CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Husbandry and Breeding Management Practices in South American Camelids kept in Europe

MASTER'S THESIS

Prague 2022

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Declaration

I hereby declare that I have done this thesis entitled “Husbandry and Breeding Management Practices in South American Camelids kept in Europe” independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 22. 4. 2022

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Kateřina Berková

Acknowledgements

First, I would like to thank my supervisor, Ing. Tamara Fedorova, Ph.D., for her support, patience, as well as for her advice and assistance in the analysis of data, and for providing me a contact with Czech zoos.

Secondly, I would like to thank to all farmers, breeders, and keepers from all studied zoos and farms for providing me the information about animals they own or keep – this thesis would not have been possible without them. In this context, I would also like to thank my colleague, Ing. Jana Marešová, for providing me the data from the zoos I was unable to visit, and for her pleasant company during the data collection.

I cannot thank enough my boyfriend, Vojta, for helping me with data evaluation, helpful proofreading assistance and mostly for his tremendous support throughout my master's studies. He's always been there for me and tried to encourage me and always helped me.

And last but not least, a thousand thanks belong to my family, especially to my parents, Pavla and Marek, for great emotional support, encouragement and for that always being always there for me and for standing by me. Without you this journey would not have been possible, for that I thank you very much.

Abstract

In the last few decades, breeding SACs has become an increasingly popular activity for many breeders. Currently, there are not enough papers summarizing the status of SACs in zoos. For this reason, the first objective of this thesis was to summarize and evaluate breeding and reproduction techniques in selected Czech zoos. European zookeepers have been regularly recording data relating to animals kept in zoos for last 50 years. In this paper, these data were exported and, by merging them with data obtained by visits of the zoo, they were compared and analysed. The analysis revealed that the selected Czech zoos were mainly breeding domesticated species - llamas and alpacas and that the percentage of mortality of young animals during the first month was 58 %. Alpacas were bred mostly in zoos (67 % of all species) and also on farms (70 % of all species). A more in-depth study would be needed to understand SACs' husbandry and breeding management methods practiced on zoos.

SACs are used primarily for their high-quality wool and because of their calm temperament as hobby companions. Several papers summarized the status of these animals on European farms and on farms outside Europe. The breeding of domestic species, llamas and alpacas, is becoming more popular nowadays compared to previous years. The second objective was also to summarise breeding and reproductive techniques, but for this matter, on selected European farms. The collection of the data was carried out by means of a questionnaire survey. Numbers, breeding techniques and reproductive information were obtained and afterwards analysed. A prevalence of farms that bred only alpaca species was observed (56 %). A total of 57 % of farmers answered that they use some breeding method, in most cases it was the selection of males and females for reproducing. For this part of the problematics, it is also in demand to analyse data about breeding and reproductive management more deeply.

Key words: SAC, husbandry of camelids, reproduction, European farms, Czech zoos

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EAZA: The European Association of Zoos and Aquaria

FAO-DAD-IS: Food and Agriculture Organization of the United Nations, Domestic Animal Diversity Information System

GAN: Generative Adversarial Network

ISIS: The International Species Information System

IUCN: International Union for Conservation of Nature and Natural Resources

JM: Jana Marešová

KB: Kateřina Berková

SAC: South American Camelid

UCSZOO: Union of Czech and Slovak Zoological Gardens

ZIMS: Zoological Information Management Software

1. Introduction and Literature Review

1.1. History of family Camelidae

Camelidae originally inhabited North America in Eocene period (Rocha-dos-Santos et al. 2017), that was about 55 – 34 million years ago (Licht et al. 2014). During late Pleistocene, 120 000 – 130 000 years ago (Kim & Chang 2021), Camelidae reached also area of South America through Panamá isthmus. Later, they went extinct in the continent of North America (Rocha-dos-Santos et al. 2017). Nowadays, introduced back to North America, there are frequently traded and bred (Dodaro et al. 2019).

Archaeologists using a biochronostratigraphic perspective claim that Quartenary mammalian fauna was one of the most abundant and diverse in the South America in the Region of Pampa. Tomassini et al. (2014) revealed radiocarbon works about presence of guanacos in Argentina during the late Holocene. Group of guanacos was recorded in Pampean region. These records are dated from around 2350 years ago and show that guanaco species was present and was affected by floods that occurred in higher frequencies in Quartenary (Tomassini et al. 2014).

In prehistoric Andean period, societies relied on South America Camelids (SACs) because of their meat as a food and raw materials for clothes and ropes. SACs were used also as pack-animals. Evidences from rock-art or from ceramic modelled vessels prove SACs' importance in past (Yacobaccio et al. 2009).

1.2. Taxonomy

South American camelids, shortly SACs, are classified into the order *Cetartiodactyla* (IUCN Red list, 2022), suborder *Tylopoda* (Fuller 2004), family *Camelidae* (Wheeler 1995). Family Camelidae includes 6 species in Old and New World (Rocha-dos-Santos et al. 2017). All living camelids are then divided into 2 subfamilies - Camelini and Lamini. Camelini, with genus *Camelus* (Rocha-dos-Santos et al. 2017), includes Old World camels, Bactrian and dromedary camels. Lamini, with genuses *Lama* and *Vicugna* (Rocha-dos-Santos et al. 2017), includes New World camels, South American camelids (O'Brien 2017). All llamas, alpacas, guanacos and vicuñas belong to the group of SACs (Wheeler 1995; O'Brien 2017).

Family Camelidae consist of 7 species – 3 of them are larger camels and 4 of them are smaller camels. One-humped dromedary (*Camelus dromedaries*), Wild Bactrian camel (C. *ferus*) and Domestic Bactrian camel (C. *bactrianus*) belong to the group of larger camels (Fuller 2004; Agnew 2018). Smaller camels are then divided into wild and domesticated species (Yacobaccio et al. 2016). Vicuñas (*Vicugna vicugna*) and guanacos (*Lama guanicoe*) are wild species and llamas (*L. glama*) and alpacas (*V. pacos*) are domesticated species (Fuller 2004; Yacobaccio et al. 2016).

1.3. Description of species

1.3.1. The guanaco (*Lama guanicoe*)

Guanacos are considered as wild and the largest from wild species of SACs. Archaeological remains date guanacos to the period of 2 million years ago (Wheeler 1995).

We distinguish 4 subspecies of *Lama guanicoe* (Figure 1), those are: *Lama guanicoe guanicoe*, *L. g. huanacus*, *L. g. cacsilensis* and *L. g. voglii* (Wheeler 1995; Rocha-dos-Santos et al. 2017). These subspecies vary in distribution. *L. g. guanicoe* and *L. g. huanacus* are southern species. Patagonia, Tierra den Fuego and Argentina are home to *L. g. guanicoe*, Chile is home for *L. g. huanacus*. Northern species live in high altitudes in Peru (*L. g. cacsilensis*) and in Argentine Andes (*L. g. voglii*) (Yacobaccio et al. 2016).

Figure 1. Guanaco in its natural habitat. Credit: https://www.pexels.com/photo/guanaco-standing-in-pampas-11422442/.

Southern subspecies, such as *L. g. guanicoe*, have rather darker pelage coloration than northern species, such as *L. g. cacsilensis*, those have yellow tones of their pelage. All subspecies are characterized by typical dark black coloration of head and white parts around lips, eyes and ears. Their chest, abdomen and inner parts of legs have typical white coloration. Hair in fur are quite short, diameter of guanaco's fibre varies from 16 to 24 μ (Wheeler 1995). Guanaco species has the broadest distribution of all four SAC species (Fowler & Bravo 2010). Sister taxon for *Lama guanicoe* order is *Vicugna vicugna* (Rocha-dos-Santos et al. 2017).

1.3.2. The vicuña (*Vicugna vicugna*)

Vicuñas are the second wild species of SACs. Those species are better adapted to extreme elevations in the Andes (Franklin 1982). Fossil remains date the origin of genus *Vicuña* to the period of 2 million years ago to the area of Argentine plains.

Figure 2. Running vicuña. Credit: https://www.pexels.com/photo/brown-vicuna-walking-on-brown-sand-under-the-cloudy-sky-4613387/.

Vicuña (Figure 2) is the smallest of all SACs (Fowler & Bravo 2010). There exist 2 subspecies of vicuña - *Vicugna vicugna vicugna* (the Argentinian subspecies) and *V. v. mensalis* (Wheeler 1995). Both subspecies differ in body size, height and length of molars. *V. v. mensalis*, the Peruvian subspecies, is a little bit smaller with lower height and shorter height of molars. This subspecies is also typical for its long hair on chest (Wheeler 1995). The fibre that comes from vicuña's hair is of the finest of all SAC species (Pacheco et al. 2019).

Vicuñas are characterized by darker colour of coat; head, neck, back and dorsal have brown colour. Coat has white areas on face, chest and abdomen. Hair in fur is longer than in guanaco, the average length of fibre in adult vicuñas is about 3 cm (Pacheco et al. 2019). The main differences in appearance of guanacos and vicuñas are the presence of longer chest hair that are present only in vicuña and lighter coloration of coat (Wheeler 1995). The distribution of vicuñas in natural habitat, South America, is limited to the Puna region, the highlands of the Andes (Fowler & Bravo 2010).

1.3.3. Domestication of wild species

Guanacos and vicuñas inhabited Puna ecosystems of the Peruvian Andes with elevations between 4000-4900 m (Franklin 1982). There, they became the prey of hunters together with huemul deer (*Hippocamelus antisensis*). This area was guanacos and vicuñas home for approximately 12 000 years. As it is known that domestication is a result of an interaction between people and wild living animals (Yacobaccio et al. 2016), right because people came to the contact with wild fauna more and more, it gave an origin to domesticated species (Wheeler 1995). Areas in the Moist Puna region have evidence that llamas and alpacas were brought by human control 6000 years ago (Franklin 1982). Second possible centre of domestication of SACs has been reported in the Salt Puna region 4000 years ago.

The Puna ecosystem in Altiplano region in Southern Andes is the area where the domestication of camelids took place. This process took a long time and must have occurred many times in different parts of the Puna region (Baied & Wheeler 1993; Yacobaccio et al. 2016). Camelids living in South America have been domesticated for some 4000 years (Fuller 2004). Attempts for domesticating these wild animals were mainly because they served as farm stock and pack animals (Franklin 1982). Both wild

species had a number of ecological and also behavioural adaptations that were favourable for domestication, such as taming potential or dominance hierarchy (Yacobaccio et al. 2016). On the grounds of severe environmental conditions where animals and people met, people tried to use these animals as a transporting system in draught or at extreme elevations. For these conditions, camelids are well adapted morphologically and physically (Wheeler 1995; Fuller 2004). Besides these changes that are beneficial for farmers living in high altitudes, also the territoriality is diminished. Reduced territoriality is regarded as an advantage among farmers (Fowler & Bravo 2010).

1.3.4. The llama (*Lama glama*)

Domestication of the northern guanacos led to the origin of llama species (Yacobaccio et al. 2016). Figure 3 shows the largest from two domesticated camelid species , *Lama glama* (Fowler & Bravo 2010). As well as guanaco, llama is well adapted to a wide range of environments. Name llama comes from Quechua language and is known as qawra by Aymara native speakers (Wheeler 1995).

Figure 3. A llama on grassland. Credit: https://www.pexels.com/photo/llama-on-green-grass-8490680/.

According to appearance of wool, llamas are divided into 3 main groups. The first group consists of nonwooly phenotype that lives mainly in Peru, Bolivia and northern Chile. This phenotype is typical by sparse fibre growth on the body and by absence of fibre on face and legs. Native people named this phenotype q'ara, in Quechua language. Wooly phenotype belongs to the group that lives in Argentina. These llamas have bigger density of fibre on their bodies and are distinguished by presence of fibre also on head but not on legs. Quechua people call this wooly type ch'aku (Fowler & Bravo 2010) and Aymaran people t'awrani. Both phenotypes can mix and thus give forming of intermediate phenotype that lives in both regions and shares appearance with both phenotypes (Wheeler 1995; Fowler & Bravo 2010).

1.3.5. The alpaca (*Vicugna pacos*)

Wild vicuñas gave rise to alpacas (Yacobaccio et al. 2016). Alpacas are very favourable camelids among farmers and smallholders (Windschnurer et al. 2020). They are smaller than llamas, rather ressemble vicuñas. Name alpaca comes from Quechua language paqocha and Aymarayan language allpachu.

Figure 4. Furry alpaca. Credit: https://www.pexels.com/photo/furry-alpaca-standing-on-a-cliff-4190271/.

V. pacos (Figure 4) is characterized by variety of fibre types - from fine, extra fine to wavy type of fibre. We distinguish 2 phenotypes of alpacas (Baied & Wheeler 1993; Fowler & Bravo 2010). A phenotype called suri with long straight fibre that is organized in waves that surrounding alpaca's body. The other type, huacaya, has shorter fibre than suri. Because of wavy fibre it gives the alpaca spongy appearance. As in llamas, there exists an intermediate type, chili, which is a mix of two previous phenotypes (Wheeler 1995). Both Wheeler (1995) and Fowler & Bravo (2010) claims that 90 % of all alpaca species are phenotypes of huacaya. Alpacas are honoured animals because of their fibre production, landscape management and activities connected with human amusement, trekking (Windschnurer et al. 2020).

Nowadays there exist also hybrids of these 2 domesticated species – wari and pacovicuña. Wari is a hybrid of llama and alpaca and pacovicuña is a hybrid of alpaca and vicuña. Figure 5 shows an evolutionary relationship between wild and domesticated species which led to wari (Wheeler 1995).

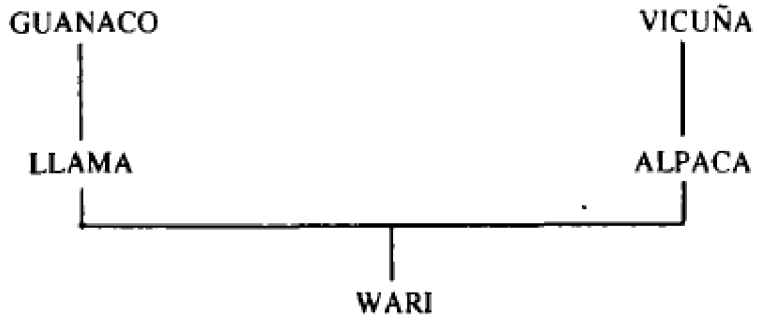

Figure 5. Evolutionary model of llama and alpaca domestication derived from archaezoological evidence. Credit: Wheeler (1995).

