Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Veterinary Medicine and Animal Science
Department of Animal Environment and Health

A descriptive study of the role of maternal behavior in the survival of Markhor (*Capra falconeri*) kids

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Degree project • 30 credits • Advanced level •
Master of Animal Science
Uppsala 2019

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Credits:	30 credits
Level:	Advanced A2E
Course title:	Independent project in Animal Science
Course code:	EX0567
Programme/education:	Animal Science – Master' programme
Course coordinating department:	Department of Animal Environment and Health

Place of publication:	Uppsala
Year of publication:	2019
Cover picture:	Daniel Asif
Online publication:	https://stud.epsilon.slu.se

Keywords:

Swedish University of Agricultural Sciences
Faculty of Veterinary Medicine and Animal Science
Department of Animal Environment and Health
Unit/section (optional)

ABSTRACT

In a herd of captive Markhors, observations were made to investigate the elements of maternal behavior, interactions of mothers with their kids, visitor's effect and welfare. Females isolated themselves from other conspecifics before parturition and selected a parturition site in the elevated part of the enclosure. After birth, the kids concealed themselves under a rock formation for at least eight days and their mothers visited them in their hiding for nursing. Each doe allowed only her own kid to suckle, after identifying the kid. When the hiding phase was over the mothers communicated with their kids by bleats. A close maternal-offspring bond was observed between does and their kids. Nursing time was significantly longer in the elevated rocky part of the enclosure (48.5 ±2.3 sec, 49 ± 1.4 sec) compared to the lower part (17.8 ±1.8 sec, 18.1 ± 1.3 sec). The higher number of nursing events were recorded in the evening or late afternoon and least suckling events were recorded during the late morning, noon and early afternoon. The number of bleats by the does were significantly more in the lower part of the enclosure (median 6/day) compared to the elevated rocky part (median 1.5/day). Babysitting behavior was observed among two mothers. Despite the display of babysitting behavior, allonursing behavior as well as the kid-stealing/adoption behavior was absent. The mothers were vigilant when they were accompanied by the kids. The kids spent relatively more time uphill than downhill with an increasing number of visitors. Moreover, the kids spent significantly more time in the elevated part of the enclosure (146.2 ± 63.9 mins) compared to the flat lower part (73.7 ± 32 mins) ($P < 0.05$, Paired t-test $t = 4.30$ $P = 0.016$) for each category of the visitors. The results of this study suggest that the Markhor individuals perceived the elevated part safer than the lower part of their enclosure. Keeping Markhors in captivity for the purpose of conservation, provision of an enclosure which mimics their natural habitat would not only provide them optimum welfare but also facilitates their successful reproduction.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisor Jenny Yngvesson for providing me this great opportunity to do my field work, as well as for making all the arrangements of travel and accommodation. My deepest appreciation to my examiner Jenny Loberg for answering my emails and calls with loads of questions.

In addition, I want to thank the team of Nordens Ark: Camilla Wikberg, for providing the requested information regarding the management and housing of the Markhors, and Ewa Wikberg for providing me with the necessary gear.

Last but certainly not least my special thanks to Aniek Oosterhoff for her support and help.

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Chapter 1 Introduction

1.1 General introduction

1.1.1 Maternal behavior

There are no mammalian species in which the offspring can survive in the absence of maternal care (Nowak *et al.*, 2000). A mother provides all the requirements that make it possible for the offspring to survive in early life. These requirements include grooming, nursing, protection, assistance, guidance, etc. Maternal care enhances the likelihood of offspring survival both indirectly, through the provision of energy requirements and directly, by strengthening the maternal-offspring bond and greater maternal car, indeed, comes with the ability of a mother to perform good maternal behavior (Nowak *et al.*, 2000). Maternal behavior is crucial for reproductive success and consists of a highly complex set of behavioral activities. These activities are displayed during the first days immediately before and after parturition. These activities can be preparatory to the arrival of the young (selection of safe parturition site), in response to the young (licking, nursing, grooming) or to threaten the conspecifics (protection) (Leckman & Herman, 2002; Numan *et al.*, 2006).

Among bovids, the emergence of maternal behavior usually occurs at or close to parturition (Nowak *et al.*, 2000). Prior to parturition females are typically wary and tend to seek remote or concealed sites to give birth (O'Brien, 1983; Rudge, 1970). Just after the expulsion of the fetus, a female shows a very rapid, intense and focused interest in the infant and the amniotic fluid on its coat and on the ground. The amniotic fluid carries chemosensory information that facilitates the exclusive maternal-offspring bond formation (Poindron *et al.*, 2010). She starts to lick her infant vigorously and consumes the amniotic fluid and membranes (Collias, 1956; Lickliter, 1985). The post-partum licking is viewed by various researchers as a mode of reciprocal stimulation which aids in increasing neuro-excitability. Thus, this promotes the rapid motor development in the infant and increases its chances for survival (Lent, 1974). Furthermore, the olfactory and gustatory stimuli received by the mother during the process of licking appear to be important in strengthening her maternal behavior in general and in particular the social bond with her neonate. The role of licking in drying the infant's coat and thus aiding thermoregulation is believed to be the reason for lower neonatal mortality in caribou (*Rangifer tarandus)* populations in severe cold weather (Pruitt, 1961; Kelsall, 1968). The events of licking, ingestion of placenta and consumption of amniotic fluid are usually accompanied with low and high pitched bleats (Sambraus and Wittmann, 1989; Numan *et al.*, 2006).

Maternal behavior in particular, as well as general social behavior of ungulates, is molded by the driving force of predation (Lent, 1974). For instance, mothers of most mammals display characteristic vocalization as a way of communication with their young and show gathering, calling and herding behaviors. These behavioral activities tend to keep the young in close proximity to the mother that ultimately protect the young from predators as well as conspecifics (Numan *et al.*, 2006). Additionally, maternal efforts such as assistance in hiding of their offspring (in hiders), lure predators away or confuse predators away by distraction enhance the chances of survival of their offspring (Altmann, 1963; Walther, 1968). However, the most important caring behavior and common pattern of maternal behavior in mammals is nursing that provides the main source of energy in the early development of the offspring (Oftedal 1985; Numan *et al.*, 2006). Maternal milk in addition to being the main source of energy, provides passive immunity to the infant, at least during the first days of its infancy (Brambell, 1958). As survival of the newborn will depend largely upon the quality of maternal behavior, therefore, the study of maternal behavior is very important for the conservation of the Markhor.

1.1.2 Maternal care and traits

For the purpose of evaluating offspring survival in mammals maternal care and offspring' development are likely the key determinants of offspring survival, but their influence is often neglected (Bernardo 1996; Therrien *et al.,* 2008). Rather, most life history studies have focused usually on the influence of environmental conditions, maternal traits and offspring characteristics in assessing the determinants of offspring survival (Gaillard *et al.*, 1998). However, it has been observed by Theoret-Gosselin *et al.* (2014) that offspring survival, which is a fundamental component of population dynamics (Gaillard *et al.*, 1998), is more directly and strongly influenced by maternal care and juvenile development than maternal traits and environmental conditions. Theoret-Gosselin *et al.* (2014) found that the strong positive effect of maternal care index on kid weight highly associates greater maternal care with offspring satisfaction for its nutritional needs. Thereby, nursing behavior directly influences offspring growth and so affects its survival. In line with Theoret-Gosselin *et al.* (2014), that offspring body weight is an important determinant of its survival. Maternal traits, such as age and condition of the mother, and offspring characteristics such as body weight of young are indeed used as proxies for maternal care (Theoret-Gosselin *et al.*, 2014). However, maternal traits, offspring conditions, and offspring survival are most likely indirectly related and probably result from maternal care and offspring developmental behaviors, as proposed by Andersen *et al.* (2000).

The welfare and nutrition of the mother are crucial as the body condition of the mother can directly affect offspring body weight and thereby indirectly influence offspring survival (Bernardo 1996; Solberg *et al.*, 2007). For instance, females in poor condition with low body fat reserves generally give birth to offspring with low body weight and are unable to satisfy the nutritional needs of their young because they produce less or low-quality milk (Landete-

Castillejos *et al.*, 2009). Age of the mother is another maternal trait that can influence offspring survival. As older mothers have increased reproductive experience, therefore, they are likely to provide greater allocation than younger mothers (Pianka and Parker 1975; Solberg *et al.*, 2007; Meijer *et al.*, 2011). Thus, behavioral components of maternal care and offspring development have stronger implications for population dynamics. Understanding the basis of maternal behavior and the factors that may affect maternal behavior of the Markhor is a prerequisite to our understanding of the population dynamics of the Markhor.

1.1.3 Maternal proximity

Part of maternal care is maternal efforts in maintaining a close proximity with the kids, in order to provide them an adequate social environment. This helps the kids to develop social and locomotor skills through play activities (Nowak *et al.*, 2000; Spinka *et al.*, 2001; Fagen and Fagen, 2004). These social and locomotor skills pay off for the kid as they acquire abilities to escape predation (Evan, 1990; Spinka *et al.*, 2001). It is believed that the greatest cause of mortality among ungulate offspring during their first summer is predation (Linnell *et al.*, 1995). Agile juveniles show good coordination in their movements that is acquired through play experiences. Therefore, the chances of being caught by a predator are probably very low for an agile juvenile as well as such juvenile could also show a proper response to the stress during and after an attack (Spinka *et al.*, 2001).

1.1.4. Mother-offspring bond formation and imprinting

The mother-offspring bond is directly related to offspring survival because it is the mother who provides protection from predators, shelter from weather as well as maternal milk which is a crucial factor in offspring energy intake before weaning (Nowak *et al.*, 2000; Grovenburg *et al.*, 2012; Theoret-Gosselin *et al.*, 2014). In sheep, experiments with playback sounds of offspring showed individual recognition both by mothers and their offspring. For instance, Smith (1965) experimented with playbacks of lamb bleats made on their second day of life to ewes and observed five ewes attracted to recordings to their own lambs. In addition to auditory cues, studies on many species of ungulates indicated an important role of olfaction in the process of individual recognition especially by the mother (Lent, 1974). Experiments were performed by Klopfer and Klopfer (1968), on the role of olfaction in the formation of individual mother-kid bond in goats *(Capra aegagrus)*. Does with unaltered olfaction at parturition rejected alien kids, however, on the other hand, does with altered olfaction accepted any kid presented to them. It was noted in the same experiment that alien kids were accepted if presented for five minutes post-parturition. According to Klopfer and Gamble (1966), olfactory experience at parturition is a requirement for bond formation between mother and offspring. They further suggested the existence of a sensitive period after parturition with changes in oxytocin levels.

Additionally, Lent (1974) suggested that for the establishment of a permanent bond between a mother and her infant, a contact period of 20-30 minutes for licking and grooming is sufficient but that varies from species to species, for instance, five minutes may be sufficient for goats.

A mother plays an important role in strengthening and maintaining mother-offspring bond by driving away the alien offspring that may approach her (Lent, 1974). In a study on goats Gubernick (1980) hypothesized that the recognition and acceptance of her own kid by a doe is due to the labeling process by the doe either directly by deposition of odorous substances through licking or by indirectly through the kid's milk intake. During the event of licking her kid right after parturion, a doe may transfer her rumen micro-fauna to the kid's body surface. Besides milk ingestion, digestion and subsequent defecation by the kid may influence mouth, body and anal odors respectively. As a result of labelling, such labelled kids may then be recognized and accepted only by their own mothers (Gubernick, 1980). The survival of young would be at stake if the mother rejects, abandoned or fails to recognize her young or on the other hand, if the neonate fails to recognize its own mother. Therefore, a strong mother-offspring bond is very crucial for the survival of offspring.

1.2 Introduction to the Markhor

1.2.1 Description and biology of Markhor

The Markhor *(Capra falconeri)* was first described by Wagner in 1839 (Huffman, 2004) and is a wild mountain goat belonging to the family *Bovidae* and subfamily *Caprinae* (Robert,1977 & Schaller, 1977). Markhor occurs in Central Asia (Michel & Rosen, 2015). The name Markhor apparently derived from the Persian words 'mar' meaning snake and 'khor', meaning eater or from Pashto language words 'mar' meaning snake and 'akhkar' meaning horn. The Markhor does not consume snake but its twisting horns like a snake gave it the name 'Marakhkar' which changed to Markhor with the passage of time (Robert,1977). Robert (1977) describes Markhor as a sturdy animal and, for an ungulate, having comparatively short legs and broad hooves with hard, horny edges that act as suction cups. These body characteristics enable the Markhor to negotiate difficult terrain. In addition, because of their sturdy legs and broad hooves, Markhors makes huge leaps from a standing position and traverse rock faces, therefore, very few predators would dare to follow them (Roberts, 1969). The coat color of the Markhor varies from brown to blackish brown and grey. An average adult male Markhor stands 99-115 centimeters at the shoulder and has a total body length 132-185 centimeters whereas females are about half of the size of mature males (Huffman, 2004). The weight of male Markhor ranges from 100-110 kg and for females this range is from 32-50 kg (Ranjitsinh *et al.,* 2005). Agostini (2005) and Khan *et al.* (2014) noted adult males with horns more than 40 inches long that can grow up to 64 inches long while the horns in females are much smaller and can grow up to 10 inches in length (photo 1 & 2).

Photo 1: An adult female Markhor at Nordens Ark. Source: Daniel Asif

Photo 2: An adult male Markhor at Augsburg Zoo. Source: Rufus46

Markhors are gregarious animals and live in small herds of around 6-9 individuals. Roberts (1969), however, observed even bigger herds of 12 individuals in Gilgit (Pakistan) and 20-25 individuals in Baluchistan (Pakistan). Such herds comprise primarily of females with young and immature males. Adult males live solitary and join the females only during the rutting season (Robert, 1977; Huffman, 2004). Markhors are diurnal feeders and are most active in the early morning and late afternoon or evening. In winter, however, they feed intermittently throughout the day. It is a common practice for Markhor to spend a greater part of the day regurgitating and laying down (Roberts, 1969). Markhors consume grasses and foliage with seasonal alteration between grazing (summer) and browsing (winter). In summer they graze primarily on grasses and herbs and when the snow covers the ground in winter and makes the grasses inaccessible, Markhors depend heavily on the browse of evergreen oak tree (Aleem 1976; Schaller 1977; Michel & Rosen, 2015). They have been seen climbing into the oak trees and standing on rear legs to reach foliage of lower branches (Roberts, 1968). In

Gilgit, Pakistan, Roberts (1969) observed that Markhors usually descend to a spring in the early evening to drink and climb up back to the high cliffs.

Reproductive maturity occurs at the age of 18-30 months and is reached later in males than in females. In the wild, they live up to 12-13 years and in captivity, the life span of males is about 12 years, while females can live up to 20 years (Agostini, 2005). The rutting season lasts for about one month from late October to early December (Roberts, 1977). The gestation period lasts approximately 135-170 days. Females ≤ 5 years old usually give birth to one kid while the birth of twins is common in older females. Young are usually born in the months of May and June and weaning occurs at the age of 5 or 6 months (Aleem and Malik, 1977; Huffman, 2004; Michel and Rosen, 2015).

1.2.2 Distribution and population of Markhor

The Markhor occurs in semiarid, cliffside mountain areas of southern Uzbekistan, southwestern Turkmenistan, southern Tajikistan, northern and central Pakistan, northern India and northeastern Afghanistan (Figure 1), at an elevation of 600 – 3,600 m (Grubb, 2005; Michel & Rosen, 2015). The total global population of Markhor is about 5,800 mature individuals. Out of this number, about 3000 mature animals occur in Pakistan (Michel & Rosen, 2015), which makes it the country of having the majority of the total world population of Markhor (Shackleton, 1997; Weinber *et al.*, 1997). In recent years the Markhor has been struggling for its survival because its number has been generally decreasing. As it was observed in a study conducted by Khan *et al.* (2014) in Gilgit-Baltistan, Pakistan, that the female to kid ratio was unexpectedly low (30:1). The low female to kid ratio could probably be a result of higher mortality due to predation on young ones (Haller, 1992) or due to low reproductive success (Ahmad *et al.*, 2016). Nevertheless, according to more recent (2015) assessment of the IUCN red list, there is a stabilization of the key subpopulations and an increasing trend in the overall population of this species due to effective conservation measures (Michel & Rosen, 2015).

Figure 1: The red shaded areas show distribution of the markhor (*C. falconeri*) modified after Brent Huffman. The arrows indicate markhor populations that might have gone extinct already (Weinberg *et al.* 1997).

1.2.3 Conservation status and Taxonomy of the Markhor

Wild-living Markhor occurs mostly in a highly fragmented population of relatively small size (Ashraf *et al.*, 2014). On IUCN red list published in 2008, *Capra falconeri* species was assessed as endangered. However, the Markhor was down listed as near threatened on more recent (2015) IUCN red list (Figure 2 & table 1), thanks to successful community-based conservation measures (Michel & Rosen, 2015).

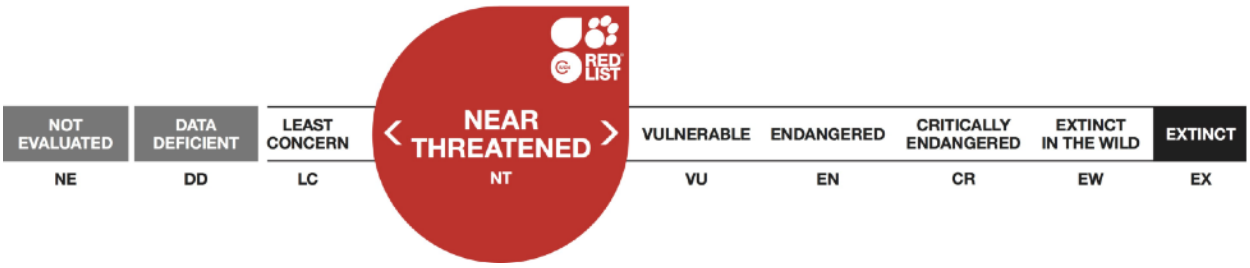

Figure 2: Status of Markhor (*Capra falconeri)* according to The IUCN Red List of Threatened Species 2015.

Table 1: Subspecies of Capra falconeri recognized by different sources (Michel & Rosen, 2015)

Subspecies	Common name	Status on ICUN Red List
C. f falconeri **(Wagner, 1839)**	Astor	Near threatened
C. f. megaceros **(Hutton, 1842)**	Kabul	Near threatened
C. f. heptneri **(Zalkin, 1945)**	Bukharan or Tajik	Near threatened
C. f. jerdoni **(Hume, 1875)**	Sulaiman	Near threatened
C. f. cashimriensis **(Lydekker, 1989)**	Kashmir	Near threatened

According to Roberts (1969), various subspecies of Markhor fall into two distinct types in their home range. In the northern and Himalayan regions, the Markhor individuals are much bigger in size and they develop winter ruff on their neck and chest and tend to get longer horns with a distinctive angular or more open type of spirals (figure 3). On the other hand, a much smaller Markhor type occurs in the lower and southwestern portion of their range with practically no winter ruff and straight horns (figure 4). On the basis of horn-shape and body characteristics, Schaller and Khan (1975) gave similar classification to Roberts (1969) and considered the Astor Markhor *(C. f. falconeri)* and Kashmir Markhor *(C. f cashmiriensis)* to be one subspecies: the Flare-horned Markhor. The Kabul Markhor *(C. f. megaceros)* and Sulaiman Markhor *(C. f. jerdoni)* on the other hand are classified as one subspecies of their own: the Straight-horned Markhor (Ashraf *et al.*, 2014; Michel & Rosen, 2015).

