

Additional foraging elements reduce abnormal behaviour – fur-chewing and stereotypic behaviour – in farmed mink (*Neovison vison*)



Jens Malmkvist^{a,*}, Rupert Palme^b, Pernille M. Svendsen^a, Steffen W. Hansen^a

^a Department of Animal Science, Aarhus University, Denmark

^b Department of Biomedical Sciences, University of Veterinary Medicine Vienna, Austria

ARTICLE INFO

Article history:

Accepted 1 October 2013

Available online 14 October 2013

Keywords:

Foraging

Fur-chewing

Neovison vison aka *Mustela vison*

Stereotypies

Stress

Welfare

ABSTRACT

We investigated whether provision of additional appetitive and consummatory elements of foraging reduces baseline stress and abnormal behaviour – in terms of fur-chewing and stereotypic behaviour – in farmed mink. We studied 200 juveniles ($n = 100$ females and 100 males) during the 5-month growth period with plenty of feed, and subsequently the females as adults during the 2-month feed restriction period before mating. The mink were distributed in four equally sized groups: (i) FARM, conventional finely ground feed (<8 mm) without additional foraging elements; (ii) ROPE, access to biting ropes; (iii) CONS, chunky feed (parts up to 42 mm), replacing conventional feed; (iv) BOTH, access to both biting ropes and chunky feed. In growing mink, biting ropes reduced fur-chewing ($P = 0.044$) and chunky feed reduced stereotypic behaviour ($P = 0.038$) and fur-chewing in female mink ($P = 0.019$). During the season of feed restriction, the wear/tear of biting ropes increased. Females on the chunky diet had a higher concentration of faecal cortisol metabolites ($P = 0.033$), probably due to a more severe slimming resulting in a 6.2% lower body weight ($P = 0.006$) than the mink on the finely ground diet; still the chunky diet reduced time spent in pre-feeding stereotypies ($P = 0.001$). In the restrictively fed females, fur-chewing was reduced both by access to biting ropes ($P = 0.005$) and chunky feed ($P = 0.007$). Consequently, 54% of group FARM mink displayed fur-chewing compared to 21% in group BOTH. In conclusion, stereotypic behaviour was reduced by provision of chunky feed, increasing the consummatory element in daily foraging. Fur-chewing was reduced upon access to either biting ropes or chunky feed in female mink throughout the study. Our findings support frustrated foraging, mainly consummatory, behind abnormal behaviour.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

In keeping of animals in captivity, a considerable discrepancy typically exists between the provided foraging possibilities and the foraging to which the species is

adapted to and displays in nature. This is also the case for American mink (*Neovison vison*) – an obligate carnivorous mammal with an opportunistic foraging strategy – kept in animal parks and bred on farms for large-scale fur production. In nature, mink eat a wide range of prey, such as small mammals (rodents and lagomorphs), fish, amphibians, echinoderms, crustaceans and birds, dependent on local availability, season and competition (Chanin and Linn, 1980; Wise et al., 1981; Birks and Dunstone, 1985; Ben-David et al., 1997; Sidorovich, 2000). Hunting of living prey by mink involves several stages: searching, localisation,

* Corresponding author at: Department of Animal Science, Aarhus University, PO Box 50, DK-8830 Tjele, Denmark. Tel.: +45 8715 7956; fax: +45 8715 4249.

E-mail address: jens.malmkvist@agrsci.dk (J. Malmkvist).

recognition, chase, capture and killing, followed by eating or transport back to the home den (Dunstone, 1993). In contrast, mink on farms experience a steady and relatively uniform food supply. Typically, a portion of finely ground wet feed paste is delivered on top of cage wire in regular intervals (at least once daily); this farm feed can easily be swallowed without much manipulation.

Lorenz (1937) suggested that hunting and eating in predatory animals are to be considered as separate instincts, both of which require satisfaction independently. Likewise, animals may choose to work for food even in the presence of identical and easily obtainable food e.g. demonstrated in captive maned wolf (*Chrysocyon brachyurus*), reflecting that the expression of foraging behaviour beyond consumption can be important (Vasconcellos et al., 2012). Long-term performance of elements of appetitive behaviour without the animal proceeding to the consummatory phase of foraging has been suggested to lead to repetitive and stereotypic behaviour (Hughes and Duncan, 1988). Additionally, it has been suggested that species-specific appetitive and consummatory foraging behaviour can explain the types of stereotypic behaviour – e.g. oral or locomotory, occurring pre- or post-feeding – observed in different species of farm animals (Mason and Mendl, 1997). So in theory, natural foraging behaviour and abnormal behaviour displayed in captivity may be linked.

Two main types of abnormal behaviour are observed in farm mink: stereotypies and fur-chewing (De Jonge and Carlstead, 1987), increasing in occurrence during periods of feed restriction (Hansen et al., 2007). Stereotypies are defined as repetitive, unvarying and apparently functionless behaviour (Mason, 1991). Fur-chewing is characterised by sucking and gnawing – typically without penetration of the skin – leading to the destruction of hair (Malmkvist and Hansen, 2001). The main form of stereotypic behaviour in farmed mink is pre-feeding pacing (Hansen et al., 2007; Svendsen et al., 2007), which may resemble patrolling and searching for prey. In contrast, the display of fur-chewing behaviour may rather resemble eating or grooming. This has not been studied in detail for mink; but in domestic hens (*Gallus gallus*), the motor patterns involved in abnormal, severe feather pecks have been found morphologically identical to foraging pecks (Dixon et al., 2008).

The objective of the present study was to investigate whether provision of additional appetitive and consummatory elements of foraging (at all, independently or synergistically) reduces the development of abnormal behaviour in farmed mink. As target for additional appetitive behaviour, we provided mink with access to biting ropes and we increased the size of animal parts in their daily feed to allow for additional consummatory behaviour. Since thwarted motivation can lead to increased stress in farm animals (Jensen and Toates, 1997), we included measurement of baseline stress hormones. Fearfulness was also evaluated as linked to stress and cortisol responses in mink (Malmkvist et al., 2003). Given that performance of appetitive and consummatory behaviour reduces the motivation (Hinde, 1953), we hypothesised (i) that provision of additional possibilities for appetitive and consummatory acts reduces baseline stress, fur-chewing and stereotypic behaviour, and predicted; (ii) increased occurrence of

abnormal behaviour in farmed mink during a period of high feeding motivation. Alternatively, it has been suggested that home-range size, rather than searching for food/hunting and eating, is the main predictor for the performance of stereotypic behaviour in captive carnivores (Clubb and Mason, 2007); consequently provision of foraging elements can be ineffective in reducing abnormal behaviour in the standard-sized farm cages.

