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Group size and space allocation in farmed juvenile blue foxes (Alopex lagopus)

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Abstract

Farmed juvenile blue foxes were housed either singly, in pairs, or in quartets at a stocking density of either 0.6 m² or 1.2 m² per animal. The effects of group size and space allocation on physiological, behavioural and production-related parameters were assessed. The results showed that the larger space allocation, although having only minor effects on the measured parameters, allowed the foxes to maintain their individual space even in the larger group sizes. Social tension within the groups affected the behavioural and production-related parameters to a greater extent than did space allocation. The sex-related dominance order, with males having easier access to feed than females, and females having more bite scars and higher serum cortisol levels than males, appears to be the major factor affecting the general performance of mixed-sex group-housed farmed blue foxes. These results suggest that group housing of farmed juvenile blue foxes could be considered as an alternative, socially enriched way of housing these animals.

Keywords: *animal welfare, behaviour, blue fox, group housing, physiology, space allocation*

Introduction

Housing conditions for farmed foxes, the silver fox (*Vulpes vulpes*) and the blue fox (*Alopex lagopus*), have been claimed by some — for example, the general public — to be barren, small and not sufficiently enriched to meet the animals' needs (see Nimon & Broom 2001). Several attempts have been made to enrich the living environment of farmed blue foxes, for example through the provision of gnawing blocks and straw (Korhonen *et al* 2002) and platforms and nest boxes (Mononen 1996). However, the results from these studies are by no means unequivocal with regard to the welfare effects of these objects. Increasing the opportunity for social behaviour has also been suggested as a powerful way to enrich the housing environment of farmed animals (Fraser & Broom 1990; Mendl & Newberry 1997; Ahola 2002). In farmed foxes, social enrichment through group housing also leads to a greater total space allowance for each individual when adhering to minimum space requirements for the species (EU 1999). Studies by Ahola *et al* (2000b, 2002a) suggested that welfare was better in group-housed farmed blue foxes compared to their pair-housed counterparts and that group housing could represent an alternative way of housing these animals. However, it was not conclusive whether the apparent welfare effects were due to group size alone, or to the associated differences in space allocation (Ahola *et al* 2000b).

Therefore, the aim of the present study was to determine more precisely the effects of both group size and space allocation. Farmed blue fox cubs in outdoor fur sheds were housed singly, in pairs, or in quartets, with a space allocation of either 0.6 m² or 1.2 m² per individual. Both behavioural parameters (activity level, use of available cages, preference for staying in groups, locomotor stereotyped behaviour, feeding test behaviour) and physiological parameters (stress-induced hyperthermia [SIH], serum cortisol level after adrenocorticotrophic hormone [ACTH] administration, urinary cortisol:creatinine ratio [C:C], body weight, and mass of the heart, adrenals and gastrocnemius muscle [GAST]) were measured. Assessments were also made of fur quality and number of bite scars in skins.

Materials and methods

Approval to conduct the present study was issued by the Institutional Animal Care and Use Committee of the University of Kuopio (Licence number 00-36).

Animals and cage constructions

Ninety-eight blue fox cubs, born in traditional fox cages (115 × 105 × 70 cm, length × width × height) in May–June from 34 vixens, were divided into five housing systems with different group sizes (1, 2 or 4 animals per group) and different space allocations (1.2 m² [Large] or 0.6 m² [Small] per individual) at the time of weaning (when approximately eight weeks old). The housing systems were:

(i) Large-1 — a male or a female cub (siblings) housed singly in a traditional cage (1.2 m² per animal);

(ii) Small-2 — a male–female sibling pair housed in a traditional cage (0.6 m² per animal);

(iii) Large-2 — a male–female sibling pair housed in two traditional adjacent cages connected together by an opening (20 × 20 cm) (1.2 m² per animal);

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(iv) Small-4 — two male and two female siblings housed in two traditional cages connected together (0.6 m^2 per animal);

(v) Large-4 — two male and two female siblings housed in four traditional cages connected together (1.2 m^2 per animal).

Each cage was furnished with a resting platform (105 × 30 cm, length × width, 25 cm from the cage ceiling) and a feeding tray.

