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Social interactions, time activity budgets and movement patterns in dairy goats (Capra hircus) housed in two different group sizes.

Sosiale interaksjoner, aktivitetsbudsjett og bevegelsesmønster hos melkegeiter (Capra hircus) oppstallet i to forskjellige gruppestørrelser.

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Acknowledgment

This thesis is submitted to obtain a Masters degree (30 sp) in Animal Science at the Norwegian University of Life Sciences (NMBU). With this thesis I am ending six wonderful years at UMB/NMBU. Although employment is waiting, it will be very strange no longer being a student.

Ever since I was little, I have always been fond of animals and thrived in their company. After a year as an intern at EKT Langedrag it became clear to me that when I would begin to study it had to be within biology and animal behaviour. And thanks to Inger Lise Andersen I decided after three years with biology to proceed with a master in Ethology.

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".. animals are the most complicated and perfectly designed pieces of machinery in the known universe .... it is hard to see why anyone studies anything else."

Richard Dawkins 1989

Department of Animal and Aquaculture Sciences, NMBU

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Abstract

Goats are, like most farm animals, group living animals. In todays animal husbandry of goats there is considerable variation in group size. Larger group sizes are generally associated with less aggressive interactions and more movement activity. In this thesis the main objective was to examine the effect of group size on social interactions, activity time budgets and movement patterns in Norwegian dairy goats. The experiment was conducted at the goat barn at the Norwegian University of Life Sciences (NMBU).

During this study a total of 90 pregnant goats were used. Out of those 36 were semi-randomly selected to look at the effects of group size. The goats were housed in two different group sizes; 6 and 24, and space per animal was 1.4 m^2. The goats remained in the same group throughout the experiment. The experiment was performed with three observation periods with both direct observations and video observations of social interactions, activity budget and movement patterns (November, December / January and January / February). A mixed model analysis of variance was used to analyse the effect of group size, week and time on social interactions, activity time budgets and movement patterns.

The results show that there was a higher frequency of defensive behaviour ($P = 0.02$) and a tendency towards more social activity ($P = 0.07$) in goats housed in large group than goats housed in small groups. In small groups, there was a higher frequency of resting than in large groups ($P = 0.01$). Goats in large groups were more active and had a higher frequency of moving ($P < 0.0001$) and moved generally larger total distances ($P < 0.0001$) than goats in small groups. The distance to the "furthest neighbour" was smaller in small groups than in large groups ($P < 0.0001$). The goats had a smaller distance to “nearest neighbour” in the first and third time period than during the second in the two first observational weeks ($P < 0.0001$). During the first and third time period 57.7% ± 1.9% and 58.8% ± 1.8% of the behaviours performed were feeding, whereas 63.7% ± 2.5% of the behaviours performed in the second time period was resting.

Sammendrag

Geiter er, som de fleste husdyr, gruppelevende dyr. I dagens husdyrhold av geiter er det stor variasjon på gruppestørrelse. Større grupper er generelt forbundet med mindre aggressive interaksjoner og mer bevegelse. Formålet med denne oppgaven var å se på hvilke effekter gruppestørrelse har på sosiale interaksjoner, aktivitetsbudsjett og bevegelsesmønster hos norske melkegeiter. Forsøket ble utført ved geitefjøset hos Norges Miljø og Biovitenskapelige Universitet (NMBU)

I dette forsøket ble det totalt brukt 90 drektige geiter, hvorav 36 av disse ble semi-tilfeldig valgt for å se på effekter av gruppestørrelse. Geitene ble oppstallet i to forskjellige gruppestørrelser; 6 og 24, og plass per dyr var 1.4 m^2. Geitene ble i samme gruppe under hele forsøket. Forsøket ble utført med tre observasjonsperioder med direkteobservasjon og videobservasjon av sosiale interaksjoner, aktivitetsbudsjett og bevegelsesmønster (november, desember/januar og januar/februar). En mixed model variansanalyse ble brukt for a undersøke effekten av gruppestørrelse, uke og tid på sosiale interaksjoner, aktivitetsbudsjett og bevegelsesmønster.

Resultatene viser at det var en høyere frekvens av defensive atferder (P=0.02) og en tendens til mer sosial aktivitet (P=0.07) hos geiter oppstallet i store grupper enn hos geiter oppstallet i små grupper. I små grupper var det en høyere frekvens av hvile enn i store grupper (P=0.01). Geitene i store grupper var aktive og hadde en høyere frekvens av bevegelse (P<0.0001) og beveget seg generelt større avstander (P<0.0001) enn geitene i små grupper. Avstanden til ”lengst borte nabo” var mindre i små grupper enn i store P<0.0001). Geitene hadde generelt en kortere avstand til ”nærmeste nabo” i første og tredje tidsperiode enn under den andre tidsperioden i de to første observasjonsukene (P<0.0001). Spising var under den første og tredje tidsperioden 57,7%±1,9% og 58,8%±1,8% av atferdene utført , mens under den andre tidsperiode var hvile 63,7%±2,5% av atferdene utført.

1. Introduction

The domestic goat (*Capra hircus*) descends from the bezoar goat (*Capra aegagrus*; Rutter, 2002). Today there are over 200 goat breeds, with a big phenotypic variety (Jensen, 2002). The goat was one of the first animals to be domesticated. The domestication of goats started in Mesopotamia (today Iran) ten thousand years ago (Boyazoglu et al., 2005). The goats played an important role in the older civilizations, providing the people with milk, meat and skin, which could be used for clothes and bottles. Because goats can graze on pastures with lower quality they became more popular than sheep (Boyazoglu et al., 2005). In Europe there has been a decrease in goat populations, while in Africa and Asia there have been an increase in the last years (Boyazoglu et al., 2005). In Norway there is today approximately thirty thousands dairy goats kept in 291 different farms (Ewa Wallin, personal coummincation, January 2015).

1.1. Living in groups

Many of our domestic animals originally lived in groups, and goats are no exception. It is thought that living in groups has been an advantage for the domestication of animals (Weary & Fraser, 2009). A group can be defined as "any set of organism belonging to the same species, that remain together over a period of time and who also are more social with each other than with other species" (Wilson, 1975).

1.1.1. Costs and benefits

For animals living in a group there are both benefits and costs. From an ecological point of view, the benefits of group living are increased foraging efficiency, reduced risk of predation, increased access to mates and help from kin. The costs of living in a group can be competition for food, increased risk of disease or parasites, attraction of predators, brood parasitism, loss of paternity and loss of individual reproduction (Krebs, 2009).

When living in a group the animals' chance of finding food is higher, since they can learn about food location from older animals and get information about food location from other members of the group. Social insects, such as bees, are a good example of this. Karl von Frisch discovered that bees that had found food flew back to the hive and communicated, through a waggle dance, the location of the food to the other members (Krebs, 2009). When many animals are feeding at the same time at the same place there is a higher level of group vigilance (Shrader et al., 2006). When there are more eyes to detect danger, each individual in the group can spend more time feeding. But if the food is limited or in a clumped distribution, it can lead to competition and animals will favour being in smaller groups (reviewed by Estevez et al., 2007).

Living in a group can decrease the chance of being the animal taken by a predator from 20% if living in a group with 5 animals to 2% if living in a group with 50 animals. This is called "dilution effect" and is a passive benefit of living in larger groups (Krebs, 2009). There is however, a balance between the benefit from the dilution effect and the costs of being many because it is easier to for the predators to find the animals.

Social learning and social thermoregulation are important positive effects of living in a group. By using social thermoregulation the animals reduce their heat loss (reviewed by Estevez et al., 2007). They can do this by lying or standing close to each other to reduce the body surface that is in contact with the cold air, as seen in penguins in the Antarctica. This way they can decrease their own body temperature loss (reviewed by Estevez et al., 2007). Croney and Newberry (2007) defined social learning as " the acquisition of new skills, information or behaviour as a result of interacting with other individuals". Through social learning animals can easier discover food and learn to avoid dangerous situations (reviewed by Estevez et al., 2007).

Synchronised behaviours are an important benefit of living in a group. It is a way to maintain the group's cohesion and stability (Conradt & Roper, 2000). Gregarious animals are seen grazing and resting at the same time for up to 90% of the time under ideal conditions (reviewed by Miranda-

de-la Lama & Mattiello, 2010). Synchronised behaviours are often reduced when housed in intensive production systems (DeVries et al., 2004). Reduction in synchrony can be an effect of domestication, since synchronised behaviours can be an important anti-predator strategy or due to higher competition for valuable resources such as food, water and a preferred resting place in intensive production systems (Jørgensen et al., 2009).

1.1.2. Hierarchy

When living in a group there will often be competition for valuable resources, such as food, mate and a place to lie down. This causes animals to compete for these resources, for both current and future access, and those who win often become more dominant than others. Dominant animals will have access to desirable or limited resources while subordinate animals will not. Subordinate animals will get access to resources when there is a shift in activity, e.g. the subordinates get access to food while the dominants rest (Lindberg, 2001). Dominant males will have access to oestrus females, while dominant females will have priority of access to food resources and favourable resting places (Fournier and Festa-Bianchet, 1995). Social dominance can reduce the risk of injury and energy cost of fighting and create a stabile social environment (Côte, 2000). Age, size and horns are factors that influence dominance in goats (Côte, 2000; Barosso et al, 2000).

Within a group every individual has a different behavioural strategy, which is used to achieve a certain goal (Mendl et al., 1992). A study conducted by Miranda-de-la Lama et al. (2011) showed that goats use different behavioural strategies in an attempt to cope with their social environment. By using a multivariate analysis it has been suggested that there are four different identity profiles to explain social strategies: the aggressive profile, the affiliative profile, the passive profile and the avoider profile (Miranda-de-la Lama et al., 2011). A study conducted by Barosso et al. (2000) showed that middle ranked animals were most productive, due to the high amount of energy and time dominant animals spend on protecting their food or other resources.

1.2. Group size

In the wild, there is a fine balance on how big a group can or should be. Optimal group size is "the size of the group that results in the largest relative benefit" (Krebs, 2009). Wild animals can choose to leave the groups when the costs outweigh the benefits; this is not possible for domestic animals. For farm animals the cost of living in a group is quite similar to those in the wild (reviewed by Estevez et al., 2007), but there is no risk of predation (except from when kept on pastures), brood parasitism or loss of paternity. The farmer chooses the group composition and the animals live within a limited space and environment. When resources become limited, animals kept in confined space will have nowhere to retreat from agonistic interactions or competition for the resources. Animal density (Vas et al., 2013), age (Bøe et al., 2013) familiarity (Færevik et al., 2007) and group size (Estevez et al., 2003) are important factors influencing social life in farmed animals.

Many of the domestic animals today originally lived in smaller groups than they are kept in today. In small group sizes it is easier for the animals to recognize each other, an important factor in establishing social bonds, than in larger groups. When group size increases it is harder for the individuals to recognise each other, and this makes it easier to form dominant hierarchies in small groups (reviwed by Estevez et al., 2007). Social recognition is a social memory from previous encounters that established a social status (Lindberg, 2001). How many individuals an animal remembers and for how long, varies between species. Sheep can remember as many as 50 conspecific for 2 years (Kendrick et al., 2001), while hens can recognise up to 96 conspecifics (reviewed by Rodenburg & Koene, 2007) and will treat an individual as a stranger after being separated for at least a few weeks (Lindberg, 2001). Individuals living in a large group can form subgroups and will stay closer together with these individuals than to the rest of the group members (Arnold et al., 1981).

Cognitive processes are linked to the social complexity in a group, and the social complexity increases with increased group size (reviewed by Croney & Newberry, 2007). When living in a large group there are more social stimuli from the other members of the group, and for wild

animals also from meeting other social groups. Living in farmed environmental conditions can result in a reduction in social stimuli, which again can lead to reduced social skills (reviewed by Croney & Newberry, 2007). Other effects of domestication can be rapid phenotypic changes, reduced fear and anti-predator response, increased sociability and an increased threshold for agonistic behaviour (Jørgensen et al., 2011). These changes can lead to a change in optimal group size in domestic animals.