2. Materials and methods

2.1. Animals

We used 200 mink (100 female, 100 male) from one production line of the brown colour type, born late April/early May, weaned at 8 weeks and housed at the research farm of Aarhus University in standard size wire cages (from Hedensted Gruppen, DK-8722 Hedensted, Denmark; *W*: 30 cm, *H*: 45 cm, *L*: 91 cm) connected to a wooden nest box (*W*: 28 cm, *H*: 20 cm, *L*: 23 cm) with ad libitum access to straw and water. The mink were kept in outdoor sheds with natural lighting and ambient climate. In the growth season, from July 8 (approximately 10 weeks after birth) until pelting of males November 16th, the mink were kept in sibling pairs, one male and one female per cage. In the winter season (13 weeks from pelting to mating), November 16–February 22, females were kept individually in the same cages. Each cage was equipped with one wire tube (*l*: 32 cm, diameter: 11 cm) fixed in the cage ceiling. This housing and management practice represents commercial standards of mink fur production in accordance to European and Danish legislation (Danish Ministry of Justice, 2006).

2.2. Study design and treatment

The study had a complete two-factorial design, with the factors: (1) 'Appetitive': biting ropes absent or present and (2) 'Consummatory': feed texture finely ground (<8 mm) or chunky (<42 mm), with larger animal parts – resulting in four equally sized groups of mink:

- (i) FARM, Farm feeding group – biting ropes absent and feed texture finely ground,
- (ii) ROPE, Appetitive feeding group – biting ropes present and feed texture finely ground,
- (iii) CONS, Consummatory feeding group – biting ropes absent and feed texture chunky,
- (iv) BOTH, Combined feeding group – biting ropes present and feed texture chunky.

In total, we used 200 mink of equal age from 25 litters having a minimum of 4 females and 4 males per litter. The four sibling pairs with a male and a female were randomly allocated to treatment, with a balanced distribution to groups (FARM, ROPE, CONS, BOTH). Consequently, we had 50 mink per level of the two factors, consisting of 25 pair-wise housed siblings during the growth season, i.e. from July to mid-November. During the pre-mating season, from mid-November to early March, we observed individually housed females only (25 cages per treatment group, *N* = 100 females), as the males were killed to harvest pelts in

mid-November. The reason for focussing on females in the adulthood was that more males are normally pelted, therefore the ratio of males to females is around 1:5 on mink farms, until new litters are born late April. The experiment ended before the onset of the mating season in the beginning of March.

The mink wet feed was produced from fresh ingredients by a commercial company (Holstebro Minkfodercentral, DK-7500 Holstebro, Denmark), using identical ingredients and recipe for all experimental groups. The grinding and sifting process, however, differed; leaving parts up to 42 mm intact in feed to mink allocated to groups CONS and BOTH, but only up to 8 mm – equivalent to standard feed at commercial farms – to mink allocated to groups FARM and ROPE.

Each cage allocated to groups ROPE and BOTH was equipped with two biting ropes (60 cm plastic-covered metal wire, with 10 cm of 50 mm wide cotton rope at the end), hanging centrally from the ceiling in the front third and the back third of the cage, respectively. The biting ropes were checked every second weekday (Monday, Wednesday, Friday) and replaced in case of less than 2 cm left of the cotton rope endings. The same days, the amount of straw was checked per cage, and supplemented in case of less than 50 g. Based on recoding of these procedures, biting rope and straw consumption was estimated per cage. Once monthly (September to March), all biting ropes were collected, cotton rope ends measured to nearest 0.1 cm and replaced. The mink allocated to the groups FARM and CONS had no biting ropes in their cages.

The mink were fed once daily, 4 h after sunrise, to fix the feeding time to the activity rhythm of the mink controlled by sunrise and sunset. The constituent and energy density of the feed were adjusted three times during the experimental period to meet the changing energetic needs of the mink: (1) Early growth period, energy density 137.6 kcal/g (metabolisable energy, ME: 45.2% protein, 43.2% carbohydrate, 11.6% fat) for the first 0.9 month; (2) Main growth period, energy density 190.0 kcal/g (ME: 32.0% protein, 49.4% carbohydrate, 18.6% fat) for the next 4.2 months; and (3) Pre-mating period, energy density 122.7 kcal/g (ME: 50.1% protein, 39.9% carbohydrate, 10.0% fat) for the last 2.7 months. The portions were made and frozen at the mink feed company and thawed up prior to feeding individual cages by hand at the research farm. In the growth season from July to December, the mink had ad libitum access to feed, whereas in the main part of the pre-mating period (December 12 to February 23), females were fed restrictively (144 (9.3) g per day) to induce slimming prior to the reproductive season. The last 10 days of the pre-mating period, females had again surplus access to feed (303 (9.5) g per day), as this procedure increases the number of eggs ovulated in the following mating period (Tauson, 1985). This seasonally adjusted feeding strategy is typical in commercial mink production.

2.3. Sampling

2.3.1. Body weight

The juvenile males and females were weighed at the beginning of the study (July 6, age 2.3 months).

Additionally, females were weighed as adults (1) 156 days later (7.5 months of age), at the beginning of the singly-housed period and (2) 308 days later (10.3 months of age) at the end of the study period (March 2).

2.3.2. Utilisation of biting ropes – groups ROPE and BOTH

In order to estimate the wear and tear of biting ropes, all biting ropes were measured to nearest 0.1 cm and replaced once monthly during early September to early March. There was no difference in the length of biting ropes between the two placement positions in the cage (front vs. back; *t* test: $P=0.67$). Consequently, the two positions were not considered separately and the length of the biting ropes was totalled per cage for each sampling date.

2.3.3. Behaviour

We observed the mink during pair housing in the late part of the growth season (2 days in November) and from video recordings of individually housed females in the late part of the pre-mating period with feed restriction (2 days in February). The location of the mink was recorded as one out of three possibilities: (1) In the wire-cage: at least one pair of legs touch the bottom, sides or top of the wire-cage; (2) in the tube fixed to the cage ceiling: at least parts of body within tube, at least one pair of legs are not touching the bottom of the cage; or (3) in the nest-box: otherwise. Additionally, the behaviour of each individual was recorded in accordance to the definitions in Table 1.

Behavioural observation was done on two consecutive days. The first day, novel biting ropes were given to groups with biting rope access, one hour before feeding. Comparing first and second days of observations can, therefore, be used for investigating potential effects of novelty on the mink's use of biting ropes (groups ROPE, BOTH). During the growth season, direct observations via scan sampling rounds were performed from sunrise to sunset, scoring each sex of mink per cage both for location and behaviour (Table 1). During the pre-mating period, observations from video recordings of female mink consisted of 15 min continuous registration for each hour during 48 h, resulting in 12 h of observations per mink evenly distributed around the clock for two consecutive full days.

2.3.4. Fur-chewing score

Animals were scored for fur-chewing twice, mid-November (males and females) and at the end of the study period in March (females). During scoring, each individual was captured in a pelt grading cage and visually examined for the occurrence of fur damage induced by chewing with score 0 – no damage; 1 – tail sucking, hair damage on the tail tip but no clear hair removal; 2 – hair clipping/chewing over minor areas (<2 cm diameter on body/neck or <1 cm in tail); 3 – hair clipping/chewing over larger areas or up to 1/3 of the tail; 4 – widespread areas of damage or over 1/3 or tail without hair.