The housing units were located in an outdoor fur shed with two cage rows. There was a total of seven housing units for each type of housing system. The order of the housing systems in each row was determined randomly. All sibling pairs and quartets were from different vixens. Accordingly, seven male and seven female cubs (sibling pairs, from seven vixens) were housed singly in 14 traditional cages (Large-1); 14 sibling pairs (from 14 vixens) were housed either in a system comprising one cage (Small-2) (seven pairs) or two cages (Large-2) (seven pairs); and 14 sibling quartets (from 14 vixens) were housed in a system comprising either two cages (Small-4) (seven quartets) or four cages (Large-4) (seven quartets).

The animals were fed, according to the recommendations given by The Finnish Fur Breeders' Association, on fresh fur-animal feed twice per day until late September, and thereafter once per day. The daily feed portion per animal was the same for each group and it was delivered evenly onto one, two or four feeding trays in groups with one, two or four cages available for the animals, respectively.

Measured parameters

The foxes were weighed at weaning in July, in late September, and at pelting in December.

The feeding test (see Rekilä *et al* 1997, 1999) was performed four times: at the beginning and end of August, in late September, and in mid-November. The day before the test, each fox was individually marked with paint on its fur. During the test, an observer entered the shed and stopped either at the front of the cage (Large-1, Small-2), or at the front of the first cage (Large-2, Small-4) or the second cage (Large-4) of the housing system. The observer presented food on the feeding tray, remaining in front of the cage for 60 s whilst recording which individuals came to eat. The number of tests during which each individual ate was recorded (maximum = 4).

Each housing unit was video-recorded, as described in Ahola *et al* (2002a), for 24 h both in late August and in mid-November. The behaviour of the foxes was analysed from the videotapes using instantaneous sampling with a 5 min sampling interval (Martin & Bateson 1993). Altogether, 56 350 behavioural observations were recorded. The behavioural categories recorded were (i) active (moving, standing or sitting); and (ii) lying (lying awake or asleep). The occurrence of locomotor stereotyped behaviour (ie repeated pacing or jumping along the cage wall without any obvious goal or function, and not accompanied by the neighbour) was also noted. Activity levels were determined separately for the morning (0000h–0800h), working (0800h–1600h) and evening hours (1600h–0000h). The group preference index (GPI), a comparative value of the preference for staying in groups computed from the paired relations occurring in a group, was also calculated during these three separate periods for Small-2, Large-2, Small-4 and Large-4 according to Gattermann (1990) (see Ahola *et al* 2002b). Where there was more than one cage available for the foxes (Large-2, Small-4, Large-4) the location of the foxes in their home cages was also recorded.

In mid-October, urine was collected from foxes in all housing units over a 24 h period, giving a total of 42 urine samples. The concentrations of cortisol and creatinine in the urine were measured as described in Ahola *et al* (2002a). Because of variation in the dilution of urine, the results of cortisol concentration were expressed as the cortisol:creatinine ratio (C:C) (Novak & Drewsen 1989; Lasley & Kirkpatric 1991). In Large-1, the urine samples of the siblings housed in different cages were analysed separately but the results were thereafter pooled together.

Rectal temperature was measured to assess the effect of human handling and restraint on SIH (see Moe 1996; Moe & Bakken 1997; Ahola *et al* 2000a, 2001). In the SIH test (conducted at the beginning of November), 14 foxes situated in cages on one side of the shed were successively caught from their home cages. The time was measured from the moment humans entered the shed to the time the first rectal temperature (T1) was obtained (TIME). After T1 was taken, the foxes were restrained in smaller single cages (70 × 35 × 35 cm) situated inside the shed. In order to measure the maximum rectal temperature (Moe & Bakken 1997), a second recording (T2) was taken after 35 min of restraint. Only one or two sets of 14 foxes were tested on any one day. When two sets were tested on the same day, the foxes involved were situated in the shed some 12 m apart from each other, and those in the second set were not disturbed by humans before their test.

