

NORWEGIAN UNIVERSITY OF LIFE SCIENCES



Preface

This thesis is written at the Department of Animal and Aquacultural Sciences at the Norwegian University of Life Sciences, Ås.

First, I would like to thank my supervisor Dr. Anne Lene Hovland for guidance and patience during the long lasting period it took to complete this thesis. You have been an important support both mentally and academically, and an inspiration in all our discussions. My best regards to you and your family. I also wish to thank the employees at the farm for their good service. I would like to thank my family for invaluable support and help. A special thanks to my little son for his patience and love - you have been the most important motivational factor for me. My friends and my colleagues at Gjøvik VGS, I thank you all for your belief in me and for several pep talks during these last years.

I could not have finished this work without you.

Raufoss, May 2010

Hildegunn Witzøe Brøste

Abstract

In recent years there has been an increasing concern for the welfare of animals in the fur production, especially regarding the housing conditions. The aim of this study was to examine the effect of two different housing environments with different access to resources on adult silver fox vixens' social behaviour during autumn. Agonistic interactions, different play behaviour, grooming and resting behaviour were studied in particular, in addition to weight gain and occurrence of wounds. The silver fox vixens were separated in two groups and housed in pairs. Vixens in group 1 (n=9 pairs) were housed in two standard wire mesh cages linked together. The cages contained two top nest boxes, two resting shelves, and two food trays. Vixens in group 2 (n=9 pairs) were housed in similar linked cages, however, the cages contained only one top nest box and one food tray, including two resting shelves. Occurrence of wounds was registered within pair, and differences in weight gain were calculated for each vixen twice during the experiment. Differences within pairs and between groups were analysed. Three separate video recordings were conducted each recording day (three days in total) and the recordings were analysed during three separate hours (morning, feeding time and evening), a total of 9 hours per pair. During these hours the duration and frequency of social behaviour and play were continuously observed. The results showed no significant difference between groups regarding weight gain, occurrence of wounds, and frequency of social behaviours and play ($P>0.10$). There was just observed a few, superficial wounds in the experimental period, and thereby no significant effect of various cage environments on the occurrence of wounds. There was a higher level of aggression in group 2 than in group 1 in December, however, this was not significantly different. Vixens in group 2 showed also slightly less play in December, although there was no significant difference. The overall weight gain from October to December was not affected by housing environment, but the difference in weight gain within pairs were slightly larger for vixens in group 2. These results show some weak differences resembling our predictions; however, the reason why there were no clear effects may be due to more stable dominance relations with increasing days subsequent to mixing. Studies on competitive behaviour around feeding time should be conducted to reveal possibly monopolisation in pair housing of silver fox vixens, as we could only find slight differences between the groups regarding agonistic interactions. There should be further investigations before concluding on the effects of cage environments on welfare of pair housed adult silver fox vixens in autumn.

Sammendrag

I de senere årene har interessen rundt velferden til pelsdyrene økt, spesielt når det gjelder oppstallingsmiljøet. Målet med dette studiet var å undersøke effekten av to ulike typer oppstallingsmiljøer med forskjellig tilgang på ressurser på voksne sølvrevtispers sosialatferd om høsten. Agonistiske interaksjoner, forskjellige lekeatferder, sosialt pelsstell og hvileatferd ble studert, i tillegg til vektøkning og forekomst av sår. Sølvrevtispene ble separert i to grupper og oppstallet i par. Tisper i gruppe 1 (n=9 par) ble oppstallet i to standard nettingbur som var satt sammen. Burene inneholdt to toppmonterte kasser (kunstig hiplass) og to forbrett. Tispene i gruppe 2 (n=9 par) ble oppstallet i identiske bur, foruten at disse burene inneholdt kun en toppmontert kasse og et forbrett. Forekomst av sår ble registrert per par, og forskjeller i vektøkning ble kalkulert for hver tise to ganger i løpet av eksperimentet. Forskjeller innen par og mellom grupper ble analysert. Tre separate videoopptak ble utført hver opptaksdag (totalt tre dager) og opptakene ble analysert i tre separate timer (morgen, foringstid og kveld), totalt 9 timer per par. I løpet av disse timene ble varighet og frekvens av sosial atferd og lek observert kontinuerlig. Resultatene viste ingen signifikante forskjeller mellom grupper i forhold til vekt, andel sår eller forekomst av sosialatferd og lek ($P > 0.10$). Det ble kun observert få overfladiske sår i løpet av forsøksperioden og derfor ingen klar effekt av oppstallingsmiljø. Det var et forhøyet aggresjonsnivå i gruppe 2 i desember men denne forskjellen var ikke statistisk signifikant. Tispene i gruppe 2 viste også litt mindre lek i desember men forskjellen var heller ikke her signifikant. Tispenes kroppsvekt var ikke forskjellig ved slutten av forsøket i desember men det var en tendens til at en større forskjell i vektutvikling mellom par hos tispene i gruppe 2. Disse resultatene gjenspeiler til en viss grad våre forventninger og årsaken til at man ikke fant klare forskjeller kan være at det sosiale forholdet mellom tispene stabiliserte seg med økende antall dager etter blanding. For å kartlegge eventuelle tydeligere effekter av ressursmonopolisering hos parvis oppstallede tisper bør studier av revens konkurranseatferd rundt føring gjennomføres i fremtidige forsøk.

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1 Introduction

Farm-bred silver foxes (*Vulpes vulpes*) are generally housed on wire mesh flooring in standard farm cages throughout their lives. The nest boxes provide the exception, with their solid wooden floor. Such a housing environment has ensured the production of foxes of large body size and good fur quality (Korhonen and Niemelä, 1997). In recent years there has been an increasing concern for the welfare of animals in the fur production, especially regarding the housing conditions. Several studies have been completed on different housing alternatives in various animal species over the last few years (mink: Hanninen et al., 2008 cattle: Tuomisto et al., 2008, Wolf et al., 2010) and Ahola with co-workers have conducted studies on silver foxes showing that housing foxes together could be considered an alternative to solitary housing (Ahola et al., 2000a, Ahola et al., 2000b).

There is probably no specific ideal group size or density in different animal species when it comes to group housing (Estevez et. al., 2007). The possibility of leaving the group when the costs are higher than the benefits does not exist in a farm environment. If a species or breed should be housed in pairs or in larger groups the consequences of different housing conditions needs thorough investigation with respect to all the animals' fitness and welfare. When housing animals in pairs or groups one must be aware that there relationships between the animals is complex. Consequently, stronger emphasis should be placed on the dynamics of different social strategies under varying environmental conditions, in order to gain knowledge that can be used to maximize performance and welfare (Estevez et al., 2007).

An experiment performed on family housing in silver foxes indicated improved welfare for the cubs which were separated and housed together in pairs with a sibling from the time of natural dispersal compared to cubs housed solitarily (Ahola et al., 2002b). A study of farmed blue foxes housed in groups indicated increased biting injuries in female cubs with decreased space allocation (Ahola et al., 2002a), although space allocation seems not to influence the animals' welfare as negatively as social tension (Ahola et al., 2005). However, as foxes have high motivation for locomotor activity, it must also be taken into account that each fox in a social housing environment has twice the area as those housed solitarily.

