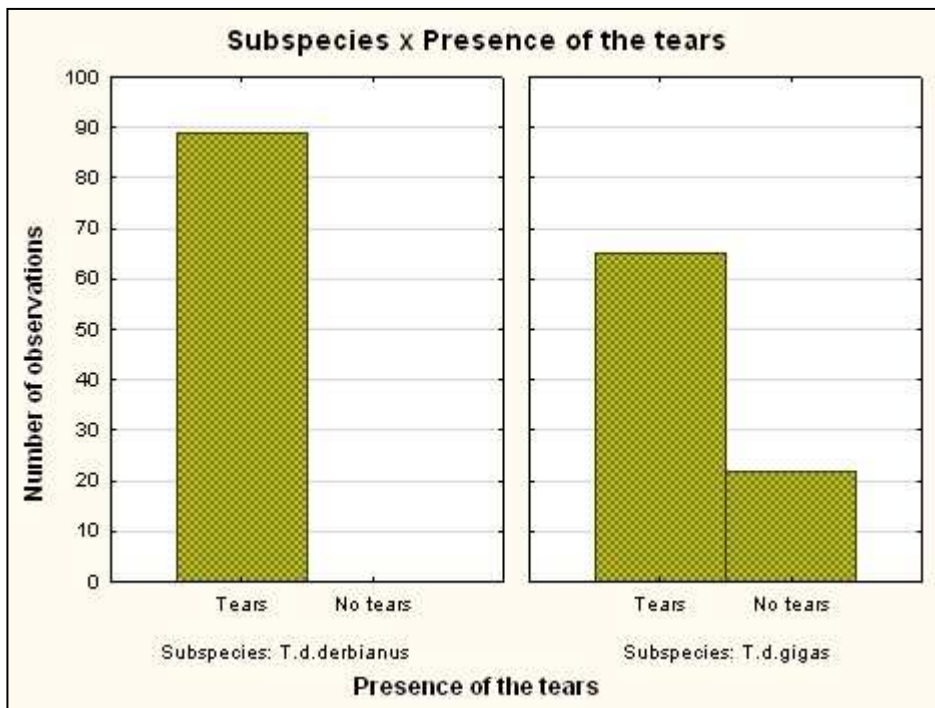
Graph 1. Dependence of the number of stripes on the left flank on the subspecies, Mann-Whitney U test, $p=0.032553$.



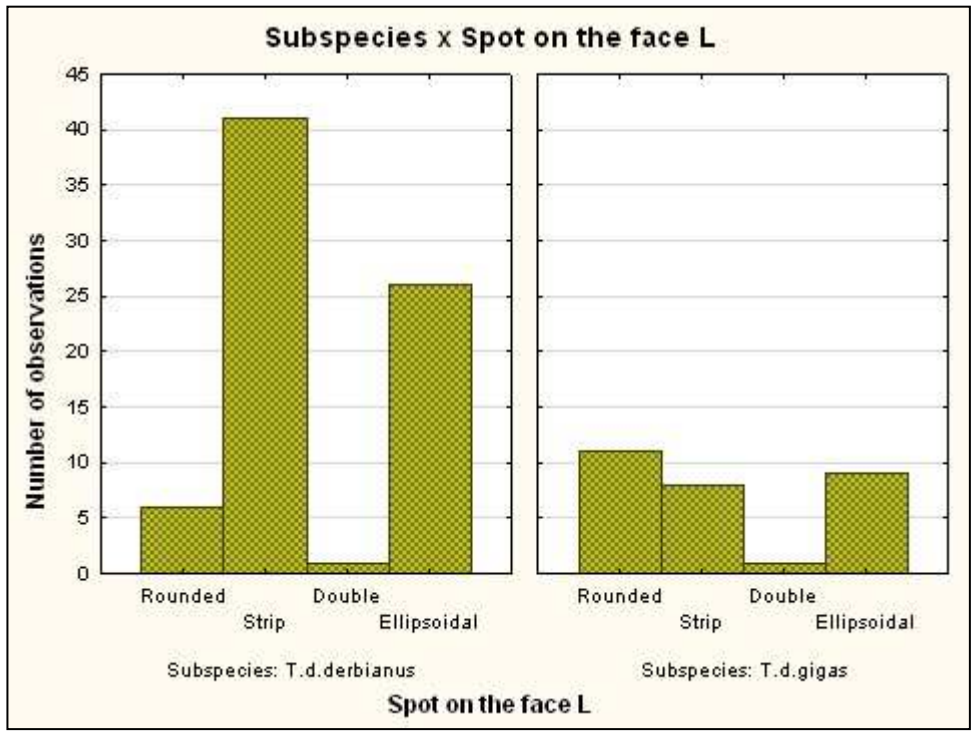
Graph 2. Dependence of the number of splits of the stripes on the back (the right flank) on the subspecies, Mann-Whitney U test, $p= 0.048089$.