2.3.5. Stick test

The stick test is an approach-avoidance test towards humans widely used for testing exploration/fear in mink (e.g. Hansen and Møller, 2001; Malmkvist and Hansen, 2002; Korhonen et al., 2002; Malmkvist et al., 2011) and

Table 1

Mink behaviour, observed directly during the growth period and from video recordings during the pre-mating period. Behaviours were mutually exclusive, except for 'Scream' occurring with another behaviour.

Behaviour	Definition
Passive	Lying without activity, including being in the nest box and thus not visible for the observer
Manipulation biting rope ^a	In contact with/moving biting rope, including orally (biting, licking, chewing) and with paws. Raid/play attacks directed against biting rope included. Accidental touching biting ropes while passing is not included
Manipulation other	Biting/licking/scratching cage-wire, inventory (drinking nipple/nest box/straw/tube) without obvious function, i.e. not in connection with eating and drinking; not stereotypically
Running ^b	Running, but not stereotypically
Stereotypic	A uniform pattern of movement apparently without purpose repeated minimum three times without interruption
Eating	Muzzle within a few cm close to fed dollop or visible chewing movements when away from fed dollop
Drink	Muzzle in contact with the water dispenser nipple, making drinking possible
Aggressive interaction ^c	Overt aggressive contact between mink
Non-aggressive social interaction ^c	Non-aggressive contact between mink (e.g. grooming, play)
Other activity	Other types of behaviour (e.g. walking, standing, climbing, defecating) than above
Scream ^c	High-pitched vocalisation

^a For the groups (ROPE, BOTH) with biting rope access.

^b From video recording on individually housed females only.

^c During the period of pair-housing only.

was performed in November and in February. During testing, the mink was excluded from the nest box and tested in the wire cage. The test person placed a tongue spatula through the wire mesh in the upper part of the front lid section and scored the female reaction as: (1) Explorative; if the mink sniffed the stick persistently, oral manipulation may occur; (2) Fearful; if the mink escaped and did not touch the stick; (3) Aggressive; if the mink attacked and intensively bit the stick; (4) Uncertain if the mink showed a mixture of responses, and could not be placed in one of the first three categories. Additionally, durations of contact, bite, time spent in different parts of the cage (near, back half of cage in relation to stick entry), number of conflicts (defined as approach followed by withdrawal minimum 1 cm each way with head oriented towards stick) and screams were registered during the test time of 30 s.

2.3.6. Faecal cortisol metabolites (FCM)

Faeces are the predominant excretory route of cortisol metabolites in mink, and FCM reflect concentrations of circulating cortisol with a time-lag (Malmkvist et al., 2011). We collected a fresh sample of faeces from wire nets placed under the cage defecation zone. The collection took place 0–5 h after feeding once weekly during the period when the singly housed females were fed restrictively, i.e. 8 times starting at January 6 and ending February 24. The weighed samples (0.50 g) were frozen immediately and stored at –20 °C until analysis. The faecal sample was extracted with 5 ml (80%) methanol (Palme, 2012) and FCM measured in an aliquot of the supernatant with an 11 β -hydroxyaetiocholanolone enzyme immunoassay (EIA; Malmkvist et al., 2011). The sensitivity of this method was 6 ng/g, with intra- and inter-assay coefficients of variations of 9.1 and 13.1%, respectively.

2.4. Statistical analysis

We used the software SAS (version 9.2., Statistical Analysis Systems Institute, Cary, NC) for the statistical analyses. Time structure was modelled using compound symmetry in ANOVA models with repeated measures. A probability

level (P) of 0.05 was chosen as the limit of statistical significance, and only two tailed tests were used. P -values between 0.05 and 0.10 are reported as tendencies, and models were reduced by stepwise removing insignificant terms ($P > 0.10$) starting with the highest order of interactions, however, keeping as minimum the principal treatment factors (biting ropes and feed structure) in the model. The demand for dispersion and variance homogeneity was evaluated from plots of the final model residuals. Results are reported as mean \pm standard error of mean, unless otherwise stated.

The body weight development was analysed using a normal linear regression model with repeated measures for females over time (procedure 'mixed' in SAS) including the two treatment factors, and their interaction was analysed separately for the (1) growth season and (2) pre-mating season. Logarithmic transformation of body weight during the growth season was used as it resulted in improved variance homogeneity.

The length of biting rope measured at the monthly replacement was analysed using a linear model with repeated measures for cage over the sampling times (procedure 'mixed' in SAS) including the groups (ROPE and BOTH), sampling date and their interaction. Based upon graphical representation of data (Fig. 1), we divided the data into three periods, (1) growth season, (2) winter season, female in cage under restrictive feeding, and (3) late pre-mating period, female in cage under ad libitum access to feed; period 3 with one sampling and, therefore, without repeated measures. In addition, the number of biting rope replacements was totalled per cage for the periods (1) and (2). The biting rope replacement was analysed using ANOVA with the feed structure factor as explanatory variable for the groups with biting rope access (ROPE and BOTH).

For scanning observations (November), the location of mink and their behaviour (defined in Table 1) were summed over two time periods, before and after feed delivery. This was done per mink, except for the social interactions 'aggressive interaction' and 'non-aggressive social interaction'; these were summed up per cage with

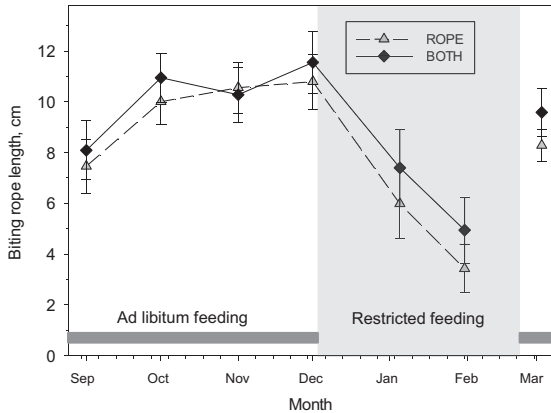


Fig. 1. The length of the biting-rope at the monthly replacement differed over time. The biting rope use depended on feeding intensity, and increased during the winter rope period with restricted feeding, with no difference ($P > 0.36$) between mink with access to finely ground (group ROPE) or chunky (group BOTH) feed. Returning to ad libitum feeding in March reduced the biting rope use by female mink.

two mink. For scanning observations, the location and behaviour are reported as the proportion (%) of total number of scanning rounds. For video recordings (February), the location and behaviour of mink (Table 1) were summed as time spent (%) per hour. The proportions were analysed using repeated measures per mink/cage (procedure 'mixed' in SAS). The start models included the treatment factors, sex (male, female – relevant in November only), feed delivery (before, after) and all two-factor interactions. For video observations, additionally repeated measures per mink over two days and over two periods (pre-feeding: 08–12 h, and rest of day 12–7 h), and interactions between treatment and these periods were included in the statistical models. Logarithmic transformation was used for 'Stereotypic' in November and for 'Manipulation other' in February as it resulted in better residuals in terms of normal distribution and variance homogeneity.