1.4. Distribution

1.4.1. Natural habitat

SACs are native to the South America, to the Andes mountains (Figure 6). They are adapted to high altitudes (O'Brien 2017) and are specialists for living in arid hilly areas (González et al. 2006). According to Fowler & Bravo (2010) SACs occupy some of the most inhospitable habitats in the World. For coping with extreme conditions in there they have number of physiological adaptations. In high altitudes, many animal species would not survive. Camelids yet evolved special coping mechanism for hypoxia (O'Brien 2017), widely fluctuating diurnal temperature (Baied & Wheeler 1993) and low atmospheric pressures (González et al. 2006; O'Brien 2017).

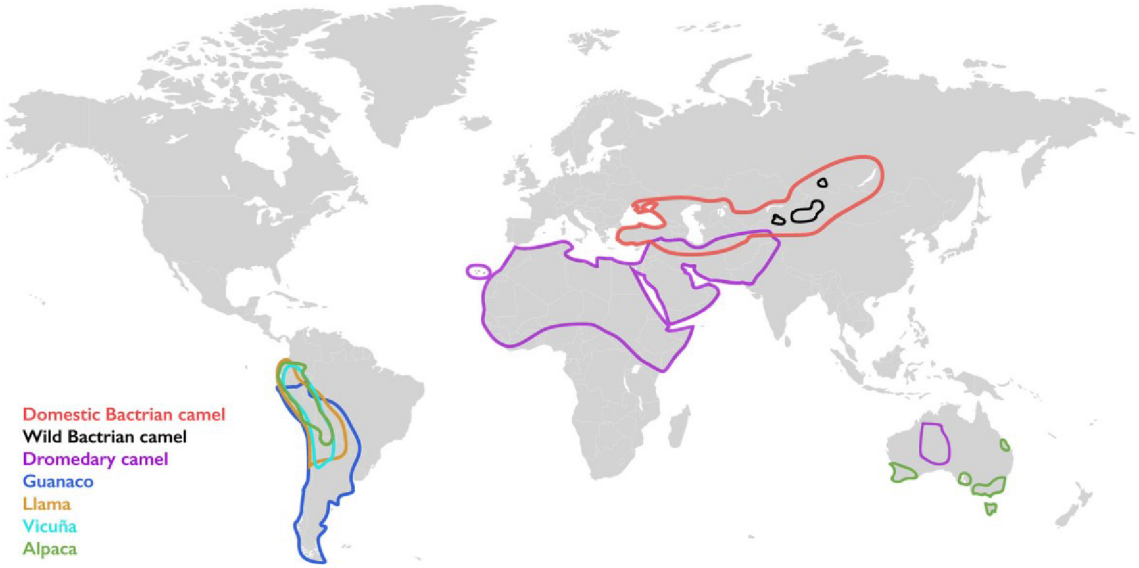

Figure 6. Map of distribution of a family Camelidae. Credit: Zarrin et al. (2020).

1.4.2. Numbers

1.4.2.1. Guanacos

According to IUCN Red list, the total continental population of guanacos is between 1.5 and 2.2 million and is still increasing. In the work of Franklin (1982) the highest numbers of guanacos were estimated in Argentina (83 %) and Chile (16 %). A very similar percentage distribution of the guanaco population is recorded in a recent IUCN Red list study.

1.4.2.2. Vicuñas

Vicuña's population has an increasing trend, too. The total population of vicuñas in the South America is estimated to be around 350,000 individuals with the highest numbers in Perú (42 %), Argentina (20 %) and Chile (3 %) (IUCN Red list 2022). The total number of all vicuñas in the World is estimated to be around 0.5 million individuals.

1.4.2.3. Alpacas and llamas

Domesticated species are gaining in popularity worldwide (Raggi et al. 1994; Gutierrez et al. 2018). Their numbers are increasing, too. Nowadays, there are estimated 7 million llamas and alpacas together located in the South America according to The British Llama Society (2022). According to FAO-DAD-IS, estimated population of alpacas was 3.4 million individuals in Peru and Chile in 2014 and is increasing. In a study of Cardellino et al. (2004) and Gutierrez et al. (2018), the population of alpacas in the World was estimated to 3.5 million individuals, from which 86 % is situated in Perú. The total population of llamas in Peru was estimated to 745,000 individuals (Gutierrez et al. 2018), which is according to del Valle Ferreyra et al. (2022) 90 % of the World's alpaca population.

1.4.3. The Puna region

In the Andes mountains, typical mountain ecosystem is Puna region (Figure 7). The Puna region takes up highlands between 3,000 and 5,500 metres above sea level (Baied & Wheeler 1993; Yacobaccio et al. 2009). It is situated between around 70° and 27° South latitude (Baied & Wheeler 1993). Generally, soils that are found in the Puna

are poor and limited by phosphorus concentration. The Altiplano region is the exception, there the soils are limited to amounts of nitrogen and carbon (Rolando et al. 2017a).

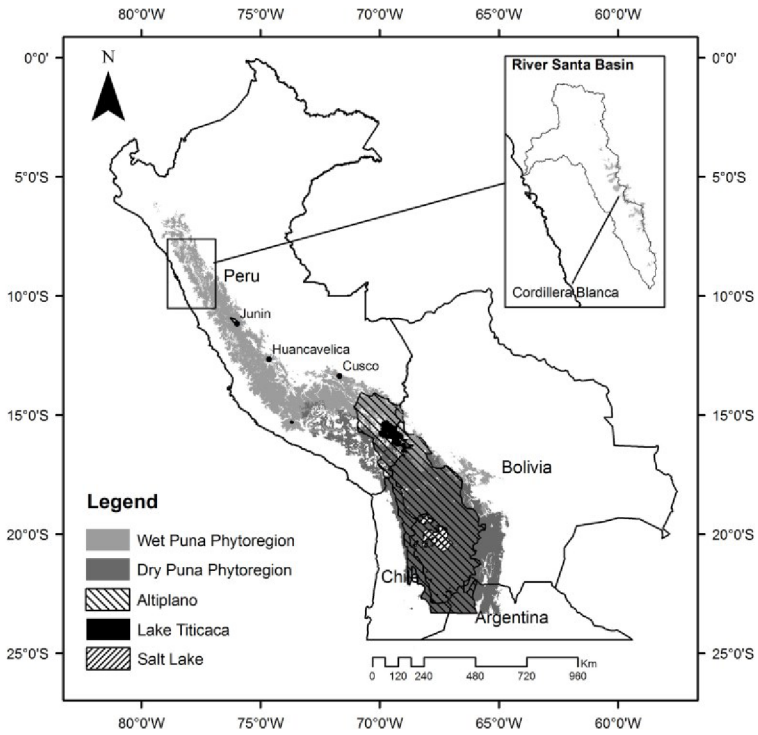

Figure 7. Geographical representation of the Puna region with highlighted area of studied region in the paper. Credit: Rolando et al. (2017).

This region is characterized by high biological diversity and endemism (Rolando et al. 2017a), by high solar radiation, low atmospheric pressure (Yacobaccio et al. 2009), by reduced atmospheric pressure, changing diurnal temperatures, reduced moisture and extended droughts (Baied & Wheeler 1993). Puna has spatial and temporal climatic variability (Rolando et al. 2017a). Major animals that inhabit Puna region are cattle (*Bos taurus*), sheep (*Ovis aries*) and of course, camelid species (*Vicugna vicugna*, *Llama guanicoe*) (Yacobaccio et al. 2009; Rolando et al. 2017b). Domesticated camelid species, *Llama glama* and *Vicugna pacos*, inhabit Puna as well as the wild species (Rolando et al. 2017a).

The Andes mountains are considered to be an extreme habitats due to hypoxic conditions and cold temperatures (Friedrich & Wiener 2020). In the course of evolution, animals have adapted to these conditions in various ways, both physiologically and

morphologically (Ayalew et al. 2021). For living in such harsh conditions, SACs evolved coping mechanisms, that persist also in domesticated species that are no longer bred in high-altitude conditions. These adaptations include, among other things, changes in haemoglobin structure (Weber 2007).

1.5. Social behaviour

Both wild and domesticated species are considered to be very social (Fowler 2013; Cebra et al. 2014). Llamas together with alpacas, that are used to human contact, are extremely inquisitive (Cebra et al. 2014). Their temperament is curious. Llamas and alpacas are a bit shy of other species (Fowler 2013).

1.5.1. Herd composition of wild species

Guanaco and vicuña species differ slightly in the flexibility of their social ranks. Vicuñas are less flexible than guanacos (Cebra et al. 2014), they form either sedentary populations or migratory populations depending on weather conditions and food supply (González et al. 2006). Guanacos' populations can be sedentary and migratory, too (Cebra et al. 2014).

1.5.1.1. Vicuñas

Many studies describe a group composition of vicuñas. Gordon (2009) described 3 main types – family harems, bachelor groups and individuals. Franklin (1971) in his work also summarized what the social structure of vicuñas looks like. Vicuñas can form populations of:

- permanent territorial family groups,
- marginal territorial family groups,
- mobile family groups,
- male groups,
- solo males.

First two populations, the permanent territorial family group and marginal territorial family group, is typically consist of 1 adult male, several females and their crias and yearlings. These groups are highly territorial and stable (Gordon 2009; McElderry-Maxwell 2019). In the study of Cebra et al. (2014) it was demonstrated that these groups consist of 1 adult male, 2-5 females with offspring (and according to Yacobaccio et al. (2016) also 3-4 females with 2 offspring). Males in both groups defend a territory that comprised of a feeding territory, where animals spent most time of the

day; and of a sleeping territory, where animals spent the night. Both territorial groups are stable units with the same adult females that remain in the herd throughout the year (Arzamendia & Vilá 2008).

A mobile family group is a next type of vicuña's social unit. Animals in there form temporary groups in which a male did not established a territory. Males together with females and their yearlings form mobile family groups in a number from 2 to 5 animals. Besides groups that consist of both males and females, vicuñas can also form groups that comprise only male individuals. Male groups which include only non-territorial males number from 2 to 100 individuals, but often around 20 individuals. These males occupy habitat that is non-preferred and is not occupied by other territorial males (Correa et al. 2013).

Sexually and physically mature individuals who left these all-male groups then live in solitude (Bonacic et al. 2002). They can either be individuals that have been driven out of the herd by the territorial alpha male and are thus ready to establish their own territory, or they can be injured. Old males that are no longer fulfilling their function in the herd can be found in all-male groups (Franklin 1971; Gordon 2009).

1.5.1.2. Guanacos

Guanacos form very similar family groups as vicuñas (Young & Franklin 2004; González et al. 2006) and they establish a hierarchy by the degree of asymmetry in the interactions among individuals in the herd. These interactions consist of fights from which each victory contributes to higher rank in the herd. In the study of Correa et al. (2013), these hierarchical ranks were quite stable during observed period.

According to Yacobaccio et al. (2016), guanacos can form a family groups as previous mentioned in vicuñas (McElderry-Maxwell 2019). These groups consist of 5–13 adults and around 4–9 offspring (González et al. 2006). This group organization was also confirmed in the study of Correa et al. (2013), where there was revealed that groups consist of 1 adult male that defend a territory for 6 lactating females, 2 non-lactating females and 6 young ones on an average. Single male groups that are not territorial can be also formed, neither with the females nor with the young ones. As well as male vicuñas, guanaco males can live in solitude (Young & Franklin 2004).

In every family group that is comprised of one breeding male and several females, is an offspring driven away from the group. This does not differ in sex of the young, both young males and females are chased away with a difference of length of leaving the herd. Males are driven away from 4 to 9 months (Cebra et al. 2014) or 6 to 10 months (Correa et al. 2013); females from 10 to 12 months (Cebra et al. 2014). This trend in driving young males out of the herd happens because of the territoriality of a breeding male, a macho (González et al. 2006).

1.5.2. Herd composition of domesticated species

Group composition of wild and domesticated species slightly differs. Mixed herds of camelids and sheep are usually found in the South America (Markemann & Zárate 2010). Outside its native range, alpacas and llamas can be bred with other livestock, such as goats or others (Turner 2014). These mixed herds can be provided because of camelids' gentle temperament. Both alpacas and llamas have retained a territoriality, which is very beneficial to the breeders if the alpacas share grazing with other livestock. They play a role of livestock flock guardians (AAA Inc. Education 2008). Llamas, as well as alpacas, are bred in small family herds (Cebra et al. 2014).

1.5.3. Territoriality

Territoriality was defined in a study of Kamath & Wesner (2020, p. 6) as "an accurate enough abstraction for understanding space use, resource use and mating patterns but can be resistant to acknowledging its limitations as an explanatory framework". Territorial system forms the origin of how animals' populations were organized (Franklin 1971).

Wild camelids are known for their high aggressiveness and territoriality against their own species of same sex (Capriles Flores & Tripcevich 2017). Territorial males defend their space with high quality of vegetation and low abundance of predators (González et al. 2006). Territoriality is typical for SACs' males (Windschnurer et al. 2020) that are found in groups where females occur. (Franklin 1971). This territoriality can be both offensive (aggressive displays, chase; Franklin, 1971) and defensive (postures and humming; Windschnurer et al., 2020). A food supply is also correlated with

territoriality. When there is no stable food supply, territoriality is lost and the group is broken apart until a food supply is found (Yacobaccio et al. 2016).

The territoriality includes for example fight attempts, vocalization, biting, bumping etc. This type of behaviour was seen even in domesticated species and can result in injuries to human and other animals in the herd (Windschnurer et al. 2020). Groups of both wild species, guanacos and vicuñas, are stable and territorial all year round (González et al. 2006; Yacobaccio et al. 2016). Territory's size is around 25 ha and does not vary among all types. Smaller areas results in high visibility among neighbouring territories (Young & Franklin 2004; Arzamendia & Vilá 2008). Young & Franklin (2004) revealed that 70 % of all guanaco males are loyal to the territory they chose last season. A process of establishing a new territory is consisted in:

- male discovering a likely location by spending most of his time feeding and resting,
- integrating of females into the herd and turning the attention toward keeping the new members in his territory,
- male becoming increasingly aggressive towards juvenile males in the territory.

Even domesticated species retained territoriality that includes territorial dung piles and territorial behaviour near water and food resources (Capriles Flores & Tripcevich 2017). Once females in a harem are pregnant, the male then defends a territory against other males or predators (McElderry-Maxwell 2019).

