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Animal Welfare 2007, 16: 63-76
ISSN 0962-7286

Do double cages and access to occupational materials improve the welfare of farmed mink?

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Abstract

The effects of cage enrichments and additional space were studied in 60 pairs of mink kits kept in standard cages (STD) and 67 pairs of mink kits kept in enriched cages (ENR). During the period from mid July to the end of September both groups had alternate access to one and two connected cages. From October, half of the mink in each group had permanent access to one cage and the other half permanent access to two cages. The enrichment of the cages consisted of extra resting places (tubes made of wire mesh and plastic) and occupational materials in terms of table-tennis balls and ropes to pull and chew. The mink were observed for an experimental period of nine months, from late lactation until the beginning of the following mating season. The welfare was assessed through behavioural traits (use of nest box and enrichments, activity out in the cage, stereotypies and fur-chewing) consumption of food and straw, bodyweight and level of faecal corticoid metabolites. The presence of enrichments resulted in less tail-chewing, fewer stereotypies, and a reduced level of faecal corticoid metabolites. In addition, the presence of enrichments led to fewer social interactions and reduced the consumption of straw. Regarding the frequency of utilising different occupational materials, the mink did not use the table-tennis balls, but the tubes and pull-ropes were given extensive use. Access to one or double cages had no effect on stereotypies, fur-chewing and physiology linked to welfare, but mink with access to double cages used the nest box less, had a lower consumption of straw and pull-ropes than the mink with access to only one cage. However, there were no indications of frustration when the mink were deprived of using double cages. We conclude that increased environmental complexity in the form of occupational materials improved the welfare of the mink, whereas doubling the cage size had little or no effect in relation to mink welfare.

Keywords: *animal welfare, behaviour, cage environment, enrichment,* Mustela vison, *space allowance*

Introduction

The farming of mink (*Mustela vison*) occurs extensively in several countries, particularly in the Northern hemisphere, where approximately 34 million pelts are produced annually (2003-2004). For more than 80 years, artificial selection of mink has been practiced by fur farmers seeking to accentuate certain traits eg large litter, pelt quality and size. In addition, it has been normal practice to cull and pelt individuals that display deviant behaviour, such as extreme timidness or fear vocalisation thereby removing them from the breeding population. This selection has resulted indirectly in most farmed mink responding to humans with curiosity as opposed to fear (Hansen & Møller 2001). The temperament of mink is highly hereditary (Malmkvist & Hansen 2001; Berg *et al* 2002); selection of mink that display confidence towards humans has been shown to result in mink less prone to experience fear in certain situations, whether in relation to humans, other mink or novel situations (Malmkvist & Hansen 2002).

