CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

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DOES METEOROLOGICAL MODIFIERS INFLUENCE TIME ACTIVITY BUDGET IN CAPTIVE GUANACOS (*Lama glama guanicoe*)?

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled Does Meteorological Modifiers Influence Time Activity Budget in Captive Guanacos (*Lama glama guanicoe*)? 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 August 2018

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MOHAMMED SULAIMAN ILIYASU

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Abstract

Weather has been one of the major determinants of the survival and distribution of animals. The problems related to weather and climate on animal production is beyond the knowledge of variation in the atmospheric boundary layer and topography but also understanding how the environmental stressors can affect the behaviours and performance of the animal. Guanacos *(Lama glama guanicoe)* can adapt to harsh and variable climates throughout their distribution and environmental conditions. The main aim of this study was to determine the influence of meteorological modifiers on the time activity budget of captive guanacos. Twenty guanacos of different sex (eight males and 12 females) were used in this research. Different observations were made on the activities of the animals to compare their behaviours with meteorological modifiers. The observations were done with the use of binoculars to differentiate the behaviours of the guanacos while Kestrel 4500 was used to record meteorological modifiers readings. The meteorological modifiers, which include temperature, relative humidity, heat index, barometric pressure, wet bulb, wind speed and wind chill, were analysed using the dimension reduction model through principal component analysis (PCA) with varimax rotation to see their level of relationship with each other. This lead to the formation of three factors representing the meteorological modifiers which were used to compare their effect on the time activity budget in captive guanacos. A set of generalized linear models using the software SPSS were designed to test the influence of meteorological modifiers on the time activity budget in captive guanacos. The influence of meteorological modifiers on the behaviours and locations of captive guanacos shows that wind chill, temperature, heat index and wet bulb show a positive influence on resting behaviour, open space and under shade with negative influence on feeding behaviour, bedding behaviour and under tree while relative humidity is having a positive effect on feeding behaviour, bedding behaviour and to stay under tree with a negative influence on resting behaviour, open space and under shade at $p<0.001$. The result also indicates that both dew point and barometric pressure show a positive influence on browsing behaviour and to stay under tree with a negative effect on grazing behaviour and to stay in an open space at $p<0.001$. It has been concluded that captive guanacos respond behaviorally to different meteorological conditions on different farm situations.

Key words: Behaviour; Grazing; Observations; Temperature; Locations

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List of the abbreviations used in the thesis

BP:	Barometric pressure
BD:	Bedding
BR:	Browsing
DP:	Dewpoint
FD:	Feeding
GML:	Generalized linear models
GR:	Grazing
HI:	Heat index
OS:	Open space
PCA:	Principal component analysis
RH:	Relative humidity
RT:	Resting
TP:	Temperature
US:	Under shade
UT:	Under tree
WB:	Wet bulb
WC:	Wind chill
WS:	Wind speed

1. Introduction and Literature Review

Weather is one of the major determinants of the survival and distribution of organisms (LOSOS 1984). Thus, this can be broadly being seen in the Camelidae family with camel widely distributed in Africa and some parts of Asia and guanacos, alpaca, llamas and vicuñas which are long-neck mammals of South America (Muller 1776). The problems related to weather and climate on animal production is beyond the knowledge of variation in the atmospheric boundary layer and topography but also understanding how the environmental stressors such as temperature (TP), relative humidity (RH), thermal radiation and wind speed (WS) can also affect the behaviour, performance and well-being of the animal (de Lamo et al. 1998). The Camelidae family members are animal species occupying remote areas, arid lands or high mountains. This is linked to the high adaptation of those species to their ecosystem. This explains the interest of this family for maintaining rural activities in the most inhospitable places of the planet (Faye 2015).

Furthermore, Guanacos are territorial animals which composed of a dominant male with many females and juveniles in a family; the role of adult male is to protect territory, females and yearling against a member of another herd and make some signals such as loud vocal chords in the presence of predator (Franklin & Grigione 2015). As members of camelid family, they can be able to survive with small quantity of water for a very long period as they efficiently use water from the leaves they eat.

Vicuñas prefer grasslands at high altitudes while guanacos and other livestock live within shrublands at lower elevations (Wurstten et al. 2014). This difference between guanacos and vicuñas sometimes reduces competition between the two species. Due to the low density of livestock there seems no competition with camelidae (Wurstten et al. 2014).

Ungulates experience reasonable seasonal and climatic changes in resource distribution, particularly in tropical environments, where such changes are at high level (Illius & O'Connor 2000). Ungulates suffered limited access to main resources due to: human activities, information on the relationships among species of herbivore assemblage, its environment etc.

Guanacos can occupy habitats with different vegetation structure, topography, and climate, from sea level and can move seasonally where the winters are rigorous, also part of the guanaco population moves seasonally to gain access to resources and escape harsh weather conditions (de Lamo et al. 1998).

It is obvious the Guanacos originated from southern America, but with interest in cultural diversity, safari zoo, tourism, preference and the need to increase meat, fur hair and skin production makes it necessary to ensure good habitat for this species. There has been much research on the time activity budget of guanacos particularly in Americas but with little of such in Europe. Meanwhile, for proper breeding of this animal in Europe there is need to have a broad understanding of the influence of meteorological modifiers on their time activity budget. Thus, this would go a long way in everywhere ensuring their welfare and productivity.

During this research observation were made on the activities of the animals to compare their behaviour with ambient condition. The data for the ambient condition were collected using the Kestrel 4500 weather environmental device. The Kestrel 4500 Pocket Weather Tracker is a complete weather instrument with instant and accurate measurement of WS, TP, RH, barometric pressure (BP) and numerous other derived functions. In addition, the Kestrel 4500 has in-built digital compass. This allows to track and log wind direction as well as wind speed.

1.1. Lama guanaco

1.1.1. History of Camelidae

The current species of Camelidea family can be recognized since the list glaciation of ice age. History shows that they originated in the great plains of west-north America. A branch among this family migrated into Eurasia through land bridges at the Bering straits for more than 3 million years back toward the end of the Tertiary period and originated the present-day camels of Africa and central Asia (Adams et al. 2002).

1.1.2. Description

Guanacos as a camelid have long slender, necks and long legs (Franklin 2011), they belong to family Camelidae, order Artiodactyla, class Mammalia (Marin et al. 2007). Guanacos are the larger of the two wild camelid species, they stand about four feet tall at the shoulder and about five feet to the top of the head. Their body is about six feet with an approximately ten-inch long tail. Mostly they weigh up to 210 pounds. Their wooly coat is tawny to brown and grey head (Franklin 2011). They can live between fifteen to twenty years in the wild and their males are bigger than females (Zoo San Diego 2009). There are differences in colour between populations (MacDonagh 1949). Guanacos have two kinds of coat, under coat and guard hair (Martinez et al. 1997). They are generally marked with brown or cinnamon coats. They have symmetrical white undersides with dark faces (Hoffman & Kaehler 1993). Guanacos and llamas have spatulate, closed-root lower incisors, and both the labial and lingual surfaces of each crown are enameled (Fowler 2010). The adaptation to harsh and variable climates they encounters throughout their broad distribution, guanacos have developed physiological adaptations which allow them to respond flexibly to changes in environmental conditions (de Lamo 1998). By adjusting their body position, for example, individuals can “open” or “close” thermal windows—areas of very thin wool located in their front and rear flanks so that they can vary the amount of exposed skin available for heat exchange with the environment (de Lamo et al. 1998). This makes quickly reduce heat loss when the ambient TP drops.