Another experiment carried out by Ahola et al. (2006) also indicates that group housing in

litters may increase the welfare of silver fox cubs. Hovland et al. (2008) performed an experiment on young silver fox vixens where they found that the vixens were motivated for social contact which indicates that they benefit from social interactions. However, the older the juvenile vixen gets, the more aggressive she will become against unfamiliar females (Akre et al., 2009). These results demonstrate the challenges in designing housing alternatives for silver foxes, especially adult silver fox vixens. Although the present results indicate that young silver fox vixens may be housed in pairs, further investigation is needed to examine the costs and benefits for adult silver fox vixens in social housing. When housing adult vixens together, social stress may decrease with time when mixed with an unfamiliar vixen (Akre et al., 2010). Therefore, it is important to examine the welfare consequences of housing adult vixens together over a prolonged time period. If animals show aggression during the first days after mixing it may affect the animals' welfare negatively. However, silver fox vixens in social housing experiments show an increase in social play after mixing which indicates a creation of a stable dominance hierarchy and this may have positive effect on their welfare (Akre et al., 2010). In a permanent group or dyad the dominance relationships are stable and often help to resolve conflicts that occurs between animals (Bouissou and Boissy, 2005).

As agonistic interactions are mostly viewed as a welfare costs, play in all forms are often viewed as welfare benefits. Animals do not play if they are in a stressful state or if they are under stressful conditions, instead, play occurs when the animals are both physically and mentally healthy (Oliveira et al., 2010). Tacconi and Palagi (2009) found that dyads of bonobos showing higher levels of agonistic encounters and displays were less likely to engage in social play. Prevalence of play behaviour can therefore be used as an indicator of positive environmental conditions and healthy state of the animals (Oliveira et al., 2010). According to the study of Fagen and Fagen (2009) the chance of surviving to independence increased if the young bears in the study of played more. Corresponding results are shown in young horses (Cameron et al., 2008) which supports the use of play as a positive welfare indicator and that the occurrence of play may indicate good welfare.

Studies carried out on social grooming behaviour in primates indicate that females use grooming to create bonds between herself and a possibly helper in cooperative breeding systems (Lazaro-Perea et al., 2004) and that female grooming partners may aid one another in agonistic episodes (Matheson and Bernstein, 2000). Social licking in cattle was investigated by Nakanishi et al. (1993). Their results indicated that social licking was negatively

correlated with agonistic encounters, and that this licking may have been a participating factor in controlling aggression in the herd. These findings indicate that social grooming may strengthen the dominance relationships and enhance the welfare of the animals participating in social grooming sessions (Bouissou and Boissy, 2005). Hovland et al. (2008), therefore, used social grooming as a positive welfare indicator when studying the strength of social motivation among young silver fox vixens. Another indicator of social adaptation in animals is synchronised behaviour. The occurrence of synchronised rest and feeding may be an indicator of low levels of stress and, therefore, may be used as a measurement of welfare (chickens and cattle: Alvino et al., 2009, Napolitano et al., 2009).

Experiments performed on calves show that the space allocation are essential for the play behaviour in calves (Jensen et al., 1998), indicating that a low space allowance reduces the quality and amount of locomotor play and thus endangers their welfare. Other factors in the housing environment are also important for the behaviour of the animals. Studies on cage enrichment indicates increased welfare in different animals in the fur industry (blue fox and mink: Koistinen et al., 2009, Mononen et al., 2008, Pyykonen et al., 2010) but that with defendable resources the welfare may be at risk. Resource distribution may affect the level of competition between the animals resulting in increased levels of agonistic interactions, wounds and decreased body weight gain (Akre et al., 2010). Important resources in both the wild and in farm environments can be food, areas for nesting and possible mates. According to the tolerance hypothesis (Estevez et al., 2007), whether or not to defend an important resource is influenced by the distribution and amount of the resource, and by the pressure to compete for the resources. If resources are clumped or limited it will favour resource monopolisation. Competition in farm environments may be intense and perhaps resulting in severe aggression and wounds as the animals are unable to leave the group and thereby avoid getting too close to the resource. This will most likely affect the welfare of the animals negatively (Estevez et al., 2007) as the risk of severe wounds increases. In addition chronic mental and physical stress harms the metabolism processes directly as the animal is not getting sufficient amount of food, and indirectly as a stressed animal will not exploit the nutrients in the food in an optimal manner (Awerman and Romero, 2010).

The aim of this study was to examine the effect of two different housing environments with different access to resources on vixens' social behaviour during autumn. In particular, the

study looked at agonistic interactions, different play behaviour, grooming and resting behaviour. In addition, weight gain and occurrence of wounds were also examined.

Due to expectations of more competition in pairs where resources can be monopolised, we expected that there would be more agonistic interaction and less positive interactions in these pairs, especially around feeding time, thereby causing a difference in weight gain within each pair due to stress on the metabolism system. In the pairs where resources can not be monopolised, there was a prediction of less competition and thus less agonistic interactions and increased level of positive interactions. As the amount of wounds were predicted to follow the same pattern as physical agonistic interactions, the prediction was that there would be more wounds in the pairs sharing one food tray and top nest box (Akre et. al., 2009). There was a weak expectation that the level of agonistic interactions and amount of wounds should be at the highest in December due to social tension between the vixens before the breeding season, although no known experiments have been carried out on increased aggression when approaching the breeding season in pair housed adult silver fox vixens. The amount of registered behaviours, except synchronised resting, was predicted to be at the highest around feeding time due to increased activity just before and after feeding.

2 Methods

2.1 Animals and housing

Forty adult (1.5 years old) silver fox vixens from a standard Norwegian commercial line participated in the study. Prior to the study, the experimental vixens were housed solitarily in standard wire mesh cages (76x106x120 cm) in a standard uninsulated fox house with four parallel cage rows. At this time each vixen had access to a top nest box, resting shelf, food tray and gnawing stick, and they were housed next to the vixen that they would be paired with for a minimum of one week before the experiment started. The experimental vixens had previous social experience from pair housing with a female littermate until six months of age (Hansen, 2007). The reproductive experience, i.e. whether or not they weaned cubs the previous season, differed between vixens. The animals were fed a standard food paste for fur animals at approximately 12:00h daily and had free access to drinking water from automated drinking nipples. One vixen in group 2 was found dead in the nest box due to a bite wound in the neck region 24 days subsequent to mixing, and one vixen in group 1 escaped. Both pairs

were excluded from the experiment leaving 9 pairs in each group, giving a total of 18 pairs, to be observed.

2.2 Experimental procedure

September 4th was the day of mixing. The vixens were then moved to a new but identical fox house and housed in pairs in their respective experimental groups. The vixens were separated into two groups and were housed together in pairs in two different housing environments. The groups were balanced with regard to the date of birth, social experience and cage position. Vixens in Group 1 (n=9 pairs) were housed in two standard wire mesh cages (76x106x120 cm) linked together with an entrance measuring 30 cm in diameter. The cages contained two top nest boxes (45x55x95 cm), two resting shelves (28x106 cm, placed 35 cm over the cage floor) and two food trays (10x100 cm) positioned in front of the cages (see figure 1). Vixens in Group 2 (n=9 pairs) were housed in similar linked cages, however, the cages contained only one top nest box and one food tray positioned in one of the cages, including two resting shelves (see figure 2). Both cages were equipped with one drinking nipple and one wire mesh resting shelf, also needed as a stairway to access the top nest box.