At pelting time in December, the foxes were caught and injected intramuscularly with ACTH (0.3 mg synthetic $ACTH_{1–24}$ per animal [Synacthen Depot: Novartis Pharma S.A., Huningue, France]), and then placed alone in a smaller cage (70 × 35 × 35 cm). Two hours after injection they were euthanased by electrocution, according to the methods recommended by the Standing Committee of the European Convention for the Protection of Animals Kept for Farming Purposes (EU 1999). Blood samples were obtained immediately by cardiac puncture. The serum cortisol level (nmol l^{-1}), as a maximum response to ACTH administration (Fraser & Broom 1990; Rekilä *et al* 1999; Ahola *et al* 2000a), was measured using a competitive immunoassay technique (Coat-A-Count Cortisol Assay: Diagnostic Products Corporation, Los Angeles, USA).

After pelting, the gastrocnemius muscle (GAST) from the left hind limb, the adrenals and the heart were removed, cleaned and weighed. The number of bite scars on the fleshed skins was counted. Professional fur graders at the Finnish Fur Sales Ltd (Helsinki, Finland) evaluated the

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Table 1 Mean body weight (± SD) of male (M) and female (F) blue fox cubs at weaning in July, in late September, and at pelting in December in the five different housing systems.

Housing system	Mean body weight (kg)					
	July		September		December	
	M	F	M	F	M	F
Large-1	2.0 ± 0.5	2.0 ± 0.3	9.9 ± 1.7	8.9 ± 1.0	12.3 ± 1.6	11.2 ± 1.4
Small-2	2.1 ± 0.2	1.9 ± 0.3	9.9 ± 1.6	8.9 ± 1.3	13.1 ± 2.1	11.4 ± 1.7
Large-2	2.1 ± 0.4	2.0 ± 0.2	9.3 ± 1.5	8.4 ± 0.7	12.2 ± 1.0	10.8 ± 1.1
Small-4	2.0 ± 0.2	1.9 ± 0.2	9.2 ± 0.9	9.0 ± 1.3	12.4 ± 0.6	11.5 ± 0.8
Large-4	1.9 ± 0.3	1.8 ± 0.3	8.9 ± 0.8	8.2 ± 0.7	12.1 ± 1.1	10.9 ± 1.3

Significance levels (GLM for repeated measures): month $P = 0.000$, sex $P = 0.000$, group size $P > 0.1$, space allocation $P > 0.1$. Interaction month × sex $P = 0.000$, other interactions $P > 0.1$.

quality of the furs using a 10-point scale (1 = poorest, 10 = best).

Statistical analysis

Because individuals in Small-2, Large-2, Small-4, and Large-4 housing units were not identifiable in the videotapes, behaviour (activity, use of available cages, locomotor stereotyped behaviour) was expressed as the mean value of the siblings in each unit (n = 7 for each housing system). In Large-1, the behavioural and C:C data from the male and the female siblings housed in different cages were pooled (n = 7). Furthermore, since each housing unit with more than one animal comprised cubs from the same litter (ie they were not independent of each other), the mean values of the feeding test scores, physiological parameters, quality scores of the furs, and the numbers of bite scars within each housing unit, for male and female cubs were used separately in statistical analyses (Martin & Bateson 1993) (n = 7 for both males and females in each housing system).

Statistical analyses were performed using SPSS for Windows. A General Linear Model (GLM) for repeated measures (between-subject factors: group size and space allocation) was used to analyse differences between the five housing systems in activity levels and the GPI. Cage preference in Large-2, Small-4 and Large-4 was tested against a random (50%) preference using a paired samples *t*-test (in Large-2 and Small-4 the first cage versus 50%; in Large-4 the two first cages versus 50%).

Differences in body weight were analysed using a GLM for repeated measures (within-subject variables: month and sex; between-subjects factors: group size and space allocation). A GLM for repeated measures (within-subjects variable: sex; between-subject factors: group size and space allocation) was also used for the statistical analyses of the heart, GAST and adrenal masses as well as for evaluation of the serum cortisol concentration after ACTH administration. Since no sex difference in TIME, T1 or T2 was revealed (GLM for repeated measures: $P > 0.1$ in each case), data from males and females were pooled with regard to the SIH results. Furthermore, because TIME correlated significantly with T1 ($r = 0.292$; $P = 0.015$), TIME was used as a covariate in the further analysis of the SIH data. Since the variances of the variable TIME were unequal in the five experimental groups, the effects of space allocation and group size on this variable were tested using a Mann-Whitney *U* test and a Kruskal-Wallis test, respectively. Differences between the housing systems in T1, T2 and C:C were analysed using a univariate GLM.