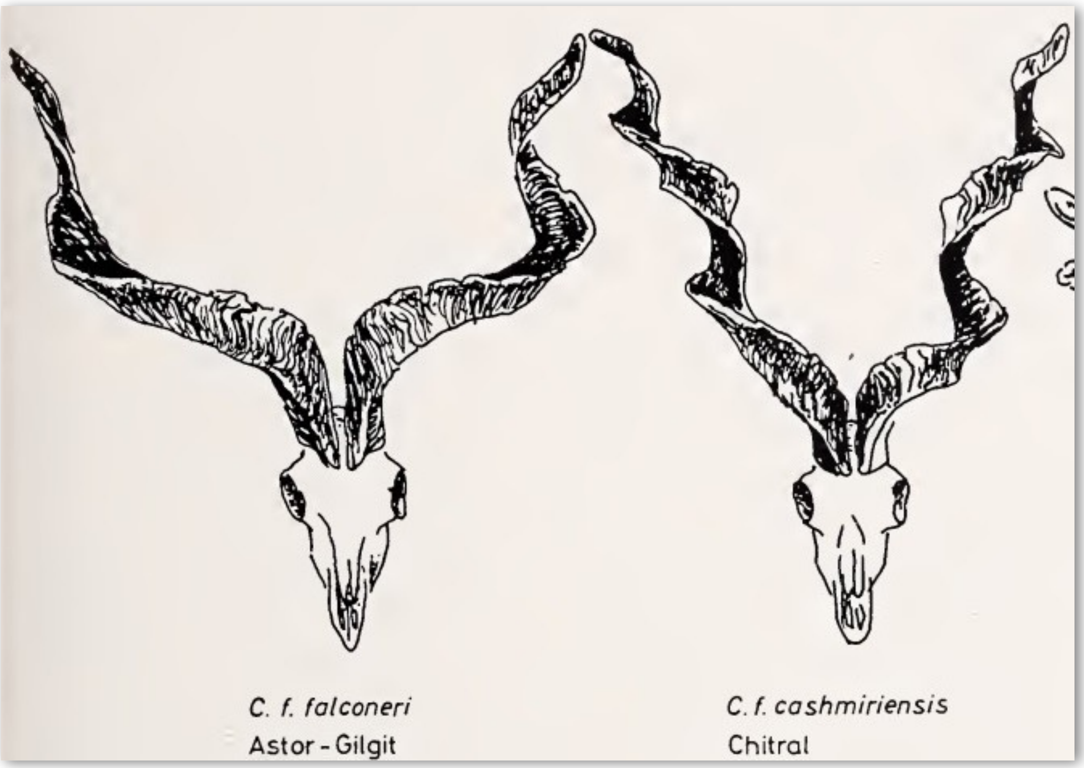

Figure 3: Illustrations of the shape and size of the horn of Markhor from northern and Himalayan regions (Roberts, 1969).

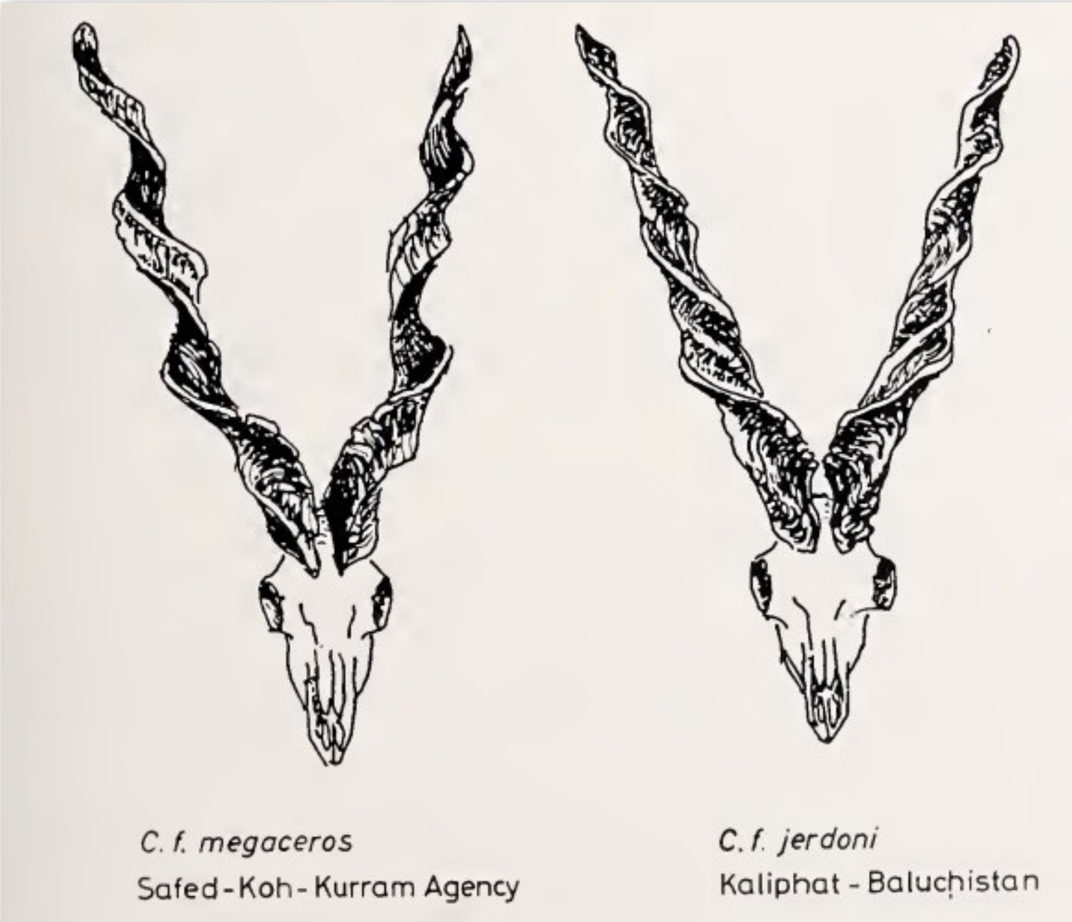

Figure 4: Illustrations of the shape and size of the horn of Markhor from south-western lower regions (Roberts, 1969).

1.2.4 Threats

The major threats to the Markhor's population include predation, illegal hunting, poaching, disturbance and destruction of habitat and competition in grazing from livestock mainly domestic goats *(Capra aegagrus hircus)* (Ashraf *et al.*, 2014; Michel & Rosen, 2015). After a prolonged winter period of lean forage access and then following parturition and lactation, female Markhors would tend to use areas with more nutritious forage. However, Ahmad *et al.* (2016) noted in a study carried out in the western Himalayas that female Markhors did not use areas with nutritious forage because they were prevented to access such areas due to the presence of livestock in these areas. Forage limitation imposed by livestock grazing may likely to affect reproductive performance of Markhors, as it was recorded by Ahmad *et al.* (2016).

In addition to competition in grazing from livestock, the risk of disease transmission from livestock, mostly domestic sheep *(Ovis aries)* and domestic goat, may pose a threat to the population decline of Markhors. A pneumonia outbreak killed at least 64 Markhors in 2010 in the Morkhur conservancy (Tajikistan). In the corps of Markhors, Mycoplasma bacteria *(Mycoplasma capricolum)* were detected as the sole infectious agent and cross-species transmission from domestic goats was suggested by Ostrowski *et al.* (2012).

1.2.5 Community-based conservation

Community-based conservation efforts in Gilgit-Baltistan (Pakistan) have resulted in a considerable increase in the number of Markhor (Khan *et al.*, 2014). Stefan *et al.* (2015) conducted a survey in M-Sayod and Morkhur conservancies (Tajikistan) in which it was found that not only the number but also the dispersion of Markhor to the adjacent areas of the conservancies have increased, as a result of protection given by community-based conservancy (Stefan *et al.*, 2015). However, conservation measures are only fruitful if the offspring survive successfully and reproduce.

1.2.6 Markhor in zoos

Since Markhors are listed on IUCN red list as near threatened, zoos and animal parks keep Markhors and operate several coordinated ex-situ breeding programs as conservation measures (Michel & Rosen, 2015; WAZA). There are about 48 institutions worldwide in three different regions: Asia, Europe, and North America that keep around 399 *Capra falconeri heptneri* individuals (species360, 2018). Comprehensive conservational measures have appeared to have positive effects on at least some Markhor populations (Virk, 2000). However, keeping the Markhor in zoos and animal parks is challenging because Markhors are sensitive and difficult to manage. The challenges are husbandry, nutrition, management, and disease.

In captivity, both sexes of Markhors encounter the problem of overgrown hoofs that may lead to lameness, which ultimately results in poor reproductive performance and culling of the animal (Wiesner, 1985). The problem of overgrown hoofs is probably due to the lack of hoof wear when the animals are housed on a soft floor such as grass or straw bedding (Smith and Sherman, 1994). Anzuino *et al.* (2010) have found a correlation between the prevalence of severely overgrown hoofs and lameness in farm goats.

According to Wiesner (1985), aggressive interactions of males towards other males, females towards other females and adult males towards kids are common. Adult dominant males tolerate only those young males that are not sexually mature yet. Kids on the other hand, do face aggression of other adult males. The rutting season is very critical regarding the management of bucks if there is more than one buck in the enclosure. The buck chases an individual female — who is not fully oestrus yet — until she reaches the point of exhaustion, which may end up in serious losses (Wiesner, 1985).

Attack by the red fox *(Vulpes vulpes)* may happen, as both the red fox and the European badger *(Meles meles)* have been sighted in the enclosure of the Markhors at Nordens Ark Zoological Park (Loberg, personal communication, November 7, 2018). Markhors in captivity can get an infection with *B. odocoilei* and remain a subclinical carrier of this protozoal parasite (Susan *et al.*, 2009).

1.2.7 Relationship with the domestic goat

It was found in a study conducted by Hammer *et al.* (2008) that 35.7% of all studied Markhors from three zoos had mitochondrial DNA introgressed by the domestic goat. Further, Hammer *et al.* (2008) speculated that introgressed wild living ancestors of *C. felconeri* might have been the source population of captive Markhors. Harris (1962) proposed a hypothesis that Markhor is a possible candidate as an ancestor for the domestic goat. However, Markhor was ruled out as a possible candidate ancestor by Takada *et al.* (1997) in a study conducted on phylogenetic analysis of cytochrome b. The results of this study showed that the Markhor is distantly related to the domestic goat. Markhor, on the other hand, might be the progenitor of Changthangi goat (a breed of the domestic goat) of Ladakh and Tibet as proposed by Menard *et al.* (2002). Moreover, Hayes (1868), hypothesized that Angora goat (a breed of the domestic goat) is a direct descendant of central Asian Markhor. In Quetta and Gilgit, Roberts (1969) witnessed two cases of progenies born after captive mating between a male Markhor and a domestic goat. However, the fertility status of the progenies was not known.

1.2.8 Sexual segregation

Like in most other polygynous and highly dimorphic mammals, sexual segregation — described as the differential use of space by sexes of a species — is common in Markhors (Bowyer 1984; Ahmad *et al.*, 2017). Sexual segregation starts increasing from the pre-parturition period to its peak during the post-parturition period and continues until autumn (Ahmad *et al.*, 2017). It is influenced by multiple proximate factors such as offspring survival with the ultimate aim of increasing reproductive success (Main and Coblentz 1996; Bleich *et al.* 1997; Main 2008). Female Markhors use areas close to cliffs and steep rocks to secure their offspring from predators at the cost of access to forage as these areas typically have less forage cover. On the other hand, male Markhors occur at habitat farther away from cliffs, with increased quantity and quality of forage to replenish their bodies after winter and rut (Ahmad *et al.*, 2017). Therefore, due to the fact of sexual segregation among Markhors, only female Markhors give parental care to their kids (Oftedal 1985), including nursing, protection (from predators & conspecifics), shelter and development of social as well as locomotor skills of kids.

1.3 Babysitting behavior

Babysitting (alloparenting, allomothering) behavior is the provision of care to offspring by individuals other than the genetic parent of the offspring i.e. conspecifics, for instance, adult or sub-adult females. This particular behavior may also call aunting behavior (Hunt *et al.*, 1978). Riedman (1982) has found that in a variety of mammalian taxa, babysitting behavior has evolved independently, apparently for a similar reason i.e. to increase foraging freedom for mothers. Some form of alloparenting has been reported in over 120 species of mammals belonging to most major orders including *Artiodactyla* (Riedman, 1982). Among Markhors, babysitting behavior in detail has not been described to date.

1.4 Allosuckling and allonursing behavior

Allosuckling refers to when a young performs suckling on a female other than its own mother and allonursing (non-offspring nursing) is the provision of milk to the offspring of other mothers (Packer *et al.*, 1992; Roulin, 2002). Nursing the offspring of another female is the most extreme manifestation of communal care by female mammals. Allosuckling has been reported in more than 100 mammalian species; however, the frequency of allosuckling is usually low in many mammals (Packer *et al.*, 1992). Further, Packer *et al.* (1992) state that allonursing is more commonly observed in captive animals than in wild counterparts and this behavior is more common in polytocous females with larger litter sizes than monotocous females.

Allonursing has been reported in farmed Red Deer (*Cervus elaphus)* (Drabkova *et al.*, 2008), captive Iberian Red Deer *(Cervus elaphus hispanicus)* (Landete-Castillejos *et al.*, 2000), domestic Bactrian Camel *(Camelus bactrianus)* (Brandlová *et al.*, 2013), captive common Hippopotamus *(Hippopotamus amphibius)* (Pluháček & Bartošová, 2011) and captive Reindeer (*Rangifer tarandus)* (Engelhardt *et al.*, 2015). One of the direct negative effects impose by allonursing is decreased amounts of nutrients available to an allonursing mother's own young (Packer *et al.* 1992; Roulin 2002), since nursing behavior of the mother directly influences offspring's growth and so affects the survival of the offspring. It is a question how allonursing behavior, which to date has not been described in Markhors, would affect the Markhor kids.

Chapter 2 Aim

The major objective of captive-held species is captive breeding. This is a central focal point of ex-situ conservation. For captive breeding and reintroduction purposes, captive populations must have good reproductive fitness as well as good welfare - as poor welfare may lead to a decrease in reproductive fitness. Direct reproductive fitness of a parent is defined as the number of adult offspring left by the parent in the next generation (Williams, 1996). Survival of offspring is indeed important for a conservation program as well as to determine the reproductive fitness of the parents. Therefore, the purpose of this study was to primarily acquire knowledge about the maternal care behavior of the Markhor and the interactions between the Markhor mother and the kid which may influence the survival of the kid. The specific aims were to investigate other related behaviors (babysitting behavior, allonursing behavior) and factors (welfare, visitor's effects, enclosure properties) that may affect captive breeding, maternal behavior, survival of the kid and ultimately conservation and on the basis of the results of this study, to produce advice to increase welfare ex situ and, in the long run, increase conservation success.

CHAPTER 3 METHODOLOGY

3.1 Study site

The study was conducted at Nordens Ark, a zoological park which is situated on the west coast of Sweden.

3.2 Enclosure design and management

The enclosure (3600 m^2) of the Markhors was divided into two different habitats due to its properties: an elevated (uphill) with small rocks grass and trees and a flat (downhill) with grass and forbs. One gate was placed on the elevated part to provide access to this part while two gates were placed on the flat part; however, only one gate was mainly used by the zookeepers to get access into this part of the enclosure. The height difference between the elevated part and the flat part was around 2-4 meters, where the elevated part had a couple of high rocks and some small rocks. A wooden shelter and a feeding and drinking place (feed stall 1) were built in the elevated part. The other feeding and drinking place (feed stall 2) without shelter was built in one half of the flat part (figure 5) away from the visitor path and visitors were not allowed to have access to this side of the enclosure. Feeding was only offered in feed stall 2.

In the other half of the flat part, about 7-10 meters far from the visitor's path, big wooden logs were placed. Green leafy tree branches were tied on the wooden logs to offer to the Markhors. The distance of the elevated part from the point of observations was around 45-55 meters. Additionally, the elevated part of the enclosure had several rocks, trees and a cover of vegetation that provides the animals with good hiding spots. This made this part well protected as well as away from the sight of observers and visitors. All animals usually spent most of their time in the elevated part of the enclosure. In addition, the animals were so well camouflaged with their surroundings that it was challenging to spot and identify the animals with the naked eye. Therefore, the use of binoculars was imperative in order to reliably record observations. The visitor's path was situated between the enclosures of Markhors and Eurasian lynx *(Lynx lynx)* (photo 3). Towards the elevated part of the enclosure, the visitor's path joins the entrance which leads to the viewing point (photo 4) from where a view of Amur tiger *(Panthera tigris altaica)* enclosure could be obtained.

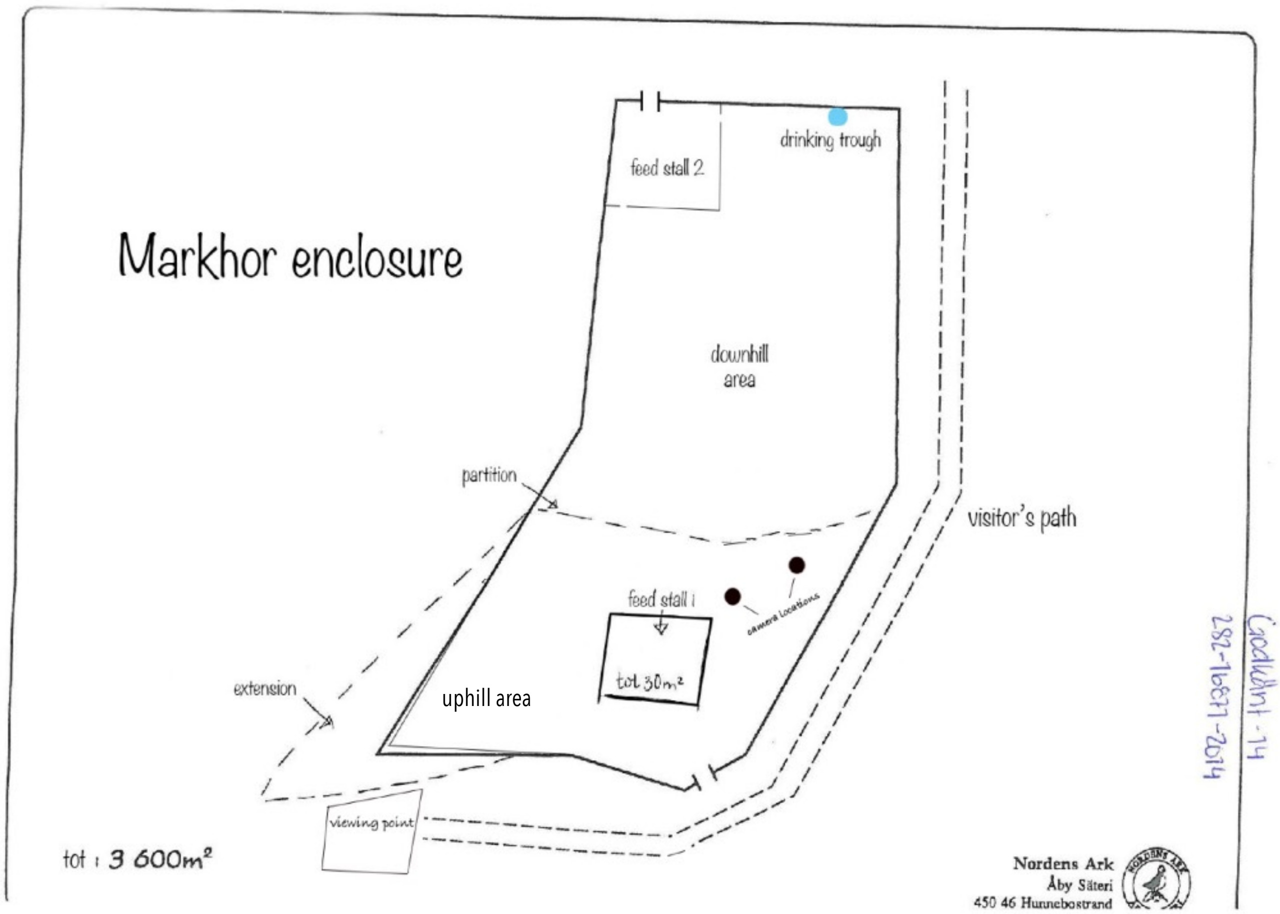

Figure 5: Sketch of Markhors *(Capra falconeri heptneri)* enclosure obtained from Nordens Ark and modified by Daniel Asif. Observations were made from the visitor's path as well as from the point where drinking trough is placed.

Photo 3: Markhor enclosure is on the right side of visitor's path and on the left side is Lynx enclosure. Source: Google maps

Photo 4: Feed stall 1 with the wooden roof in the elevated part of the enclosure is very close to the viewing area while on the left side is the Amur tiger enclosure. Source: Google maps

3.3 Animals

According to Loberg (personal communication, November 7, 2018), Nordens Ark has had Markhors since 1991 for conservation purpose as they were endangered animals back then. At the time of the start of this study, there were total 10 Tajik or Heptner's Markhor *(Capra falconeri heptneri)* individuals in the park, including 4 kids, 3 mothers (house name: Zuzy, Judy, Löss) one pregnant female (house name: Zaga), one young female (house name: Zucchini) born in September 2017 and one 4 years old neutered male (house name: Blitz). Observations (table 2) of maternal behavior (post-parturition) of mothers and their interactions with their kids were made on 3 mothers (Zuzy, Judy, Löss). On the other hand, pre-parturition behavior of the pregnant female (Zaga) was observed until she gave birth to a male kid on 11th of June and thereafter she was added in the post-parturition group. Before the study started, only one intact (fertile) adult male Markhor was brought into the herd during the breeding season. After the breeding season, he developed severe hoof problems. A detailed clinical examination of his hooves was conducted by the zoo veterinarian and it was decided to euthanize him.