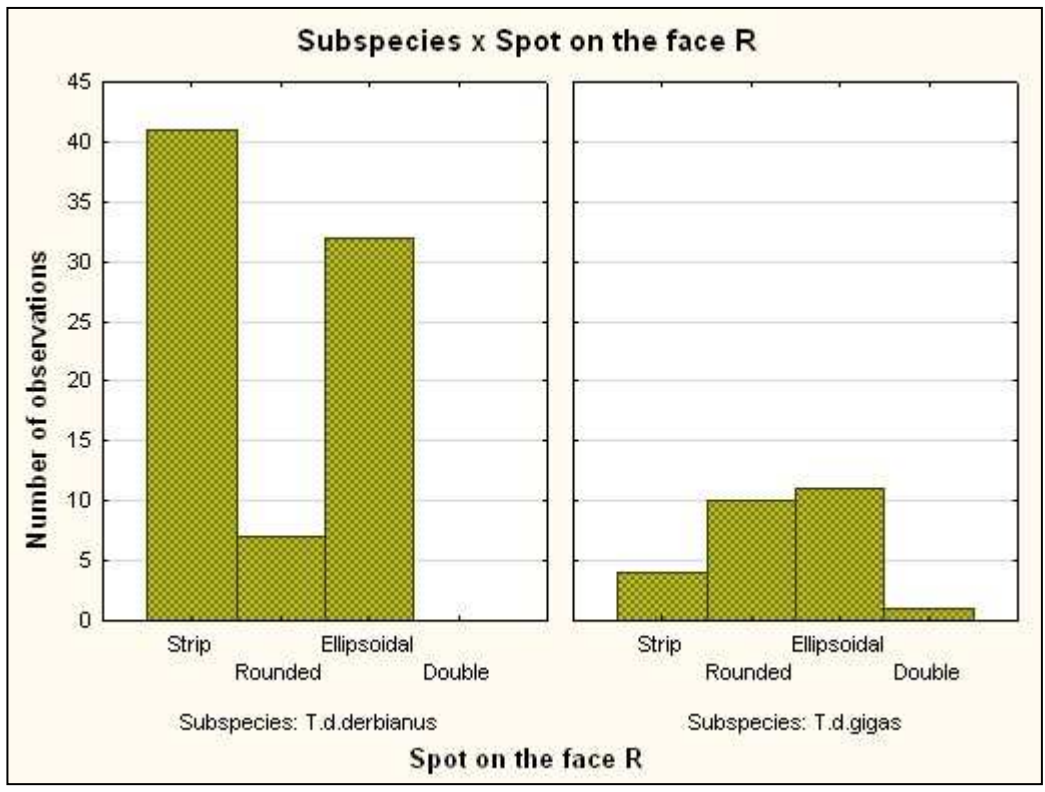
Graph 3. Dependence of neck coloration on the subspecies, Pearson's chi-squared test, $p=0.003525$.



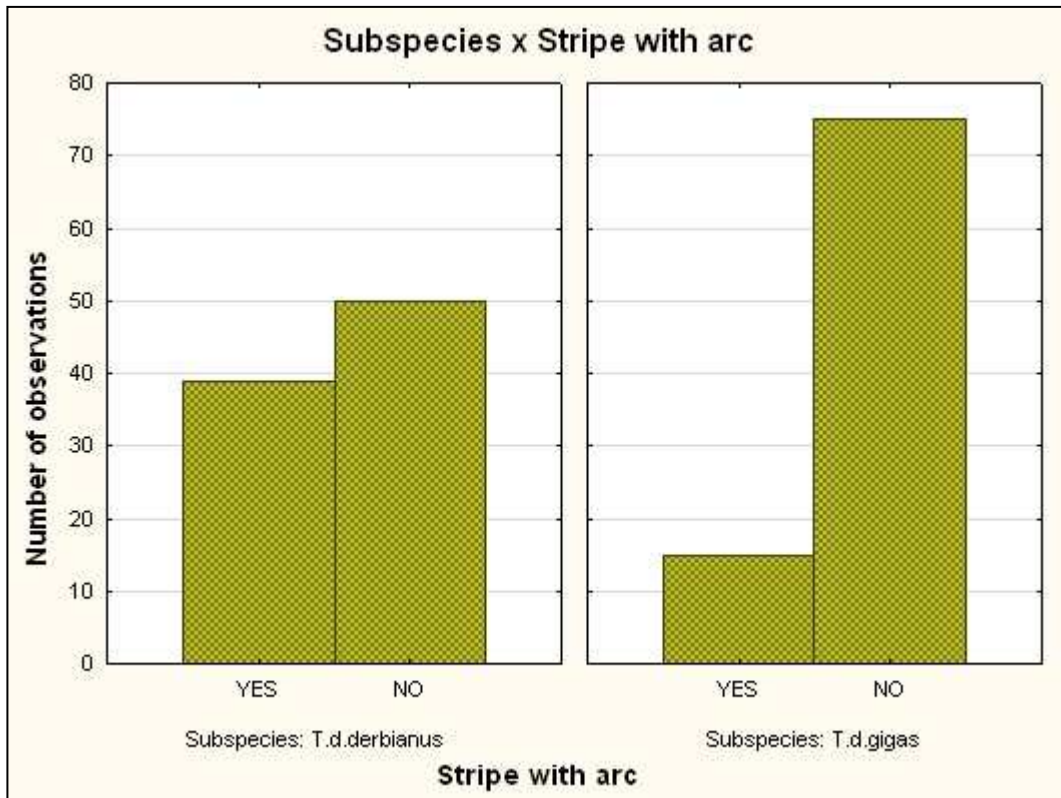
Graph 4. Dependence of the presence of tears under the eyes on the subspecies, Pearson's chi-squared test, $p<0.001$.



