

Effects of housing conditions on behaviour and physiology in the Finnraccoon (*Nyctereutes procyonoides ussuriensis*)

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Abstract

The welfare of juvenile Finnraccoons (*Nyctereutes procyonoides ussuriensis*) was compared between various housing conditions through the measurement of day-time behaviour and physiological variables. For the small control treatment (SC), Finnraccoons were raised in pairs in small cages; in the large area treatment (LA), in pairs in large cages; in the large control treatment (LC), in groups of four in large cages and in the large enrichment treatment (LE), in groups of four in large cages with access to a nest-box and a large tube, from weaning to pelting time. Study subjects consisted of a total of 152 Finnraccoons. As autumn progressed, day-time resting increased, especially allohuddling; while active behaviours decreased. Allohuddling was the most common type of resting; apart from in the LE treatment, resting shelters were used effectively alongside allohuddling. Locomotion was observed more frequently in LA and LC treatments, ie in large cages without shelters. The nest-box roof was preferred to the platform as an elevated location, and the nest-box to the tube as a resting shelter. Agonistic interactions were not observed. Males grew heavier than females and had heavier organs. No systematic differences in haematological and other physiological parameters were found between the treatments. Catching time was shortest in the SC treatment. The LE treatment compromised animals' cleanliness. Based on the intensive positive social interactions and regular shelter use, group housing and access to resting shelters are recommended for juvenile Finnraccoons.

Keywords: animal welfare, cage, fur farming, nest-box, raccoon dog, resting

Introduction

Housing condition greatly influences the welfare of farm animals and the principle factors are the availability of the area and the social and physical complexity of the environment. The European Convention (1999) set minimum requirements for these variables in fur animals by stipulating a minimum area available and an obligatory activity object as well as discouraging farmers from single housing of juveniles. These minimum requirements provide a certain level of welfare for the Finnraccoon (*Nyctereutes procyonoides ussuriensis*), a medium-sized canid raised for fur since the 1970s. However, in the case of this particular species, research into housing condition has been limited, and therefore there is a lack of information on how various housing conditions affect Finnraccoon welfare (Koistinen 2016).

The behaviour of wild conspecifics has been used as a guide in developing housing for captive animals (Broom & Fraser 2015). Adoption of environmental features utilised by wild conspecifics allows the design of the captive housing environment to meet the possible behavioural needs of captive

individuals. The wild conspecific of the Finnraccoon, ie the raccoon dog, mates for life (Drygala *et al* 2008a) as paternal behaviour plays a significant role in the nursing of young (Kauhala *et al* 1998; Drygala *et al* 2008b). Offspring disperse from the natal denning area in late summer or autumn (Sutor 2008; Drygala *et al* 2010). Raccoon dogs do not actively defend a territory but instead show tolerance towards the neighbouring conspecifics (Drygala *et al* 2008c; Sutor & Schwarz 2012). Various habitats are utilised opportunistically, in particular those with dense vegetation (Drygala *et al* 2008c; Sutor & Schwarz 2013) and water sides (Süld *et al* 2017). Though crossing a lake through ice cover has been reported, for example, they typically avoid moving in open areas (Mustonen *et al* 2012). Virtually their entire resting time is spent in natural shelters (Kowalczyk & Zalewski 2011). Opportunistic foraging behaviour is readily practiced as this omnivorous species seeks out small food items which are manipulated using the mouth and paws (Rudert 2008; Sidorovich *et al* 2008; Sutor *et al* 2010). It can thus be extrapolated that housing of juvenile Finnraccoons should include social companionship, sufficient area for locomotion, complexity, a shelter for resting and objects for manipulation.

Earlier research has shown group housing with conspecifics to provide social enrichment in juvenile Finnraccoons (Ahola *et al* 2007) with a tendency to synchronise behaviour (Korhonen 1988a) and allohuddle (Ahola *et al* 2007; Koistinen & Korhonen 2018). Agonistic behaviour is rarely observed (Korhonen 1988a; Korhonen & Harri 1988a). Group-housed juveniles are more active and perform less stereotypic behaviour than those housed in pairs (Ahola *et al* 2007) and have heavier *gastrocnemius* muscles (Hänninen *et al* 2002) — an indication of higher level of physical activity (cf Duncan *et al* 1998). Group size (Hänninen *et al* 2002) and family housing (Kasanen *et al* 2000) have not been shown to affect cortisol levels after ACTH administration, however the total adrenal mass is lower at pelting time in pair-housed juveniles compared to those housed in sibling groups with the mother (Kasanen *et al* 2000) and this also tends to be the case in groups where the mother is absent (Hänninen *et al* 2002). Group size does not affect animals' growth (Korhonen *et al* 1986; Kasanen *et al* 2000) or temperament (Korhonen & Harri 1988a), but heavier spleen and kidneys, and lighter thyroid glands have been found in pair-housed juveniles compared to those housed in groups of four (Korhonen & Harri 1988b). Thus, the behavioural results indicate social interactions which are positive with respect to welfare, but the physiological measurements are somewhat contradictory.

The above results concerning group size are somewhat confounded with area available, ie the larger the group, the larger the available area. When group size remains unchanged and available area varied, pair-housed Finnraccoons sit more in a very small cage compared to a larger one (Korhonen & Harri 1988b). However, merely increasing the available area may not enhance welfare, it may simply be that a larger available area allows more behavioural complexity which may, ultimately, be more meaningful to the animal (silver fox [*Vulpes vulpes*]: Ahola 2002; mink [*Neovison vison*]: Hansen *et al* 2007). When the space available and the complexity are increased via provision of an outdoor run from the cage, the extra area is used for locomotion and not resting (Korhonen & Alasuutari 1993). When comparing cage housing and more complex enclosures, weight gain is found to be lower in the enclosure than the cage (Fortuńska & Kasanen 2002). This may be due to increased activity, and more variable behaviour, as has been demonstrated in foxes (increased available area: silver fox: Ahola [2002]; blue fox [*Vulpes lagopus*]: Korhonen *et al* [2001]). Finnraccoons readily make use of increasingly complex resources, such as nest-boxes (Koistinen *et al* 2018), a large tunnel-like tube (Kasanen *et al* 2000), a platform (Korhonen *et al* 1997; Koistinen & Korhonen 2018) and activity objects (bone: Koistinen *et al* 2017, 2018). In a comprehensive study, Korhonen and Harri (1985b) showed that organ masses, such as liver, kidneys, heart, thymus, thyroid glands and spleen are affected by Finnraccoons' previous life history. Furthermore, when comparing captive Finnraccoons with wild raccoon dogs, lymphocyte and monocyte levels are

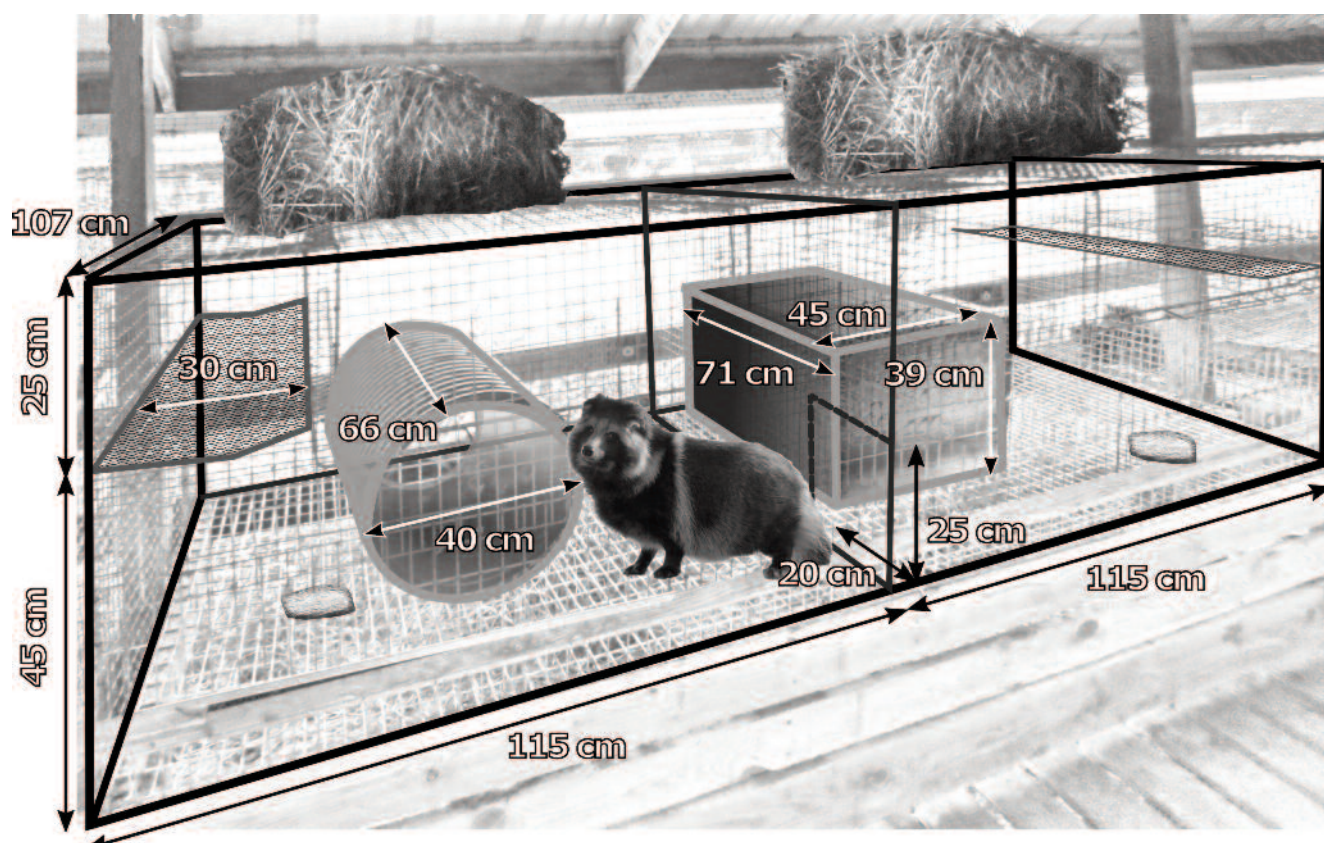
higher and neutrophil levels lower in the captive variety (Nowakowicz-Debek *et al* 2013).