Animals were marked with plastic ear tags in different colors. Adults were tagged on the right ear and kids were tagged on the left ear. Ear tagging made it easy to identify every individual during the study. Although detailed observations regarding maternal behavior were carried out on 4 mothers and their kids (table 2), records were supplemented by observing interactions of other conspecifics with both kids and their mothers. All does were born at Nordens Ark and their age was calculated on the day when the observations started i.e. 5th of June 2018. On the 5th of June 2018, two kids (white tagged and unmarked) were 11 days old, the pink tagged kid was 8 days old and the orange tagged kid was 6 days old. Later, Zaga gave birth to the 5th kid on the 11th of June, 7 days after the start of the study.

Table 2: A detailed description of all mothers and their kids.

House name	Parity	Age	Identification	No. of kids and their identification
Zuzy	multiparous	4 years 16 days	purple	1 male * (pink)
Judy	multiparous	4 years 15 days	pink	1 female (white) 1 male ** (untagged)
Zaga	primiparous	2 years 4 days	untagged	1 male (green)
Löss	primiparous	2 years 3 days	orange	1 male (orange)
* Zuzy gave birth to two kids. One kid was seen no more and was presumed dead				
** The male kid was unmarked because after birth it could not get caught for tagging				

3.4 Feeding routines and management

In the morning at 8:30, zookeepers offered Markhors hay in the hay feeder and pellets in the pellets feeder (photo 5) in feed stall 2 (Figure 5).

Photo 5: A Markhor individual is eating pellets from the pellet feeder while the other behind is eating hay from the hay feeder in feed stall 2. Source: Daniel Asif

Around 14:00 in the afternoon Markhors were offered browse in the form of leafy twigs on wooden logs (photo 6 & 7) and chopped carrots as enrichment. Drinking water was available 24/7 from NELSON (series 300) self-filling drinking bowl. Before feeding fresh hay and pellets, cleaning of the leftovers of hay and pellets was a daily practice by zookeepers.

Photo 6: A zoom-in view of Markhors eating from leafy twigs. Source: Daniel Asif

Photo 7: Leafy twigs as part of enrichment tied and placed on logs while in the background feed stall 2 can be seen. Source: Daniel Asif

3.5 Observations

The data was collected from the 5th of June to 1st of July 2018 over 11 observation days by instantaneous scan sampling method. All animals were observed every observation day. The observations (table 3) were made both by the naked eye and by binoculars (8 × 56) from outside the enclosure and were recorded on a data record sheet (table 4). Moreover, observations from video filming with a 12 megapixels G-series stealth cam (G42NG) were also included in this study. The video camera was mounted on trees on the elevated part of the enclosure at two different locations (figure 5). In order to avoid any disturbance to the animals, battery, memory card and position of the video camera were changed every morning at the time of feeding after all animals went downhill to feed.

The park opened for visitors at 10 in the morning and closed at 5 in the evening. The observations were recorded in two sessions in a day. The first session of observations started every morning at the time of first feeding as at this time animals were most active and visible. The second session of observation started in the afternoon at the second feeding time until the park closed in the evening. In one observation session animals were scanned for a minimum of 20 minutes up to a maximum of 160 minutes.

Table 3: Description of behavioral variables, representing maternal care

Variables		Description
Suckling	**Suckling**	The oral contact of the kid with the mother's teat accompanied by tail wagging by the kid
	Suckling bout	When kid suckles for 5 seconds or more
	Facilitate suckling	Giving call by the mother for nursing and allow the kid to suckle
	Terminate suckling	When there is an abrupt termination in suckling
	Suckling rejection	When the mother shows no willingness for nursing the kid
Protection	**Protect kids**	Showing protective behavior towards kids by the mother from other conspecifics
Vocalisation	**High bleats**	Calling the kid when the kid is left far behind or when the kid is out of the sight of the doe as well as to give warning in dangerous/anxious situation

Variables		Description
	Low bleats	Calling the kid for nursing or to call the kid out of the hide or on the reunion with the kid
Identification	Sniffing the kids	Sniffing to identify the kid when a kid approaches for nursing
Guidance	Laying kids in the hide	Guiding the kid towards hiding place when danger is felt
	Use of resources	Guiding the kids to resources: feed stalls, drinking bowl, uphill and downhill parts of the enclosure
Close proximity	Being around	A close proximity between the kids: about 3 m distance for 5 minutes, when both mother and kid are visible.
Vigilance		A Markhor individual is considered as vigilant when it held its head above its shoulder height with eyes and ears focused
Communal care	Babysitting	The kids are accompanied/taken care by doe(s) in the absence of their own biological mothers
	Allonursing	When one doe allows an alien kid to suckle herself

Table 4: Maternal behaviour's ethogram data record sheet.

Time (min)	Suckling bout		Facilitate suckling	Terminate suckling	Suckling rejection	Protect kid(s)	Vocali-sation	Guidance	Close proximity (3m)
	Uphill	Downhill							
0									
5									
10									
15									
20									
Break									
0									

In order to record the bleats with confirmation regarding the identity of the animals, the low bleats were only recorded when the animals were present downhill because of 1) less distance between the animals and the observing point so the bleats could be heard 2) all the animals were visible in this part of the enclosure. The time duration of each suckling was recorded by stopwatch, whenever suckling activity happened during observation sessions. The identity of suckling kid and doe being suckled, was confirmed by ear tags of both kid and its mother.

3.6 Data collection of visitor's effect

The behavior of kids was observed with respect to the number of visitors as well as the presence of noisy visitors. The observations were made in two sessions per day. One continuous scan comprised of 20 minutes of a total of 40 minutes scan in one session with a 10 minutes break between the two scans (table 5). Time spent in the elevated part or in the flat part by the kids was recorded irrespective to the activity of the kids. Kids were considered present in the flat part even if they were sitting, hiding or sleeping under/between the wooden logs. On the other hand, kids were considered present in the elevated part when they were absent in the lower part of the enclosure.

Table 5: Data record sheet of the influence of zoo visitors on the behavior of Markhor.

Time (minutes)	Visitors 0	Visitors 1-10	Visitors 11-20	Visitors >20	Noisy visitors present	Kids present/ visible downhill	Kids present/ visible uphill
0							
10							
20							
break							
0							
10							
20							

3.7 Statistical analysis

Minitab and Microsoft Excel 2007 were used for statistical analysis and for performing following tests: One way ANOVA, Paired t-test, Mann-Whitney test as well as for calculating Standard deviation, standard error, P-value and W-value.

3.8 Limitations in data collection

The comparison between the pre-parturition behavior of Zaga and other does was not possible as other does had already given birth before the study had started. Maternal behavior of does (except Zaga) during the first-week post-parturition could not be observed. Due to the occurrence of holidays during observation days, everyday development in the behavior of kids could not be recorded. After two days of Zaga's parturition, the video camera was mounted on a tree next to the hiding place of her kid. It would have been better if the camera had mounted prior to parturition to get details of the whole process of pre-parturition, parturition and other related events.

Chapter 4 Results

4.1 Pre-parturition behavior

All the does successfully reared at least one kid. At the time of start of the study, three does (Suzy, Judy & Löss) had already given birth to their kids but only Zaga was still waiting for her time of parturition. Therefore, the pre-parturition behavior of only Zaga could be observed. Zaga exhibited changes in both behavior and physical appearance. Isolation from other conspecifics was observed on the day of parturition and she was not seen the whole day anywhere in the enclosure. She most likely concealed herself beneath a rock on the elevated part of the enclosure, from where she was seen emerging later with her kid. The hiding place was so well covered that the parturition process could not be observed. Prior to parturition, certain changes in her physical appearance were observed; her udder became enlarged and tightened, as well as her abdomen got sagged with an increase in the size of her flank hollow (photo 8).

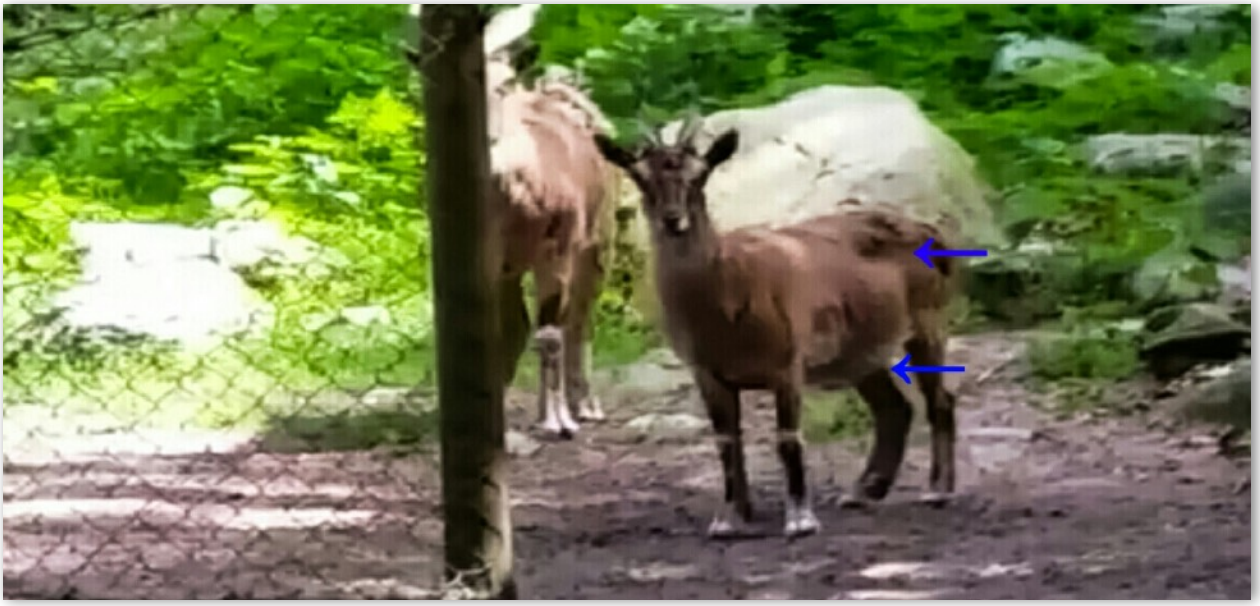

Photo 8: Zaga, two days before parturition, one arrow (lower) points towards her sagged big abdomen while other (upper) points towards her increased size flank hollow. Source: Daniel Asif

4.2 Post-parturition behavior

Zaga was seen emerging from the hide with her newborn kid the next morning after giving birth the day before. After emerging from the hide, she stayed there near the opening of the hide with her kid. There was a big vertical rock in front of the opening of the hide facing the visitor's path and the kid stayed behind that rock the whole morning with his mother. Therefore, not all activities of the kid were possible to observe from the visitor's path. However, at noon it was observed only once that the kid, after suckling, went into the hide while Zaga came down from the rock for foraging and drinking in the lower part of the enclosure. Later on that day, after feeding herself, she was seen returning towards the hiding place. However, it could not be observed whether she went into the hiding place or if she made any contact with her kid. She laid down on a rock uphill facing the visitor's path and ruminated with in a close distance of approximately five meters from the hiding place of her kid. Later on, the same day, when leafy branches were fed in the afternoon, only Zaga was absent as she did not come down to eat from leafy branches neither was she seen sitting on any rock next to hiding place. She most likely stayed uphill with her kid inside the hide.

On the 3rd day post-parturition, a video camera was mounted on a tree located in the elevated part of the enclosure pointing towards the hiding place of Zaga's kid. In one video footage, it can be seen that she went near the hide, she looked into the hide and then looked around with an alert pose, she repeated this behavior three times and then she gave a low bleat in response, the kid emerged from the hide and she let her kid to suckle herself. The suckling bout lasted for about a minute; the kid kept wagging its tail fast while sucking. During this suckling bout, Zaga sniffed the perineum region of her kid and also kept looking around with the same alertness. After the bout ended, she came down from the hill and the kid followed her. It could not be recorded on camera whether the kid followed Zaga all the way to the downhill part of the enclosure or if the kid stayed close to the hiding place. However, it was observed with binoculars that during the first two days of the kid's life, both Zaga and her kid were observed only next to the birthplace where the kid hid for most of the hiding phase of his life. In addition, the kid was concealed in hiding when Zaga went down for foraging, feeding or drinking. Further, during feeding occasional bleating and looking back towards the hiding of her kid was displayed by Zaga (photo 9). After two days following parturition, Zaga was observed close to the hiding place either accompanied or not accompanied by her kid.

When Zaga's kid was three days old he started following her up to 20 meters distance from his hiding place, but only in the elevated part of the enclosure near the closing hours of the park. During the opening hours, however, he remained hidden. Zaga communicated with her kid by low pitched bleats while grazing in the elevated part and the kid followed her. At 15 days of age, the kid could be seen following her all day long and all over the enclosure and no hiding by the kid was noted.

Photo 9: Zaga two days post-parturition, while eating leaves she is looking back towards the hiding place of her kid. Her flank hollow and abdomen are small. Source: Daniel Asif

4.3 Hiding behavior

When Zaga's kid was two days old, it was captured in the morning for ear tagging and a green tag was given to the kid on left ear (photo 10). After this process of tagging, efforts were made to release the kid with his mother but she fled along with other conspecifics leaving behind her kid, she might get scared by the zookeepers. Therefore, the kid was placed under the wooden shelter area built on the elevated part in the enclosure. The kid remained under the wooden shelter for at least eight hours and during this time period, the kid barely changed its place. For most of the time, the kid adopted prone position (photo 11).

Photo 10: The kid is receiving a green colored tag on the left ear. Source: Daniel Asif

Photo 11: The kid is laying in the prone position after being ear-tagged, under wooden shelter in the elevated part of the enclosure. Source: Daniel Asif

Zaga, on the other hand, was baffled and she was giving continuous high bleats in the downhill part of the enclosure. Although, she was seen running towards the elevated part yet it was not observed that she made contact with her kid. Finally, the re-union between the kid and Zaga was established later on that day and the kid started hiding again beneath the rock, the principal hiding site. On the 3rd day, when a video camera was mounted on a tree next to the principal hiding site of the kid, the kid was seen lying in its hiding place completely still (photo 12). Further activities of the kid were not possible to record neither by the naked eye nor with a video camera as the kid was so well hidden and walking in the enclosure every day could cause stress to the hidden kid. On the 3rd day post-partum, Zaga's kid was seen hiding other locations (vegetation, rock crevices) than its principal hiding site.

Photo 12. The kid is in hiding which is well protected from the weather and sight of visitors. Source: Daniel Asif

4.4 Maternal proximity

After Zaga's kid started showing up from the hiding, her efforts to keep close proximity (ca. 3 meters) with the kid were evident (photo 13). A close relationship between Zaga and her kid was observed. During the 10 days following parturition, Zaga was primarily responsible for keeping proximity by following her kid. On the other hand, beyond 10 days parturition, the distance between Zaga and her kid started increasing (> 3 meters). However, she remained in the vicinity of her kid and now the kid was mainly responsible for maintaining proximity with Zaga by following her (photo 14). Maternal proximity (10 days post-parturition) of other three mothers (Judy, Zuzy, Löss) with their kids was also recorded and they showed a similar behavioral pattern (figure 6 & photo 15).

Photo 13. Zaga is foraging while her kid is playing on logs within 3 meters from her. Source: Daniel Asif

Photo 14. Zaga is walking towards wooden logs to eat from twigs and her kid is following her. Source: Daniel Asif

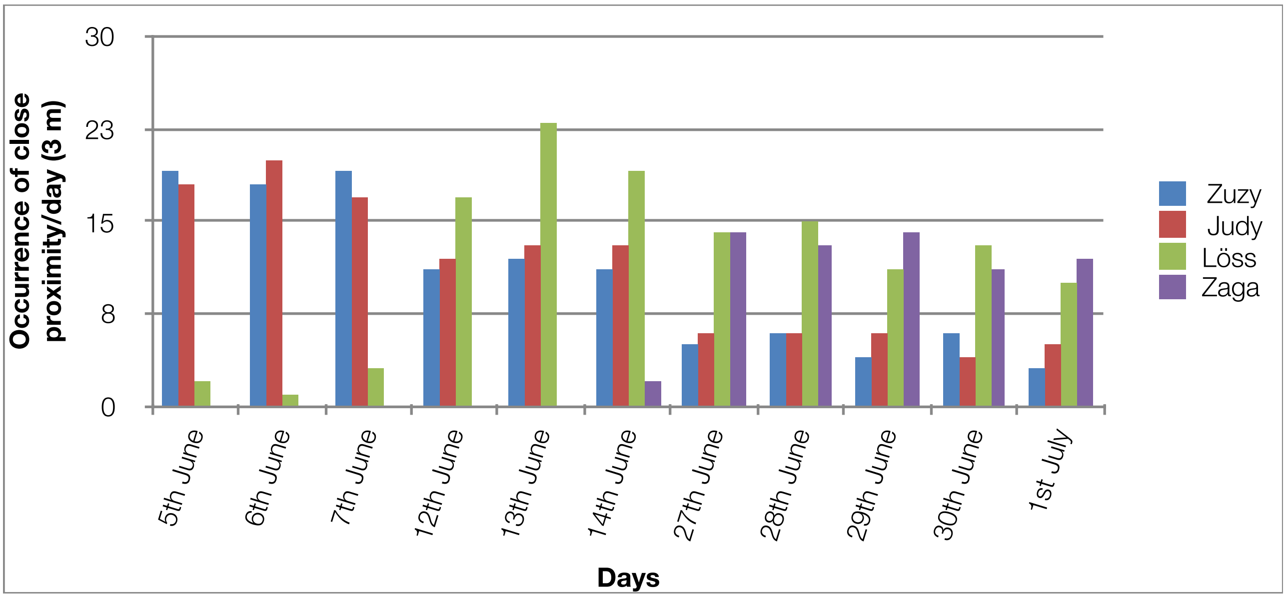

Figure 6: Number of time mothers were in close proximity (3 meters) with their kids on different days of the study period.

Photo 15. Zuzy is watching over her kid while her kid is playing on rocks within 3 meters from her. Source: Daniel Asif

4.5 Behavioral similarities

It was noted that the behavioral pattern of both Löss and Zaga during the hiding phase of their kids were very similar. For instance every morning, during the hiding phase of Zaga's kid, all the animals including Zaga were seen downhill feeding in the feeding area while her kid was in hiding uphill. After feeding on hay and pellets, Zaga usually drank water and then, returned back to her hidden kid uphill to nurse it. Löss's kid was 6 days old and was still in hiding phase when this study was started and she showed similar behavior as Zaga. After nursing, Löss and Zaga either laid down or stand guard on a rock close to the hiding place to ruminate (Photos 16 & 17). The behavioral pattern of kids was also similar (table 5), after one week of their age, two younger kids (orange and green tagged) showed a similar behavior pattern as of the 3 older kids (pink tagged, white tagged & unmarked). No kid was seen hidden after

Photo 16: Löss is laying down on a rock close to her hidden kid. Source: Daniel Asif

Photo 17: Zaga alert and vigilant, standing guard on a rock facing towards the visitor's path very next to her kid while the kid is in the hide. Source: Daniel Asif

one week of age except for only one morning when Zaga was feeding downhill but she was not accompanied by her kid till noon. Nevertheless, after one week all kids stayed with their mothers and followed them when they grazed or fed themselves at the time of feeding. The kids nibbled on vegetation even though they did not graze yet at this stage of life. They still suckled and spent much time playing or lying down. Both orange and green tagged kids, while being with their mothers, selected their laying out sites with some cover. When they felt a need to sleep or to rest, the kids always laid down either under the wooden logs or concealed themselves in crevices covered by vegetation while their mothers kept on foraging within a distance of 5-10 meters. On the other hand, when their mothers laid down for ruminating or for resting, the kids laid down next to them or against their body on a rock in the elevated part of the enclosure.

Table 5: Behavioral development of the kids during the course of study.