1.1.3. Distribution

It is not easy to assess the specific number of camels in the world, this is because it is usually a nomadic animal and pastoralists who are moving frequently and are not usually subjected to obligatory vaccination. Therefore, an exhaustive census for the camels is quite difficult (Faye 2015). Guanacos are the widest distributed of the four species of south American camelids and they occupy the most diverse range of habitats (Franklin 1982).

The guanaco inhabits environments characterized by highly seasonal weather, snow cover, dry winters, cold to freezing TP, moderate to high winds and precipitation that combine to produce high evapotranspiration and dry conditions that lead to low productivity. The altitude span by guanacos is within the range from sea level to over 4,000 m (Eisenberg & Redford 2000). Historically, it was the dominant wild mammalian herbivore in most of the arid lands of the southern cone of the South American continent (Franklin & Johnson 1994). They live mostly in high altitude environments of the Andean highlands in treeless pastoral zones (Brown 2000). There are lot of grasses of the genera *Stipa, Festuca* and *Calamagrostis* species which are the dominant grass vegetations (San Martin and Bryant 1989).

The guanaco´s wide and successful distribution has been made possible by its flexible social organization and adaptable ecology. They are sedentary and migratory; its versatile foraging strategies include being both grazers and browsers. Adaptation to dry environments is surely related to its ability to live for long period without drinking water when the water content of forage is sufficient, and its ability to drink brackish and saline water. During the last century, the populations of guanacos have decreased and their distribution has declined by 60% (Puig & Rabinovich 1995).

1.1.4. Benefit of guanacos

The wool of guanaco is highly valued on the international market and prized for its softness and warmth (Baldi et al. 2010; Franklin 2011). However, some guanacos are being caged for wool production. Efforts to capture, shear, and release wild guanacos have rapidly increased in the late 1990’s when these initiatives began (Baldi et al. 2010). The demand for guanaco shearing is growing, and Argentina produces 1500 kg of guanaco wool yearly (Baldi et al. 2010; Franklin 2011).

1.2. Reproduction of guanacos

Guanaco reproductive strategy is a form of resource-defense polygyny: dominant males defend feeding territories against the other males (Franklin 1982). Usually, the size of a guanaco family group is between five and 13 adult animals with an average of 2.9 young (Puig & Videla 1995). Experiments in various zoological gardens around the globe shows that they are capable of year-round breeding (Sumar 1996). There is no regular period of sexual conceptivity for females along with induced ovulation by copulation of mature ova and they become sexually receptive shortly after parturition (Pollard et al. 1994). Guanacos reproduce in seasonal pattern and there is peak of breeding season once per year in their natural habitat even it is not true seasonality. Mating occurs during early summer, virtually between early December and early January (Franklin 2011). Environmental conditions have influence on the timing of birth and thus varies widely by latitude, but offspring are mostly born in November and December (Sarno et al. 2003). Period of gestation is about 11.5 months, and a single offspring, with birth weight about 10% of maternal weight, is born to each breeding female every year (Sarno et al. 2003). Twins are extremely rare, and only one neonate survives (Franklin 2011).

1.2.1. Puberty

Young males may show sexual interest in females at one year of age but are incapable of mating because the penis sticks to the prepuce from birth and is not completely liberated until puberty is reached (Brown 2000). Male alpacas reach their full maturity at the age of five but they are commonly mated at the age of three (Pollard et al. 1995). Female guanacos reach sexual maturity at two years old and breed for the first time at age of three (Franklin 2011).

1.3. Behaviour

1.3.1. Communication and territorial behaviour

Guanacos are territorial animals which composed of a dominant male with many females. The role of adult male is to protect the females and yearling against a member of another herd and make some signals such as loud vocal chords in the presence of predator (Franklin & Grigione 2015). Males become territorial at age of four to six and thereafter they engage in violent competition in defense of feeding territories and control of family groups (Fowler & Bravo 2010). Communication in guanacos includes ear signaling, spitting, chest ramming, tail pointing, submissive crouching, body posturing and locomotion displays. They applied a range of vocalizations for sending information and negotiating social roles (Franklin 2011).

Spitting is used regurgitated food from its forestomach. Spitting can be mild or severe (Hoffman & Kaehler 1993). These types of communication are important for territorial males to protect attack from predators and lesser males, for females and to create their own internal linear hierarchies too (Hoffman 2005). The open character that guanacos manifest facilitates visual communication by allowing gestures to be seen over long distances (Franklin 2011). Male guanacos applied different kind of methods to assert dominance over potential rivals (Franklin 2011).

1.3.2. Feeding behaviour

The guanaco may be classified as an intermediate herbivore or opportunistic (Hofmann 1989). The main source of forage during the year is herbaceous vegetation stratum with preferences displayed for some plant species (Puig et al. 1997). Nevertheless, they usually feed from shrubs or tree strata during winter when the availability of herbaceous strata decreases (Puig et al. 1997). This flexibility to change diet according to availability or preference extends to the consumption of lichens and succulent plants in the arid coast of the Atacama Desert (Raedeke & Simonetti 1988). It appears that guanacos are highly selective in their feeding (FD) and grazing (GR) only on a small portion of the potential food spectra. Furthermore, when the availability and diversity of feed in the field changes due to increased amount of rainfall, guanacos do not show a parallel change in their diets (Cortés et al. 2003). Guanacos and sheep change their diet seasonality, where by changes in the diet of guanacos are more pronounced than that of sheep (Demment & Van Soest 1985). The higher proportion of monocots in the diet of guanacos compared to sheep during spring may result due to the guanaco's larger body size, as larger animals are expected to utilize lower-quality feed in higher proportions than smaller animals (Baldi et al. 2010). Guanaco relative species one humped camels spent 39% of their time ruminating, 29% eating and 32% resting (RT). About 97% of the eating, 44.4% for ruminating, and 45% for resting activity occurred during daytime (Hedi & Khemais 1990). Rumination and eructation take place three to four times during every cycle (Ehrlein & Engelhardt 1971; Engelhardt & Rubsamen 1977). On average camels spent 37, 32, 27, and 4% time for GR, rumination, idling, and resting/sleeping, respectively (Iqbal & Khan 2001). It is known that guanacos only browse leaves, leaving branches intact (Arroyo et al. 1996).

1.3.3. Mating behaviour

Non-pregnant females are essentially in continuous heat and when males are introduced to a herd they normally attempt to mate with the first female they encountered (Brown 2000). Courtship begins when male pursued the females and attempting to mount them (Brown 2000). However, the length of courtship may be influenced by the level of male sexual performance as a result pursuit of a female by males of high libido may last longer than ten minutes before the males give up (Fowler 1998). While accepting a male, the female takes a bow or seated position, RT on her brisket with her pelvis elevated and permits the male to straddle her from behind. In this position, the head of the male is above and slightly behind that of the female, his elbows hold her at the shoulders, and his forefeet on the ground (Novoa 1970). In the process of penetration of the vulva, the male maneuvers his penis into the vagina and through the cervix. In contrary to the forceful pelvic thrusting movements characteristic of rams, intromission in male camelids is achieved only after a certain period spent searching and probing with the penis, starting with the perineal area for the vulva and then in traversing the vagina and cervix (Brown 2000). With mild thrusting movements, semen is released directly into the uterine horns (Franco et al. 1981).