Finnraccoon behaviour in various housing conditions along with associated welfare implications have not yet been fully explored, therefore the aim was to report the behaviour and physiology of juveniles raised from weaning (July) to pelting (December) in housing conditions varying as regards available area, social and physical complexity. Only housing conditions fitting the European Convention (1999) minimum requirements were chosen. Furthermore, to cover both genders, juvenile Finnraccoons were raised in male-female pairs and groups, which is a common procedure on commercial farms.

A variety of measurements were used as animal welfare is multifaceted and assessable via various physiological (eg Broom & Fraser 2015), behavioural (Mench & Mason 1997) and emotional (eg Boissy *et al* 2007) measures. Resting preferences, general activity level, including stereotypic behaviour, social interactions and interactions with the available resources were measured. Since no recognised convention exists for the utilisation of specific physiological welfare measurements and relatively little information exists on this species' physiological parameters, those implemented in previous studies or that proved meaningful in other (fur animal) species were adopted, to compare treatments and clarify the effectiveness of such measurements. At this early stage, only measurements part of routine husbandry protocols or post mortem variables were selected. Chosen variables indicated stress level, immune system function and health and included, bodyweight (Fortuńska & Kasanen 2002), adrenal mass (Kasanen *et al* 2000; Hänninen *et al* 2002), mass of lymphoid organs (Korhonen & Harri 1988b; mink: Díez-León *et al* 2016), mass of other organs utilised previously in this species (eg Korhonen & Harri 1985b), haematology (Nowakowicz-Debek *et al* 2013; blue fox: Korhonen *et al* 2002; silver fox: Jeppesen & Pedersen 1991), cleanliness of the fur (foxes: WelFur 2015) and duration to catch the animal (blue fox: Korhonen *et al* 2001). Taking into account the behaviour of wild conspecifics, not to mention data from earlier studies, we hypothesise that Finnraccoons utilise their opportunity for social interactions irrespective of group size and activity level. We hypothesise that the least amount of physical activity is observed in the small cage and, therefore, weight gain is higher than in other treatments, but that organs are smaller in relation to body size and red blood cell values lower. And, finally, that in the most complex cage, animals use shelters while resting, but due to the increased risk of faecal soiling within the housing environment (eg nest-box: Korhonen & Nurminen 1986), their health status is worse than for other treatments, which could be seen in leucocyte total levels and differential counts.

Table 1 Description of the four study treatments.

Treatment	Group size (M + F)	Floor area (m ²)	Area per animal (m ²)	Furnishings	Number of units
Small control (SC)	1 + 1	1.2	0.6	Platform, wooden block, straw	14
Large area (LA)	1 + 1	2.4	1.2	Two platforms, two wooden blocks, straw	14
Large control (LC)	2 + 2	2.4	0.6	Two platforms, two wooden blocks, straw	12
Large enrichment (LE)	2 + 2	2.4	0.6	Two platforms, two wooden blocks, straw, nest-box, plastic tube	12

Figure 1

The experimental cage of the LE treatment, including the two sections of the cage, two platforms, the nest-box and the tube with the dimensions. The two bales of straw are situated on top of the cage above the platforms and the two wooden blocks are situated on the cage floor. The Finnracon in the figure illustrates the size of a fully grown adult with mature winter fur at the end of the study in December.

Materials and methods

Ethical note

This study was part of a large experiment carried out at Kannus Research Farm Luova Ltd in Finland (63.54°N, 23.54°E). It was approved by the Animal Care Committee of Southern Finland Regional State Administrative Agency (ESAVI/6137/04.10.07/2015).

Study animals and housing

Study subjects consisted of a total of 152 Finnracons from 52 separate litters. They were born on a private fur farm in western Finland in May 2015. Natal cages (floor area 2 m², height 70 cm) were situated in two outdoor sheds and

equipped with a wooden, two-room nest-box, platform, activity object and bale of straw on the top of the cage. Finnracons suckled until weaning at nine weeks of age after which time they were taken to the Kannus Research Farm.

Here, Finnracons from each litter were randomly allocated to one of four experimental treatments, differing as regards number of animals raised in the cage, available area, animal density and physical complexity (enrichment) of the cage (Table 1). In the small control treatment (SC), Finnracons were raised as pairs in small cages; in the large area treatment (LA), they were raised in pairs in large cages; in the large control treatment (LC) as groups of four in large cages and, finally, in the large enrichment treatment (LE), as groups of four in large cages, equipped with a nest-box and a large tube (Figure 1).

The small cage floor area amounted to 1.2 m² while the larger area (2.4 m²) was constructed from two adjoining cages connected via an opening. All housing conditions had a slightly V-shaped resting platform mounted 45 cm above the cage floor per 1.2 m² section, as well as one loose activity object (a wooden block, approximately 30 × 7 cm; [length × diameter]) on the cage floor and one bale of straw on the top of the cage, which animals could reach through the mesh. Finnraccoons were able to carry the wooden activity objects in their mouths. For the LE treatment, a nest-box was placed in one of the available cage sections and turned upside down to prevent Finnraccoons from defaecating inside it. The other section had a large, plastic tube. Each resting shelter was adjusted in size to ensure individual animals would view it as a snug shelter as opposed to simply an area with solid walls. Therefore, not all fully grown individuals in a particular cage could enter the same shelter simultaneously. Two different shelters, differing in shape and material, were provided to enable simultaneous allohuddling (ie two animals inside each shelter) and allow comparison of the preference between different types of shelter. Cage walls consisted of standard wire mesh (mesh size: 2.5 × 2.5 cm) while the floor and platform were plastic-coated wire mesh (5 × 2.5 cm). All the experimental cages were situated in one outdoor shed and Finnraccoons remained in these housing conditions until the end of the study period in mid-December.

The Finnraccoons were fed a fur animal feed paste (Kalajoen Jäähdyttämö Ltd, Finland) throughout the study with the main portion provided in the morning (0800–1000h). An afternoon feed was provided if necessary (1400–1500h), a regimen that ensured *ad libitum* feeding. The mean daily feed portion increased from 250 g in July to 1,000 g per animal in December. There was a feeding tray in each cage section, and the feed portion was always divided into the two trays in larger cages (2.4 m²). Water was available *ad libitum* via an automatic frost-protected watering system.

Behavioural recordings

Due to limited availability of video equipment, eight randomly selected SC and LE cages and nine LA and LC ones were able to be included in the behavioural recordings. Finnraccoon behaviour was recorded with Bosch cameras (Robert Bosch, Germany) and a Mirasys recorder (Mirasys, USA) for three separate 24-h periods in mid-September (SEP), the end of October (OCT) and early December (DEC), to represent, respectively, the intensive growing period, the end of the body growth and the onset of winter-time lethargy.

Behaviour was analysed from the recordings using instantaneous sampling (Martin & Bateson 2008) with the same sampling interval of 5 min that has been utilised previously in this species (Koistinen *et al* 2018; Koistinen & Korhonen 2018). The behaviour of all Finnraccoons in the cage was registered, but it was impossible to differentiate specific individuals.

