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Factors influencing weight fluctuation in giraffids

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Declaration

I hereby declare that this thesis entitled Factors influencing weight fluctuation in giraffids is my own work and all the sources have been quoted and acknowledged by means of complete references.”

In Prague 27.4.2018

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Kateřina Gašparová

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Abstract

Giraffe and okapi are taxonomically related African browsers belonging to family *Giraffidae.* They share some common features but also have several dissimilarities. The keeping of okapi is more challenging than the keeping of giraffe, but manipulation of okapi is easier, and their weighing is part of the daily routine at many facilities. However, the data on weight is rarely published.

This study aimed to describe growth pattern of okapi calves, weight changes during pregnancy of okapi, mean body weight of adult okapi males and females and fluctuation in body weight influenced by changing season, husbandry, social composition and stress. Results for okapi were compared with results for giraffe and weight fluctuation in giraffe herd caused by changes in diet, husbandry and social structure was also analysed. Okapi data was collected from 3 males and 2 females kept in Dvůr Králové Zoo from August 2004 until May 2017. Each weight record included information about age, sex, season and social situation. Giraffe data are from Prague Zoo from September 2009 until December 2013. Data of seven adult individuals was analysed. Every weight record included additional information about changes in husbandry, diet or social composition.

Results confirmed that unlike giraffe, okapi females are heavier than males. There was no significant difference in body weight between new born males and females, but males tended to be heavier till the age of 2.5 years. According growth curve it seems that at the age of 2.5 years female continues in growth when male stopped. It seems that adult okapis are significantly affected by changing season as well as by social structure. As a solitary living species, they may lose weight in company of another animal. It is suggested that they are sensitive to stress and changes in their enclosure. Significant weight was lost during roof reconstruction undertaken during the study period. In giraffes, only social factors and improved diet significantly influenced weight fluctuation in giraffe herd.

Despite a limited data set, these results provide an overview of the growth pattern of okapi and factors influencing weight fluctuation in okapi as well as giraffe. This knowledge can be a useful tool for husbandry.

Key words: Giraffe, Okapi, giraffids, weight, fluctuation

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1. Introduction

Giraffe and okapi, belonging to family *Giraffidae*, are large ruminants (Kingdon et al. 2013) commonly kept and bred in captivity. Giraffes are part of zoo collections in 153 facilities across Europe (Jebram 2012). Okapi are kept in 21 institutions in Europe (Wondergem 2016). Both are browsers, with giraffes inhabiting open-country or bushland habitat (Kingdon et al. 2013), and okapi endemic to the forests of Democratic Republic of Congo (Wilson et al. 2011). Their elusive behaviour, coupled with the remote nature of their habitat resulted in okapi being unknown to science until 1900 (SSP 2004). Giraffe as a species is listed as vulnerable (IUCN Red List of Threatened Species, 2016) and Okapi is listed as endangered (IUCN Red List of Threatened Species, 2015). Knowledge about growth and weight fluctuation of animals bred in captivity is a useful management tool for conservation, as well as husbandry purposes (EEP 2006; Glonková et al. 2016). For example, in the case of females, weight gain can be also indicator of pregnancy and general health (SSP, 2004). Weight loss can be a sign of environmental factors resulting in individuals becoming stressed (Morgan and Tromborg, 2006).

1.1. *Giraffidae*

Giraffe and okapi are the only species who represent family *Giraffidae*. There is very little known about okapi in comparison with giraffe. It is an elusive animal which inhabits the Congo Basin. Whilst is shares some traits with giraffe, there are also a lot of differences. What is obvious on first sight is size, shape and coloration. Unlike the giraffe, in okapi only males have ossicones. Further differences include the okapi's hoof glands, and scent and voice are important in their communication. The okapi is not a social species, and calves are raised using a hiding strategy (Estes 1992). Jarman (1974) explain that generally diet is correlated with social structure and body size. Species small in body size have a higher metabolic demand per unit weight size, meaning that these animals need to select high quality patches of food. These occur in forest and are dispersed in distribution. Therefore animals are forced to live solitarily, and in this case the best strategy to avoid predators is to hide. In contrast, species larger in body size eat poor quality food on plains. It is hard to defend this type of food and these animals wander in herds and follow rains. In dangerous situations when a predator approaches, they cannot hide in such a big open space. They can either run away or rely on safety in numbers in the herd.

1.1.1. Sexual dimorphism

In general males in dimorphic polygynous species are characterized by higher weight and postnatal growth rate compared to females (Lee and Moss 1986). Reproductive success of males can be influenced by body size (McElligott et al. 2001). In giraffe, sexual dimorphism is apparent, as males have a larger body size. Mean body weight of a captive male is 1307.77 kg; a female is significantly lighter at 808.67 kg (Gloneková et al. 2016). The mean body weight may vary with respect to location, wild individuals seem to be heavier than captive ones. (Gašparová 2016). Bigger males have access to females in oestrus and they are more successful in feeding competition (Simmons and Scheepers 1996). The growth of giraffe males is faster and size dimorphism starts to appear at around 1-2 years of age (Dagg and Foster 1976, Gloneková et al. 2016). Growth in the postnatal period is faster and more intensive in males, but both sexes also increase their weight in adulthood (Gloneková et al. 2016).

Unlike the giraffes, in okapi, females are larger in size. On average they are taller by about 7 cm at the withers, and on average have 8% larger body mass (Kingdon et al. 2013). In mammals, larger females are more common than usually thought. In the case of forest dwelling species such as okapi, males are smaller for easier mobility in dense habitat to mate with females (Ralls 1976).

1.2. Growth and factors influencing weight fluctuation

Growth and weight increase starts after conception (Robbins and Robbins 1979). Energy needed for somatic growth is limited. Once gained energy is transformed and can be either stored or used for maintenance, growth or reproduction (Kozlowski and Wiegert, 1987). All reproductive processes such as gametogenesis, foetal and embryonic development, lactation and parental investment are energetically consuming (Cooke et al. 2006). Environmental variability can affect switching from growth to reproduction. It is supposed that after reaching maturity, individuals stop using energy for growth and allocate surplus energy to reproduction (Kozlowski and Wiegert 1987). However, some species grow throughout their whole lifetime, but the growth rate is slower, for example Formosan Reeves' Muntjac (*Muntiacus reevesi Micrurus*, Pei 1996) or Rotschild giraffe (*Giraffa camelopardalis rothschildi*, Gloneková et al. 2016).

The most intensive growth period for ungulates is as calves, and this slows down at the age of 2 years, when size dimorphism starts to develop. Males reach their adult height at 4-5 years (Dagg and Foster 1976). The growth rate varies between male and female; males grows faster and the weight difference appears at the point of sexual maturity (Festa-Bianchet et al. 1996). It can be also influenced by factors connected to mother, such as age (Aktas et al 2014) or weight (Birgersson and Ekvall 1997). In some species it was confirmed that a heavy mother produces heavy offspring, for example in sheep (Burfening and Carpio 1993) or reindeer (Skogland 1984). The weight of adult animals can also fluctuate. Pregnancy, parturition and hormonal changes have the biggest influence on body weight in females (Thorne et al. 1976). Breeding season can have high energy demand on males, and they can lose their body weight during this period (Mysterud et al. 2005). The weight of adult males and females can fluctuate in addition to season, weather, photoperiod or diet (Wade et al. 1985; Weladji et al. 2002; Kappen et al. 2014).

Most vertebrates can metabolically transform bodily tissue to energy during starvation (Wang et al. 2006). There are several examples of behavioural adaptation to unstable environment. Some species store energy as adipose tissue before mating, which is used as an energy source for energetically expensive future gestation and lactation; some females save energy for their foetus by reducing flight or locomotion; mammals increase food intake during lactation (Gittleman and Thompson 1988). Lactation is the most energetically expensive period of reproductive cycle (Bercovitch et al. 2004). Storing energy is especially important in habitats where availability of food is unpredictable and can fluctuate. The period of eating and fattening which precedes mating and caring for offspring is important for reproductive success (Bronson 1989). During spring, when new-born calves are highly vulnerable their mothers move them to areas with lower predation risk. Increased vigilance leads to reduced time spent foraging which results in rapid loss of fat reserves and body weight (Barten et al. 2001). Some species stop eating during courtship, mating, migration and hibernation. Red deer (*Cervus elaphus*) decrease food intake and body weight in a period of rut, even when the food is available (Mitchell et al. 1976) which may be a side effect of physiological changes (Miquelle 1990). Female jungle fowl (*Gallus gallus*) lose 20 % of their body weight during first twenty days of sitting on their eggs (Sherry et al. 1980). Diurnal and seasonal changes in foraging and weight fluctuations may be influenced by changes in the cost and benefits of fat reserves. In the case of temperate passerine birds, increased fat reserves and body weight during the period of low food availability can increase the predation risk (Gosler et al.1995). To create adequate fat reserves, animals have to increase time spent foraging and reduce the time spent on activities such as reproduction and anti-predatory activities (Clutton-Brock et al. 1996). The weight of adult animals can fluctuate throughout life. Energy expenditure, food intake and fat storage fluctuate to keep energy homeostasis (Friedman 2008). Body condition of female giraffe is significantly poorer in the dry season compared to the wet season, and behaviour is also changed. Herds are smaller during dry season, strength of association is weaker and individuals forage farther from each other (Dagg 2014). Diet is one of the most important factors of giraffe husbandry, and providing a proper diet to giraffes is challenge. Giraffes in captivity weigh less than wild individuals, which is probably caused by unnatural diet. Captive calves weigh half as much as wild new born calves (Skinner and Hall-Martin 1975). The body weight of new born captive calves ranged from 55 (Dagg 2014) to 64 kg (Reason and Laird 2004), while wild new born calves weigh between 77 and 101 kg (Kingdon et al. 2013). Weight of new born calves in Prague Zoo ranged from 51-81 kg, with no difference in sex (Gloneková et al. 2016). Growth of giraffes is incredibly fast. They can grow up to 23 cm in height in one week during the first month of life. During the second year, their growth slows (Dagg and Foster (1976). The growth of okapi calves is also fast, they double their birth weight within 28 days. Mean body weight of new born okapi is 20.13 kg range 14.50-27.63 kg (Bennett and Lindsey 1992).