The effect of sex on the feeding test score, quality of furs and number of bite scars was analysed using Wilcoxon signed-ranks tests. Kruskal-Wallis tests and Mann-Whitney *U* tests were used to evaluate the effects of group size and space allocation, respectively, on the feeding test scores, quality of the furs and number of bite scars, as well as on the incidence of stereotyped behaviour.

Results

In general, the blue fox cubs grew well in their experimental housing systems. No noticeable illnesses were observed among the foxes, and only one individual (a male from Large-2) died during the experiment.

Body weight increased with the advance of autumn and was significantly greater in males than in females from September onwards (Table 1). Group size and space allocation had no effect on body weight.

The percentage of time spent engaged in active behaviours did not change from August (21% ± 0.1) to November (22% ± 1) (Figure 1). However, the daily activity rhythm changed from predominantly night activity in August to day activity in November. Group size and space allocation did not have a direct effect on the activity levels of the animals. In Small-2 and Large-2, however, the percentage of time spent in active behaviours decreased from August until November, whereas for animals housed as singles and quartets the opposite occurred.

In August, cubs that had a space allowance of 1.2 m^2 per animal, and where more than one cage was available, spent a greater percentage of time in the cage (Large-2) or the two cages (Large-4) nearest to the door from which humans normally entered the shed, than in the cage/cages further back (Figure 2). With a space allocation of 0.6 m^2 per animal, the opposite was observed. In November, the preference for the nearest two cages became even more pronounced in Large-4, but in Large-2 and Small-4 the preference for any particular cage seemed to disappear.

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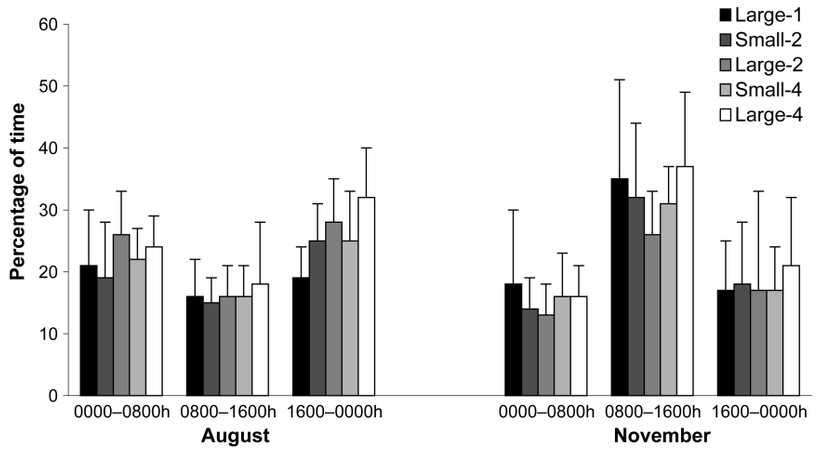

Figure 1 Activity levels (percentage of time engaged in active behaviours) of the experimental groups during morning (0000h–0800h), working (0800h–1600h) and evening hours (1600h–0000h). Significance levels (GLM for repeated measures): month $P > 0.1$, hours $P = 0.006$, group size $P > 0.1$, space allocation $P > 0.1$, month × group size $P = 0.019$, month × hours $P = 0.000$, other interactions $P > 0.1$.