Several studies have shown that when group size increases, there is a decline in aggression (pigs: Andersen et al., 2004; domestic turkey: Buchwalder & Huber-Eicher, 2005; goats: Andersen et al., 2011). However increased group size can have a negative effect i.e. leading to increased damaging behaviour, fear and stress (reviewed by Rodenburg & Koene, 2007). In the study conducted by Andersen et al. (2004), they found that there was a decline in number of aggressive behaviour in the large groups, but that fights were more intense and lasted longer. A mathematical model explained this where aggression was a function of group size. In large groups more animals will choose a non-aggressive strategy, and the reason can be that when the number of contestants increases it is harder to monopolize a resource (Andersen et al., 2004). However, in domestic fowl aggression does not seem to be a problem in large or small groups, but may be a problem in medium sized groups and can affect the production (reviewed by Rodenburg & Koene, 2007). What determines a large group differs between different species. The number of animals needed in a group to have the positive effect of large group size: e.g. reduced aggression; varies.

1.3.Social instability

In farming systems today animals are continuously changing groups, and this can lead to social instability, reduced feed intake and stress for the animals (reviewed by Estevez et al., 2007; Patt el al., 2013). Even reintegration of a familiar group member after a short time away from the group can have a negative effect on the welfare (Patt et al., 2013). When mixing unfamiliar individuals there is often an increase in aggressive behaviours, but once the social bonds are established aggression decreases (Buchwalder & Huber-Eicher, 2005; Færevik et al., 2007).

Introducing a new individual into an established group can have the same effect since it temporarily disrupts the social structure in the group (Addison & Baker, 1982). A study conducted by Addison and Baker (1982) showed that goats had a more aggressive behaviour towards an introduced female than an introduced male. In most studies looking at the effect of group size on agonistic behaviour, newly grouped animals are used (Jørgensen et al., 2009; Færevik et al., 2007; Andersen et al., 2011), but there have been few studies conducted on more stable groups.

Group size can have an effect on the level of aggression showed by the group members towards the introduced animal. A study conducted by Buchwalder and Huber-Eicher (2005) showed that individuals from small groups initiated more aggressive behaviours towards the new group member than the individuals in the large groups. Færevik et al. (2007) found a similar result, smaller groups of young calves showed more agonistic behaviours toward unfamiliar group members than calves in larger groups. However, this was only seen in the first day after regrouping. It is not just the size of the group the individuals live in at the present time that influences their level of agonistic behaviour, but also their previous experience. Animals originating from small groups show more aggressive behaviour towards their new group members than the animals originating from the large groups (Buchwalder & Huber-Eicher, 2005; Samarakone & Gonyou, 2009).

1.4 Movement patterns

How animals use space depends on how much space is available, as well as location and availability of resources, the complexity of the environment and social components (Averós et al., 2014). Spacing behaviour can provide knowledge about the social structure in a group of gregarious animals (Aschwanden et al., 2008). When housing animals in intensive systems their ability to move freely is removed, which can lead to an increase in aggressive behaviour. A study conducted by DeVries et al. (2004) showed that when feeding space was increased, the frequency of aggressive behaviours in dairy cows decreased by 43%. Enclosure size, group size and density may affect the animals' movement and use of space (Leone et al., 2008).

1.4.1. Definitions

When talking about spacing behaviour and individual distance, there are two main groups of factors controlling this, ultimate and proximate factors. The main ultimate factors are risk of predation and probability of finding food or other important resources, in combination of competition between other group members. These factors keep individuals closer together. The main proximate factors are position in dominance and behavioural activity. These factors increase the distance between the animals (reviewed by Keeling, 1995). The distance between two animals will result from the interaction between the ultimate and proximate factors.

There are many different terms referring to the area around an animal; e.g. personal space, intolerance space, personal distance. Keeling (1995) defined personal space as "the area around the individual which it tries to keep free from other individuals", while the individual distance is "the distance from the subject to the perimeter of the personal space". This is the minimum distance the animal will have between itself and another individual without responding with aggressive behaviour or by moving away from the intruder (reviewed by Keeling, 1995). Drickamer et al. (2002) defined individual distance as "the minimum distance that an animal keeps between itself and other members of the same species". Aschwanden et al. (2008) distinguished between two types of social distances, the "freely chosen distance" and the individual distance. The freely chosen distance was the distance the goats kept between each other when they had an option to keep a large distance between them, while individual distance was the smallest distance between individuals without agonistic or avoidance behaviour. Another term used in spacing behaviour is inter-individual distance and this describes: " the positioning of animals with respect to one another" (Leone et al., 2007).

1.4.2 Factors influencing movement patterns

Social distance is the maximum distance of dispersal in a group, and is affected by the group cohesion (Jørgensen et al., 2011). The meaning of cohesion within a group is how the group members disperse themselves. The members of a group keep a short distance between

themselves, often within communication range (Michelena et al., 2008). The balance between attraction and repulsion between group members is the basis for cohesion within in a group (Warburton & Lazarus, 1991). If cohesion within a group is strong, a group should be stable and keep together, but if it is weak the group might disintegrate. Flocking behaviour is mainly influenced by distribution and availability of resources and of predator pressure (Jørgensen et al., 2011). If the animals live in an environment with high risk of predation, groups should be large and with a high level of cohesion. When the animals stay closer together they can easier communicate with each other (Warburton & Lazarus, 1991). In contrary, if the animals live in an environment with low risk of predation, the groups should be smaller and have a low level of cohesion (Leone et al., 2007). A study conducted by Leone et al. (2010) showed that birds in the small groups did not maximize their individual distance, but kept closer together than was expected from mathematical simulations. It is expected that birds kept in small groups would maintain a higher level of group cohesion. This has been shown in a study conducted by Leone et al. (2007) where the birds in the smallest groups had the shortest "furthest neighbour" distances. Activity level is an important factor influencing group cohesion. A reduction in synchronised activities can lead to a reduced level of cohesion within a group (Michelena et al., 2008).

Group size can affect the way the animals organise themselves and alter the way the group uses the available space (Leone et al., 2010). The animals will also adjust how they use the space when there is a change in group size or environmental complexity (Leone et al., 2007). When enclosure size increased, and group size was kept constant, the use of space increased (Leone et al., 2010), while animals kept in enclosures with high animal density tended to move less (Estevez & Christman, 2006). When kept in larger groups, with a constant animal density, the enclosure will increase in size and the animals can have more movement opportunities (Liste et al., 2015). A study conducted by Leone et al. (2010) showed that with increased group size, with constant animal density, the movement activity increased in the larger groups. However, there was no difference in the total distance moved between the three different group sizes. In contradiction, Liste et al. (2015) found that animals kept in large groups moved larger total distances, as well as the animals had a higher level of locomotion.

1.4.3. Factors that affect proximity

The proximity to other members of the group will vary according to activity. Previous studies have shown that birds and cows have a larger individual distance when feeding than when moving, standing or resting (reviewed by Keeling, 1995). The reason can be risk of predation i.e. the animals will be closer together when performing behaviour that makes them more vulnerable, such as resting (reviewed by Keeling, 1995). Increasing the distances between themselves while feeding can also reduce the level of competition between group members.

Access to resources; i.e. food, water and resting place, can affect the proximity between individuals. When food was not available, goats had shorter distances between themselves than when food was available, either in free or limited distribution (Haugland, 2010). The animals' environment is not constant, and the animals will change their individual distance and distribution according to the available resources, in accordance to Fretwell´s theory (1972) on ideal free distribution.

Breed can have an effect on the minimum distance between two individuals. In a study conducted by Jørgensen et al. (2011) a heavier, more productive breed of sheep had larger individual distances than a smaller, less selected breed of sheep. Arnold and Dudziński (1978) found a similar result, where breeds of mountain sheep kept longer distances between themselves than lowland breeds. The reason for can be that the older breeds, which lived with the presence of predators, were selected by humans for their ability to flock, and therefore could be herded easier. When predators were less common, fast growth and better wool quality became more important than flocking ability (Jørgensen et al., 2011).

A study by Bøe et al. (2013) showed that younger goats had shorter distances to each other while feeding than older animals. A similar result has been found in savannah baboons where younger animals stayed closer to other group members than older animals (Pereira, 1988). This is thought

to be because younger animals are more at risk of predation than older individuals (Bøe et al., 2013).

Rank influences the individual distances (goats: Loretz et al 2004; pigs: McCort & Graves, 1982; dairy cows: Manson & Appleby 1990), but according to Aschwanden et al (2008) it is rather the quality of social bonds and age at grouping that influence the individual distance. Goats that grow up together and goats with amicable social bonds had shorter individual distances than goats with aggressive or neutral bonds (Aschwanden et al., 2008). A study conducted by Færevik et al. (2007) showed that calves kept in larger groups had a stronger preference for familiar group members and had an increased proximity to other calves than calves kept in small groups. There was also a higher frequency of social grooming between familiar calves kept in large groups, indicating that in large groups social bonds are more important than dominance.

Animals kept in confinement can adjust their inter-individual distance according to group size, enclosure size and animal density. Calves kept in larger groups had a lower inter-individual distance than calves kept in small groups (Færevik et al., 2007). This is in contradiction to other studies showing that when group size increases, and animal density was kept constant, there is little effect on the distance to the nearest neighbour (Leone & Estevez, 2008). However, when the space increased, and the group size was kept constant, the proximity between the individuals increased. A study conducted by Michelena et al. (2008) showed that when group size increased, while enclosure size was kept constant, the distance to nearest neighbour decreased. It seems that density, more than group size, is an important factor influencing the proximity to other group members.

1.5. Social interactions in goats (wild and domestic)

"Social behaviour is the glue that allows a group of animals to function" (Weary & Fraser, 2009) and happens anytime animals interact with each other. An agonistic interaction is defined as "an encounter between two individuals that result in the loser, the subordinate, backing away from

the winner, the dominant" (Fournier and Festa-Bianchet, 1995). Miranda-de-la Lama and Mattiello (2010) defined social behaviour as " all of the interactions between two or more individuals in a group that modify the activity of the group".

Although social behaviour of goats and sheep is often discussed under the broader term small ruminant, the social system of theses two species is somewhat different. Goat kids are "hiders", which means that the first days after parturition the mother leaves them while she is feeding, whereas lambs are "followers" and follow the ewe (Dwyer, 2009). However, goat kids develop a follower strategy 2-4 days after parturition (Dwyer, 2009). Adult goats tend to be more aggressive than adult sheep (reviewed by Miranda-de-la Lama & Mattiello, 2010), e.g. in the presence of a predator goats will face the predator and defend the kids and themselves, whereas sheep flee (Dwyer, 2009). Female mountain goats show more aggressive interactions than other female ungulates (Fournier and Festa-Bianchet, 1995).

Wild goats (*Capra aegagrus and Capra falconeri*) normally live in groups of 2-10 animals, but when food is abundant they can live in groups as big as 100-150 (Shackleton & Shank, 1984). Goats are matrifocal, meaning that the females and the offspring live together, while the sexually mature males will segregate and live in small bachelor groups with overlapping territory to the female groups (Dwyer, 2009). Although in some populations studied, sexually mature males remained with the females (reviewed by O´Brien, 1988). This occurs in areas where there is year-round breeding (Shackleton & Shank, 1984).

Social behaviour in goats, both agonistic and non-agonistic, is well described (Shackleton & Shank, 1984; O´Brien, 1988; Fournier and Festa-Bianchet, 1995; Barosso et al., 2000; Côte 2000) Goats are gregarious animals and are rarely seen alone (Albuquerque Paulo & Lopes, 2014). When separated from the group goats react with increased cortisol levels and behavioural signs of stress (Kannan et al., 2002; Patt et al., 2013). Goats communicate with each other by olfactory,

vocal, tactile and visual signals. By letting an isolated goat have visual, tactile and vocal contact with other goats can lead to a reduced stress reaction (Patt et al., 2013).