1.2.1. Season

Body weight of wild animals can fluctuate in relation to season as weight gain and loss depends on forage and its availability (Mitchell et al. 1976; Adamczewski et al. 1997). Fluctuations are connected to energy quality and quantity derived from dry matter, or connected to dietary composition (Kuntz et al. 2006). Przewalski horses living in semi-natural habitat shows seasonal weight fluctuation. Their body weight is higher in autumn and lower in spring; body weight increases in the energetically abundant season and decreases in energetically deficient season (Scheibe and Streich 2003; Parker et al. 1996). Large ruminants can decrease voluntary food intake, increase gut passage time and utilize body fat reserves (Kunz et al. 2006). Recent studies revealed that weight fluctuation of domesticated or captive animals can depend on environmental changes such as temperature or photoperiod (Brinkmann et al. 2012; Brinkmann et al. 2014; Kappen et al. 2014). According to study carried out in Prague Zoo, body weight of giraffes is significantly influenced by season. Females were heavier during winter and lighter during autumn, but it can be result of different diet and reduced movement during winter time. Only one male in the study was lighter in spring and summer, which may be because of its interest in females in oestrus, which is mainly in spring and summer (Gloneková et al. 2016).

1.2.2. Pregnancy and parturition

The weight fluctuation of adult females is usually related to pregnancy and parturition. Giraffe reproduce throughout the year and can lactate during most of pregnancy, which is unusual among large mammals. Females come into oestrus for the first time at the age of 3 years. Oestrous cycles last 15 days and females give a birth after 457 days (Dagg 2014). Conception in giraffes is dependent on female condition (Hall-Martin 1975). The okapi gestation period is similar, it lasts 430-450 days (Kawasaki et al. 2012), the oestrous cycle is around 15 days (Kusuda 2007).

In wild ruminants, timing of birth is important. Calves of heavier and/or older females are born earlier then calves of lighter and/or younger females (Feder et al. 2008). Offspring born earlier can increase body weight more than later-born offspring, the survival rate is higher in earlier-born calves (Coté and Festa-Bianchet 2001). According to a study undertaken in Tanzania, giraffe calves born in dry season have higher survival probability (Owen-Smith and Ogutu 2013). Giraffes, as other large ungulates are classified as capital breeders. Their energy requirements to cover reproduction is dependent on accumulated body reserves (Jönsson 1997). A study on giraffes undertaken at Prague Zoo suggests that mean weight gain during pregnancy is 163.56 kg, the mean lost is 111.89 kg, and the mean daily gain was 0.36 kg. The difference of daily gain between first half of pregnancy (0.148 kg) and the second half of pregnancy (0.548 kg) was significant (Gloneková et al. 2016).

1.2.3. Lactation

The period of lactation is energetically expensive and demands immobilization and the export of a large amount of nutrients. Anecdotally, it is often said by deer keepers that the best looking offspring have the poorest looking mother. In the case that the female is not able to cover these demands by dietary intake, she must mobilize nutrients from tissue or reduce milk output, what can be fatal for her offspring (Mitchell et al. 1976). In many ungulates birth and lactation are timed to the beginning of the spring or season of food abundance. Females can therefore cover lactational needs by food intake and do not have to choose between their own life and that of their descendent. Females of some species store nutrients in tissue during periods of food abundance and then mobilize these nutrients into milk (Oftedal 1993). Large-bodied mammals have developed the ability to buffer short-term deficits in nutrient by stored reserves. However small animals spend energy at higher rates and are unable to store enough energy to cover deficiencies for any length of time (Owen-Smith 1988). Rate of growth and composition of mother's milk are closely related. If the growth rate is slow the offspring has low protein requirements and the mother can conserve tissue protein. But there is a trade-off - slow growth rate means a longer period of dependence, which can be too energetically expensive for females during a period of starvation. If the entire lactation period is during starvation, growth rate must be fast to allow early weaning (Oftedal 2000). Females who lactate during the period of starvation must reduce glucose use or rapidly lose tissue proteins, because glucogenic amino acids are used for glucose synthesis (Oftedal and Iverson 1995). Giraffe's milk contains approximately 5% protein and 8% fat (Osthoff et al. 2016), which results in fast growth (Dagg and Foster 1976). Okapi's milk contains an average of 8.5% fat and 7.5% protein (Kawasaki and Suginaka 2012).

1.2.4. Weaning

The weaning process includes phased and mutual changes in the behaviour, anatomy and physiology of the mother as well as of the offspring. Weaning weight is key for survival of offspring; when an offspring has reached about four times its birth weight it can be weaned. Offspring with low birth weight and with a slow growth rate has a reduced chance of survival (Clutton-Brock 1982). Early weaning may be connected to female disability to maintain lactation and offspring growth. In this case, mortality is often high. Early weaning can also be associated with high food quality and availability. If the female can transfer more nutrients to the milk it leads to faster growth and early optimal weaning weight (Lee et al. 1991).

1.2.5. Stress

Animals living in captivity are affected by potential abiotic sources of stress. The greatest stressors for captive animals are those from which they cannot escape. Animals housed in captivity face many environmental challenges such as constant sound, cage cleaning and elimination of scent-marks, odour of potential predators, unnatural diet and artificial lighting conditions. They have psychological (behavioural) and physiological responses to maintain homeostasis. Stressors can be acute (short-term) or chronic (long-term). Acute stressors are usually connected with behavioural responses such as alarm or increased vigilance. Increased isomers of glucocorticoids shift the metabolism towards energy mobilization instead of energy conservation. Chronic long-term stress may lead to increased production of isomers of glucocorticoids which can damage areas of brain (Morgan and Tromborg 2006). Physiologically, chronic stress can inhibit immune response (Barnett et al. 1992; Ferrante et al. 1998), reduce growth hormone, suppress growth rate (Chrousos 1997; Cooper 1995) and reduce body weight (Bartolomucci et al 2004; Konkle et al 2003). Stress also has an influence on behaviour (Gronli 2005) and on aggression (Bartolomucci et al. 2004; Mineur et al. 2003). Restriction of movements due to small pen or enclosure size seems to be one of the biggest stressors for captive animals. Space limitations can be one of the primary reasons for abnormal behaviour (Hediger 1964). The effect of small enclosure size on growth is interpreted as a sight of chronical stress. Studies on pigs (Pearce and Patterson 1993) and sheep (Horton et al. 1991) show that animals in smaller pens show reduced growth rate in comparison with animals kept in bigger pens. On the other hand, even an increase in pen size can be stressful for some species, especially for prey animals that are hunted in open environments such as rodents, or for species living in large open space (Hughes 1969). Absence of retreat space may be a significant stressor for some species of captive animal; they are unable to move away from another animal or from visitors. For instance, Pygmy goats and Romanov sheep in a zoo exhibit which allowed contact with visitors displayed more aggressive behaviour to visitors when they could not retreat (Anderson et al. 2002).

1.2.6. Social composition

Giraffe social structure is a fission/fusion system, meaning that the composition of the herd is not always the same. Adult males are usually loners, sometimes seen in company with other males, females or young. Females tend to be in groups, but the composition of herds changes frequently (Dagg 2014). Giraffes in captivity should not be kept alone, it is recommended to keep at least three individuals either in a breeding group or in a single sex group. Mixed enclosure with other African species is also possible (EEP 2006). Okapi are solitary animals, small groups which can be seen are either females with their recent calf or a female in the company of male. In captivity, the most stable groups are related females (SSP 2004). Keeping social animals in isolation or in abnormal mixed groups can affect animal well-being. Stress caused by social instability can have an influence on physiology and behaviour such as increased aggression, weight losses or mortality (Morgan and Tromborg 2006).