1.3.4. Suckling behaviour

Lactation could be an expensive behavior exhibitated in mammalian species (Zapata et al. 2009). The young receive passive immunity from the colostrum in the mother's milk as a result of increase in the milk few days after birth (Brown 2000). Chulengo (young guanacos), habitually spend more time grazing than suckling as they grow older. (Prescott 1981). The approximate weaning period is normally between seven to nine months (Brown 2000).

1.3.5. Social organisation of guanacos

During the breeding season, guanacos are categorize in three basic social units namely: territorial family harems, non-reproductive male groups (bachelor) and solitary males (Franklin 1982). While the variety in the compositions outside the breeding season are based on environmental conditions. Sedentary populations are observed when weather and forage supply is stable, allowing populations to live in stable territories all year round (Franklin 1983).

However, during snowy winters specifically with a drastic reduction of food availability, guanaco may displace to more sheltered areas, losing their territoriality and forming large mixed herds (Franklin 1983).

1.4. Adaptation

Universally, adaptation is defined as a change which reduces the physiological strain due to the stressful component of the total environment. For domestic animals to adapt to hash environmental weather condition, several methods are being observed and strategized (King 2004). Several means are used to analyze animal responses to harsh environments (Yousef 1987). The change may occur within the lifetime of an organism or be the result of genetic selection in a species or subspecies (Bligh & Johnson 1973).

Adaptation happened through genetic change over generations which involves evolutionary processes and environmental stimulation within the life time of the animal (Hafez 1968). This is based on the selection of animals by natural or human selection (Hafez 1968). For example, the identification of weather tolerant phenotypes within existing breeds for weather tolerance could be a partial solution (Parsons 1994).

Animals could positively adapt to environmental change with their ability to respond when exposed cold and to climate change (Hafez 1968). However, acclimatization and habituation are also seen as an animal response to climate change (Folk 1974).

1.4.1. Behavioural response to presence of a human

Habituation is an increase in the intensity of disturbance that an individual tolerates without responding in a defined way (Bejder et al. 2009). Guanacos assumed a higher risk having been closer to the human activity seems likely to habituate to human presence (Colman et al. 2001). The guanaco responses to tourists was also measured whenever possible (Stankowich 2008).

1.4.2. Feed availability

Adequate nutrition can be derived by free ranging camelids through the forage resources in any seasonal condition, camels are considered mainly to be browsers (Coppock et al. 1986a, 1986b). Camelids are also opportunists and they engage in diet selection in any opportunity (Lu 1988). They are selective feeders and eat the freshest vegetation available. During the growing season, they tend to choose the more nutritious part of plants and their diets generally reflect the plant coverage (Elmi 1990). The Camels ate high amount of grasses during the raining season (Doerges & Heuckes 1996).

1.4.3. Drought and Water availability

Drought influences most the animals to fight against environmental factors particularly where there is little or no rainfalls and lack of water in some areas where ruminants live which is often lethal to them. A study shows that animals die of thirst in the process of searching for water that may not be available, in circumstances where there is enough water supply the feeds will eaten up by the animals therefore become shortage, for example the sub-Saharan African desert species did not move south for water but for food (Spinage 1986). However, there is also a high rate of mortality because of diseases caused by drought in the sub-Saharan Africa. Periodic drought factor is the most important and widespread that shorten the number of herbivores (Spinage 1986). Free from availability of drinking water, or the lack of a need to drink, represents the greatest challenge facing to evolution of mammals (Spinage 1986). Camelids can survive severe droughts and continue to contribute to household nutrition and economy in dry periods (Adams et al. 2002).

1.5. Environmental factors

1.5.1. Influence of environmental factors on behaviour

Some of the greatest impacts of global warming can be seen in grazing systems in arid and semi-arid areas (Hoffman & Vogel 2008). Temperature increment and decrease in rainfall affects the growth of rangelands and contribute to their degradation. Higher TP cause the reduction of animal feed intake and lower feed conversion rates (Rowlinson 2008).

1.5.2. Temperature

Temperature represents a major portion of the driving force for exchange of heat between animal and its environment (Hahn 1999). Body TP of some species could be labile due to their capacity to survive substantial changes, for example, the core body TP of camels can vary between 34°C and 42°C (Fowler 1999). Some antelopes and ground squirrels show large fluctuations of core TP between 37°C to 43°C. Therefore, they hide under shade whenever TP increases to 43°C (Willmer et al. 2000).

Mammals are homeothermic endotherms and maintain a core body TP between 35°C and 40°C depending on the species (Langlois 1994). Through a narrow range TP, they are irradiative, conductive, convective, and evaporative exchanges to generally maintain core body TP (Langlois 1994). In some of the species of animals which may include cattle, horses and sheep, 5-7^{0}C increase or decrease in body TP can affect the activities of these animals as a result may lead to death (Ames 1980).

Camelids are primarily dependent on evaporative cooling via the thermal windows despite they are having sweat glands over the entire surface of the body. Heat stress can cause neurological damage, congenital damage or abortion in pregnant females and lower sperm count in intact males (Fowler 1994).

1.5.3. Wind

Wind is very important environmental factor in daily activities especially movement. Although other conditions and factors with respect to wind could affect some groups of animals (Underwood 1975). An example is the size of the herd, size of the animals, wind force, wind intensity as well as landscape and terrain. The herds of ruminants can be influenced by wind particularly in the wild whereas other ruminants that live in temperate climatic zone and in forests are influenced less than those in the savannah or desert (steppe antelopes as hartebeest, wildebeests, eland or saiga) (Underwood 1975).

1.5.4. Relative humidity

Relative humidity under cold stress affects livestock reared in outside conditions which shows a poor coat drying conditions. Thus, an increase in RH leads to a slight decrease in apparent TP. An opposite effect is found under hot conditions with high increase in TP and humidity, due to the inability of the animal to transfer body heat (Mader et al. 2010). Moreover, the detrimental effects of wet, humid conditions in which TP reduced to –15°C because of winter precipitation, energy requirements were found to be 2.5 times greater than normal and 2.1 times greater than that predicted by the NRC, 2000 (Wagner et al. 2008). Too much moisture contributes to poor drying of the animal and increased maintenance energy requirements, wet surface conditions seems to maintain increased humidity, to which dry surfaces allow moisture to migrate away from the animal, thus reducing RH and allowing for greater haircoat drying opportunities

(Mader et al. 2010). High ambient TP attached with high humidity during the day, can adversely affect feed intake and nutrient utilization in sheep (Bhattacharya & Hussain 1974).

1.5.5. Heat index

Development of a thermal stress index for cattle as an ungulate should be based on biological factors (Hahn et al. 2003). It is important for a large data to develop and test an index which makes the biological parameter used, be easy to measure and be a good indicator of heat load. Behavioral changes are reliable indicators of heat load status; feedlot location, feedlot layout, and pen microclimate influence the behavior of cattle (Castaneda et al. 2004).

1.5.6. Barometric pressure

A study has shown that BP has a positive relationship with GR, ruminating and lying behaviours with a negative relationship with standing behavior in cattle (Malechek & Smith 1976). A strong relationship has been shown between BP and the behaviour of domestic dogs and rats (Stewart 1898). Therefore, BP may provide an important environmental signal on an animal, but its ecological significance remains largely unknown (Kreithen & Keeton 1974).