Behaviour was split into five main categories (Koistinen *et al* 2018), ie resting, sitting, standing, activity and stereotypic behaviour (Table 2). Resting behaviour was further divided

according to location, ie cage floor, platform, the roof of the nest-box, inside the nest-box and inside the tube (the latter three of which could occur only in the LE treatment). Activities were further divided into ten categories describing locomotion, eating, drinking, grooming, interacting with the activity objects (wooden block and straw), activity on high locations (platform and roof of the nest-box), other interactions with the nest-box and tube, and other behaviours. Stereotypic behaviour was divided into locomotor stereotypies, head twirling, oral stereotypies and scratching. It was also noted whether the animal maintained clear, physical contact with the cage-mate, eg allohuddling or sitting huddled together. The definition of physical social contact was clear and obvious body contact with, for example, a paw or tail touching a cage-mate not being registered. Only for resting behaviour were numbers of animals involved also recorded, eg four animals allohuddling together.

Measured physiological parameters

Bodyweight (BW) was measured at weaning (July), at the end of the growing season (early October) and at the end of the study in mid-December. The time taken to catch the Finnraccoon, from opening the cage door to removing the animal (cf Ahola *et al* 2002) was noted to the exact second while the animals were caught for weighing in October and mid-December. An experienced animal handler from the Research Farm used neck tongs to catch individuals and each time it was the animal closest to the cage entrance that was targeted. The order of capture was then recorded.

Fur cleanliness and fur chewing were evaluated by the same person every two weeks until ambient temperature dropped permanently below zero in mid-October (ie in early, mid- and late August, mid- and late September and mid-October) and, thereafter, every four weeks (mid-November and mid-December). The cleanliness of the fur was assessed using the WelFur on-farm welfare assessment protocol for foxes (WelFur 2015), with three categories ('clean', 'slightly dirty' [small dirty areas] and 'dirty throughout'). Fur chewing (Malmkvist & Hansen 2001) was assessed by using two categories, yes and no and occurrence recorded when the affected area was larger than the palm of a hand (approximately 10 × 10 cm) on the animal's body or more than half the length of its tail.

In mid-December, Finnraccoons were taken from their cages and euthanased via through-body electrocution, in accordance with the Code of Practice (Korhonen & Huuki 2013). Blood samples were taken immediately following euthanasia by cardiac puncture and animals were weighed and measured with body length taken along the dorsal midline from the base of the tail to the tip of the nose. From these data, the Body Mass (BMI; Nieminen *et al* 2002) and Obesity Indexes (OBI; Korhonen *et al* 1982) were calculated using, respectively, the body mass (kg) (body length³ [m])⁻¹ and Body mass (g) × 100 (0.026 × length³ [cm])⁻¹ formulae. As predicted (cf Nieminen *et al* 2004), a high correlation between BMI and OBI was found ($r = 1.00$; $P < 0.001$). Therefore, only the results of the more familiar BMI (eg Mustonen *et al* 2004) will be presented.

Table 2 Ethogram of Finnraccoon behaviours.

Main and detailed categories	Description
<i>Resting</i>	
Resting on cage floor	Lying down or sleeping on the cage floor
Resting on platform	Lying down or sleeping on the platform
Resting on roof of the nest-box	Lying down or sleeping on the roof of the nest-box (only in the LE treatment)
Resting inside the nest-box	Staying inside the nest-box, which was interpreted as resting (only in the LE treatment)
Resting inside the tube	Staying inside the tube, which was interpreted as resting (only in the LE treatment)
Sitting	Sitting still on the cage floor, without any other obvious activity
Standing	Standing still on the cage floor, without any other obvious activity
<i>Activity</i>	
Locomotion	Walking, running and jumping on the cage floor
Eating	Eating from the feeding tray and any other manipulation of the feeding tray
Drinking	Drinking and any other manipulation of the water point
Grooming	Grooming of their own or cage-mates' bodies by licking, itching, etc, being groomed by the cage-mate and any other affiliative behaviour (greeting rituals)
Interacting with wooden block	Interaction with the wooden block, eg gnawing, carrying, poking, pawing
Interacting with straw	Interaction with straw, ie standing against the cage wall or platform or staying on the platform and simultaneously taking straw from the bale on the top of the cage or interacting with the straw on the cage floor
Activity on the platform	Any other non-resting behaviour on the platform than interaction with the straw
Staying on the roof of the nest-box	Any non-resting behaviour on the roof of the nest-box (only in the LE treatment)
Other interaction with the nest-box and tube	Any other interaction with the nest-box and tube, eg gnawing, scratching and standing against (only in the LE treatment)
Other behaviours	Any other active behaviour on the cage floor
<i>Stereotypy</i>	
Locomotor stereotypy	Pacing along one side of the cage or circling the cage
Head twirling	Head twirling against the wall or ceilings of the cage (Hovland 2017), and other stereotypic head movements
Oral stereotypy	Persistent biting or licking the cage or other constructions
Scratching	Persistent scratching of the cage or constructions or 'scrabbling' (Diez-León <i>et al</i> 2016)

Animals were pelted manually and post mortem autopsies carried out before carcasses had a chance to cool down. Right and left adrenal glands, spleen and *gastrocnemius* muscle from the left hind feet were removed by one person (TK), and thymus, liver, heart and kidneys were removed by another (HK) from all animals. Fat removal from the adrenals and organ weighing were carried out by three other persons and all those involved in dissection were blinded from the treatment of the animals.

The haemoglobin (Hb), haematocrit (Ht), red blood cell count and differential white blood cell counts were determined the day following sampling using Siemens Advia 2120i (Movet Ltd, Kuopio, Finland).

Statistical analysis

One Finnraccoon (LC3) failed to thrive, remaining substantially smaller than conspecifics and demonstrating altered behaviour. Data from this dwarf Finnraccoon were removed from all analyses and can be provided on request.

Behavioural data analysis

Due to the poor quality of the night-time video recordings only data collected between 0600 and 2200h were used in the statistical analysis. The initial analysis of the full-day (24 h) circadian activity of the Finnraccoons showed that they tended to rest for long bouts during the discarded

night-time hours, which is in accordance with earlier observations taken in the autumn (eg Koistinen & Korhonen 2018). No clear differences could be detected between treatments from the night-time activity level. This indicates that a similar activity rhythm was followed in all four treatments and, therefore, only including day-time behaviour in the analysis is justified.

One cage from both the LE and LC treatments was missing from the data, both in SEP and OCT, and one cage from LA treatment in OCT. Furthermore, due to issues with video retrieval, approximately 3% of randomly distributed observations were missing from the final data. Finally, the total number of behavioural observations from individuals included in the statistical analysis from the 17 cages of pair-housed and 17 quartet-housed Finnraccoons from the three recordings was 53,382.

Since Finnraccoons were not be individually differentiated within each cage, the cage was used as an experimental unit. The percentage of observations from the total number of daily observations was used in the statistical analyses of the five main behavioural categories (resting, sitting, standing, activity and stereotypic behaviour). The analyses were carried out using a linear mixed model (IBM SPSS Statistics software for Windows®, Version 25). Treatment, month and their interaction formed the fixed effect part of the model. The random effect part included the repeated measurements (month) of each experimental unit (cage), and the error term. Since only the three pair-wise comparisons were considered interesting, ie SC vs LA representing the effect of the available area, LA vs LC representing the effect of group size and LC vs LE representing the complexity, no multiple pair-wise comparisons were carried out, and therefore no adjustment of the *P*-values in pair-wise comparisons were used. Based on Akaike's information criterion, the covariance of the repeated measurements was modelled as Compound Symmetric. The assumptions of the model were tested by using the Kolmogorov Smirnov test and visually inspected from the distribution of the residuals. In order to secure normal distribution of the residuals in the model, the data were $\log_{10}(x + 2)$ transformed, except in the case of resting.

To inspect the resting preferences, the distribution of the resting behaviour (out of all resting observations) within resting alone on the cage floor, social resting on the cage floor (allohuddling), resting on high locations (alone and allohuddling) and staying inside the shelters (nest-box and tube, alone and in the company of cage-mate[s]) was analysed using a similar model to that of the main behavioural categories. The resting on high locations data were $\log_{10}(x + 2)$ transformed for the analysis.

From the ten more detailed categories of active behaviours, only three could be analysed quantitatively, ie locomotion, eating and drinking. Furthermore, the activity on the platform and roof of the nest-box (later only in the LE treatment) were grouped together for analysis of activity on high locations. The other active behaviours were noticed for less than 1% of the observation time and are only presented qualitatively. The percentage of non-resting behaviour (sitting, standing,

activity and stereotypical behaviour) performed in physical contact with a cage-mate was calculated out of the total non-resting time for statistical analysis. The total time spent interacting with the nest-box and the tube was further calculated in the LE treatment and analysed including only the repeated effect of the month as a fixed term.

Irrespective of data transformation for statistical analysis, original data are provided to ease the biological interpretation of the results.