1.2.7. Feeding and diet

Giraffids are classified as browsing ruminants (Van Soest, 1988; Hofmann, 1989; Kingdon et al. 2013), and browsers are generally considered to be more challenging to feed in captivity than grazers (Clauss et al. 2003). The degree of selectivity of feeding behaviour in giraffes is intermediate. Because of large body size, giraffe cannot select feed in the same way as smaller ruminants (Van Soest 1994). The content of fibre (cell wall) in diet of browsing ruminants is high, as well as the content of tannins that reduce protein digestibility and terpens that may reduce dry matter digestibility and toxins (Robbins 1993, Robbins et al. 1995). The diet of browsers is more heterogenous, plant parts have varied nutritional quality (Jarman 1974) and can also have spines and thorns (Cooper and Owen-Smith 1986). Differences in digestive system in comparison to grazing ruminants are seen in less-developed masseter muscles, teeth with less chewing efficiency, larger mandibular glands, smaller rumen and smaller omasum (Pérez et al. 2012). It is hard to describe the diet of a giraffe, because different regions have different vegetation, and the diet can also differ according to season. Generally, it can be said that the main part of the diet is comprised of *Acacia* spp. *Commiphora* spp., *Grewia* spp., *Combretum* spp. Osteophagy and geophagy is a common behaviour occurring when they need to add some minerals to their diet (Dagg 2014).

Okapi prefer to browse in treefall gaps. Such a habitat is relatively rare, and is an elusive food patch. The major component of their diet is the mature foliage of understorey treelets, shrubs and lianas. Their diet is very diverse. They feed selectively even within individual plants and move between different plant species as they feed. Examples of the main plant families in their diet are: *Acanthaceae, Ebenaceae*, *Euphorbiaceae*, *Flacourtiaceae* and *Rubiaceae* (Kingdon et al. 2013). For addition of minerals, they consume clay, burnt charcoal and bat guano (Wondergem, 2016).

Wild animals spend a large part of the day searching for and consuming food. Food which is provided in captivity is considerably different, it can be more concentrated, higher in protein, lower in fibre and different in structure to the diet of wild animals. Food in captivity generally takes less time to eat. Restricted feeding of giraffe in captivity results in food-seeking and increased locomotor activity (Veasey et al. 1996). It also positively correlates with stereotypic behaviour such as licking in giraffe and okapi (Bashaw et al. 2001). Because of the patchy distribution of browse trees and shrubs, wild giraffes must move constantly during feeding. Time spent foraging and ruminating is considerable and simulation of these times is major task of giraffe husbandry (EEP 2006). Giraffe in captivity should have the same diet as wild animals, but it is impossible to provide them only browse. Browse can be supplemented by lucerne hay and pelleted feed (Dagg 2014). According to a study performed by Gussek et al. (2017) lucerne hay is fed in 89 % of giraffe facilities from 81 facilities across Europe. Ninety-six percent of facilities fed fresh browse, with the most commonly used being willow followed by birch, beech, oak and ash. Dehydrated lucerne pellets are used in 30 % of European giraffe facilities. Okapi diet in captivity has been improved enormously. Nutrition of okapi in the past contained a high amount of easily digestible components such as milk, corn porridge and fruits but these animals died from rumen acidosis (Hummel et al. 2006).

2. Aims of the Thesis

We aimed to provide an overview of weight gains and growth curve of okapi calves. We aimed to find out if there are any differences in growth pattern between males and females and compare mean body weight between sexes. Further aims were to describe the pregnancy of okapi, describe seasonal weigh fluctuations and the day to day fluctuation in relation to stress. All results were compared and discussed with an already published study on giraffes (Glonekova et al. 2016). The final aim was to compare body gains and losses in connection to changes in husbandry, social structure and diet in giraffe.

3. Methods

3.1. Giraffe data

3.1.1. Data collection

Data were collected in Prague Zoo from September 2009 until December 2013. Weight data are from 43 Rotschild giraffes (*Giraffa camelopardalis rotschildi*), who were weighed every week. The weighing system used was TONAVA VT6220 TM3000, which is in the giraffe corridor. Giraffes are trained to walk through the corridor individually. Seven fully grown individuals were chosen for the present study (1 male and 6 females).

Each weight record includes date of weighing, season of weighing (spring, summer, autumn, winter), age of animal in months, sex and age category (juvenile, subadult, adult). For pregnant females, month of pregnancy is also recorded (using 460 days as duration of pregnancy) (EEPs 2006). Calves were not weighed on the day of birth, they were first weighed at the age of 14 days. During the study period twelve calves were born.

Prague Zoo has high quality stables, enclosures and equipment. Due to high investment to husbandry and technology they have a long tradition of being proud breeders of Rotschild giraffe. The giraffe stable includes an outside and inside enclosure. Animals are kept in the temperate inside enclosure during the winter time and during warmer days they have access to inside part of their stable. Their diet contains ad libitum hay and branches, with limited supplements, fruit and vegetables. Fresh browse and green alfalfa is provided from April to October, which is replaced by alfalfa hay during rest of the year. Females at advanced stages of pregnancy were separated from the herd and milk supplements were provided. The age of animals was divided to three categories - according EEPs (2006) juveniles are dependent calves till 12 months, subadults are animals between 1 and 3 years, individuals older than 3 years are considered to be adult.

3.1.2. Data evaluation

We created table in Excel 2016 with weekly fluctuations for all individuals recorded as well as additional information about changes in husbandry, diet and social structure. Firstly, gains and losses of all individuals were summed for every week. The data had a normal distribution and so an ANOVA was run in Statistica StatSoft. Secondly, each week individuals who lost weight were counted. This data was not normal and so the non-parametric Kruskal-Wallis test was used.

3.2. Okapi data

3.2.1. Data collection

Unique, long term data were collected in Dvůr Králové. Zoo Dvůr Králové is the only zoo in Czech Republic that keeps and breeds okapi (*Okapia johnstoni*). Records are available for three males and two females, and from those there have been two calves born in zoo, one female and one male. For weighing, a system from KTKom company has been used. There are only two inside enclosures connected with a corridor, which is where the scale is located. This means that only two adult animals with a calf could be weighed – other individuals were in a different pen without weighing system. Animals have been trained to walk through corridor and stop on scale.

Each weight record includes date of weighing, sex, age in months, season (spring, summer, autumn and winter) and social situation (lone male, two males, male and female, male female and calf). For females there are some extra notes (pregnant and lactating). The date when a female was paired with a male is known, so the beginning of pregnancy was estimated according to known data about gestation period, which takes 430-450 days (Kawasaki et al. 2012). Calves were weighed after two days and each record include notes about if the calf was suckling or weaned. The age of animals was classified to three categories (juvenile, subadult, adult). Okapi reaches adulthood at the age of 3 years (Bodmer and Rabb, 1992).

Roof reconstruction in okapi stable during the study period influenced body condition of three animals. Reconstruction lasted from beginning of October 2011 until end of October same year.

Okapi are kept in an inside enclosure during unfavourable months and during warmer part of the year they have access to an outside enclosure. Their diet is composed of ad libitum high quality alfalfa hay and browse throughout the whole year with limited supplements. During favourable months they have fresh browse instead of dry, which is what they are offered during winter time. Due to their solitary way of life, they are kept separately. The only time they were not apart was either when a female was paired with male or a female was with a dependent suckling calf.

3.2.2. Data evaluation

´Data was statistically analysed in Statistica StatSoft. A t-test was used to estimate mean body weight of fully grown male and fully grown, non-pregnant female okapi and to count the difference between them. For visualization of weight increasing in pregnancy and for the growth curve of calves, a scatterplot graph was used. Difference in mean daily weight gain in the first and second half of gestation was assessed by t-test and the same test was used for estimation of mean daily gain of calves within the first year, as well as difference between sexes. Excel was used to graphically visualise growth from birth to the age of 9 years. Influence of factors such as season, stress (roof reconstruction) or social changes on body weight was evaluated by General Linear Model (GLM) with the "name" as random factor. Fishers LSD was used as a post-hoc test. For evaluation of factors such as husbandry or social changes a table was prepared with weekly gains or losses for every individual. The first column was summed and in the second column the number of individuals who lost weight was recorded. Extra information about changes in husbandry or social structure was also added. There were also cases when animals lost weight but without any information in the diary, therefore these situations were labelled as "unknown". The sum of gains and losses of all individuals had a normal distribution so ANOVA was used for analysis.

4. Results

4.1. Okapi

The difference in body weight between male and non-pregnant female was significant (t= -33.77; $p < 0.01$, Fig. 1). The mean weight of females (n=2) was 263.4 ± 9.4kg. The mean weight of males (n=3) was 254.9 ± 5.5 kg. Females were significantly larger in body size.