The occurrence of fur-chewing was analysed as Poisson distributed, using a generalised mixed linear model (procedure 'glimmix' in SAS) with cage as random factor, taking into account that each cage contained one female and one male mink in November. The explanatory factors in the start model were the two treatment factors, their interaction as well as all interactions with sex (male, female). The occurrence of fur-chewing prior to mating (early March) was analysed in a similar but more simple model, omitting cage as random factor and sex as fixed factor as only the females were present at this time (procedure 'genmod' in SAS).

The FCM concentration was analysed using a linear model with repeated measures for females over the weekly sampling times (procedure 'mixed' in SAS) including the treatment factors, their interaction and all interactions with sampling week. Passage time, i.e. duration from feeding until faeces collection within each day of sampling, was included as a covariate. Logarithmic transformation was

used as it resulted in better residuals in terms of normal distribution and variance homogeneity.

The score in the stick test (Explorative, Aggressive, Uncertain or Fearful) was converted into the mink being Explorative or not and the mink being Fearful or not, analysed as binomial distributed (Dobson, 1997). However, as very few mink were categorised as Fearful in February (1.0% of animals), instead the score Aggressive (81.2%) was analysed this time of year. The other observations in the stick test (contact duration, duration of maximum distance to human, bite duration, conflicts) were analysed in a normal distributed ANOVA model with treatment factors, sex (relevant in November only) and interactions.

3. Results

3.1. Body weight

During the growth period from juvenile to adult, females grew at the same rate – resulting in 85% increase of initial weight – with no treatment effects (biting ropes: $F_{1,97.5} = 0.4$, $P = 0.53$; feed structure: $F_{1,97.5} = 0.5$, $P = 0.47$). Following restricted feeding in the pre-mating period, the females lost on average 10 (1.1%) of their body weight. At the end of the study period, females fed with the finely ground feed were less effectively slimmed, and thus heavier (1.35 ± 0.02 kg vs. chunky feed: 1.27 ± 0.02 kg; $F_{1,93} = 8.0$, $P = 0.006$), whereas access to biting ropes had no effect ($F_{1,93} = 0.0$, $P = 0.97$) on the final body weight before mating.

3.2. Use of biting ropes – group ROPE and BOTH

The use of biting ropes increased for the females during the pre-mating period with feed restriction (Fig. 1). Although only one mink inhabited each cage during this pre-mating period, a higher number of biting ropes were worn down and, therefore, replaced during this period (39.1% of check times) than during the growing season (25.9% of check times) with two minks per cage. After increased feed allowance (March), females reduced their biting rope use again (Fig. 1). The effect of feed texture on the length of the biting rope was not significant (growth season: $F_{1,48} = 0.2$, $P = 0.70$; winter: $F_{1,47} = 0.8$, $P = 0.36$; March: $F_{1,47} = 1.3$, $P = 0.26$). Likewise, for the number of replacements of worn down biting ropes, there was no difference between the mink fed the finely ground or the chunky feed (growth season: $F_{1,48} = 0.1$, $P = 0.83$; winter: $F_{1,48} = 0.0$, $P = 0.99$).

3.3. Behaviour

The feed texture, but not biting rope access ($F_{1,197} = 0.1$, $P = 0.78$), affected the amount of stereotypic behaviour in November. The access to chunky feed reduced significantly the proportion of stereotypic behaviour ($F_{1,197} = 4.4$, $P = 0.038$), occurring at a low level (0.1% vs. 0.8% of observations in mink receiving the finely ground feed) this time of year. We found no treatment effects ($P = 0.25$ – 0.98) on other types of behaviour (defined in Table 1) or on the

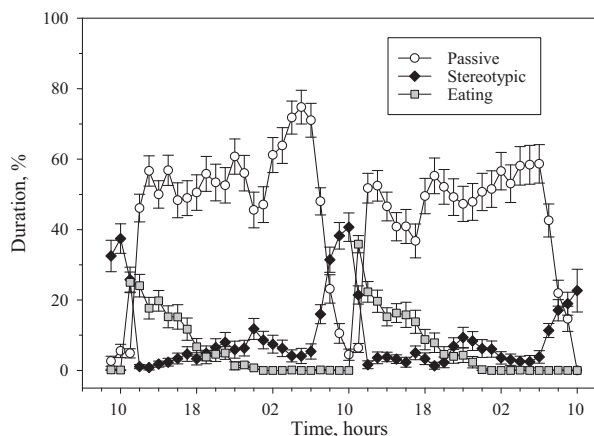


Fig. 2. Proportion (mean \pm SE%) of time, adult females ($n=92$) spent being passive/in nest box, performing stereotypic behaviour and eating, per hour for two consecutive days of observations from digital recordings in February during feed restriction. The mink were fed once daily 4 h after sunrise, i.e. around h 12. Time spent passive and eating were unaffected by treatment ($P=0.24$ – 0.89). Mink fed chunky feed spent less time on pre-feeding stereotypic behaviour ($P=0.001$).

location of mink ($P=0.23$ – 0.73) during the scanning observations.

Before feeding, mink spent less time in the nest box (50.2% vs. 72.1% after feeding; $P<0.001$), but more time within the wire tube in the cage (14.1% vs. 6.7% after feeding; $P<0.001$), manipulating with the biting rope (3.0% vs. 0.0% after feeding; $P<0.001$), performing non-aggressive social interactions (2.1% vs. 0.6% after feeding; $P<0.001$) and other activity in the cage (39.9% vs. 15.1% after feeding; $P<0.001$). Females spent more time than males in the tubes within the cage (12.7% vs. 8.1%; $P=0.003$) and displayed more 'Other activity' (31.1% vs. 23.9%; $P<0.001$). Due to low occurrence, we were not able to perform the statistical analysis of the types of behaviour 'Manipulation other' (0.4% of observations), 'Aggressive interaction' (0.2% of observations, 3 cages), and 'Scream' (absent) in November.

Scanning observations performed on the day when the biting ropes were replaced, compared with the following day, allowed us to estimate whether changing the ropes influenced the biting rope manipulations performed by mink. The mink manipulated the novel ropes markedly more ($F_{1,148}=34.7$, $P<0.001$; 15.7% of pre-feeding observations) than the ropes that were replaced the day before (2.8% of pre-feeding observations). At the day of rope replacement only, texture of the feed influenced the proportions of biting rope manipulations ($F_{1,148}=7.8$, $P=0.006$); mink on the chunky feed treatment manipulated the biting rope more (10.7%) than did the mink (5.2%) on the finely ground feed (pair-wise post test $P<0.001$), but not significantly when the biting rope was day-old (pair-wise post test $P=0.64$).

Based on the 48 h video observations in February, the activity of mink changed over the duration of the day, with an increase in activity out in the cage during the pre-feeding hours as illustrated in Fig. 2. The time spent passive was unaffected by treatment (Structure in

Table 2

Time spent in stereotypic behaviour, mean \pm SE%, in February.