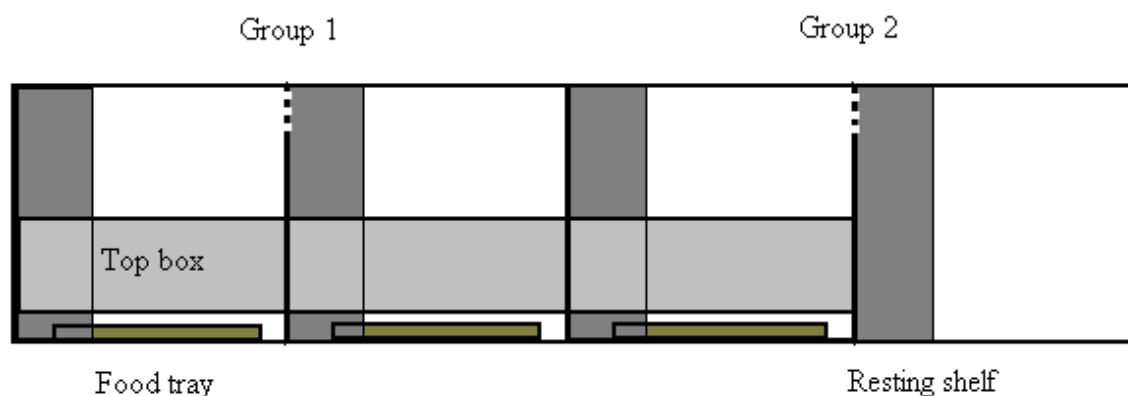


Fig. 1. Aerial view of the cages. Group 1 had two top nest boxes, and two food trays. Group 2 had one top nest box and one food tray.

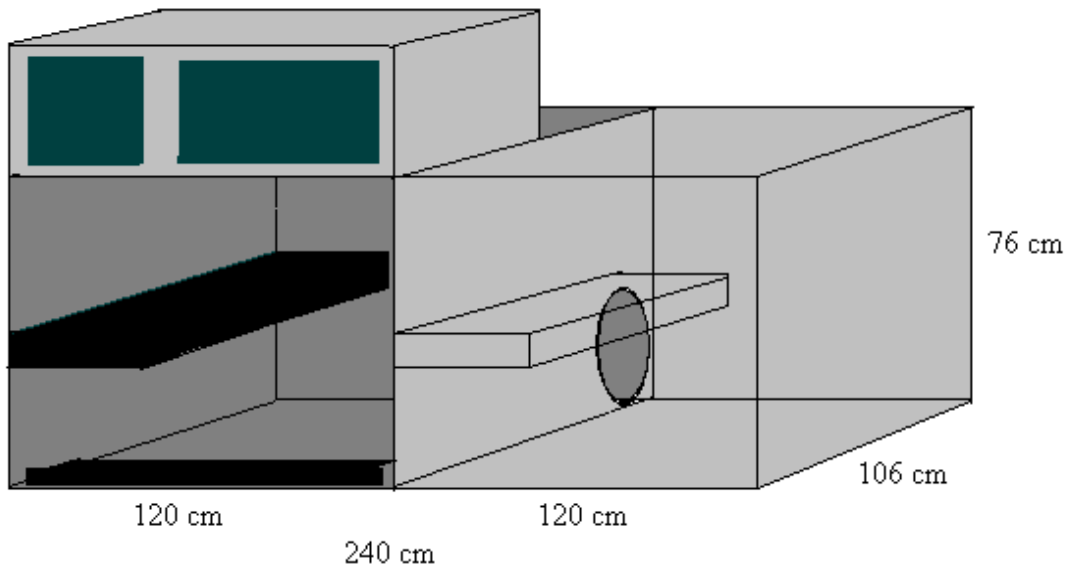


Fig. 2. An illustration of the cages in group 2 containing one top nest box, one food tray and two resting shelves. In group 1 there were two cages similar to the one to the left.

At the day of mixing the vixens' body weight were recorded and one random vixen in each pair got its tail trimmed by removing a small amount of fur just above the tip of the tail for individual recognition. All animals, including those who did not get their tail trimmed, were handled in a similar way to avoid bias between the animals. The two vixens in each pair were put in their experimental cages simultaneously. On October 22nd the animals' tails were remarked and the similar handling procedure was completed for all animals.

Each vixen had access to a gnawing stick which was replaced when needed. The vixens were given a titbit twice a week. The amount of food was adjusted according to the consumption within each pair. Sick or injured animals were taken out of the study and given adequate care until they recovered and then put back with their partner. Both animals were removed from the experimental cage during medical treatment. Dead animals were registered and sent to post-mortem examination. Injuries, general health condition and body weight was recorded October 22nd and December 18th. The experiment ended December 18th after which all foxes were housed solitarily. The study was approved by the Norwegian Animal Research Authority.

2.3 Data collection

In addition to visual checks for health problems and injuries on a daily basis, the foxes were taken out of the cages and examined two times during the experiment. The procedure was the same each time; one person held the animal while another person examined the fox by

palpation and visually checking the foxes' health. During weighing one person held the fox while standing on the weight. Differences in weight gain were calculated for each vixen, and differences within pairs and between groups were analysed. The data collection in September was analyzed by Akre et. al. (Akre, 2010).

2.4 Behaviour recordings

MSH-Video System and 28 infrared cameras were used to record the foxes' behaviour. Each camera recorded one pair of foxes. The Observer ® XT (Noldus Information Technology) was used to analyse the recordings. Three separate video recordings were conducted at October 20th, November 17th and December 15th. Behaviour was recorded during weekends to reduce disturbance from the daily work at the farm on weekdays. Moreover, the recordings were carried out during the brightest period of the day, so as to avoid lower quality recordings during dark hours. Behaviour was analysed during three separate hours on Saturdays in each weekend, a total of 9 hours per pair. The animals were recorded once in the morning (09:30-10:30h), once around feeding time (11:30-12:30h) and once in the afternoon, but before dark (13:30-14:30h). During these hours the duration and frequency of social behaviour and play were continuously observed. The registered behaviours are listed in table 1 and 2.

Table 1. Ethogram showing agonistic behaviour (modified from Hansen, 2007, Hovland et.al., 2008).

Behaviour	Description
Agonistic signals	
Intensity 1	Agonistic displays without physical contact including:
Gaping	Open mouth signal directed towards other fox
Staring	The foxes stare at each other's face, standing completely still
Intensity 2	Physical contact, without harming the other, including:
Upright posture	Mutual forepaw stabbing and pushing. The foxes stand on their hind legs, ears turned backwards, seizing each other with the front paws, pushing and displaying threat-related gapes.
Mount	One fox mounts the other
Blocking	One fox blocks the other fox with its body when feeding
Intensity 3	Intense fighting that can cause wounds, or even death
Physical fighting	Attack followed by wrestling and bites directed towards neck region of opponent

Table 2. Ethogram describing the components of play behaviour, social grooming and synchronized rest that was registered (modified from Hansen, 2007, Hovland et.al., 2008).