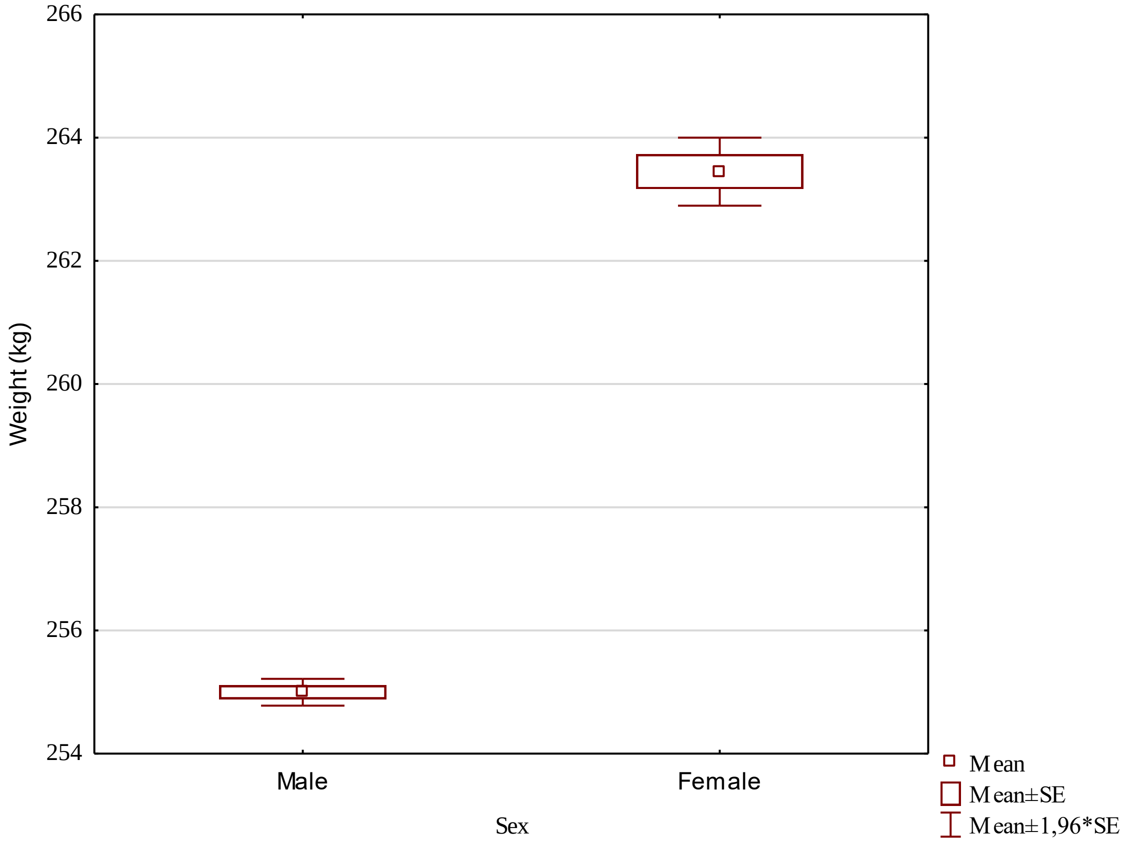

Figure 1. Comparison of mean body weight between okapi male and female.

4.1.1. Pregnancy

The mean weight of one female during two pregnancies was 288.08 ± 18.3 kg. The mean daily gain was 0.14 ± 2.02 kg and it did not significantly differ between the first (0.18 ± 2.2 kg) and second (0.09 ± 1.9 kg, $t=0.61$, $df=849$, $p > 0.05$) half of pregnancy.

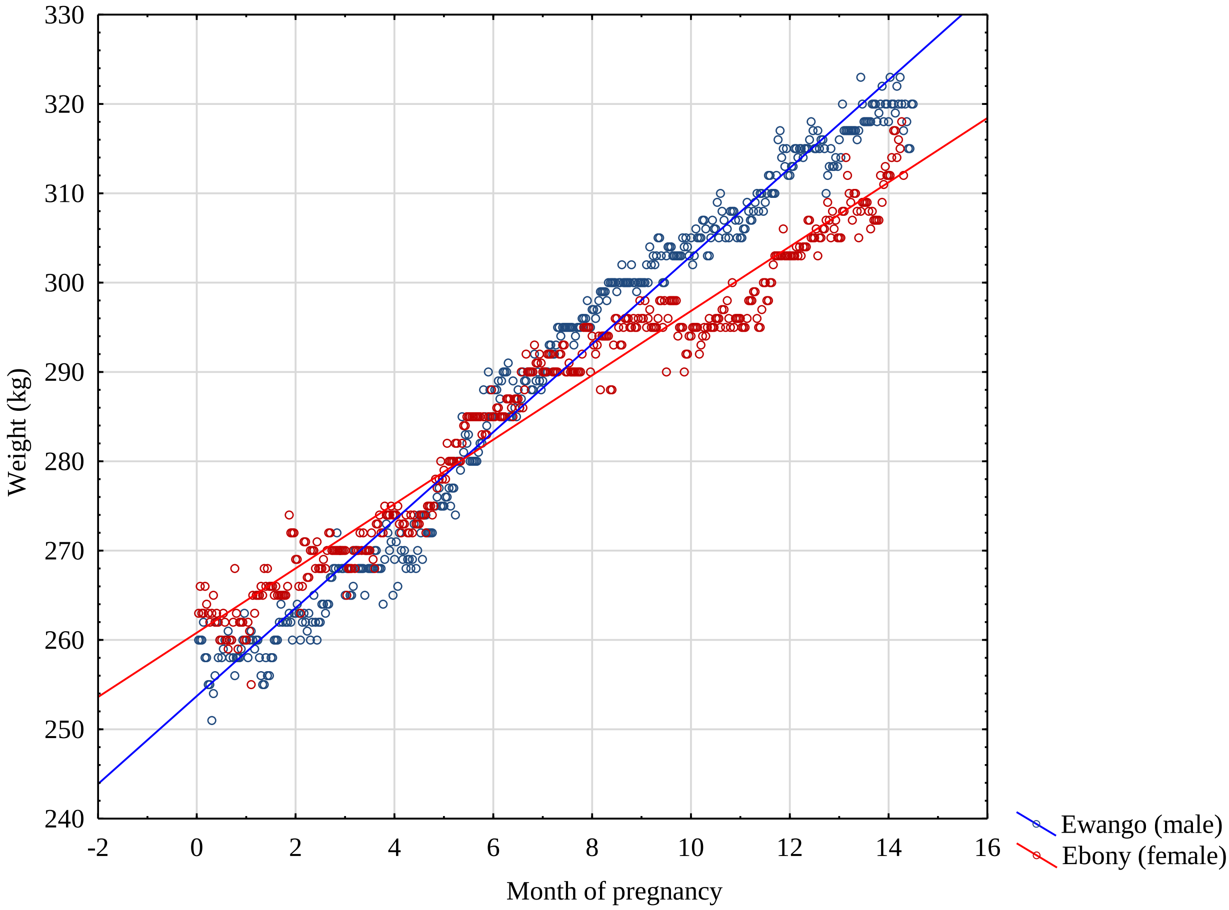

Figure 2. Visualization of increasing weight during pregnancies.

4.1.2. Growth of calves

The birth weight of two calves born during the study period was 28.5 kg (male) and 25.5 kg (female). The weight of both suckling calves continually increased until the age of 61 and 21 days, respectively, when the first day to day weight losses appeared. Weight losses larger than 2% appeared regularly until the calves reached the age of 3 months in the male calf and as late as at 7 months in female calf. The highest weight loss recorded in a suckling calf was 4% of body weight (5.5kg), in a 7 month old male calf. Mean daily gain did not significantly differ during first year between sexes (t=-0.59, df= 563, $p > 0.05$). Mean daily gain during first year was 0.40 ± 1.22 kg (female) and 0.48 ± 1.85 kg (male).