1.5.7. Wind chill

This is the combine cooling effect of wind and TP which gives a more accurate reading of how the body feels cold. Wind chill (WC) is a crucial factor affecting animal health and welfare during cold periods, while TP and RH affect the animal health and welfare during hot periods Brouček et al. (2006). The WC is directly influenced by heat transfer Brauner & Shacham (1995) and it has been shown in the study of Wilson (1964) that excessive WC factor can be a health hazard, meanwhile excessive heat loss from the body may result in hypothermia.

2. Aims of the Thesis

A lot of studies have shown the effect of meteorological modifiers on the behaviours of different species of animals. Researchers have also conducted several studies in Americas on guanacos but limited in Europe. Also, studies related to meteorological modifiers on the behaviours of this species are limited. Therefore, the primary aim of this study is to determine the influence of meteorological modifiers on the time activity budget of captive guanacos while the secondary aims are to determine the influence of meteorological modifiers on:

- the behaviours of captive guanacos.
- the location of captive guanacos.

2.1. Hypothesis

H_1- Higher temperature will increase the percentage of resting behaviour, the stay under shade and reduce feeding and bedding behaviour.

H_2- Higher relative humidity will increase the percentage of resting behaviour, stay under the shade and reduce feeding behaviour, bedding behaviour and to stay in the open space.

H_3- Higher wind chill will increase the percentage of resting behaviour, the stay under shade and reduce feeding and bedding behaviour.

H_4- Higher heat index will increase the percentage of resting behaviour, the stay under shade and reduce feeding and bedding behaviour.

H_5- Higher wet bulb will increase the percentage of browsing behaviour, stay under the tree and reduce feeding and bedding behaviour.

H_6- Higher dew point and barometric pressure will increase the percentage of browsing behaviour, to stay under the tree and reduce grazing behaviour and to stay in an open.

3. Materials and methods

3.1. Observed animals

Twenty guanacos *(Lama glama guanicoe)* of different sex (eight males and 12 females) were use in this research. Different observations were made on the time activity budget of the animals to compare their behaviour and location/position with the meteorological modifiers. The observations were made with the use of binoculars. Tables 1 and 2 show the description of the studied animals.

Table 1. List of guanaco's herds number 1.

Number	Colour ear of tag	Sex	Birthdate	From
1	Blue	F	14.06.1991	Zoo Brno
2	Orange	F	17.10.2000	Zoo Brno
4	Yellow	F	01.09.2007	Zoo Brno
5	Red	M	2008	Zoo Jihlava
7	Yellow	F	16.10.2011	Lány
13	Red	F	13.07.2009	Kotrba
15	Pink	F	16.07.2010	Kotrba
28	Pink	F	21.05.2015	Lány
29	Yellow	M	22.06.2015	Lány
31	Yellow	M	01.07.2015	Lány
30	Pink	F	14.07.2015	Lány
32	Yellow	M	04.09.2015	Lány

Table 2. List of guanaco's herds number 2.

Number	Colour of ear tag	Sex	Birthdate	From
16	Yellow	M	22.06.2013	Lány
18	Orange	M	10.09.2013	Lány
24	Green	F	07.06.2014	Lány
25	Yellow	M	23.06.2014	Lány
26	Pink	M	24.08.2014	Lány
B1	Red	M	26.07.2014	Tierpark Berlin
B2	Red	M	13.04.2014	Tierpark Berlin
O1	Red	M	12.05.2015	Opel Zoo Kronberg
O2	Pink	F	12.06.2015	Opel Zoo Kronberg
O3	Pink	F	12.05.2014	Opel Zoo Kronberg
O4	Pink	F	22.06.2014	Opel Zoo Kronberg
O5	Pink	F	08.07.2013	Opel Zoo Kronberg

3.2. Data collection

The observation was done from September to November 2017, three hundred and seven (307) observations were made on each animal with two observation period of twenty minutes each per hour. Some number of days were skip during the experiment to obtain different days with different ambient conditions. The data for the meteorological modifiers were collected using the Kestrel weather environmental meter. The modifiers recorded using this instrument include: wind speed (WS), WC, RH, TP, BP, wet bulb (WB), heat index (HI) and dewpoint (DP). Several behaviours were observed in the study, but due to less occurance of some behaviours the ones with high frequency of occurance were selected to test the effect of the meteorological modifiers on each of them. The selected behaviours include: GR, FD, browsing (BR), RT and bedding (BD) were observed (Figures 2 to 6). The position or location of the animals included under shade (US), uunder tree (UT) and open space (OS).

Figure 1. Observing metrological modifiers using Kestrel 4500 environmental meter.

3.3. Method of observation

Before the commencement of the data collection on each day the Kestrel 4500 was set to record condition of the meteorological modifiers (Figure 1). The process of setting the Kestrel 4500 include:

Installation of the tripod: the tripod is removed from its jacket and all the clips on the leg were unclipped and freed; afterward they were clipped again to have a firm stand. The tripod was vertically erected in order not to affect the reading of the device. This was achieved by adjusting the bubble at the top to align with the circle in the middle. Precaution was taking to make sure the tripod was not close to shade, metallic objects, access to children or animals, which might likely affect the compass calibration of the Kestrel. Time and date were set by clicking on the red button (●) to go to main menu, the navigation keys alongside the central key were used to achieve a proper date and time setting. The conditions of the meteorological modifiers were recorded after every 20 minutes which tally with the observation time of the animal's behaviours. The

Bluetooth setup helps in transferring the stored data in the kestrel to the computer for further processing and analysis.

After the installation of the Kestrel device, the observation of the captive guanaco's behaviours commences. Scan sampling technique (Altmann 1997) was used. However, before starting the observation of the captive guanaco's behaviours I usually wait for 10 minutes for habituation and then proceed. The animals were observed two times in every hour at 20 minutes interval and taking 20 minutes for resting before the subsequent circle of scan. All behaviours observed were recorded in the record sheet later impute into the excel sheet for interpretation and ready for the statistical analysis.

Figure 2. Bedding behavior of captive guanacos observed inside the pen during the data collection.

Figure 3. Grazing behavior of captive guanacos observed in an open space during the data collection.

Figure 4. Feeding behavior of captive guanacos observed inside the pen during the data collection.

Figure 5. browsing behavior of captive guanacos observed under the tree during the data collection.

Figure 6. Resting behavior of captive guanacos observed in an open space during the data collection.

3.4. Place of the observation

The research was conducted at Czech University of Life Sciences experimental farm at Lány, Czech Republic, established in 2009. This place is outdoor enclosure area of 1.2 hectare placed at apple orchard. This area is divided into two separated paddocks. First paddock is from two sides surrounded by roads and from one side by meadows. Second paddock is from one side surrounded by road and from two sides by meadows. There is shared fence between both paddocks.