Analysis of the physiological data

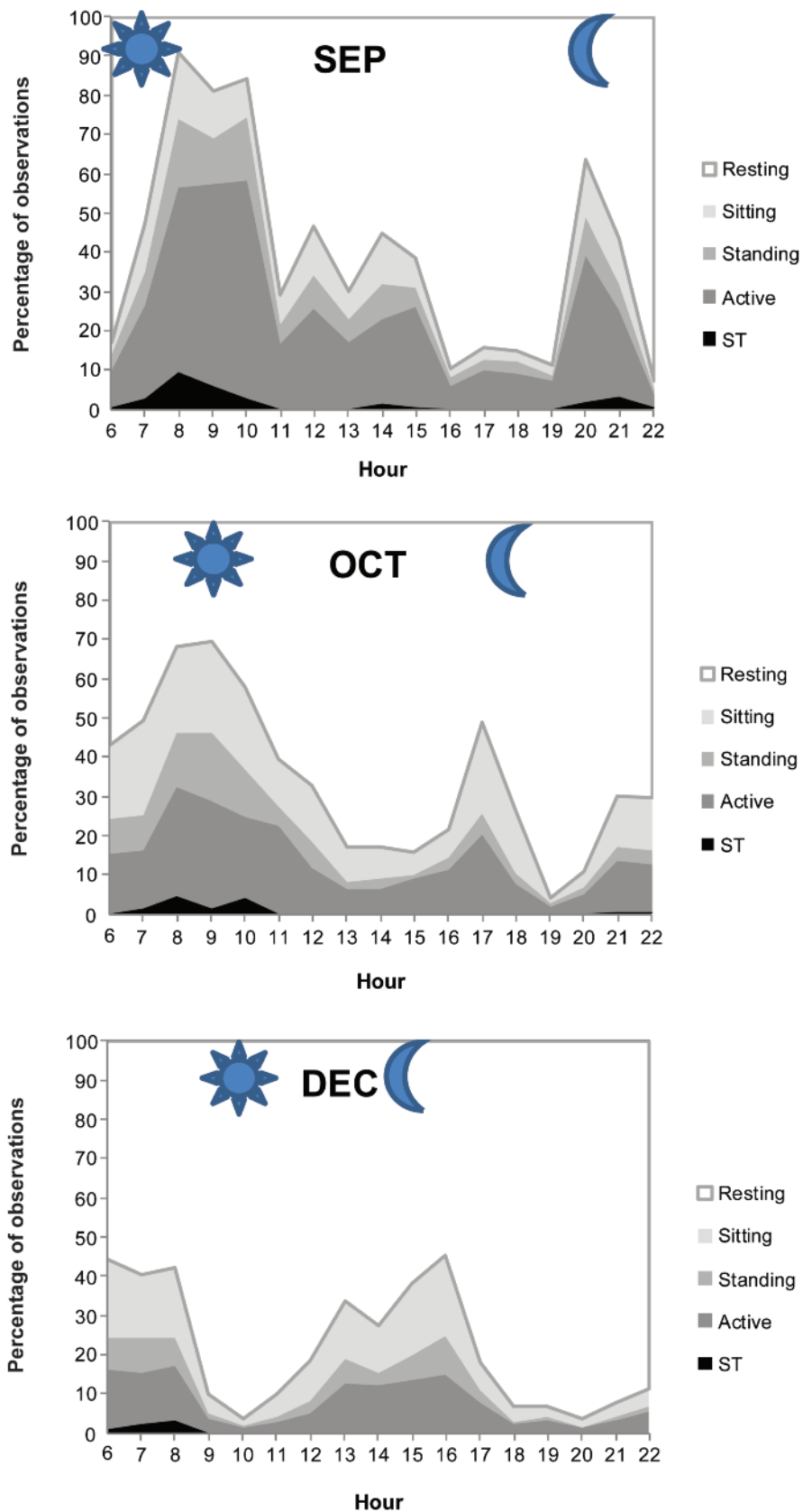
Some data were missing from the final analysis. The weight of one spleen, one liver, one left and right kidney, one heart, one thymus, two *gastrocnemius* muscles, four right and three left adrenals were missing from the final data. Haematological parameters were able to be analysed from 96 samples. Missing samples were randomly distributed across the treatments.

Since the weight of the right and left kidney correlated ($r = 0.814$; $P < 0.001$), and the initial analysis showed very similar results for both kidneys, the mass of the two kidneys was summed for the final analysis. There was also a correlation between the weight of the right and the left adrenal ($r = 0.804$; $P < 0.001$), but these were kept separate in the analysis, due to different function of the adrenals (Perel'muter & Paderov 2004). The degree of asymmetry between the adrenals was calculated using the formula $([R-L] [R+L]^{-1}) \times 2$, where R is the mass of the right adrenal and L the mass of the left (Trut *et al* 2002). Since different people caught Finnraccoons in October compared to December, which would very possibly have affected the time taken to carry this out, October and December data were analysed separately.

Data were analysed using Linear mixed model with the fixed effect part of the model including the treatment, gender and the interaction between the treatment and gender as categorical variables. In the analysis of body length, organ weights and asymmetry between the adrenals, the final BW was included in the model as a continuous variable. In the analysis of the duration of catching the animal, BW in October was used as a covariate in the analysis of the duration to catch the animal in October, whilst, for the December analysis, the final BW was used as a covariate. The random part of the model included the random effect of the cage unit, the individual within the cage unit and the error term. The cage unit was used as a subject in the analysis, and the Finnraccoons housed in the same cage were treated as repeated measurements of the cage. The assumptions of the models were reached after $\log_{10}(x + 2)$ transformation in the case of the time taken to catch the animal in October and December, spleen mass and mass of both adrenal glands. Regardless of the transformation of the data, all are provided as original values.

The connections between the physiological welfare parameters were analysed using the Spearman's or Pearson's correlation tests, depending on the type of the variable. No statistical analysis for fur chewing and fur cleanliness is provided, due to low prevalence.

Figure 2



The mean diurnal resting, sitting, standing, activity and stereotypic behaviour observations in the Finnraccoons from the four experimental groups per hour from 0600 to 2200h in September (SEP), October (OCT) and December (DEC). The sun indicates sunrise and the moon indicates sunset.

Table 4 The mean (\pm SD) percentages of resting observations for Finnraccoons on the cage floor, high locations (platform and roof of the nest-box) and nesting inside the nest-box or tube, singly and in social contact (allohuddling).

Type of resting	Month	Treatment				Statistics		
		SC	LA	LC	LE	Treatment	Month	Treatment \times Month
Cage floor, singly	SEP ^a	27.9 (\pm 17.3)	26.7 (\pm 15.3)	15.2 (\pm 9.6)	16.1 (\pm 11.9)	$F_{3,30.3} = 1.49$; ns	$F_{2,57.3} = 17.8$; $P < 0.001$	$F_{6,57.3} = 1.46$; ns
	OCT ^a	25.5 (\pm 16.0)	26.3 (\pm 16.6)	18.7 (\pm 8.7)	26.6 (\pm 15.6)			
	DEC ^b	7.5 (\pm 4.2)	7.6 (\pm 7.3)	4.9 (\pm 3.8)	14.3 (\pm 10.1)			
Cage floor, allohuddling	SEP ^a	46.4 (\pm 22.6)	48.8 (\pm 22.5)	69.7 (\pm 15.4)	22.6 (\pm 25.1)	$F_{3,28.2} = 9.32$; $P < 0.001$	$F_{3,55.3} = 47.5$; $P < 0.001$	$F_{6,55.3} = 2.12$; ns
	OCT ^a	59.1 (\pm 18.4)	61.0 (\pm 19.6)	64.7 (\pm 17.3)	17.1 (\pm 29.1)			
	DEC ^b	84.5 (\pm 20.2)	74.7 (\pm 28.6)	82.6 (\pm 11.9)	33.9 (\pm 32.8)			
High location, singly	SEP ^{*a}	9.9 (\pm 7.2)	11.8 (\pm 6.8)	8.3 (\pm 2.3)	9.5 (\pm 5.0)	$F_{3,29.7} = 0.45$; ns	$F_{3,55.8} = 20.8$; $P < 0.001$	$F_{6,55.8} = 1.49$; ns
	OCT ^{*a}	6.0 (\pm 4.8)	9.7 (\pm 11.7)	12.3 (\pm 11.8)	11.3 (\pm 11.0)			
	DEC ^{*b}	0.8 (\pm 1.5)	3.8 (\pm 3.9)	6.0 (\pm 6.4)	7.4 (\pm 8.4)			
High location, allohuddling	SEP ^{*a}	15.9 (\pm 23.7)	12.7 (\pm 12.7)	6.8 (\pm 8.5)	14.7 (\pm 20.8)			
	OCT ^{*a}	9.4 (\pm 21.6)	3.0 (\pm 8.0)	4.3 (\pm 6.6)	4.8 (\pm 8.7)			
	DEC ^{*b}	7.2 (\pm 20.4)	13.9 (\pm 28.7)	6.5 (\pm 8.6)	1.2 (\pm 2.7)			
Inside, singly	SEP [*]	–	–	–	12.6 (\pm 9.5)	–	$F_{3,12.9} = 0.21$; ns	–
	OCT [*]	–	–	–	15.7 (\pm 11.6)	–		–
	DEC [*]	–	–	–	12.0 (\pm 7.6)	–		–
Inside, allohuddling	SEP [*]	–	–	–	24.5 (\pm 14.2)	–		–
	OCT [*]	–	–	–	24.5 (\pm 17.3)	–		–
	DEC [*]	–	–	–	31.2 (\pm 23.2)	–		–

SC (Small control), LA (Large area), LC (Large control) and LE (Large enrichment) treatment in September (SEP), October (OCT) and December (DEC).