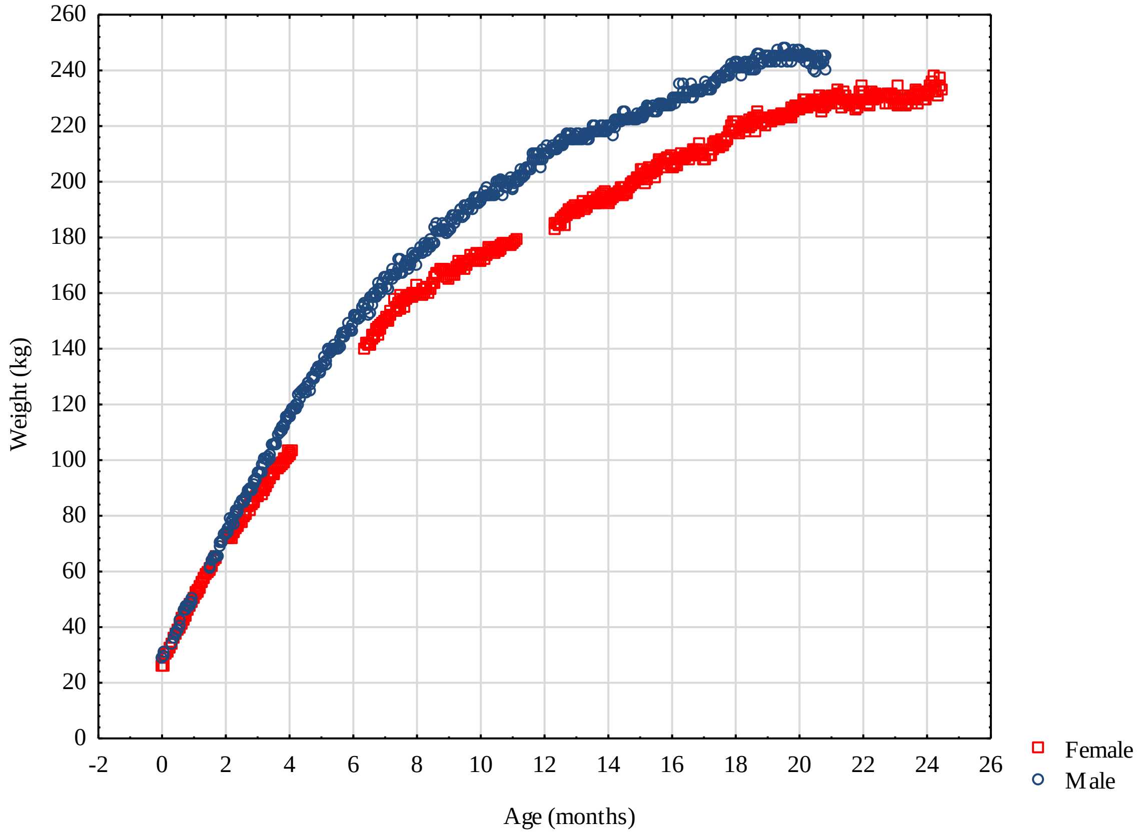

Figure 3. Visualization of increasing weight of okapi from birth to 2 years.

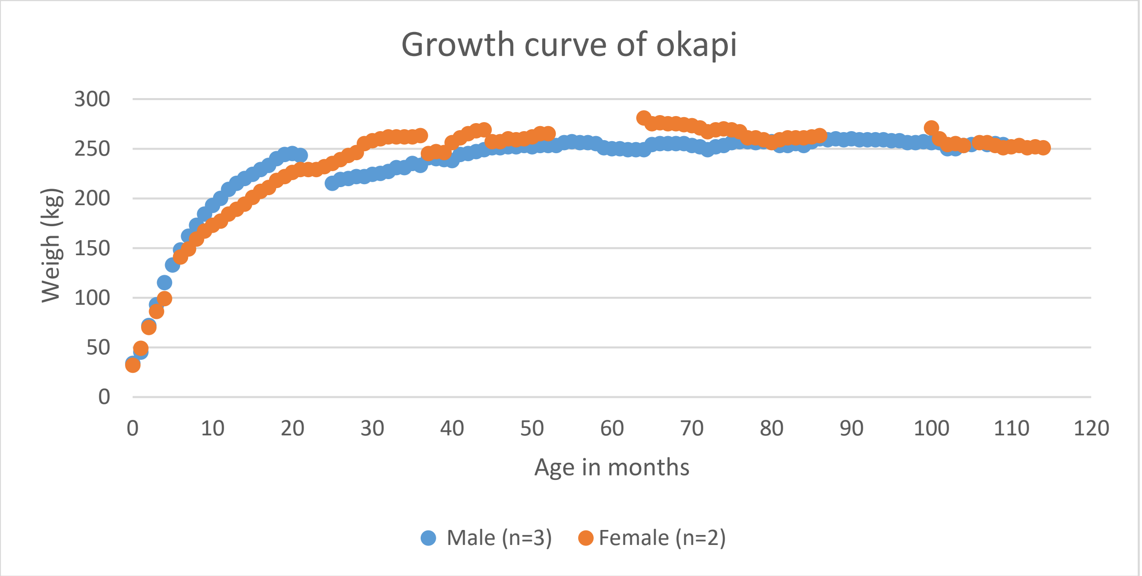

Figure 4. Growth curve of okapi.

4.1.3. Weight fluctuation influenced by season

As shown in Figure 5, body weight of adult and non-pregnant animals (n=5) was significantly influenced by season ($F=20.174$, $p < 0.01$). They were heavier in spring and winter (259.6 ± 7.8 kg, 258.2 ± 7.6 kg respectively) and significantly lighter in summer and autumn (255.6 ± 6.1 kg, 256.6 ± 9.4 kg respectively).

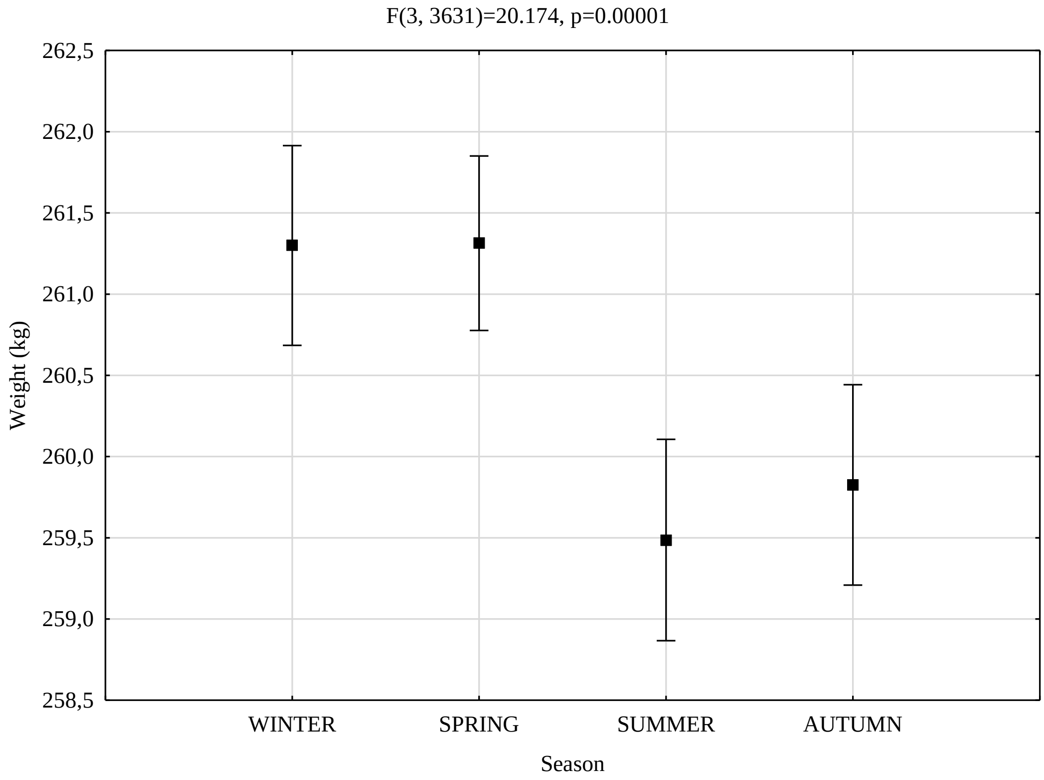

Figure 5. Season influencing mean body weight of adult okapi.

4.1.4. Roof reconstruction of okapi enclosure

Roof reconstruction as a potential stress factor significantly decreased the body weight of the male (n=1, $F=184.38$, $p < 0.01$, Figure 7) and the female (n=1, $F= 238.83$, $p < 0.01$ Figure 6). Reconstruction started in beginning of October and ended at the end of the same month. Male reached his pre-reconstruction weight after three months while female's weight stayed constant even five months after reconstruction.