Feed texture	Period (h)	Stereotypies (%)
Finely ground	Pre-feeding, 8–12 h	32.0 \pm 1.72a
Finely ground	Post-feeding, 12–7 h	5.8 \pm 1.45b
Chunky	Pre-feeding, 8–12 h	25.5 \pm 0.17c
Chunky	Post-feeding, 12–7 h	4.6 \pm 1.43b

Different letters 'a' and 'b' indicates significant difference in post tests ($P<0.05$).

feed: $F_{1,89.9}=1.4$, $P=0.24$; Biting rope access: $F_{1,89.9}=0.0$, $P=0.89$). The amount of stereotypic behaviour was higher in February than observed in November and peaked during the pre-feeding hours (08–12 h: 28.8 \pm 1.2%) compared to the rest of the day (12–07 h: 5.2 \pm 1.01%; Fig. 2). The mink fed the chunky feed daily spent less time on stereotypic behaviour than mink fed the finely ground diet during the pre-feeding hours (treatment and period interaction: $F_{1,90}=11.0$, $P=0.001$), cf. Table 2. Similar to November, there was no effect of biting rope access on the time spent in stereotypic behaviour ($F_{1,89}=0.0$, $P=0.87$).

Mink with access to biting ropes (groups ROPE, BOTH) used them significantly more ($F_{1,45}=6.8$, $P=0.012$) pre-feeding (8–12 h: 1.6 \pm 0.32%) than outside this period (0.7 \pm 0.17% per hour). The time spent manipulating biting ropes increased on the days when the ropes were replaced, and with an interaction with the feed texture ($F_{1,44}=10.0$, $P=0.003$). Thus, in February, adult mink fed the finely ground feed (group ROPE) spent more time than mink fed the chunky feed (group BOTH) in manipulating the biting ropes when novel.

Access to biting ropes increased the time the female mink spent in the tube out in the cage during pre-feeding periods (interaction between treatment and period; $F_{1,90}=8.8$, $P=0.004$; No biting ropes: 3.1 \pm 0.30% vs. Biting ropes: 4.3 \pm 0.20%). The rest of the day, the use of the tube was low (0.5%) and unaffected by treatment. Likewise, no treatment effects ($P=0.22$ – 0.99) were evident on the time spent in the types of behaviour 'manipulation other', 'eating', and 'drinking' and in the mink's use of the nest box in February.

3.4. Fur-chewing

Fur-chewing of the tail (including sucking on the tail) was the most prevalent occurring type of fur-chewing behaviour, observed in 22.5% (December) and 30.2% (March) of the experimental mink. Fur-chewing on other body parts (neck, body) was mild and less frequent (between 4.1 and 11.5% of the mink affected). Both treatment factors influenced, without interaction, fur-chewing throughout the study period. Access to biting ropes reduced the occurrence and intensity of fur-chewing on the tail scored in December ($F_{1,90}=4.2$, $P=0.044$) in both males and females. Twenty-nine per cent of mink without biting ropes had tail-chewing, compared to 16% in mink with access to biting ropes. Additionally, there was a significant interaction between the feed texture and sex ($F_{1,90}=5.8$, $P=0.019$). Chunky feed reduced fur-chewing on the tail in females only (post test $P=0.049$), not in males ($P=0.52$), while it

Table 3

Fur-chewing of the tail as mean \pm SE score, and the proportion of affected mink (%) in (A) December, i.e. at the end of the growth period, and in (B) March, i.e. in females before mating. Both treatment factors influenced independently the amount of fur-chewing on the tail ($P < 0.05$, NS interaction). In December, the feed texture treatment affected females only (treatment \times sex interaction, $P = 0.019$).

Time	Treatment factor	Level	Tail-chewing score	Affected mink (%)	
(A) December	Feed texture	Finely ground	0.3 \pm 0.12a (Male)	20.0	
		Chunky	0.7 \pm 0.17b (Female)	32.7	
	Biting ropes	None	0.4 \pm 0.13a (Male)	20.8	
		Present	0.3 \pm 0.11a (Female)	16.3	
	(B) March	Feed texture	None	0.6 \pm 0.11a	26.0
			Present	0.3 \pm 0.07b	19.0
(B) March	Feed texture	Finely ground	0.9 \pm 0.18a	36.2	
		Chunky	0.4 \pm 0.12b	24.5	
	Biting ropes	None	0.9 \pm 0.17a	41.7	
		Present	0.4 \pm 0.13b	18.8	

Different letters 'a' and 'b' indicates significant difference (post test $P < 0.05$) within each time of scoring and treatment factor.

halved the occurrence of female fur-chewing compared to those fed the finely ground diet (Table 3).

In March, both access to biting ropes ($F_{1,93} = 7.9$, $P = 0.005$) and chunky feed ($F_{1,93} = 7.3$, $P = 0.007$) independently (NS interaction between factors) reduced fur-chewing on the tail. Without biting ropes, the average fur-chewing score was 0.9 ± 0.17 , with 41.7% of the females affected, compared to 18.8% and milder scores (0.4 ± 0.13) with biting ropes. On the finely ground diet, the average fur-chewing score was 0.9 ± 0.18 , with 36.2% of the females performing this abnormal behaviour, compared to 24.5% and milder damage (0.41 ± 0.12) in females on the chunky diet.

3.5. Stick test response

In the stick test in November, 60.2% of the mink reacted as Explorative (approaching the human test person and touching the tongue spatula put into the cage), 25.2% Fearful and 1.0% Aggressive (persistently biting the spatula). The rest 13.5% were categorised as Uncertain, as they did not fit into the three first categories. There was no treatment effect on the scores (biting rope: $P = 0.13$ – 0.32 ; texture of feed: $P = 0.80$ – 0.99). Mink with access to biting ropes spent shorter time near the test person (23 ± 1.0 s vs. without biting ropes 28 ± 1.0 s; $F_{1,95} = 10.6$, $P = 0.002$), probably as they used the tube fixed in the cage ceiling more (9.1% vs. 3.8%, $F_{1,95} = 6.7$, $P = 0.011$) during the test. The female mink used the tube more than the males during the test (females: 25%, males: 4%), and likewise, the male spent longer time than females near the test person ($F_{1,95} = 8.0$, $P = 0.006$). Mink fed chunky feed did also spend longer time near the test person (27 ± 1.0 s) than the mink given the finely ground conventional feed (23 ± 1.0 s; $F_{1,95} = 6.4$, $P = 0.013$). So based on the approach behaviour, males and mink without biting ropes or mink with access to chunky feed appeared more explorative. Likewise, mink without biting ropes tended to spend longer time in explorative (non-aggressive) contact with the stick ($F_{1,94,8} = 3.0$, $P = 0.085$), with no effect of feed structure ($F_{1,94,8} = 0.2$, $P = 0.69$) on duration of stick contacts.

In February, the stick test reactions were markedly different, with a shift towards the score Aggressive in the

tested adult females under feed restriction: 8.3% Explorative, 1.0% Fearful and 81.2% Aggressive. The rest of the females (9.5%) scored as Uncertain. There were no treatment effects on the scores or in any other variables sampled during the stick test ($P = 0.16$ – 1.00).

3.6. Straw consumption

During the growth period, there was no effect of the treatment factors on straw consumption (biting rope: $F_{1,97} = 0.1$, $P = 0.82$; feed structure: $F_{1,97} = 0.0$, $P = 0.86$). However, during the pre-mating period, the mink fed with the chunky diet used more straw (28.7% of check times additional straw was necessary) than the mink given the finely ground conventional feed (20.9%; $F_{1,98} = 7.9$, $P = 0.006$), with no effect of biting ropes access ($F_{1,97} = 0.0$, $P = 0.98$).