Kids	5-7 June	12-14 June	27 June -1 July
Zuzy's Kid	Followed Zuzy	Followed Zuzy	Followed Zuzy / independent play
Judy's Kid	Followed by Judy	Followed Judy	Followed Judy / independent play
Löss's kid	Hiding/followed by Löss	Followed by Löss	Followed Löss
Zaga's Kid	Not born	Hiding	Followed by Zaga

4.6 Interactions of mothers, kids and other conspecifics

Mothers interacted with their kids by either low or high bleats, depending on the nature of circumstances. At some point during eating, when the twigs were fed on wooden logs in the afternoon, a kid fell off the log and could not see its mother. It gave a wailing cry to which the mother responded by finding the kid with a low bleat. In addition, low bleats were also given to inviting for nursing. If a kid left its mother far behind during grazing and foraging or if she felt any possible danger, in either situation she usually gave a high pitched bleat and kid would respond by running towards its mother (photo 18). The mother-kid interaction appeared to be so well executed that the hidden kid of neither Löss nor Zaga was seen out of the hiding when their mothers were away. Every time when kids came out of the hiding they were accompanied by their own mothers. As well, no kid was seen showing up when females other than their own mothers were close to their hiding. Markhor mothers, in addition to showing interactions for the sake of protection of their kids, also displayed guidance to their kids to use resources in the enclosure, for instance to the feeding area, wooden logs and drinking trough.

Photo 18: Judy is looking at the observer (Daniel Asif) while one of her kids is walking towards him. After assessing the presence of possible danger she gave a high pitched bleat and in response, the kid ran towards her. Source: Daniel Asif

High bleats were always given when a doe detected the danger either to warn the kid or to guide the kid. These high pitched bleats by the does were noted when they were both downhill and uphill, however, the number of high bleats by the does were significantly more in the lower part of the enclosure (median 6/day) compared to the elevated rocky part (median 1.5/day) (Mann-Whitney test W=33.5 P≤0.05) (Figure 7).

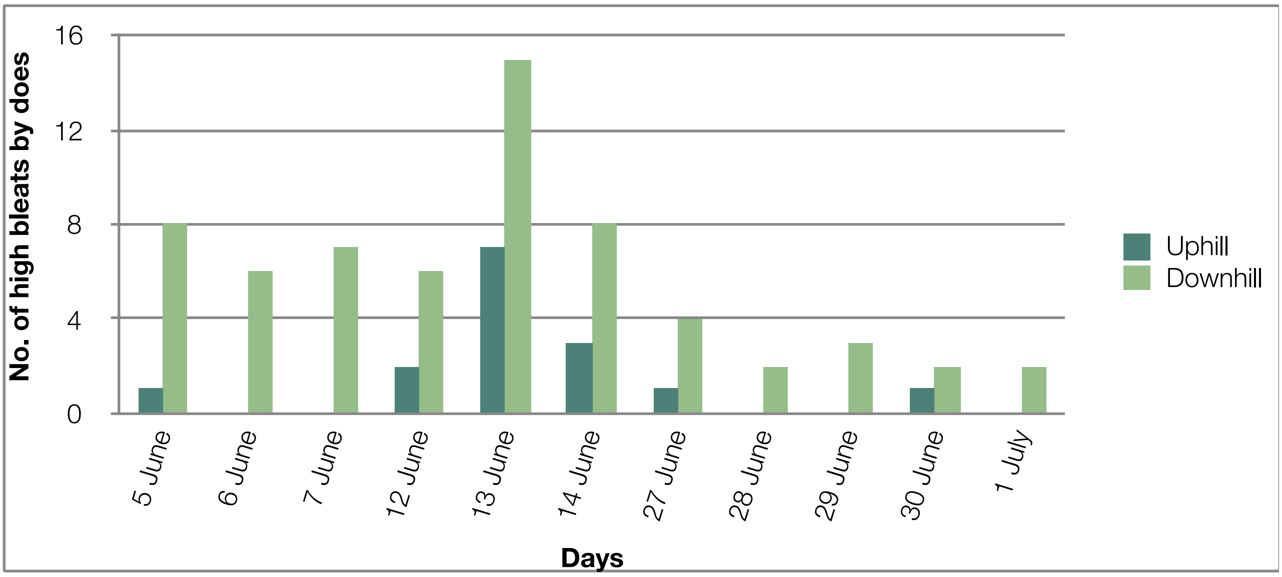

Figure 7: Number of high bleats uphill versus downhill on different days of the study period. The high number of bleats on 13th of June because the kid was placed under the wooden shed on that day after tagging.

During the last 4 days of the study, all kids (except the green tagged kid) were seen playing together 10-15 meters away from their mothers whereas it was observed during the first two weeks of their life that all kids used to stay and play within five meters distance from their mothers. Their mothers however still communicated with them by low bleats to call them for suckling or when the mothers walked uphill and were not being followed by their kids. In addition, mothers of elder kids were seen giving fewer calls than mothers of younger kids (figure 8) and the elder kids followed their mothers often even without getting any call from them.

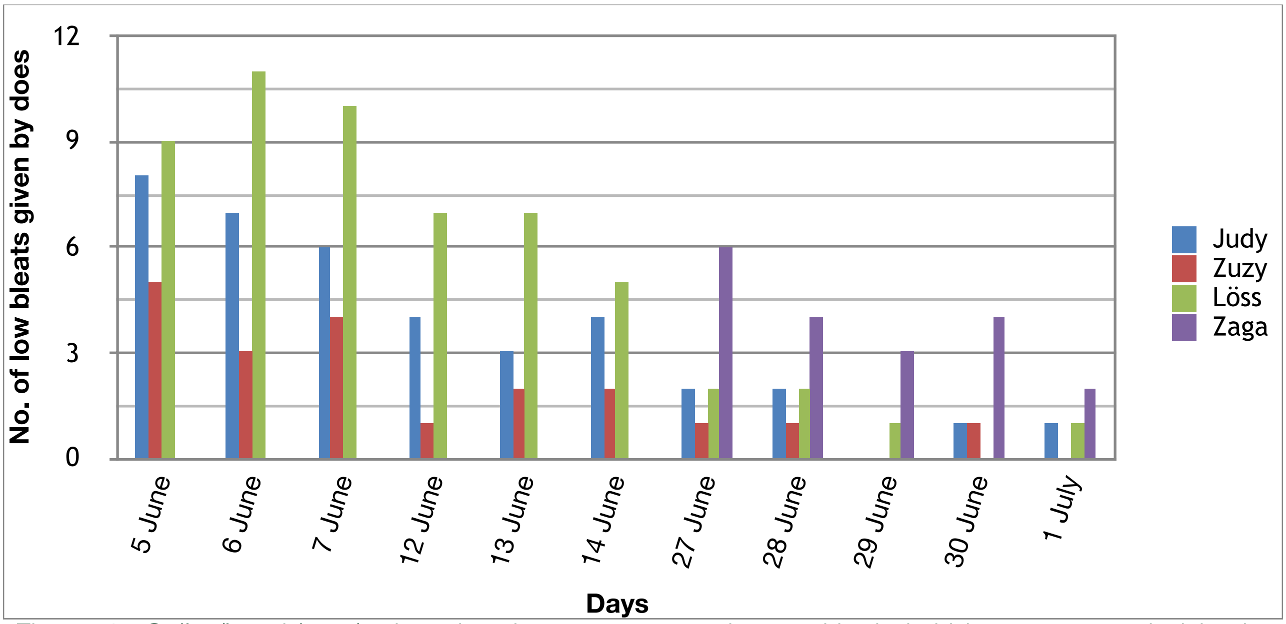

Figure 8: Calls (low bleats) given by does to communicate with their kids were recorded in the downhill part of the enclosure.

Kids were protected from other conspecifics usually by headbutting conspecifics away. The alien kids were discouraged by nosing or headbutting. Aggressive interactions between females were observed especially at the time of feeding. These aggressive interactions were mostly seen between a dominant female and a subordinate female, where the dominant female was aggressive towards subordinate (photo 19).

Photo 19: At the time of eating leafy twigs a dominant female is making to run away a subordinate female by head butting. Source: Daniel Asif

4.7 Sucklings

The nursing bouts were almost always started by a nursing invitation given by a doe with/without a low bleat. However, a nursing bout was also initiated by an approaching kid after getting the permission of her mother. All the kids suckled from the side or under their mother, with their hind-quarters facing their mother's head (photo 20). None of the kid was seen suckling from the rear of their mothers. The nursing activity was performed by each mother, every time, in a standing posture with or without slightly lowering hind quarter. Not a single nursing event occurred when any of the does were sitting. Bunting or striking of the udder was performed by the kid in each nursing bout. None of the mothers displayed nursing rejections or made any efforts to stop/prevent nursing own kid with/without agonistic behavior. Judy, the mother of twin kids, never allowed only one kid to suckle and was always suckling both siblings together at the same time.

Sniffing the front part of their kids by each doe when the kids approached them for suckling and then keeping on sniffing the perineum region of the kids during every suckling bout was a consistent behavioral display by all Markhor mothers (photo 21). Each time, the nursing termination was done by does with a forward movement with or without lifting the hind leg.

Photo 20: Zuzy is displaying nursing behavior. Source: Daniel Asif

Photo 21: Löss is sniffing the perineum of the kid when the kid is suckling.
Source: Daniel Asif

Nursing time was significantly longer in the elevated rocky part of the enclosure (48.5 ±2.3 sec, 49 ± 1.4 sec) compared to the lower part (17.8 ±1.8 sec, 18.1 ± 1.3 sec) (One way ANOVA $F=116.1$ $P\leq0.001$, Paired t-test $t=16.4$ $P\leq0.001$) (Figure 9 & 10). Most suckling events occurred in the evening or late afternoon and the least suckling events were recorded during the late morning, noon and early afternoon (figure 11).

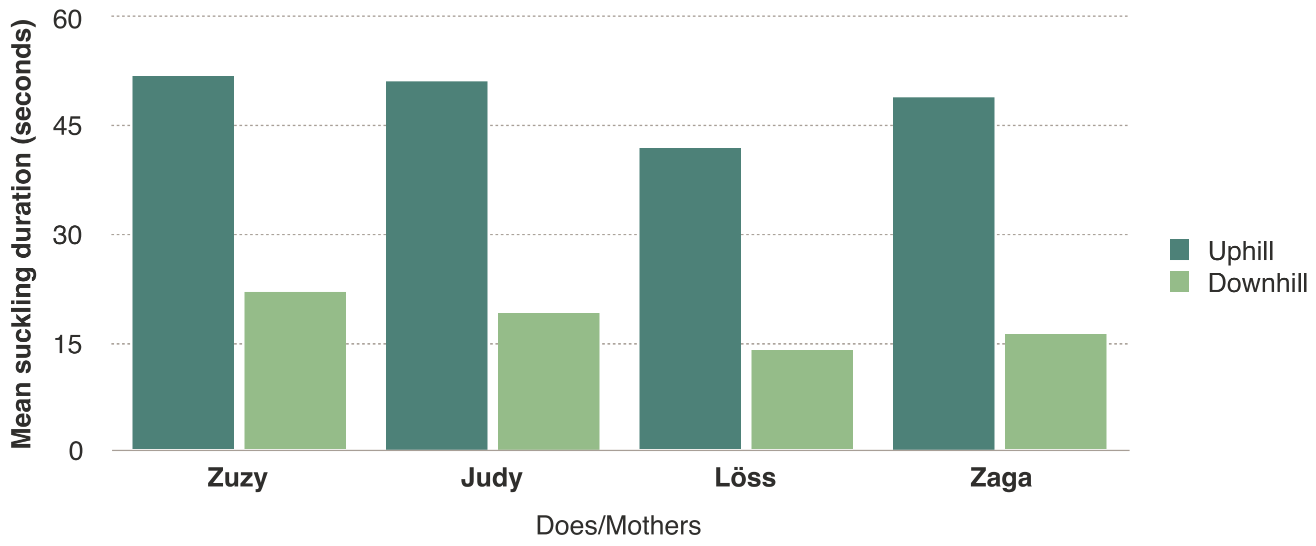

Figure 9: The comparison of mean time allowance given for suckling to kids by their mothers uphill and downhill.

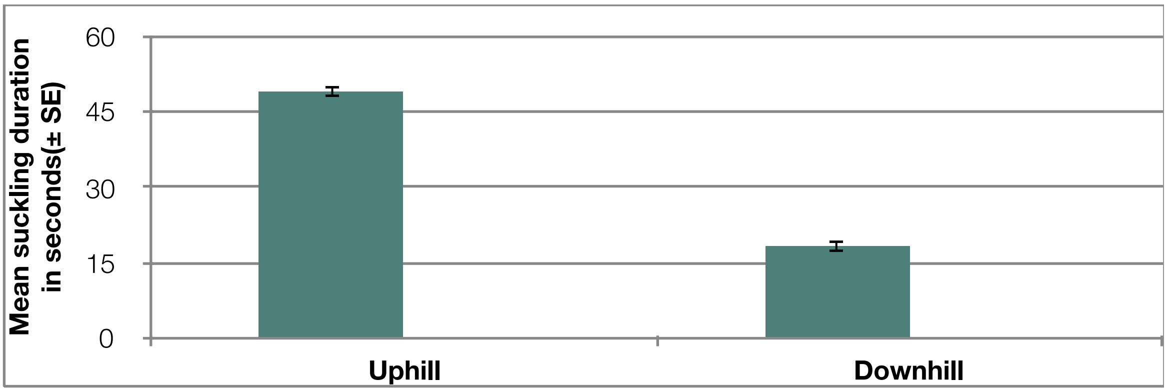

Figure 10: Mean suckling time allowance given by all mothers uphill and downhill.

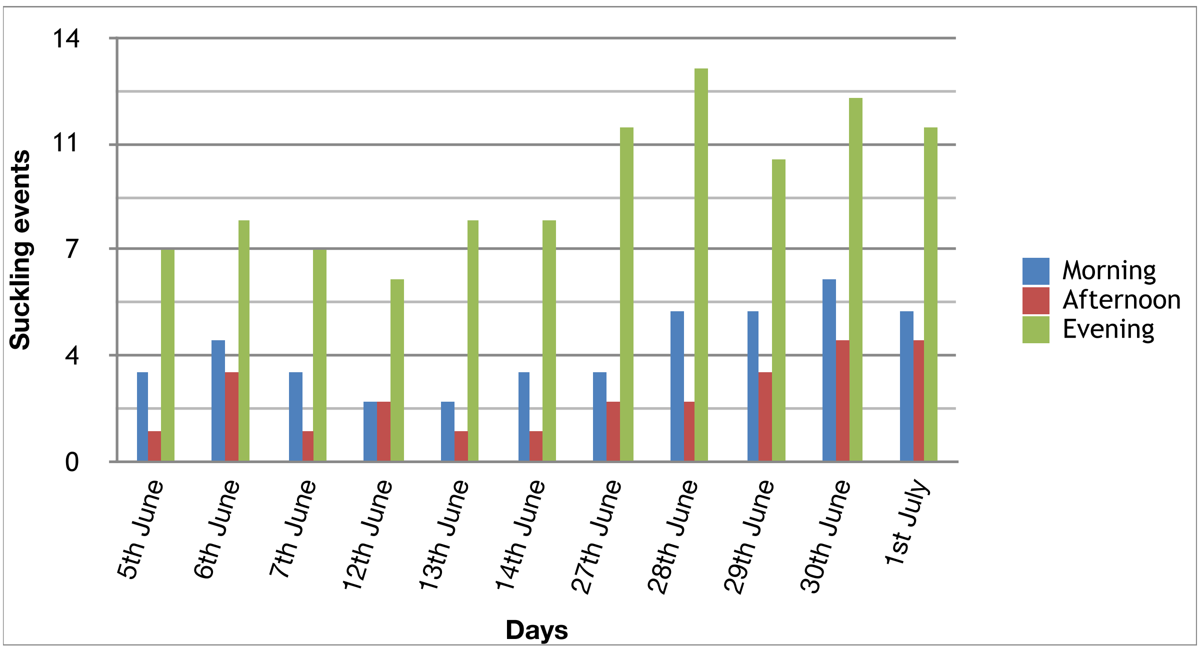

Figure 11: Suckling events occurred in morning, afternoon and evening on different days of the study period.

4.8 Babysitting behavior

Babysitting behavior was observed among Markhor females. Usually one of the mothers (babysitter) stayed with all the kids when other mothers were in the lower part (downhill) feeding or drinking. The babysitting female usually laid down or stood on a higher point, usually a rock from where she had good visibility (photo 22). Although the babysitting female, while guarding the kids, kept on ruminating, she remained active and alert and whenever she sensed any potential danger she stopped ruminating. The mothers of the kids - those were accompanied by the babysitting female - occasionally look towards their kids and gave high bleats. Markhor females displayed babysitting behavior only in the elevated part (uphill) of the enclosure (photo 23). The reunion of foraging-mothers and their kids usually occurred in the elevated part of the enclosure and coincide with nursing activity. Switching the babysitting role was observed among two mothers (Judy & Löss)

Photo 22: Judy is accompanied by her own kids as well as she is babysitting kids of other mothers. Source: Daniel Asif

where Löss performed the role of babysitter less frequent than Judy. Zuzy and Zaga, on the other hand, did not show babysitting behavior. However, in the absence of Zuzy, Löss and Zaga their kids were guarded by Judy and similarly, Löss accompanied the kids of Zuzy, Judy and Zaga when they were feeding downhill.

Photo 23: On another occasion, Judy is accompanied by her own kids as well as she is babysitting kids of other mothers. Source: Daniel Asif

4.9 Allonursing and kid-stealing behavior

Despite the display of babysitting behavior, Markhors in this study did not show allonursing behavior. Alien kids tried to approach the babysitting doe most likely to suckle on some occasions, however, they faced rejection. Besides the babysitting doe, other does were also approached by alien kids but every time the kids were rejected. The rejection was usually done by nosing the alien kid away, after sniffing the naso-oral region of the kids. In addition to the absence of allonursing behavior, the kid-stealing behavior was also absent among Markhor females.

4.10 Vigilance behavior

Markhor mothers were vigilant when they were accompanied by their own kids as well as when they were babysitting for the kids of other mothers. In both cases, they were either simultaneously vigilant and ruminating/foraging or only vigilant. As a reaction to certain stimuli such as the roar of the tiger, spotting a lynx or presence of any other potential danger, the Markhor mothers engaged themselves in intense vigilance and stopped ruminating or foraging. Besides the Markhor mothers, Blitz & Zucchini were also vigilant if they assessed the possible danger first. They lifted their heads up, erect their ears (photo 24) and gave a snort or a sneeze as an emergency alarm by blowing air through their nose. The kids responded by watching their mothers closely; if their mothers ran uphill, they followed them without assessing the nature of the danger.

Photo 24: Two Markhor individuals engage in vigilance facing two different directions. Source: Daniel Asif

Further, in the evenings the ruminating Blitz & Zucchini laid down on the rooftop of the wooden shed in the elevated part of the enclosure and when they detected any danger, the same emergency alarm was sent to other conspecifics by a snort or a sneeze. In response, other individuals retreated to a safe location and the kids followed their mothers. None of the mothers, however, were seen laying down on the rooftop.

4.11 Visitor effect

The kids spent relatively more time uphill than downhill with an increasing number of visitors (table 6). Moreover, kids spent significantly more time in the elevated part of the enclosure (146.2 ± 63.9 mins) compared to the flat lower part (73.7 ± 32 mins) ($P < 0.05$, Paired t-test $t = 4.30$ $P = 0.016$) for each category of the visitors (figure 12).

Table 6: Percentage (%) of time spent uphill and downhill by the kids in each category of visitors.