^{a,b} Months with differing superscripts differ in pair-wise comparisons at the level of $P < 0.05$.

* Note that in the statistical analysis, the social resting (allohuddling) was analysed separately only in the case of allohuddling on the cage floor.

Results

General health of the animals

Besides the dwarf Finnraccoon found in one cage (LC3), a small skin injury was observed on the front paw of one Finnraccoon in cage LC9 in August and an ear mite infection was observed in cage LE3 in August, both of which were duly treated. Severe carpal joint laxity, causing bent feet, was observed in one male (SC13) from mid-October onwards. Otherwise, the general health of the Finnraccoons remained good for the duration of the study.

Main behaviours

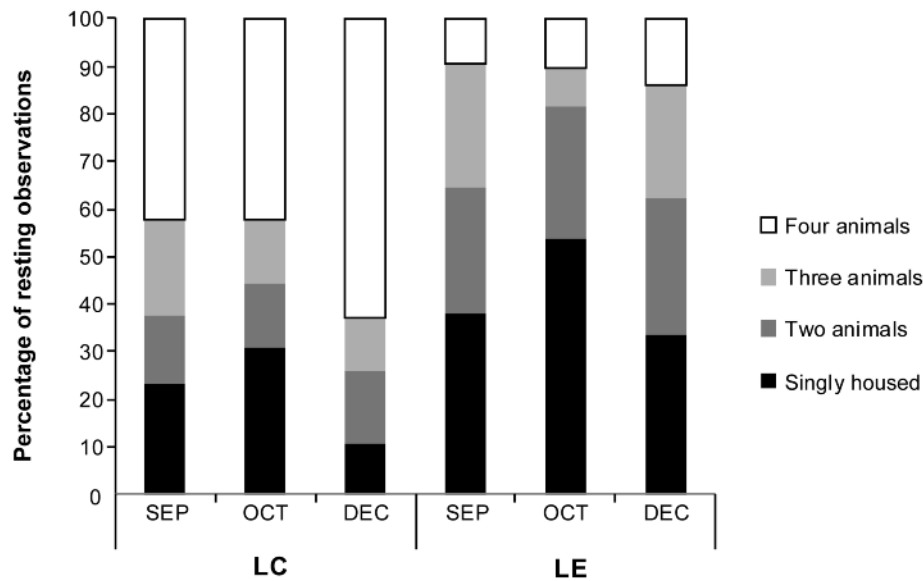
The day-time behaviour did not differ between treatments in the case of resting, sitting, standing, activity or stereotypic behaviour (Table 3; see supplementary material to papers published in *Animal Welfare*: <https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material>). In contrast, month had an effect on behaviour: day-time resting increased steadily through autumn in all treatments. Sitting was more common in OCT than in SEP and DEC, similarly for all treat-

ments. Less standing was observed in DEC compared to SEP and OCT, similarly for all treatments. The level of activity decreased steadily as autumn progressed in all treatments.

Stereotypic behaviour was higher in SEP than OCT and DEC (Table 3; <https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material>). Out of all stereotypies, 92% were locomotor and 8% included a head twirling-like movement against the front wall of the cage. Stereotypic scratching was registered twice ($< 1\%$ of stereotypic behaviour). Oral stereotypies were not observed. Stereotypic behaviour was not observed in eleven out of 34 cages (one in SC, four in LA, two in LC and four in LE).

The Finnraccoons followed a circadian activity rhythm (Figure 2). Activity peaked just after, at and just before sunrise, in SEP, OCT and DEC, respectively. Another, smaller peak in activity occurred around sunset. The occurrence of stereotypic behaviour followed the general activity rhythm: up to 73 and 91% of the daily stereotypic behaviour occurred between 0700 and 1100h in SEP and OCT, respectively. In DEC, 84% of the stereotypies occurred from 0600 to 1000h.

Figure 3



The distribution of the resting observations to resting singly, allohuddling in group of two, three and four animals in the Finnraccoons of the LC (Large control) and LE (Large enrichment) treatment in September (SEP), October (OCT) and December (DEC). Note that all resting sites (cage floor, high locations and shelters) are combined in the data.

Distribution of resting behaviour

Allohuddling on the cage floor was a more common type of resting in the SC, LA and LC treatments compared to the LE treatment (Table 4). No difference between treatments was found in resting alone on the cage floor or on high locations, ie on the platform and roof of the nest-box. Finnraccoons in the LE treatment rested inside the shelters (the nest-box and tube) for 38–43% of the resting observations.

Resting behaviour changed as autumn progressed: resting alone on the cage floor was less common, while allohuddling on the cage floor was more common in DEC than in SEP and OCT (Table 4). The trend for increased allohuddling in DEC tended to be less intense in the LE than in other treatments. Resting on high locations decreased steadily as autumn passed, similarly for all treatments. Resting inside shelters remained at a stable level throughout autumn in the LE treatment.

In the pair-housed Finnraccoons (SC and LA treatments), allohuddling (irrespective of location) occupied 62, 64–67 and 89–92% of the resting observations in SEP, OCT and DEC, respectively. In group-housed animals (LC and LE), all four inhabitants of the cage could be observed allohuddling on the cage floor throughout the study, while only two did so on a platform. In the LC treatment, half of the resting observations occurred in the group of four animals, while resting singly, allohuddling in pairs and groups of three were less common (Figure 3). In the LE treatment, resting singly was most common, while allohuddling in a group of four animals was least common. In SEP, all four Finnraccoons were often observed inside the nest-box at the same time while a maximum of three Finnraccoons were occasionally observed in OCT and DEC. Up to four individuals were observed allohuddling on the roof of the nest-box in SEP, but

only two in OCT and DEC. A maximum of three animals were observed inside the tube in DEC, otherwise only two animals were observed using the tube simultaneously.

Detailed description of the active behaviours

Locomotion decreased from 5–7% of all observations in SEP to 2–4% in DEC (Table 3; <https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material>). Similarly, eating decreased from 6–7% of observations in SEP to 2–3% in DEC and drinking from 2% in SEP to < 1% in DEC. Activity on high locations decreased from 3–7% of observations in SEP to 1–2% in DEC.

Both the available area and the complexity of the area affected the time spent in locomotion; more locomotion was observed in the larger cage (LA treatment) than in the small one (SC), and more in the empty cage (LC treatment) than in the complex one (LE) (Table 3; <https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material>). The available area and group size affected the time spent eating; less time was spent eating in the larger cage (LA treatment) than in the small (SC) and in pair-housing (LA treatment) compared to group (LC treatment). No difference between treatments was found in drinking behaviour (this also included a degree of social play with the water point preceding or following actual drinking).

The complex cage invited more activity on high locations. More such activity was observed in LE compared to LC treatments, which was solely down to activity on the roof of the nest-box. Activity on high locations included sitting, standing and locomotion (55% of observations), taking straw through the ceiling mesh of the cage while on the platform (29%), standing against the platform or 'hanging from the platform' (13%) and standing/walking simultane-

Table 5 The mean (\pm SD) percentages of non-resting behaviours of Finnraccoons (main categories combined: sitting, standing, activity and stereotypic behaviour) performed in physical contact with the cage-mate(s) from all non-resting observations.

Month	SC	LA	LC	LE
September	11.7 (\pm 4.6)	11.2 (\pm 5.6)	17.2 (\pm 3.0)	20.6 (\pm 10.6)
October	10.9 (\pm 6.6)	12.6 (\pm 5.6)	16.0 (\pm 10.1)	13.7 (\pm 10.5)
December	17.4 (\pm 9.6)	13.6 (\pm 12.0)	20.5 (\pm 8.9)	20.0 (\pm 12.4)

SC (Small control), LA (Large area), LC (Large control) and LE (Large enrichment) treatments.

ously on both, the platform and roof of the nest-box (possible only in the LE treatment; 3%).