Behaviour	Description
Social play	Play which involves more than one individual in parts or the complete play session. Including:
Pounce	One fox suddenly jumps onto the back of the other in a rapid movement
Lunge	One fox jumps toward the other fox with body stretched upwards and forepaws clearly elevated
Play wrestling	Wrestling and tumbling during play interaction
Side wrestling	Both individuals lie on their side and play wrestle
Chase and run	Both foxes runs back and forth, may jump up and down on walls and resting shelves.
Face pawing	The fox extend one of the forelimbs toward the face of the other fox.
Play bow	The fox crouches its forelegs and elevates its hind end. Ears turned towards the other fox.
Pre-attack position	The fox crouches down, focussed on the other fox. Ears turned towards the other fox. Often followed by sham attack.
Sham attack	The fox rushes against the other fox
Play with object	Play with an object in parts or the complete play session, including:
Gnawing	The fox bites or gnaws on the object
Carrying	The fox carries the object in its mouth, in movement
Play bow	The fox crouches its forelegs and elevates its hind end. Ears turned towards the object.
Pre-attack position	The fox crouches down, focussed on the object. Ears turned towards the object. Often followed by sham attack.
Sham attack	The fox rushes against the object
Social grooming	One fox sniffs/licks/nibbles the other fox's head, neck or back
Synchronous resting	Both foxes rest at the same time (all lying postures)
Close	The foxes rest close (distance < 10 cm)
Not close	The foxes do not rest close (distance > 10 cm)

2.5 Statistical analysis

All data were analysed using the statistical software JMP 7.0 (© 2007. SAS Institute Inc., Cary, North CA). Mixed (fit) model were used to evaluate effects of different groups, period and time of day. The model were $Y = \text{Intercept} + \text{Group} + \text{Time} + \text{Period} + (\text{Group} \times \text{Period}) + (\text{Group} \times \text{Time}) + (\text{Period} \times \text{Time}) + \text{Pair}(\text{Group})_{\text{rand}} + \text{Time} \times \text{Pair}(\text{Group})_{\text{rand}} + \text{Period} \times \text{Pair}(\text{Group})_{\text{rand}} + \text{residual}$. 'Group', 'Time' and 'Period' were included as fixed effects, whereas 'pair' and interactions including 'pair' was defined as a random effect. In addition, a paired t-test was used to test for significant effects of dependent variables, and an unpaired t-test was used to test for significant effects of independent variables. Oneway ANOVA was used to test for significant differences in number of wounds and weight gain. Results was accepted as significant if $P \leq 0.05$, while $P \leq 0.10$ was considered to indicate tendency. All mean values are given with standard errors, and mean number/duration is average number/duration per hour.

3 Results

3.1 Agonistic interactions

3.1.1 Gaping signals (intensity 1 signals)

There were no general effect of group on number of gaping signal-sequences ($F_{1, 15.6} = 0.03$, $P = 0.960$). However there was a significant effect of time of day ($F_{2, 31.8} = 6.41$, $P = 0.005$) which showed a decrease in the total number of gaping signal-sequences from morning to evening. The differences between groups within time of day are shown in figure 3.

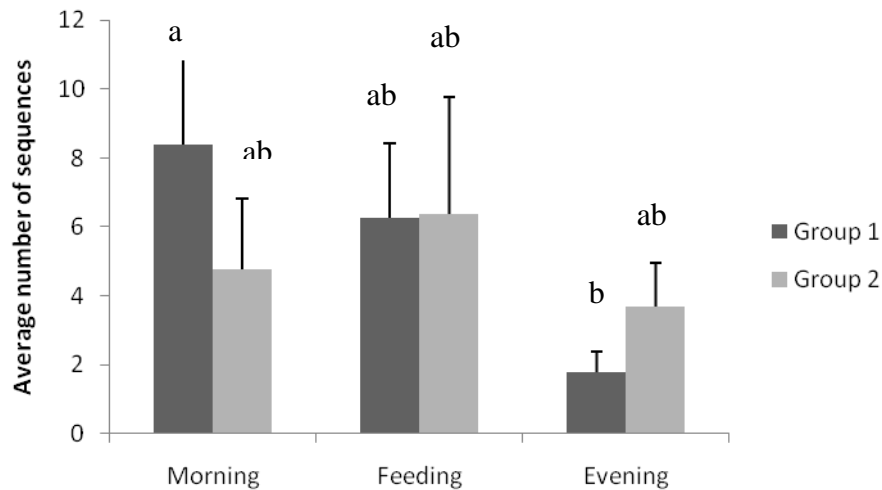


Fig. 3. Average number (mean + SE) of gaping signal-sequences between groups within time of day. There was no difference between groups ($P > 0.100$), but there was an effect within groups; group 1 showed a significant decrease in number of gaping signal-sequences from morning to evening ($T_8 = 4.09$, $P = 0.004$), while group 2 showed no significant difference ($P > 0.100$). There was a total significant difference from morning to evening, where there were more gaping signal-sequences in the morning ($T_8 = 2.89$, $P = 0.020$).

There was a significant effect of period on number of gaping signal-sequences ($F_{2, 30.9} = 7.12$, $P = 0.003$), the average number and duration of gaping signal sequences decreased clearly from October to November in both groups. Average number is shown in figure 4.

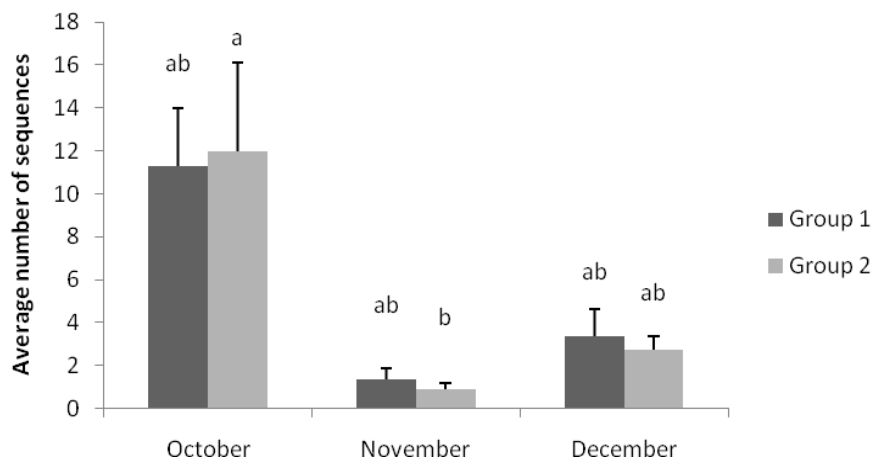


Fig. 4. Average number (mean + SE) of gaping signal-sequences in the three different periods. Different letters indicate a significant difference ($P < 0.05$). There was no difference between groups ($P > 0.100$), but there was a significant difference within group 2 between October and November ($T_6 = 2.63$, $P = 0.039$), a tendency towards a difference between October and November within group 1 ($T_6 = 2.06$, $P = 0.085$), and there was tendency towards a difference between November and December within group 2 ($T_6 = 1.96$, $P = 0.097$). There was a total significant difference between October and November ($T_8 = 2.19$, $P = 0.006$) and between November and December ($T_8 = 2.68$, $P = 0.028$).

3.1.2 Physical signaling (intensity 2 signals)

There was no general effect of group ($F_{1, 16.2}=1.17$, $P=0.295$) and time of day ($F_{2, 32.5}=1.96$, $P=0.158$) on number of physical signaling-sequences. There was a tendency towards a general effect of period on number of physical signaling-sequences ($F_{2, 31.2}=3.13$, $P=0.058$) where the number of sequences in November were lower than in December as shown in figure 5.