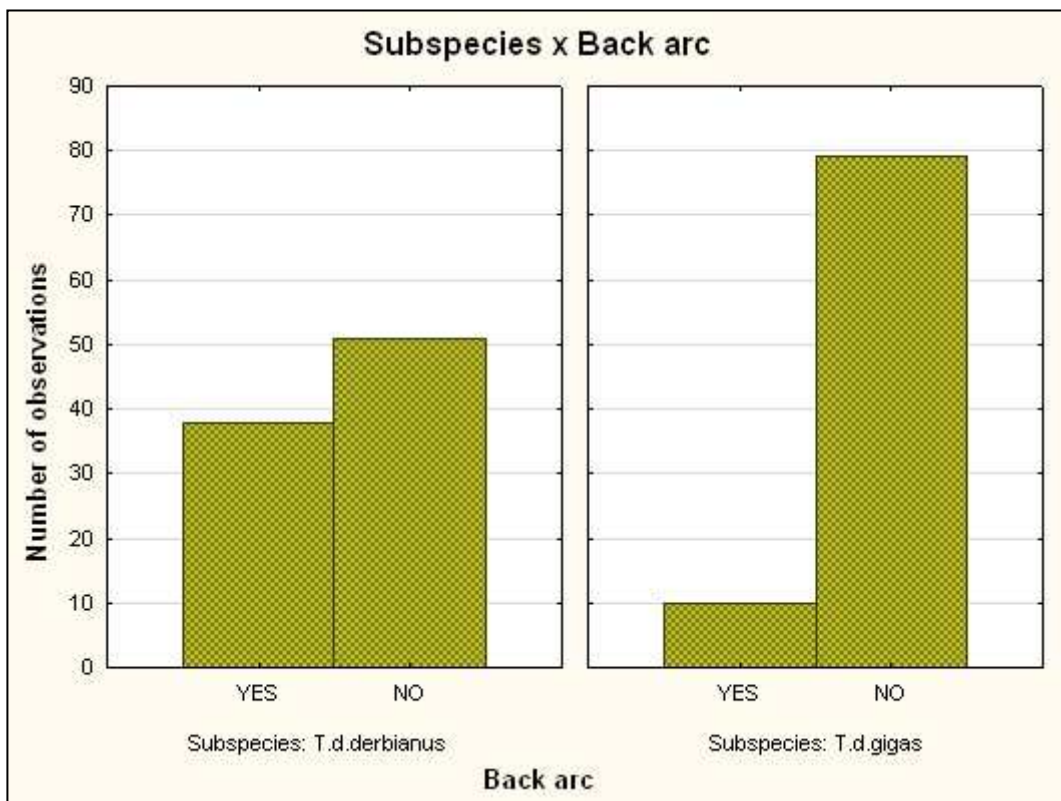
Graph 5. Dependence of the spot on left face on the subspecies, Pearson's chi-squared test, $p=0.001660$.