No of visitors	Uphill (in %)	Downhill (in %)
0	54.25	45.74
1-10	62.54	37.45
11-20	66.91	33.08
>20	76.47	23.52

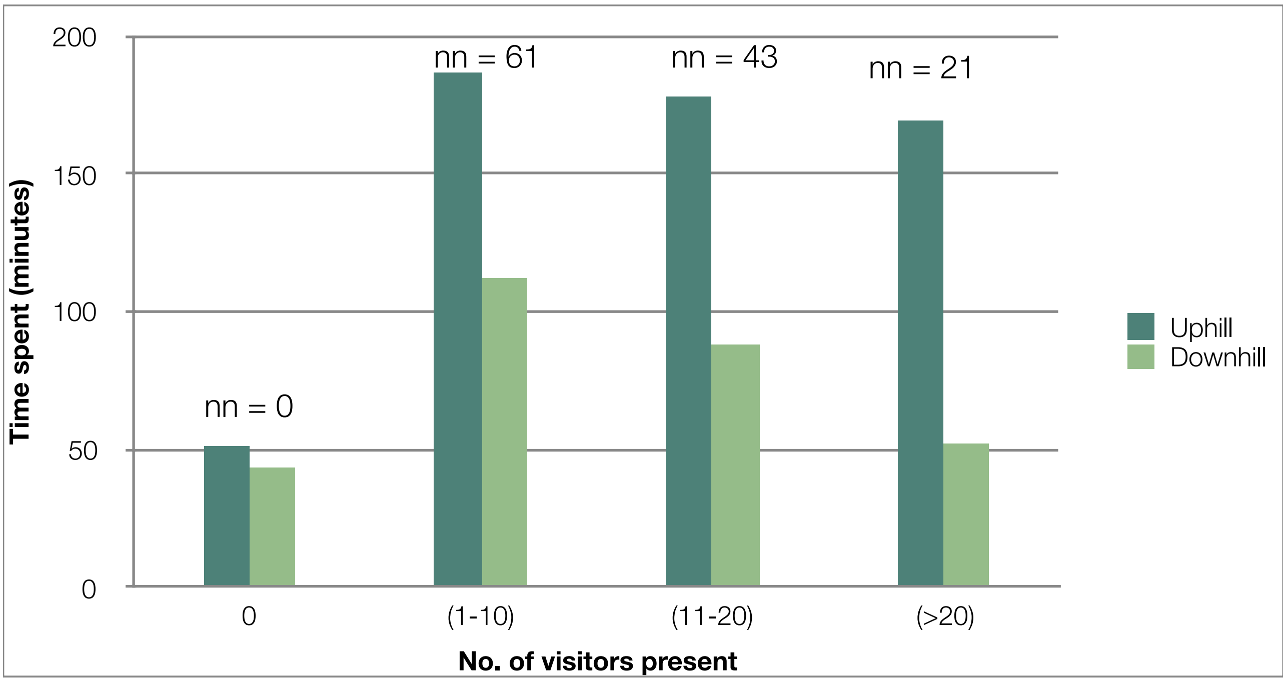

Figure 12: Time spent by the kids in the elevated part (uphill) and in the flat part (downhill) of the enclosure with respect to the number of visitors present where (nn) is the number of noisy visitors out of the total visitors in each category.

Chapter 5 Discussion

As maternal behavior in Markhors in details has not been studied to date, the results of this study will mostly be compared with mountain goats *(Oreamnos americanus)*, feral goats *(Cupra hircus Linnaeus)*, domestic goats and other domestic and wild ungulate species. Before conducting this study, the plan was to study maternal behavior in Bukhara Urial *(Ovis orientalis bochariensis)*. However, after birth, one Urial lamb died and the mother of the other two lambs abandoned them. Therefore, those two abandoned lambs had to be hand-reared and fed with bottle milk by zookeepers. Due to all these unforeseen events, maternal behavior in Urials was not possible to observe. Instead, it was decided to observe maternal behavior in Markhors, and by that time three of the Markhor females had already given birth. Therefore, pre-parturition and early post-parturition behavior, as well as the events of her kid's initial life, could only be observed in one doe - Zaga. Despite the fact that Markhors individuals included in this study were captive, the findings of this study suggest that they maintain most of their natural instincts. Details of their natural instincts and influence of captivity on their overall welfare and behavior will be discussed below.

5.1 Reproductive synchrony

In the present study, a short birth season and birth synchrony was noted in Markhors. This is common among many ungulates and could be a strategy to maximize fitness and survival chances of the new generation (Ims, 1990). In order to explain short parturition period and birth synchrony as a mean to increase survival chances of a newborn especially in prey animals, several hypotheses have been proposed. First, the predator-satiation hypothesis, which suggests that prey animals born at high population densities during the birth peak, reduce the probability of a predator to capture and eat an individual offspring due the handling difficulty of such high number of prey animals by the predator i.e. predator swamping (Estes, 1976; Linnell *et al.*, 1995). Second, the breeding synchrony hypothesis, according to which females breeding synchronously could use group vigilance to detect predators more efficiently (Ims, 1990). Additionally, a large number of synchronous breeder groups, with their collective power, may be able to defend their young from predators (Estes, 1976; Packer and Pusey, 1983). Third, the plant phenology hypothesis which states that synchrony between the timing of birth and forage availability affects offspring growth rate and consequently survival (Ruthberg, 1987). Parturition should be synchronized with forage availability, as in temperate and subarctic climates a marked seasonality in forage availability occurs (Festa-Bianchet, 1988). Therefore, offspring born with the onset of vegetation growth have higher survival probabilities. Because the greatest seasonal forage availability and quality will coincide with high lactation demands (Ruthberg, 1984), the mother will be able to produce high-quality milk that influences the growth and over-winter survival of the offspring (Landete-Castillejos *et al.*, 2000).

The youngest Markhor's kid in the present study was born after three weeks of the first birth of twin kids. However, the second and third kids were born after three and five days of the first birth, respectively. This shows that the beginning of the birth season was more synchronized compared to the end of the birth season. In mountain goats, Côté and Festa-Bianchet (2001) observed similar short birth peak and synchrony at the beginning of the birth season with a few late births from mid-June to early July. The gap of three weeks between the first birth and the last birth in this study can be explained by the suggestion of Côté and Festa-Bianchet (2001) in which the late birth of last kid may have resulted because Zaga failed to conceive in her first estrus. Zaga was a subordinate female in social ranking; consequently, she might have failed to conceive due to her ranking, as it was observed in ungulates that reproductive success was lower in subordinate females than dominant females (Clutton-Brock *et al.,* 1984; Alados & Escos, 1992). On the other hand, Löss was also a subordinate female and seemingly she conceived successfully in her first estrus. As Markhor mothers involved in this study conceived naturally and due to the unavailability of the data about their conception date it is not possible to conclude that Zaga did not conceive in her first estrus. It is also plausible to assume that Zaga might experience her estrus later than her other female conspecifics, rather than that she failed to conceive in her first estrus.

Berger (1992) suggested that variation in conception date or gestation length (the period between conception and birth) could drive variation in birth date in mammals. However, studies on gestation length in both captive and wild ungulates have found a negative association between conception date and gestation length (Asher *et al.*, 2005). Further, Loudon *et al.* (1984) state that in order to give birth closer to an optimum time window, early or late conceiving females may be able to adjust gestation length. The tactic of gestation length adjustment in order to give birth closer to an optimum time window brings advantage for the mother. She will be able to better match the period of availability of highest food resources to the period of highest nutritional demands by her offspring which supports the birth synchrony phenomenon. Therefore, taking into consideration the tactic of gestation length adjustment, Zaga should have adjusted her gestation length even if she was a late conceiver. Hence, for better understanding further investigation is needed.

5.2 Isolation behavior

The exclusive display of isolation behavior by pre-parturient Zaga can be regarded identical to her free-living counterparts as similar behavior in wild Markhor females was observed by Roberts (1969) in Gilgit, Pakistan. Isolation from companions and preference for parturition site by pre-parturient females, has also been noted in both domesticated and wild ungulate species (Lent, 1974), for instance, domestic goats (Lickliter, 1985), feral goats (O'Brien, 1983; Rudge, 1969), bighorn sheep *(Ovis canadensis)* (Smith *et al.,* 2015) and free-ranging mouflon sheep *(Ovis orientalis musimon)* (Langbein *et al.*, 1998). The profound behavioral changes i.e. separation from the herd and selection of a safe isolated site to give birth by gregarious mothers have a number of conspicuous functions that may increase the likelihood of survival for the female and her offspring. The first functional explanation of the isolation behavior is decreasing the chances of predation for both the mother and her neonate. As during the first few days of the neonate life, the movements of the neonate are generally restricted and therefore, during this time the neonate is typically most vulnerable to predation (Gaillard *et al.*, 2000, Raithel *et al.*, 2007, Grovenburg *et al.*, 2011, Smith *et al.*, 2014). That is why the selection of a hidden isolated site for birth reduces the chances of both mother and her defenseless offspring being detected and captured by predators (*ibid.*). The second functional explanation of this behavior is that during parturition, the female is less mobile and when parturition occurs without isolation, she may easily draw the attention of other conspecifics including males (Dittrich, 1968; Lent, 1974). Thus, isolation from the herd reduces the chances of any potential harm to her neonate from conspecifics. The third explanation is that both mother, and particularly, the offspring may require different environmental conditions, for instance, the neonate may require protection from extremes of weather or the mother may need food and water in her close proximity (O'Brien, 1983). The selection of an isolated safe birth site by pre parturient females can be regarded as preparation for the expected infant.

Habitat and environmental features play an important role in the selection of an isolation site. Mountain sheep were considered to be attracted to the security of high cliffs (Geist, 1971). Feral goats usually sought an isolation site with good shelter (O'Brien, 1984). The chosen site for parturition by Zaga was believed to be in the elevated part (uphill) of the enclosure under a rock formation. She considered the rock formation a secure site for giving birth. The site had a rock cover forming overhang as well as another rock in front of the opening of the parturition site that was believed to provide her and her infant a good shelter. The characteristics of the chosen site by Zaga correspond to the 2 site-characteristics theory of O'Brien (1983), which states that the site preferred by females for parturition had two characteristics i.e. the presence of cover and close proximity to a vertical object. The same theory further suggests that these characteristics may protect both mother and neonate from wind and precipitation, which was indeed witnessed in this study. As it was observed in one video footage that Zaga guided her kid into the hide when it started heavy rain at one evening. She retrieved her kid after the rain stopped. Zaga paid frequent visits to her hidden kid during the rain. She did not call the kid out of the hide though; instead, on every visit of her, she looked into the hide, sniffed her kid and showed vigilance behavior by looking around. In view of the fact that the mother-neonate bond is directly related to offspring survival (Nowak *et al.*, 2000; Grovenburg *et al.*, 2012; Theoret-Gosselin *et al.*, 2014), the third functional explanation of seeking isolation prior to parturition and giving birth in isolation may facilitate the formation of a strong, individual-specific social bond between mother and neonate (Lent, 1974).

5.3 Maternal imprinting or labeling

In this study, after the event of tagging the kid of Zaga, the kid was placed under a wooden shelter, which was not the birthplace of the kid. After a period of more than eight hours, reunion of Zaga and her kid was established. Although, Zaga became baffled and anxious after her kid was placed under the wooden shelter and she was bleating for her kid. She did look for her kid in the elevated part of the enclosure, she however did not go in search of her kid in the wooden shed. This could perhaps be due to the presence of visitors, and particularly the noisy children, in the viewing area. Usually, during the opening hours of the park, none of the Markhor individuals were seen visiting the wooden shed because its closeness to the viewing point.

Zaga's kid was seen under the wooden shed until the closing time of the park. The re-union between Zaga and her kid was most likely took place after the closing hours of the park. Even the kid was handled by zookeepers, the recognition and subsequent acceptance of her kid after eight hours by Zaga was due to the fact that a strong bond had been established between Zaga and her kid. This strong bonding occurred after parturition when they spent a whole day together before the tagging process. Development of bonding between Zaga and her kid may correspond to the bonding develops between mother and kid in domestic goats during a brief period, as short as five minutes, immediately after parturition (Klopfer *et al.*, 1964). In caribou, Lent (1966) estimated that one hour is necessary for the formation of such a strong bond so that the reunion between mother and her calf will be established after the two were separated for the tagging process. Rudge (1969) and Collias (1956) suggested this bonding as an imprinting-like process that occurs immediately after parturition, by the olfactory cues of the mother distinctive to the kid or its enveloping birth fluids. Further, in hider species, the period of intensive contact after parturition serves as the driving force for the formation of a strong social bond between a mother and her infant. This bonding makes the mother respond selectively to her own infant after separations, returns to it and remembers its locations (Lent, 1974).

5.4 Selection of hiding and laying out sites

It is not clear whether the mother or the infant in hider species chooses the hiding site. Various authors have proposed three different opinions regarding this question: the first opinion is that, in order to avoid predation, it is the infant who chooses its hiding site (Lent, 1974; Walther, 1968; Bowyer *et al.*, 1998; Grovenburg *et al.*, 2012). The second opinion is that both mother and infant participate in choosing the location of the hiding site (Linnell *et al.*, 2004; Panzacchi *et al.*, 2010), where the third opinion proposes that only mother decides the location of her infant hiding site (Ozoga and Verme, 1986; Blank, 2017). The findings of this study suggest that selection of hiding site is a coordinated activity by both Zaga and her kid. Although Zaga's kid was not placed under the wooden shed by Zaga, the kid remained concealed there for about eight hours. Whereas, on various occasions, Zaga was seen guiding her kid to the principal hiding site under the rock. The behavior and posture of the kid under the shed and in the principal hiding place was similar, which was an indication that the kid perceived the location under the wooden shed as a hiding site. Further, both the orange and green tagged kids were seen concealing themselves in vegetation and under wooden logs while their mothers were busy foraging. It can be assumed that the concealing activity of both kids was not controlled by their mothers. However, taking into account that a mother memorizes the location of her hidden infant (Lent, 1974; Torriani *et al.*, 2006), it would not be practical that the selection of the hiding site is controlled by the infant only. For instance, if the infant would change its location where it has been hidden, the mother would not be able to find it upon her return.

At least two kids (orange & green tagged) selected their hiding place where they were apparently born. Lent (1974) gave reference of many studies e.g. (Bubenik, 1965 of red deer; Schaller, 1967 of blackbuck; McCullough, 1969 of Tule elk and Jungius, 1970 of reedbuck) in which it was found that the selected hiding place by the infants was away from the parturition site. As a matter of fact, the parturition process of any of the does in the present study could not be observed; therefore, it is not clear if they gave birth at the same place where kids used to hide the most (principal hiding site). Nevertheless, findings of this study revealed that kids chose to hide or layout at several places in the elevated part as well as in between and under the wooden logs in the lower part of the enclosure. Therefore, the kids obviously chose their hiding and laying out places somewhere else than the principal hiding site. Hnida (1985) suggested that having more than one site to hide may provide the infants with "backups" if they would have to abandon a site.

The selection of hiding and laying out site with a cover by the kids in this study indicates that they keep their natural instincts as in wild it is a practical adaptation by the Markhor kids against possible predation. It was witnessed by Roberts (1969) that the free-living Markhor kids concealed themselves in rock clefts when their mothers left for foraging. Similar adaptation characteristics had also been noted by O'Brien (1983) in feral goats and by Barrett (1981) in pronghorn *(Antilocapra Americana)*. The best way for the neonate to escape predation during hiding or lying out is to avoid being detected by a predator (O'Brien 1983). Therefore, structural features of the hiding or laying out site may be particularly important, for instance, the use of cover such as rocky overhangs or crevices covered with vegetation. The laying out site of Gazelles (Gazella spp.) consisted of a small hollow close to a vertical object (Walther, 1968). Whereas, O'Brien (1983) noted the laying out site of feral goats are characterized by rocky overhangs. In wild Markhors, Roberts (1969) observed that the hiding and the laying out sites were in the form of rock clefts and crevices. Markhor kids in the present study used hiding and laying out sites with almost all characteristics stated in above-mentioned studies. They were even seen concealing themselves under and between the wooden logs in the lower part of the enclosure as well as the root hollows of trees in the elevated part of the enclosure.

5.5 Finding the hidden kid

After feeding and foraging, the navigation back to her hidden kid by Zaga was very accurate. She made no efforts in search of her hidden kid instead every single time she returned to the hiding place with utmost accuracy. Similar exact navigation back to the kid in feral goats was observed by Rudge (1969), where females returned to feed the kid often through thick forest and over numerous gullies and rock falls. One female in Rudge's (1969) study climbed a 300 meter steep slope and reached the exact bush where her twin kids were hidden. Because in hider species an infant is completely dependent on the mother for feeding, the hidden kid may die of hunger if the mother is unable to find the place where her kid is hidden. Thus, finding the hidden infant by the females is very crucial and they accomplish this by memorizing the approximate location of the hiding place of their infants (Lent, 1974; Torriani *et al.*, 2006).

Rudge (1969) noted that the period of absence and the time of returning back to the hidden kid in feral goats was very variable. For instance, one doe hid her kid for over eight hours on two successive days and return to nurse her hidden kid in the evening. In the present study, during the first 2 days of post-parturition, Zaga returned to the hiding place in the evening. Thereafter, she returned back to her hidden kid at least three times during the observation hours and the amount of time spent on grazing was not more than 2 hours between two visits. Zaga was observed directly approaching and calling out her kid out of the hide when she detected no danger around. Walther (1964) observed similar behavior in Sitatunga or Marshbuck *(Tragelaphus spekii),* where the mother in captivity moves directly to her calf and made nose to nose contact with it. Lent (1974), however, contradicts this by stating that mothers of hider species instead of approaching and making direct contact with their offspring, will await the emergence of offspring from a distance away. Leuthold (1967) recorded this distance as 20-40 meters for Uganda kob *(Kobus kob thomasi)*. In Dik-Dik *(Madoqua)* this distance was recorded 10 meters by Hendrichs and Hendrichs (1970), whereas Walther (1964) reported 10-15 meters distance in greater kudu (*Tragelaphus strepsiceros).* The Markhor of the present study and Marshbuck of Walther's (1964) study were both captive and showed similar behavior in approaching their hidden offspring. Keeping in to account the general description of the maternal behavior in hider species (Lent, 1974), it appears that in wild, nursing initiation by mothers at a close distance has rarely been observed (Hnida, 1985). Further, both Zaga and Löss were seen utilizing the entire enclosure space both downhill and uphill when their kids were in hiding and the maximum distance they could go away from their hidden kids was about 50-60 meters, whereas in feral goats (Rudge, 1969) the maximum distance was recorded as far as 500 meters. Therefore, the effect of captivity and the inter-species differences regarding these behaviors need to be further investigated in their natural habitat.

5.6 Predator avoidance strategies

As Markhors belong to the category of hider species, therefore to avoid predation the Markhor kids have adopted a concealment strategy which improves their survival probability. The observations were made in this study that the kid in hiding laid down motionless with its chin resting on the ground and its ears flattened against its head (photo 12, page 32). This posture is referred to as 'freezing' or 'lying prone' and the reason behind this posture is to reduce visibility by the predator (Lent, 1974). A similar posture in the young of Coke's hartebeest *(Alcelaphus buselaphus cokii)* and Grant's gazelle *(Gazella granti)* was observed by Gosling (1969) and Spinage (1986) respectively. Further, Walther (1969) and Fitzgibbon (1990) noted that hidden Thomson's gazelle *(Gazella thomsonii)* fawns were safe from detection by cheetahs *(Acinonyx jubatus)*, spotted hyenas *(Crocuta crocuta)* and jackals *(Canis mesomelas),* even though they were passing by within a 5-meter distance to the hidden Thomson's gazelle. Additionally, Barrett (1978) found that mortality among infants of pronghorn increased with the waning of the hiding phase. In the present study, the duration of hiding phase for Löss's kid was recorded as one week. Whereas, in wild ungulates, the duration of hiding phase has been recorded the shortest as 2-3 days in Siberian ibex *(Capra sibirica)* by Savinov (1962) and the longest as 2-4 months in Reedbucks *(Redunca)* by Jungius (1970).

In addition to concealing themselves from predators as an anti-predator strategy, infants of hider species, however, have to be able to recognize the calls of their own mothers. As by leaving their hiding site after hearing a different adult female call may increase the chances of detection by predators. This characteristic of hider species has been explained by Torriani *et al.* (2006) as that hider species show strong individuality in mother calls and low individuality in offspring call that leads to unidirectional recognition of mothers by offspring. The practical display of this characteristic of hider species by the Markhor kids was observed in the present study. None of the Markhor kids came out of the hide without her own mother. Every time when a hidden Markhor kid was seen out of the hiding, it was accompanied by its own mother. Furthermore, whenever a mother of the hidden kid came downhill for eating, her kid remained concealed in hiding until she came back to it. This indicates good communication between kids and their mothers which is crucial for the survival of the kids.