Although the process of domestication has subtly altered many mink traits, farmed mink remain explorative and behaviours such as fur-chewing and stereotypies are observed in captivity. This has led many to the question whether or not the needs of such an active and exploratory animal can be met in the present cage environment. Regarding the size of the production cage, the Council of Europe (1999) recommends cages measuring 0.255 m^2 and 0.45 m high for single, adult mink or pairs of mink kits. Hansen (1988) and Hansen *et al* (1994) compared behaviour and physiological stress parameters between juvenile pair-housed mink kept in Danish standard sized cages (0.90 × 0.30 × 0.45 m; length × breadth × height) and in larger cages (1.10 × 0.96 × 0.76 m; length × breadth × height). The results showed that a four-fold increase in the recommended cage size as well as a doubling of height did not improve mink welfare in so far as reducing stereotypic behaviour or physiological stress. On the contrary, mink in large cages performed significantly more stereotypic behaviour than those in standard-sized cages. It therefore appears reasonable to assume that merely increasing cage size, without further addition of enriching environmental stimuli, is insufficient to meet the minks' requirements in terms of being active and exploratory. The Council of Europe (2001) emphasises the need for more research into cage enrichment for mink and has suggested the possibility of group-housing as well as the addition of more occupational materials into the cage. The recommendation on group-housing is complex, in this instance, and means greater than two animals. This kind of group-housing, though, is unlikely to guarantee enhanced mink welfare due to their inherently territorial and solitary nature (Hansen *et al* 1997; Jeppesen *et al* 2000; Pedersen & Jeppesen 2001) The addition of more occupational materials, thereby creating a greater complexity of the cage environment, may be more likely to address certain key issues, notably biting and chewing and playing and hiding. Some factors in the cage environment are of considerable importance to the welfare of the mink, such as having permanent access to a nest box (Hansen *et al* 1994) and full social contact with one cage-mate of the opposite sex during the rearing period (Damgaard & Hansen 1996; Hansen *et al* 1997). However, even under traditional farm conditions with access to a nest box and with social pair-wise housing during rearing, mink may still display behaviours such as stereotypies (eg Mason 1993) and tail-chewing (Malmkvist & Hansen 1997; Hansen *et al* 1998); behaviours normally perceived to be indicators of reduced welfare (Nimon & Broom 1999). Attempts to improve the production environment have been made by equipping cages with shelves and wire-netting cylinders suspended from the ceiling or lying free on the bottom of the cage. Such shelves and cylinders are now part of a new Dutch housing system (Vinke *et al* 2002). Vinke *et al* (2002) focused on the integration of several physical, social environmental and management factors, which had documented positive effects or were assumed to have a positive effect on the minks' welfare. Due to the experimental design, a causal relationship could not be deduced in this study and the inclusion of restricted feeding, which has a documented effect on stereotypies, made it difficult to evaluate the direct effects of the initiatives involved, eg group-housing, on mink welfare. The idea that several small positive factors could act synergistically on the welfare of mink was tested in 600 female mink in a study by Jeppesen (2004). Again, no causal relationship could be deduced, but the result indicated that combining enrichment with selection against fearfulness was able to reduce stereotypic behaviour and fur-chewing in farmed mink.

Investigations in farm and zoo animals have demonstrated that animals often lose interest in static play objects that are permanently present in their environment (Young 2003). Jeppesen and Falkenberg (1990) found that mink lost interest in hard plastic balls over time - they barely used them after approximately one month - and therefore no long-term positive effects could be shown. However, the mink were given access to the balls relatively late in the rearing season (October), and an earlier provision may have been more successful in reducing stereotypies and fur-chewing. The prioritisation of mink regarding different types of resources and occupational materials has also been tested by the use of operant conditioning techniques (Cooper & Mason 2001; Hansen & Jensen 2006). Overall, the results indicate that mink give high priority to novelty and dynamic resources and that these characteristics should be included in the enrichment of the mink cage. However, the interactive/combined effects of enriching the cage with manipulable and complex structures together with an increase in space allowance have not been investigated.

In this study we investigated the effects of the birth environment and the actual housing environment on the welfare of mink. The birth environment was either standard or enriched. During a period of nine months we studied the synergy between space (one or two cages) and cage enrichments (standard or enriched) fulfilling different facets of minks' motivation. Furthermore, we studied the effect of shifting between access to one and access to two cages. The welfare of the mink was assessed by measuring behavioural elements (use of the nest box and enrichments, activity out in the cage, stereotypies and fur-chewing) consumption of food and straw, bodyweight and faecal corticoid levels. The overall aim was to clarify whether access to double cages, to occupational materials or both affects the welfare of farmed mink.

Materials and methods

Animals, housing and management

Fifty adult, female mink of the brown colour 'Wild' type were housed after mating in either standard (n = 25) or enriched (n = 25) cages (90 × 30 × 45 cm; length × breadth × height) connected to a covered nest box (23 × 28 × 20 cm; length × breadth × height). Forty-four of the females gave birth in late April/early May and nursed their kits in the two types of cages, respectively. When the kits were eight weeks of age, the females were removed from the litters. The kits born in standard cages (n = 128) were distributed to 30 standard cages (STD) and 34 enriched cages (ENR) in unfamiliar pairs (male and female), and similarly the kits born in enriched cages (n = 126) were distributed to 30 standard cages and 33 enriched cages.