3.7. Faecal cortisol metabolites (FCM)

FCM declined slightly during the pre-mating period ($F_{1,586} = 6.4$, $P = 0.012$) and was influenced by the feed texture treatment (Fig. 3). The females on the chunky diet had a higher ($F_{1,99,8} = 4.7$, $P = 0.033$) concentration of FCM (402 ± 30.4 ng/g) than the females on the finely ground diet (298 ± 27.9 ng/g). We failed to demonstrate any statistical significant effect of biting rope access on FCM ($F_{1,96,6} = 0.1$, $P = 0.71$).

4. Discussion

Provision of additional foraging elements reduced the occurrence of abnormal behaviour in farmed mink. Both resources independently reduced fur-chewing, whereas only chunky feed reduced stereotypic behaviour. Access to biting ropes reduced fur-chewing, both during the growth season and during the pre-mating period. The use of biting ropes increased with restricted feeding, and they were used mainly pre-feeding, supporting our expectations that biting ropes are used by mink during their active part of foraging. Previous mink studies have not tested the effects of biting ropes in isolation; biting ropes in combination with other cage elements (e.g. tube attached to the cage ceiling) reduced female fur-chewing, stereotypies and stress

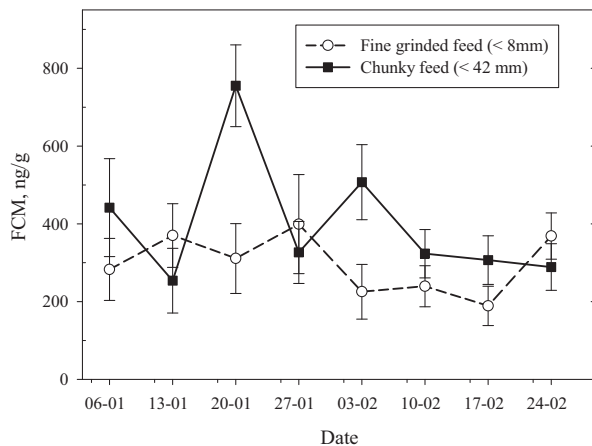


Fig. 3. Changes in faecal cortisol metabolite (FCM) concentration (mean \pm SE, ng/g), over time in the winter period, i.e. the pre-mating period. FCM was in average higher in females given chunky feed ($P=0.033$), with no effect of biting rope access on FCM ($P=0.71$).

hormone concentration during winter, compared to mink without any of these cage resources (Hansen et al., 2007). We demonstrated for the first time that specifically access to biting ropes reduces fur-chewing, but not stereotypic behaviour, in farmed mink.

Access to timer-controlled feeding boxes reduced stereotypic pacing in zoo tigers (*Panthera tigris*; Jenny and Schmid, 2002), supporting the frustrated appetitive foraging hypothesis behind stereotypic behaviour. In our mink study, the appetitive characteristics of biting ropes – and thus ability for reducing stereotypic behaviour – may have been reduced as food was delivered at regular times (4 h after sunrise), not directly contingent on the mink's behaviour. Further studies are needed to investigate whether feed release actively induced/controlled by the mink may reduce their stereotypic behaviour, e.g. under periods of feed restriction in commercial production.

Oral abnormal behaviour similar to fur-chewing in mink is reported in other caged mammals, for example fur-chewing/pelt-biting in chinchilla (Vanjonack and Johnson, 1973; Tislar et al., 2002; Ponzio et al., 2007, 2012), excessive fur-licking in rabbits (Lidfors, 1997) and barbering in laboratory mice (Garner et al., 2004). Although both stereotypies and fur-chewing may increase with different stressors in caged mink – e.g. early weaning (tail-chewing: Mason, 1994; stereotypies: Jeppesen et al., 2000) and restricted feeding (present study; Hansen et al., 2007) – our findings (and also Svendsen et al., 2013) suggest different mechanisms behind the development of fur-chewing and stereotypic behaviour; at least the tested foraging elements reduced the two types of abnormal behaviour differently and without interaction. Likewise, in laboratory mice, a different mechanism behind barbering and stereotypy behaviour has been suggested, although the types of behaviour sometimes are coined into the same term, Abnormal Repetitive Behaviour (Garner et al., 2011).

We hypothesised that fur-chewing is related to an unsatisfied consummatory phase of foraging. Therefore,

we expected it to be reduced in mink with more complex texture in the daily diet, increasing their chewing opportunities. This was confirmed. Further, we expected biting ropes to be less efficient in reducing fur-chewing, as we by introducing hanging ropes aimed to mimic the appetitive act of hunting (chasing, attacking prey) and tearing prey apart before eating. But also biting ropes effectively reduced tail-chewing behaviour. Combined, these results can be interpreted as fur-chewing non-specifically is reduced by cage enrichments in mink; we cannot, however, exclude that fur-chewing is linked to the consummatory act as well: mink could not only chase/manipulate, but did also chew and destroy the biting ropes, which were replaced frequently during the study period. This is also supported by mink spending more time in tubes, chewing/biting the ropes. Thus, both appetitive and consummatory elements of foraging were added to mink in cages with these biting ropes. Besides, a strict division between appetitive and consummatory acts of foraging may be somewhat artificial, as stated by Hinde (1953), “We see, then, that ‘variable’ appetitive behaviour (such as the first generalised food-seeking behaviour) and ‘rigid’ consummatory act (such as swallowing or ejaculation) represent two extremes of continuous series”.

Besides unsatisfied elements of foraging leading to abnormal behaviour (cf. Section 1), it has been suggested that fur-chewing could be linked to under-stimulation, leading to over-expression of other behaviour such as grooming (self-inflicted tail-chewing in mink: Hansen et al., 1998; in mice: Sarna et al., 2000; in rabbits: Lidfors, 1997). Coarsely ground feed appeared more variable and during the hours prior to feeding, mink manipulated longer with novel ropes than with the ropes replaced the day before. Accordingly, increased daily stimuli could be the reason for both biting ropes and chunky feed reducing fur-chewing. Further, fur-chewing has been suggested to be caused by long-term non-specific stress in caged mammals. Fur-chewing chinchillas may experience a higher stress hormone concentration (indicated in Tislar et al., 2002 comparing adrenals from 11 fur-chewers with 3 control animals) and severely chewed females were more fearful and had a higher baseline cortisol (Ponzio et al., 2012), indicating a link between stress and fur-chewing behaviour. Another chinchilla study reported that fur-chewing is concurrent with lower rectal temperature, probably due to loss of hair/insulation capacity (Vanjonack and Johnson, 1973); suggesting that the higher glucocorticoid activation also could be explained by the increased energy mobilisation for thermoregulation following severe fur-chewing. We failed to demonstrate effects of biting rope access on other stress indicators, such as baseline concentration of female stress hormone metabolites (FCM) or levels of fearfulness. Thus, besides the reduction in tail-chewing behaviour, we have no evidence for a general stress-reducing effect of biting rope access in the current study.