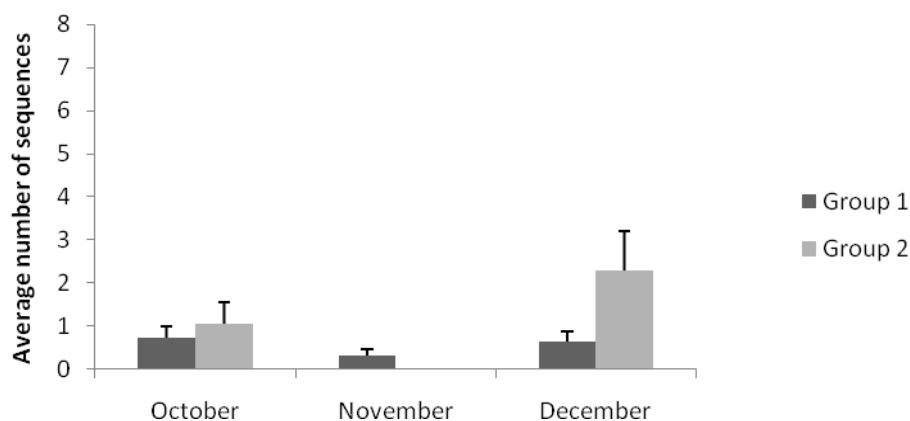


Fig. 5. Average number (mean + SE) of physical signaling-sequences in the two groups within period. There was a strong tendency towards a difference between November and December ($T_8=2.10$, $P=0.069$). There were no physical signaling-sequences in group 2 in November.

3.1.3 Fighting (intensity 3)

There was no general effect of group ($F_{1, 16.0}=1.71$, $P=0.209$), time of day ($F_{2, 32.2}=1.51$, $P=0.235$) or period ($F_{2, 31.2}=1.61$, $P=0.216$) on number of fight-sequences. Average numbers of fight-sequences in the two groups within period are shown in table 3.

Table 3. Average number (mean ± SE) of fight-sequences in the two groups within period. Group 1 showed no fighting in November. _

Group	October	November	December
1	0.30 ± 0.15	0	0.11 ± 0.08
2	0.50 ± 0.30	0.04 ± 0.04	0.70 ± 0.38

3.1.4 Total physical aggression

There was no general effect of group ($F_{1, 16.2}=1.35$, $P=0.262$), and time of day ($F_{2, 32.6}=1.97$, $P=0.156$), but there was a tendency towards a general effect of period on number of physical aggression-sequences ($F_{2, 31.3}=2.61$, $P=0.090$), where there were less physical aggression-sequences in November compared to December ($T_8=2.06$, $P=0.074$). Number of pairs

showing physical aggression-sequences in the different groups and periods are shown in table 4.

Table 4. Number of pairs in the different groups in the different periods showing all types of physical aggression. Total number: Total number of pairs observed. Mean \pm SE: Average number and standard error of sequences observed in the pairs who showed the behaviors.

Period	Group	Number of pairs	Total number	Mean \pm SE
October	1	4	9	7.00 \pm 1.47
	2	5	8	7.40 \pm 4.78
November	1	6	8	1.33 \pm 0.21
	2	1	9	1.00
December	1	7	9	2.86 \pm 0.63
	2	7	9	11.57 \pm 5.15

3.2 Social grooming

There was no general effect of group ($F_{1, 16.3}=0.31$, $P=0.585$), time of day ($F_{2, 32.5}=0.77$, $P=0.472$) or period ($F_{2, 31.1}=0.55$, $P=0.585$) on number of social grooming-sequences. Table 5 shows the average number of sequences for all three periods.

Table 5. The average number (mean \pm SE) of social grooming-sequences in October, November and December.

Group	October	November	December
1	1.48 \pm 0.63	0.75 \pm 0.58	1.00 \pm 0.42
2	1.71 \pm 0.72	1.63 \pm 0.79	0.96 \pm 0.34

3.3 Play

3.3.1 Social play

There was no general effect of group ($F_{1, 16.5}=1.44$, $P=0.709$), but there was a tendency towards a general effect of time of day ($F_{2, 33.1}=2.88$, $P=0.070$) on duration of social play-sequences, where there were more social play-sequences in the evening than around feeding and in the morning ($T_8=2.03$, $P=0.077$) (morning: mean = 1.25 \pm 0.72, feeding: mean = 1.10 \pm 0.86, evening: mean = 6.88 \pm 3.29).

There was a strong tendency towards a general effect of period on number of social play-sequences, ($F_{2, 31.8}=3.23$, $P=0.053$), where the number of play behavior in October was higher than in December as shown in figure 6.

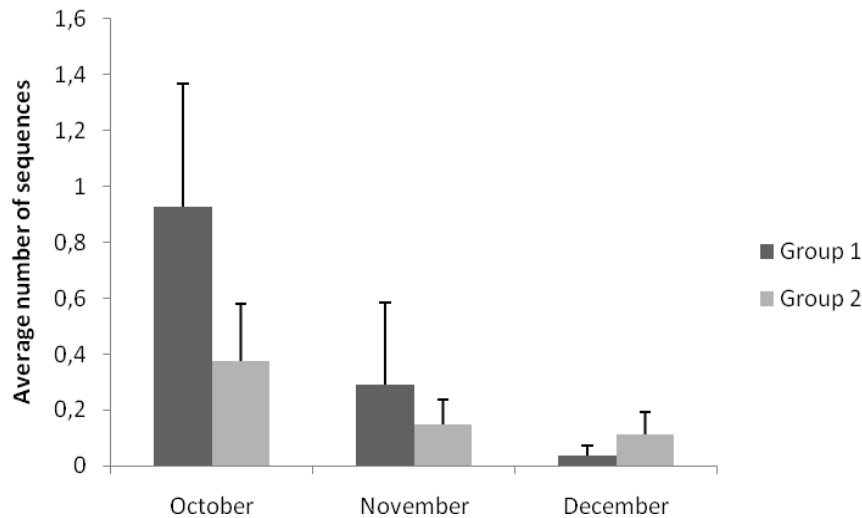


Fig. 6. Average number (mean + SE) of social play sequences in groups within period. There were a tendency to be more social play-sequences in October than in December ($T_8=2.09$, $P=0.071$).

3.3.2 Object play

There was no significant difference between groups ($F_{1, 15.5}=0.63$, $P=0.439$) or time of day ($F_{2, 32.1}=2.46$, $P=0.101$), but there was a significant effect of period on number of object play sequences ($F_{2, 30.6}=4.98$, $P=0.014$), where there were significantly more object play in October than in November ($T_8=3.04$, $P=0.016$), and the observations in December showed a tendency towards more object play than the observations in November ($T_8=2.13$, $P=0.066$) as shown in figure 7.