Dominant relationships in a group are established through agonistic behaviours. Intense competition for resources is quite common in goats. The agonistic behaviours in goats can be with physical contact, e.g. biting and pushing, or without physical contact, e.g. threat displays, and chases (reviewed by Miranda-de-la Lama & Mattiello, 2010). When kept indoors goats show more aggressive interactions than they do on pastures. A study conducted by Barosso et al. (2000) showed that on pastures 75.5% of the behaviours observed were passive, while indoors this decreased to 52%, and the percentage of aggressive behaviours increased from 24.5% on pastures to 48% indoors. This increase in agonistic behaviours can be due to the limitation in space when keeping the goats inside. The presence of horn can also influence the agonistic behaviours in goats. A study conducted by Loretz et al (2004) showed that horned goats were more aggressive, than dehorned goats. However, a study conducted by Aschwanden et al. (2008) showed that dehorned goats had more physical interactions than goats with horns, while the opposite was true for agonistic interactions without physical contact.

While agonistic behaviours establish dominance relationships, non-agonistic behaviours – or affiliative behaviours, like social grooming, exploring, sniffing and licking the base of the udder can improve group cohesion, reduce aggression and create or strengthen social bonds between individuals (reviewed by Miranda-de-la Lama & Mattiello, 2010).

Goats kept inside often compete for resources, i.e. food, water, space and lying place, and their ability to get access to the resource is affected by their social status. The social dominance in goats is thought to be stable and have nearly linear hierarchical order (Addison & Baker, 1982; Barosso et al., 2000; Aschwanden et al., 2008). A study conducted by Aschwanden et al (2008) showed that the goats grouped when adult had a complete linear hierarchy, while the goats grouped as young had a near-linear hierarchy. In female goats, once the group has been

established, the social status remains stable for the rest of their life (Shackleton & Shank, 1984). Contrary to these findings, Fournier and Festa-Bianchet (1995) found that the hierarchy in mountain goats are non-linear and non-random.

Limitations in feeding space can lead to an increased level of aggressive behaviours in goats (Jørgensen et al. 2007). a study conducted by Jørgensen et al. (2007) showed that by increasing the number of goats per feeding space, the aggression level increased and for some of the animals the feeding time was reduced by 80%. Usage of partitions and elevated levels, and in this way giving the goats visual cover, can have a positive effect on feeding- and agonistic behaviour (Aschwanden et al., 2009). In contrast, size of lying area had no significantly effect on aggressive behaviour, but having resting area organised in two levels reduced the overall level of aggressive behaviours (Andersen & Bøe, 2007). When decreasing the resting area, Andersen and Bøe (2007) found that time spent resting and resting synchronously decreased and resting in activity area increased.

Group size can have an effect on social interactions in goats. In a study conducted by Andersen et al. (2011) goats were housed in groups of six, twelve and twenty-four individuals, either starting as one large group, or four small groups. Goats that were kept in the largest group had the lowest level of social interactions, both agonistic and non-agonistic.

1.6 Aim

There are large variations in group sizes in dairy goats, and factors such as group size and density can affect social interactions and activities. The aim of this project was to study the effect of two different group sizes on social interactions, activity budgets and movement patterns in goats.

Our predictions were:

- More social interactions, both agonistic and non-agonistic, in small groups than in large groups
- More movement in large groups than in small groups
- Less resting in large groups than in small groups
- No difference in proximity to other group members between the two group sizes
- Goats kept in large groups will have a larger distance to furthest neighbour than goats housed in small groups

2. Material and methods

2.1. Project

This experiment was a part of a larger project called Animal Welfare Indicators project (AWIN). It was financed by the 7th Framework programme of the European Union (FP7-KBBE-2010-4).

2.2. Experimental design

Thirty-six pregnant Norwegian dairy goats were used to investigate the effect of different group sizes on social behaviour, movement patterns and activity time budgets during their pregnancy (approximately 154 days). The density was kept constant at approximately 1.4 m^2 per goat, and the group size was either six or twenty-four goats (containing eighteen non-focal goats). There were three groups with six goats and three groups with twenty-four goats. The goats were kept in the same group in the same pen throughout the study. During the study there were three direct observations for each pen as well as video recordings.

2.3. Animals and housing

A total of ninety pregnant Norwegian dairy goats were used in this experiment and all were from the experimental herd of the Norwegian University of Life Science. Thirty-six of these goats were semi-randomly chosen to investigate the effect of group size on social behaviour, activity time budgets and individual distances during their pregnancy. All age categories were represented in each pen, and the goats in the same pen had a close predicted parturition time. They were kept in the same group and in the same pen throughout the experiment, with the exception of one non-focal animal in large group 2. This goat had to be replaced after two weeks because of abnormal sexual behaviour and aggression towards the other goats.

The focal goats were marked with coloured collars (purple, grey, green, red, blue and yellow) and painted with fur paint spray (1,2,3,4,5 and 6). There were six focal goats in each pen. All of

the goats were dehorned, and they were between 1 and 4 years old, mean age 2.08 ± 0.2 years. The mean weight of the goats were 52.8 ± 1.4 kg at the start of the experiment, and increased to a mean weight of 64.17 kg ± 1.6 kg at the end of the experiment. The goats were familiar with each other as they have been on pastures together during the summer (May to September) before the experiment started.

All the pens were located in the goat barn at the Norwegian University of Life Sciences. This barn has two insulated and mechanically ventilated rooms (Figure 1, Figure 2), and a room temperature of approximately 10 ^{o}C .The walls in the pens were 1.5 meter high to avoid contact between the different groups. The floor was expanded metal flooring and there was a 60 cm deep area made of solid wood at the end of the pen (see grey on Figure 3 & Figure 4). The pens were cleaned before morning feeding and sawdust was added to the area made of solid wood. There was some natural light through windows on both sides of the room, but artificial light was kept on between 8 am and 5 pm.

The goats were grouped in 6 different pens, three small and three large pens. The size of the pens were:

Small 1,2,3: 350cm x 230cm

Large 1: 1230cm x 270cm

Large 2: 1450cmx230xm

Large 3: 1340cmx260cm.

The goats were kept in the same groups and pens from the start of the experiment (early November) until kidding (mid February).

The goats had free access to fresh water, grass silage and salt blocks with copper. In all of the pens the animals had access to a common feeding trough so all animals could eat at the same

time. The trough was cleaned twice a day; mornings and afternoons, and new grass silage was supplied afterwards. In the last part of the experiment the goats were also given hay in the afternoon (from January). In addition the goats were fed 0.2 kg per goat of concentrate each morning, before given the grass silage. The amount of concentrate was gradually increased to 0.5 kg per goat during the last part of the experiment.

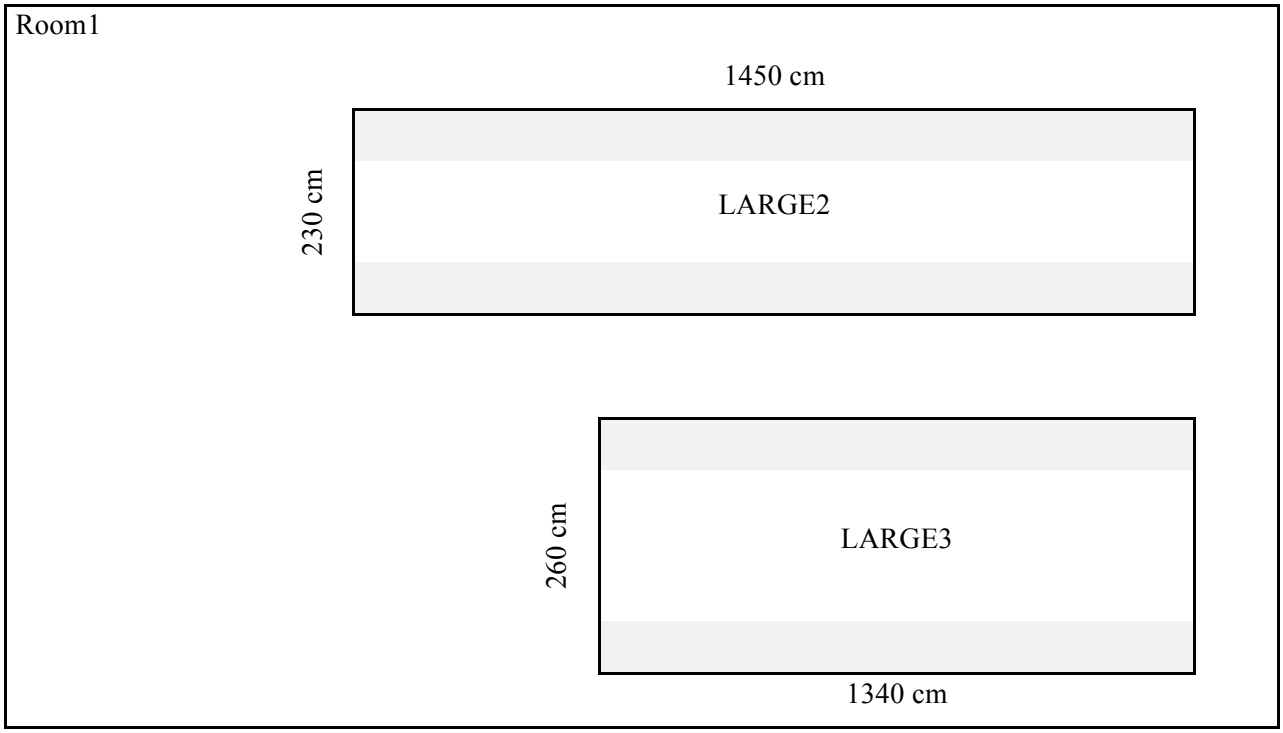

Figure 1. Overview of the pens in experimental room 1. The grey areas indicate solid wooden flooring.

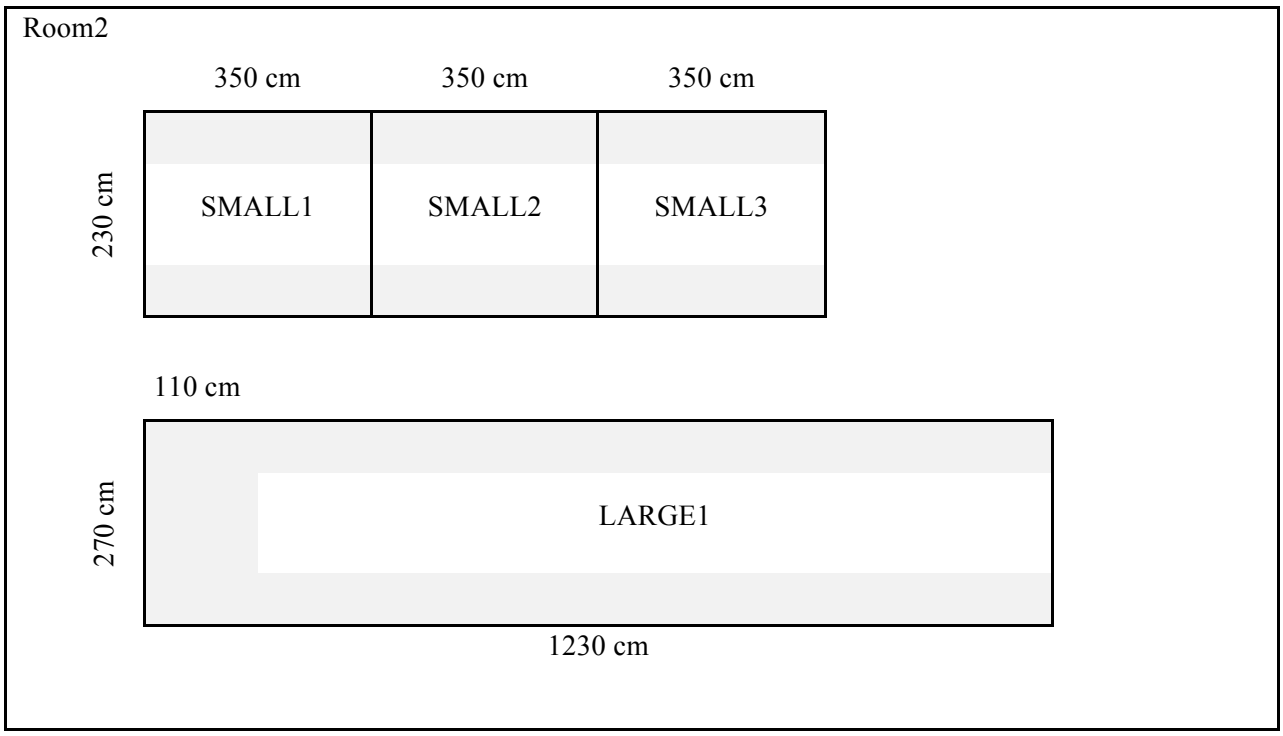

Figure 2. Overview of the pens in experimental room 2. The grey areas indicate solid wooden flooring.