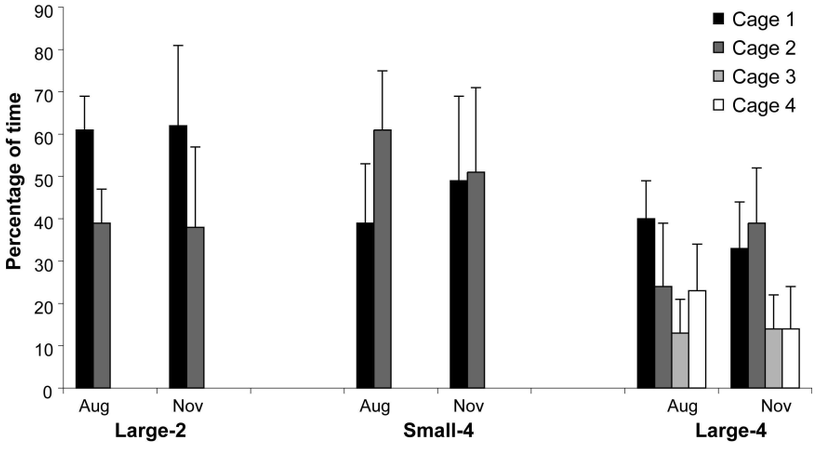

Figure 2 Percentage of time spent in cages 1–4 (1 = the cage nearest to the door humans normally entered) by cubs in housing systems with more than one cage. Significance levels (paired samples *t*-test; Large-2 and Small-4, cage 1 vs 50%; Large-4, cages 1 and 2 vs 50%): Large-2 — Aug $P = 0.015$, Nov $P > 0.1$; Small-4 — Aug $P = 0.069$, Nov $P > 0.1$; Large-4 — Aug $P = 0.022$, Nov $P = 0.012$.

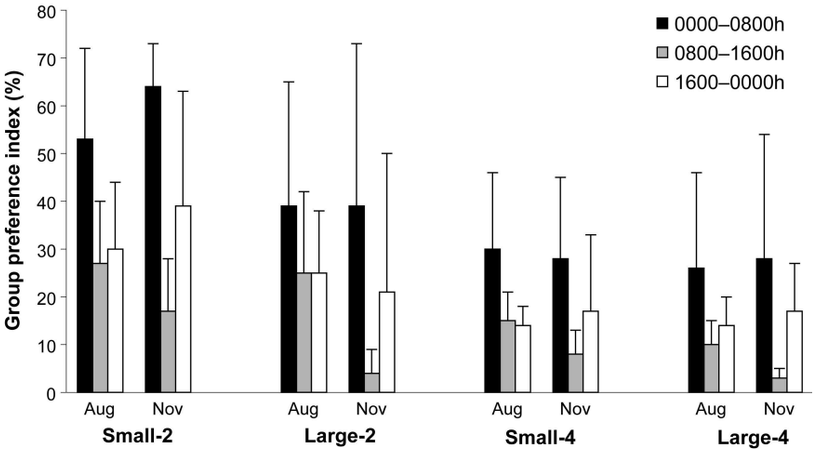

Figure 3 Group Preference Index (GPI) (%) in blue fox cubs housed either in pairs or in quartets. Significance levels (GLM for repeated measured): month $P > 0.1$, hours $P = 0.000$, space allocation $P = 0.044$, group size $P = 0.001$, month × hours $P = 0.000$, other interactions $P > 0.1$.

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Table 2 Mean (± SD) time taken to catch foxes from their home cage and measure the first rectal temperature (TIME), and the mean rectal temperature immediately after capture (T1) and 35 min after capture and restraint (T2).

Housing system	TIME (s)	T1 (°C)	T2 (°C)
Large-1	420 ± 302	39.3 ± 0.4	40.0 ± 0.4
Small-2	418 ± 160	39.2 ± 0.3	39.9 ± 0.3
Large-2	539 ± 288	39.6 ± 0.4	40.1 ± 0.3
Small-4	488 ± 156	39.6 ± 0.5	40.0 ± 0.3
Large-4	529 ± 197	40.0 ± 0.5	39.9 ± 0.3
***P* value**			
Group size	NS[a]	0.000[c]	NS[d]
Space allocation	NS[b]	0.004[c]	NS[d]

[a] Kruskal-Wallis test
[b] Mann-Whitney *U* test
[c] GLM for univariate measures with TIME as a covariate
[d] GLM for univariate measures
In GLM: no significant interactions
NS = no significant difference ($P > 0.1$)

Table 3 Feeding test scores (max 4; mean/median) for blue fox cubs in five experimental groups.