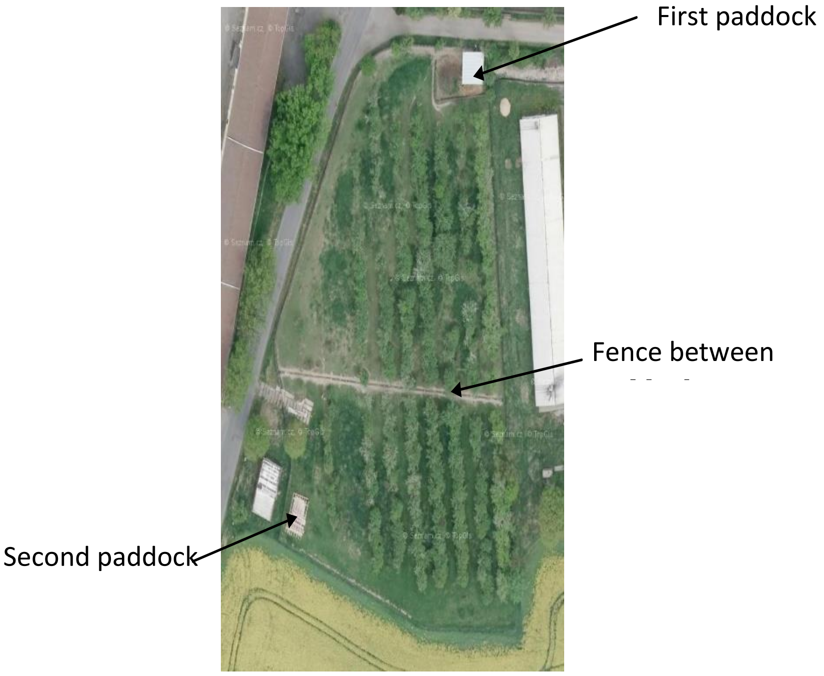

Figure 7. Aerial photo of paddock at the experimental farm.

Figure 7 shows aerial look of paddock at the experimental farm in the picture we can see fence divides the whole paddock into two smaller paddocks. In each paddock is placed a shade where guanacos can find hay, water and mineral lick. Feeding was carried out by hay and pasture *ad libitum*. Water and mineral lick was also available there to free access (figure 7 and 8).

Figure 8. Shade with hay in first paddock at the experimental farm.

Figure 9. Shade with hay in second paddock at the experimental farm.

3.5. Statistical analysis

The data were analysed using statistical software SPSS version 20.0. The calculation of significance level was established at $\alpha=0.05$ and 0.01. The meteorological modifiers which include TP, RH, HI, BP, WB, WS and WC were analysed using dimension reduction model through principle component analysis (PCA) with varimax rotation, to see their level of relationship with each other, which lead to the formation of three factors representing the meteorological modifiers and compare their effect on the time activity budget in captive guanaco. A set of generalized linear models using the software SPSS were designed to test the influence of meteorological modifiers on the time activity budget in captive guanacos. The behaviours of the animals analysed using this model include GR, FD, BR, RT, BD, and the location of the animals that is US, UT and OS were also analysed. All data were initially tested for normality, a non- parametric test was applied (one-sample Kolmogorov-Smirnov Test). Correlations among the meteorological modifiers as well as the corresponding behaviours and location of the animals were also analysed using Spearman correlation.

4. Results

4.1. Proportion of the activity time budget of captive guanaco

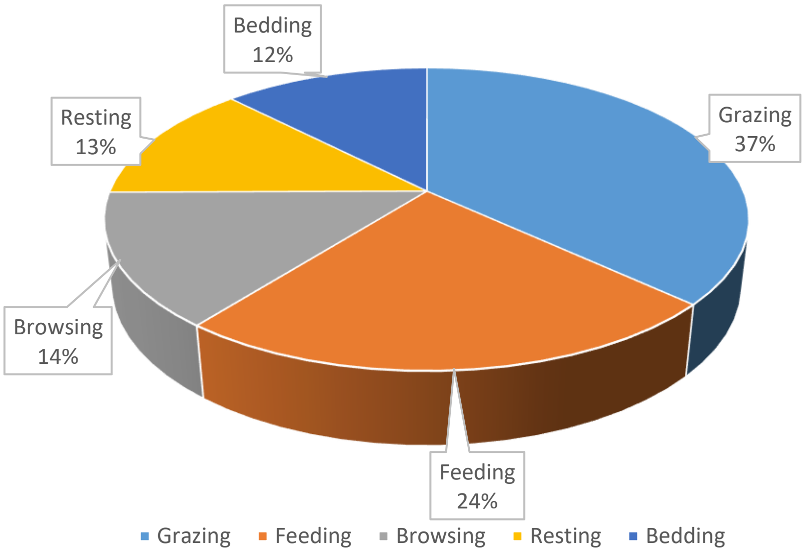

Figure 10. Proportion of grazing, feeding, browsing, resting and bedding behaviours of captive guanacos Observed during the data collection.

Figure 10 shows the observed behaviours of captive guanacos, GR has the highest percentage followed by FD while BD has the lowest percentage. Figure 11 shows the observed location of captive guanacos. The result shows that OS has the highest percentage and US has the lowest percentage.

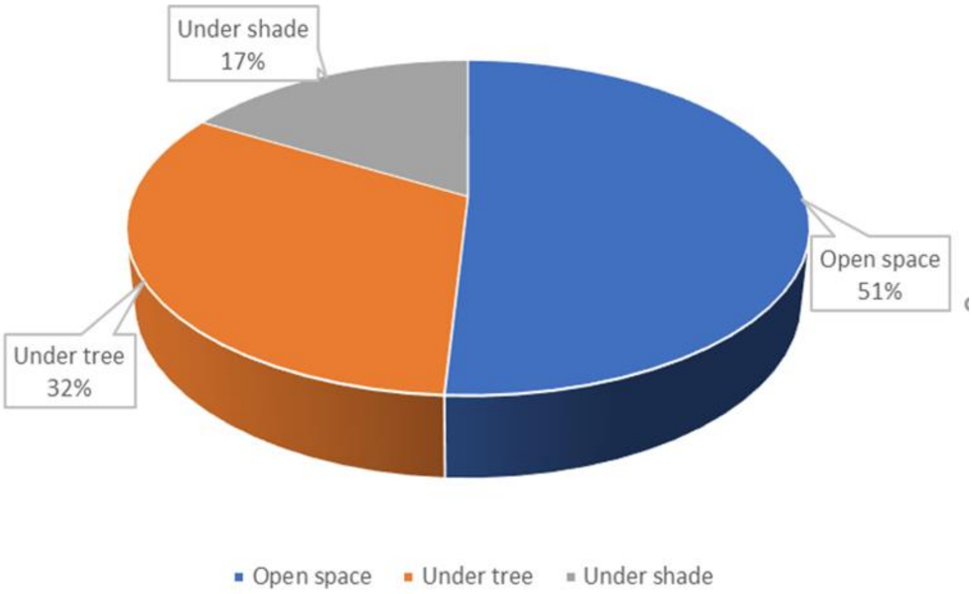

Figure 11. Proportion of open space, under tree and under shade (location) of captive guanacos observed during the study.

4.2. Relationship among the meteorological modifiers

Table 3. Spearman correlation analysis of meteorological modifiers which include TP, RH, HI, BP, WB, DP, WS and WC.

	WS(m/s)	TP(°C)	WC(°C)	RH (%)	HI(°C)	DP(°C)	WB(°C)
TP(°C)	0.239**						
WC(°C)	0.193**	0.997**					
RH(%)	-0.197**	-0.624**	-0.620**				
HI(°C)	0.238**	0.989**	0.986**	-0.521**			
DP(°C)	0.074	0.483**	0.481**	0.325**	0.587**		
WB(°C)	0.182*	0.862**	0.859**	-0.187**	0.921**	0.839**	
BP(mb)	0.105	0.204**	0.200**	0.095	0.231**	0.408**	0.314**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
TP: Temperatures, **RH:** Relative humidity, **HI:** Heat index, **BP:** Barometric pressure, **WB:** Wet bulb, **WS:** Wind speed, **WC:** Wind chill, **DP:** Dew point.

The results show a significant correlation between all the meteorological modifiers except for WS with DP and BP as well as BP and RH. The highest correlation was recorded between WC and TP with correlation of 0.997.