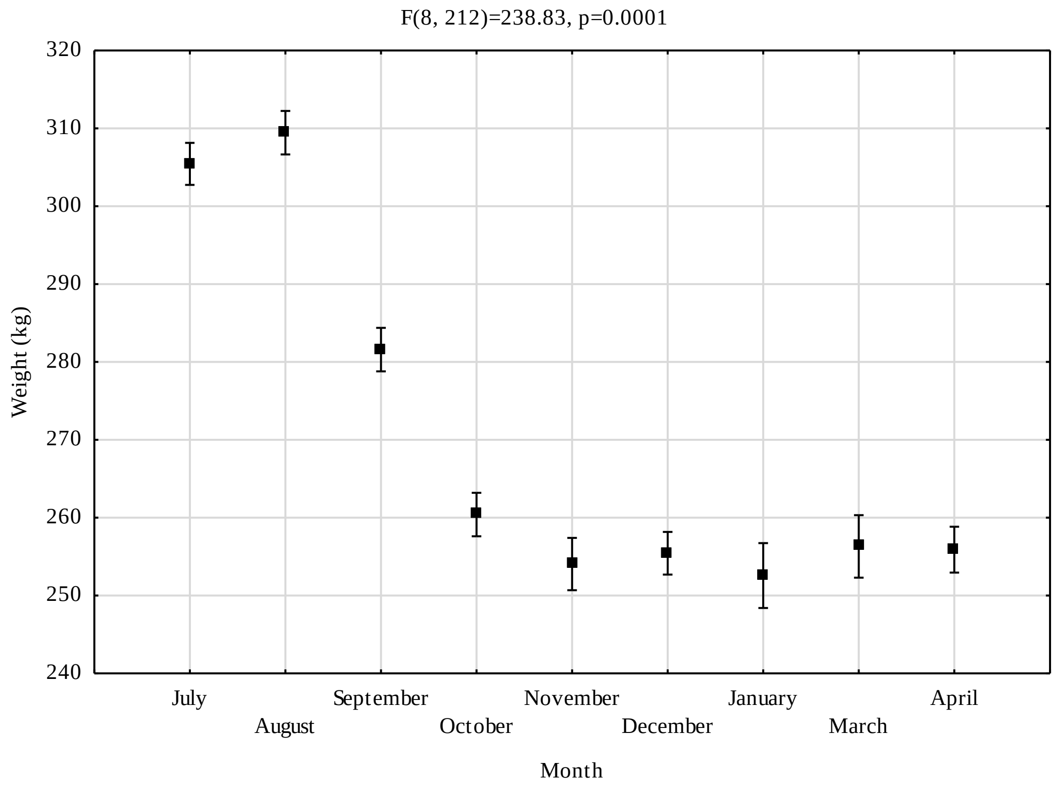

Figure 6. Decreasing of weight during roof reconstruction in female.

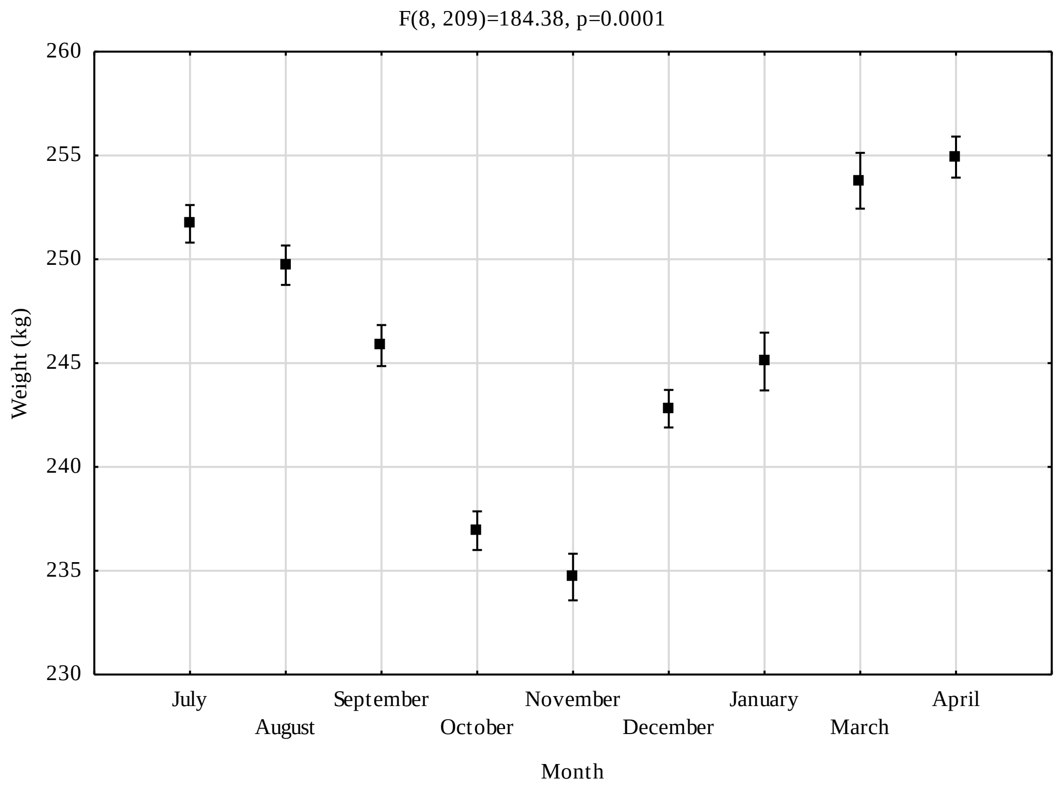

Figure 7. Decreasing of weight during roof reconstruction in male.

4.1.5. Social influence

Two males were kept alone during the study period and they were significantly ($F=7.1974$, $p < 0.05$) heavier (258.4 ± 4.3 kg) than in the company of females or another male (257.5 ± 8.6 kg; see Figure 8). Afterwards the influence of social organisation on daily weight gains for females (n=2) and males (n=3) separated was tested. There was no significant difference in males ($F=0.46$, $p > 0.05$, see Figure 9) or females ($F=0.52$, $p > 0.72$, see Figure 10).

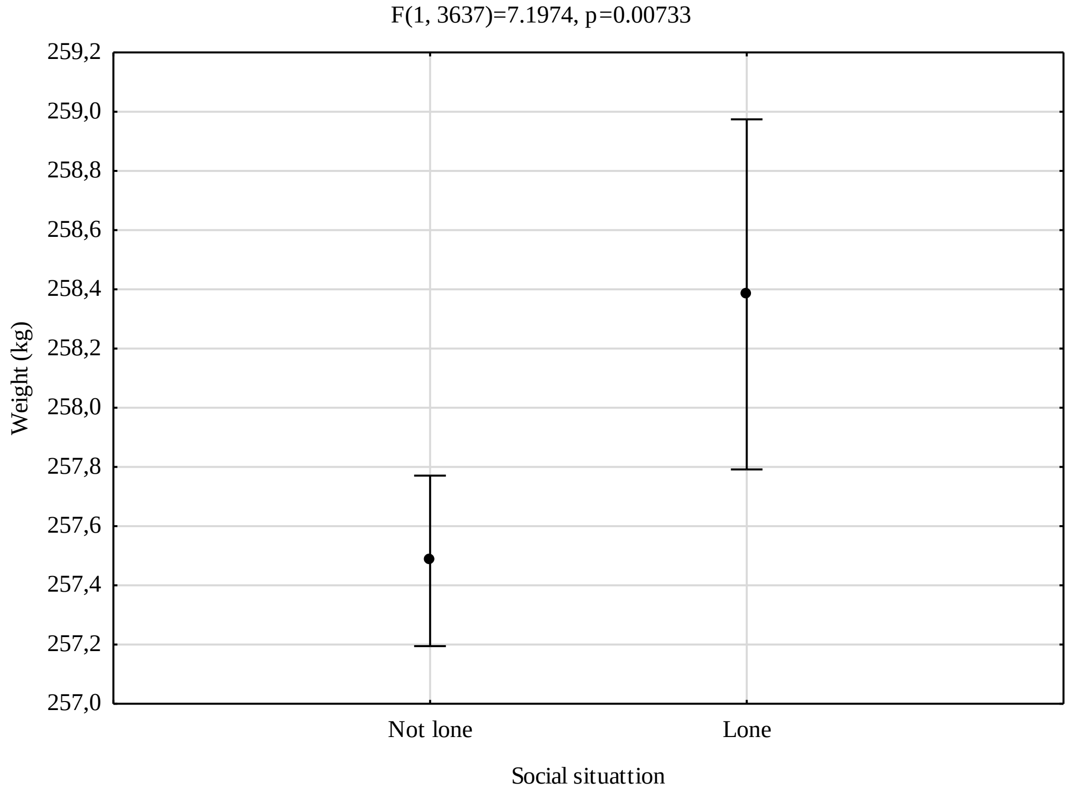

Figure 8. Comparison of body weight of lone male and not lone male.

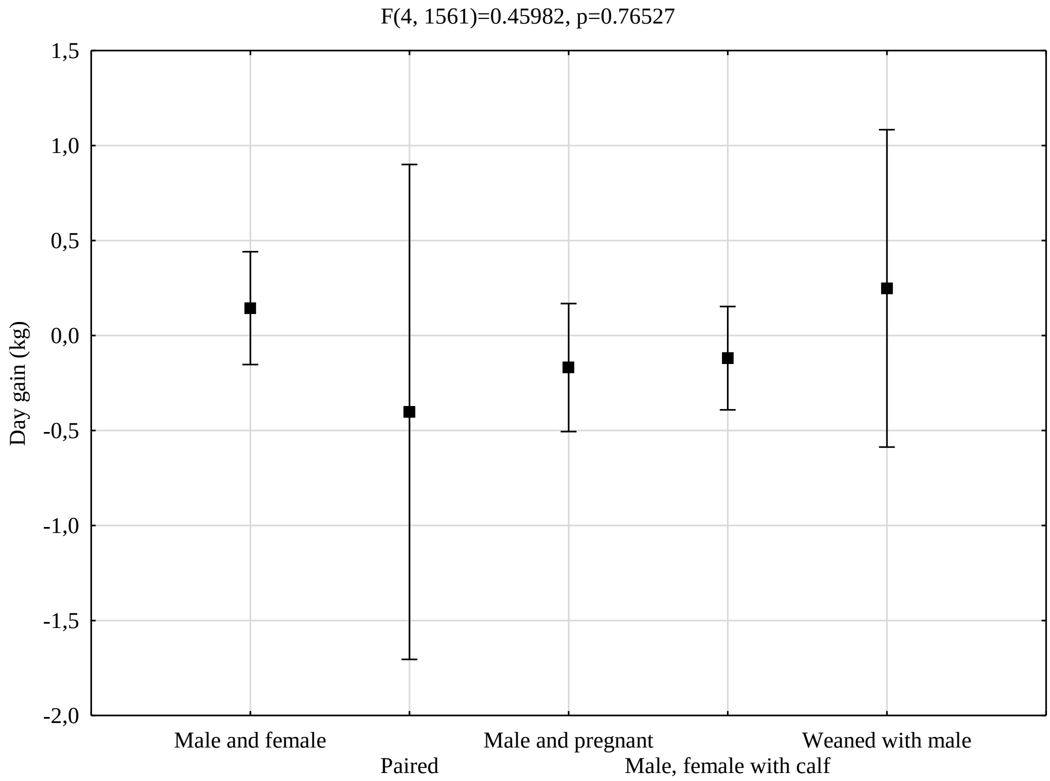

Figure 9. Comparison of daily weight gain in different social organisation in male.