	Large-1	Small-2	Large-2	Small-4	Large-4	Group size[b]	Space allocation[c]
Males	3.0/3.0	3.4/1.5	3.1/1.5	2.9/0.8	3.0/0.4	0.042	NS
Females	2.9/1.6	2.6/1.1	2.6/1.4	2.6/0.8	1.6/0.8	NS	NS
Sex[a]	NS	0.098	NS	NS	0.027		

[a] Wilcoxon signed-ranks test
[b] Kruskal-Wallis test
[c] Mann-Whitney *U* test
NS = no significant difference ($P > 0.1$)

In groups with more than one animal (Small-2, Large-2, Small-4, Large-4), the GPI did not change with time (26% ± 2 and 24% ± 3 in August and November, respectively) (Figure 3). Foxes huddled together most during the morning hours (38% ± 4) and least during the working hours (14% ± 1). The GPI decreased with increasing group size and increasing space allocation.

No stereotyped behaviour was observed in any of the experimental groups.

In the SIH test, TIME did not differ between the five experimental groups (Table 2). T1 increased with increasing group size and space allocation, while T2 was not affected by either group size or space allocation.

In general, males ate more frequently during the four feeding tests than the females (Wilcoxon signed-ranks test: $P = 0.007$). This effect of sex on feeding test behaviour was particularly pronounced in foxes from Large-4 housing units (Table 3). As a result of these sex differences, feeding test scores were analysed separately for males and females. Males housed in quartets ate less frequently than those housed singly or in pairs, but space allocation had no effect on feeding test scores. For females, the score was not affected by either group size or space allocation.

Serum cortisol levels after ACTH administration were higher in females than in males (Table 4). Group size and space allocation had no significant effect on either serum cortisol level or C:C, but males had significantly heavier hearts, GASTs and adrenals than females (Table 4). No significant differences in these masses were revealed between different group sizes or space allocations.

In general, males had better fur quality and a lower number of bite scars than females (Wilcoxon signed-ranks test: $P = 0.076$ and $P = 0.024$, respectively). This effect of sex was particularly pronounced in the quartets, where the females had significantly worse fur quality (Small-4) and a higher number of bite scars (Small-4, Large-4) than the males (Table 5). As a result of these sex differences, fur quality and bite scar data were analysed separately for males and females. Within each sex, space allocation had no effect on the quality of the furs and the number of bite scars. The number of bite scars increased with increasing group size in both males and females. Fur quality was not, however, affected by group size.

Discussion

In studies of space allocation, it has been shown that space restriction may lead to an increased incidence of abnormal behaviours or passiveness (Broom & Johnson 1993). However, Korhonen *et al* (2001a,b) demonstrated that increasing the available space from 0.5 m^2 to 15 m^2 did not increase the time spent in active behaviours in farmed blue

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Table 4 Masses of the heart, gastrocnemius muscle (GAST) (g), and adrenals (mg), serum cortisol level (nmol l^{-1}) 2 h after ACTH administration, and cortisol:creatinine ratio (C:C, × 10^{-3}) (mean ± SD) in the blue fox cubs in five experimental groups.

	Large-1		Small-2		Large-2		Small-4		Large-4		*P*		
	M	F	M	F	M	F	M	F	M	F	Sex	Group size	Space allocation
Heart	44±4	38±2	47±6	40±7	44±6	41±4	44±2	40±3	43±2	38±4	0.000[a]	NS[a]	NS[a]
GAST	30±4	26±4	32±2	28±4	33±4	29±1	33±2	30±3	33±5	29±3	0.000[a]	NS[a]	NS[a]
Adrenals	386±35	336±39	393±57	380±45	371±69	314±53	381±42	360±84	398±43	348±50	0.004[a]	NS[a]	NS[a]
Cortisol	281±124	317±109	225±76	323±59	291±62	320±83	309±76	317±73	307±58	315±121	0.041[a]	NS[a]	NS[a]
C:C	2.9±0.9		3.6±1.8		3.0±2.0		3.4±1.9		3.1±1.7			NS[b]	NS[b]

[a] GLM for repeated measures
[b] GLM for univariate measures
No significant interactions
NS = no significant difference ($P > 0.1$)

Table 5 The quality of furs (10-point scale: 1 = poorest, 10 = best) and the number of scars on the leather side of the fur (mean/median) from blue fox cubs in five experimental groups.