The cage sections consisted of six cages of equal size, alternating between standard and enriched cage sections. The kit-pairs were placed in cage number 1, 3, 4 and 6 in each cage section. Cage number 2 and 5 were empty until July 16. Thereafter and until October 1, the kit-pairs in cage number 1 or 3 had alternate two weeks of access to cage number 2, and similarly the kits in cage number 4 and 6 had alternate access to cage number 5. So 60 pairs of kits in standard cages and 67 pairs of kits in enriched cages had intermittent access to one or two cages during this period (Table 1; period II). The shifting between having access to one or two cages, allowed us to investigate if the mink experienced deprivation when they were restricted from using two cages. From October (period III) 28 pairs of kits in standard cages had permanent access to one cage and

Figure 1

(a) Mink in one of the enriched (ENR) cages, with two types of tubes and pull-ropes attached to the ceiling and a table-tennis ball. Standard (STD) cages did not include any of these tubes or manipulatory devices.

(b) Mink in double cage of the ENR type.

30 pairs of kits had permanent access to two cages. In the enriched environment 33 pairs had permanent access to one or two cages respectively.

The enrichment of the cages consisted of two tubes at the cage ceiling (one made of wire mesh and one made of plastic; diameter was 12 cm and length was 30 cm), and occupational materials in the form of two table-tennis balls (diameter 3.5 and 7 cm) and two pieces of rope (each 5 cm long) attached to plastic coated metal wires hanging down in the cage (see Figures 1 and 2). The mink were able to fully enter both tubes. The pull-ropes were checked for wear three times per week and replaced if shorter than 1 cm. The mink with access to two connected cages (double cages) had access to one rope in each of the two cages. The mink in standard cages did not have access to any of these enrichments.

All pairs of kits had access to one nest box irrespective of the number of cages available. The mink had access to straw through the wire mesh top of the nest box. Water was available *ad libitum* from a drinking nipple in each cage and the mink were fed wet feed daily on the top of the cage. Feeding time was at approximately 1100h and during the growth season (period I-III; Table 1) at least 60 % of the kit-pairs had feed left over from the previous day. On December 4 the male mink were pelted and the female remained alone in the cage system throughout winter and until the start of the mating period in March the following year. During winter the amount and energy of the food were gradually decreased and remained low in January and February in order to reduce the females' weight, thus preparing them for flushing immediately prior to the mating season in March. The purpose of flushing is to increase the

Figure 2

(a) and, below (b) Mink manipulating the pull-rope.

rate of eggs released and implanted and may be carried out by restricted feeding followed by *ad libitum* feeding (Tauson 1988).

Data collection

The time course of data collection is summarised in Table 1. The experiment was divided into five periods, based on the housing differences in (Table 1): Period 0 (May 28 – weaning), the kits grow up with their mothers in either standard or enriched environments. Period I (weaning – July 15), the kits are redistributed pairwise into either standard or enriched cages. Period II (July 16 – September 30), the kits get alternate access to one and two cages within environment. Period III (October 1 – December 4), the kits have permanent access to either one or two cages within each treatment (standard/ enriched environment), and period IV (December 5 – February 23), the females stay alone in the cage after pelting of the males.

Behaviour

Behavioural observations were made in late lactation (period 0), and several times during periods II-IV, using the ethogram in Table 2. In the late lactating period the frequency (but not the duration) of the behavioural elements (Table 2) was registered for females with kits during 1 min of observation once a week from 0830 to 1000h when the kits were 5, 6, 7 and 8 weeks old. In periods II-IV, the duration of different behavioural elements (Table 2) was registered during 1 min of continuous observation per cage unit. Due to the non-parametric distribution of the behavioural data, the durations were classified as either lower or higher than the median value of the actual behaviour within

Table 1 Data collection during the experimental period, May 28th 2003 to February 23rd 2004.