2.4. Data collection and behavioural observations

2.4.1. Direct observations

Social behaviour was observed three times during the experiment. The first observations were conducted one week after the goats were placed into their groups to ensure that the rank was established. The second observations were conducted six weeks after the first observations for pens: Large 1, Large 2 and Small 2 and seven weeks after the first observations for pens: Large 3, Small 1 and Small 3. The third observations were conducted seven weeks after the second observations for pens: Large 1, Large 2 and Small 2, and six weeks after the second observations for pens: Large 3, Small 1 and Small 3. The observations were conducted over a period of two days for each observational period. The frequency of the behaviours was observed for 1.5 hours, and was performed after morning and afternoon feeding. The total hours of social behaviour observations were fifty-four hours. There were five different trained persons conducting the

observations. On the first day of mixing, all of the observers observed the same group to see if there was a big variation in how they determined the different behaviours. This data was not used for anything else. During the observations, there were two persons observing the large pens, and one person observing the small ones.

The behaviours were registered using an ethogram containing ten different behaviours. Type of observed behaviour, initiator and recipient were noted. The ethogram was based on studies performed by Andersen and Bøe (2007). The behaviours were defined as:

Frontal clashing: a position where the actor is rearing onto the hind legs with the head and torso twisted followed by descending forcefully onto the front legs delivering a powerful strike forwards and downwards reaching the head of the receiver.
Butting: contact (sudden and forceful movement) with head towards another goat.
Push: pressing the head to any part of another goat, slowly.
Threatening: pawing or rushing towards, or directing the forehead towards the opponent without physical contact, biting or attempt to bite another goat
Withdrawing: moving the head and/or the body away from another goat (after a social interactions)
Nosing on/exploring: nose in contact with another goat
Grooming: grooming by using another goat for this activity (the other can be either a passive recipient or take part actively in the mutual grooming)
Displacement from feeding place: making another individual with or without physical contact to leave its feeding place
Displacement from resting place: making another individual with or without physical contact to leave its resting place.
Intervention: one goat going between two or more goats and ending their social interaction.

Appendix no.1 shows how the behaviours were registered.

From the observed behaviours, frequency of three new categories were calculated:

Offensive behaviours: the sum of the frequency of frontal clash, initiated butting, initiated pushing, initiated threatening, initiated displacement from food and initiated displacement from resting place.

Defensive behaviours: the sum of the frequency of withdrawing received displacement from food and received displacement from resting place.

Positive behaviours: the sum of the frequency of nosing/exploring and grooming.

Observations from morning and afternoon on the same day were merged together.

2.4.2. Instantaneous sampling from video recording

There were fifteen digital cameras in the goat barn used for filming the goats' behaviour. There was one camera for each of the small pens, four cameras for Large 1, five cameras for Large 2 and three cameras for Large 3. They were manually turned on at approximately 8 am every Wednesday and were turned off at approximately 4.30 pm the same day throughout the experiment. The video system used was MSH video system (www.guard.lv). All the videos were recorded and stored on a hard disc.

The distance between the goats were recorded as instant sampling method with 10 minutes intervals from app. 9.00-10.30, 12.00-13.30 and 15.00-16.30. In this study only videos from those weeks when there were direct observations, have been used. In total there were 81 hours of video observations in this study. The software Chickitizer was used to register position and behaviour of individual goats in a pen and X and Y coordinates of the locations were derived from the software.

The behaviours were defined as:

Resting: lying
Passive standing: standing without moving
Moving: walking or running without any social interaction
Feeding: head placed above the feeder
Aggressive social interaction: being initiator or recipient of an agonistic interaction (threatening, chasing, butting, clashing, biting, avoiding, withdrawing, displacing)
Non-aggressive social interactions: being initiator or recipient of an non-agonistic, positive or neutral social interaction (grooming, exploring)
Exploration: exploratory behaviour in the direction of the non-living environment
Self-grooming
Stereotypies: stereotypies other than self-grooming, e.g. tongue playing, suckling each other, chewing the pen
Others: any behaviour that does not fit into the earlier mentioned categories (drinking, licking salt, urinating, scratching)

From the observed behaviours frequency one new category was calculated:

Social activities: the sum of the frequency of aggressive social interactions and non-aggressive social interactions

All observations from the ten different scans during the 1.5 hour observations were merged together for all animals.

To make the spatial data for distance the individual animal moved only the data from the focal animals were used. By using Microsoft Excel, the distances moved were calculated by the difference in XY coordinates from each scan, which was then summarized and used.

To make the spatial data for nearest and furthest neighbour data for animals, both focal and non-focal, were used. By using Excel the distance to nearest and furthest neighbour for the focal

animals were calculated for each scan. The ten scans were then summarized and the average for each time was used.

2.5. Statistical analysis

All data from the direct observations and instantaneous sampling from video recordings were put into and processed in Microsoft Office Excel 2011. Descriptive and derived parameters were calculated in Microsoft Office Excel 2011 and the tables and figures were also made there. All of the data was processed in the statistical analysis program SAS (SAS, 2013).

To analyse the effect of treatment, pen, week and time on the activity time budget, social interactions and movement patterns, a mixed model analysis of variance was used. The class variables in the analysis were treatment (small and large), week (1,2,3), time (1,2,3; this was not used for social interactions) and pen within treatment (1,2,3,4,5,6). All of the class variables were fixed effects, and age was included as a continuous variable. If a difference was detected, a post hoc test (Tukey) was used to detect difference between means. The criteria for a significant difference was set p-value = 0.05, and the criteria for tendencies were set to p-value<0.10.

2.6. Ethical statement

All of the animals in this experiment were recruited from the experimental goat herd at the Norwegian University of Life Sciences in Ås, Norway. They were kept in typical commercial way that is common for dairy goats in Norway. The rules for keeping small ruminants and farm animals in Norway were followed (Landbruks- og matdepartementet, 2005). The experiment was approved by the Animal Production Experimental Centre (Senter for husdyrforsøk, SHF). The animals were not exposed to anything that is not common in the practise for keeping dairy goats in Norway, nor in the EU.

3. Results

3.1. Social interactions

During the direct observations a total of 9016 behaviours were observed. The most common behaviours were butting (25.9% of all observations), threatening (25.4% of all observations) and displacement from food (15.8% of all observations; Figure 3).

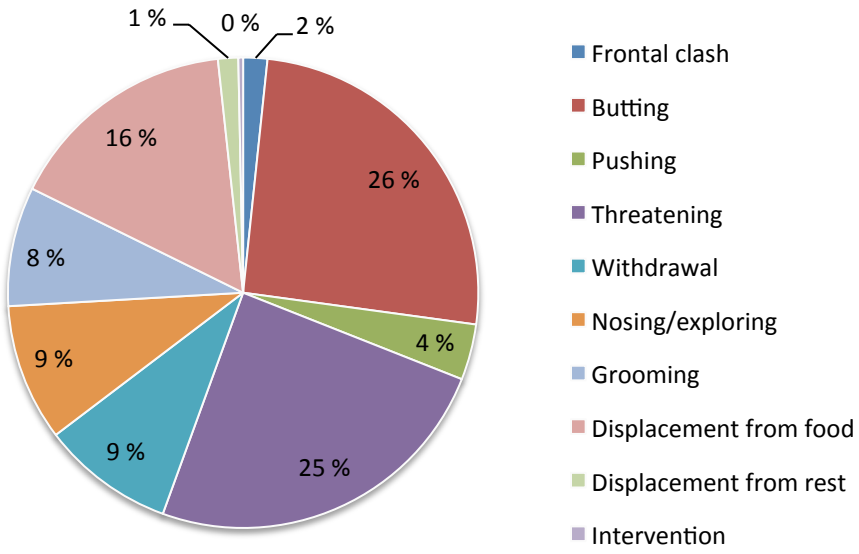

Figure 3. Percentage of all observed behaviours during the direct observations.

Only the new categories: “offensive behaviours”, “defensive behaviours” and “positive behaviours” were used for further analysis. A higher frequency of offensive behaviours was observed in the first week compared to the second and third week (Table 1a; Table 1b). During the first week, one goat in the large groups was involved in 259 offensive behaviours. All focal goats were involved in offensive behaviours for all three observational weeks. There was no effect of group size or age on the frequency of offensive behaviours. In the large groups, there was a higher frequency of defensive behaviours than in the small groups (Table 1a; Table 1b). All focal goats were involved in defensive behaviours for all three observational weeks. There was no effect of group size, week or age on the frequency of positive behaviours (Table 1a; Table 1b)

Table 1a. Social interactions in goats (mean±SE number of events per goat) with respect to group size and week.

	Treatment		Week		
Behaviour	**Small**	**Large**	**1**	**2**	**3**
Frontal clashing	1.4±0.4	1.5±0.7	2.4±1.1	1.4±0.4	0.6±0.3
Butting	19.5±1.7	23.7±7.4	31.0±11.0	16.5±1.7	17.3±1.9
Pushing	2.2±0.3	4.4±1.0	4.8±1.5	3.3±0.5	1.8±0.4
Threatening	18.8±1.9	23.7±2.2	33.4±2.3	14.6±2.1	15.7±1.9
Withdrawal	7.2±0.7	7.1±0.7	6.5±0.8	9.1±0.8	5.9±0.8
Nosing/exploring	5.9±0.7	9.3±0.8	8.2±1.1	8.1±1.0	6.4±0.7
Grooming	6.2±0.9	7.1±1.0	7.8±1.2	5.6±1.0	6.6±1.2
Displacement food	10.9±0.9	15.5±1.2	16.7±1.5	11.4±1.3	11.5±1.0
Displacement rest	1.2±0.2	0.9±0.2	0.6±0.1	0.8±0.2	1.7±0.3
Intervention	0.2±0.1	0.4±0.2	0.3±0.2	0.3±0.1	0.2±0.1
Offensive	27.0±2.8	33.5±5.1	44.6±7.6	23.6±2.2	22.5±2.4
Defensive	9.6±1.0	14.5±1.2	13.4±1.4	11.7±1.5	11.0±1.2
Positive	6.1±0.7	7.0±0.8	6.8±0.9	6.3±1.0	6.6±0.9

Table 1b. Results from mixed model analysis of variance on social interactions.

	Treatment (df=1,29)		Week (df=2,29)		Pen (df=4,29)		Age (df=1,29)		Treatment*Week (df=2,29)	
Behaviour	**F-value**	**p-value**	**F-value**	**p-value**	**F-value**	**p-value**	**F-value**	**p-value**	**F-value**	**p-value**
Offensive	0,97	NS	4,39	0,02	2,41	0,07	2,78	NS	3,95	0,03
Defensive	6,16	0,02	1,44	NS	0,08	NS	2,08	NS	0,92	NS
Positive	0,76	NS	0,10	NS	2,34	0,08	0,90	NS	1,85	NS

3.1.1 Offensive behaviours

There was an interaction between group size and week ($F_{2,29}$=3.95, P=0.03; Figure 4). Goat
in large groups showed more offensive behaviours during the first week than during the sec
and third week. The frequency of offensive behaviours was higher during the second week t
during the third week in the large groups. Goats kept in large groups tended to show more
offensive behaviours during the second week than goats kept in small groups.