	Large-1	Small-2	Large-2	Small-4	Large-4	Group size[b]	Space allocation[c]
Quality							
Males	5.9/6.0	5.6/6.0	5.2/5.5	5.5/6.0	5.4/5.5	NS	NS
Females	5.2/5.5	5.6/6.0	5.0/5.0	4.9/5.0	4.8/4.5	NS	NS
Sex[a]	NS	NS	NS	0.034	NS		
Bite scars							
Males	0.3/0.0	1.6/0.0	1.2/1.0	1.5/1.0	1.9/1.5	0.026	NS
Females	0.4/0.0	1.7/1.0	1.7/1.0	9.2/2.0	5.1/4.5	0.001	NS
Sex[a]	NS	NS	NS	0.034	0.034		

[a] Wilcoxon signed-ranks test
[b] Kruskal-Wallis test
[c] Mann-Whitney *U* test
NS = no significant difference ($P > 0.1$)

foxes. Similarly, in the present study, space allocation had no effect on the time spent in active behaviours or on the exercise-related mass parameters (ie heart and GAST masses [cf silver foxes Ahola *et al* 2000a]). Furthermore, space allocation did not affect the incidence of stereotyped behaviours — no stereotyped behaviour was observed in any of the experimental groups of foxes. Although some stereotyped behavioural patterns may have been overlooked because of the video-recording schedule, this result parallels the results of earlier studies indicating that stereotypies are rarely observed in farmed blue foxes (Wikman *et al* 1999; Korhonen *et al* 2000, 2001a,b). In addition, studies have demonstrated that cage size does not unambiguously affect the time spent in stereotyped behaviours, in either the blue fox (Korhonen *et al* 2001a,b) or the silver fox (Ahola *et al* 2002b).

Group size did not affect the time spent engaging in abnormal behaviours or the activity levels and rhythms in the present study. This result is in contrast to that reported in farmed silver foxes, where singly housed juvenile silver foxes spent significantly more time in stereotyped behaviours than individuals housed either in pairs or in quartets (Ahola *et al* 2002b). Furthermore, singly housed silver fox cubs were more active during working hours (0800h–1600h) than cubs housed with their littermates. Ahola *et al* (2002b) concluded that, in the absence of cagemates, silver foxes were possibly suffering from frustration and were seeking social stimulus from the presence of humans. The present results appear to show that social enrichment may be of greater value for farmed silver foxes than for farmed blue foxes, or that blue foxes may be better adapted to present farming conditions.

It has also been reported that problems may arise in larger housing systems because of lack of habituation to humans (Pedersen & Jeppesen 1998; Ahola *et al* 2000a, 2001). Large areas allow animals to flee from humans, and as a consequence the animals may become more fearful (see Ahola 2002). The ability to tolerate human handling and

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restraint is beneficial for farmed animals because such procedures are common, for example during health inspections. The present results from the SIH test revealed that T1 increased with increasing space allocation and group size. This suggests that habituation to humans may not have been adequate or that the animals may have become de-socialised from humans when space allocation was increased. Similar results were observed with regard to group size; foxes housed in larger groups may have been more engaged with the social organisation within the group and less engaged in habituating and socialising with humans. However, it must be borne in mind that rectal temperature increased during the test for all subjects, and that only the rate of development of SIH was slower in singly housed foxes and in foxes housed with the smaller space allocation. Moe and Bakken (1997) demonstrated that both the sympatho–adrenal–medullary (SAM) and the hypothalamic–pituitary–adrenal (HPA) systems are involved in the development of SIH. Furthermore, it has been demonstrated that repeated stress may lead to increased sensitivity to the stressor (Broom & Johnson 1993). Thus, it can be hypothesised that in the larger groups repeated exposure to within-group social tension may have resulted in more reactive individuals. On the other hand, because SIH, at least in farmed silver foxes, can be used as a measure of fear (Moe 1996; Moe & Bakken 1997), the faster development of SIH in quartets housed with 1.2 m^2 per animal could also be a sign of increased fear of humans in these individuals.