The ingredients of the commercial feed were identical between the treatment groups, only the amount of grinding differed. Daily access to feed with coarser texture – providing the mink with larger animal parts, e.g. fish heads for chewing and eating – reduced both fur-chewing and stereotypic behaviour. This result supports

the link between fur-chewing and consummatory satiation in mink. Likewise, supplementation with loose hay – partly for eating – reduced fur-chewing/excessive fur-licking in rabbits (Lidfors, 1997). It can be argued, that increased feed texture also non-specifically reduces stress, however, we found no evidence supporting this argument; actually the mink fed the chunky feed had a higher baseline cortisol concentration than the mink given the more finely ground diet. We suggest that the reason for the elevated cortisol concentration in mink on the chunky diet is due to their higher weight loss during the pre-mating period; cortisol being involved in energy mobilisation (Mormède et al., 2007). Mink on the chunky diet also had a higher straw utilisation, probably as supplemental feed intake or for thermoregulatory needs during the winter period. Previous studies have shown a higher cortisol concentration and reduced body weight in mink performing stereotypic behaviour, both as baseline and in response to handling (Malmkvist et al., 2011). Surprisingly, the chunky feed reduced stereotypic behaviour throughout the study period, even during the period of feed restriction with body weight loss. So although the general level of stereotypic behaviour – mainly pacing – increased with feed restriction, this increase can be dampened by a more complex texture in the daily diet.

Arguable, the commercial mink cages are small (c. 0.34 m²) compared to the territories of adult mink in nature. Further, the naturalistic home-range size is reported to correlate with the estimated amount of time spent in stereotypic behaviour for captive carnivores (Clubb and Mason, 2007). However, as we report, additional foraging elements in feed reduce (but not completely remove) the amount of stereotypic behaviour, without any change in cage size. Arguable, home-range size also reflects elements of foraging demands and constraints. Studies of mink in nature have reported that travelled distance largely depends on food abundance (Birks and Linn, 1982; Stevens et al., 1997). Besides, the diet of mink in nature varies greatly with season (Chanin and Linn, 1980; Sidorovich, 2000), the prey animal's presence at the actual location (Day and Linn, 1972; Lode, 1993; Maran et al., 1998), and can be affected by competition of other specialised species present, e.g. during scarcity of food during winter. Following the sex difference in size, male mink may take larger prey than females, on the other hand can better access the burrow of smaller rodents (Birks and Dunstone, 1985; Dunstone, 1993). Thus, home-range size also varies with foraging opportunities, and a correlation between behaviour and naturalistic home-range size does not simply imply that more space is the best option for reducing stereotypic behaviour in captivity. When farm mink are fed close to their demand, stereotypic behaviour can be reduced to nearly zero, even in the commercial cages. We were surprised to learn that texture of the feed (up to 42 mm instead of 8 mm in control group) significantly reduced the already low (<1%) amount of time that the mink spent in stereotypic behaviour during the growth season when fed close to ad libitum. Studies in other species, such as omnivorous bears in zoos, also link feeding motivation and difference in feeding behaviour with the type of stereotypic behaviour (Vickery and Mason, 2004). Natural

foraging behaviour remains in our opinion, together with hunger, the most important factors to target in order to reduce development of abnormal behaviour in farm mink.

5. Conclusion

Provision of additional foraging elements reduces abnormal behaviour of mink in standard-sized farm cages. The tested foraging elements reduced abnormal behaviour without any interaction. Fur-chewing in farm mink was reduced by access to either biting ropes or coarsely ground conventional diet. Stereotypic behaviour was reduced by access to the coarsely ground diet only; however, female mink on this treatment had a higher baseline cortisol concentration than controls, probably related to a higher average weight loss during feed restriction. Our findings support frustrated foraging, mainly consummatory, behind abnormal behaviour in mink, although it may be difficult to strictly separate appetitive and consummatory elements of foraging in enrichment studies and in practice.

Acknowledgement

This project was funded by the Danish Ministry of Food, Agriculture and Fisheries and Aarhus University. We also thank employees at the Department of Animal Science, Aarhus University: Birthe Houbak, Betty Skov, and Erik Decker for assistance during data collection and Tina Albertsen for language improvements.

References

- Ben-David, M., Hanley, T.A., Klein, D.R., Schell, D.M., 1997. Seasonal changes in diets of coastal and riverine mink: the role of spawning Pacific salmon. *Can. J. Zool.* 75, 803–811.
- Birks, J.D.S., Dunstone, N., 1985. Sex related differences in the diet of the mink *Mustela vison*. *Hol. Ecol.* 8, 245–252.
- Birks, J.D.S., Linn, I.J., 1982. Studies of the home range of feral mink (*Mustela vison*). *Symp. Zool. Soc. London* 49, 231–257.
- Chanin, P.R.F., Linn, I., 1980. The diet of the feral mink (*Mustela vison*) in southwest Britain. *J. Zool.* 192, 205–223.
- Clubb, R., Mason, G.J., 2007. Natural behavioural biology as a risk factor in carnivore welfare: how analysing species difference could help zoos improve enclosures. *Appl. Anim. Behav. Sci.* 102, 303–328.
- Danish Ministry of Justice, 2006. BEK nr. 1734 af 22/12/2006 – Bekendtgørelse om beskyttelse af pelsdyr (Legal act no. 1734 – Act on the protection of fur animals) (in Danish).
- Day, M.G., Linn, I., 1972. Notes on the food of feral mink *Mustela vison* in England and Wales. *J. Zool.* 167, 463–473.
- De Jonge, G., Carlstead, K., 1987. Abnormal behaviour in farm mink. *Appl. Anim. Behav. Sci.* 17, 375.
- Dixon, L., Duncan, I., Mason, G., 2008. What's in a peck? Using fixed action pattern morphology to identify the motivational basis of abnormal feather-pecking behaviour. *Anim. Behav.* 76, 1035–1042.
- Dunstone, N., 1993. *The Mink*. T & D Poyser Ltd, London.
- Dobson, A.J., 1997. *An Introduction to Generalized Linear Models*. Chapman & Hall, London.
- Garner, J.P., Dufour, B., Gregg, L.E., Weisker, S.M., Mench, J.A., 2004. Social and husbandry factors affecting the prevalence and severity of barbering ('whisker trimming') by laboratory mice. *Appl. Anim. Behav. Sci.* 89, 263–282.
- Garner, J.P., Thogerson, C.M., Dufour, D., Würbel, H., Murray, J.D., Mench, J.A., 2011. Reverse-translational biomarker validation of abnormal repetitive behaviors in mice: an illustration of the 4P's modelling approach. *Behav. Brain Res.* 219, 189–196.