Of the less frequent behaviours, grooming occupied less than 2% of observations, 42% of which was allogrooming and 58% self-grooming. The wooden block was utilised a mean of 0.5% of observations for oral interactions, nosing, pawing, combinations of these activities (94% of the interaction with wooden block) and elimination (6%). Straw was utilised in 0–2% of the observations for taking and eating the straw from the bale through the ceiling mesh while staying on the platform (81% of interactions with straw), while standing against the platform or cage wall (6%) and manipulating the straw on the cage floor (13%). The latter included eating, carrying the straw in the mouth, other oral activities and social play, eg carrying straw in the mouth with simultaneous chasing by cage-mate and tugging straw from the mouth of a cage-mate.

The Finnraccoons of the LE treatment used the nest-box and tube for other purposes in less than 1% of the observations. These activities were very variable, including standing against the object, scratching the object, gnawing of the wooden wall of the nest-box or the rim of the tube and defaecating into the tube. Even balancing on the (unfixed) tube was observed; typically, this occurred while the animal was coming down from the platform.

Finnraccoons remained in physical contact with cage-mate(s) also while not resting, eg sitting huddled together and eating side-by-side, for up to 10–20% of the non-resting observations (Table 5). No difference between treatments was found ($F_{3,29,6} = 2.59$; ns). Month ($F_{2,57,3} = 1.65$; ns) or interaction between month and treatment ($F_{6,57,2} = 0.93$; ns) was not significant. No agonistic interactions were observed, eg while eating or at the entrance of the already occupied resting shelters.

Comparison between the high locations and resting shelters in the LE treatment

In the LE treatment, subjects used the roof of the nest-box more as a high location than the platform, using it for mean of 18, 12 and 8% of all observations in SEP, OCT and DEC, respectively. This compares with 4, 3 and 1% for the platform. The majority of the time spent on these high locations was resting.

In the LE treatment, the nest-box was also preferred to the tube as a nesting site with it utilised a mean of 20, 25 and 28% of all observations in SEP, OCT and DEC, respectively, compared to 4, 3 and 6% for the tube over the same time-frame. These values correspond to 32–35% of the resting time inside the nest-box and 5–8% of resting time inside the tube.

The total time spent interacting with the nest-box (inside, on the roof and other) averaged to 39, 39 and 36% of all observations in SEP, OCT and DEC, respectively. For the same time-frames, the tube was used in 5–6% of observations. The total interaction with these resources did not change as the autumn progressed (nest box: $F_{2,12,7} = 0.09$; ns, tube: $F_{2,12,0} = 1.33$; ns).

BW, body length and BMI

At weaning, the mean Finnraccoon BW was around 2.5 kg (Table 6; see supplementary material to papers published in *Animal Welfare*: <https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material>). At the end of the growing season (October), it had risen to around 11–12 kg and at pelting (December) it was 14–15 kg. No difference between treatments, gender or interaction between treatment and gender was found in the initial BW at weaning. Males grew faster than females from weaning to October and reached a heavier final BW at pelting. No difference between treatments or interaction between gender and treatment was found in growth or in the final BW.

Treatment had no effect on body length or BMI (Table 6). Generally speaking, heavier Finnraccoons were longer than lighter animals. There was no difference in body length and BMI between genders or the interaction between treatment and gender.

Organ weights

Animals' final BW affected all organ weights; the heavier Finnraccoons had heavier organs (Table 6; <https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material>). The heavier Finnraccoons also showed a greater level of left-biased asymmetry between adrenals. Gender influenced certain organ weights, with males showing heavier liver, kidneys and heart. No general effect of treatment was observed in any of the organ weights.

Haematological parameters

No differences between males and females were found as regards haematological parameters (Table 7) and there were no differences between treatments or the interaction between the treatment and gender in any of the haematological parameters.

Duration to catch animals

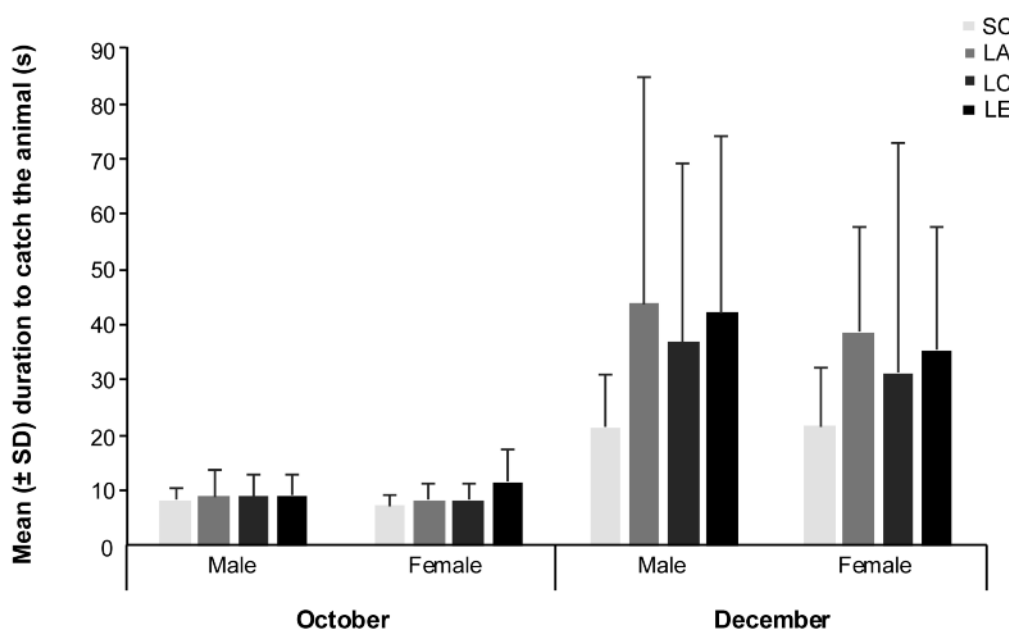
It took approximately 10 s to catch Finnraccoons in October and 20–40 s in December (Figure 4). No correlation was found between the duration to catch the animal and the order in which animals were caught (October: $r_s = -0.124$; ns, December: $r_s = -0.072$; ns).

The available area, group size and complexity of the cage did not affect catching time in October ($F_{3,55,6} = 2.48$; ns). In December, Finnraccoons in the small cage (SC) treatment

Table 7 The mean (\pm SD) haematological parameters for the males and females of the four treatments and statistics for treatment and gender and their interaction.

Variable	Gender	Treatment				Statistics		
		SC	LA	LC	LE	Treatment	Gender	Treatment \times Gender
Haemoglobin (g l^{-1})	Male	141 (\pm 11)	141 (\pm 13)	144 (\pm 12)	147 (\pm 8)	$F_{3,37.5} = 0.45$; ns	$F_{1,64.0} = 2.54$; ns	$F_{3,61.5} = 0.72$; ns
	Female	141 (\pm 9)	140 (\pm 9)	138 (\pm 9)	141 (\pm 7)			
Haematocrit (%)	Male	45.1 (\pm 3.8)	44.6 (\pm 3.7)	45.9 (\pm 3.4)	46.5 (\pm 2.4)	$F_{3,38.6} = 0.21$; ns	$F_{1,64.3} = 1.17$; ns	$F_{3,61.7} = 0.96$; ns
	Female	45.5 (\pm 3.8)	44.8 (\pm 2.2)	44.4 (\pm 3.2)	44.7 (\pm 1.9)			
Erythrocytes (10^{12} l^{-1})	Male	7.2 (\pm 0.7)	7.1 (\pm 0.6)	7.2 (\pm 0.6)	7.2 (\pm 0.4)	$F_{3,36.7} = 0.11$; ns	$F_{1,62.8} = 3.59$; ns	$F_{3,60.0} = 0.33$; ns
	Female	7.1 (\pm 0.6)	6.9 (\pm 0.5)	7.0 (\pm 0.5)	7.0 (\pm 0.3)			
Leucocytes (WBCP; 10^9 cells l^{-1})	Male	14.6 (\pm 1.5)	16.9 (\pm 2.4)	16.6 (\pm 1.4)	16.8 (\pm 2.3)	$F_{3,46.9} = 2.12$; ns	$F_{1,72.4} = 0.30$; ns	$F_{3,70.8} = 0.51$; ns
	Female	15.3 (\pm 3.0)	16.5 (\pm 2.2)	15.7 (\pm 3.1)	16.6 (\pm 2.6)			
Neutrophils (%)	Male	53.6 (\pm 3.0)	52.0 (\pm 7.7)	56.3 (\pm 6.4)	52.7 (\pm 5.2)	$F_{3,42.8} = 1.77$; ns	$F_{1,65.1} = 0.12$; ns	$F_{3,62.4} = 0.99$; ns
	Female	51.7 (\pm 7.2)	52.6 (\pm 2.9)	56.1 (\pm 6.6)	55.0 (\pm 5.2)			
Lymphocytes (%)	Male	30.3 (\pm 4.6)	32.4 (\pm 9.2)	29.8 (\pm 7.2)	32.7 (\pm 5.6)	$F_{3,43.1} = 0.59$; ns	$F_{1,61.9} = 0.07$; ns	$F_{3,59.1} = 1.27$; ns
	Female	32.8 (\pm 5.6)	31.1 (\pm 3.2)	29.6 (\pm 6.8)	30.0 (\pm 5.3)			
Monocytes (%)	Male	4.2 (\pm 0.9)	4.4 (\pm 1.3)	3.9 (\pm 0.9)	4.2 (\pm 1.8)	$F_{3,37.5} = 1.40$; ns	$F_{1,66.9} = 0.90$; ns	$F_{3,65.1} = 0.14$; ns
	Female	3.9 (\pm 1.2)	4.5 (\pm 1.5)	3.4 (\pm 0.8)	4.1 (\pm 1.5)			
Eosinophils (%)	Male	9.9 (\pm 3.4)	9.2 (\pm 2.2)	7.8 (\pm 2.2)	8.1 (\pm 1.6)	$F_{3,36.3} = 1.23$; ns	$F_{1,56.3} = 2.63$; ns	$F_{3,53.2} = 0.31$; ns
	Female	9.3 (\pm 2.4)	9.9 (\pm 1.8)	8.7 (\pm 2.0)	8.9 (\pm 2.1)			
Basophils (%)	Male	0.8 (\pm 0.2)	0.9 (\pm 0.3)	1.0 (\pm 0.3)	1.1 (\pm 0.5)	$F_{3,40.0} = 0.45$; ns	$F_{1,56.9} = 0.12$; ns	$F_{3,54.3} = 0.72$; ns
	Female	0.9 (\pm 0.4)	0.9 (\pm 0.3)	1.0 (\pm 0.4)	0.9 (\pm 0.2)			