In hider species, the behavior of mothers, on the other hand, is crucial to make sure that the predators do not detect the hidden infant. A predator may be able to reduce its search efforts in finding an infant by simply observing the behavior of the mother, even if the infant is well hidden. Predators can reduce both energy and time spent searching for the infant by locating a mother and waiting for her to retrieve her infant (Byers & Byers, 1983). In this regard, a mother should behave so that she does not indicate the site of her hidden infant to predators (Hnida, 1985); for instance, by delaying the retrieval of her infant (Byers & Byers, 1983), by not laying/sitting near her infant (Walther, 1984) or by avoiding direct contact with hidden infant for nursing (Thenius and Walther, 1972). Byers & Byers (1983) noted that pronghorn and gazelle mothers reduce the chances of a predator to detect their infants by intensifying their vigilance to be able to detect a predator as well as by delaying the retrieval of their fawns if they detect a predator. By doing so, they make it more worthwhile for a predator to seek other prey than to wait for the fawn to emerge. In the present study, night activity of the Markhors was recorded by the video camera and it can be seen on the footage that before retrieving her kid, Zaga spent 4 minutes on vigilance. She was looking towards the enclosure of lynx as if she noticed the presence of lynx. Further, at some point, both Zaga and Löss walk passed or laid down on a big rock facing visitor's path close to their hidden kids but they did not make any contact with their kids. Presumably, both Zaga and Löss spotted a lynx, which is why; instead of making contact with kids they laid down on a nearby rock facing the visitor's path and lynx enclosure. They delayed the retrieval and nursing of their kid. However, Zaga was seen sitting close to her hidden kid and she also made direct contact by approaching directly to her hidden kid. These two aspects of Markhor maternal behavior can be modified by captivity as suggested by Hnida, (1985). Further, the captivity-induced modifications in certain behaviors may make reintroduction difficult, one of these is reduced ability to escape predation.

Another aspect of maternal behavior that serves as an antipredator strategy is to clean and free the neonate from the scent of birth fluids and tissues (Leuthold, 1977; Roberts, 2012) as well as the odors of urine and feces as these scents and odors may attract predators (Leuthold, 1977). Although the parturition process and postpartum licking and grooming of the green tagged kid by Zaga was not possible to record. Nevertheless, the kid was completely clean at the time when it was caught for tagging. The Zaga must have consumed the birth fluids, urine and feces from her kid's coat, as mothers do consume birth fluids, feces and urine form their kid's coat (Leuthold, 1977).

Many prey animals engage themselves in certain behavioral displays as responses to predation risk, one such response is reduced foraging time (Sih *et al.,* 1990). Reduced foraging and suckling time shown by Markhors downhill rather than uphill in this study may be due to their natural behavioral instincts to predation risk or disturbance by the visitors, which correlates with Lent (1966) who mentions that the disturbed ungulate mother will not permit nursing. Lent (1966) has observed this on many occasions in caribou mothers. As a matter of fact, sucklings of short duration were recorded downhill, which also included those sucklings that were terminated by the does due to the disturbances by the visitors. Does might feel intrusion on their privacy in the lower part of the enclosure or they assessed the flat and open downhill part more dangerous than the elevated part.

Fleeing to the elevated part of the enclosure whenever any danger was sensed, as well as spending most of their time in the elevated part, was noted in this study. This action of Markhors was perhaps because of the natural behavior of prey animals in wild to retreat to relatively safe locations as a response to predation risk (Bergerud *et al.*, 1983; Formanowicz and Bobka, 1988; Singer and Mark, 1999; Blumstein and Daniel, 2002). Besides the fear of their traditional predators (animals), prey animals do fear human and perceive them as a potential danger. The fear of human in Elk (Cervus elaphus) was observed by Morgantini and Hudson (1985), Elk did retreat to coniferous woodlands from open grasslands as a response to humans during hunting season because they assessed coniferous woodlands to be less dangerous than open grasslands, Therefore, it can be assumed in this study that Markhors felt relatively safe and comfortable in the elevated part than the lower part of the enclosure.

5.7 Maternal proximity

Observations about close proximity were recorded only in the downhill part of the closure because in the uphill part the animals were most of the time either laying (sleeping or resting) very close to each other or were hiding. Therefore, the identity of the kids was not possible to verify with binoculars as the kids usually hid under cover. During the first 3 days of the study, the kid of Löss was still hiding for most of the day, therefore, occurrences of close proximity between Löss and her kid were few in number. Zaga's kid did not show up for the first 3 days of his life, as a result, any records of proximity between Zaga and her kid were not possible to make (figure 6, page 34).

The mothers kept close proximity (ca. 3 meters distance) with their kids more often during the first days of their kids' life. The close proximity between mothers and their kids decreased with the age of the kids. As the kids grew older, they became more independent and started playing further away than 3 meters from their mothers, yet the distance still remained 5-10 meters between kids and their mothers. Furthermore, after 10 days the kids were seen following their mothers, contrary to when their mothers followed them during the first 10 days. Therefore, it can be assumed that after 10 days the kids were responsible for maintaining proximity with their mothers. However, mothers were still giving vocal cues to their kids whenever it was needed. When the study started, Judy's twin kids were 11 days old and Zuzy's kid was 8 days old. Despite the fact that Judy's kids were older than Zuzy's kid, as well as older than 10 days, Judy showed close proximity as often as Zuzy. Moreover, Judy showed close proximity more than Zuzy when their kids were 20 days and 17 days old respectively, and Judy maintained it till the end of the study. As a matter of fact, Judy successfully reared her twin kids whereas Zuzy could only rear one kid out of her twins. The results of this study suggest that keeping close proximity by the mothers with their kids, at least during the first two weeks of their life is crucial for their survival.

5.8 Interactions among Markhors

Exclusive recognition of own kid by each doe was displayed in this study which ensured the selective nursing and care of their own kids. The mutual mother-kid recognition was executed by olfactory, visual and acoustic cues. In goats recognition by mother using her olfaction is only functional at a distance of <0.25 meters (Alexander and Shillito,1977), which makes a doe to recognize her own kid by using her olfaction only at short distances, for instance, at the time of nursing. Therefore, it is most likely that visual and/or acoustic cues were also involved in the differentiation of own kid by each mother at a greater distance. Besides maternal milk, Markhor kids needed their mothers for protection, guidance, and support in a situation of stress and fear. Thus, whenever a kid needed her mother in such situations, only her mother should respond to her kid. This is what was exactly found in this study, at many occasions mothers responded to the calls of only their own kids, even if the kids were out of their sight, they found them by following the direction of the call. Similarly, each mother recognized her own kid when she could see it at a distance. The use of both visual and acoustic (bleats) modalities by the mothers as well as by their kids were also noted in the study because the recognition of the mother by her kid is also important for the survival of the kid.

Vocal cues were used by Markhor mothers for giving guidance to their kids. Vocal communication (bleats) between a doe and her kid was more often during the first 10 days or so and it gradually became less often as the kid grew old. As it was recorded that at the beginning of this study, Löss' kid was still in its hiding phase, though not the whole day, and she communicated with her kid more than she did later in the study. In addition, Löss gave a higher number of bleats than both Judy and Zuzy whose kids were 11 days and 8 days old respectively. The decline in the number of calls as kids grew old was perhaps because the kids need more guidance and support of their mothers during early life and then gradually, due to their learning, the guidance of their mothers is less needed. Further, the kids became relatively stronger and more independent after 10 days post-partum, whereas they were weaker and more dependent during the early days of infancy. Therefore, mothers and kids maintained close spatial relationships and frequent communications during the 10 days post-partum.

Results of this study show a peak of the numbers of bleats given by Zaga on the 13th June (figure 7, page 38). Zaga gave this unusually high number of bleats on that day because her kid was placed under the wooden shelter in the uphill part of the enclosure and consequently, she became agitated and anxious. Next day, her kid was in hiding (principal hiding) and she was still giving frequent bleats and looking towards the hiding of her kid even during feeding and foraging. When Zaga's kid was more than 2 weeks old, during the last days of this study, she mostly was giving low pitch bleats to communicate with her kid, though her kid had started following her.

High pitched bleats were given in anxious or agitated situations, whereas low pitched bleats were mostly given to give cues or to guide the kids. Low pitch bleats were not audible from the uphill part of the enclosure because of the distance between the observation point and uphill part. Consequently, it was only possible to draw a comparison of only high pitched bleats given between uphill and downhill part of the enclosure. Nowak *et al.* (2000) suggested that among wild prey species' natural selection has favored vocal communication of low intensity between mother and her young as a strategy to avoid attracting predators. Therefore, chances are there that perhaps some low-intensity/pitched bleats were not audible even in the downhill part of the enclosure.

The interactions between adult individuals particularly their collective coordinated vigilance was noted in the present study. Prey animals live in groups and partly rely on each other to detect predators. This exclusive adaptation of collective predator detection brings risk dilution (Lima and Dill, 1990; Rieucau and Martin, 2008). Thus, in groups, both collective detection and risk dilution decrease the individual risk of predation (Rieucau and Martin, 2008). In case of any danger, the emergency alarm was sent by any vigilant individual to other conspecifics by producing a penetrating snort or sneeze by blowing air through the nose, which is very distinctive for goats. Agonistic interactions between adult females were observed almost always at the time of feeding. The dominant females showed aggression towards subordinate females. As kids learn from their mothers and other adult individuals therefore, it can be assumed that they learn the rule of dominance from the agonistic interaction of adult females.

5.9 Babysitting behavior

Babysitting (though no adoption) was noted in this study. The kids stayed with the babysitting female only when their own mothers were feeding downhill. When all females roam around in the enclosure independently they accompanied only their own kids. Apparently, the reason for exhibiting babysitting behavior by Markhor females, on one hand, is to achieve foraging freedom, as they could forage more safely and efficiently when they were alone and unencumbered by their kids. While on the other hand, they can make sure that the chances of predation on their kids are low when they are with the babysitting female. It was observed by Ahmad *et al.* (2017) that adult female Markhor attended to the kids of other females who had gone for foraging and left their kids behind at the parturition sites. Pfeifer (1985) observed similar babysitting behavior among captive adult female scimitar-horned Oryx (*Oryx Dammah*), where females left their offspring with babysitter females to be able to utilize resources in a patchy environment as well as minimizing the chances of predation on their offspring by doing so. In addition, babysitting behavior has been observed in several primates such as squirrel monkeys *(Saimiri sciureus)* by Hunt *et al.* (1978) and noted that just prior to departing for feeding themselves, mothers left their infant with another female.

5.10 Allonursing and nursing behavior

Regardless of the babysitting behavior, the Markhor individuals under observation in this study did not display allonursing behavior. Instead, to deter allonursing, vigorous repulsion of the alien kids by babysitter females was observed. Bubenick (1965), states that Capreolus that give birth to more than one fawn per litter allow alien fawns to suckle and even adoption of alien fawns has been noted. In contrast, Klopfer (1967) states that domestic goats do not fit in this pattern, despite the fact that they often give birth to two or even three kids but nonetheless usually limit their maternal solicitation to their own kids. The findings of the present study agree with Klopfer (1967), although Judy gave birth to two kids, she never allowed kids of other does to suckle. Moreover, let their own kids suckle and the rejection of the alien kids by Markhor females in the present study is in line with Gubernick's (1980) findings where goats discriminate between their own kids and alien kids. This would probably increase a doe's genetic fitness as there is no reciprocity among does for the care of their kids. Taking into account that the kids are labeled by their own mothers (Gubernick 1980) whenever a kid would approach a female to suckle she would first sniff the kid to recognize it and hence, each mother would only allow her own kid to suckle. Recognition of kids by first sniffing the oronasal part of the kid was displayed by Markhor females in this study which corresponds to Gubernick's (1980) labelling phenomenon.

Furthermore, after letting her own kid suckle, sniffing the anogenital and back region of the kid during each nursing bout by each mother is associated with long nursing events as Lent (1966) found in caribou. Kids initiated nursing bouts with bunting, prodding or striking their mother udders. The apparent function of this behavior as indicated by Hafez *et al.* (1969) is to induce milk flow or 'let down'. It has been reported by Lent (1974) that continued vigorous bunting appears to be uncomfortable and even painful for mother, resulted in aggression towards the offspring. In this study, however, despite the bunting and striking performed by kids, Markhor mothers displayed great maternal tolerance and showed no aggression towards their kids. Sèbe *et al.* (2008) suggested that nursing invitation by mothers is an indicator of good maternal behavior. The use of low bleats by Zaga to call out her kid out of the hide for nursing has been noted in this study. Similar nursing invitations in Ibex and in greater kudu were observed by Walther, (1961, 1964) and in feral goats by Rudge (1970). In addition to receiving nursing invitations, Markhor kids were seen approaching their mothers by themselves to make suckling attempts. Therefore, besides the mothers, infants also play an important role in the maintenance of maternal behavior by cues, such as, calls and suckling interactions. This exclusive interaction was noted by Dwyer (2009) in sheep and goats where mothers, within few hours, lost their interest in the bodies of their dead young.

5.11 Abnormal maternal behavior

In addition to the absence of allonursing behavior, mismothering and adoption of other kids as well as stealing kids of other females was not the case among Markhors in this study. Offspring stealing, however, has been observed in other mammals, for instance, Welsh and Kilgour (1970) have observed lamb-stealing among Romneys ewes and Edwards (1983) found calf-stealing behavior among dairy cows. In both cases offspring were stolen from their biological mothers and nursed by other females. Furthermore, Arnold and Morgan (1975) found that 21% ewes prior to the birth of their own lambs showed interest in the lambs of other ewes and 6% ewes showed persistent interest in alien lambs. These ewes deserted their own lambs and the lambs died later. Though, the pre-parturition behavior of only one doe (Zaga) was possible to observe in this study. Neither Zaga showed pre-parturition interest in the kids of other does nor did other does exhibit adoption or stealing of each other's kids.

5.12 Vigilance behavior

Markhor individuals displayed vigilance behavior in this study which is very crucial for the survival of prey animals. As prey animals may increase the chances of their survival by vigilance because of their antipredator function (Pulliam, 1973). Every Markhor individual was observed being engaged in both routine vigilance i.e. when they simply scan their surrounding while foraging or ruminating and induced vigilance i.e. when they reacted to a stimulus (Blanchard and Fritz, 2007) e.g. roar of the tiger from the neighboring enclosure, detection of lynx or occurrence of noisy visitors. Due to the absence of adult intact male in the enclosure, it was not possible to compare the true sex difference in vigilance. Pecorella and colleagues (2018), however, recorded that female Fallow deer (*Dama dama*) were more vigilant than males. The sex differences in vigilance behavior displayed by Fallow deer could be due to two reasons. First, females are maybe more vulnerable to predation than males (Clutton-Brock *et al.,*1982) because fallow deer have great sexual dimorphism with males being about 60% larger than females, as well as that both sexes tend to stay in large unisexual groups. Thus, as a response to higher predation risk, females could be more vigilant than males. Second, the presence of offspring can make females more vigilant. Offspring are the most vulnerable individuals to predation because offspring are less able to detect a predator and escape from it and the cost of offspring to the mother is high. Therefore, mothers may have to be more vigilant to detect potential predators and escape or hide from them (Clutton-Brock *et al.,*1982). Thus, females, due to greater duration and frequency of vigilance, may reduce the predation risk for themselves and for their young.

The aforementioned reasons can explain the vigilance behavior of Markhor individuals involved in the present study. The first reason explains the motive behind the vigilance behavior of Zucchini even though she was not accompanied by offspring, while both first and second reasons explain why Markhor mothers were vigilant. Vigilant behavior of both Blitz & Zucchini was very interesting. In addition to being vigilant during foraging and ruminating, every evening they laid down on the rooftop of the wooden shelter and performed vigilance behavior. This additional vigilance by Blitz and Zucchini can be considered helpful for themselves and for other conspecifics. As group vigilance may improve predator detection and reduce the capture probability on one hand and on the other hand, animals may get more time to feed because of less frequent scanning (Pulliam, 1973). In order to draw a comparison between the vigilance level of female Markhors accompanied by their kids and females not accompanied by kids as well as age and rank differences in vigilance, further investigation, perhaps a separate study, is needed. Moreover, it would be interesting to compare the difference in vigilance behavior between captive and wild Markhors. As it is unlikely that the predators in captivity attack their prey. It was observed in the present study that the Markhor females after detecting a lynx remained vigilant for some time and then resumed their activities even though the lynx was still at the same spot in its enclosure. Would these situations make the prey animals habituated and less vigilant than their wild counterpart? All these questions can be answered by investigating their vigilance behavior in more details which may prove helpful for a reintroduction program.

5.13 Maternal success

One twin kid of Zuzy disappeared and presumed dead, Judy however, successfully reared her twin kids. Why Zuzy could not rear her both kids successfully? This incident happened before the present study started, therefore there were no observations regarding the maternal behavior of Zuzy during her first-week post-parturition. However, to answer this question there are multiple assumptions. It has been revealed by a study on the maternal behavior of ungulates that females producing more than one offspring show limitations in the care of multiples. One such study was conducted by Langeneau and Lerg (1976) and they revealed that during gestation, undernutrition depresses maternal behavior and consequently increases neonatal mortality as the mother neglects the present offspring. Supplementary feeding, on the other hand, has opposite effects (Putu *et al.,* 1988). Why a mother would neglect her offspring? The explanation lies in parental investment theory i.e. the undernourished mother would inflict such a large cost on her future reproductive success if she nurses her young, and therefore it is more beneficial for the long term to neglect her present young. In addition, Putu *et al.* (1988) observed in Marino sheep that undernutrition during late pregnancy caused a higher proportion of permanent abandonment of at least one of their twin lambs in twin-bearing ewes compared to single bearing ewes.

In Angora kids, Snyman (2010) reported a decreased survivability of kids with low birth weight (low energy resources) and single kids have a higher survival rate than twin kids. On the basis of Snyman's (2010) findings, it can be assumed that the kid might have low birth weight and was comparatively weaker than the other twin sibling. Therefore, the weaker kid may fell down from the steep side of the elevated part of the enclosure during playing or exploring which resulted in the accidental separation of the kid from Zuzy. Lastly, Zuzy abandoned the kid, and a predator may have taken the kid. In spite of the fact that one of the twin kids of Zuzy disappeared/died, she showed normal maternal behavior to the other twin kid. Further, none of the other mothers displayed abnormal maternal behavior.

5.14 Reproductive success

All Markhor females who were sexually mature and fertile bred successfully and their parturition was quite synchronous except for Zaga, who gave birth to her kid after three weeks of Judy's parturition (mentioned earlier). Why Zaga delayed her parturition? This question can be answered by investigating if a female can delay her parturition in any circumstances. There are many factors that may affect the reproductive function of females. Stress is one of the well-known factors to depress reproductive function and to cause abnormal behavior in animals (Moberg, 1985). In ungulates, due to the stress caused by disturbance, Equidae seems to have the ability to delay parturition (Lent, 1974).

Zaga might have failed to conceive in her first estrus (Festa-Bianchet, 2001) due to the stress of captivity. Hediger (1964) has described situations in which captive animals failed to breed as a result of stress, and the main cause of this stress was their inability to escape from potential danger. This is in accordance with the findings of Carlstead and Shepherdson (2000), i.e. in captivity one of the most obvious causes of chronic stress was the inability to respond to potential danger, with active avoidance or escape responses. However, as noted in the present study, every time zookeepers entered the enclosure from the gate on the flat part, Markhors fled to the elevated part while fleeing to the flat part was seen in case of the entrance from the elevated part. Similarly, the Markhors were seen avoiding the visitors and other disturbances by fleeing to safe locations. Therefore, there was no apparent hindrance for the Markhors in the performance of the escape response due to the enclosure design; however, the size of the enclosure was indeed not a match to the size of their home range.

The life history of the Markhor individuals under observation in this study reveals that all Markhor individuals were born in captivity. Having said that, the question is: do captive-born animals assess the size of the enclosure in which they grew up as a stressor? Or do they habituate to their enclosure size, as long as they are able to perform escape response? Habituation to captivity by captive-born Mexican grey wolves *(Canis lupus baileyi)* has been suggested by Ibara *et al.* (2017). Captive born Mexican grey wolves habituated to captivity due to the availability of food and stability of the environment (Ibara *et al.,* 2017) and these two factors were also there for the Markhors. However, wolves and Markhors belong to completely different families of mammals being predator and prey animals respectively. Therefore, the more accurate measures of the stress level of a captive born prey animal can be obtained by physiochemical testing for instance enzyme immunoassays (EIAs) that may also be extremely helpful in the management of captive animals (Wheeler *et al.,* 2013).