1.5.4. Mating system

SACs are classified as nonseasonal breeders (Pollard et al. 1995), although, environmental and nutritional factors often make them behave as seasonal breeders (Cebra et al. 2014). Their reproduction can be dependent on environmental conditions, but only in harsh conditions. In their natural habitat, the Puna region, sexual activity can be seen in warm rainy months, from November to April (Brown 2000; Cebra et al. 2014; Tibary & Ruiz 2018), according to Pollard et al. (1995), the sexual activity occurs during late December to March. Warmer temperatures help keep babies from freezing. When bred on farms or zoos, where the food availability is same all year round and where there

are no bigger fluctuations in temperatures, SACs are sexually active throughout the year (Cebra et al. 2014).

1.6. Reproduction

Despite the uniqueness of the reproductive tract of SACs the information are incomplete (Cebra et al., 2014) because of its incomprehension (Vaughan & Tibary 2006). Many studies describe SACs' reproductive system like no other of traditional livestock (McElderry-Maxwell 2019).

SACs are polygynous animals. Males defend territories against predators and form stable herds together with several females and their offspring (González et al. 2006). Both wild and domesticated species are seasonal breeders – spermatogenesis in males continues throughout whole year but with the highest rate during breeding season (Han 2011). Reproduction is in a study of Brown (2000) tied to the warmer rainy months, November to April.

1.6.1. Reproduction in females

Females' ovaries are of ellipsoid or globular form. The uterus is bicornate, which means that in situ it resembles the letter Y. Bicornate also means, that it has got two horns. In SACs, left horn might be much larger, than the right one. Also, the left horn is a place where most of pregnancies take place (Hafez & Hafez 2013).

The puberty in SACs is influenced primarily by environmental conditions (e.g. forage quality) (Cebra et al., 2014). Females are induced ovulators (Pollard et al. 1995; Cebra et al. 2014), which means that age when their first ovulation occurs depends on age at first mating. Usually, the puberty occurs at 1 year (Pollard et al. 1995). The luteinizing hormone that is from physiological point of view responsible for ovulation is triggered by copulation. The ovulation occurs in a range of 24–48 hours according to Cebra et al. (2014), 26 hours in the study of (Sumar 1999) and 24–36 hours according to Pollard et al. (1995) after the copulation. In comparison to other mammals, SACs do not have regular oestrous cycles (Hafez & Hafez 2013; Cebra et al. 2014).

A fertility of SACs is comparable to other domestic animal species with an average success rate of 1 insemination per 3 mating attempts (Saun 2008).

1.6.2. Reproduction in males

Male reproductive organ, a penis, is of cartilage (McElderry-Maxwell 2019), and have a length of 35 to 45 centimetres. The two testicles are small and are situated towards the back of the tail below the anus (Brown, 2000; Cebra et al. 2014). When males reach 12 months of age, their testicles can be easily tangible. By the determination of size, conformation and other characteristics of testicles, males can already be selected as sires. One of the curiosities is that SACs lack of seminal vesicles (Cebra et al. 2014).

A puberty in males is triggered by a presence of spermatozoon, a sperm, in the ejaculate. The puberty occurs at about 2 years, may be earlier (1.5 years) or also tardier (up to 3 years). Males that have not reached sexual maturity within 3 years are then reduced from breeding (Hafez & Hafez 2013; Cebra et al. 2014).

1.6.3. Mating behaviour

The copulation itself consists first of laying the female on the ground. If she does not perform this act by herself, the male forces her to do so (Sumar 1999). After female lays down, the hard cartilaginous penis then penetrates female's cervix and the semen is deposited into both uterine horns (Cebra et al. 2014; McElderry-Maxwell 2019).

Gestation is known to last 335 to 360 days in llamas, 327 to 346 in alpacas (Davis et al. 1997; Cebra et al. 2014). Reproduction is influenced primarily by nutrition. The composition of the nutrition; e.g. energetic value, protein value, or dietary status; can affect the influence on reproductive performance (Saun, 2008).

1.6.4. Parturition and caring after new-born crias

In SACs' native habitat with a presence of dry and wet seasons (Brown 2000), most of parturitions take place during rainy seasons. Females bred in captivity give birth at any time of the year (Cebra et al. 2014). In wild nature, parturitions occur only during the early hours of the day (Fowler & Bravo 2010). The early time of parturition is one of several adaptations to harsh environment in Puna region (Cebra et al., 2014). Most of parturitions occurs at daytime.

Camelids care after their crias. Cria is a term for a baby from the period of birth to the period of the weaning (Figure 8). Usually, new-borns are covered by an epidermal

membrane. Mothers do not lick their crias to dry them, nor do they encourage them to arise in any way. Some mothers on the other side snuggle up to their babies and make a humming sound. This behaviour is described as kissing by llama owners. It is known that alpacas and llamas are excellent mothers, they do not abandon their cria very often (Fowler & Bravo 2010).

Figure 8. Perdy with her cria Mullacott Appaloosa Angel. Credit: British Alpaca Society (2020).

The first nursing occurs at about one hour after the parturition. Typical suckling position of a cria and a mother is reverse parallel – cria is standing at the side of mother's body and its tail is situated towards mother's head (Prescott 1981; Pollard et al. 1993). The first 10 days of cria's life this nursing behaviour repeats 2 or 3 times per hour during the day. The older the cria gets, the longer the suckling time becomes (Prescott 1981) and the cria tries to nibble grass 14 days after the birth. A socialization is very important for

the correct integration of cria into the herd. All females in the herd try to nose the new-born and by sniffing it, they recognize a new incoming (Pollard et al. 1993). A weaning, crucial and critical period in an operation with cria (Caldwell et al. 2011), occurs at 6 months of cria's age. In some herds, it was studied that some crias are kicked out right when they reach 4 to 5 months. The time of weaning slightly varies in guanacos and vicuñas. Vicuñas have a similar pattern as alpacas and llamas, their cria weans when it reaches 6 months. In herds that consist of guanacos, yearlings can be still found with their mother (Pollard et al. 1993).

1.7. Management of breeding practices

The breeding of SACs is becoming increasingly attractive (Neubert et al. 2021). These animals are bred mainly for their fibre, milk (Vilá & Arzamendia 2020), meat and skin (Zarrin et al. 2020). Camelids living in their native habitat, the Andes mountains, are used mainly as beast of burden (Capriles Flores & Tripcevich 2017).

Farmers have found that by making the right adjustments to their husbandry practices, they can ensure better viability and yield from their livestock. They started to use breeding management methods, that are "combinations of mating and caretaking practices (herder's interventions on the mother)" (Genin & Muriel 2006).

1.7.1. How are SACs bred in Europe?

The importance of domesticated species, llama and alpaca, is increasing each year in European states (The Ministry for Primary Industries, 2010). The main purpose of camelid breeding in Europe is a fibre (The British Alpaca Society 2020). Another purposes for which camelids are bred, are: hobby keeping, breeding itself, trekking, etc. (Hengrave Burri et al. 2005; D'Alterio et al. 2006; Bauerstatter et al. 2018; Neubert et al. 2021)

Shared housing of camelids and other livestock, such as goats or sheep, is the most common way of how to breed domestic camelids together with livestock (Hengrave Burri et al. 2005; Neubert et al. 2021). When a new animal is carried into the existing herd, it should be in a quarantine at least for 30 days to prevent spreading a disease into a healthy herd (Neubert et al. 2021).

Alpaca and llama males are usually selected for breeding according to a pedigree, fibre quality, physical conformation or show performance. In countries outside of South America, many males are mated to several females (Tibary & Ruiz 2018).

1.7.2. How are SACs bred in their natural habitat?

A pastoralism is "the husbandry of domesticated ungulates including cattle, sheep, goat, camels, horses, and donkeys, with no specification of the relative importance of animals in the overall economy, level of incorporation of production into market

economies, degree of mobility, or forms of community social organization" (Arbuckle & Hammer 2019, *p. 393*). It is pastoralism that is used in the habitat of the original range of camelids, the Andean mountains. This type of husbandry enables animals high seasonal mobility across large areas (Lichtenstein & Carmanchahi 2012). In addition to camelids, there are also goats and sheep. (Westreicher et al. 2007).

In Andean pastoral systems, mixed herds of llamas and sheep are found the most (Genin & Muriel 2006). Sheep were, together with other livestock, introduced to South America from Europe (Westreicher et al. 2007). Single-species herds are found rarely. These mixed herds are big in a size and differ in composition according to in what type of habitat they are found. In mountains, a prevalence of llamas is present, with a ratio 2:1 – llamas:sheep. At the foothills, sheep dominate over llamas. And in plains, the composition of llamas and sheep are equal (Genin & Muriel 2006).

In history, all 4 species of SACs were used for transportation of material and people over the mountains. Animals also provided fibre and skin as a material for clothing and ropes. Camelids were also a source of milk and meat (Westreicher et al. 2007; Rodriguez Vargas et al. 2021). Besides their material purpose, alpacas together with llamas were sacrificed to the gods by Inca Empire in 14th and 15th century (The British Alpaca Society 2020).

At the present time, males are used as pack animals (Westreicher et al. 2007; Rodriguez Vargas et al. 2021) that travel across mountains to carry loads. Females are used mainly for their fibre of high quality. All animals then provide meat, milk, wool, fat, and dung that can be dried and used as a fuel (Westreicher et al. 2007). Breeding of camelids in countries of South America is specialized mainly in the production of fibre and meat for local people (Yacobaccio et al. 2009). Nowadays, alpacas and llamas are also used as protection of livestock from predators (Matthews et al. 2020). In addition to all the purposes mentioned above, animals can be sold for breeding on the local, regional and national market (Rodriguez Vargas et al. 2021). Males that live solitary and are thus non-territorial, represent a harvestable surplus. They can be sold for breeding on some farms with the purpose of alpaca-vicuña hybrids, or can be simply sold to the zoos (Franklin, 1971).

Besides pastoralism, people use another management strategy for breeding SACs. Vicuñas get along with alpacas and llamas in the same herd very well (Lichtenstein &

Carmanchahi 2012). The best management strategy for breeding these vicuñas is well-protected areas. The evidence of that is method works well is as soon as the population increases, animals disperse and thus repopulate the surrounding habitats that were not occupied by other vicuñas (Franklin 1971).

1.8. General principles for the care of SACs in captivity

1.8.1. Demands

Since camelids are highly social and hierarchical animals, they must be bred in a presence of other camelids – in the same paddock or within sight in a neighbouring paddock. Camelids prefer to share a paddock with other animals of same species, but for short periods they can be kept with other livestock. Sheep and goats are the most secure, because camelids do not behave aggressively against them in most of the cases. For that reason, camelids should not be kept with equines. Despite being highly social, SACs have a natural flight respond so they need specific handling and behaviour considering giving birth, weaning, etc. (Turner 2014).

1.8.1.1. Keeping males

The aggressiveness of males, machos, can be observed very often. Adult males for that reason should be kept separated from other females who are under 12 months to avoid attacks and fights. Adult males can be bred with other adult males in the same group composition as they are in their native habitat. These groups resemble bachelor groups that are present in wild nature in guanacos (Turner 2014).

1.8.1.2. Keeping females

Special care must be given to females, hembras, based on their status (whether they are pregnant, or lactating). Females should be kept to minimize a stress to avoid neonatal losses. In guanaco species, females should be settled into a stable herd at minimum of 7 days before parturition. The supervision of parturition is recommended. However, if camelids are not used to human contact, it is better to leave them undisturbed and people should observe the parturition from a distance (Turner 2014).

1.8.1.3. Crias

Camelid calves, crias, are weaned generally before natural weaning occurs that is happening usually at 10 months. The weaning management requires special care and husbandry. After the cria is weaned, it requires camelid companions. An extra care should be given to a cria due to higher susceptibility to parasitism after weaning. For the

young to settle properly in the herd, the presence of older and well-behaved camelids is suitable. Breeders use two main techniques for weaning the crias – in the first method, cria and mother are moved out of sight of each other, in the second method cria and mother are separated but still visible to each other (Turner 2014).

1.8.2. Zoos in terms of administration

Majority of animals that are bred in European zoos are taken under control of EAZA. EAZA is European Association of Zoos and Aquas. It is the membership organization of the leading zoos and aquariums in Europe and Western Asia. Its purpose is to facilitate cooperation within the zoo and aquarium community towards the goals of education, research and conservation (https://www.eaza.net/about-us/). EAZA connects more than 400 zoos and aquariums (Lina et al. 2020).

The majority of zoological gardens in the Czech Republic (and also in Europe) is united by 2 organizations – UCSZOO and EAZA. UCSZOO is an Union of Czech and Slovak Zoological Gardens. The aim of UCSZOO is to promote mutual cooperation between zoos, to make foreign experience and international contacts available to them and to jointly influence the public and business. Not all zoos are united by UCSZOO. EAZA assists member organisations by sharing information and knowledge, facilitating animal exchanges and organising training programmes. Members of these two associations are then administered by Species360. Species360 works in partnership with zoo associations around the world. This non-profit organization maintains an online database of wild animals that are held under human care. Data obtained from breeders can be found in a software called ZIMS. ZIMS is Zoological Information Management System that contains information on 22,000 species, 10 million animals, and 82 million medical records. This database lets any authorized zoo or aquarium staffer use the new database to check and revise animal records; get answers to husbandry, veterinary, or research questions; and combine data in new and more creative ways than was previously possible (Cohn 2006).

2. Aims of the Thesis

This thesis aimed to:

1. Summarize by the literature review the biology and breeding of SACs and to pose basic information about husbandry camelids at zoo.
2. Compare current status of SACs' breeding using data acquired at the zoos and the data exported from the ZIMS database (focused of maternal breeding).
3. Evaluate the reproductive efficiency of SACs bred in Czech zoos using the data from ZIMS database and from zoo questionnaires.
4. Summarize information about current status of SACs bred on chosen European farms (divided into 5 European regions).
5. Describe data about management and reproduction of camelids bred on chosen European farms.

3. Methods

3.1. Data from zoos – using ZIMS & questionnaires

The first part of the thesis was dealing with a comparison of data of all four species of SAC – *Lama guanicoe*, *L. pacos, Vicugna vicugna and V. pacos*. Data included basic information about animals, information about their reproduction and about relationships among animals in the dataset. All input data were exported from a ZIMS database. Keepers in the selected zoos (Table 1) were then asked about information regarding SAC breeding using pre-designed questionnaire. By combining the data from the ZIMS and from the zoos, a dataset with all needed information was created, from which was then furthered analysis done.

Zoos

The time schedule of collecting the data from the zoos in the Czech Republic can be seen in the Table 1. In all zoos the same two-sided questionnaire was used (Appendix 1).