Time of sampling	Type of sampling	Housing and experimental animal
Period 0 (May 28 – weaning)	Behaviour (Table 2) Bodyweight at weaning	Forty-four litter with mother until weaning at 8 weeks in STD or ENR cages.
Period I (Weaning - July 15)	Feed consumption	Weaned male (127) and female (127) together in either STD or ENR cage.
Period II (July 16 - September 30)	Behaviour (Table 2) Feed consumption	Male and female together in either STD (60) or ENR (67) cages shifting between access to one or two cages during two weeks every 2nd week.
Period III (October 1 - December 4)	Behaviour (Table 2) Feed consumption Straw consumtion Rope replacements (ENR) Fur-chewing scores (December 4) Bodyweight (December 4)	Male and female together in either STD or ENR cage, with permanent access to either one or two cages.
Period IV (December 5 - February 23)	Behaviour (Table 2) Feed consumption Straw consumtion Rope replacements (ENR) Behaviour (0800 - 1600h) Faeces Bodyweight (February 23) Tail-chewing score (February 23)	Female alone in STD or ENR cage, with permanent access to either one or two cages.

STD Standard cage, ENR Enriched cage.

period. The observations were carried out on two consecutive days (before and after shift of access to one or two cages) every second week in period II, and once every second week in periods III and IV. For all the periods (II-IV), each observation day lasted for 2.5 hours, beginning at 0830h and ending just before feeding at 1100h. Prior to registration of behaviour in focal animals, the observer stood for 1 min in front of the cage at a distance of approximately 1 m. This procedure allowed the animals to habituate themselves to the observer.

Daily rhythms of behaviour in mink females during period IV

The female mink were observed once each hour from 0800 to 1600h on two days (January 27 and February 10). The observation procedure (1 min habituation, 1 min continuous observation) was the same as previously described, and four focal mink could be observed at a time. The following behavioural elements were registered: in nest box and active in cage (defined in Table 2), in the tubes (ENR cages only), stereotypic behaviour (defined in Table 2) and running behaviour. Stereotypic behaviour was defined as running behaviour, if the behaviour was not repeated 5 times.

Bodyweight

The bodyweight of all the experimental animals was measured at weaning at eight weeks of age, when the males were pelted (December 4), and at the end of the experiment (February 23).

Feed consumption

The same amount of feed was delivered to each cage unit. In the period from weaning to December 4 (period I-III, Table 1) the mink were fed amounts close to their *ad libitum* intake. This was not the case for period IV, when only experimental females were included. As a relative measure of feed consumption the number of cages with food left over the next morning was registered three times a week.

Fur-chewing

Fur-chewing is an abnormal behaviour characterised by the animal's oral removal of guard hairs on themselves or on the cagemate and may also include removal of some underfur. Tail-chewing in particular has been suggested to have an association with reduced welfare (eg Malmkvist & Hansen 1997; 2001). All mink were examined for tail-chewing on December 4 (males and females) and on February 23 (females). The severity of the tail-chewing was scored from 0 to 4, with 0: no tail chewing; 1: the guard hair on the tail tip is gone, but the tail tip is not completely bald; 2: less than 1 cm of the tail has been chewed; 3: between 1 and 5 cm of the tail has been chewed, and 4: more than 5 cm of the tail has been chewed.

Rope replacements (ENR cages only)

The minks' use of the ropes was measured by how often it was necessary to replace the pull-rope. The criterion for replacing the rope was that less than 1 cm of the rope remained. In the period from October 1 to February 23 (period III-IV; Table 1) the condition of the ropes was inspected three times a week.

Straw consumption

Every third day new straw was delivered on to the top of the nest box, when the wire mesh on the top of the nest box was

Table 2 Behavioural observation on mink during the late lactation (period 0) and periods II, III and IV.