All other females, especially Löss - who was of the same age as Zaga, gave birth before Zaga. The perception and reaction to stressors differ between individuals, could this be considered in Zaga's case? Is it natural for Markhor females to give birth with such a gap? Another assumption is that Zaga did conceive in her first estrus but she prolonged her pregnancy due to her nutritional status, as nutrition affects gestation length (Guinness *et al.,* 1978) while high levels of nutrition are related to a shorter gestation length (Asher *et al.,* 2005). Nutritional deprivation in late pregnancy results in retarded fetal growth which delays both lactogenesis and parturition until the critical fetal mass is attained to ensure the birth of a viable neonate (Thorne *et al.,* 1976). In African Eland *(Taurotragus oryx)* Skinner and van Zyle (1969) found longer gestation length related to poor nutritional habitats. Alexander (1956), however, found in a study on the influence of maternal nutritional status in sheep that maternal nutritional deprivation during late pregnancy caused shorting of gestation length which contradicts the aforementioned studies. It can be assumed that Zaga was deprived of nutrition in her late pregnancy because she could not manage to eat well, due to her subordinate status. Matter of fact, both Zaga and Löss were subordinate females and they did experience attacks by dominant females at the time of feeding. Then, why only Zaga remained undernourished? There is no data available on the feed intake of individual Markhor mothers during pregnancy for this study; therefore it is not possible to draw any firm conclusion. Above all, perhaps it is natural for some Markhor females to give birth at the end of the peak birth season. Another possibility is that when the Male Markhor was brought in for breeding, Zaga's oestrus cycle had not yet started. In order to obtain detailed knowledge about the birth peak in Markhors, further research is needed to investigate birth synchrony in their natural habitat.

5.15 Welfare and management

One of the benchmarks to assess the welfare of captive animals is to see if the captive animals are performing the full repertoire of behaviors shown by their wild-living conspecifics (Thorpe, 1965; Fraser & Broom, 1990). The study of the welfare of animals, particularly in captivity, is very crucial as the level of welfare may influence the normal behavior of animals (Wolfensohn et al., 2018). In their natural habitat, Markhors are both grazers and browsers in feeding habits. Markhors under observation in the present study were offered leafy twigs tied up on wooden logs as an enrichment to encourage them to perform their browsing behavior. However, hanging browse with a wooden pole (Rose e*t al.,* 2008) in the enclosure could provide Markhors a challenging feeding. This may help to increase their physical and mental activity by encouraging them to perform natural feeding posture as they have been seen in their natural habitats standing on their hind legs while browsing on leaves from branches of trees.

Isolation of prey animals from predators may result in loss or modifications in antipredator behavior (Coss, 1999; Foster, 1999). Additionally, captive-born animals can lose their capacity to recognize predators because they fail to develop predator recognition skills and such changes may occur over generations or during an animal's life in captivity (Adams *et al.,* 2006; Blumstein *et al.,* 2006). Nordens Ark keeps Markhors for the purpose of conservation (Loberg personal communication, November 7, 2018). An important conservation tool is captive breeding and release of captive-born animals in their natural habitat. Preparation of the animals before their release into the wild is very essential to increase the 'released animals" chances of survival in the wild (Griffin *et al.,* 2000). Preparation refers to the training of the animals in behaviors - antipredator, feeding, foraging behaviors - that are likely to increase the chances of survival of the animals in the wild (*ibid.*). Moreover, in order to increase the chances of survival of the 'released animals' in the wild, preparation also includes acclimation to the climatic conditions and accustomization to the food resources of the released site (*ibid.*). The housing of Markhor had an enclosure of Lynx on one side and of Amur tigers on the other side, which encourages the Markhor to perform antipredator behavior. Prey animals execute antipredator behavior by either avoiding predators (avoidance behavior) to reduce the chances of encounters with predators, or by responding to a potential predator to avoid attack after detecting it by olfactory cues derived from a predator (Lima and Dill, 1990). The display of, for instance, Individual and coordinated vigilance, alarming conspecifics, hiding kids, retreating to safe locations after sighting the Lynx, the visitors or hearing the roar of the Amur tigers, were all indicators of a well performed antipredator behavior by the Markhors.

Agonistic behavior was displayed by the Markhor females at the time of feeding. Subordinate females were forced to flee away from the feed stall by the dominant females. Two subordinate females (Löss and Zaga) were lactating mothers and during lactation, an optimum amount of feed is very crucial in order to continue lactation with good quality of milk that then again influences the growth of the kid. Scattered feeding at more than one place could minimize overcrowding and thus reduce the agonistic behavior during feeding and may increase the chances to get the optimum amount of feed by the subordinate females. Do Tajik Markhor females show agonistic behavior during grazing or browsing in their natural range, where their range is about 118,000 hectares (Stefan, 2015)? This question can only be answered by conducting a study of the agonistic behavior of Markhor in their natural habitat. However, a general idea can be acquired from this study that the Markhor females did not show aggressive competition for space during grazing, walking or resting. The agonistic exchange was only observed at the time of feeding on hay and pellets in the feed stall and leafy twigs from the wooden logs.

The presence of the rock formation of the elevated part of the enclosure mimics their natural habitat as they are adapted to mountainous terrain. The rock formation of the elevated part did provide climbing opportunities to the Markhors. Additionally, it provided hiding places from conspecifics, visitors, zookeepers as well as isolated hidden places for giving birth, something that is also a natural behavioral need of the Markhors. The process of hoof wear is important to avoid the problem of overgrown hoofs that may result in lameness, which can be found in animals housed on a soft floor (Smith and Sherman 1994). None of the Markhor individual involved in this study had or developed the problem of lameness, as the rock formation indeed provided the climbing opportunity to the Markhors and the process of hoof wear seemingly occurred during climbing, running, walking and playing on the rock formation. As described earlier there was a male Markhor in the herd and he had to be put down because he had severe lameness and pain. He was brought in to Nordens Ark on 22nd of February 2017 from Tallinn Zoo (Estonia) for breeding purpose and he was euthanized on April 19th, 2018. The male Markhor had overgrown hooves and therefore, he was sedated a month after his arrival at Nordens Ark to get his hooves trimmed. There is no information available about the housing of Markhors in Tallinn Zoo and the history of the male Markhor, so there is nothing to say with clarity about the reason of lameness of that male Markhor.

5.16 Visitor’s effect

The results of this study show that the kids spent less time both uphill and downhill in the presence of >20 visitors and more time when there were 1- 10 visitors around (figure 12, page 45). The time was recorded with respect to the number of visitors present, for instance when 20 or more visitors occurred next to the enclosure for 6 minutes and then move forward leaving behind 3 visitors, the time recording started for those 3 visitors. The higher number of visitors fell in the category 1-10, therefore, the time recordings were greater for this category. On the other hand, the occurrence of >20 visitors at one time was not as often as the category 1-10, that is why the time recordings were lesser. However, the percentage of time spent uphill and downhill by the kids shows that kids spent relatively more time uphill in the presence of >20 visitors than 1-10 visitors and for downhill, the reverse is true for both categories respectively (table 6, page 41). The visitors in the category (1-10) were mostly families with kids and the higher number of noisy visitors (n=61 in figure 12, page 45) were in this category. The categories 11-20 and >20 comprised of visitors in the form of groups from schools and guided tours. The time spent by the kids downhill also included the time when the kids were hidden in the wooden logs or when they were accompanied by their mothers in the feed stall. Interestingly, all the kids were present at the same time either in the elevated part or in the flat lower part of the enclosure. In the elevated part, the kids were altogether accompanied with the babysitting doe and in the lower part, they were with their mothers in the form a herd. Therefore, the time was recorded when all the kids were either in the elevated part or in the lower part of the enclosure.

Although during the opening hours of the park, the kids spent most of the time in the elevated part either accompanied with a babysitting doe or with their own mothers, the kids fled to the elevated part whenever they hear a loud sound such as the scream of the visitors (children). Additionally, in case of such a situation, hiding in/between the wooden logs by the kids was observed in this study. As mentioned earlier, prey animals retreat to relatively safer locations as a response to predation risk. Because of their natural instincts and perhaps learning, Markhor kids retreated either to the elevated part of the enclosure or hid themselves in/between wooden logs in the flat lower part. Seemingly, Markhor kids, as well as other Markhor individuals, experienced disturbance mostly by loud noises of visitors and zoo vehicles as well as the occurrence of running children and stones thrown by children in their enclosure.

Sound levels in natural habitats contrast sharply with the sound levels recorded at zoos. For instance, data of sound levels obtained by Tromborg and Coss (1995) from two zoological parks at Northern California shows sound pressure level ranged from a low of 62 dB to a high of 72 dB with an average of 70 dB. While on the other hand, in wild the ambient noise levels in rain forest habitats range from 27- 40 dB, in riverine habitats 27-37 dB and 20-36 dB in savannah habitats. In these habitats, noise arises by wind, the rustling of leaves and bird vocalization. As the number of visitors, the intensity of their conversations and the presence of machinery influence the noise levels and in order to investigate the influence of noise pollution on the behavior of Markhor, noise levels calculations for the setup of Markhors at Nordens Ark is essential to draw any firm conclusion, which is a whole new set of research. This study gives merely a general idea about the influence of noise and the presence of visitors on the behavior of Markhors.

CHAPTER 6 SUMMARY & CONCLUSION

The primary purpose of this study was to acquire knowledge about the maternal behavior of Markhors and its influence on the survival of the kids. The survival of offspring of any mammalian species is highly dependent on maternal care, as a mother provides all the vital needs to her offspring. These needs include nutrition, protection and guidance. Pre-parturition isolation and seeking of a safe birth site by the mother definitely increase the likelihood of survival of her kid by developing a strong bond with her kid as well as by protecting the kid from conspecifics and bad weather. Post-parturition nursing, communication, as well as close proximity with the kids by their mothers facilitates the kids to grow and develop motor skills. The mothers and their kids displayed a strong mother-offspring bond and maintained it until the end of the study. Each mother recognized her own kid by olfactory, visual and acoustic cues, due to which each mother and her kid kept a strong maternal-offspring bond. Allonursing, adoption of alien kids, kid-stealing as well as other mismothering behaviors were absent in Markhor does. All mothers successfully conceived and reared at least one kid, which shows their reproductive fitness. The animals were provided feeding enrichments in the form of leafy branches on wooden logs. The environmental enrichment was in the form of the elevated rocky part of their enclosure. The enrichments encourage the animals to perform their natural behaviors such as browsing, climbing, hiding and playing. A mother would only be able to perform good maternal behavior when her own welfare and health is optimum. During the course of the study, no individual showed any stereotypes or health issues, which indicates an optimum level of overall welfare.

The Markhor individuals spent most of their time in the elevated part of the enclosure. It seems that they felt more safe and relaxed in the elevated part than in the lower part. All females chose the elevated part for their parturition site. Besides giving birth in the elevated part of the enclosure, selection of hiding place was also in the elevated part. Additionally, the results of this study show that suckling events were significantly longer in the elevated part (48.5 ±2.3 sec, 49 ± 1.4 sec) compared to the lower part (17.8 ±1.8 sec, 18.1 ± 1.3 sec) of the enclosure. This suggests that the females perceived the lower part as a more threatening area. Findings of this study suggest that babysitting behavior displayed by the does adds up to more freedom of grazing and increases the chances of survival against predators. The display of babysitting behavior was only recorded in the uphill part of the enclosure. The findings of this study revealed that the Markhor not only displayed their vital behaviors only in the elevated rocky part of the enclosure but also they felt safe and secure in the elevated part. Thus, the inclusion of elevated rocky part along with a flat lower part in the enclosure most likely mimics Markhor's natural habitat. Besides individual vigilance, collective vigilance was also performed by the Markhors. Seemingly, Markhor kids, as well as other Markhor individuals, experienced disturbance mostly by loud noises of visitors and zoo vehicles as well as the occurrence of running children and stones thrown by children into their enclosure. The Markhor kids always took refuge either in the elevated part of the enclosure or under the wooden logs. All mothers displayed normal maternal behavior. The findings of this study showed that the survival of the kids was highly dependent on the care that was given primarily by their mothers as well as by the babysitting females.

It can be justified to conclude that keeping Markhors in captivity for the purpose of conservation, provision of an enclosure which mimics their natural habitat would not only provide them optimum welfare but also facilitate their successful reproduction. However, for a better understanding of their maternal behavior and welfare, it is much needed to study the behavior of their wild counterparts.

Chapter 7 References

Adams J L, Camelio K W, Orique M J, Blumstein D T (2006). Does information of predators influence general wariness? Behavioral Ecology and Sociobiology. 60, 742–747.

Agostini J (2005). Markhor by Friends of the Rosamond Gifford Zoo Education Volunteers. Retrieved January 31, 2019 from Rosamond Gifford Zoo page website: http://www.rosamondgiffordzoo.org/assets/uploads/animals/pdf/Markhor.pdf.

Ahmad R, Sharma N, Mishra C, Singh N J, Rawat G S, Bhatnagar Y V (2017). Security, size, or sociality: what makes markhor (Capra falconeri) sexually segregate? Journal of Mammalogy. 99(1), 55–63.

Alados C L & Escos J M (1992). The determinants of social status and the effect of female rank on reproductive success in Dama and Cuvier's gazelles. Ethology Ecology and Evolution. 4(2), 151-164.

Alexander G (1956). Influence of nutrition upon duration of gestation in sheep. Nature. 178, 1058-1059.

Alexander G and Shillito E E (1977). The importance of odour, appearance and voice in maternal recognition of the young in Merino sheep (Ovis aries). Applied Animal Ethology. 3,127-135.

Aleem A (1976). Markhor in Chitral Gol, Pakistan. Forestry. 26(2), 117-128.

Aleem A and Malik M M (1977). Litter size in Markhor. The Pakistan Journal of Forestry. 27(4), 203-206.

Altmann M (1963). Naturalistic studies of maternal care in moose and elk. Maternal behavior in mammals, ed. Rheingold H L. 233-253.

Anzuino N, Bell N J, Bazeley K J,Nicol C J (2010). Assessment of welfare on 24 commercial UK dairy goat farms based on direct observations. Veterinary Record. 167, 774-780.

Arnold G W and Morgan P D (1975). Behavior of the ewe and lamb at lambing and its relationship to lamb mortality. Applied Animal Ethology. 2, 25-46.

Asher G W, Mulley R C, O'Neill K T, Scott I C, Jopson N B and Littlejohn R P (2005). Influence of level of nutrition during late pregnancy on productivity of red deer (Cervus elaphus): Adult and primiparous hinds gestating red deer calves. Animal Reproduction Science. 86,261–283.

Ashraf N, Anwar M, Hussain I, Nawaz M A (2014). Competition for food between the markhor and domestic goat in Chitral, Pakistan. Turkish Journal of Zoology. 38, 191-198.

Barrett M W (1978). Pronghorn fawn mortality in Alberta. Proceedings of the Pronghorn Antelope Workshop. 8, 429-444.

Barrett M W (1981). Environmental characteristics and functional characteristics of pronghorn bedding sites in Alberta. Journal of Wildlife Management. 45, 120-131.

Berger J (1992). Facilitation of Reproductive Synchrony by Gestation Adjustment in Gregarious Mammals: A New Hypothesis. Ecology. 73(1), 323-329.

Bergerud A T, Butler H E, and Miller D R (1983). Antipredator tactics of calving caribou: dispersion in mountains. Canadian Journal of Zoology. 62, 1566–1575.

Bernardo J (1996). Maternal effects in animal ecology. Animal Zoology. 36, 83–105.

Blank D (2017). Antipredator tactics are largely maternally controlled in goitered gazelle, a hider ungulate. Behavioral Processes. 136, 28-35.

Bleich V C, Bowyer R T, Wehausen J D (1997). Sexual segregation in mountain sheep: resources or predation? Wildlife Monographs. 134, 3–50.

Blumstein D T, and Daniel J C (2002). Isolation from mammalian predators differentially affects two congeners. Behavioral Ecology. 13, 657–663.

Blumstein D T, Bitton A, Da Veiga J (2006). How does the presence of predators influence the persistence of antipredator behavior? Journal of Theoretical Biology.239, 460–468.

Bowyer R T (1984). Sexual segregation in Southern mule deer. Journal of Mammalogy. 65, 410.

Bowyer R T, Kie J G, Ballenberghe V V (1998). Habitat selection by neonatal black-tailed deer: climate, forage, or risk of predation? Journal of Mammalogy. 79 (2), 415-425.

Brambell F W R (1958). Passive immunity in young mammals. Biological Reviews. 33, 488-531.

Brandlová K, Bartoš L, Haberová T (2013). Camel Calves as Opportunistic Milk Thefts? The First Description of Allosuckling in Domestic Bactrian Camel (Camelus bactrianus). Martine Hausberger, University of Rennes 1, France.

Byers J A & Byers K Z (1983). Do pronghorn mothers reveal the locations of their hidden fawns? Behavioral Ecology and Sociobiology. 13: 147-156.

Carlstead K and Shepherdson D J (2000). Alleviating stress in zoo animals with environmental enrichment.The biology of animal stress: basic principles and implications for animal welfare. Edited by Moberg, G. P., Mench, J. A. CABI. 16, 337- 354.

Clutton-Brock TH, Iason GR, Albon SD, Guinnes FE (1982). The effects of lactation on feeding behavior and habitat use of wild red deer hinds. Journal of Zooloy. 198:277–236.

Clutton-Brock T H, Albon S D and Guinness F E (1984). Maternal dominance, breeding success and birth sex ratios in red deer. Nature. 308, 358-360.

Collias N E (1956). The analysis of socialization in sheep and goats. Ecology. 37, 228-239.

Coss R G (1999). Effects of relaxed natural selection on the evolution of behavior. In Foster S A and Endler J A(Eds.), Geographic variation in behavior: Perspectives on evolutionary mechanisms. Oxford University Press, Oxford, 180-208.

Côté S D and Festa-Bianchet M (2001). Birthdate, mass and survival in mountain goat kids: effects of maternal characteristics and forage quality. Oecologia. 127, 230–238.

Dittrich L (1968). Keeping and breeding gazelles at Hanover Zoo. International Zoo Yearbook. 8, 139-43.

Drabkova J, Bartosova J, Bartos L, Kotrba R, Pluhacek J, Svecova L, Dusek A, Kott T (2008). Sucking and allosucking duration in farmed red deer (Cervus elaphus). Applied Animal Behaviour Science. 113, 215–223.

Dwyer C M (2009). The ethology of domestic animals. In: Jensen, P. (ed.). The behavior of sheep and goats. CAB International, London UK, 161-176.

Edwards SA (1983). The behavior of dairy cows and their newborn calves. Animal Production. 34:339–346.

Evans R M (1990). The relationship between parental input and investment. Animal Behavior. 39, 797-813.

Engelhardt S C, Weladji R B, Holand Ø, Røed K H & Nieminen M (2015). Evidence of Reciprocal Allonursing in Reindeer (Rangifer tarandus). Ethology. 121, 245–259.

Escobar-Ibarra I, Mayagoitia-Novales L, Alcántara-Barrera A, CerdaMolina A L, Mondragón-Ceballos R, Ramírez-Necoechea R & Alonso-Spilsbury M (2017). Longterm quantification of faecal glucocorticoid metabolite concentrations reveals that Mexican grey wolves may habituate to captivity. The European Zoological Journal. 84(1), 311-320.

Estes R D (1976). The significance of breeding synchrony in the wildebeest. African Journal of Ecology. 14(2), 135-152.

Fagen R, Fagen J (2004). Juvenile survival and benefits of play behavior in brown bears (Ursus arctos). Evolutionary Ecology Research. 6, 89–102.

Festa-Bianchet M (1988). Birthdate and survival in bighorn lambss (Ovis canadensis). Journal of Zoology. 214, 653–661.

Fitzgibbon C D (1990b). Why do hunting cheetahs prefer male gazelles? Animal Behavior. 40, 837-845.

Fitzgibbon C D (1993). Antipredator strategies of female Thomson's gazelles with hidden fawns. Journal of Mammalogy. 74, 758-762.

Formanowicz D R, and Bobka M S (1988). Predation risk and microhabitat preference: an experimental study of the behavioral responses of prey and predator. American Midlands Naturalist. 121, 379–386.

Foster S A (1999). The geography of behaviour: an evolutionary perspective. Trends in Evolutionary Ecology.14(5), 190-195.

Fraser A F and Broom D M (1990). Farm Animal Behaviour and Animal Welfare. Baillere Tindall: London, UK.

Gaillard J M, Festa-Bianchet M, Yoccoz N G (1998). Population dynamics of large herbivores: variable recruitment with constant adult survival. Trends in Ecology & Evolution. 13, 58–63.

Gaillard J M, Festa-Bianchet M, Yoccoz N G, Loison A, and Toigo C (2000). Temporal variation in fitness components and population dynamics of large herbivores. Annual Review of Ecology and Systematics. 31, 367– 393.