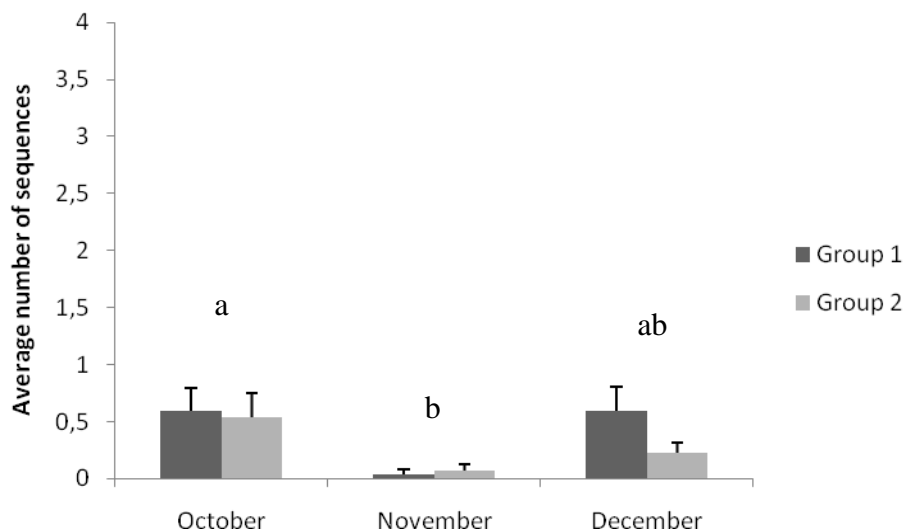


Fig. 7. Average number (mean + SE) of object play-sequences between groups within period. Different letters indicate significant difference. There was a significant effect between October and November within group1 ($T_6=2.90$, $P=0.027$), and between October and November within group 2 ($T_6=2.75$, $P=0.033$).

3.3.3 Other play

There was no general effect of group ($F_{1, 16.2}=0.01$, $P=0.930$), time of day ($F_{2, 33.0}=1.73$, $P=0.193$), or period ($F_{2, 31.6}=1.86$, $P=0.173$) on number of other play-sequences (October: mean= 0.66 ± 0.28 , November: mean= 0.37 ± 0.37 , December: mean= 1.30 ± 0.52).

3.4 Synchronised resting

3.4.1 Synchronised rest

There was no general effect of group on duration of synchronised rest ($F_{1, 16.3}=0.63$, $P=0.437$), but there was significant effect of time of day ($F_{2, 33.0}=45.42$, $P<0.001$) as shown in figure 8, and period ($F_{2, 31.3}=12.79$, $P<0.001$) as shown in figure 9.

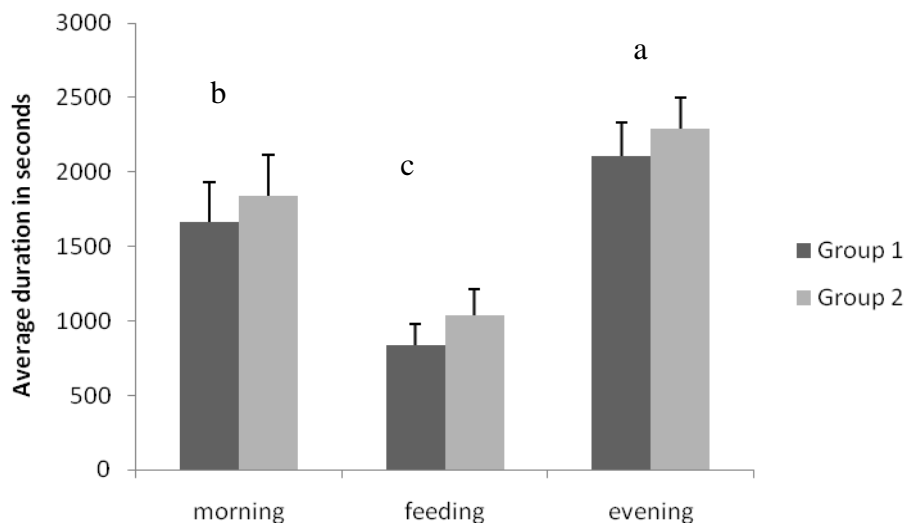


Fig. 8. Average duration (mean + SE) of synchronised rest in seconds within time of day. There was no difference between groups ($P>0.100$). There was a significant effect between morning and feeding ($T_8=7.18$, $P<0.001$), between morning and evening ($T_8=3.13$, $P=0.014$) and between feeding and evening ($T_8=8.18$, $P<0.001$).

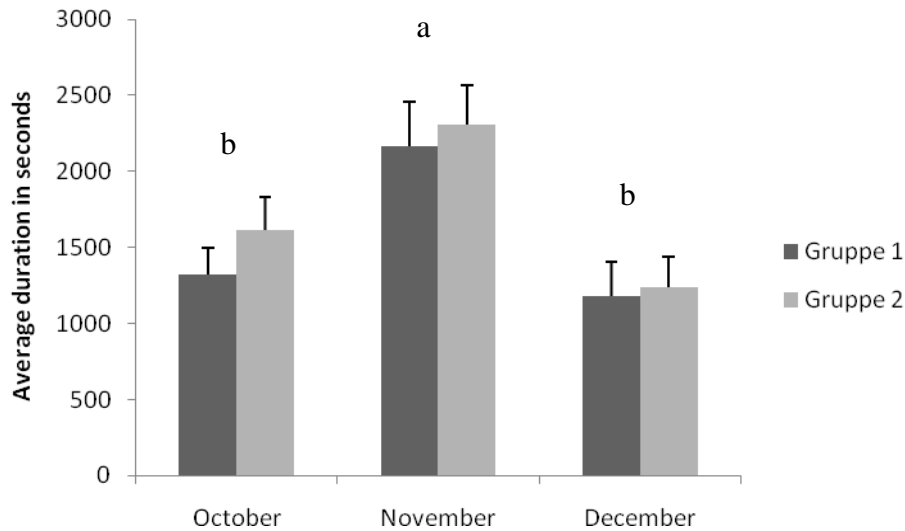


Fig. 9. Average duration (mean + SE) of simultaneously rest in seconds within period. There was no difference between groups ($P>0.100$). There was a significant effect between october and november ($T_8=3.68$, $P=0.006$) and between november and december ($T_8=4.00$, $P=0.004$).

3.4.2 Resting close < 10 cm apart

There was no general effect of group ($F_{1, 16.3}=1.61$, $P=0.222$), time of day ($F_{2, 32.8}=0.60$, $P=0.556$) and period ($F_{2, 30.9}=0.85$, $P=0.438$) on duration of close, synchronized rest. Number of pairs showing close synchronized rest are shown in table 6.

Table 6. Number of pairs showing close synchronized rest. Average duration (mean \pm SE) in seconds in the pairs showing the behaviour.

Period	Group	Number of Pairs	Total number of pairs	Mean \pm SE
October	1	1	9	188
	2	1	8	990
November	1	2	8	251 \pm 127
	2	2	9	3598 \pm 3355
December	1	0	9	0
	2	5	9	1370 \pm 488

3.4.3 Resting not close >10 cm apart

There was no general effect of group ($F_{1, 16.2}=0.00$, $P=0.965$), but there was a significant effect of time of day ($F_{2, 33.0}=40.23$, $P<0.001$), and period ($F_{2, 31.2}=10.08$, $P<0.001$) on duration of not close, synchronized rest. The recordings around feeding time show shorter duration than both morning and evening as shown in figure 10. The recordings in November show longer duration than the recordings in both October and December as shown in figure 11.