The feeding test has been developed to measure fear of humans (Rekilä *et al* 1997). However, it has already been suggested that in group-housed farmed foxes, the feeding test may measure not only the level of fear of humans, but also the social tension within the group (silver fox, Ahola *et al* 2002a; blue fox, Ahola *et al* 2000b). The effect of social tension and dominance order on feeding test behaviour was also evident in the present study (blue fox) as the males' feeding test scores were significantly higher than the females' scores. Furthermore, in the males, the feeding test score decreased with increasing group size; in other words, in the groups where there were two males, one male did not always have access to feed while the other was eating. This indicates that, in addition to the social tension between males and females, a dominance order exists between males. These results suggest that in group-housed blue foxes, as is the case in group-housed silver foxes (Ahola *et al* 2002b), the feeding test also reflects the social organisation within the group, not merely the foxes' fear of humans.

The results from the feeding test indicate that males, with their priority access to food, dominated females, as previously demonstrated by eg Wakely and Mallory (1988) and Korhonen and Alasuutari (1995). Wakely and Mallory (1988) demonstrated that in captive arctic foxes (*Alopex lagopus*) aggressive acts were more common, especially in feeding situations, prior to the autumn equinox than afterwards. After the autumn equinox, ie when the animals had reached their adult size, aggression decreased as the rank order became clearer with heavier males dominating females. In the present study, males were significantly heavier than females from September onwards. Furthermore, males had lower serum cortisol levels after ACTH administration than did females, indicating that females may have experienced more long-term stress than males. However, despite the males' higher position in the rank order, the number of bite scars increased with increasing group size for males and females, although this effect was more pronounced in females. This result indicates that at least occasionally, despite a clear sex-related dominance order, social tension may lead to fighting between individuals in larger groups. It is also possible that the bite scars were inflicted when the dominance order within the groups was still unstable and dynamic, or during play behaviour. Further studies will be required to address these questions.

Similarly to wild red fox (*Vulpes vulpes*) cubs (see Ahola 2002), some wild arctic fox cubs tend to disperse from their natal area during their first year of life (Tannerfeldt & Angerbjörn 1996; Strand *et al* 2000), mainly as a result of a shortage in food supply (Chesemore 1975). Ahola and Mononen (2002) showed that in group-housed silver foxes, aggression and the tendency to avoid cage-mates increased with the approach of autumn. Furthermore, the GPI decreased with time in silver foxes (Ahola *et al* 2002b), and the welfare of some group members decreased because of the prevention of their natural dispersal behaviour (Ahola *et al* 2000a). In the present study, the GPI for blue foxes remained constant throughout the growing season but decreased with increasing space allocation and group size. This indicates that farmed blue foxes, like farmed silver foxes, have a tendency to avoid contact with each other, staying in close contact only while resting. Furthermore, it seems that in blue foxes, unlike in silver foxes (Ahola 2002), this tendency is not connected with developmental stage. The increased tendency to avoid each other with the advance of autumn was observed in quartets with smaller space allocation (Small-4) where an early preference for particular cages disappeared and all available space was more equally used. This occurred because some of the blue foxes had to content themselves with occupying less desirable spots in the housing system in order to be able to avoid close contact with group mates. However, cage preference also disappeared in pair-housed foxes that had access to two cages; in other words, the male and the female tried to avoid each other in their housing unit. This result, like those presented above, shows that the sex-related dominance order was possibly the major factor affecting the physiological and behavioural performance of the experimental blue foxes.

Conclusions and animal welfare implications

The present results, like those reported by Ahola *et al* (2000b, 2002a), show that group housing of farmed blue foxes could possibly be considered as an alternative, socially enriched way of housing these animals. The group sizes and space allocations used had only minor effects on behaviour and physiology. Despite this, the results showed that a larger space allocation allowed the foxes to maintain

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their individual space even in the larger groups. Furthermore, it was revealed that social tension within the groups may have had a greater impact than space allocation on behaviour and production-related parameters. Despite the increased number of bite scars in group-housed blue foxes, the quality of furs was not affected by either group size or space allocation. The sex-related dominance order, which develops as the animals reach maturity, may, however, lead to some welfare problems in group-housed blue foxes. The females showed potentially impaired welfare, with higher serum cortisol levels than males and more bite marks, especially when housed in quartets. Further research with field experiments is required in order to investigate whether group housing of blue foxes under production conditions, including, for example, male- or female-biased litters, could be considered a feasible method of housing these animals.

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