4.3. Relationship between the meteorological modifiers and the activity time budget of captive guanaco.

Table 4. Spearman correlation analysis between the meteorological modifiers which include; TP, RH, HI, BP, WB, DP, WS and WC and the behaviours observed GR, FD, BR, RT and BD.

	GR%	FD%	BR%	RT%	BD%
WS(m/s)	0.136	-0.046	0.044	0.182*	-0.147*
TP(°C)	0.267**	-0.109	0.222**	0.460**	-0.471**
WC(°C)	0.271**	-0.101	0.212**	0.457**	-0.469**
RH (%)	-0.413**	0.002	0.073	-0.279**	0.405**
HI(°C)	0.229**	-0.129	0.242**	0.474**	-0.441**
DP(°C)	-0.134	-0.146*	0.333**	0.220**	-0.071
WB(°C)	0.099	-0.153*	0.288**	0.417**	-0.316**
BP(mb)	-0.154*	0.210**	0.192**	0.165*	-0.024

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
TP: Temperatures, **RH:** Relative humidity, **HI:** Heat index, **BP:** Barometric pressure, **WB:** Wet bulb, **WS:** Wind speed, **WC:** Wind chill, **DP:** Dew point, **GR:** Grazing, **FD:** Feeding, **BR:** Browsing, **RT:** Resting, bedding

The result of correlation between meteorological modifiers and behaviours of captive guanacos observed are shown in Table 4. The result shows that RH has a medium and inverse correlation with GR and RT behaviours. The results also indicate that RT behaviour has medium and positive correlation with TP, WC, HI, and WB, finally the result shows that BD behaviour has a medium and inverse correlation with TP, WC, HI and WB.

Table 5. Spearman correlation analysis between the of meteorological modifiers (which include temperatures, relative humidity, heat index, barometric pressure, wet bulb, wind speed and wind chill), and location of animals observed (under shade, under tree and open space).

	OS%	UT%	US%
WS(m/s)	0.181*	-0.188**	0.037
TP(°C)	0.155*	-0.311**	0.392**
WC(°C)	0.157*	-0.314**	0.393**
RH(%)	-0.301**	0.429**	-0.292**
HI(°C)	0.131	-0.278**	0.378**
DP(°C)	-0.151*	0.115	0.166*
WB(°C)	0.032	-0.148*	0.338**
BP(mb)	-0.333**	0.274**	0.060

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
TP: Temperature, **RH:** Relative humidity, **HI:** Heat index, **BP:** Barometric pressure, **WB:** Wet bulb, **WS:** Wind speed, **WC:** Wind chill, **DP:** Dew point, **US:** Under shade, **UT:** Under tree, **OS**: Open space.

The results of correlation analysis between meteorological modifiers and location of captive guanacos observed are shown in Table 5. The results show that all the meteorological modifiers have significant correlation with the location of captive guanacos observed with exception of WS and US, HI and OS as well as BP and US. All the correlations are weak but only RH and TU have medium correlation.

Due to high correlation (multicollinearity) between the meteorological modifiers, principle component analysis (PCA) was used to group them into factors using SPSS statistical package (Table 6).

4.4. Principal component analysis

Table 6. Factors loadings from the principle component analysis performed on different meteorological modifiers with greatest effect on the extracted factors are shown in bold (loading ≥ 0.7). (Budaev 2010).

	Factor1	Factor2	Factor3
Eigenvalue	4.818	1.569	0.991
Explained variance	60.221	19.612	12.385
WC	**0.971**	0.230	0.050
TP	**0.965**	0.238	0.104
HI	**0.925**	0.368	0.070
WB	**0.781**	0.609	-0.005
RH	**-0.753**	0.570	-0.249
DP	0.406	**0.870**	-0.129
BP	0.151	**0.695**	0.287
WS	0.088	0.065	**0.954**

4.5. Generalized linear models

Table 7. Generalized linear models showing the influence of meteorological modifiers on the behaviours of captive guanacos. Meteorological modifiers grouped through PCA.

Target	Variable	β	Standard error	95% confidence interval		p-value
Grazing (%)	(Intercept)	3.381	0.0515	3.280	3.482	<0.001
	Factor 2	-0.202	0.0520	-0.304	-0.100	<0.001
Feeding (%)	(Intercept)	2.842	0.0174	2.808	2.876	<0.001
	Factor 1	-0.097	0.0173	-0.131	-0.063	<0.001
Browsing (%)	(Intercept)	10.337	0.7558	11.818	187.026	<0.001
	Factor 2	2.722	0.7578	4.207	12.902	<0.001
Resting (%)	(Intercept)	9.275	0.8773	7.555	10.994	<0.001
	Factor 1	3.408	0.8796	1.684	5.132	<0.001
Bedding (%)	(Intercept)	2.519	0.0576	2.632	1914.936	<0.001
	Factor 1	-0.274	0.0514	-0.173	28.350	<0.001

The influence of meteorological modifiers on the behaviours of captive guanacos using PCA is shown in Table 7. The result shows that factor two has significant influence on GR and BR behaviours with negative and positive coefficient respectively. The results also indicate that factor one has significant influence on FD, RT and BD behaviours with negative coefficient on FD and BD while RT having a positive coefficient.

Table 8. Generalized linear models showing the influence of meteorological modifiers on the location of captive guanacos. Meteorological modifiers were grouped through PCA.

Target	Variable	β	Standard error	95% confidence interval		p-Value
Open space (%)	(Intercept)	46.891	1.2508	49.343	1405.423	<0.001
	Factor 1	3.955	1.2541	6.412	9.944	0.002
	Factor 2	-6.617	1.2541	-4.159	27.839	<0.001
Under tree (%)	(Intercept)	3.411	.0423	3.328	3.494	<0.001
	Factor 1	-0.214	.0375	-0.288	-0.141	<0.001
	Factor 2	0.204	.0435	0.119	0.289	<0.001
Under shade (%)	(Intercept)	15.337	.7594	13.848	16.825	<0.001
	Factor 1	4.192	.7613	2.699	5.684	<0.001

The influence of meteorological modifiers on the location of captive guanacos observed using PCA is shown in Table 8. The result indicates that factor one has significant influence on captive guanacos to stay in an OS, UT and US with positive coefficient OS and US while UT having a negative coefficient. The results also indicate that factor two has significant influence on OS and UT with positive and negative coefficient respectively.

5. Discussion

This study showed that the meteorological modifiers are influencing time activity budget in captive guanacos. Among the behaviours observed, GR behaviour had the highest number of occurrence, while the locations of the captive guanacos observed indicated that OS had the highest percentage. Due to high correlation between the meteorological modifiers, PCA was used to reduce the variables to the minimum independent factors using SPSS. Factor one comprises of WC, TP, HI, WB and RH, factor two includes DP and BP, while WS stands independently as factor three. Generalized linear models shows that factor one had a significant influence on FD, RT and BD behaviours. Wind chill, TP, HI and WB show a positive influence on RT behaviour with negative influence on FD and BD behaviours while RH is having a positive effect on FD and BD behaviours with a negative influence on RT behaviour. The result also indicated that factor one had a significant influence on captive guanacos to stay in an OS, UT and US. Wind chill, TP, HI and WB shows a positive influence on the captive guanacos to stay in an OS and US with a negative influence on UT while RH is having a positive effect on the captive guanacos to stay UT with a negative effect on OS and US. Factor two has a significant influence on GR and BR behaviours. Both DP and BP showed a positive influence on BR behaviour with a negative effect on GR behaviour. Finally, the results indicate that factor two had a significant influence on OS and UT. Both DP and BP showed a positive influence for the captive guanacos to stay UT with a negative effect for them to stay in an OS.