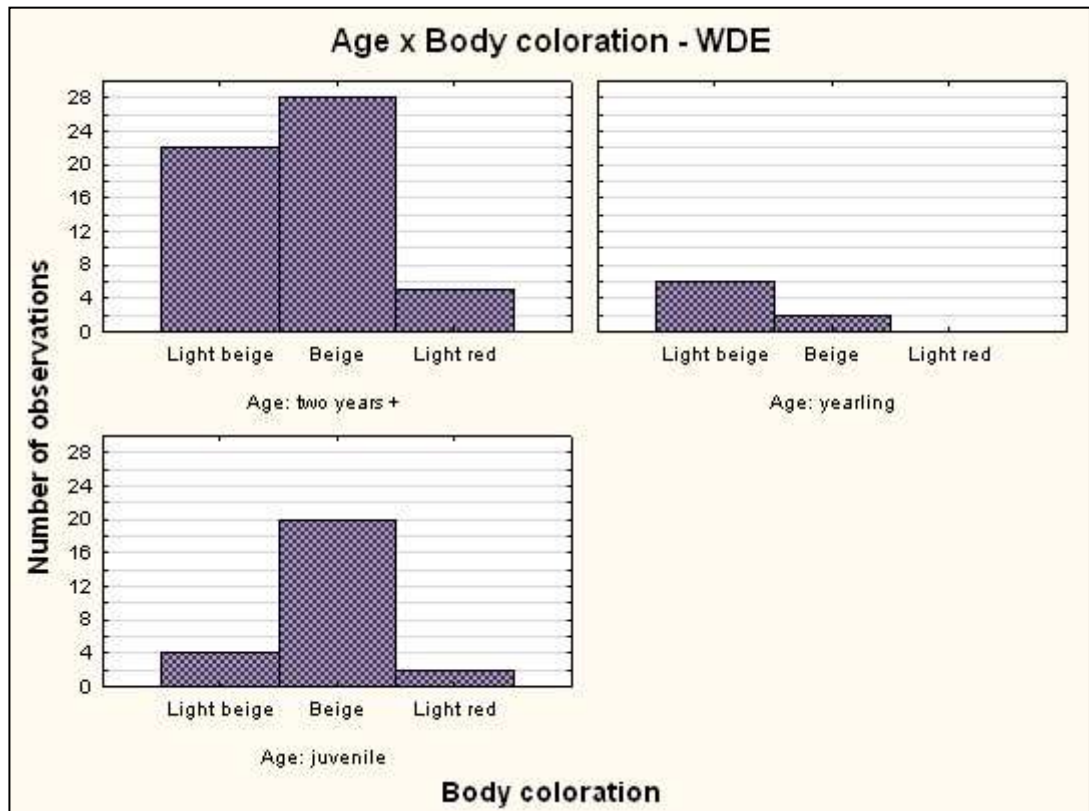
Graph 6. Dependence of the spots on the right face on the subspecies, Pearson's chi-squared test, $p=0.000182$.



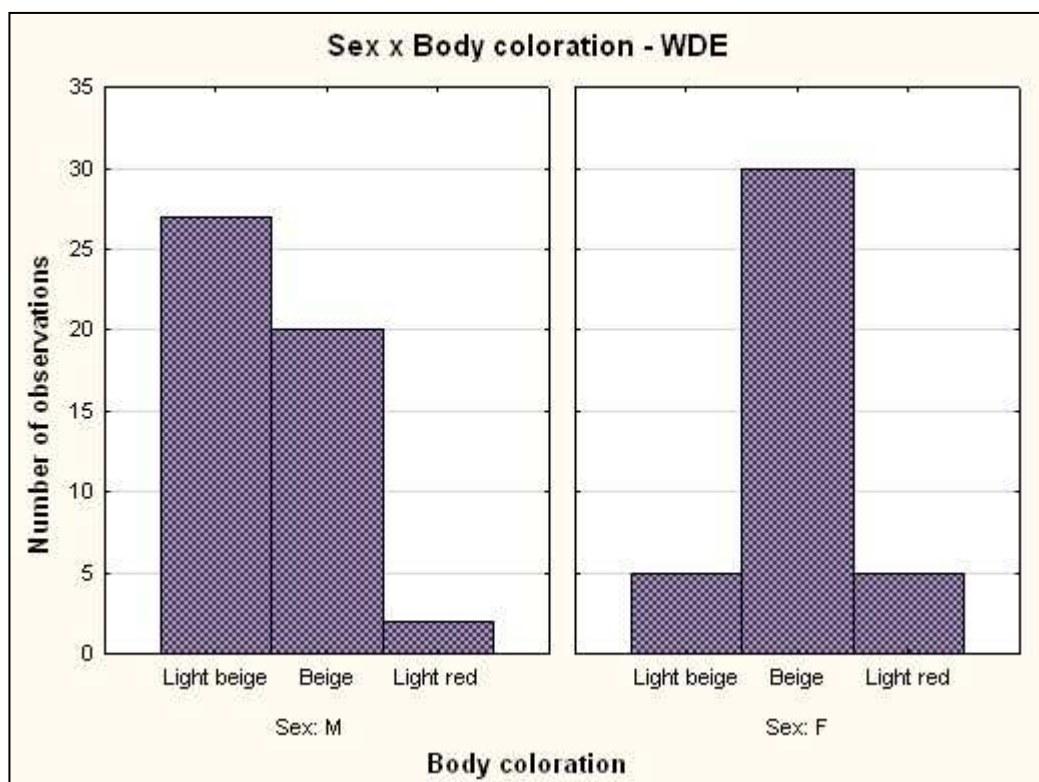
Graph 7. Dependence of the presence of stripe with arc on the subspecies, Pearson's chi-squared test, $p=0.000076$.