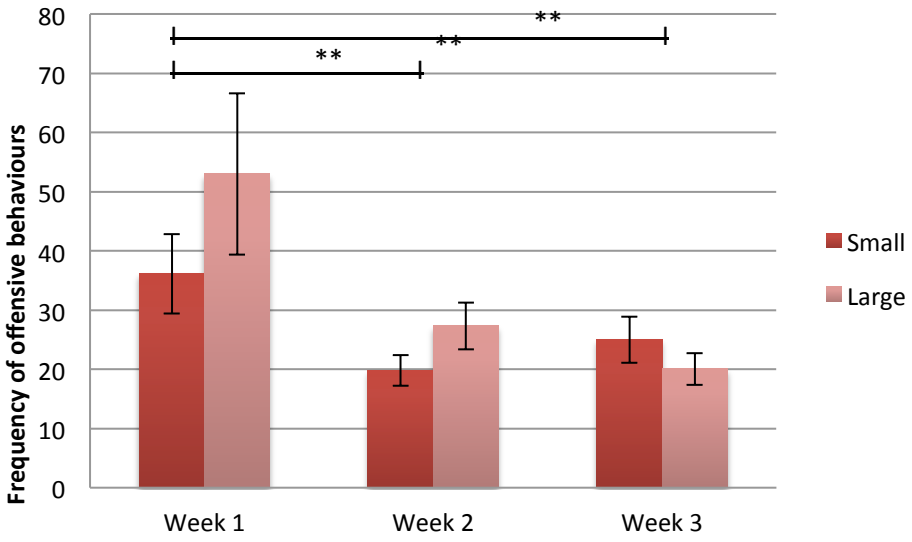

Figure 4. Interaction between group size and week on the frequency of offensive behaviours (mean±SE).** indicates difference between weeks at P<0.01 level.

3.2. Activity time budget

From the video recordings a total of 3240 behaviours were observed. The most common ones were feeding (43.6% of all observations), resting (29.4% of all observations) and passive standing (14.5% of all observations; Figure 5).

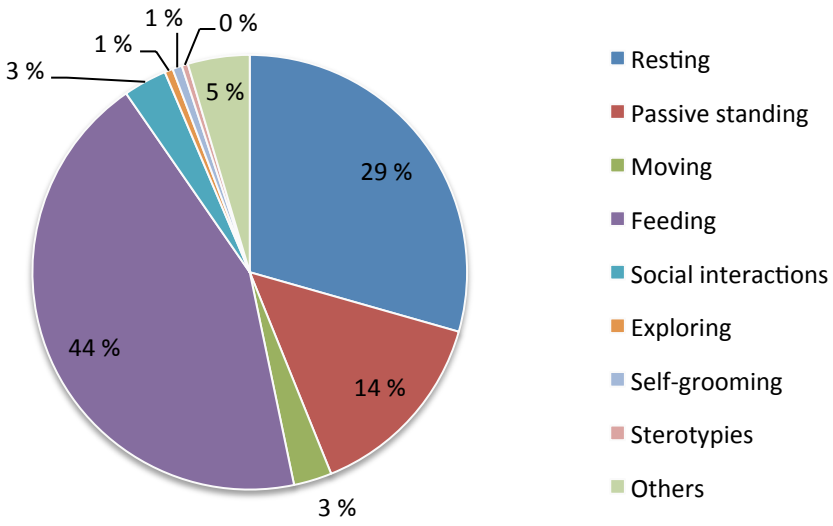

Figure 5. Percentage of all observed behaviours during the video recordings.

Due to the low percentage of the frequencies of the behaviours "exploring", "self-grooming" and "stereotypies", these behaviours were not used for further analysis (Figure 7; Table 2a). The behavioural category "others" was not used because it contains several different behaviours such as drinking, scratching and licking on the salt blocks.

Goats kept in small groups had a higher frequency of resting than goats kept in large groups. There was a higher frequency of resting during the third week than in the two former weeks. The goats rested more during the second time period than in the first and third time period (Table 2a; Table 2b).

There was a higher frequency of passive standing in the third week than in the second, but no significant difference between the first and second week or between the first and third week.

There was no effect of group size, time or age on the frequency of passive standing. (Table 2a; Table 2b).

Goats in the large groups had a higher frequency of moving compared to goats in the small groups. The frequency of moving was higher in the second time period than in the third time period, but there was no significant difference between the frequency of moving in the first time period compared to the second time period or between the first time period compared to the third time period (Table 2a;Table 2b). There was no effect of week or age on the frequency of moving.

In the third week the goats had a lower frequency of feeding compared to the two former observational weeks.. The frequency of feeding was lower during the second time period than in the first and third time period (Table 2a; Table 2b). There was no effect of group size or age on the frequency of feeding.

The goats in the large groups tended to have a higher frequency of social activities than the goats in the small groups (Table 2a; Table 2b). There was no effect of week, time or age on the frequency of social activities.

Table 2a. Activity time budget (means ±SE% of events per goat) with respect to group size, week and time.

	Treatment		Week			Time		
Behaviour	**Small**	**Large**	**1**	**2**	**3**	**1**	**2**	**3**
Resting	31.0±2.4	27.8±2.5	26.9±3.1	27.3±3.1	34.0±2.9	12.7±1.7	63.7±2.5	11.9±1.6
Passive standing	13.6±1.0	15.4±1.0	12.5±1.3	12.5±1.2	17.5±1.3	14.7±1.2	13.6±1.4	15.1±1.2
Moving	2.2±0.4	3.5±0.5	2.5±0.5	3.0±0.6	3.1±0.5	2.9±0.5	1.9±0.4	3.7±0.6
Feeding	43.5±2.0	43.8±2.2	47.9±2.9	46.7±2.6	36.4±2.2	57.7±1.9	14.4±1.3	58.8±1.8
Social activities	2.9±0.5	3.6±0.6	4.0±0.7	3.4±0.7	2.3±0.7	3.9±0.7	2.9±0.8	3.0±0.6
Exploring	0.6±0.2	0.7±0.2	0.9±0.3	0.8±0.3	0.1±0.1	0.6±0.3	0.5±0.2	0.1±0.1
Self-grooming	0.9±0.2	0.6±0.2	0.3±0.2	1.2±0.3	0.6±0.2	1.4±0.3	0.1±0.1	0.6±0.3
Stereotypies	0.6±0.2	0.4±0.1	0.2±0.1	0.6±0.2	0.6±0.2	0.6±0.2	0.5±0.2	0.3±0.2
Others	4.9±0.5	4.3±0.5	3.9±0.6	4.5±0.6	5.4±0.7	5.6±0.6	2.4±0.6	5.8±0.7

Table 2b. Results from mixed model analysis of variance on activity time budget.

	Treatment (df=1,29)		Week (df=2,29)		Time (df=2,29)		Pen (df=4,29)		Age (df=1,29)	
Behaviour	**F-value**	**p-value**	**F-value**	**p-value**	**F-value**	**p-value**	**F-value**	**p-value**	**F-value**	**p-value**
Resting	7.12	0.0124	4.80	0.02	217.89	<.0001	217.89	<.0001	0.01	NS
Passive standing	1.24	NS	3.38	0.05	0.48	NS	2.15	NS	0.20	NS
Moving	28.81	<.0001	0.26	NS	3.65	0.04	6.88	<.001	0.22	NS
Feeding	1.80	NS	20.86	<.0001	293.78	<.0001	3.85	0.01	0.63	NS
Social activities	3.49	0.0718	2.05	NS	0.70	NS	1.03	NS	0.64	NS

	Treat*week (df=2,29)		Treat*time (df=2,29)		Week*time (df=4,29)	
Behaviour	**F-value**	**p-value**	**F-value**	**p-value**	**F-value**	**p-value**
Resting	0.86	NS	10.63	<.001	9.00	<.0001
Passive standing	0.16	NS	2.40	NS	1.87	NS
Moving	0.46	NS	1.42	NS	0.82	NS
Feeding	1.14	NS	2.89	0.07	4.37	<.01
Social activities	0.60	NS	4.85	0.02	3.64	0.02

3.2.1. Resting

There was an interaction between group size and time ($F_{2,29}$=10.63, P<0.001; Figure 6). For both small and large groups there was a higher frequency of resting during the second time period compared to the first and third time period. Goats in the small groups had a higher frequency of resting than goats in the large groups during the third time period.

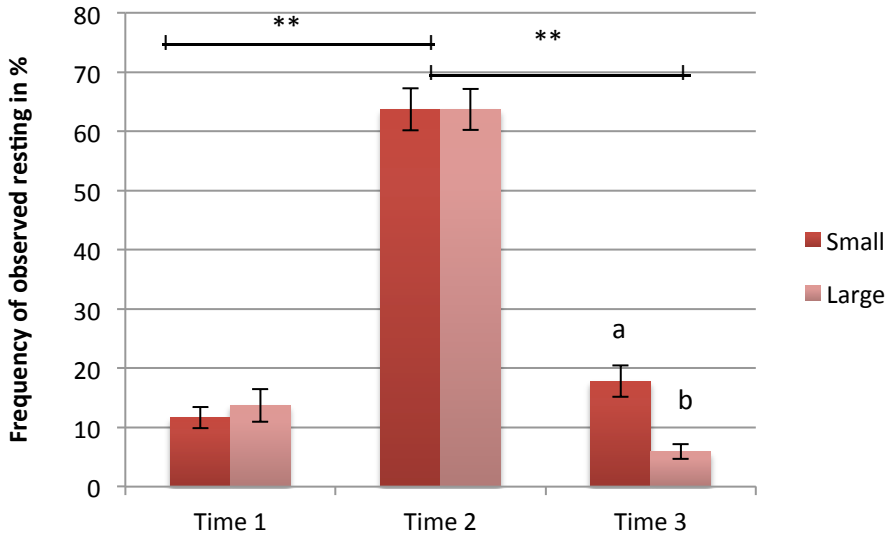

Figure 6. Interaction between group size and time on the frequency of resting (mean±SE %). Different letters indicate differences between group size within time at P<0.05 level, ** indicates difference between time at P<0.01 level.

There was an interaction between time and week ($F_{4,29}$=9.00 P<0.0001; Figure 7). For all three weeks there was a higher frequency of resting during the second time period compared to the first and third time period. In the first week there was a higher frequency of resting during the third time period than in the first time period, while it was the opposite during the third week.

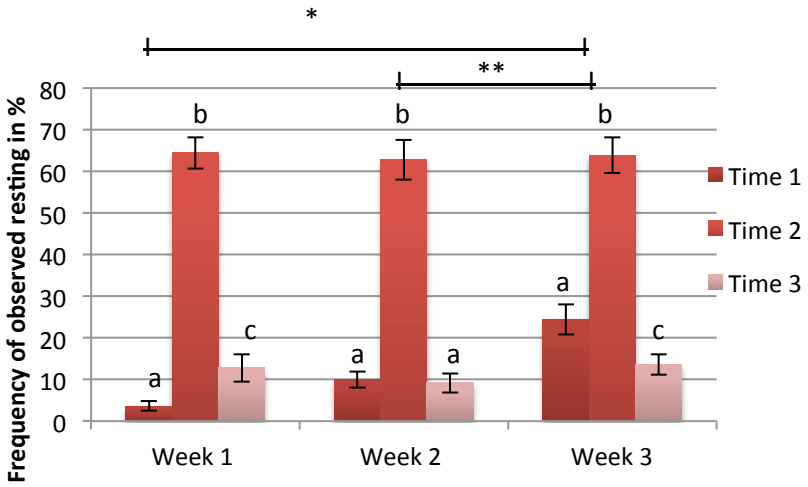

Figure 7. Interactions between time and week on the frequency of resting (mean±SE%). Different letters indicate differences between times within week at P<0.05 level, * indicates difference between weeks at P<0.05 level, ** indicates difference between weeks at P<0.01 level.

3.2.2. Feeding

There was an interaction between time and week, on the frequency of feeding ($F_{4,29}$=4.37, P<0.01; Figure 8). For all three observational weeks there was a higher frequency of feeding in the first and third time period compared to the second time period. The goats were feeding more in the two first observational weeks than in the last week the during the first and third time periods.