Table 1. A summary of zoos where the visits were done (and in which month), alternatively where the call was made (and in which month). (*Note: The shortcut JM stands for Ing. Jana Marešová, a Ph.D. colleague and a shortcut KB stands for Kateřina Berková, the author of this thesis*).

Zoo	Visited by	Had a call
Brno	JM (02/2022)	
Děčín	KB (03/2022)	
Liberec	JM, KB (01/2022)	
Olomouc		03/22
Ostrava		03/22
Plzeň	JM (02/2022)	
Praha	JM, KB (12/2021)	
Ústí nad Labem		03/22
Zlín		04/22

ZIMS database

At first, the data considering all 4 SAC species kept in selected zoos (see Table 1) that have been written into the database so far, were exported by supervisor of this thesis, Ing. Tamara Fedorova, Ph.D. in cooperation with doc. Ing. Karolína Brandlová, Ph.D. into one table. From this table, information about zoos that have not been visited were excluded. The data contained information about animals' identification, status, sex, date of birth, date of death, birth location, information about mother and father and last reported owner. The data contained both live and dead animals.

The acquired data were modified according to following methods:

- The "calf" was an animal that was born in selected zoos (see Table 1), had the information from the ZIMS about itself and also about its mother (date of birth and date of death), regardless on its age (a total of 450 animals were considered as "calf").
- The "mother" was an animal that was living in selected zoos, contained information about itself and information about its own calf/calves too (a total of 102 animals were considered as "mother").
- A survival of calf was calculated by analysing whether the calf's age was greater than or equal to 1 month.
- A calving interval was calculated as a period from one birth to another birth.
- Mean calving interval was calculated based on how many calves females had.
- A seasonality of calves was analysed from the data in which the male has not been separated (i. e. where farmers answered that animals are together in one herd throughout the year).
- All seasons in calculating seasonality were defined according to a study of G. Barnett & J. Dobson (2010): spring (March, April, May), summer (June, July, August), autumn (September, October, November) and winter (December, January, February).

Questionnaire used in the zoo survey

A questionnaire (see Appendix 2) was compiled based on similar studies conducted in Europe in past. A total of 15 questions were compiled covering the following sections: a) basic information about zoo, b) husbandry, c) problems & diseases, d) management and e) reproduction. It consisted mainly of multiple choice questions, and also a few open questions. Data were then rewritten into the MS Excel table and assigned to the data exported from the ZIMS database.

3.2. Data from farms – using questionnaires

Farms

The author of this thesis searched by herself for farms located in Europe that were focused on breeding llamas, alpacas or both species at the same time. Using a website https://www.google.com/maps, farms located in the Czech Republic, Germany, Poland, Austria, Switzerland, the United Kingdom, Italy, Ireland, Sweden, Finland, Norway, Slovakia, Estonia, Latvia and Lithuania were searched. During March 2021 – March 2022, the questionnaires were sent to searched farms via email. In some cases the emails were sent multiple times to obtain more data.

Questionnaire used to interview farmers

The questionnaire was carried out anonymously using the website https://www.click4survey.cz/. A questionnaire was compiled based on a studies of D'Alterio et al. (2006); Neubert et al. (2021) and Rüfli et al. (2021). A total of 21 questions were compiled covering the following sections: a) basic information about farm, b) husbandry, c) problems & diseases, d) management and e) breeding. Questions were of single, multiple choice, or of open question character. An the end of questionnaire, farmers were voluntarily asked for their email if they wanted the results of this study sent to them. The data were then exported into the MS Excel and statistically evaluated.

In total, 184 farms were sent an email with a questionnaire. A total of 48 answers were useful for analysis after the data that were left out, which means a 26% return rate of questionnaires. Due to the relatively low number of responses, the 5 regions were created for greater confidence in the statistical evaluation (Table 2 and Figure 9).

Table 2. An overview of regions that were created and countries that are included together with the % of respondents.

Region + countries included	Number of farms searched	Responded	% of respondents
Region 1 (The Czech Republic)	16	6	37,5
Region 2 (Norway + Finland + Sweden)	29	4	13,8
Region 3 (the United Kingdom + Ireland)	40	12	30,0
Region 4 (Germany + Austria + Switzerland + Italy)	77	20	26,0
Region 5 (Poland + Baltic states)	22	6	27,3
Summary	**184**	**48**	**26,1**

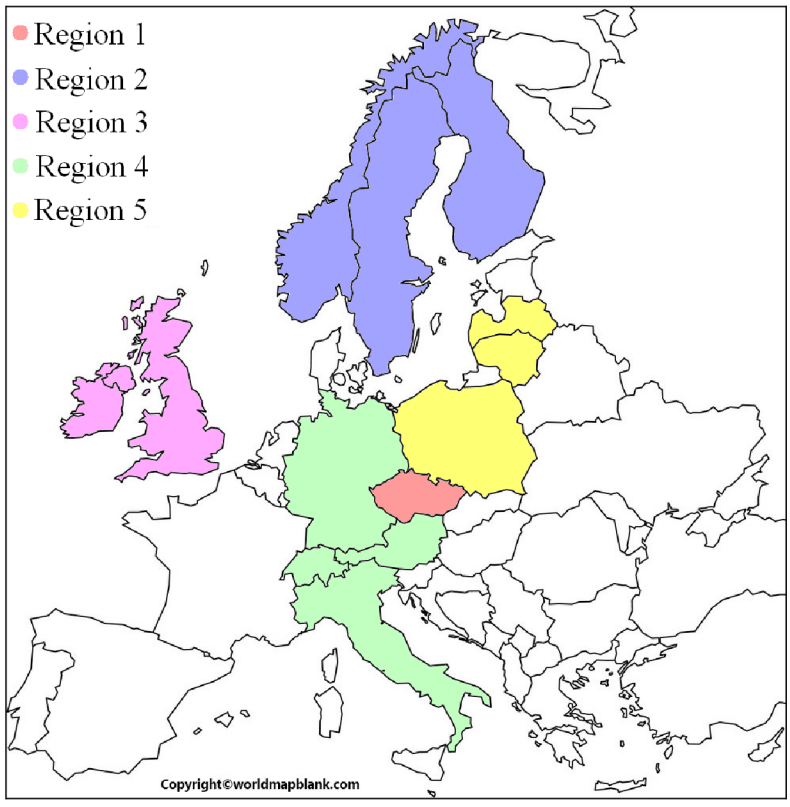

Figure 9. A map of 5 studied regions described in Table 2. Credit: https://worldmapblank.com/blank-map-of-europe/.

Statistical analysis

The significance level in all evaluations was set to 0.05. A Chi-square test was used to examine whether a population distribution differs in 4 studied species (*Vicugna vicugna*, *V. pacos, Lama glama, L. guanicoe*). Since the presence of alpacas in the Czech zoos is higher than the rest of species, it is assumed that a statistical difference will be present.

The reproductive data were conducted using means, minima and maxima. A survival and mortality were conducted using Chi-square test. A calving interval was calculated according to a study of P.A.C. et al. (2013). Testing the assumptions that calving interval depends on mother's age, a Chi-square test was used (with a significance level of 0.95). The dependence of calving interval on animal species was calculated using Kruskal–Wallis one-way ANOVA and also by using covariance testing.

The data obtained from farms were evaluated using means, maxima and minima. The question whether a month of birth of calf depends on mother's age at parturition, a Chi-square was used.

4. Results

4.1. Data from zoos – using ZIMS & questionnaires

4.1.1. Numbers of animals from ZIMS

The ZIMS database numbered together 497 SAC individuals – 334 alpacas, 56 vicuñas, 82 guanacos and 25 llamas (see Table 3). Percentage overview is represented in Table 3 and Figure 10. Alpacas were represented by the highest numbers, they formed almost 70 % of all species that were bred on studied zoos. Out of a total of 497 animals, there were 253 males and 244 females.

Table 3. A summary of all SACs bred on interviewed Czech zoos from whom the data were collected.

	Females	**Females %**	**Males**	**Males %**	**Total sum**
Alpaca	154	31	180	36.2	**334**
Vicuña	29	5.8	27	5.4	**56**
Guanaco	48	9.7	34	6.8	**82**
Llama	13	2.6	12	2.4	**25**
Total sum	**244**	**49.1**	**253**	**50.8**	**497**

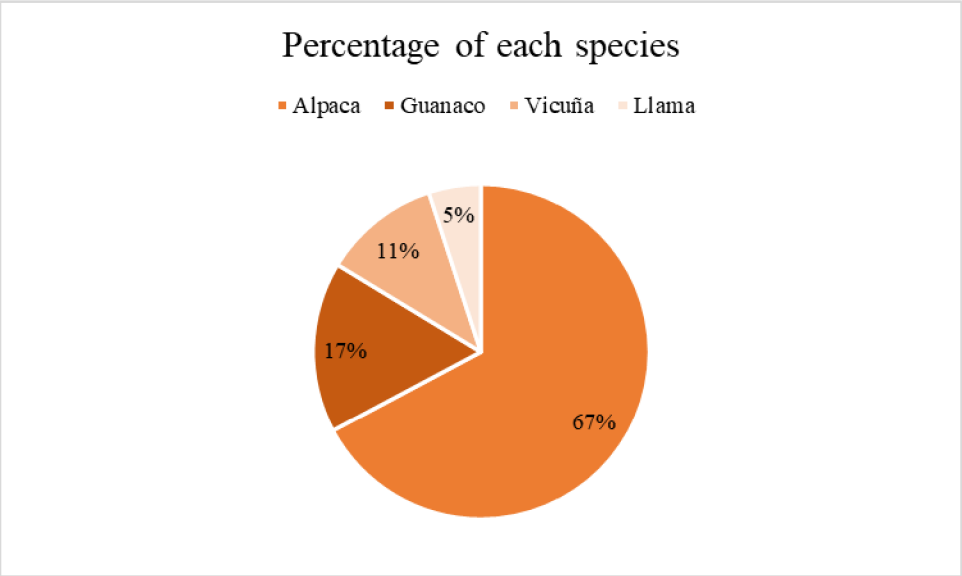

Figure 10. A percentage summary of all 4 species presented in studied Czech zoos.

The representation of both sexes across all 4 species was subjected to a normality test and the result was that there was no significant difference in distribution of females and males in all 4 species ($p = 0.225$; Chi-square = 4.37; $df = 3$).

4.1.2. Calves

The data distribution showed a trend of similar (alpaca, guanaco) and equal (vicuña, llama) representation of both genders (Table 4).

Table 4. Number of animals marked as "calf" in the dataset.

	Alpaca	**Vicuña**	**Guanaco**	**Llama**	**Count**
Males	164	27	32	10	233
Females	140	27	40	10	217
Total of animals	304	54	72	20	**450**

4.1.2.1. Seasonality in calves

In the Figure 11 the result of calves' seasonality is present. Peaks of both, births and deaths, occurs in July (20 % in both). In total, most of births took place in summer, followed by autumn and spring, and the fewest calves were born in winter. Barring July, calves were born most frequently in June (16 %) and August (13 %). The lowest number of births was recorded in February (1.6 %), March (1.8 %) and December (2.2 %).

A similar trend can be observed when talking about months of deaths (Figure 11). The highest occurrence of deaths, regardless of age or cause of death, was observed in July and in June (13 %). The lowest occurrence of deaths was noted in April (2 %) and February (3 %).

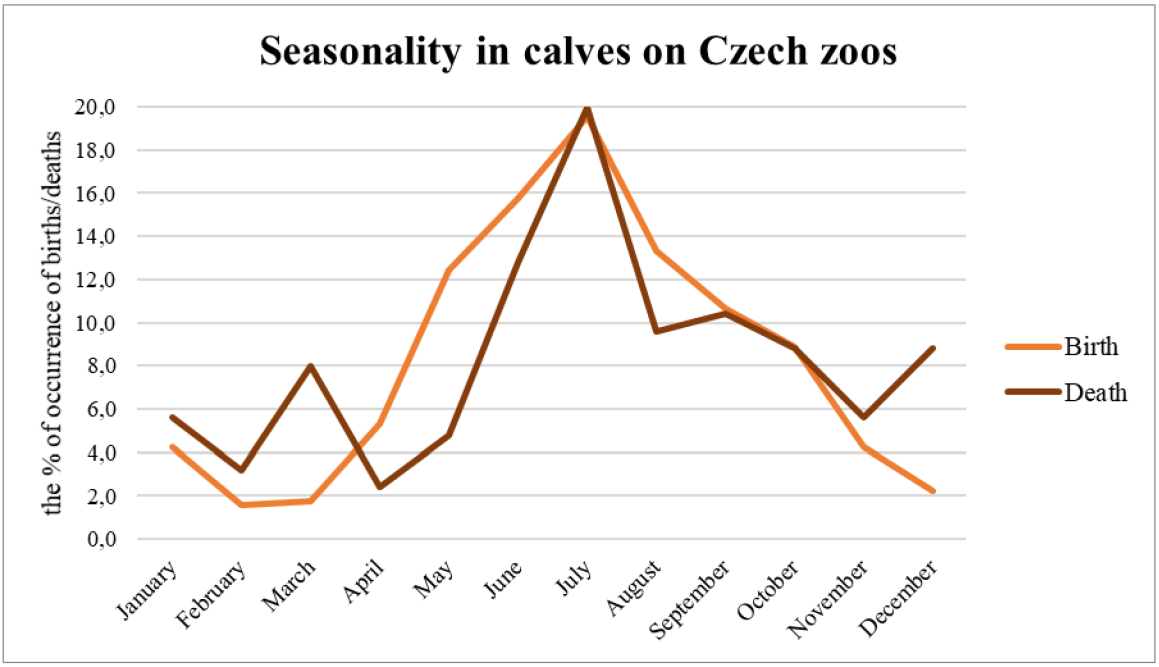

Figure 11. A line graph showing a seasonality in calves in Czech zoos. Light orange line represents months of birth, dark orange line represents months of death.

4.1.3. Reproductive data

Mother's average age of survival was ascertained to 13 years and an average age of the first parturition was calculated to 4.9 years. The average number of calves differed among mothers, some of them had only 1 calf, some of them even 13. The mean number of calves per 1 mother was calculated to 5 calves per 1 mother in her whole lifetime (Table 5).

Table 5. A summary of background information for calculating reproduction efficiency. (Note: The number of all mothers in dataset was calculated to 99).

	Average	MIN	MAX	SD
Age of mothers' survival (years)	13.1	2	27.1	±5.6
Age at first parturition (years)	4.9	1	22.7	±3.6
Number of calves per 1 mother	5	1	14	±3.3

4.1.3.1. Survival and mortality of all animals in dataset

A mortality rate during calves' first month of life was calculated to 58 %, thus a survival rate of calves during the first month of life was 42 % (see Figure 12).