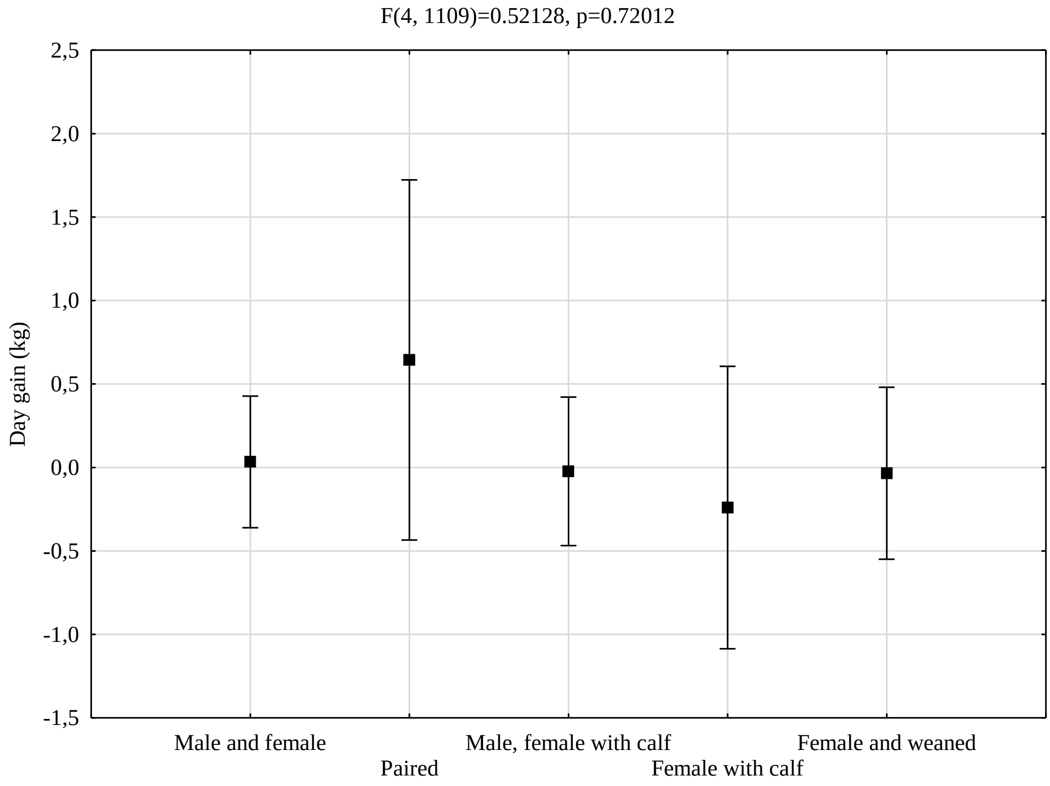

Figure 10. comparison of daily weight gain in different social organisation in female.

4.1.6. Different factors influencing weight fluctuation

Weekly weight fluctuation of all animals (n=5) was not significantly ($F=0.52$, $p > 0.05$) influenced by changes in husbandry or social changes (see Figure 11)

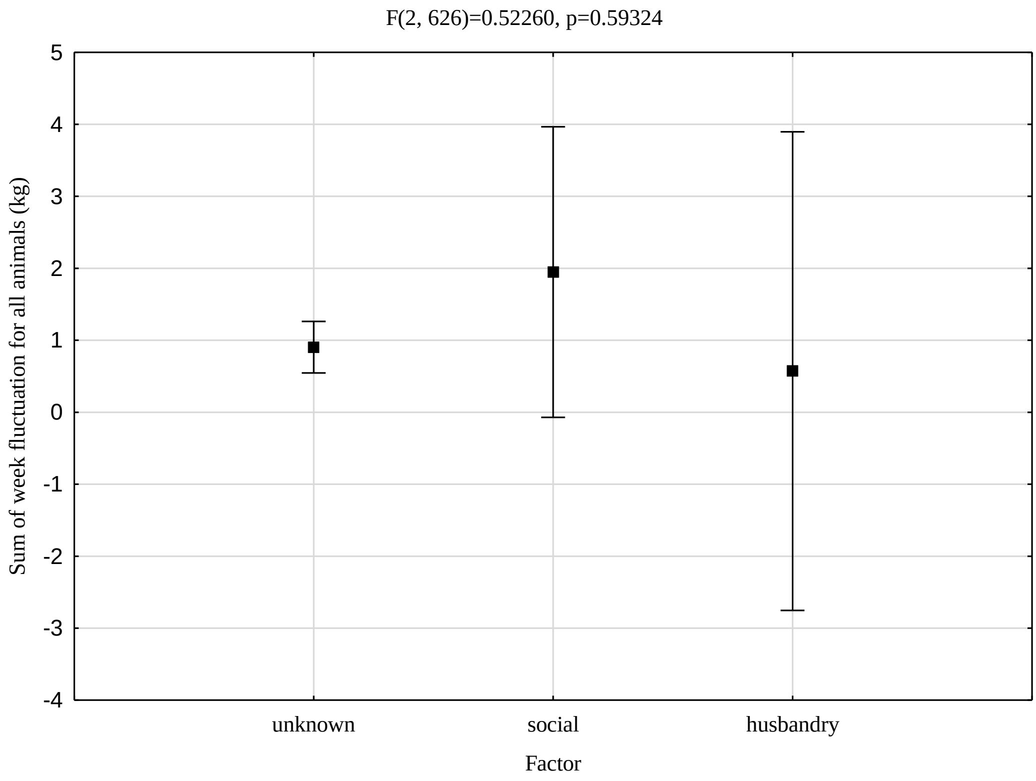

Figure 11. Weight fluctuation of all animals influenced by different factors.

4.2. Giraffe

4.2.1. Factors influencing weigh fluctuation

There was no significant difference among factors which could influence weight gain. We assessed the total number of animals with decreased weight (n=7, $H_{(4,\ n=182)} = 7.655$, $p > 0.05$, see Figure 12) the total weight change of whole herd (n=7, $F=1.28$, $p > 0.05$, see Figure 13). However, according to the post-hoc test of amount of fluctuating animals, there is a significant difference between social factor and improved diet ($p < 0.05$).