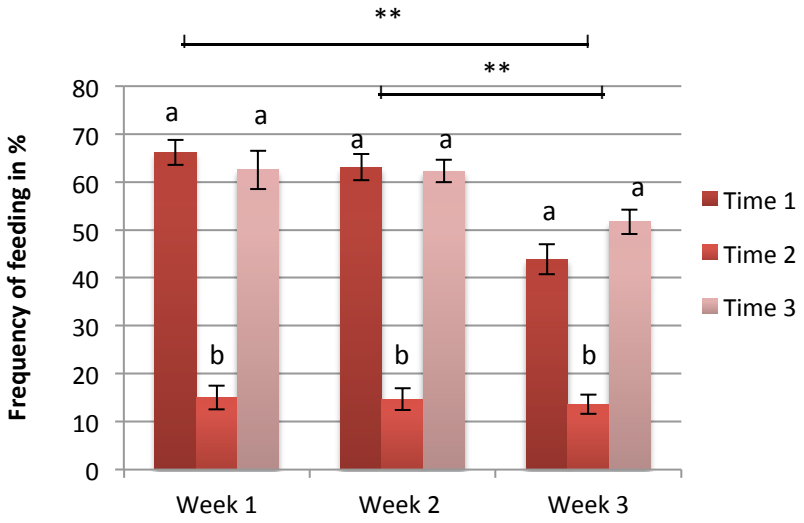

Figure 8. Interaction between time and week on the frequency of feeding (mean±SE %). Different letters indicate differences between times within week at P<0.05 level, ** indicates difference between weeks at P<0.01 level.

3.2.3. Social activities

There was a significant interaction between group size and time on the frequency of social activities ($F_{2,29}$=4.85, P=0.02; Figure 9). Goats kept in large groups were involved in more social activities than goats kept in small groups during the third time period. There was a tendency of decreased frequency of social activities in the small groups, with the highest frequency in the first time period and lowest in the third time period.

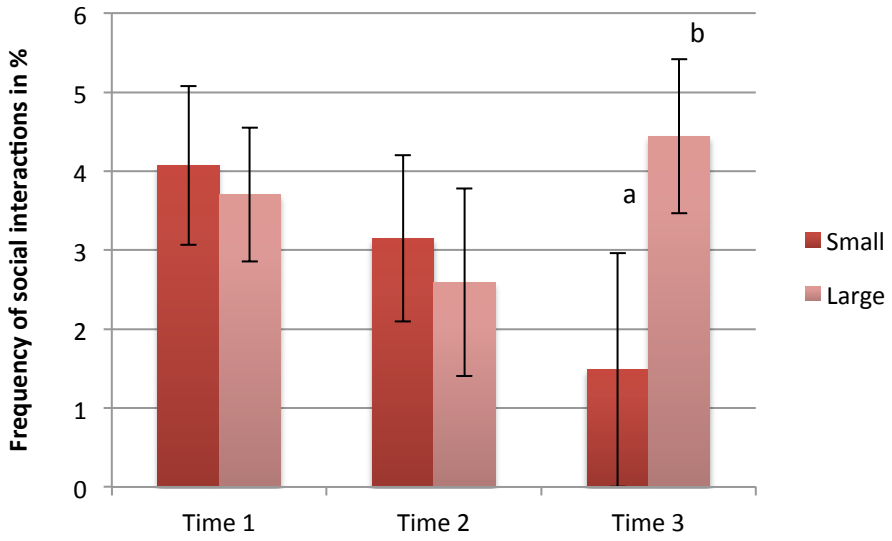

Figure 9. Interaction between group size and time on social activities (mean±SE%). Different letters indicate differences between group size within time at P<0.05 level.

There was a significant interaction between time and week on the frequency of social activities ($F_{4,29}$=3.64, P=0.02; Figure 10). During the first week the frequency of social activities was lower in the second time period than in the first and third time period. In the third week, the frequency of social activities was lower in than in the first and second week during the first time period.

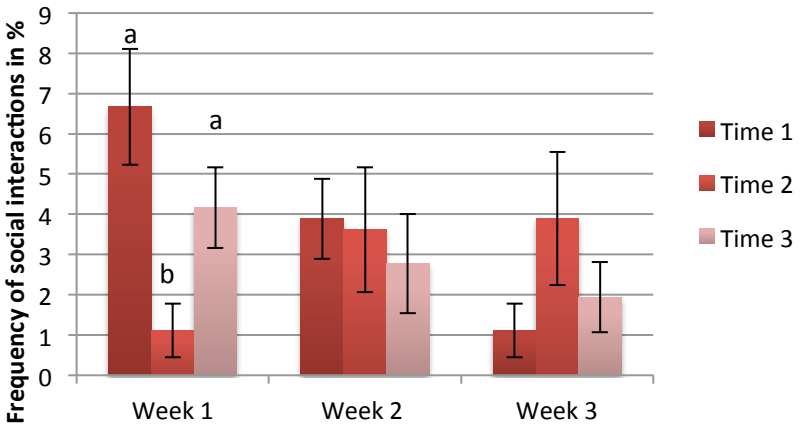

Figure 10. Interaction between time and week on social activities (mean±SE %). Different letters indicate differences between times within week at P<0.05 level.

3.3. Movement patterns

The largest distance moved was found in the one of the large groups and this individual moved 57.8 meters while the shortest distance moved was found in the one of the small groups where the individual moved 0.9 meters. The largest and shortest distance to nearest neighbour was in the small groups, with 1.7 meters and 0.4 meters to the animals nearest neighbour. The largest distance to furthest neighbour was in the large group. The individual was 13.2 meters from its furthest neighbour. The shortest distance to the furthest neighbour was in the small groups. The individual was 2.1 meters from its furthest neighbour

Goats in large groups general moved larger distances than goats in the small groups. During the second time period the goats moved shorter distances than in the first and third time period. There was no effect of week on the distance moved (Table 3a; Table 3b).

The goats had the largest distance to the nearest neighbour in the third week, and the smallest in the second week. During the second time period the goats had the largest distance to the nearest

neighbour. The distance in the first and third time period was approximately the same. There was no effect of group size or age on the distance to nearest neighbour (Table 3a; Table 3b).

The goats in the small groups had shorter distances to their furthest neighbour than the goats in the large groups. There was no effect of week or time on the distance to furthest neighbour (Table 3a; Table 3b).

Table 3a. Movement patterns in goats (mean±SE meters per goat) with respect to group size, week and time.

	Treatment		Week			Time		
Behaviour	**Small**	**Large**	**1**	**2**	**3**	**1**	**2**	**3**
Distance moved	10.81±0.31	29.94±0.88	21.03± 1.35	19.32± 1.14	20.77± 1.18	21.83± 1.18	15.39±0.98	23.90± 1.35
Nearest neighbour	0.85± 0.02	0.84±0.01	0.85±0.02	0.79± 0.02	0.89±0.02	0.79± 0.01	0.94±0.02	0.81±0.02
Furthest neighbour	2.53± 0.02	9.38± 0.10	5.97± 0.35	6.02± 0.35	5.88± 0.33	5.89± 0.34	6.08± 0.35	5.90± 0.33

Table 3b. Results from mixed model analysis of variance on movement patterns.

	Treatment (df=1,29)		**Week (df=2,29)**		**Time (df=2,29)**		**Pen (df=4,29)**		**Age (df=1,29)**	
Behaviour	**F-value**	**p-value**	**F-value**	**p-value**	**F-value**	**p-value**	**F-value**	**p-value**	**F-value**	**p-value**
Distanced moved	1374.89	<.0001	2.52	0.10	52.73	<.0001	24.10	<.0001	4.36	0.05
Nearest neighbour	0.16	NS	8.41	<.01	30.29	<.0001	2.27	0.09	1.61	NS
Furthest neighbour	2935.04	<.0001	0.81	NS	1.33	NS	34.58	<.0001	5.25	0.03

	Treat*week (df=2,29)		**Treat*time (df=2,29)**		**Week*time (df=4,29)**	
Behaviour	**F-value**	**p-value**	**F-value**	**p-value**	**F-value**	**p-value**
Distanced moved	5.68	0.01	16.43	<.0001	0.75	NS
Nearest neighbour	0.94	NS	3.77	0.04	8.52	<.0001
Furthest neighbour	2.84	0.08	0.09	NS	1.33	NS

3.3.1. Distance moved

There was an interaction between group size and week on the total distance moved ($F_{2,29}$=5.68, P=0.01; Figure 11). For all three weeks goats in the large groups moved longer distances than goats in the small groups. Goats in the large group moved larger distances in the first and third week than in the second week, while this was not significant for goats in the small groups.

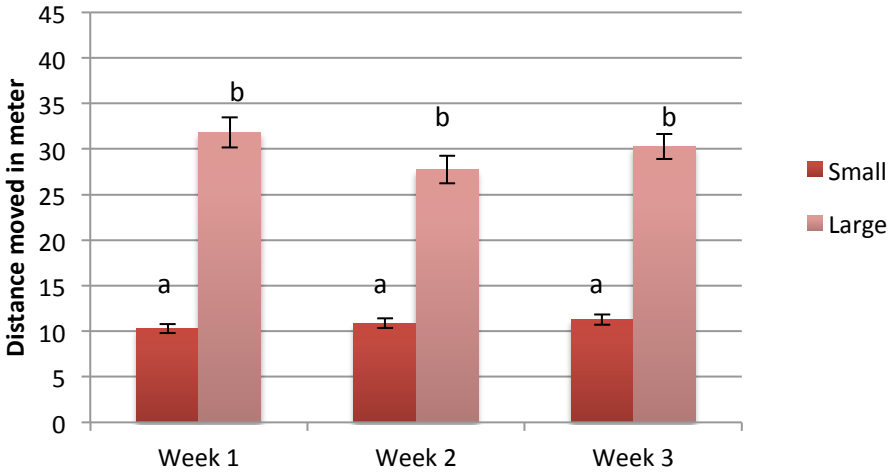

Figure 11. Interaction between group size and week on distance moved (mean±SE). Different letters indicate differences between group size within week at P<0.05 level.

There was an interaction between group size and time on the distance moved ($F_{2,29}$=16.43, P<0.001; Figure 12). For all three time periods goats in the large groups moved larger distances than goats in the small groups. During the first and third time period goats in both group sizes moved larger distances than in the second time period. It was a tendency for goats in the large groups to move more in the third time period than in the first time period

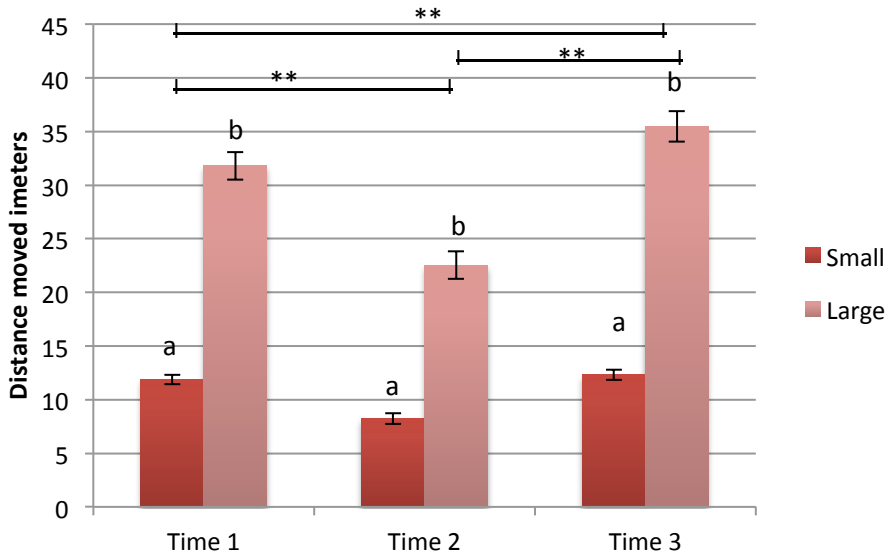

Figure 12. Interaction between group size and time on distance moved (mean±SE). Different letters indicate differences between group size within time at P<0.05 level, ** indicates difference between time at P<0.01 level.

There was a significant effect of age on the distanced the goat moved ($F_{1,29}$=4.36, P=0.05; Figure 13). As seen in the figure the younger goats moved more then the older ones.