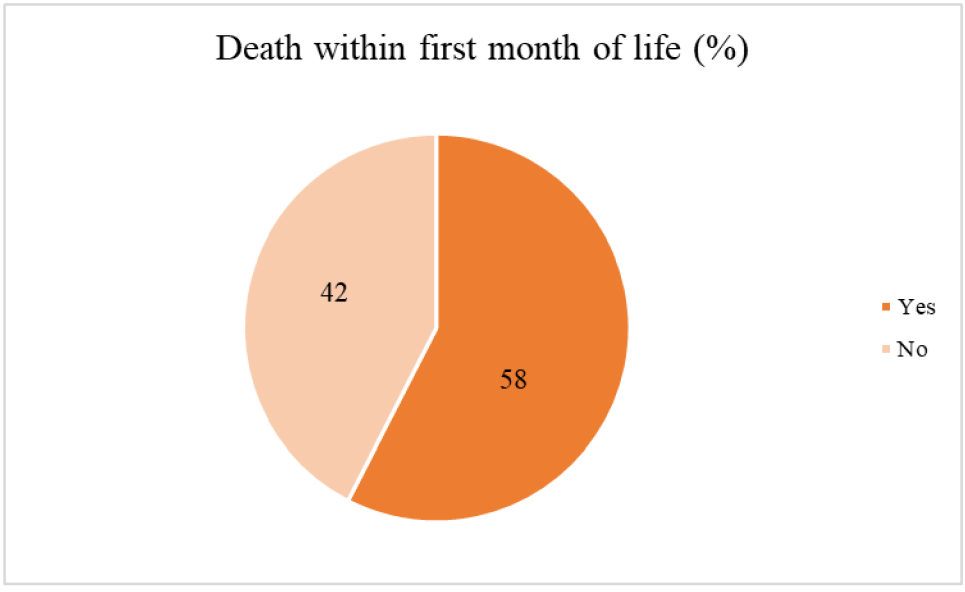

Figure 12. A pie diagram showing the percentage of calves' mortality.

The death of animal in first month was influenced by sex of animal (p=0.0008, χ^2=11.2, df=1). The males died more often than females. The season of animal's birth was the factor that influenced whether animal died during first month, too (p=0.0006, χ^2=17.5, df=3). Animals died mostly during spring season. And thirdly, the death in first month was influenced also by species of animal (p<0.0001, χ^2= 49.90, df=3). Alpacas died more often than other species. Groups of domesticated (alpaca and llama) and wild species (vicuña, guanaco) were subjected to Chi-square testing, and with the result of χ^2=24.47, p=0.000001, df=1, domesticated species died more often than wild species.

Besides basic description of seasonality of animals, interesting information (deviations from normal data) were found. These interesting data can be seen in Table 6. An existence of 1 pair of twins was present. Also, there were several females (31.3 %) which had only 1 calf during their lifetime (with an average age 8.2 years at first parturition). In the dataset, there were also mothers who had higher amounts of calves. A total of 8 females (8.1 %) had 10 or even more calves during their lifetime.

Table 6. Interesting information found during analysis.

Number of twins in the dataset	1
Number of mothers with only 1 calf	31
Average age of mother at first parturition (having 1 calf)	8.2
Number of mothers having ≥ 10 calves	8

4.1.3.2. Calving interval

The totals of all mothers were divided into the groups according to how many calves they had in their lifetime (Table 7).

Table 7. An overview of the number of calves of all mothers during their lifetime.

Number of calves during whole lifetime	Number of mothers
1 calf	18
2 calves	13
3 calves	14
4 calves	13
5 calves	6
6 calves	6
7 calves	6
8 calves	7
9 calves	5
10 calves	1
11 calves	3
12 calves	1
13 calves	3

The results of calculated calving interval can be seen in Table 8. The longest calving interval was observed in a situation when female had 4 calves (2.01±1.9), 3 calves (1.87±1.3) and 5 calves (1.86±1.5). According to the assumption, mothers who had more calves had shorter calving interval. The shortest calving interval was in females having 10 calves (1.03±0.5), 11 calves (1.28±0.5) and 8 calves (1.25±0.8).

Table 8. Mean number calving interval based on how many calves the female had (including standard deviation).

	Mean calving interval (years)	Standard deviation
2 calves	1.44	±0.9
3 calves	1.87	±1.3
4 calves	2.01	±1.9
5 calves	1.86	±1.5
6 calves	1.49	±1.0
7 calves	1.55	±1.1
8 calves	1.25	±0.8
9 calves	1.51	±0.9
10 calves	1.03	±0.5
11 calves	1.28	±0.5
12 calves	1.23	±0.7
13 calves	1.17	±0.7

Calculation of calving intervals' means pointed out that llamas had the longest calving interval and alpacas the shortest (Table 9).

Table 9. The means of calving intervals with standard errors.

	Mean	Std. Err.
Alpaca	1,37	±0,07
Llama	2,27	±0,30
Vicugna	1,44	±0,18
Guanaco	1,38	±0,15

The analysis on whether the number of calves influenced the length on calving interval was done. The correlation coefficient, *r*, was calculated to 0.1357, p value was calculated to 0.012, which means that the calving interval is dependent on the number of calves mother had. The *r* was in positive values which means that the more calves mother had, the longer calving interval was recorded.

The results from Kruskal–Wallis one-way ANOVA refuted that calving interval was influenced by the species of animal, p=0.6402. The results are represented in the Figure 13.

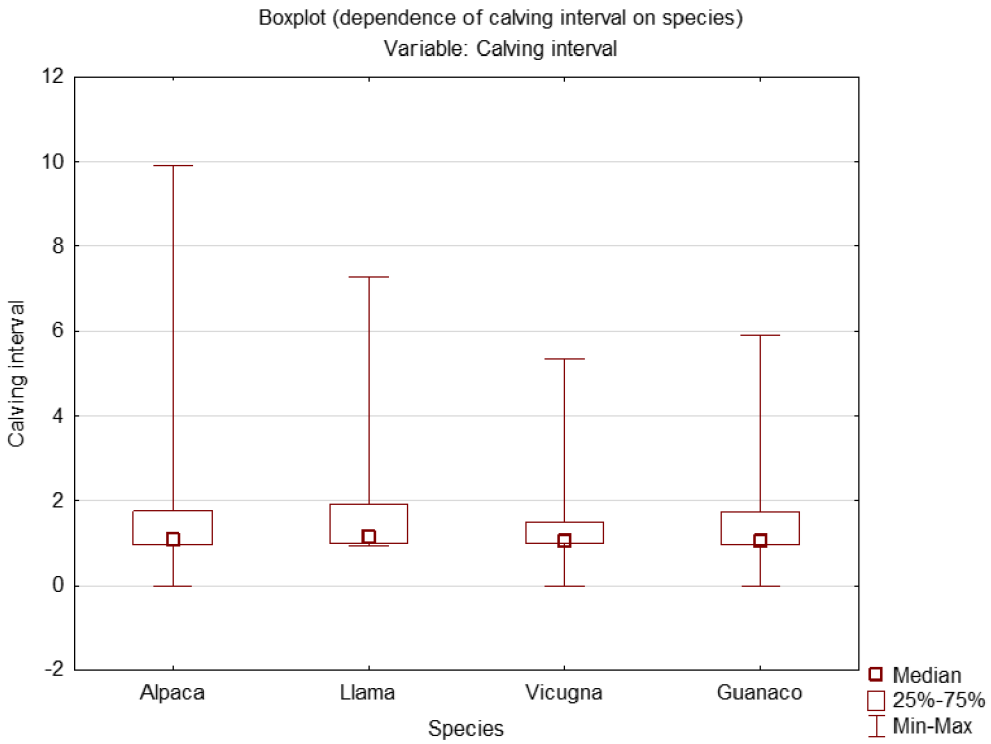

Figure 13. A boxplot showing the results of K-W ANOVA testing of dependence of Calving interval on the species. The points represent medians of calving interval, the whiskers represent minima and maxima.

4.2. Data from farms – using questionnaires

4.2.1. Animal population

Farmers kept either alpacas only (42 farms), or llamas only (19 farms), or alpacas and llamas together (13 farms). They did not breed any guanacos or vicuñas. Counts of alpacas in all regions can be seen in Table 10, their numbers are quadruple than llamas'. A prevalence of females in both species was observed. In llamas, the ratio of females:males related to all regions was 3:1 and in alpacas it was 2:1. Calves, compared to the total number of all SACs, represented 13 % of the SAC population on farms that were included in present (see Figure 14).

Table 10. Numbers of animals in each region (related to the farms that were included in analysis.

Region	Llamas	Alpacas	Calves	Total count
1	15	30	6	51
2	5	137	28	170
3	455	1766	291	2512
4	266	892	243	1401
5	14	338	23	375
Total count	**755**	**3163**	**591**	**4509**

Table 10 contains the numbers of SACs in each region. In all regions, alpacas prevailed in both sexes. The highest number of animals was recorded in the Region number 3 (the UK and Ireland).

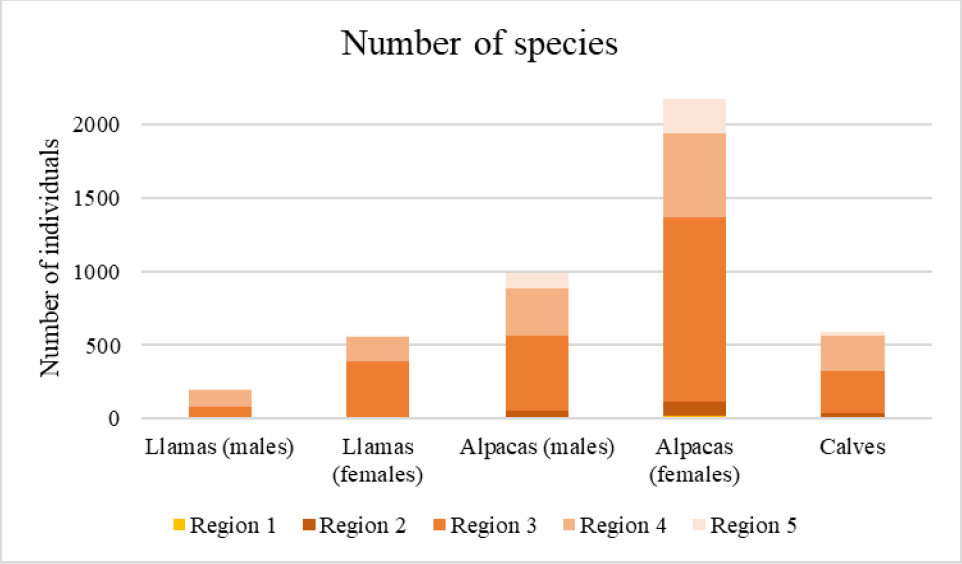

Figure 14. A line graph showing numbers of llamas and alpacas in each region. (*Note: The number of animals in the Region 1 is not well visible due to the lowest numbers of individuals from all regions. Region 1 numbered: 6 llama males, 9 llama females, 12 alpaca males, 18 alpaca females and 6 calves.)*

4.2.2. Purpose of breeding

A questionnaire contained also a question focused on primary purpose of farms. As can be seen in Figure 15, the primary purposes for which SACs are bred on European farms, were breeding/trade (26 %), fibre (25 %) and tourism (23 %). On the other hand, purpose of skin and ritual/ceremony purpose were not selected at all (0 % for both). Region 1 bred SACs primarily for a tourism purpose (55 %), breeders from the Region 2 bred SACs mainly for breeding/trade (43 %). Farmers from both Region 3 and 4 selected their primarily purpose as fibre (25 and 26 %) and breeding/trade (31 and 25 %). And the fifth region's primary purpose was chosen to be fibre (29 %) as well as tourism (29 %).

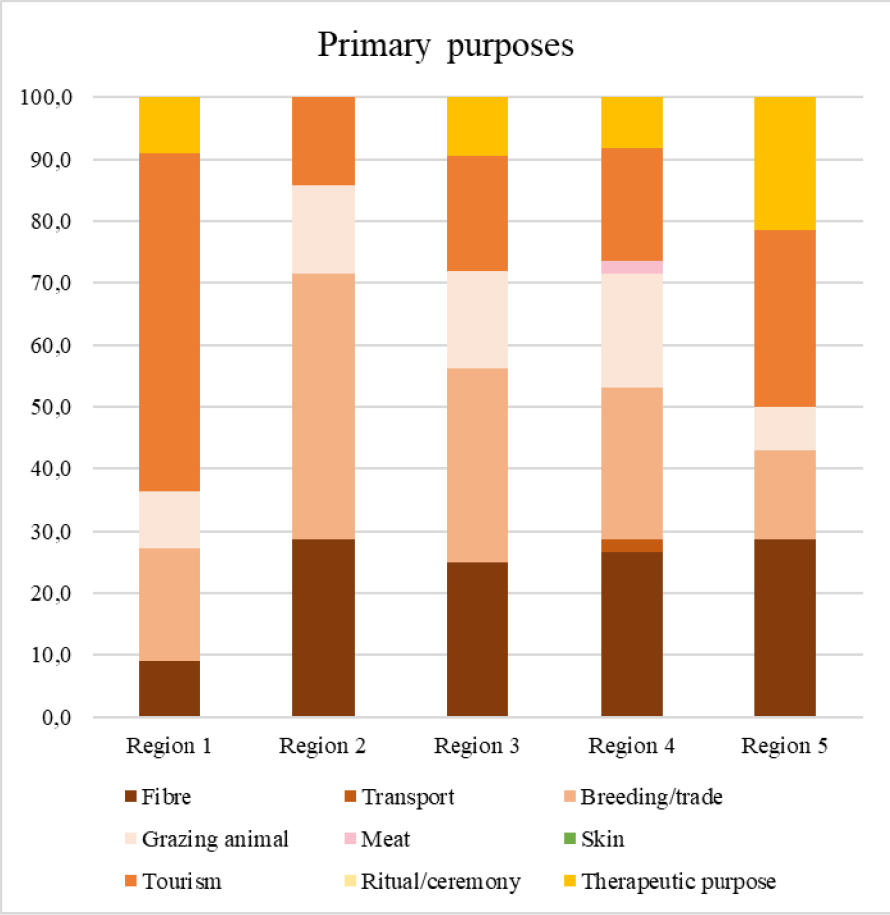

Figure 15. A bar chart showing percentage of primary purposes in all 5 regions.