Behaviour	Definition
In nest box	The mink has at least both front legs and head inside the nest box. Thus, it is totally or half withdrawn in the nest box. If not 'In nest box', the mink is scored as in the wire cage.
Active in cage[1]	Any type of activity (walking, standing etc) in the wire cage.
Lie in cage[1]	Lying (for more than 15 s) on the floor in the wire cage. (Registered in the late lactation period only).
Stereotypy[1]	Regularly repeated (at least 5 times) and morphological identical movements without any obvious function.
In wire tube[1] (ENR)	The mink is in the wire tube. In the late lactation period it was also registered whether the mink was active (for more than 15 s) or lying in the wire tube.
In plastic tube[1] (ENR)	The mink is in the plastic tube. In the late lactation period it was also registered whether the mink was active (for more than 15 s) or lying in the wire tube.
Manipulate rope[2] (ENR)	The mink is biting/manipulating the rope, using mouth or front limbs.
Biting cage wire[2]	The mink is biting the wire mesh of the cage.
Climbing[2]	The mink is climbing up the walls of the wire cage.
Social interaction[2]	Any type of social interaction (play or aggression) between cagemates involving physical contact.

ENR, Enriched cages only.
[1] duration;
[2] only occurrence and not duration, for this behaviour.

visible as noted. From October 13 onwards the frequency of delivering straw were noted for both groups.

Physiology

Physiological measures of stress on mink can be difficult to obtain due to the rapid stress responses seen when mink are captured for blood sampling. In order to avoid acute stress reactions, faeces from undisturbed female mink were collected in period IV (when the females were alone) for non-invasive determination of adrenocortical activity via measurement of a group of corticoid metabolites (11, 17-dioxoandrostanes [Möstl *et al* 2002; Malmkvist *et al* 2004]). Fresh samples were collected from the cleaned manure drain below cages between 0-3 hours after feeding. A total of 0.5 g of faeces from each individual was weighed and stored in capped plastic tubes at -21°C until analysis for corticoid metabolites. After methanol extraction the samples were analysed with an 11-oxoaetiocholanolone enzyme-immunoassay (EIA) to determine the concentrations of 11, 17-dioxoandrostanes as described earlier (Palme & Möstl 1997).

Statistical analysis

Differences in behavioural elements were treated statistically by testing the differences in the frequencies of animals performing the actual behavioural element (in nest box, active in cage, in tubes, stereotypies) in more than 50% of the median time for that behavioural element. The differences in the frequencies of the animals were tested using a generalised linear model designed for binomial data (GENMOD procedure) with birth environment, housing environment, number of cages/shift in number of cages, date, sex and all significant two-way interactions between these effects as general fixed effects.

The scores of tail-chewing were tested statistically using χ^2 test (Siegel & Castellan, 1988). Treatment effects on bodyweight, weight gain and concentrations of faecal corticoid metabolites were tested using an ANOVA. Effects on the consumption of straw, feed and pull-ropes were tested using the Poisson distribution in a generalised linear model (GLM). The start model included enrichment (ENR, STD), number of cages (one, two), and the interaction between these factors. In addition, duration from faeces collection beneath the cages until cool storage of each sample was included as covariate in the model of effects on the corticoid metabolite. The models were reduced by stepwise removal of insignificant terms ($P > 0.10$), starting with the interactions. The calculations were all made in the SAS software (8.02, SAS Institute, Cary, NC) (Littell *et al* 1996). All significant effects are presented in the text. A probability level (P) of 0.05 was chosen as the limit for statistical significance in all tests. P-values of 0.05 – 0.10 are reported as tendencies.

Results

Behaviour

The frequencies of observed behavioural elements in the final part of lactation (period 0) are shown for female mink and kits in Table 3. As the behaviours are not mutually exclusive during the 1 min observation period registered, the sum may exceed 100 percent. No significant differences were observed between the females and kits kept in standard or enriched cages. In the enriched cages both females and kits used the tubes and the pull-ropes, but mink were never observed using the table-tennis balls.

The frequency of mink performing the actual behaviour for longer than the median value in period II, III, IV is shown in Table 4. In period II values obtained after the mink had had access to one or two cages for two weeks were used. Values obtained before and after shifting between number of cages are shown in Table 5.