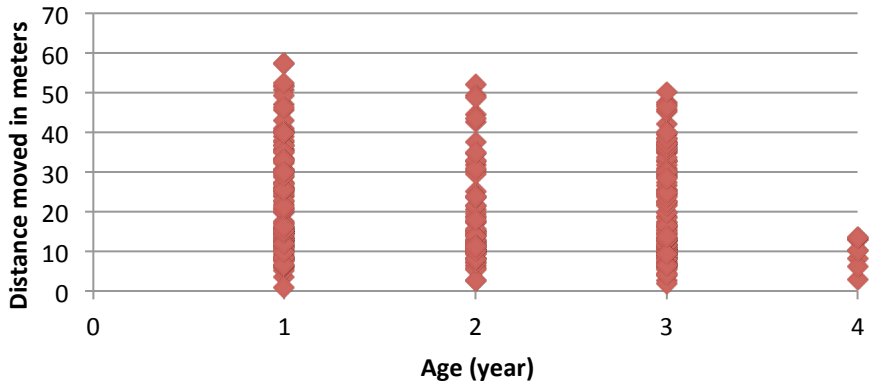

Figure 13. The distance moved according to age (mean±SE).

3.3.2. Nearest neighbour

There was an interaction between treatment and time on the distance to nearest neighbour ($F_{2,29}$=3.77, P=0.04; Figure 14). The largest distance to the nearest neighbour was during the second time period for both group sizes. During the third time period goats in the small groups had a larger distance to the nearest neighbour compared to goats in the large groups.

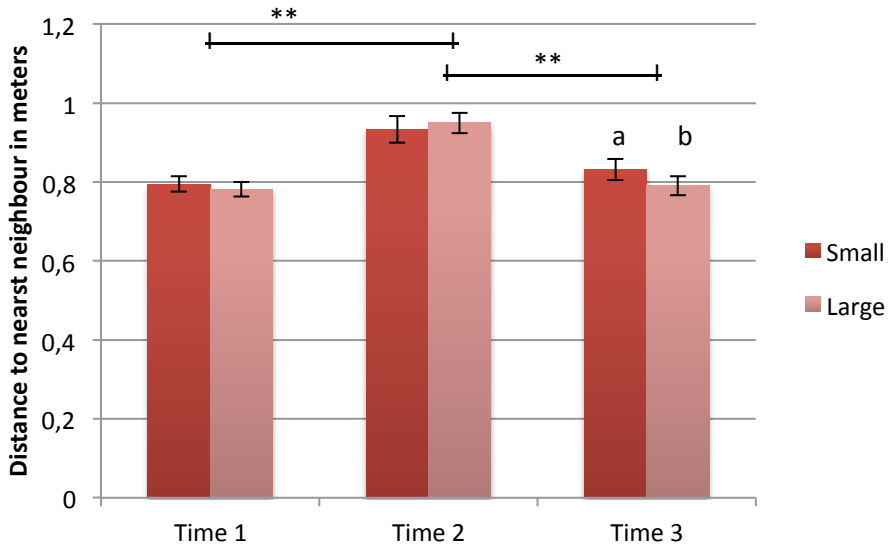

Figure 14. Interaction between group size and time on distance to nearest neighbour (mean±SE). Different letters indicate differences between group size within time at P<0.05 level, ** indicates difference between times at P<0.01 level.

There was an interaction between week and time on the distance to nearest neighbour ($F_{4,29}$=8.52, P<0.0001; Figure 15). In the first week, the goats had larger distances to nearest neighbour during the second time period compared to the first and third time period. The goats also had a larger distance to nearest neighbour in the third time period compared to the first time period. In the second week the goats had a larger distance to nearest neighbour in the second time period compared to the first and third time period, while in the third week there were no significant differences.

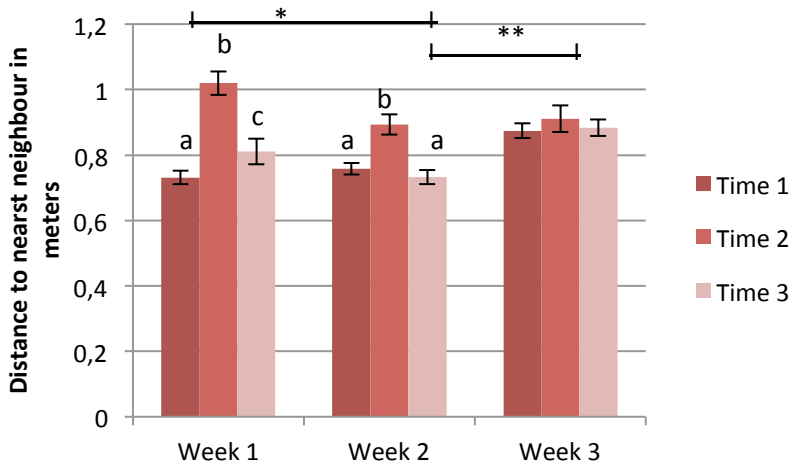

Figure 15. Interaction between week and time on distance to nearest neighbour (mean±SE). Different letters indicate differences between time within week at P<0.05 level, * indicates difference between weeks at P<0.05 level, ** indicates difference between weeks at P<0.01 level.

3.3.3. Furthest neighbour

There was a significant effect of age on the distanced to the furthest neighbour ($F_{1,29}$=5.25, P=0.03; Figure 16). As seen in the figure the goats that are 3 years old have the largest distance to their neighbours.

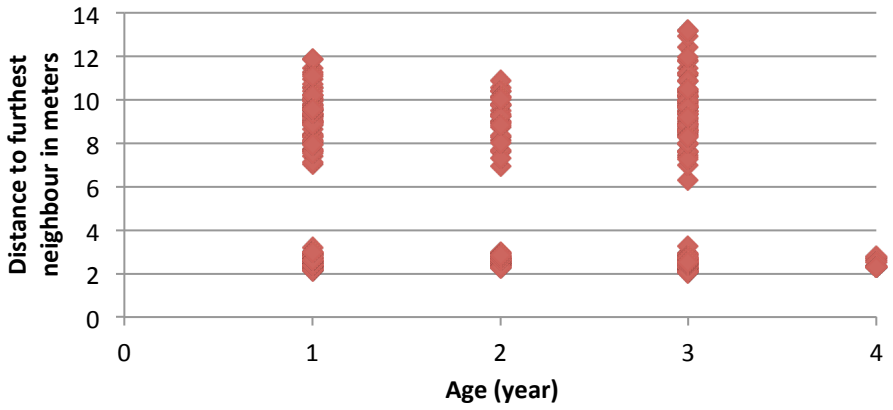

Figure 16. Distance to furthest neighbour according to age (mean±SE).

4. Discussion

Contrary to the first prediction goats housed in large groups showed a higher frequency of defensive behaviours than goats housed in small groups. In addition, there was a tendency of more social activity in the larger groups. However, there was no difference in positive or offensive behaviours between the two group sizes. In accordance to the second and third prediction, goats kept in small groups rested more and moved less when compared to goats kept in large groups. The results from this study did not find any difference between distances to nearest neighbour in goats kept in small and large groups. The goats kept in large groups had a larger distance to their furthest neighbour compared to goats kept in small groups.

In both group sizes there were a higher frequency of offensive behaviours in the first week than in the second and third week. After regrouping there is often an increase in aggressive interactions, but this quickly decreases once the social bonds between the animals are stable (Buchwalder & Huber-Eicher, 2005). In an attempt to avoid this, the goats were grouped one week before starting the behavioural observations. Alley and Fordham (1994) showed that an unfamiliar goat introduced to an established herd of goats could be accepted after only twenty-four hours. A study of pregnant goats kept in different densities (Chojnacki, 2014) showed that the highest numbers of agonistic and defensive behaviours were performed during the first week of observation. It appears that goats might need more than a week to establish a stabile hierarchy (Vas, 2013) and that they might engage in fewer conflicts late in pregnancy (Andersen et al., 2008).

In both group sizes the frequency of offensive behaviours were higher than the frequency of defensive behaviours. This might be because not all aggressive behaviours will be responded with a defensive behaviour (Vas et al., 2013). In contrast to previous results, there were more defensive behaviours performed in large groups than in small and there was also a tendency of more social activity in the large groups. Since there were no difference between the two group sizes on the frequency of offensive behaviours, there must have been more offensive behaviours

performed by the non-focal animals in the large groups to get the observed increased frequency of defensive behaviours. One explanation for the increase in defensive behaviours with increased group size might be that the focal animals were subjected to a disproportionate amount of aggression from the rest of the group members (Estevez et al., 2003). Another explanation for this increase of defensive behaviours can be that in one of the large groups, one goat was very aggressive and showed abnormal sexual behaviour towards the other goats. This animal was removed after the first observation, but could still have had an effect on the mean frequency of defensive behaviours.

Agonistic and non-agonistic social interactions have been shown to decline with increased group size in several different animals; e.g. domestic fowl (Estevez et al, 2003), turkey (Buchwalder and Hubert, 2005), pigs (Andersen et al., 2004) and goats (Andersen et al., 2011). According to the theory described by Andersen et al. (2004) the higher costs of being dominant in a large group, due to more opponents, should make more animals choose a less aggressive strategy. Some studies, however, did not find this effect of group size. Calves (Færevik et al., 2007) and sheep (Jørgensen et al., 2009) housed in different group sizes showed no effect of group size on the level of aggressive behaviour. Most behavioural studies observe social behaviour shortly after grouping (Buchwalder & Huber-Eicher, 2005; Andersen et al., 2004; Andersen et al., 2011). In a previous study on group size in goats (Andersen et al., 2011) the behaviours were observed on the first and fifth day after grouping, whereas in this study the behavioural observations were conducted 1, 8, and 14 weeks after grouping. The behavioural observations during the present study have been performed on more stable groups and this might be the reason for the difference observed in social interactions. When comparing the frequency of aggressive behaviours in the present study and that conducted by Andersen et al. (2011), there is an overall lower frequency of aggressive behaviours in this study.

In addition, 24 individuals in a group might not be a large group for goats. In moderate group sizes there have been shown more aggressive interactions than in small and large group sizes (reviewed by Rodenburg & Koene, 2007, Andersen et al., 2011). This could explain the increase

in defensive behaviours in the large groups in the present study. However, a study conducted by Stanley and Dunbar (2013) showed that feral goats formed a core group consisting of twelve to thirteen individuals, and was consistent across distribution and originally group sizes. They suggested that this could be the optimal group size for goats. However, a study conducted by Andersen et al. (2011) showed that there was a higher frequency of clashing in groups with twelve goats than in groups with twenty-four goats. Research on kids from the goats in the present study, showed that kids from the goats kept in large groups were more timid and were less socially motivated than kids from goats kept in small groups (Inger Lise Andersen, personal communication, April 2015). This could be signs of prenatal stress (Chojnacki et al., 2014), indicating that it is more stressful for the female goats in the present study to live in groups consisting of twenty-four individuals than six individuals.

Domestic animals may compete to get access to important resources such as food, water nipple and preferred resting place. Previous studies have shown that domestic animals have a strong preference to rest against a wall (sheep: Bøe et al., 2006; goat: Ehrelnbruch et al., 2010; domestic fowl: Cornetto & Estevez, 2001). This may be because it is more comfortable, but it has been explained as an anti-predator strategy in domestic fowl (Andersen et al., 2007). In the wild, animals use cover to protect themselves from predators, aggressive conspecifics and bad weather (Cornetto & Estevez, 2001). When the total area increases, the ratio between area and peripheral (wall) space decreases (Leone et al., 2010). In larger groups, when density was kept constant, there was less relative amount of wall that the goats could rest against. This can be a resource worth competing for and could explain the increased frequency of defensive behaviours in the large groups.