The finding of this research indicated that captive guanacos have preference for GR above any other behaviour. The GR behaviour emerged the highest behaviour with 37 percent (%) which is in line with the finding of Iqbal & Khan (2001) whose result shows that camels spent 37%, 32%, 27% and 4% time for GR, ruminating, idling, and resting/sleeping respectively. The result also agrees with the finding of Puig et al. (1997) which stated that the main source of forage for guanacos during the year is herbaceous vegetation stratum. The higher occurrence of GR behaviours over the rest of the behaviours could be due the availability of herbaceous vegetation. The location or position of the animals shows that OS has the highest percentage. This agrees with the finding of Brown (2000) which indicates that guanacos mostly live in treeless pastoral zones in the high-altitude environments of the Andean highlands. Franklin (1983) found that during snowy winters specifically with a drastic reduction of food availability, guanacos may displace to more sheltered areas, losing their territoriality and forming large mixed herds, therefore the highest percentage of the guanacos living in an OS may be due to moderate TP and availability of herbaceous grasses for the animals.

Factor one had a significant influence on FD, RT and BD behaviours. Wind chill, TP, HI and WB show a positive influence on RT behaviour with negative influence on FD and BD behaviours which implies that a unit increase of each lead to an increase on RT behaviour and a decrease on FD and BD behaviours, while RH is having a positive effect on FD and BD behaviours with a negative influence on RT behaviour. This result agrees with the study of Paola et al. (2015) which shows that the amount and distribution of animal's activities can be influenced strongly by TP during the day. It is also reported that there is a positive relationship between GR behaviour and TP in free ragging cows during winter (Malechek & Smith 1976). Factor one also had a significant influence on captive guanacos to stay in an OS, UT and US. Wind chill, TP, HI and WB shows a positive influence on the captive guanacos to stay in an OS and US with a negative influence on UT. This also indicated that a unit increase of each lead to an increase on the captive guanacos to stay in an OS and US and a decrease lead to stay UT, while RH is having a positive effect on the captive guanacos to stay UT with a negative effect on OS and US. This is in line with the study of Willmer et al. (2000) which indicated that animals cannot resist to higher TP therefore, hide US whenever TP increases. From the result of this study it has been shown that with an increase of WC, TP, HI or WB the animals can comfortably stay both in OS and US. This might be due to the adaptation to harsh and variable climates by guanacos throughout their broad distribution and development of physiological adaptations which allow them to respond flexibly to changes in environmental conditions (de Lamo 1998). The BD and RT behaviours agreed with a study which indicated that guanacos can "open" or "close" thermal windows—areas of very thin wool located in their front and rear flanks so that they can vary the amount of exposed skin available for heat exchange with the environment which makes quickly reduce heat loss when the ambient temperature drops (de Lamo et al. 1998).

Factor two has a significant influence on GR and BR behaviours. Both DP and BP showed a positive influence on BR behaviour with a negative effect on GR behaviour. This implies that a unit increase of DP and BP lead to an increase on BR behaviour and decrease on GR behaviour. This is contrary to Malechek & Smith (1976) whose study indicated a positive relationship between GR behaviour and BP in free ragging cows during winter. This might be due to the differences of seasons in which the two studies were conducted. Factor two also shows a significant influence on OS and UT. Both DP and BP showed a positive influence for the captive guanacos to stay UT with a negative effect for them to stay in an OS. This indicated that a unit increase of DP and BP lead to an increase for the captive guanacos to stay UT and a decrease to stay in an OS.

6. Conclusions

It has been observed from this study that the meteorological modifiers have significant influence on the activity time budget of captive guanacos. In relation to this, the studied meteorological modifiers affect the behaviours of the animals such as GR, BR, RT, FD and BD. More so, the meteorological modifiers also affect the location of the animals such OS, US, and UT.

There is an indication from the outcome of this study that captive guanacos had a high frequency of GR in comparative to other behaviours. Therefore, it is concluded that captive guanacos have the capability of adapting to different meteorological conditions on different farm situations and they use behavioural thermoregulation in extent. Therefore, vegetation cover (trees) providing shade can be improvement for welfare of animals.

Finally, I am recommending that further observation should be carried out on different seasons of the year as guanaco's physiological adaptations allow them to respond flexibly to changes in environmental conditions.

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Appendices

List of the Appendices:

Appendix 1: Appendix 1: Measured features helping to describe meteorological modifiers.

True North:

True north is a navigational term referring to the direction of the North Pole relative to the navigator's position. The direction of true north is marked in the skies by the celestial North Pole.

Magnetic North:

The point on the Earth's surface where the Earth's magnetic field points directly downwards. This pole is constantly wandering.

Wind Chill:

The cooling effect of combining wind and temperature. The wind chill gives a more accurate reading of how cold it really feels to the human body. The Kestrel Meter's wind chill is based on the National Weather Service standards as of November 1, 2001.

Relative Humidity:

The amount of water vapor in the air divided by the maximum amount of water vapor the air could hold at that temperature, expressed as a percentage.

Temperature:

The ambient air temperature.

Heat Index:

A practical measure of how hot the current combination of relative humidity and temperature feels to a human body. Higher relative humidity makes it seem hotter because the body's ability to cool itself by evaporating perspiration is reduced.

Dewpoint:

The temperature to which air must be cooled in order for condensation to occur. The difference between dewpoint and temperature is referred to as the "temperature/dew point spread". A low dewpoint spread indicates high relative humidity, while a large dewpoint spread indicates dry conditions

Wet Bulb:

The lowest temperature to which a thermometer can be cooled by evaporating water into the air at constant pressure. This measurement is a holdover from the use of an instrument called a sling psychrometer. To measure wet bulb temperature with a sling psychrometer, a thermometer with a wet cloth covering over the bulb is spun rapidly through the air. If the relative humidity is high, there will be little evaporative cooling and the wet bulb temperature will be quite close to the ambient temperature. Some exercise physiology guides use wet bulb temperature, rather than heat index, as a measure of the safety of exercise in hot and humid conditions.

Barometric Pressure:

The air pressure of your location reduced to sea level. Pressure will change as weather systems move into your location. Falling pressure indicates the arrival of a low-pressure system and expected precipitation or storm conditions. Steady or rising pressure indicates clear weather. A correct altitude must be input for the Kestrel Meter to display barometric pressure correctly.