- Hansen, S.W., Houbak, B., Malmkvist, J., 1998. Development and possible causes of fur damage in farm mink – significance of social environment. *Acta Agric. Scand. A* 48, 58–64.
- Hansen, S.W., Møller, S.H., 2001. The application of a temperament test to on-farm selection of mink. *Acta Agric. Scand. A* 30 (Suppl.), 93–98.
- Hansen, S.W., Malmkvist, J., Palme, R., Damgaard, B.M., 2007. Do double cages and access to occupational materials improve welfare of farmed mink? *Anim. Welf.* 16, 63–76.
- Hinde, R.A., 1953. Appetitive behavior, consummatory act, and the hierarchical organization of behavior – with special reference to the great tit (*Parus major*). *Anim. Behav.* 5, 189–224.
- Hughes, B.O., Duncan, I.J.H., 1988. The notion of ethological ‘need’, models of motivation and animal welfare. *Anim. Behav.* 36, 1696–1707.
- Jenny, S., Schmid, H., 2002. Effect of feeding boxes on the behavior of stereotyping Amur Tigers (*Panthera tigris altaica*) in the Zurich Zoo, Zurich, Switzerland. *Zoo Biol.* 21, 573–584.
- Jensen, P., Toates, F.M., 1997. Stress as a state of motivational systems. *Appl. Anim. Behav. Sci.* 53, 145–156.
- Jeppesen, L.L., Heller, K.E., Dalsgaard, T., 2000. Effects of early weaning and housing conditions on the development of stereotypies in farmed mink. *Appl. Anim. Behav. Sci.* 68, 85–92.
- Korhonen, H.T., Jauhainen, L., Rekilä, T., 2002. Effect of temperament and behavioural reactions to the presence of a human during the pre-mating period on reproductive performance in farmed mink (*Mustela vison*). *Can. J. Anim. Sci.* 82, 275–282.
- Lidfors, L., 1997. Behavioural effects of environmental enrichment for individually caged rabbits. *Appl. Anim. Behav. Sci.* 52, 157–169.
- Lode, T., 1993. Diet composition and habitat use of sympatric polecat and American mink in western France. *Acta Ther.* 38, 161–166.
- Lorenz, K., 1937. Über die bildung der instinkthandlung. *Folia Biotheoretica* 2, 17–50 [About the formation/shaping of the instinctive action], (in German).
- Malmkvist, J., Hansen, S.W., 2001. The welfare of farmed mink (*Mustela vison*) in relation to behavioural selection: A review. *Anim. Welfare* 10, 41–52.
- Malmkvist, J., Hansen, S.W., 2002. Generalization of fear in farm mink, *Mustela vison*, genetically selected for behaviour towards humans. *Anim. Behav.* 64, 487–501.
- Malmkvist, J., Hansen, S.W., Damgaard, B.M., 2003. Effect of the serotonin agonist buspirone on behaviour and hypothalamic-pituitary-adrenal axis in confident and fearful mink. *Physiol. Behav.* 78, 229–240.
- Malmkvist, J., Jeppesen, L.L., Palme, R., 2011. Stress and stereotypic behaviour in mink (*Mustela vison*): a focus on adrenocortical activity. *Stress* 14, 312–323.
- Maran, T., Kruuk, H., Macdonald, D.W., Polma, M., 1998. Diet of two species of mink in Estonia: displacement of *Mustela lutreola* by *M. vison*. *J. Zool.* 245, 218–222.
- Mason, G.J., 1991. Stereotypies: a critical review. *Anim. Behav.* 41, 1015–1037.
- Mason, G.J., 1994. Tail-biting in mink (*Mustela vison*) is influenced by the age at removal from the mother. *Anim. Welf.* 3, 305–311.
- Mason, G., Mendl, M., 1997. Do the stereotypies of pigs, chicken and mink reflect adaptive species differences in the control of foraging? *Appl. Anim. Behav. Sci.* 53, 45–58.
- Mormède, P., Andanson, S., Auperin, B., Beerda, B., Guemene, D., Malmkvist, J., Manteca, X., Manteuffel, G., Prunet, P., van Reenen, C.G., Richard, S., Vessier, I., 2007. Exploration of the hypothalamic-pituitary-adrenal function as a tool to evaluate animal welfare. *Physiol. Behav.* 92, 317–339.
- Palme, R., 2012. Monitoring stress hormone metabolites as a useful, non-invasive tool for welfare assessment in farm animals. *Anim. Welf.* 21, 331–337.
- Ponzio, M.F., Busso, J.M., Ruiz, R.D., Fiol de Cuneo, M., 2007. A survey assessment of the incidence of fur-chewing in commercial chinchilla (*Chinchilla lanigera*) farms. *Anim. Welf.* 16, 471–479.
- Ponzio, M.F., Monfort, S.L., Busso, J.M., Garlini, V.P., Ruiz, R.D., de Cuneo, M.F., 2012. Adrenal activity and anxiety-like behaviour in fur-chewing chinchillas (*Chinchilla lanigera*). *Horm. Behav.* 61, 758–762.
- Sarna, J.R., Dyck, R.H., Whishaw, I.Q., 2000. The Dalia effect: D57BL6 mice barber whiskers by plucking. *Behav. Brain Res.* 108, 39–45.
- Stevens, R.T., Ashwood, T.L., Sleeman, J.M., 1997. Fall–early winter home ranges, movement, and den use of male mink, *Mustela vison* in Eastern Tennessee. *Can. Field Naturalist* 111, 312–314.
- Sidorovich, V.E., 2000. Seasonal variation in the feeding variation in the feeding habits of riparian mustelids in river valleys of NE Belarus. *Acta Ther.* 45, 233–242.
- Svendsen, P.M., Hansen, B.K., Malmkvist, J., Hansen, S.W., Palme, R., Jeppesen, L.L., 2007. Selection against stereotyped behaviour may have contradictory consequences for the welfare of farm mink (*Mustela vison*). *Appl. Anim. Behav. Sci.* 107, 110–119.
- Svendsen, P.M., Palme, R., Malmkvist, J., 2013. Novelty exploration, baseline cortisol level and fur-chewing in farm mink with different intensities of stereotypic behaviour. *Appl. Anim. Behav. Sci.* 147, 172–178.
- Tauson, A.-H., 1985. Effects of flushing on reproductive performance, ovulation rate, implantation rate and plasma progesterone levels in mink. *Acta Agric. Scand.* 35, 295–309.
- Tisljar, M., Janic, D., Grabarevic, Z., Simpraga, B., Marinculie, A., Pinter, L., Janicki, Z., Nemanic, A., 2002. Stress-induced Cushing’s syndrome in fur-chewing chinchillas. *Acta Vet. Hungarica* 50, 133–142.
- Vanjonack, W.J., Johnson, H.D., 1973. Relationship of thyroid and adrenal function to “fur-chewing” in the chinchilla. *Comp. Biochem. Physiol.* 45A, 115–120.
- Vasconcellos, A., da Silva, Adania, C.H., Ades, C., 2012. Contrafreeloading in maned wolves: implications for their management and welfare. *Appl. Anim. Behav. Sci.* 140, 85–91.
- Vickery, S., Mason, G., 2004. Stereotypic behaviour in Asiatic black and Malayan sun bears. *Zoo Biol.* 23, 409–430.
- Wise, M.H., Linn, I.J., Kennedy, C.R., 1981. A comparison of the feeding biology of mink *Mustela vison* and otter *Lutra lutra*. *J. Zool.* 195, 181–213.