In accordance with the second prediction, goats kept in large groups moved more than goats kept in small groups. This is consistent with what is found in calves (Færevik et al., 2007), sheep (Jørgensen et al., 2009) and domestic fowl (Liste et al., 2015). An increase in moving activity in the larger groups can be explained by an increased level of social complexity or because the animals were more often avoiding other group members (Jørgensen et al., 2009). In larger group

sizes, with constant animal density, there will be larger enclosures and therefore more space the animals can use. In the present study the goats kept in large groups moved longer distances than goats kept in small groups. Earlier studies showed that pen size had a stronger effect on travelled distance and dispersion than group size or density (Leone et al., 2010). A previous study in domestic fowl (Leone & Estevez, 2008) showed that the total distances moved was more influenced by pen size than by group size. When group size was kept constant and pen size increased, the animals moved longer distances, but when density was kept constant and group size increased they found no difference. They concluded that the distances moved in large groups were smaller due to more obstacles (individuals) in the large groups. They did however find an effect of group size on movement activity, same as was found in the present study. With the increase in movement activity, but no increase in total distance moved, Leone and Estevez (2008) concluded that the increase of movement activity was that animals were constantly repositioning themselves. In contradiction to the study conducted by Leone & Estevez (2008), Liste et al (2015) found that young domestic fowl in larger group sizes had a larger total distances moved when compared to those in smaller group sizes. An increase in total distance moved, as a result of increased group size, could be because larger pens give more opportunities to move around (Liste et al., 2015). In the wild, hens live in groups with 4-30 while goats can live in up to 150 if the local environment conditions allows it (Shakleton & Shank, 1984). The large variation in group sizes could reflect the goats flexibility in terms of social complexity (Andersen et al., 2010).

In accordance with the third prediction, goats kept in small groups rested more than the goats kept in large groups. This has previously been shown in other domesic animals, e.g. in sheep (Jørgensen et al., 2009) and in calves (Færevik et al., 2007). In the study of Jørgensen et al. (2009) the sheep in the large group rested approximately 50% less compared to the sheep in small groups on the first day after grouping. Since the goats kept in small groups in the present study rested more than goats kept in large groups, they would naturally move less. This could influence the distances the animals moved.

During the present study there was as expected no effect of group size on the distance to nearest neighbour. In the present study the mean distance to nearest neighbour was 0.85 meters in small

groups and 0.84 meters in large groups. This is similar to what Aschwanden et al (2008) found with individual distance varying from 0.4-1.4 meters. However the distances from the present study is smaller than what has previous been shown in in goats (Haugland, 2010) and sheep (Jørgensen et al., 2009), but the animals in those studies had a larger area per individual. In this study there was, however, an effect of time on the distance to nearest neighbour. The goats had larger distance to nearest neighbour during the second time period where the most seen activity was resting (63.7%±2.5%). The goats kept a smaller distance to nearest neighbour during the first and third time period where the most frequent activity was feeding (57.7%±1.9%; 58.8%±1.8%). This was only significant for the first two observational weeks. Previous studies have shown that animals have a larger proximity to group members during feeding than when resting (sheep: Jørgensen et al., 2011; domestic fowl: Keeling & Duncan, 1991.). A study in birds showed that the distances between individuals were larger when feeding compared to when the birds were resting (reviewed by Keeling, 1995). Similar results have been shown in a smaller breed of sheep (Spæl; Jørgensen et al., 2011) and in age heterogeneous groups of goats (Bøe et al., 2013). In contradiction the age homogenous groups of adult goats had no difference in proximity during feeding and resting, while the age homogenous groups of young goats had larger distance when resting than when feeding (Bøe et al., 2013). The groups in the present study were age heterogeneous groups, but showed the same results as the young goats from the Bøe et al. (2013) study. A reason for this might be that the goats in the present study where able to rest in the feeding area, which was not possible in the study conducted by Bøe et al. (2013). In addition, the goats in the present study were in more stable groups and the last observations were conducted 14 weeks after grouping. The study conducted by Bøe et al. (2013) lasted only for three days, and the study conducted by Jørgensen et al. (2011) only lasted 7 days. Another reason for the result can be that in this study the goats were familiar with another, having been on pastures together during the summer. Goats that grow up together and have amicable bonds have a shorter individual distance between them (Aschwanden et al., 2008).

In the present study the goats in the small groups had shorter distances to their furthest neighbour than the goats in the large groups. This is in accordance with a study conducted by Leone et al. (2007), which showed that an increase in group size led to an increase in maximum inter-

individual distance. A study conducted by Averós et al. (2014) showed that sheep kept in higher densities had shorter distances to furthest neighbour compared with sheep kept in lower animal densities. The reason for the increased distance to furthest neighbour with increased group size in the present study can be because they had more space to disperse themselves, but also due to reduced group cohesion. Previous studies have shown that in large groups the synchrony of activities is lower (DeVries et al., 2004) and less synchronized activities can lead to reduced group cohesion (Michelena et al., 2008).

In the present study younger goats moved larger distances than older goats. Færevik et al (2010) found similar results, where young calves were more active compared to older calves on the first day after grouping. Younger animals might move more because they try to avoid older animals, or because they are more often displaced (Færevik et al., 2010). However, in the present study there was no effect of age on the frequency of moving, so younger goats moved in general larger distances when moving.

During the present study there was an effect of week. The goats kept larger distances to their nearest neighbour during the third observational week. This could be because they tried to isolate themselves before giving birth (Averós et al., 2014), but can also be because they got bigger and heavier and therefore required a larger individual distance. During the third observational week the goats rested more and spent less time feeding than in the two first observational weeks. This can be an effect of pregnancy and the goats alter their behaviour when they are closer to parturition. In a previous study in pregnant goats there was an increase in positive behaviours during the last observational week (Vas et al., 2013). This was however not found in the present study.

Previous studies indicate that when pen size increases, and with this a decrease in animal density, the proximity to other group member increases. This effect has not been documented as an effect of group size (Leone et al., 2010). A study conducted by Kondo et al (1989) showed that the

distance to nearest neighbour increased with decreased group size, when pen size was kept constant. When animal density decreases, the animals will disperse throughout the pen in a way to reduce competition between them (Leone et al., 2007). Previous studies indicate that differences in animal density is more important than differences in group size when in comes to alter movement patterns in domestic animals (DeVries et al., 2004; Leone &Estevez, 2008; Leone et al., 2010). High animal density can lead to reduction of use of space, since the animals are less active (Newberry & Estevez, 1997). Lower animal density and more space allowance leads to less aggressive behaviour in calves (Kondo et al., 1989), and by giving the animals larger areas, the individuals can avoid coming too close to another individuals space, and therefore avoid conflicts between them (Gonyou, 2001).

For practical implications, the results from the present study indicated that keeping goats in groups of twenty-four individuals can lead to a higher level of aggressive behaviours, and might therefore not be an optimal group size for dairy goats. However, altering the design of the pens so there is more wall space available could be a way to reduce the level of aggressive behaviours (Andersen & Bøe, 2007). Although there has previously been shown that keeping goats in group sizes with twenty-four individuals can lead to reduced levels of aggressive behaviours (Andersen et al., 2011), that study only lasted for five days. The present study was conducted on more stable groups, and might be more representative for traditional animal husbandry of dairy goats.

5. Conclusion

In this thesis I studied the effect of group size on social interactions, activity time budgets and movement patterns in Norwegian dairy goats. Some of the results in this study were not consistent with previous findings concerning the effect of group size on social behaviour or on individual distances during different activities.

The frequency of offensive behaviours decreased over time, regardless of group size. But the frequency of defensive behaviours was surprisingly higher in large groups than in the small groups. The goats in the large groups were also more involved in social activities. Group size had an effect on frequency of moving and total distance moved, with goats moving more and larger distances in the large groups. The goats in the large groups kept larger distances to their furthest neighbour compared to the goats kept in small groups. There was no effect of group size on the individual distance, but the goats kept a smaller individual distance when feeding than resting.

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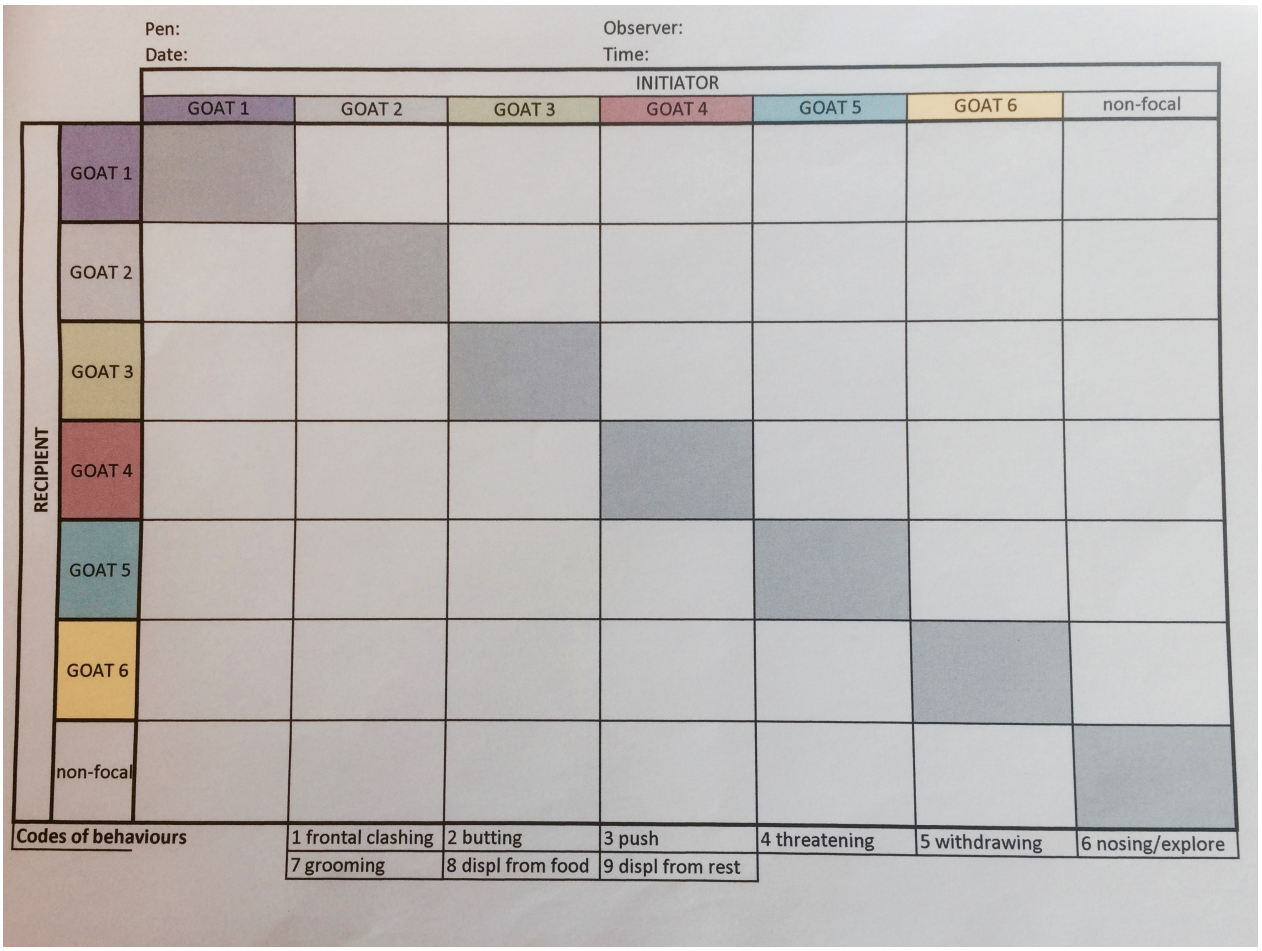
7. Appendix

Intervention were written in the grey areas.



Pen:
Date:
Observer:
Time:

RECIPIENT \ INITIATOR	GOAT 1	GOAT 2	GOAT 3	GOAT 4	GOAT 5	GOAT 6	non-focal
GOAT 1							
GOAT 2							
GOAT 3							
GOAT 4							
GOAT 5							
GOAT 6							
non-focal							

Codes of behaviours						
	1 frontal clashing	2 butting	3 push	4 threatening	5 withdrawing	6 nosing/explore
	7 grooming	8 displ from food	9 displ from rest			

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