4.2.3. Management

4.2.3.1. Type of pasture present on farms

The most frequent type of pasture was a rotational pasture (59 %). 35 % of farmers chose that they keep SACs on free pasture all year around, 4 % practiced mixed grazing and none of respondents chose an option of having a pasture with shepherd (see Figure 16).

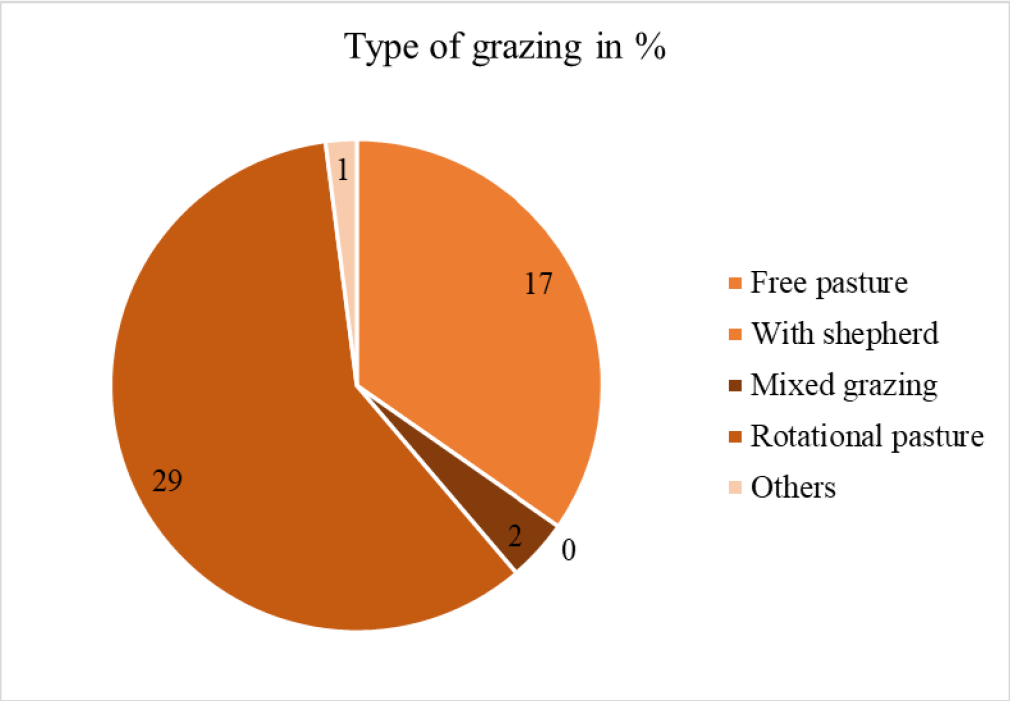

Figure 16. A pie diagram showing a percentage of different types of pastures present on interviewed farms. (*Note: A category "with shepherd" was not selected at all.*)

A question providing further information on mixed grazing resulted in that horses were being kept most frequently together with SACs (31 %), cattle and sheep were being kept in 19 % together with SACs and donkeys were being kept in 13 % of all cases (Figure 17).

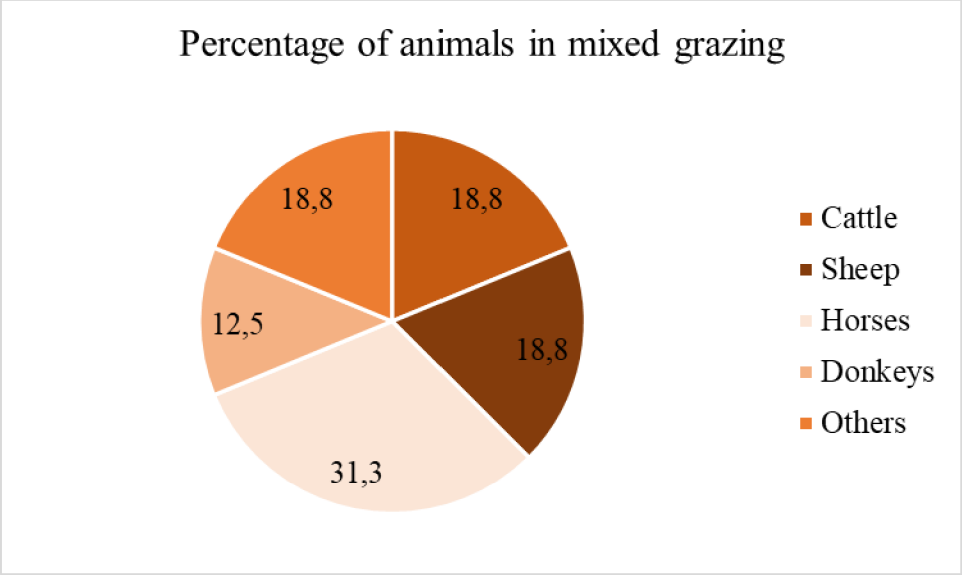

Figure 17. A pie diagram showing with what animal species a mixed grazing was realized.

4.2.3.2. Management of breeding

Figure 18 shows the results from a question considering an organization of herd which is the most used on farms. The separation of males and females was being used most frequently (52 %). Farmers together with this option also chose the separation of the young ones after weaning (27 %).

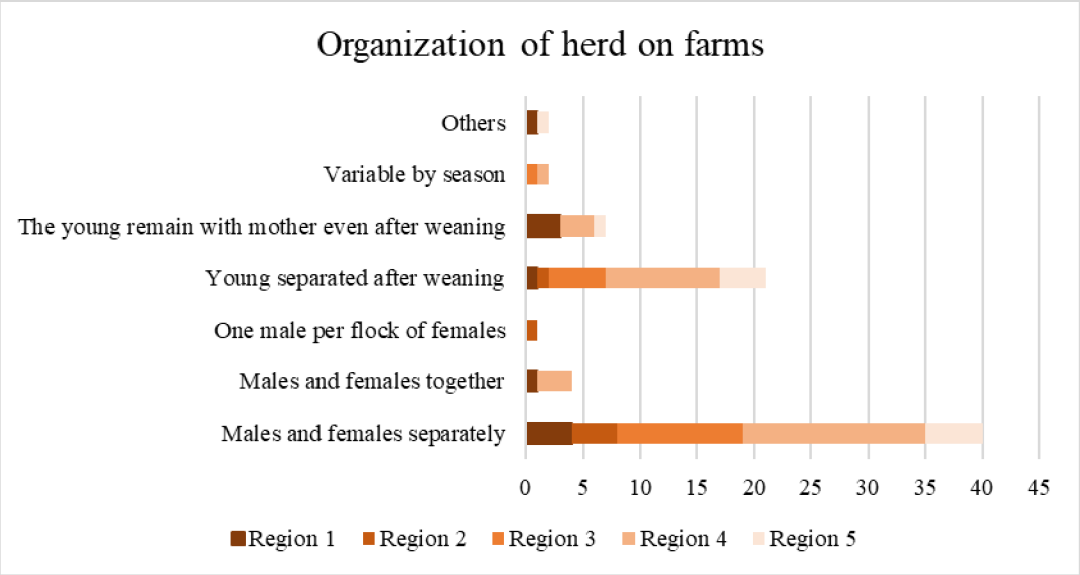

Figure 18. The most common organizations of herd on studied farm.

More than a half of farmers (57 %) used some method for breeding (Figure 19). Further analysis showed that a method in which males and females are selected for mating was used the most frequently (see Figure 20). Almost 44 % of farmers selected males and females for mating, 34 % practiced controlled admission and 20 % of herds were young ones left after weaning and females remained in the herd together with males.

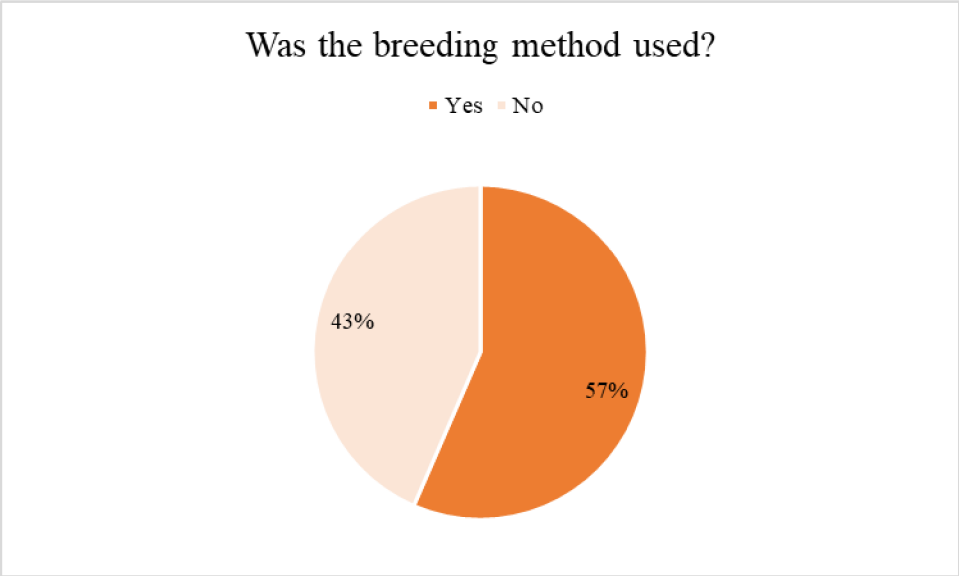

Figure 19. A pie diagram showing a proportion of answers on a question whether some methods of breeding have been used.

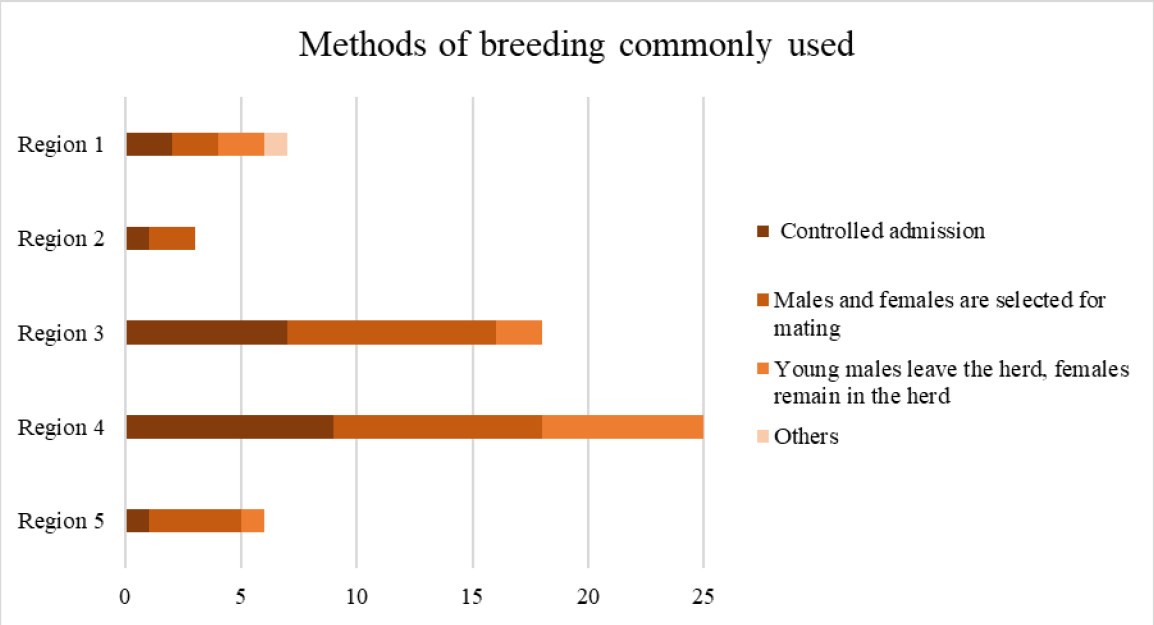

Figure 20. Methods of breeding that are commonly used in each Region (on chosen farms).

4.2.3.3. Seasonality

Figure 21 shows a frequency of months in which calves were born. Peaks across all regions were observed in June (23 %), July (21 %) and May (19 %), where the most birth occurred. On the contrary; January, February, March, October, November and December were the months, where births occurred the least (1 %).

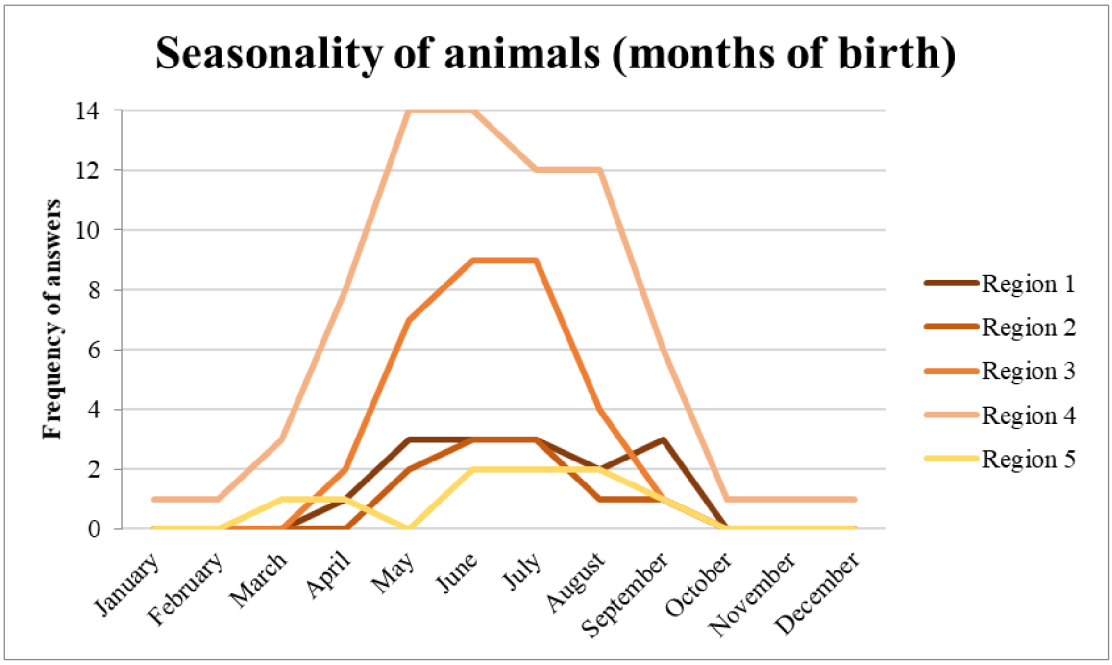

Figure 21. A line graph visualizing seasonality of calves.