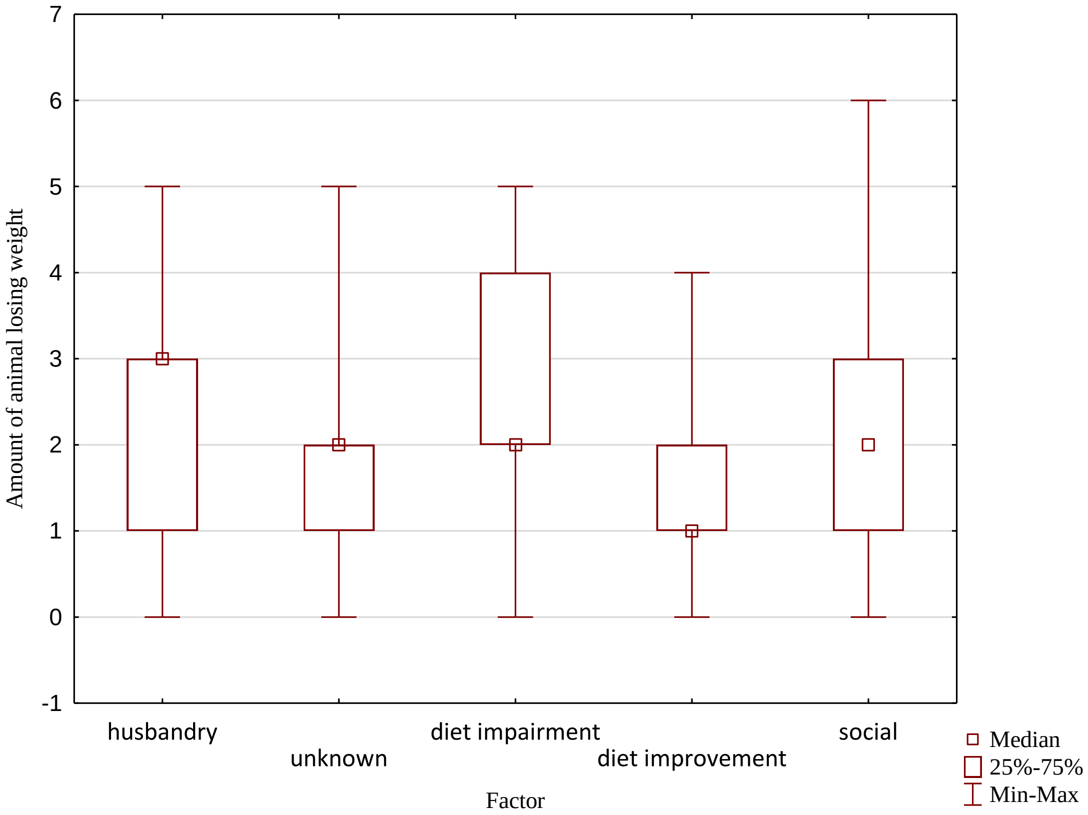

Figure 12. Factors influencing weight fluctuation in giraffes.

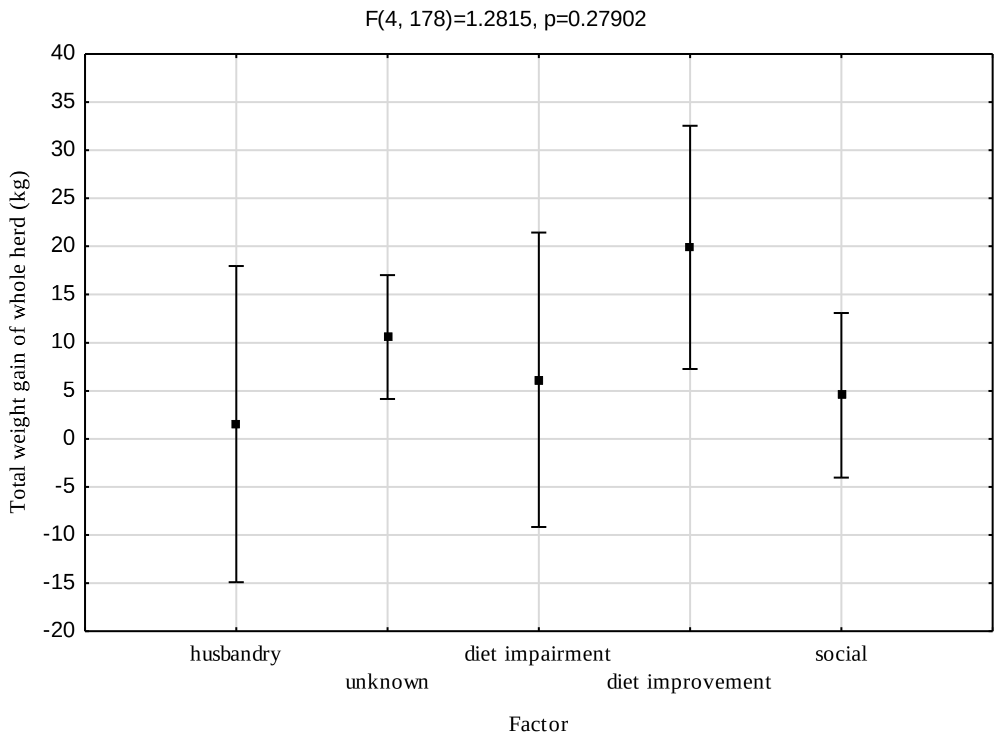

Figure 13. Factors influencing weight fluctuation in giraffes.

5. Discussion

Our results confirmed the fact that female okapi is significantly heavier in body weight than males. There is sexual dimorphism between males and females. Despite only males having ossicones, on average males are lower than females by about 7cm and on average 8% larger in body mass (Kingdon et al. 2013). In contrast, female giraffe is significantly smaller than males, which is usual in dimorphic polygynous species (Lee and Moss 1986). It may be surprising but females are larger than males in more species of mammals than is supposed, for example Common marmoset (*Callithrix jacchus*, Wettstein 1963), Golden hamster (*Mesocricetus auratus,* Swanson 1967), Common duiker (*Sylvicapra grimmia,* Wilson 1968) or Kirk's dikdik (*Madoqua kirki,* Kellas 1955). This phenomenon seems not to be correlated with male parental investment, polyandry, female dominance or maturity either. Probably the most common selective pressures are connected to the fact that a bigger mother is usually better mother and those are resulting from stronger competition among females. Also, smaller males can be more successful in competing for females, as in some environments smaller body size can be advantageous and connected to greater agility or speed (Ralls 1976). For okapi, as for other solitary living mammals it can be difficult to walk in dense forest to find a female to mate, and so smaller body size of males can be an advantage.

The body weight of females is mostly affected by pregnancy (Hewison and Gaillard 1999). It may be surprising from our limited results that in okapi, the mean daily weight gain in the first and second half of pregnancy is the opposite to the trend in giraffe. Okapis gain more in the first half of pregnancy, while giraffes gain more in the second half. We can discuss why this may be. For example, the roof reconstruction of okapi enclosure started after the second parturition. Some pre-reconstruction actions could affect the second half of pregnancy and the result impact the mean of both pregnancies.

Body weight of new born males and females (28.5 kg and 25.5 kg respectively) is higher than the mean body weight recorded in study of Bennett and Lindsey (20.13 kg, 1992). We did not find significant difference of daily gains between males and females during the first year, but males tended to be heavier up to the age of 2.5 years. Unfortunately, data is missing for this time, but according to the long-term growth curve it seems that at the age of 2.5 years, females start to be bigger than males. The weight difference between sexes in giraffes appears around 15 and 18 months of age (Gloneková et al. 2016). Our sample is too small to make a conclusion, we can only suspect when the weight difference appears.

Adult animals were significantly affected by changing season. Okapis were lighter in summer and autumn and heavier in winter and spring. Study of giraffes brought the same results. Females were lighter in autumn and heavier in winter, only one male in study was lighter in spring and summer probably because of his interest in females in oestrus. In giraffes it is due to changes in diet and in movement. They spend more time in the outside enclosure during the favourable season and their diet is not as abundant as during colder months (Gloneková et al. 2016). The diet of okapi does not change throughout the whole year, but the time when they can be outside is the same as in giraffes, and the decrease of weight during summer and autumn can be due to increased physical activity.

The solitary way of okapi life leaded us to test if change in social structure can influence body weight. We tested two males and they were significantly heavier when they were alone than in the company of females or another male, even if each animal has its own enclosure. Fluctuation of both sexes due to social changes is visible but not significant, presumably due to low sample size. In males, the most weight was lost when they were paired with females. It is not a surprising result, it is known from other species, for example in reindeer, moose or elephant seal, and it is connected to reproductive effort (Franzman et al.1976; Deutsch et al. 1990; Mysterud et al. 2003). While females gained the most in the same time period, it is probably, because she was already pregnant.

The roof reconstruction resulted in a significant decrease in overall weight of adult okapi. While the weight of male okapi reached the pre-reconstruction value as soon as after 3 months after the end of work, adult female okapi weight remained similar during 5 months following reconstruction, probably because of her lactation load combined with recorded glycosuria. Glycosuria is present in a number of captive okapi across United States, Europe and Japan. It is abnormal and may have an infectious, inherited, metabolic or familial etiology. It is supposed that current dietary recommendations can play a role, as okapi fed in situ diet do not have glucosuria (Fleming et al. 2005). It is also confirmed that increased stress may intensify the glycosuria (Ingle and Nezamis 1950). Animals kept in captivity are influenced by many biotic and abiotic factors which can cause stress and result in weight loss and changed physiology or behaviour (Morgan and Tromborg 2007). Weight of adult giraffes fluctuate under changing condition in husbandry, diet or social structure.

Due to a small sample size the statistical analyses are not significant and further study will be necessary to obtain more data from more individuals.

6. Conclusions

Even if giraffes and okapi are taxonomically related and share some common features, there is also several dissimilarities. Solitary and hidden living okapi and in herd living giraffe are iconic animals representing challenge for breeders. Their different life strategy leaded us to compare their growth pattern, mean body weight of both sexes in different age and weight fluctuation caused by different factors. From husbandry point of view, manipulation with okapi is much easier than with giraffe and weighting of okapi is common in many facilities but the data are rarely published. The data what were analysed are limited, but the results can be useful for keepers and breeders. The body weight fluctuates through year in giraffes as well as in okapi due to changing season, husbandry, diet or social structure. These factors are visible and expected, but there are still some unknown factors affecting the body weight.

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