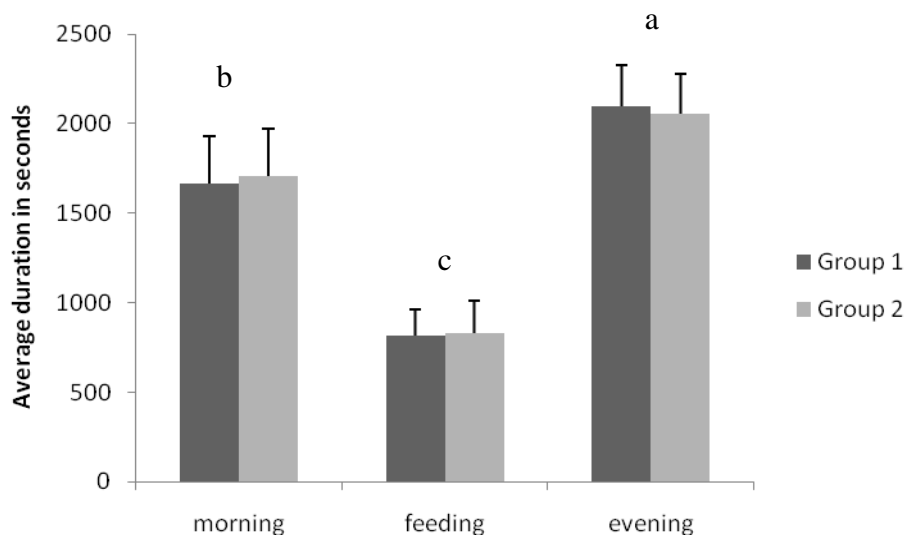


Fig. 10 Average duration (mean + SE) of not close, synchronized rest in seconds within time of day. There was a significant difference between morning and feeding ($T_8=6.91$, $P<0.001$), between morning and evening ($T_8=2.59$, $P=0.032$), and between feeding and evening ($T_8=6.70$, $P<0.001$).

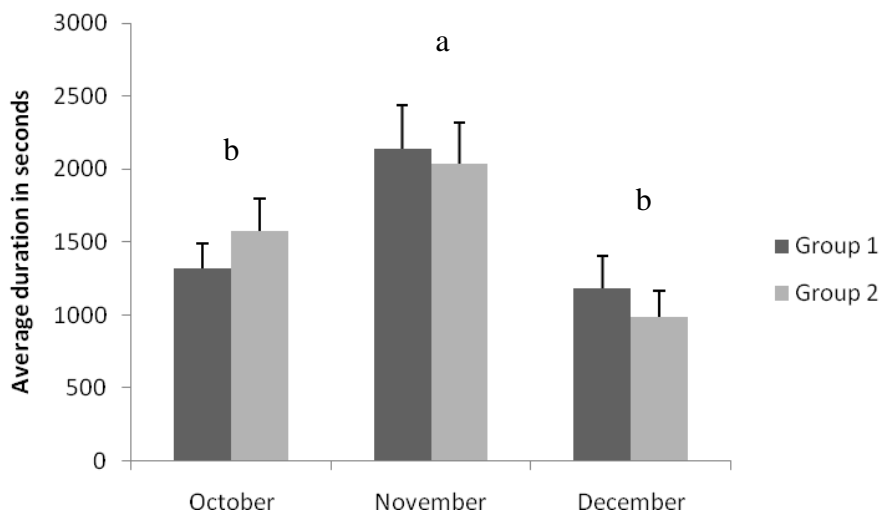


Fig. 11. Average duration (mean + SE) of not close, synchronized rest in seconds within period. There was a significant difference between October and November ($T_8=2.63$, $P=0.030$) and between November and December ($T_8=4.28$, $P=0.003$).

3.5 Body weight and wounds

3.5.1 Body weight

At the first control there was no significant difference in body weight between the three groups ($F_2=0.23$, $P=0.794$) (Group 1: mean = 5.4 ± 0.1 kg, group 2: mean = 5.5 ± 0.1 kg, control group: mean = 5.4 ± 0.1 kg). There was no significant difference between the three groups in body weight gain during the experimental period ($P>0.100$). At the end of the

experimental period in December there was still no significant difference in weight between the three groups ($P>0.100$) (Group 1: mean = 7.7 ± 0.2 kg, group 2: mean = 7.6 ± 0.2 kg, control group: mean = 7.9 ± 0.2 kg).

Throughout the experimental period there was no significant difference in weight gain within pairs between groups ($P>0.100$), but there was a significant difference in weight gain within pairs within group 1 between the start and end of the experimental period ($T_7=3.25$, $P=0.014$) and within pairs between October and December within both group 1 and 2 (group 1: $T_7=2.48$, $P=0.042$, group 2: $T_7=2.86$, $P=0.024$). Average body weight differences are shown in table 7.

Table 7. Average body weight differences in kg (mean \pm SE) within pairs in the two groups.

Group	22. Oct	18. Des
1	0.52 ± 0.21	0.66 ± 0.15
2	0.59 ± 0.18	0.70 ± 0.15

3.5.2 Wounds

There was no difference in number of animals with wounds in the two controls in October and December ($P>0.100$). (Pearson chi square: $\chi^2=1.0$, $N=56$, $df=2$, $P=0.609$). In October there were no foxes with wounds, but in December there was one fox in group 2 which had a wound on its tail, and one control fox which had a wound on its paw.

4 Discussion

In the present study body weight gain, injuries and social behaviour related to different access to important resources were examined in pair housed silver fox vixens. The vixens in group 1 had access to two top nest boxes and two food trays, while the vixens in group 2 had access to only one top nest box and one food tray.

We predicted that vixens in group 1 would have significantly lower levels of observed agonistic interactions (intensity 1, 2 and 3) and thereby less wounds than vixens in group 2 who had to share their nest box and food tray. The prediction of more aggressive encounters in group 2 reflects most animal species' motivation to establish a dominance relationship to

avoid damaging stress and wounds due to competition (Bouissou and Boissy, 2005). However the results showed no clear difference between the two groups in general, throughout the day and throughout the experimental period regarding amount of gaping signals, physical signalling, fighting and quantity of wounds. These results resemble partly the findings of Akre et al. (2010) that found no difference between the two groups regarding agonistic interactions. Instead they found differences in amount of wounds where group 2 had significantly more pairs with wounds compared to group 1. In addition, the dead vixen which died due to a bite wound was from group 2. Akre et al. (2010) found that physical aggression was more pronounced during feeding, but the present study could not reveal the same pattern indicating a more stable dominance relationship from 1.5 months subsequent to mixing. These results may indicate that agonistic behaviours may be challenging to use as welfare indicators due to the amount of severe agonistic behaviours. Since aggressive behaviours are relatively rare and thus difficult to measure properly by continuous observation quantity of wounds may serve as a better measure of costs in pair housing. By wound controls we are able to measure the results from the last days' agonistic interactions and to some extent the consequences of these interactions. In farmed foxes these wound controls may be complicated because the handler will disrupt the foxes, and because wounds might be difficult to find due to the amount of fur. The reason why the results of the present study show no differences between the groups regarding amount of wounds and agonistic behaviour may be because the vixens had established a stable dominance relationship at the end of October and thus displayed more relaxed behaviour, or because of the small amount of recordings analysed. Perhaps just observing competitive behaviour around feeding time would have revealed more clearly the negative aspects of pair housing with monopolisable resources. This method could provide better opportunities for more frequent and longer observation periods resulting in more data collected. Only one day of observation per month may give limited information about the vixens' total behaviour pattern as there is always a possibility that random factors can affect the vixens' behaviour during recording. However to the author's knowledge, all routines were followed according to the experimental plan.