SC: Small control; LA: Large area; LC: Large control; LE: Large enrichment. Note that the number of analysed samples was 96.

Figure 4

The mean (\pm SD) duration (s) to catch the male and female Finnraccoons in the four experimental treatments (SC = Small control, LA = Large area, LC = Large control, LE = Large enrichment) at the end of the growing season in early October and at the end of the study in mid-December.

were caught faster than those from the other treatments ($F_{3,51.3} = 3.86$; $P < 0.05$). The BW ($F_{1,140.8} = 0.34$; ns, $F_{1,140.5} = 0.05$; ns), gender ($F_{1,107.5} = 0.002$; ns, $F_{1,104.4} = 1.58$; ns) or gender in relation to the treatment ($F_{3,106.0} = 1.99$; ns, $F_{3,101.8} = 0.15$; ns) did not affect the duration to catch the animal in October or December, respectively.

Animal cleanliness and fur chewing

In SC and LA treatments, all animals' fur remained clean for the duration of the study. In the LC treatment, all subjects remained clean throughout the study, with the exception of one individual in cage LC5 which was scored as slightly dirty (small dirty areas) in mid-December. In the LE treatment, three cages of animals (LE1, LE4 and LE6) remained clean throughout the study while the remaining nine cages had slightly dirty or dirty animals. In one (LE3), all the animals were dirty throughout the study and in seven others variable numbers of individuals were scored as either slightly dirty or dirty during the last three observations, ie mid-October onwards. Fur chewing was not observed in any of the Finnraccoons during the study.

Discussion

The wild raccoon dog is remarkably adaptable to various environments (eg Drygala 2008c; Kowalczyk & Zalewsky 2011; Suld *et al* 2017). The behaviour and physiology of *N. procyonoides* is characterised with diurnal and seasonal fluctuations as an adaptation to seasonal fluctuation in climatic conditions and food availability in the wild (Korhonen 1987b; Asikainen 2013; Mustonen & Nieminen 2018). In autumn, the animals' metabolism prepares for wintering by increasing subcutaneous fat retention to function as an energy reservoir during winter (eg Asikainen *et al* 2004). At the arrival of winter, activity levels decline and appetite is reduced, following facultative, intermittent, superficial hibernation in mid-winter (eg Mustonen & Nieminen 2018).

In the present study, Finnraccoons were euthanased at the typical pelting time, after maturation of the winter fur (cf Xiao 1995), which coincides with physiological (endocrinological) changes associated with the onset of winter (Asikainen 2013). For example, liver mass is higher in late autumn compared to winter and summer, due perhaps to seasonal fattening (Asikainen *et al* 2004). Therefore, both behavioural and physiological data indicate how well Finnraccoons succeeded in preparing themselves for wintering in the housing conditions provided. This preparation consisted of an increase in day-time resting as autumn advanced and a decrease in various other behaviours, such as eating, drinking, locomotion and stereotypic behaviour. The Finnraccoons also modified their diurnal activity rhythm according to the daylight, irrespective of an unchanged management rhythm.

Housing conditions

As expected, the Finnraccoons made effective use of social companionship. Our findings confirmed those from previous studies, both in autumn (Ahola *et al* 2007; Koistinen & Korhonen 2018) and winter (Koistinen *et al* 2018), that Finnraccoons spend the majority of their resting

time allohuddling with cage-mates in social housing units. Juvenile Finnraccoons sought physical contact with cage-mates also while active. They often allogroomed, sat huddled together, stood in a huddle and performed other activities while maintaining physical contact with the cage-mate. No clear, agonistic interactions were observed, not even competition for the limited resources. In contrast, in the treatment with greatest space availability per animal, ie when eating alone in a cage compartment was possible (LA treatment), animals spent the least time eating. As a contrast to the social behaviour of, for example, juvenile silver foxes (Ahola 2002), the tendency to allohuddle intensified as autumn progressed. These results, when taken together, indicate a high social tolerance, and enhanced welfare in sibling groups compared to pairs. The motivation for social interaction may vary in the course of the autumn, from seeking security from siblings post-weaning to seeking comfort during the winter-time lethargy or even protection from cold weather. Finnraccoons' social motivation requires further attention, however, our results would suggest group housing to be highly recommended for juvenile Finnraccoons.

Additionally, the complexity of the housing conditions crucially affected selection of the resting site. The resting shelters saw a lot of use throughout the autumn for resting as well as other activities when available. Although Finnraccoons used the shelters in over 40% of the observations during the autumn, the result may underestimate actual willingness to use the shelters, since it was not possible for all animals to enter their preferred nest-box simultaneously and shelters seemed to come under intensive use for resting, especially during the hours of night which were not included in the data. In comparison, in a 24-h recording in winter, young females used the nest-box over 90% of their resting time (Koistinen *et al* 2018). Irrespective of the limitations in the data presented, our results clearly demonstrate that juvenile Finnraccoons seek shelter, besides, or in addition to, social contact, while resting.

The size of the available area and complexity of the cage affected the occurrence of active behaviours. Although weight gain, BMI or physiological measurements of physical activity, eg *gastrocnemius* muscle mass (cf Duncan *et al* 1998; Hanninen *et al* 2002) and heart mass (cf silver fox: Ahola *et al* 2000) did not differ between the treatments, more locomotor activity was observed in the Finnraccoons that had a larger empty area available (LC and LA treatments) compared to those raised in the complex (LE) or small cage (SC) treatments. As with blue foxes (Koistinen & Korhonen 2013), Finnraccoons seem also to value open areas for locomotion. However, it must be borne in mind that complex housing potentially enables the expression of a larger scope of the behavioural repertoire.

The complex cage (LE treatment) caused animals to become soiled. Finnraccoons are known to soil solid objects by defaecating on them (resting plate: Korhonen 1987a; wooden platform: Korhonen *et al* 1997; nest-box: Korhonen & Nurminen 1986), which then readily soil the animals' fur. The soiling may impinge on the animals' welfare due to the

increased risk of parasitic infection or decreased thermoregulatory capacity of the fur. It may also detract from the quality of the end product (Koistinen & Korhonen 2017). However, any possible impaired health status could not be detected in the present study. Our plan to prevent animals becoming soiled by turning the nest-box upside down was only partially successful since only three out of the 12 cages, featured animals that remained clean throughout the autumn. It might be worth exploring whether providing access to the nest-box or other shelters later in the autumn and not at weaning, ie after appropriate sites for defaecation have become clear (see Mohaibes *et al* 2008), might enable shelters to be used without the risk of soiling.

Both increased area availability and cage complexity increased the time required for catching the Finnraccoon. They were quickly caught from small cages, but the larger and more complex cages allowed Finnraccoons to evade capture by moving between compartments and into shelters. Thus, both the size and complexity of the cage create challenges for the management of Finnraccoons, making handling more time-consuming.