Altitude:

The distance above sea level. The Kestrel Meter calculates altitude based on the measured station pressure and the input barometric pressure - or “reference pressure”

Density Altitude:

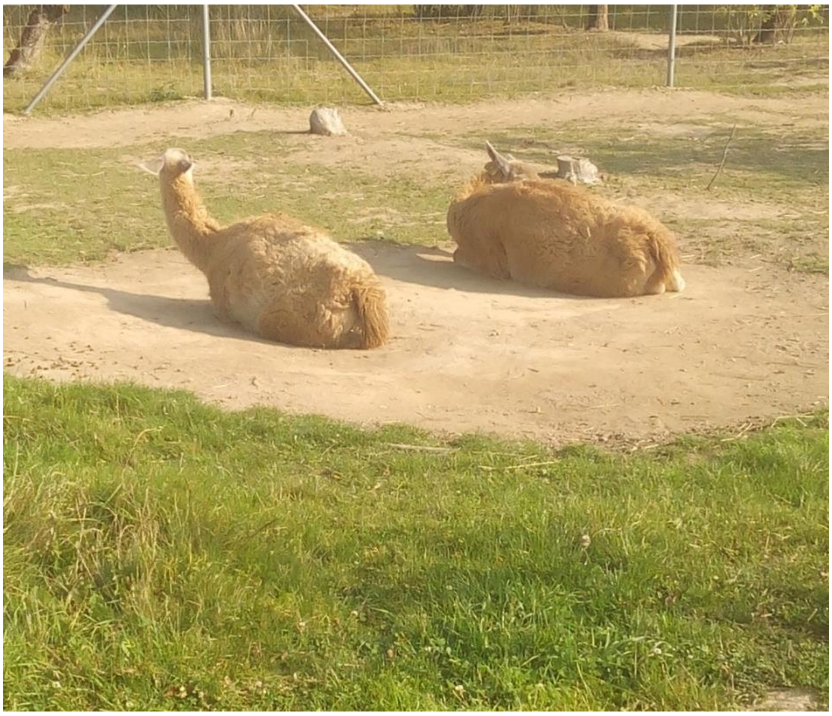
The altitude at which you would be, given the current air density. Often used by pilots to determine how an aircraft will perform. Also, of interest to individuals who tune high performance internal combustion engines, such as race car engines.

Cross Wind:

A crosswind is any wind that has a perpendicular component to the line or direction of travel. This affects the aerodynamics of many forms of transport. Moving non-parallel to the wind's direction creates a crosswind component on the object and thus increasing the apparent wind on the object; such use of cross wind travel is used to advantage by sailing craft, kiteboarding craft, power kiting, etc. On the other side, crosswind moves the path of vehicles sideways and can be a hazard.

Appendix 2: Farm activities

Record taking:



Bedding behaviour:

Salt lick:

Appendix 3: Statistical tables

The tables below are the full initial models of the statistical analysis. FAC1, FAC2 and FAC3 are corresponding to factor one, factor two, factor three of table six to eight in chapter four above respectively.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	3.351	.0510	3.251	3.451	4310.527	1	.000
FAC1_1	.150	.0566	.039	.261	6.973	1	.008
FAC2_1	-.217	.0520	-.318	-.115	17.362	1	.000
FAC3_1	.040	.0535	-.065	.145	.549	1	.459
(Scale)	.431[a]	.0439	.354	.527			

Dependent Variable: GR

Model: (Intercept), FAC1_1, FAC2_1, FAC3_1

a. Maximum likelihood estimate.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	10.337	.7490	8.869	11.805	190.438	1	.000
FAC1_1	.956	.7510	-.516	2.427	1.619	1	.203
FAC2_1	2.722	.7510	1.250	4.194	13.137	1	.000
FAC3_1	1.036	.7510	-.436	2.508	1.902	1	.168
(Scale)	108.287[a]	11.0233	88.700	132.198			

Dependent Variable: BR

Model: (Intercept), FAC1_1, FAC2_1, FAC3_1

a. Maximum likelihood estimate.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	2.842	.0174	2.807	2.876	26585.011	1	.000
FAC1_1	-.097	.0174	-.131	-.063	31.356	1	.000
FAC2_1	-.011	.0175	-.045	.023	.414	1	.520
FAC3_1	.019	.0171	-.014	.053	1.242	1	.265
(Scale)	1[a]						

Dependent Variable: FD
Model: (Intercept), FAC1_1, FAC2_1, FAC3_1
a. Fixed at the displayed value.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	9.275	.8700	7.569	10.980	113.653	1	.000
FAC1_1	3.408	.8722	1.698	5.117	15.263	1	.000
FAC2_1	1.236	.8722	-.473	2.946	2.008	1	.156
FAC3_1	.978	.8722	-.731	2.688	1.258	1	.262
(Scale)	146.072[a]	14.8697	119.651	178.327			

Dependent Variable: RT
Model: (Intercept), FAC1_1, FAC2_1, FAC3_1
a. Maximum likelihood estimate.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	2.504	.0567	2.393	2.615	1948.311	1	.000
FAC1_1	-.278	.0511	-.378	-.178	29.657	1	.000
FAC2_1	.018	.0552	-.090	.126	.106	1	.745
FAC3_1	-.117	.0532	-.221	-.013	4.840	1	.028
(Scale)	.375[a]	.0450	.297	.474			

Dependent Variable: BD
Model: (Intercept), FAC1_1, FAC2_1, FAC3_1
a. Maximum likelihood estimate.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	46.891	1.2464	44.448	49.334	1415.420	1	.000
FAC1_1	3.955	1.2496	1.505	6.404	10.015	1	.002
FAC2_1	-6.617	1.2496	-9.066	-4.168	28.038	1	.000
FAC3_1	1.464	1.2496	-.985	3.913	1.373	1	.241
(Scale)	299.816[a]	30.5204	245.587	366.020			

Dependent Variable: OS
Model: (Intercept), FAC1_1, FAC2_1, FAC3_1
a. Maximum likelihood estimate.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	3.409	.0421	3.327	3.492	6556.545	1	.000
FAC1_1	-.217	.0375	-.290	-.143	33.380	1	.000
FAC2_1	.202	.0430	.118	.286	22.003	1	.000
FAC3_1	-.049	.0405	-.128	.031	1.447	1	.229
(Scale)	.318[a]	.0319	.261	.387			

Dependent Variable: UT
Model: (Intercept), FAC1_1, FAC2_1, FAC3_1
a. Maximum likelihood estimate.

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	15.337	.7594	13.848	16.825	407.925	1	.000
FAC1_1	4.192	.7613	2.700	5.684	30.313	1	.000
FAC2_1	.002	.7613	-1.490	1.494	.000	1	.998
FAC3_1	-.079	.7613	-1.571	1.414	.011	1	.918
(Scale)	111.287[a]	11.3288	91.158	135.861			

Dependent Variable: US
Model: (Intercept), FAC1_1, FAC2_1, FAC3_1
a. Maximum likelihood estimate.

Appendix 4: Combine effect of factors loadings from the principle component analysis performed on meteorological modifiers, and from generalized linear models showing the influence of meteorological modifiers on the behaviours and locations of captive guanacos.

meteorological modifiers	Behaviours and locations with + β coefficient	Influence	Behaviours and locations with - β coefficient	Influence
Wind chill+	Resting	Positive	Feeding	Negative
	Open space	Positive	Bedding	Negative
	Under shade	Positive	Under tree	Negative
Temperature+	Resting	Positive	Feeding	Negative
	Open space	Positive	Bedding	Negative
	Under shade	Positive	Under tree	Negative
Heat index+	Resting	Positive	Feeding	Negative
	Open space	Positive	Bedding	Negative
	Under shade	Positive	Under tree	Negative
Wet bulb+	Resting	Positive	Feeding	Negative
	Open space	Positive	Bedding	Negative
	Under shade	Positive	Under tree	Negative
Relative humidity-	Resting	Negative	Feeding	Positive
	Open space	Negative	Bedding	Positive
	Under shade	Negative	Under tree	Positive
Due point+	Browsing	Positive	Grazing	Negative
	Under tree	Positive	Open space	Negative
Barometric pressure+	Browsing	Positive	Grazing	Negative
	Under tree	Positive	Open space	Negative