When comparing the observations in the morning, around feeding and in the evening, there is a significant decrease in gaping signal sequences (intensity 1) from morning to evening in group 1 which indicates a low level of activity in the evening compared to the morning and feeding time. In group 2 we see another pattern, where the gaping signals occur more often

around feeding time than in the morning and evening. Although these results in group 2 are not significant there is an interesting aspect that there might be higher levels of gaping signals around feeding time within pairs with monopolisable resources that may indicate higher levels of stress. These findings also support the suggestions of more competitive behaviours around feeding time in environments where resources can be monopolised.

There were no differences in amount of physical signalling and fighting around feeding time compared to the observations in the morning and evening. But as we found increased levels of gaping signals in group 2, this should be investigated further to examine possible monopolising of food. Since there was no effect on physical signalling and fighting around feeding time, there might have been established a stable dominance relationship which in group 2 is seen only by low intensity gaping signals suggesting a more relaxed dominance relationship featured by agonistic signalling rather than fighting.

The one vixen which died was from group 2, and this is a dramatic consequence of housing vixens in pairs. When looking at both the negative and the positive welfare parameters the incidence of one vixen dying from wounds caused by agonistic interactions is a serious argument for not housing vixens together in cages where they have to compete for resources. Foxes are known to prefer elevated nest boxes for shelter (Jeppesen et al., 2000) and Akre et al. (2010) found that vixens in group 1 spent more time in a nest box compared to vixens in group 2 indicating that vixens prefer solitary rest inside a nest box if having the opportunity to do so. Another aspect with having access to two top nest boxes is the possibility to withdraw from any social interactions including agonistic interactions, and this may be important for avoiding stress and wounds. The vixen died within the first month after mixing which is the most critical period regarding agonistic encounters and severe wounds because the animals are establishing a dominance relationship just after mixing. For more information on the first days subsequent mixing see Akre et al. (2010).

The incidence of death among the vixens shows that aggressions between animals may be severe, and from an animal welfare point of view it is important to raise a discussion on what levels of agonistic behaviours that is acceptable in farmed animals. What levels of agonistic interactions and amount of severe wounds and death are tolerated? When reading other studies that examine levels of agonistic interactions and welfare of the animals there is no discussion on what is tolerated (Puppe et al., 1997, Otten et al., 1997). Although a scientific

research should be objective when presenting the results attained, the researchers should perhaps offer some recommendations on what levels of agonistic interactions that can be tolerated without jeopardising the welfare of the animals in question.

Although there were more pronounced differences in weight gain within the pairs in group 2 than in group 1, there were no significant differences. According to Akre et al. (2010) there is a relationship between weight gain and resource distribution as their results showed that vixens in group 1 gained significantly more weight than vixens in group 2. These results indicate that the subordinate vixen was in a stressed state subsequent to mixing, and that this stress decreased with time after mixing due to relaxed relationship between the two vixens. Akre et al. (2010) found that there was a significant increase in weight gain within the pairs in group 2 compared to the pairs in group 1 indicating that there probably is a clear dominance relationship in dyads of silver fox vixens resulting in monopolisation of the food and increased levels of stress. In the present study we found no differences between groups however, the total differences in weight within pairs increased significantly from October to December. This supports the indications of dominance relationships in silver fox vixens, and the indications of a gradually stabilisation of these relationships with time subsequent to mixing.

In the present study there was no statistical difference between the two groups regarding social play, and corresponding results were found by Akre et al. (2010) where there were no significant difference regarding social play between the group 1 and 2. This is surprising as we suggested that the level of social play would be higher in groups where resources could not be monopolised because play commonly occurs when the animals' primary needs are fulfilled, especially the level of food intake (Sharpe et al., 2002). Level of play depends more on the amount of attainable energy than having more time available to play, and evidences of the costliness of play are seen in weight gain as levels of weight gain are positively correlated to rates of play (Sharpe et al., 2002). This should result in lower levels of play observed in vixens with poor weight gain. In addition, this means that the subordinate vixens should play less in pairs with a more pronounced dominance relationship indicated by significant differences in weight gain within these pairs. Even though there are no significant results, we find that the differences in body weight within pairs in group 2 are greater than the differences in group 1, and that the differences in group 2 are decreasing from October to December. This may indicate an effect of food monopolising which decreases with days subsequent to mixing.

And when considering that the levels of social play were lower (although not significant) in group 2 than in group 1 in October and November, and decreasing from October to December, one may speculate that the subordinate vixens in group 2 suffered from more substantial levels of stress than subordinate vixens in group 1. We suggest from these results that vixens in pairs where resources can be monopolised are more stressed due to social tension than vixens in pairs where resources can not be monopolised. The results from Akre et al. (2010) and the present study also indicate that differences are more pronounced one to two months subsequent to mixing, however, the correlations between weight and play need further investigations.

Mean number of all social play sequences in both pairs within one hour was 0.2 in the study of Akre and her co-workers (2010), and identical with the mean number in this study. This is very interesting because the amount of social play was increasing with number of days following mixing in Akre et al. (2010), but in the present study the amount was decreasing with days after mixing. The reason for this pattern is uncertain but the level of social play peaked at 33 and 46 days subsequent to mixing, and before day 33 the relationship were probably not as relaxed as after day 33. The reason for a decrease in social play after day 46 may be due to seasonal changes and changes in hormone levels caused by the forthcoming breeding season.

There was not found any differences regarding the behaviour *rest close* probably due to a small number of observations. Five pairs in group 2 rested close in December and none of the pairs in group 1 which may indicate less social tension in group 2 which was not what we predicted. One explanation may be that social tension decreases as the subdominant accepts its status, and the motivation for positive interactions increases in both the dominant and subdominant vixen. As social grooming is commonly used to reinforce and stabilise dominant relationships in mammals (cattle: (Val-Laillet et al., 2009) silver foxes do not necessarily use only agonistic interactions to establish and maintain social relations (Harris and White, 1992) but perhaps also social grooming, social play and resting close to one another. There was a significant difference in amount of synchronised resting during the day indicating less social activity in the evening and more activity around feeding time as predicted due to increased activity just before feeding, and no resting while feeding. The observations of synchronised resting also showed a significant higher level in the evening than in the morning indicating least activity in the evening and medium activity level in the morning.

4.1 Conclusion

The present study examines effects of different cage environments on social behaviours and other welfare parameters regarding the relationships between adult silver fox vixens in autumn. Based on the present results there were no clear effects of different housing procedures on any of the recordings between the groups. There was just observed a few, superficial wounds in the experimental period, and thereby no significant effect of various cage environments on the occurrence of wounds. There was a higher level of aggression in group 2 than in group 1 in December; however, this was not significantly different. Vixens in group 2 showed also slightly less play in December, although there was no significant difference. The overall weight gain from October to December was not affected by housing environment, but the differences in weight gain within pairs were slightly larger for vixens in group 2. These results show some weak differences resembling our predictions; however, the reason why there were no clear effects may be due to more stable dominance relations with increasing days subsequent to mixing. Studies on competitive behaviour around feeding time should be conducted to reveal possibly monopolisation in pair housing of silver fox vixens, as we could only find slight differences between the groups regarding agonistic interactions. The results from Akre et al. (2010) and the present study also indicate that differences in behaviour and weight gain between groups are more pronounced one to two months subsequent to mixing. In addition, a possibly correlation between weight and play needs further investigations. Due to limited data collection there should be further investigations before concluding on the effects of cage environments on welfare of pair housed adult silver fox vixens in autumn. As the welfare of especially the subordinate vixens may be endangered, it is important to take the distribution of highly valued resources into consideration when designing the future social housing environments for farmed foxes.

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