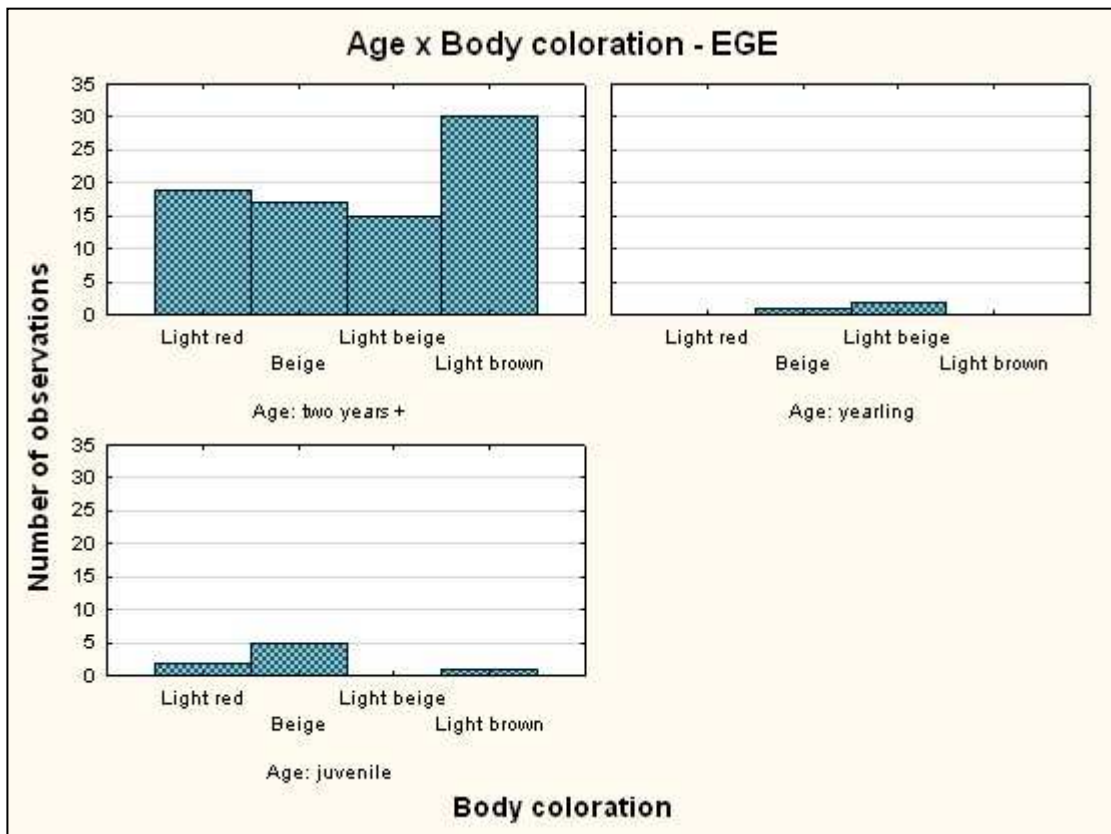
Graph 8. Dependence of the presence of back arc on the subspecies, Pearson's chi-squared test, $p=0.000002$.



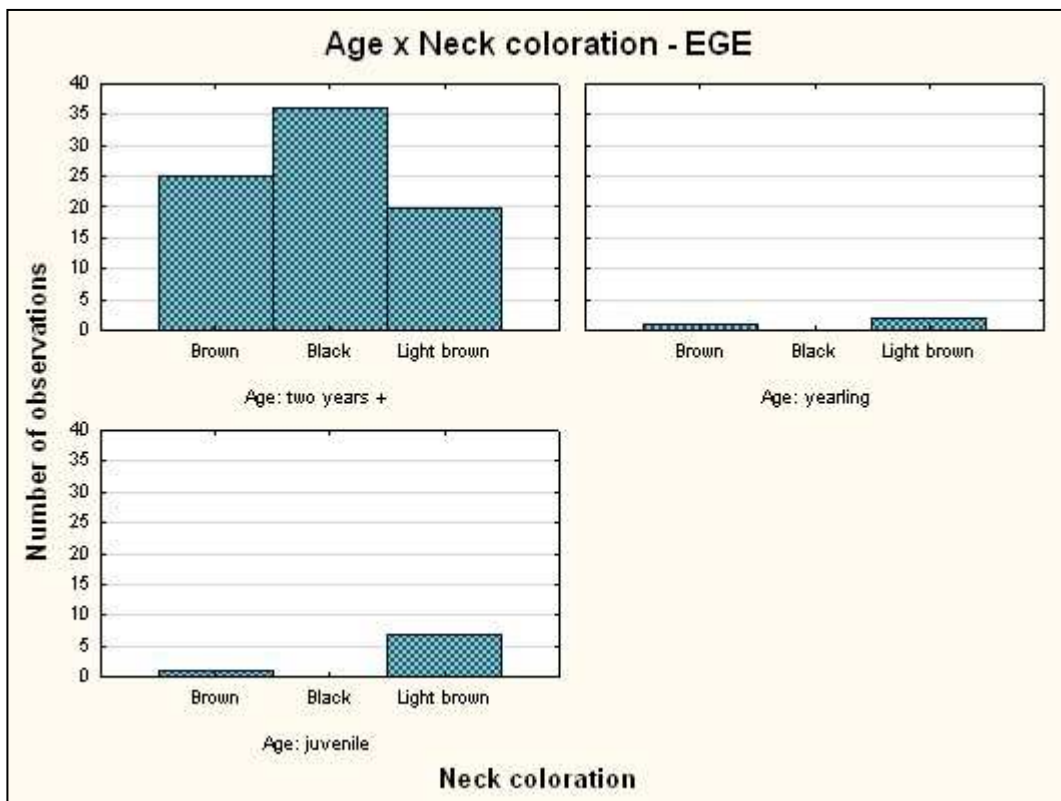
Graph 9. Dependence of the body coloration on the age in Western Derby eland, Pearson's chi-squared test, $p=0.025624$.