Geist V (1971). Mountain sheep: a Study in Behavior and Evolution. 383. University of Chicago, Chicago.

Gosling, L M (1969). Parturition and related behavior in Coke's hartebeest (Alcelaphus buselaphus cokii) . Journal of Reproduction and Fertility. 6, 265-286.

Griffin A S, Blumstein D T and Evans C S (2000). Training captive-bred or translocated animals to avoid predators. Conservation Biology. 14(5), 1317-1326.

Grovenburg T W, Swanson C C, Jacques C N, Klaver R W, Brinkman T J, Burris BM, DePerno C S, and Jenks J A (2011). Survival of white-tailed deer neonates in Minnesota and South Dakota. Journal of Wildlife Management. 75, 213–220.

Grovenburg T W, Monteith K L, Klaver R W, Jenks J A (2012). Predation evasion by white-tailed deer fawns. Animal Behavior. 84, 59–65.

Grovenburg T W, Jenks J A, Jacques C N, Klaver R W and Swanson C C 2012). Aggressive defensive behavior by free-ranging white-tailed deer. Journal of Mammalogy. 90 (5) , 1218-1223.

Grubb P (2005). Order Artiodactyla. In: Wilson DE, Reeder DM (editors) Mammal species of the world—a taxonomic and geographic reference, 3rd edition, vol 1. John Hopkins University Press, Baltimore, 637–722.

Gubernick D J (1980). Maternal "imprinting" or maternal "labeling" in goats? Animal Behavior. 28 (1), 124-129.

Guinness F E, Albon S D, Clutton-Brock T H (1978). Factors affecting reproduction in red deer (Cervus elaphus) hinds on Rhum. Journal Reproductive Fertility. 54(2), 325–334.

Haller H (1992). On the ecology of the lynx in the course of its resettlement in the Valais Alps. Mammalia depicta, Z. Saugetierkd (Suppl.). Paul Parey, Hamburg, Berlin, Germany.

Hammer S E, Schwammer H M, Schwammer F (2008). Evidence for Introgressive Hybridization of Captive Markhor (Capra falconeri) with Domestic Goat: Cautions for Reintroduction. Biochemical Genetics. 46,216–226.

Harris D R (1962). The distribution and ancestry of the domestic goat. Proceedings of the Linnean Society of London. 173(2),79–91.

Hayes J L (1868). The Angora goat: its origin, culture, and products. Boston, 1868.
Hediger H (1964). Wild 9animals in captivity. New York, Dover Publications.

Hendrichs H and Hendrichs U (1970). Field Examinations on Ecology and Ethology of the dwarf antelope (Madoqua) (Rhynhotragus) kirki Gunther, 1880. 1-75. Munich: R. Piper & Co. Verlag.

Hnida J A (1985). Mother-infant and infant-infant interactions in captive sable antelope: Evidence for behavioral plasticity in a hider species. Zoo Biology. 4(4), 339-349.

Huffman B (2004). Capra falconeri. Retrieved January 31, 2019, from The Ultimate Ungulate Page Web site: http://www.ultimateungulate.com/Artiodactyla/Capra_falconeri.html.

Hunt M S, Gamache M K and Lockard S J (1978). Babysitting behavior by age/sex classification in squirrel monkeys (Saimiri sciureus). Primates. 19(1), 179-186.

Ilaria P, Niccolò F, Elisabetta M, Francesco F (2018). Sex/age differences in foraging, vigilance and alertness in a social herbivore. acta ethologica. 10.1007/s10211-018-0300-0.

Ims R A (1990). On the Adaptive Value of Reproductive Synchrony as a Predator-Swamping Strategy. The American Naturalist. 136(4), 485-498.

Jungius H (1970). Studies on the breeding biology of the reedbuck in the Kruger National Park. Zeit. Säugetierk. 35, 129-46.

Kelsall, J. P (1968). The migratory barren-ground caribou of Canada. Canadian Wildlife Service. 3, 340.

Khan B, Ahmed E, Khan M. Z, Khan G, Ajmal A, Ali R, Abbas S and Ali M (2014). Abundance, distribution, and conservation of key ungulate species in Hindu Kush, Karakoram and Western Himalayan (HKH) mountain ranges of Pakistan. International Journal of Agricultural Biology. 16, 1050–1058.

Klopfer P H, Adams D K and Klopfer M S (1964). Maternal "imprinting" in goats. Proceedings of the National Academy of Sciences. 52, 911-914.

Klopfer P H and Gamble J (1966). Maternal 'imprinting' in goats: The role of the chemical senses. Animal Psychology. 23, 588-93.

Klopfer, P. and Klopfer, M. S. 1968. Maternal 'imprinting' in goats: The fostering of alien young. Animal Psychology. 25, 862-66.

Landete-Castillejos T, Garciá A, Garde J, Gallego L (2000). Milk intake and production curves and allosuckling in captive Iberian red deer (Cervus elaphus hispanicus). Animal Behavior. 60(5), 679-687.

Landete-Castillejos T, Garcia A, Carrion D, Estevez J A, Ceacero F, Gaspar-Lopez E, Gallego (2009). Age-related body weight constraints on prenatal and milk provisioning in Iberian red deer (Cervus elaphus hispanicus) affect the allocation of maternal resources. Theriogenology. 71, 400–407.

Landete-Castillejos T, Garcia A, Molina P, Vergara H, Garde J and Gallego L (2000). Milk production and composition in captive Iberian red deer (Cervus elaphus hispanicus): effect of birth date. Journal of Animal Science. 78(11), 2771-2777.

Langbein J, Scheibe K M and Eichhorn K (1998). Investigations on periparturient behavior in free-ranging mouflon sheep (Ovis orientalis musimon). Journal of Zoology. 244, 553-561.

Langenau E E and Lerg J M (1976). The effects of winter nutritional stress on maternal and neonatal behavior of penned white-tailed deer. Applied Animal Behaviour Science. 2, 207–223.

Leckman J F, Herman A E (2002). Maternal behavior and developmental psychopathology. Biological Psychiatry. 51(1), 27-43.

Lent P C (1966). Calving and related social behavior in the barren-ground caribou. Animal Psychology. 23 , 702-756.

Lent P C (1974). Mother-infant relationships in ungulates. Geist V and Walther F (editors), in: The Behaviour of Ungulates and its Relation to Management. IUCN, Morges, Switzerland, 14-55.

Leuthold W (1967). Observations on the youth behavior of the Kob antelopes. Säugetierk. 32, 59-62.

Leuthold W (1977). African Ungulates: a Comparative Review of Their Ethology and Behavioral Ecology. Springer-Verlag, Berlin.

Lickliter R E (1985). Behavior associated with parturition in the domestic goat. Applied Animal Behavioral Science. 13, 335 -345.

Lima S L and Dill L M (1990). Behavioral decisions made under the risk of predation: a review and prospectus. Canadian Journal of Zoology. 68(4), 619-640.

Linnell J D C, Aanes R, Andersen R (1995). Who killed Bambi? The role of predation in the neonatal mortality of temperate ungulates. Wildlife Biology. 1(4), 209-223.

Linnell J D C, Andersen R (1998). Timing and synchrony of birth in a hider species, the roe deer (Capreolus capreolus). Journal of Zoology. 244, 497–504.

Linnell J D C, Nilsen E and Andersen R (2004). Selection of bed sites by roe deer fawns in agricultural landscape. Acta Theriologica. 49 (1),103-111.

Loberg J (2018). Personal communication. Educational manager. Nordens Ark
Åby säteri, Hunnebostrand, Sweden.

Loudon A S I, Darroch A D and Milne J A (1984). The lactation performance of red deer on hill and improved species pastures. The Journal of Agricultural Science. 102(1), 149-158.

Main, M B, Coblentz, B E (1996). Sexual segregation in Rocky Mountain mule deer. The Journal of Wildlife Management. 60, 497–507.

Main, M B (2008). Reconciling competing ecological explanations for sexual segregation in ungulates. Ecology. 89, 693–704.

Meijer T, Norén K, Angerbjörn A (2011). The impact of maternal experience on post-weaning survival in an endangered arctic fox population. European Journal of Wildlife Research. 57, 549–553.

Menrad M, Stier C, Geldermann H & Gall C.F (2002). A study on the Changthangi pashmina and the Bakerwali goat breeds in Kashmir - I. Analysis of blood protein polymorphisms and genetic variability within and between the populations. Small Ruminant Research. 43 (1).

Michel S & Rosen Michel T (2015). Capra falconeri (errata version published in 2016).The IUCN Red List of Threatened Species 2015.

Moberg G (1985). Influence of stress on reproduction: Measure of well-being. Animal Stress. G.P. Moberg (editor) . American Physiological Society. 245-267.

Moberg G (2000). Biological response to stress: implications for animal welfare. The biology of animal stress: basic principles and implications for animal welfare. edited by Gary P. Moberg, Joy A. Mench. CABI. 1,1-22.

Morgantini L. E and Hudson R. J (1985). Changes in diets of wapiti during a hunting season. Journal of Range Management. 38, 77–79.

Nowak R, Porter R H, Levy F, Orgeur P, Schaal B (2000). Role of mother-young interactions in the survival of offspring in domestic mammals. Reviews of Reproduction. 5, 153–163.

Numan M, Fleming A S, Levy F (2006). Maternal behavior J.D. Neill (Editor) (Third edition), The Physiology of Reproduction. 2, 1921-1993.

O'Brien P H (1983). Feral goat parturition and lying-out sites: spatial, physical and meteorological characteristics. Applied Animal Ethology. 10, 325-339.

O’Brien P H (1984). Leavers and stayers: maternal postpartum strategies in feral goats. Applied Animal Behavior Science. 12, 233–243.

Oftedal O T (1985). Pregnancy and lactation. In: Hudson RJ, White RG (editors). Bioenergetics of wild herbivores. CRC, Boca Raton, 215–238.

Ostrowski S, Thiaucourt F, Amirbekov M, Mahmadshoev A, Manso-Silván L, Dupuy V (2012). The fatal outbreak of Mycoplasma capricolum pneumonia in endangered markhors. Emerging Infectious Diseases. 17, 2338–2341.

Ozoga J J and Verme L J (1986). Relation of maternal age to fawn-rearing success in white-tailed deer. Journal of Wildlife Management. 50 (3), 480-486.

Packer C and Pusey A E (1983). Male takeovers and female reproductive parameters: a simulation of oestrus synchrony in lions (Panthera leo). Animal Behavior. 31, 334-340.

Packer C, Lewis S & Pusey A E (1992). A comparative analysis of non-offspring nursing. Animal Behavior. 43, 265-281.

Panzacchi M, Herfindal I, Linnell J D C, Odden M, Odden J and Andersen R (2010). Trade-off between maternal foraging and fawn predation risk in an income breeder. Behavioral Ecology and Sociobiology. 64 (8), 1267-1278.

Pfeifer S (1985). Flehmen and Dominance among Captive Adult Female Scimitar-Horned Oryx (Oryx Dammah). Journal of Mammalogy. 66 (1), 160–163.

Pianka E R, Parker WS (1975). Age-specific reproductive tactics. The American Naturalist. 109, 453–464.

Pierrick B and Hervé F (2007). Induced or Routine Vigilance while Foraging. Oikos.116(10): 1603-1608.

Pluháček J & Bartošová J (2011). A case of suckling and allosuckling behavior in the captive common hippopotamus. Mammalian Biology, 76: 380-383.

Poindron P, Otal J, Ferreira G, Keller M, Guesdon V, Nowak R, Lévy F (2010). Amniotic fluid is important for the maintenance of maternal responsiveness and the establishment of maternal selectivity in sheep. Animal. 4, 2057-2064.

Pruitt W O (1961). On post-natal mortality in barren-ground caribou. Journal of Mammalogy. 42, 550-51.

Pulliam H R (1973). On the advantages of flocking. Journal of theoretical biology. 38(2):419–422.

Putu I G, Poindron P and Lindsay DR (1988). A high level of nutrition during late pregnancy improves subsequent maternal behavior of merino ewes. Proceedings of the Australian Society for Animal Production. 17, 294–297.

Raithel J D, Kauffman M, and Pletscher D H (2007). Impact of spatial and temporal variation in calf survival on the growth of elk populations. Journal of Wildlife Management. 71,795–803.

Ranjitsinh M K, Seth C M, Ahmad R, Bhatnagar Y V, and Kyarong S S (2005). Goat on the border. A rapid assessment of the Pir Panjal markhor in Jammu and Kashmir: Distribution, Status, and Threats. Publisher, New Delhi : Wildlife Trust of India.

Riedman, M L (1982). The Evolution of Alloparental Care and Adoption in Mammals and Birds. The Quarterly Review of Biology. 57(4): 405-435.

Rieucau G and Martin J G A (2008). Many eyes or many ewes: vigilance tactics in female bighorn sheep *(Ovis canadensis)* vary according to reproductive status. Oikos. 117(4), 501-506.

Roberts T (1969). A note on Capra falconeri. Z. Saeugetierkd. 34, 238-249.

Roberts T J (1977). The mammals of Pakistan. Ernest Benn, Ltd., London, England. 195-199.

Roberts B A (2012). An attack by a warthog Phacochoerus africanus on a newborn Thomson's gazelle. African Journal of Ecology. 50, 507-508.

Rose P, Roffe S & Jermy M (2008). Enrichment Methods used for Giraffa camelopardalis & Gazella dama mhorr at The East Midland Zoological Society: Twycross Zoo. RATEL. 35 (1), 19-24.

Roulin A (2002). Why do lactating females nurse alien offspring? A review of hypotheses and empirical evidence. Animal Behavior. 63, 201—208.

Rudge M R (1969). Mother and Kid Behaviour in Feral Goats (Cupra hircus Linnaeus). Ethology. 27 (6), 641-760.

Rutberg A T (1984). Birth synchrony in American bison (Bison bison): response to predation or season? Journal of Mammalogy. 65(3), 418–423.

Ruthberg A T (1987). Adaptive hypotheses of birth synchrony in ruminants: an interspecific test. The American Naturalist. 130 (5), 692-710.

Sambraus H H, Wittmann M (1989). Observations of the birth and suckling behavior of goats Tierarztliche Praxis. 17, 359-365.

Savinov E S (1962). The reproduction and growth of the Siberian ibex in the Dzhungarian Ala Tau of Kazakhstan.

Schaller G B (1977). Mountain monarchs—wild sheep and goats of Himalayas. University of Chicago Press, Chicago. 425.

Sèbe F, Aubin T, Boué A and Poindron P (2008). Mother–young vocal communication and acoustic recognition promote preferential nursing in sheep. Journal of Experimental Biology. 211, 3554-3562.

Shackelton D M (1997). Wild sheep and goats and their relatives. Status survey and conservation action plan for Caprinae. IUCN/SSC Caprinae Specialists Group, IUCN, Gland, Switzerland.

Singer F J and Mack J A (1999). Predicting the effects of wildfire and carnivore predation on ungulates, 189–237 in Clark, T. W., Curlee, A. P., Minta, S. C., and Karieva, P. M., editors. Carnivores in ecosystems: the Yellow-stone experience. Yale University Press, New Haven, Connecticut, USA.

Sih A, Krupa J and Travers S (1990). An experimental study on the effects of predation risk and feeding regime on the mating behavior of the water strider. The American Naturalist. 135, 284 -290.

Skinner J D and van Zyle J M H (1969). Reproductive performance of the common eland, (Taurotragus oryx) in two environments. Journal of reproduction & fertility. 6, 319-322.

Smith F V (1965). Instinct and learning in the attachment of lamb and ewe. Animal Behavior. 13, 84-86.

Smith M C & Sherman D M (1994). Musculoskeletal system. In Goat Medicine. Eds C. Cann, S. Hunsberger, R. Lukens, M. Denardo. Lippincott Williams & Wilkins. pp 63-113.

Smith J B, Jenks J A, Grovenburg T W and Klaver R W (2014). Disease and predation: sorting out causes of a bighorn sheep (Ovis canadensis) decline. PLoS ONE 9(2), e88271.

Smith J B & Grovenburg T W & Jonathan A J (2015). Parturition and bed site selection of bighorn sheep (Ovis canadensis) at local and landscape scales: Bighorn Birth and Bed Site Selection. The Journal of Wildlife Management. 79(3), 393-401.

Solberg E J, Heim M, Grotan V, Saether B E, Garel M (2007). Annual variation in maternal age and calving date generate cohort effects in moose (Alces alces) body mass. Oecologia. 154:259–271.

Spinage C A (1986). Maternal reproduction and health in the Grant's gazelle (Gazella granti). Journal of Zoology.1, 461-520.

Spinka M, Newberry RC, Bekoff M (2001) Mammalian play: training for the unexpected. The Quarterly Review of Biology.76:141–168.

Susan L B, Noha A M, Joanne B M, Adam B, and George V K (2009). Diagnosis and treatment of Babesia odocoilei in captive reindeer (rangifer tarandus tarandus) and recognition of three novel host species. Journal of Zoo and Wildlife Medicine. 40(1), 152-159.

Synman M A (2010). Factors affecting pre-weaning kid mortality in South African Angora goats. South African Journal of Animal Science. 40 (1), 54-64.

Takada T, Kikkawa Y, Yonekawa H, Kawakami S, Aniano T (1997). Bezoar (Capra aegagrus) Is a Matriarchal Candidate for Ancestor of Domestic Goat (Capra hircus): Evidence from the Mitochondrial DNA Diversity. Biochemical Genetics. 35(9-10), 315-326.

Thenius E and Walther F R (1972). Horned ungulates. 273-307, in Grzimek's Animal Life Encyclopedia. Van Nostrad Reinhold (ed), new York.

Therrien J F, Côté S D, Festa-Bianchet M, Ouellet J P (2008). Maternal care in white-tailed deer: trade-off between maintenance and reproduction under food restriction. Animal Behavior.75, 235–243.

Thorne E T, Dean R E, Hepworth W G(1976) .Nutrition during gestation in relation to successful reproduction in elk (Cervus elaphus). Journal of Wildlife Mangment. 40 (2), 330-335.

Thorpe W H (1965). The assessment of pain and distress of animals in intensive livestock husbandry systems. In: Brambell F W R (chaired) Report of the Technical Committee to

Enquire into the Welfare of Animals Kept Under Intensive Livestock Husbandry Systems. 71-79. Her Majesty's Stationary Office: London, UK.

Torriani V G, Vannoni E, McElligott A G (2006). Mother-young recognition in an ungulate hider species: a unidirectional process. The American Naturalist.168, 412–420.
Tromborg C T, Coss R C (1995). Denizens, decibels, and dens. In: Annual Proceedings of the American Association of Zoos and Aquariums, Seattle, WA, 521–528.

Walther F R (1961). Some behavioral observations on the mountain game. Animal researchers. 1960-1961, 53-89.

Walther F R (1964). Behavioral Studies of the Genus Tragelaphus de Blainville (1816) in captivity, with particular attention to social behavior. Journal of Animal Psychology. 21 (4), 393-467.

Walther F R (1968). Behavior of the gazelles. A. Ziemsen Verlag, Wittenberg Lutherstadt, 144.

Walther F R (1969). Flight behavior and avoidance of predators in Thomson's gazelle (Gazella thomsoni)(Guenther 1884). Behavior. 34, 184-221.

Walther F R (1984). Communication and expressions in hoofed mammals. Bloomington, IN, Indian University Press.

Weinberg P I, Valdez R and Fedosenko A K (1997). Status of the Heptner´s Markhor (Capra falconeri heptneri) in Turkmenistan. Journal of Mammalogy. 78 (3), 826–829.

Welsh RAS and Kilgour R (1970). Mismothering among Romneys. New Zealand Journal of Agriculture. 121(4): 26–27.

Wheeler B C, Tiddi B, Kalbitzer U, Visalberghi E, Heistermann M (2013). Methodological Considerations in the Analysis of Fecal Glucocorticoid Metabolites in Tufted Capuchins (Cebus apella). International Journal of Primatology. 34(5), 879–898.

Wiesner H (1985). Problems in the Management of Chamois in Captivity. Lovari S (editor). The biology and management of mountain ungulates. 233-242.

Williams G C (1996). Adaptation and natural selection: a critique of some current evolutionary thought. Princeton (NJ) : Princeton University Press.

Wolfensohn S, Shotton J, Bowley H, Davies S, Thompson S, Justice WSM (2018). Assessment of Welfare in Zoo Animals: Towards Optimum Quality of Life. Animals (Basel). 8(7),110.

World Association of Zoos and Aquariums.