Behaviour

Platform use matched earlier reported levels in juvenile Finnraccoons (Koistinen & Korhonen 2018) but decreased with the advance of autumn. The platform operates as a refuge in social housing units in silver foxes, since platform use increases with group size (Ahola 2002). This did not appear to be the case in the Finnraccoons. Differing, also, from blue foxes (Koistinen & Korhonen 2013), Finnraccoons under LE treatment preferred to rest on the roof of the nest-box as opposed to the platform. These two elevated locations do not differ much in size (platform: 0.315 vs roof: 0.275 m²), however they do differ in terms of shape (narrow vs rectangular), walls (three net walls vs no walls), material (net vs wood) and height from the cage floor (45 vs 38 cm). Behavioural observations revealed the design of the platform to limit all-huddling more than the roof of the nest-box, which may partly explain the preference for resting on the roof of the nest-box. Similar to blue foxes (Koistinen & Korhonen 2013), the nest-box roof also elicited a greater amount of activity than the platform, which may also be related to the design of the high location. Finnraccoons seemed to enter the roof with greater ease than the platform. As discussed earlier (Koistinen & Korhonen 2018), standing and stretching against the edge of the platform — also observed in the present study — may indicate attempts to climb the platform. Although the agile behaviour on the unfixed tube does not quite support the discussion of the clumsy nature of the species, the design of the platform, originally developed for farmed foxes (cf Mononen 1996), requires attention when used in the Finnraccoon. The optimal platform height for Finnraccoons should probably be mounted to somewhat lower than seen for foxes and the design should enable appropriate all-huddling in social housing units.

The Finnraccoons utilised the nest-box more than the tube. The two resting shelters differed in terms of material (net vs

plastic), wall material (wood vs plastic), number of walls (four vs open ends) and shape (rectangular vs 'round'). Obviously, all these features finally made the nest-box more comfortable for resting and performing various other activities. The Finnraccoons may have also considered the nest-box more stationary as a resting site, than the tube, which they could easily turn. The tube probably facilitates better species-specific active behaviours, such as passing through a tunnel-like structure, as opposed to comfortable resting. Finnraccoons also often chose to rest against a shelter, instead of the free floor area in the cage and this physical contact with a solid surface could serve as a valuable resource. Alternate resting shelter designs with only one, two or three solid walls require further attention. These may also be attached to the platform. A solid resting plate situated on the cage floor is, however, not the preferred resting site (Korhonen 1987a).

Interaction with straw (0–2% of observations) remained at approximately the same level in autumn and winter (1–3%: Koistinen *et al* 2018). Straw acts as an additional source of fibre to prevent self-injurious, fur-chewing behaviour, which was not observed in the present study. Straw use may be associated with the season and the species' natural feeding habits: juveniles grow fast during autumn when their appetite is voracious (eg Korhonen 1988b,c). They may not be searching for this extra source of fibre, beyond the high energy feed, however straw can act more as an activity material during this period. This is supported by the observation that besides straw being taken and eaten from the bale, it was used on the cage floor for various activities, including play. In winter, adaptations for poor quality feed and even for total fasting exist (Asikainen 2013; Mustonen & Nieminen 2018) and, here, straw may function primarily as a natural source of fibre alongside or instead of the feed. Leaving aside activity objects that provide a source of fibre, the most commonly used items are the wooden block and bone, although the interaction with the wooden block remained low (< 1% of observations). In comparison, pair-housed Finnraccoons interacted with a cattle bone 2–8% of the time in autumn (Koistinen *et al* 2017) and singly housed animals 1–2% of the time in winter (Koistinen *et al* 2018).

In the autumnal activity rhythm, the high level of sitting observed in October turns out to be interesting. Similar findings have been reported earlier but tend to be more pronounced in juveniles raised in a small cage (Korhonen & Harri 1988a) and in pairs (Ahola *et al* 2007) compared to those raised in a large cage and groups, respectively. The increased sitting behaviour in October might be the initial stages of winter-time lethargy; but earlier studies have suggested it may reflect a boredom-like state of inactivity (cf mink: Meagher & Mason 2012; Meagher *et al* 2017) and, thus, increased sitting behaviour may indicate sub-optimal housing conditions and warrant further investigation.

Stereotypic behaviour took up 0–3% of the observations, which is the same as previously reported in this species (Ahola *et al* 2007; Koistinen & Korhonen 2018; Koistinen *et al* 2018). Our results confirm earlier findings that stereo-

typic behaviour is more prevalent earlier in autumn than at the onset of the winter, in parallel with the general activity level of Finnraccoons (Koistinen & Korhonen 2018). In the wild, juveniles begin to disperse from the natal area from July–September (Drygala *et al* 2010), which may partly explain some of the locomotor restlessness, ie higher level of stereotypic-like movement in SEP. Dispersion is typically at its most pronounced during night-time (Herfindal *et al* 2016), a trait we were unable to verify in the present study. During day-time, stereotypic behaviour peaks in the morning/before noon which may be related to sunrise or morning feeding (cf Ahola *et al* 2007; Koistinen & Korhonen 2018). Similar to our observations in winter (Koistinen *et al* 2018), locomotor pacing and circling were the most common stereotypic behaviours in the Finnraccoon. Despite stereotypic drinker pressing having been described in pigs (Broom & Fraser 2015), it would be hard to make a case for occasional, excessive attention towards the water point being interpreted as stereotypic behaviour in the Finnraccoons.

Physiological variables

Males grew heavier than females. This shows that notwithstanding the general increase in BW (4–8 kg: Korhonen & Harri [1985b, 1986] vs 14 kg in the present study), a degree of sexual dimorphism in BW has evolved in the Finnraccoon with the lengthening history in captivity. Thirty years ago, the BW of males and females barely differed (eg Korhonen & Harri 1985b), in keeping with wild conspecifics (Kauhala 1993; Korablev & Szuma 2014), since sexual dimorphism tends not to be typically associated with monogamous species (Kleiman 1977). In contrast to results from the 1980s (Korhonen & Harri 1985b), but similar to those gained more recently (eg Hänninen *et al* 2002), some sexual dimorphism was also found in the mass of organs. Selection of large males for breeding in the polygamous mating system on modern farms has evidently favoured a slight move towards sexual dimorphism in this captive species.

Similar to humans (Gerendai & Halász 2001), silver foxes, mink, rats (Sullivan & Gratton 1999; Trut *et al* 2002) and mice (Perel'muter & Paderov 2004), a left-biased asymmetry between adrenals was found in the Finnraccoon. Diet (Díaz-Aguila *et al* 2016) and temperament (Trut *et al* 2002) may be two things that influence this asymmetry. Here, housing condition had no effect on asymmetry between the adrenals. Adrenal weight has been measured in several Finnraccoon studies, but only the total adrenal mass has been reported (eg Korhonen & Harri 1988b; Kasanen *et al* 2000; Hänninen *et al* 2002; Mohaibes *et al* 2008). It is recommended that future studies report right and left adrenal mass separately and inspect the results in detail.

Various issues, including health, physical activity, nutrition and emotional state, influence an animal's haematological parameters (Sjaastad *et al* 2003). Some blood cells are stored in the organs, eg lymphocytes in spleen and thymus. This mechanism affects both the haematological variables and mass of organs, which can make interpreting results

challenging. Here, no systematic differences between the treatments were found for these parameters. Average erythrocyte and leucocyte values remained at a similar level to those previously reported (Nowakowicz-Debek *et al* 2013). Finnraccoons and wild-caught conspecifics have been shown to differ in their differential leucocyte counts (Nowakowicz-Debek *et al* 2013), which may be a direct result of their differing living environments and parasitic loads. Korhonen and Harri (1988b) reported a heavier spleen and kidneys in pair-housed juveniles compared to those housed in groups of four, a finding not replicated in this study. Similar to other Finnraccoon studies comparing various housing conditions (Korhonen & Harri 1988b; Mohaibes *et al* 2008), no differences in other organ masses were found. These are often measured in Finnraccoon research experiments but appear to shed little light on the welfare state of the animals in question.

Animal welfare implications and conclusion

The results show Finnraccoons to be generally healthy animals. Males grow heavier than females and internal organs are heavier in males compared to females. Housing condition has an effect on the behaviour of Finnraccoons, but do not have any systematic effect on the selected physiological variables. Irrespective of the limitations of our behavioural data (ie day-time only), the results clearly demonstrate that juvenile Finnraccoons seek comfort from cage-mates and shelters while resting. Taking into account intensive interaction with cage-mates while resting and active, not to mention the complete lack of agonistic interactions, leads us to highly recommend the social housing of juvenile Finnraccoons. Furthermore, data illustrating the tendency for all four animals to allohuddle together further support group-housing instead of housing in pairs. Also, intensive and variable use of resting shelters support provision of shelters, although these may compromise the cleanliness of the animals. The results show that greater emptiness in the cage, and not complexity, is needed for locomotor activities. Even though complexity enables greater expression of the species' behavioural repertoire. In conclusion, a large cage supplemented with social company and enrichment materials is necessary to promote welfare of juvenile Finnraccoons.

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