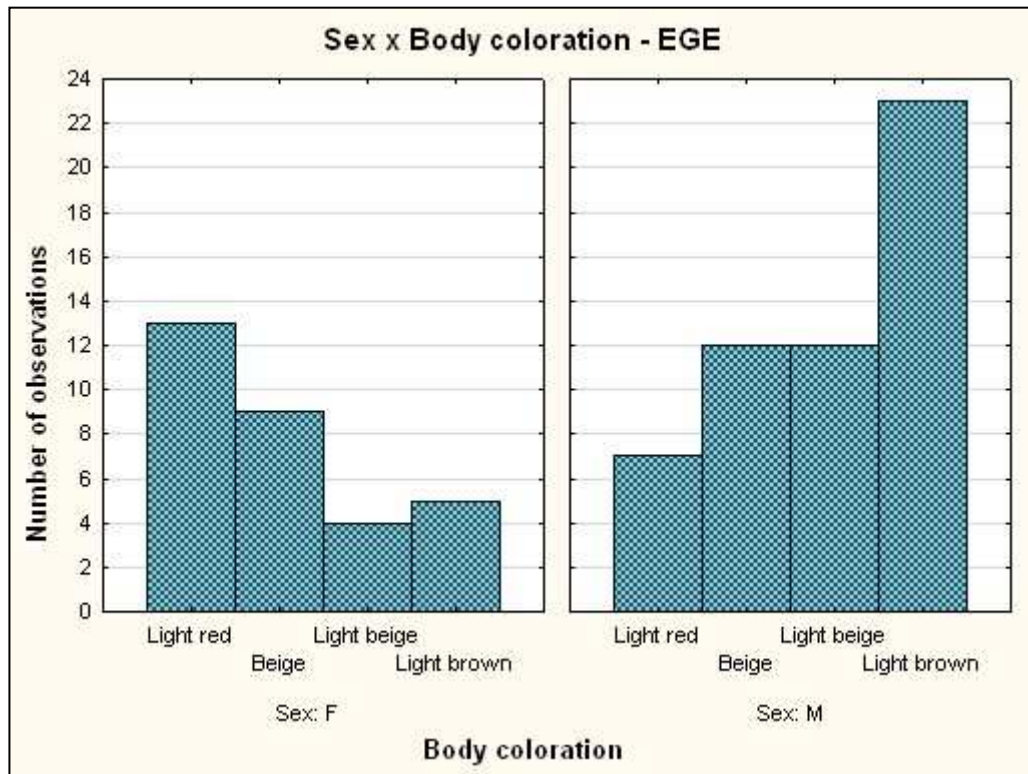
Graph 10. Dependence of body coloration on sex in Western Derby eland, Pearson's chi-squared test, $p=0.000145$.



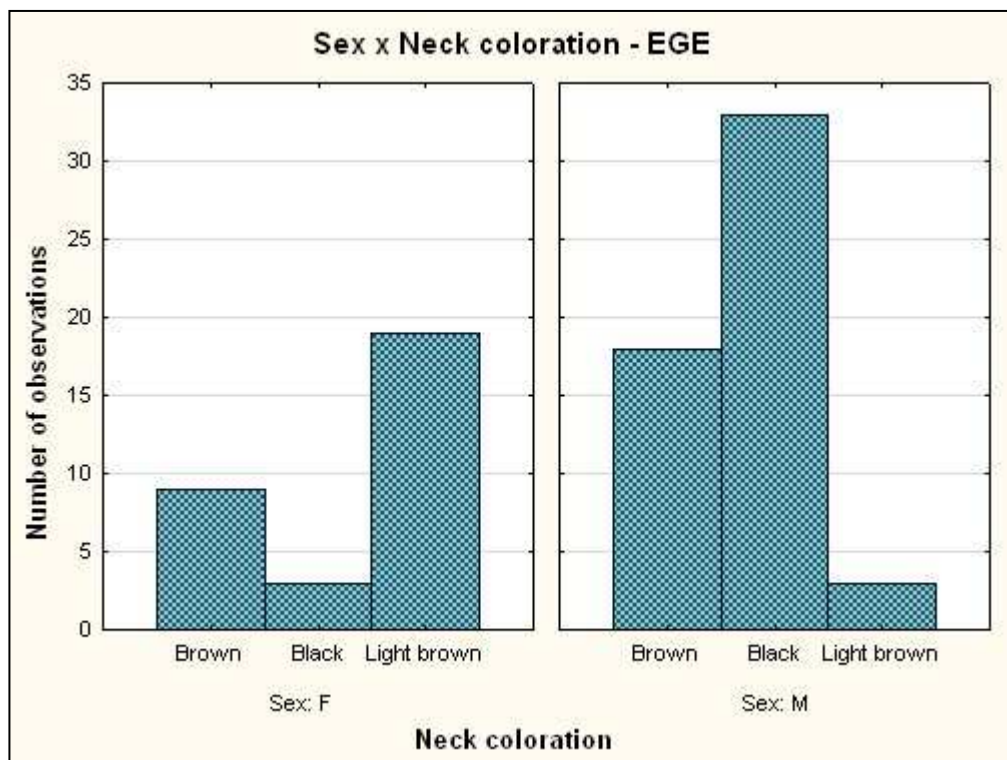
Graph 11. Dependence of the body coloration on the age in Eastern Giant eland, Pearson's chi-squared test, $p=0.036904$.