In period II (Table 4) the mink in standard cages (STD) used the nest box and the cage significantly more than the mink

Table 3 Total frequencies of observed behavioural elements expressed as percentage of total number of observations of adult females with kits during the late lactation period.

	Standard		Enriched	
	Female	Kits	Female	Kits
In nest box	56	83	57	85
Active in cage	51	25	49	24
Lie in cage	12	12	8	8
Biting cage wire	5	0	1	0
Stereotypies	18	0	17	0
In wire tubes				
Active	-	-	11	10
Lying	-	-	4	3
In plastic tubes				
Active	-	-	16	11
Lying	-	-	3	4
Manipulate rope	-	-	4	5

No significant differences were found between standard and enriched-kept females and kits within rows.

in enriched cages (ENR) (Nest box: $\chi^2_1 = 31.6$, $P < 0.001$; Cage: $\chi^2_1 = 45.30$, $P < 0.001$). The mink with access to one cage used the nest box more than the mink with access to two cages ($\chi^2_1 = 7.96$, $P < 0.01$). The females used the nest box significantly more than the males ($\chi^2_1 = 4.01$, $P < 0.05$), were less active out in the cage ($\chi^2_1 = 12.36$, $P < 0.001$) and used the tubes more ($\chi^2_1 = 7.07$, $P < 0.001$). The mink increased their use of the nest box throughout period II ($\chi^2_5 = 100.79$, $P < 0.001$, data not shown). The birth environment had no effect on the use of the nest box, activity in cage or use of tubes and there were no interactions between environment and number of cages.

In period III there were no significant effects of housing environment on behaviour. The females used the tubes significantly more than the males ($\chi^2_1 = 43.85$, $P < 0.001$). The mink born in standard environment used the nest box less than mink born in the enriched environment ($\chi^2_1 = 11.47$, $P < 0.001$) and were more active out in the cage ($\chi^2_1 = 12.23$, $P < 0.001$). The birth environment did not affect the use of the tubes or the performance of stereotypies. The mink with access to one cage used the nest box more ($\chi^2_1 = 6.65$, $P < 0.01$), were less active out in the cage ($\chi^2_1 = 4.53$, $P < 0.05$) and used the tubes less ($\chi^2_1 = 4.13$, $P < 0.05$) than the mink with access to two cages. The number of cages had no effect on the stereotypies and there were no interactions between housing environment and number of cages on the behavioural elements.

In period IV the females were housed individually. The females in STD cages were more active ($\chi^2_1 = 65.81$, $P < 0.001$) and performed more stereotypies ($\chi^2_1 = 38.68$, $P < 0.001$) than the mink in ENR cages. The birth environment and the number of cages had no effects and there were no interactions between housing environment and number of cages.

In period II (Table 5) the effect of shifting between having access to one and two cages was studied by comparing the behaviours before and after the shifts on July 30-31, August 13-14, August 27-28 and September 10-11.

On two occasions we found significant differences in the number of mink out in the cages before and after shifting between number of cages. On 30-31 July, the mink were seen to be more out in the cage after shifting, than before ($\chi^2_1 = 7.69$, $P < 0.01$), irrespective of shifting from one to two cages or from two to one cage ($\chi^2_1 = 0.03$, $P = 0.85$). On August 13-14, we found the opposite was the case, in that the mink were out less in the cage after shifting than before shifting ($\chi^2_1 = 13.23$, $P < 0.001$) but again irrespective of the number of cages. On August 13-14, for the behaviour "in nest box" we found an interaction between number of cages and day. The mink that shifted from two to one cage were in the nest box more after the shift (35.9%) than before (14.2%) ($\chi^2_1 = 4.84$, $P < 0.05$), whereas the mink that shifted from one to two cages did not change their use of the nest box. This was the only significant effect we found between day and number of cages. The housing environment had a significant effect on the use of the nest box and use of the cage, irrespective of the number of cages and date (before or after the change). The mink in ENR cages, with access to tubes, were observed less in the nest box and less active out in the cage than mink in STD cages. The differences in the use of nest boxes were significant at all four times of shifting ($\chi^2_1 = 4.10 - 35.22$, $P < 0.05 - 0.001$) and the differences in the use of cage were significant in three out of the four shifts ($\chi^2_1 = 7.81 - 56.49$, $P < 0.01 - 0.001$).