Another question in the questionnaire was focused on weaning time of calves (Figure 22). The longest weaning period on average was observed in the Region 1 (9–10 months) and the shortest weaning time was observed in the Regions 3 and 4 (5–6 months).

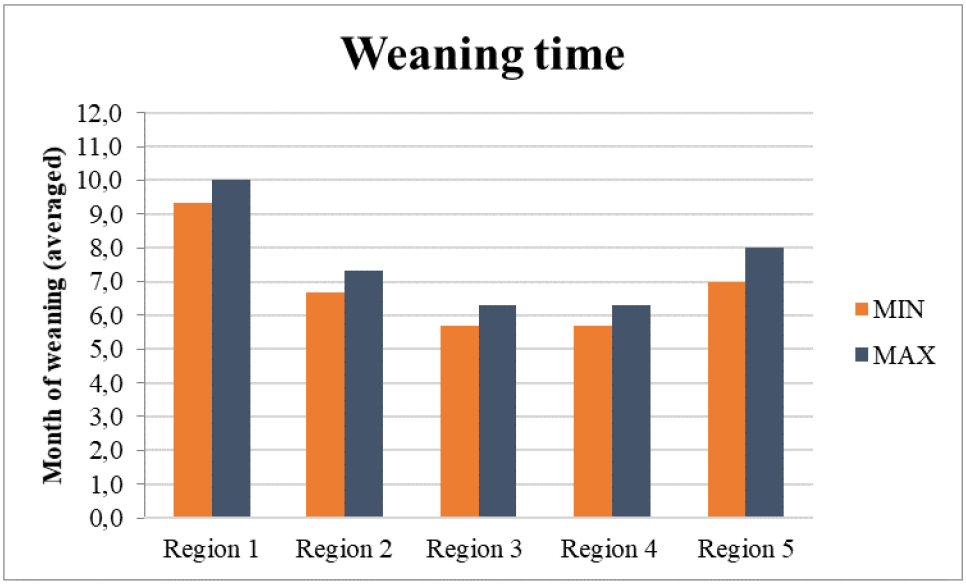

Figure 22. Minimal and maximal periods of weaning recorded in calves.

4.2.3.4. Problems of farms

A questionnaire contained also questions about problems and then related distribution of diseases. Table 11 shows the results of present problems on chosen European farms. 50 % of farms did not mention any problems. The largest part of the remaining 50 % belonged to internal (17 %) and external parasitic diseases (11 %). Breeders did not mention any congenital malformations nor infectious diseases on their farms.

Table 11. A table showing the percentage of problems.

Problem	%
Lack of pastures	9.3
Congenital malformations	0,0
Internal parasitic diseases	16.7
External parasitic diseases	11.1
Infectious diseases	0.0
Fertility problems	3.7
Technical/handling problems	1.9
Administrative problems	5.6
None	50.0
Others	1.9

The largest percentage of all problems formed diseases. In the Figure 23, the distribution of different types of diseases can be seen. The highest percentage of the diseases belonged to the internal parasitic diseases (41 %) and external parasitic diseases (30 %).

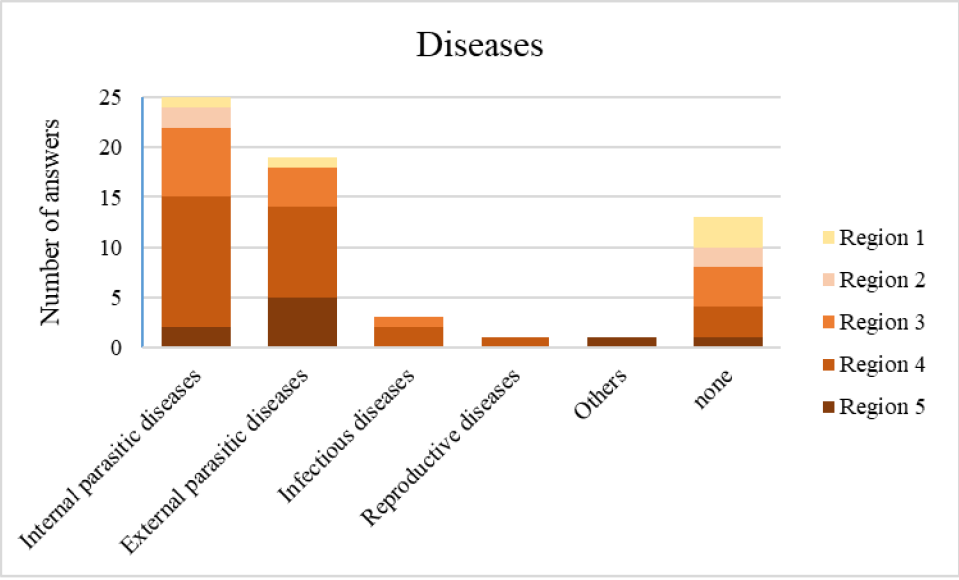

Figure 23. A stacked bar chart showing a distribution of diseases on studied farms.

4.2.4. Selection criteria for breeding

25 % of respondents did not reproduce SACs on their farm and 62 % of respondents chose that they reproduce animals (see Figure 24). These farmers were then asked to choose according to which criteria they reproduce animals (see Figure 25 and Figure 26). 13 % of respondents did not choose any option, thus their data were not included in analysis.

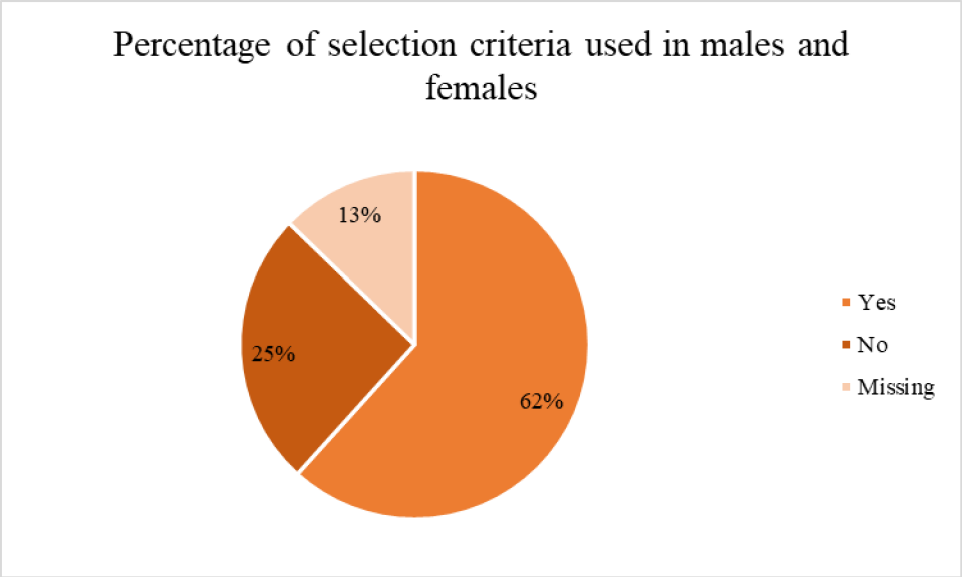

Figure 24. A pie diagram showing percentage of answers whether a farm uses selection criteria

Figure 25 shows the results of selection criteria in males. The most important and most frequently chosen category was health condition (17.4 %) and colour and quality of animal's fibre (17 %). The options others (11 %), animal's libido (12.6 %) and animal's origin (13 %) were chosen least often.

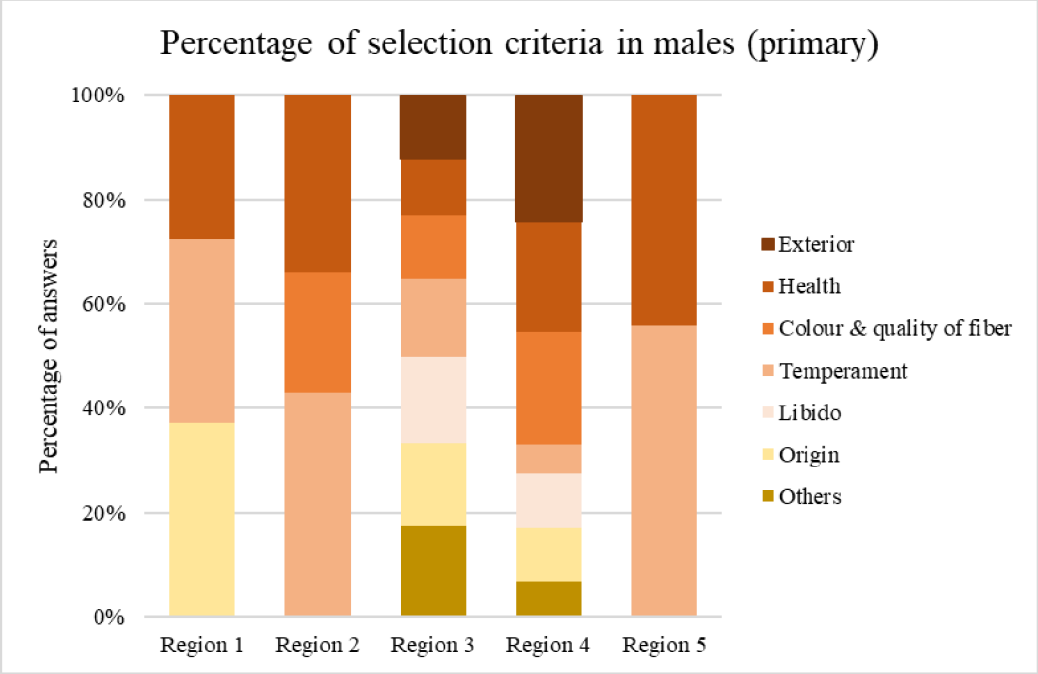

Figure 25. Percentage of applied primary selection criteria in males.

In females (Figure 26), health condition of animal was chosen the most frequently (24.7 %), same as in males. Not much less percent had the option of animal's exterior (24 %). Same as in males, options others (7 %), origin (7.6 %) and libido (8.8 %) were chosen the least frequently.

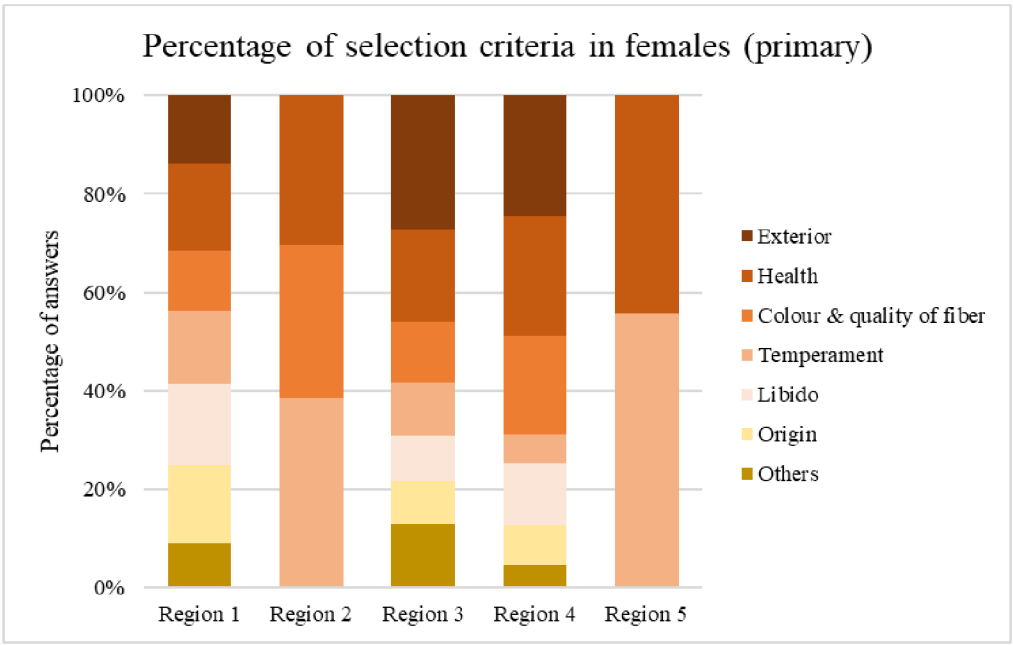

Figure 26. Percentage of applied primary selection criteria in females.

5. Discussion

Currently there are only few papers focusing on this topic which is the reason why the review was written using sometimes relatively old studies. Despite the older date, the information is still current, there just are not updated reviews on it. Similarly, detailed information on the reproductive system together with reproductive behaviour is scarce (D'Alterio et al. 2006; Bauerstatter et al. 2018; Kapustka & Garbiec 2022). It would be useful to supplement this study with questions on farmers' awareness of breeding/problems/diseases etc. This could help to educate farmers on a regular basis to discover new ways to improve keeping, breeding and how to deal with diseases or mortalities in calves.

Numbers of alpacas and llamas in captivity

Collected data showed that alpacas outnumbered llamas in all chosen European zoos and interviewed farms which is consistent with the study of Twomey et al. (2014) in England, Neubert et al. (2021) in Germany, Bauerstatter et al. (2018) in Austria and D'Alterio et al. (2006) in the UK. Alpacas made up majority of the population in every study. On the contrary, different results were reported by Kriegl et al. (2005) in Austria, Germany and Switzerland and Hengrave Burri et al. (2005). In Switzerland – there the prevalence of llamas over alpacas was present. It can be observed that older studies reflected higher popularity of llamas over alpacas. This could be due to the improvement of techniques for processing alpaca wool and the increased popularity of alternative materials to produce clothing, blankets or carpets. Nowadays, alpacas become more favourable in keeping worldwide. Almost 67 % of all SAC that are bred on chosen Czech zoos are alpacas. The ratio of females to males was almost 1:1 with a slight majority of males (51 %). The situation on farms was quite same, alpacas were kept in the highest numbers on almost all farms (70 % of all species being kept were alpacas). And the ration of males to females was in both alpacas and llamas similar – a prevalence of females was present.

Seasonality of calves in zoos and on farms

Since the seasonality of SACs both in zoos and on farms was quite similar, joint discussion can be used. The animals living in the Czech zoos were born in the summer the most frequently as well as animals living on chosen European farms. May, June, July and August were the most abundant for births in both types of captivity. These results differ in a study of Sharpe et al. (2009) that was done in Ohio, the USA. In that study animals were born the most in autumn and in spring.