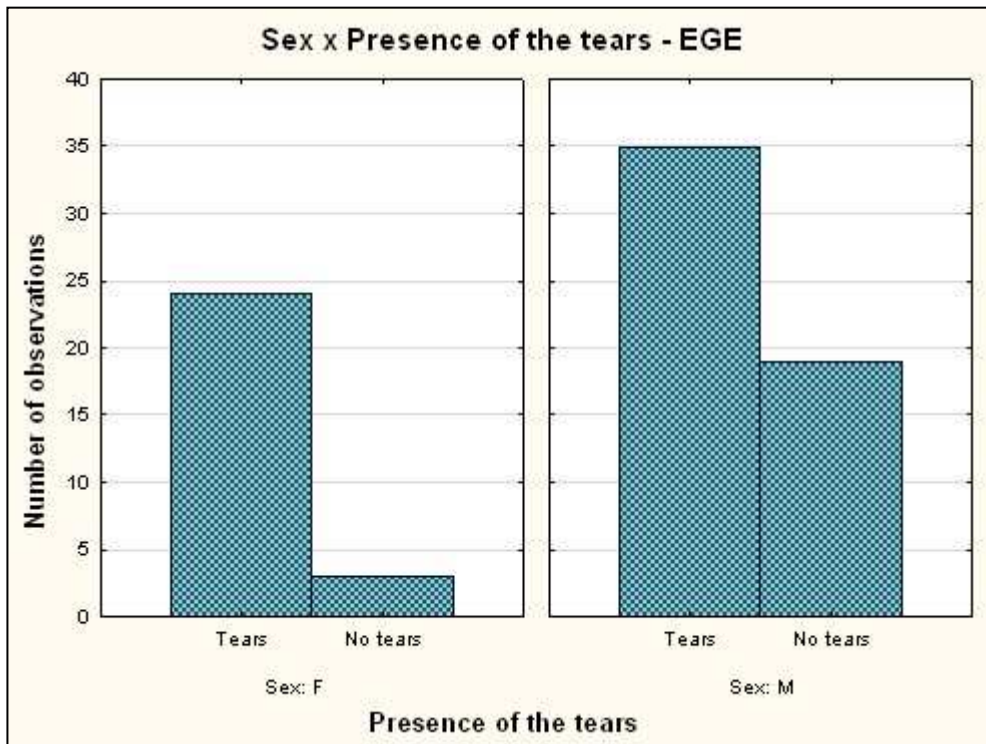
Graph 12. Dependence of the neck coloration on the age in Eastern Giant eland, Pearson's chi-squared test, $p=0.002927$.