The females were more in the nest box than the males (August 13-14: $\chi^2_1 = 4.29$, $P < 0.05$), less active in the cage than the males (July 30-31: $\chi^2_1 = 3.94$, $P < 0.05$; August 13-14: $\chi^2_1 = 10.71$, $P < 0.001$; August 27-28: $\chi^2_1 = 8.77$, $P < 0.01$) and more in the tubes than the males (August 13-

Table 4 The effects of birth environment, housing environment, number of cages and sex on the frequencies of mink (percent) in period II-IV with duration of behaviour longer than the median value.

	Birth environment		Housing environment		Number of cages		Sex	
	Standard	Enriched	Standard	Enriched	1 cage	2 cages	Male	Female
Period II								
In nest box	34.2	35.9	42.4^a	28.4^b	36.3^a	33.7^b	33.3^b	36.7^a
Active in cage	49.8	50.0	58.6^a	42.2^b	49.1	50.6	54.2^a	45.6^b
In tubes	35.7	33.0		34.4	32.8	35.9	28.1^b	40.7^a
Period III								
In nest box	44.6^b	54.6^a	49.5	49.5	53.6^a	45.5^b	52.1	46.9
Active in cage	55.1^a	44.6^b	52.8	47.3	46.6^b	53.2^a	48.5	51.3
In tubes	20.3	17.4		18.9	15.5^b	22.1^a	8.2^b	29.6^a
Stereotypies	1.2	2.2	2.3	1.1	1.6	1.8	1.7	1.6
Period IV								
In nest box	39.9	47.3	39.9	46.7	46.5	40.3	-	43.5
Active in cage	51.3	47.3	68.4^a	33.3^b	46.9	52.1	-	49.5
In tubes	50.4	40.2		45.2	41.1	49.2	-	45.2
Stereotypies	16.0	14.5	25.7^a	6.5^b	13.6	16.8	-	15.2

Significant differences: ^{ab} $P < 0.05$.

Table 5 The effects of day, birth environment, housing environment, number of cages and sex on the frequencies of mink (percent) performing the actual behaviours for longer than the median value observed during 1 min of continuous observation on the day before and after mink alternated from having access to 1 or 2 cages during period II.

	Day before and after		Birth environment		Housing environment		Number of cages		Sex	
Date	Before	After	Standard	Enriched	Standard	Enriched	1 to 2	2 to 1	Male	Female
30 - 31/7										
In nest box	24.4	18.5	19.8	23.2	25.4a	19.7b	19.1	23.8	18.5	24.4
Active in cage	52.0^a	63.4^b	60.1	55.2	74.6^a	42.5^b	59.4	56.0	61.8^a	53.5^b
In tubes	49.3	38.1	41.3	46.2		43.7	42.7	44.7	42.5	44.8
13 - 14/8										
In nest box	19.0^a	33.2^b	23.0	29.3	33.9^a	19.1^b	27.1	25.1	22.1^a	30.0^b
Active in cage	63.2^a	47.8^b	56.0	55.0	66.1^a	46.1b	56.2	54.9	62.5^a	48.6^b
In tubes	35.8	39.9	39.9	35.7		37.8	34.4	41.2	30.6^a	45.1^b
27 - 28/8										
In nest box	25.8	38.6	36.8	37.6	50.4^a	25.4^b	37.9	36.5	33.5	40.9
Active in cage	50.8	48.8	48.1	51.6	50.4	49.3	48.8	50.8	56.3^a	43.3^b
In tubes	36.6	28.4	37.7	26.9		32.5	36.0	28.8	25.4^a	39.6^b
10 - 11/9										
In nest box	42.3	36.4	38.4	40.3	45.3^a	34.1^b	35.1	43.7	38.7	40.0
Active in cage	47.8	52.4	48.2	52.0	56.8^a	44.2^b	53.8	46.4	51.8	48.4
In tubes	31.3	33.1	25.5	28.7		32.2	31.3	33.1	24.6^a	39.9^b

Significant differences: ^{ab} $P < 0.05$.