The data coming from the ZIMS database also included periods of death in SACs. These data about animals' death were related to all animals in the dataset, not only to calves. Those periods were recorded mostly in summer months, same as in case of birth months of all adult ones. The highest occurrence of deaths was recorded in July and June. The birth and death periods occurred in the same period due to the fact that SACs have a birth duration of ± 1 year and frequent deaths during the first 3 months of calf's life are quite common (Pinto Jiménez et al. 2010; Valenzuela et al. 2021). In terms of species, alpacas died more often than other species. Generally, domesticated species died more often than wild ones. Or a heat stress could be another possible factor, due to the warmer summers occurring in Europe compared to the native habitat in the Andes mountains.

5.1. Processing of data from zoos

Calves

The data used for analysis of both calves and mothers contained only basic records about animals. There were no records of factors that could have affected the results, such as a presence of artificial breeding, or euthanasia. It is also not clear from the data whether the male was in the herd for the whole time or whether it was taken away from the herd for a part of the year, which could also affect the results. However, these factors did not show up as strongly on such a small dataset and can therefore be neglected.

A survival percentage was calculated to 42 %, thus a mortality was 58 %. Only one twin was registered during the whole period of data entry into the ZIMS database (50 years). The presence of only one twin is not surprising due to the fact, that SACs do not give birth to twins so often, which is supported in a study of Brown (2000).

The mothers formed an important part of the results and reproductive efficiency was further evaluated based on their data. The average life expectancy of mothers was estimated to 13 years. Considering calves, most mothers had only 1 calf (19 %), the least number of mothers had 10 and 12 calves (1 %). The average number of calves per 1 mother was 5 and the average mother's age at first parturition was 5 years. In other studies, it was not possible to find data to compare these results and therefore it would be useful to do a more in-depth study on the reproductive behaviour of SACs kept in captivity (predominantly in zoos).

The calving interval, which can be also used to assess reproductive efficiency, was observed to be the longest for llamas and shortest in alpacas. This is in accordance with the fact that the highest number of calves was observed in alpacas and the shortest in llamas, thus intervals between parturitions were not surprisingly longer in animals that had less calves.

5.2. Processing of data from farms

The regions that were used for generalization of results were not equally distributed by populations of camelids. Since the author comes from the Czech Republic and firstly cooperated with Czech zoos, special region was set aside just for the Czech Republic. For that reason, the numbers that came from the Region 1 were much lower than from other regions and thus the data may be skewed. This can also be observed in figures in the results, where the Region 1 had sometimes not so well visible results.

Purpose of breeding

The main purpose of the most of interviewed farms in Europe was breeding/trade. The "breeding/trade" category (mainly of alpacas in this case) was the most selected (in 26 % of all cases), probably because the highest number of farms choosing this option were in the Region 3 (the UK and Ireland). Both countries maintain a world class pedigree register for all alpacas in the UK national herd and a European directory for all alpacas domiciled in Europe. A production of fibre was also selected by a larger number of farmers (25 % of all interviewed farmers). In the similar studies focusing on this issue, fibre production has also been chosen very often, regardless of whether it was llama or alpaca farm (D'Alterio et al. 2006; Bauerstatter et al. 2018; Neubert et al. 2021).

Traditional livestock farming in Europe for meat and milk production tends to focus on species such as cattle, sheep, and pigs. For this reason, SACs' farming is more of hobby, entertainment, and recreational character. Similar studies comprised relatively high numbers of primary purpose in a category "hobby" (Kriegl et al. 2005; Bauerstatter et al. 2018; Neubert et al. 2021). To this category, trekking, recreational purpose, and hiking belong. Results from this thesis confirmed this trend with a 23% presence of the "tourism" category selection which also includes activities previous mentioned.

Management

SACs were bred mostly on rotational pastures (59 %). A free pasture was chosen also in fewer cases (17 %) and is not corresponding to the results of Wurzinger et al. (2008) but probably because this study was done in Bolivia, in High Andes, where this type of pasture is mostly used. A mixed grazing, a type in which SACs were being kept together with other animals, was chosen in 4 % of all cases. The most favourable animal species that shared a herd with SACs were horses (31 %), cattle (19 %), sheep (19 %) and donkeys (13 %). Mixed herding is popular on farms in the United Kingdom together with sheep (D'Alterio et al. 2006), but also on farms in South America, Bolivia. Sheep is a predominant animal that share a herd with SACs on many farms worldwide (Wurzinger et al. 2008; Markemann & Zárate 2010). Unfortunately, this otherwise beneficial method of breeding has one major disadvantage for breeders, namely that mixed breeding creates an unwanted huarizo hybrid in the population of camelids (Markemann & Zárate 2010).

The males and females were kept separately from each other on most of the interviewed farms (52 %). It is the most common method for SACs in captivity keeping because of macho's (a breeding male) aggressivity. Also, the aggressivity of machos was mentioned by most of the breeders from the zoos. Thus, this could be the reason why guanacos and vicuñas, the wild species, were not being kept on farms. The aggressivity makes breeding difficult for breeders in situations when they breed several animals at the same paddock. Owing to the aggressivity of males, the young ones are separated after weaning (27 % of farms responded). The weaning itself was performed from 5–6 (minimum) to 9–10 (maximum) months of calves' age, which is consistent with the results of the D'Alterio et al. (2006) study done in the UK, which recorded weaning in the 6th month of the calf's age kept in captivity.

A total of 57 % of interviewed farms used some breeding method. Farmers were selecting males and females for breeding in 44 % of cases and they were practising a controlled admission in 34 % of cases. Young ones were taken away from the herd after weaning in one fifth of all cases.

Problems

50 % of interviewed breeders did not mention any problem occurring on their farm which could mean that they did not have any problem or did not want to indicate them in the questionnaire. The rest 50 % of respondents mentioned mainly diseases and lack of pastures. Internal and external diseases were mentioned in 28 % of all cases of present problems on chosen farms. Surveyed farms that were characterized by higher number of animals struggled with endoparasites more times than farms with just few animals. Farms from this study that kept SACs together with other livestock (mixed herds) mentioned frequently a presence of endoparasites, too. These results are confirmed by the studies of Hengrave Burri et al. (2005), D'Alterio et al. (2006) and Neubert et al. (2021) in which animals living together in one herd struggled with higher occurrence of endoparasites due to transmission between species. 30 % of all interviewed farms that mentioned some problem that occurred on their farm struggled with ectoparasites. Ectoparasites were also present in a study of D'Alterio et al. (2006) and Twomey et al. (2014) with the highest abundance of *Sarcoptes scabiei* (an itch mite) that causes mange. It would be useful to complete the analysis of diseases and the influence on the survival during the first months of calf' life (e.g., some reproductive diseases and neonatal diseases or problems).

Selection criteria

Larger part of camelid population was reproduced on studied European farms (62 %). Males were selected according to their health status (17 %) and colour and quality of their fibre (17 %). The origin and libido were not important when selecting a breeding male. Females were selected according to their health status (25 %) as well as according to their appearance (24 %). Just like males, females were not selected according to their origin or libido. In their native habitat, the Andes mountains, both males and females were in a study of Markemann & Zárate (2010), Wolfinger (2012) and Pacheco et al. (2019), selected for breeding according to a quality and colour of their fibre and also according to their exterior. The selection criteria, if they were followed by farmers, in most cases also matched with the purpose of the farm. Most farmers kept SACs on the farm for fibre production and at the same time farmers were selecting their animals according to the quality and colour of animal's fibre.

6. Conclusions

The result of this work was a comprehensive overview of information about SAC species.

The data from chosen zoos in the Czech Republic were acquired from the ZIMS database and by visiting of selected zoos. A total of 497 animals were analysed in the study. The highest numbers of animals bred on selected Czech zoos comprised of alpacas and llamas were represented by the lowest numbers, which is the difference in comparison to older studies on that matter. Calves were born and died mostly in summer months and their overall mortality in the first month of life was 58 %, which corresponded to the results in other studies focused on similar problematics.

A husbandry and reproduction were analysed also on chosen European farms. A total of 4509 animals were recorded. Same as in zoos, alpacas were abundant. Most farmers kept SACs for a fibre and for breeding and trade, which is mentioned in other studies, too. The breeding and trade went together with the option of selection criteria in breeding males and females that were selected according to a quality of their fibre.

For a deeper understanding and study of the subject, this thesis could serve as a guide to a more detailed analysis of how SACs are behaving in European zoos and farms and how different types of breeding affect their reproduction and profitability.

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Appendices

List of the Appendices:

Appendix 1. Questionnaire brought to the zoo.

Questionnaire to the zoo

• Llamas, alpacas •

1. **Name of zoo**

2. **Purpose of zoo**

a. Fibre
b. Breeding/Trade
c. Grazing animal
d. Meat
e. Skin
f. Therapeutic purpose
g. Contact zoo, zoo for children

3. **For how long do you breed llamas/alpacas?**

4. **Type of pasture**

a. Free pasture
b. Pasture with shepherd
c. Mixed grazing together with other livestock
    a. What are the others animal species?
d. Rotational pasture

5. **What is the organization of herd?**

a) Males and females separately
b) Males and females together
c) One male per flock of females
d) Young separated after weaning
e) The young remain with mother even after weaning
f) Variable by season
g) Others

6. **What are the main problems in a breeding?**

a) Lack of pastures
b) Congenital malformations
c) Internal parasitic diseases
d) External parasitic diseases
e) Infectious diseases
f) Fertility problems
g) Technical problems or handling problems
h) Management administrative problems
i) None
j) Others

7. **What diseases have you noticed in your breeding?**

a) Internal parasitic diseases
b) External parasitic diseases
c) Infectious diseases
d) Reproductive diseases

e) Others
f) None

8. What breeding management methods do you use?

a) None – all animals in one herd all year around
b) Controlled admission - selected males with females on mating season
c) Males and females are selected for mating
d) Young males leave the herd, females remain in the herd
e) Others

9. History of breeding management practices that have been used:

10. Selection criterias for the MALES: YES X NO

	Primary	Minor	Unimportant
Size			
Health			
Color and quality of fiber			
Temperament			
Libido			
Origin			

11. Selection criterias for the FEMALES: YES X NO

	Primary	Minor	Unimportant
Size			
Health			
Color and quality of fiber			
Temperament			
Libido			
Origin			

12. If the animals are not born in a zoo, where are they from?

13. How many males do you use for breeding?

14. At what age are the young ones weaned?

15. Have you noticed an occurrence of allosuckling in your herd? If so, how frequently?

(allosuckling = suckling of youngs from different females than from own mother)

Appendix 2. Questionnaire sent to the farms.

Questionnaire about llama/alpaca breeding

Hello!

Welcome to our questionnaire about llama breeding. This questionnaire was created by Jana Marešová (Ph.D. student) and Kateřina Berková (Msc. student), both from the Czech Republic. We are working on our theses about husbandry and maternal care of llamas and alpacas.

We would like to ask you for a couple of minutes to fulfill this questionnaire, the results will really help us.

There are 24 questions, in most of them you can choose multiple answers, some of them needs to be explained by text. Questionnaires are sent to several farms in the Czech Republic, to some farms in Europe and also to farms in the South America. For that reason, there are possible answers considering all cultures.

Thank you very much for your time and willingness :)

Date:
Location of your farm:
Name of farm:
Breeder/owner:

1. **What is the purpose of your llama breeding?**

	Primary	Minor	Unimportant
Fibre	○	○	○
Transport	○	○	○
Breeding/trade	○	○	○
Grazing animal	○	○	○
Meat	○	○	○
Skin	○	○	○
Tourism	○	○	○
Ritual/ceremony	○	○	○
Therapeutic purposes	○	○	○

2. **How long do you breed llamas?**

3. **How many llamas do you breed?**

Males	
Females	
Calves (until weaning - 6 months)	

4. **How many alpacas do you breed?**

Males	
Females	
Calves (until weaning - 6 months)	

5. **How many other animals do you breed?**

Males	
Females	
Calves (until weaning - 6 months)	

6. **What is the type of grazing?**

a) Free pasture - method of grazing, in which the animals are on a single area for a long time (1,5 - 3 months) or for the whole grazing period and the grazed stand grows continuously during grazing

b) With shepherd

c) Mixed grazing with other livestock

d) Rotational Grazing System (when the entire pasture is divided into portions of land called paddocks, only one part of the pasture is grazed while the remaining area rests)

e) Others

7. **If you apply mixed grazing, what are the others animal species?**

a) Cattle

b) Sheep

c) Horses

d) Donkeys

e) Others

8. What is the organization of herd?

a) Males and females separately
b) Males and females together
c) One male per flock of females
d) Young separated after weaning
e) The young remain with mother even after weaning
f) Variable by season
g) Others

9. What are the main problems in your llama breeding?

a) Lack of pastures
b) Congenital malformations
c) Internal parasitic diseases
d) External parasitic diseases
e) Infectious diseases
f) Fertility problems
g) Technical problems or handling problems
h) Management administrative problems
i) None
j) Others

10. What diseases have you noticed in your breeding?

a) Internal parasitic diseases
b) External parasitic diseases
c) Infectious diseases
d) Reproductive diseases
e) Others
f) None

11. What breeding management methods do you use?

a) None – all animals in one herd all year around
b) Controlled admission - selected males with females on mating season
c) Males and females are selected for mating
d) Young males leave the herd, females remain in the herd
e) Others
f) Controlled weaning – all youngs leave the herd at the age of

12. If young males leave the herd, at what age?

13. Do you breed llamas on your farm?

a) Yes

b) No

If you chose "No" in the previous answer, continue to the next page, this is the end of the questionnaire for you.

(This page of the questionnaire concerns the breeding of llamas)

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14. In what months are llamas born on you farm?

a) January

b) February

c) March

d) April

e) May

f) June

g) July

h) August

i) September

j) October

k) November

l) December

15. At what age are animals included in breeding? (in months)

16. What are your selection criteria for the MALES?

	Primary	Minor	Unimportant
Size	☐	☐	☐
Health	☐	☐	☐
Color and quality of fiber	☐	☐	☐
Temperament	☐	☐	☐
Libido	☐	☐	☐
Origin	☐	☐	☐
Others	☐	☐	☐

17. What are your selection criteria for the FEMALES?

	Primary	Minor	Unimportant
Size	☐	☐	☐
Health	☐	☐	☐
Color and quality of fiber	☐	☐	☐
Temperament	☐	☐	☐
Libido	☐	☐	☐
Origin	☐	☐	☐
Others	☐	☐	☐

18. How many males do you use for breeding?

19. At what age are the young ones weaned?

20. Have you noticed an occurrence of allosuckling in your herd?

a) yes

b) no

21. If so, how frequently?

By clicking on "Finish" the questionnaire ends.

We would like to thank you very much for your time!

Wishing you all the best :)

(*If you would like to see the results of questionnaires, fulfill your email address, so we can send it to you after the evaluation.)*