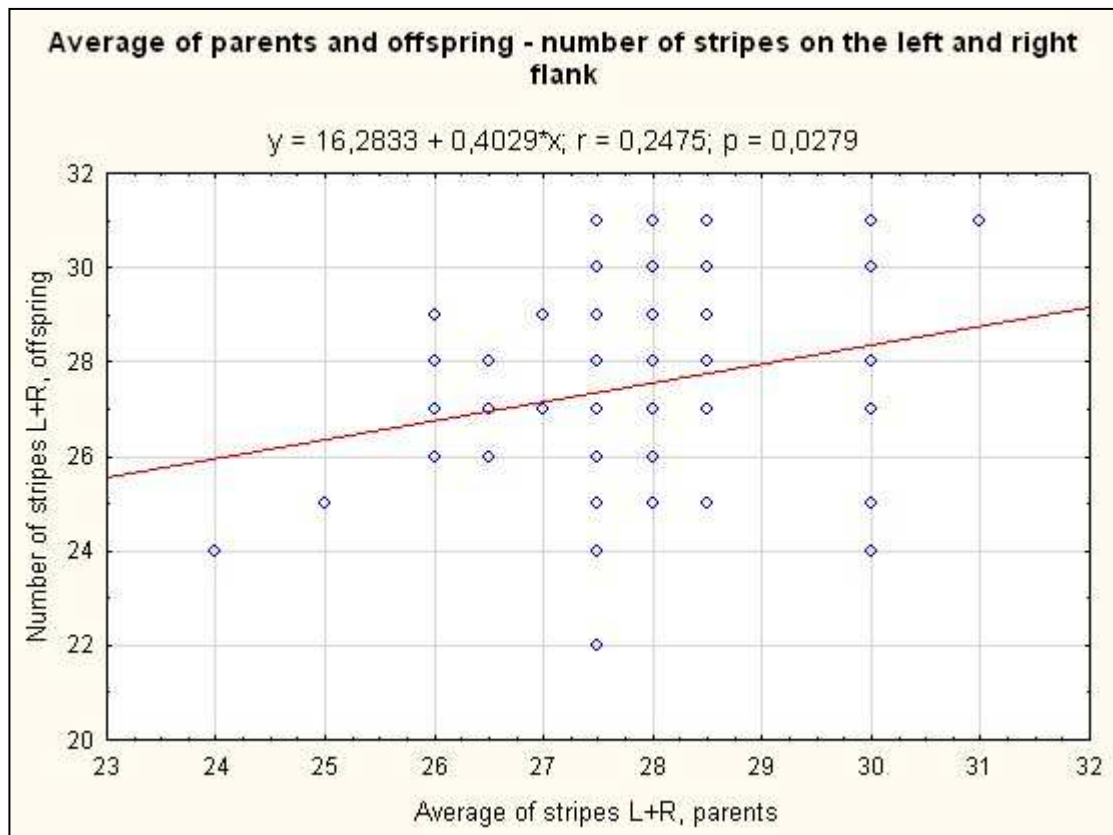
Graph 13. Dependence of body coloration on the sex in Eastern Giant eland, Pearson's chi-squared test, $p=0.005877$.



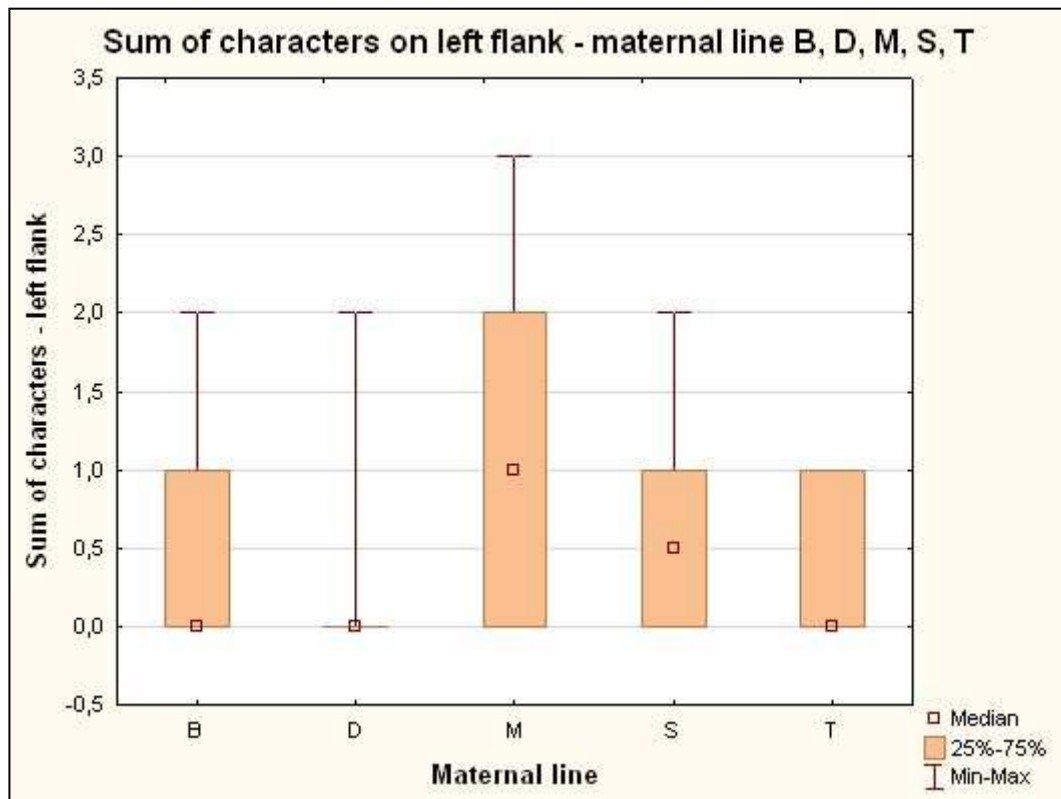
Graph 14. Dependence of the neck coloration on the sex in Eastern Giant eland, Pearson's chi-squared test, $p<0.001$.



Graph 15. Dependence of the presence of tears under the eyes on the sex in Eastern Giant eland, Pearson's chi-squared test, $p=0.021657$.



Graph 16. Coefficient of the heritability counted for the sum of stripes on the left and right flank, linear regression, $p=0.0279$.



Graph 17. Dependence of sum of the characters on the left flank on the maternal line, Western Derby eland, Kruskal-Wallis test, $p=0.0454$.