14: $\chi^2_1 = 4.59$, $P < 0.05$; August 27-28: $\chi^2_1 = 4.73$, $P < 0.05$; September 10-11: $\chi^2_1 = 6.12$, $P < 0.05$). The birth environment had no significant effects on the behavioural elements.

The frequency of behavioural elements in periods II, III and IV are presented per sex in Table 6. In period II males in STD cages used the nest box more than those in ENR cages ($\chi^2_1 = 54.86$, $P < 0.001$). Males in STD cages started social interactions more frequently than males in ENR cages ($\chi^2_1 = 10.90$, $P < 0.001$) and males did so more often than females ($\chi^2_1 = 4.66$, $P < 0.05$). Males, irrespective of cage type, were rarely seen to climb and did so less often than females ($\chi^2_1 = 50.879$, $P < 0.001$), but were more likely to bite the wire mesh than females (STD: $\chi^2_1 = 56.49$, $P < 0.001$; ENR: $\chi^2_1 = 38.39$, $P = 0.001$).

In period III females in STD cages climbed more in the wire mesh than those in ENR cages ($\chi^2_1 = 5.63$, $P < 0.05$) and females, generally did so significantly more than males, irrespective of cage type (STD: χ^2_1 = 32.19, P < 0.001; ENR: χ^2_1 = 18.68, P < 0.001). Females manipulated the ropes more than the males (χ^2_1 = 5.88, P < 0.05).

In period IV females in STD cages climbed more in the wire mesh than females in ENR cages (χ^2_1 = 5.25, P < 0.01).

Daily rhythm (0800 to 1600h) in behaviour

There was no difference in the duration of different behaviours between mink with access to one or two cages, respectively. There was, however, a significant difference between mink in standard and enriched cages. While these groups spent the same proportion of time in the nest box, STD mink spent more time running and performing stereotypical behaviour before feeding at 1100h than ENR mink (P < 0.05; Figure 3). This difference disappeared as activity decreased (P < 0.001) and the time spent in the nest box increased (P < 0.001) after feeding.

Bodyweight

The bodyweight (mean ± SD) of males: (818 ± 138 g) and females (648 ± 92 g) placed in single or double STD or ENR cages at the start of the experiment were not significantly different (Males: $F_{3,\ 46.3}$ = 0.34, P = 0.79, Females: $F_{3,\ 83.7}$ = 0.93, P = 0.42). The cage environment had no effect on the bodyweight of males and females at the end of period III (Males: cage type, $F_{1,\ 50.6}$ = 0.48, P = 0.49, number of cages, $F_{1,\ 50.6}$ = 0.97, P = 0.33; Females: cage type, $F_{1,\ 122}$ = 2.23, P = 0.14, number of cages, $F_{1,\ 122}$ = 1.67, P = 0.19). However during period IV the females in single enriched cages had a higher mean bodyweight (1124 ± 137 g) than females in double enriched cages (1046 ± 153 g; $t_{1,\ 88.2}$ = 2.59, P = 0.01), in single standard cages (1018 ± 117 g; $t_{1,\ 70.1}$ = 2.59, P = 0.005), and in double standard cages (1014 ± 103 g; $t_{1,\ 81.5}$ = -2.79, P = 0.006). The bodyweight gain of males (July-December) was not affected by the type of cage ($F_{1,\ 119}$ = 0.99, P = 0.32) or the number of cages ($F_{1,\ 119}$ = 0.93, P = 0.33), neither was the bodyweight gain of females (cage type: $F_{1,\ 118}$ = 2.91, P = 0.09; number of cages: $F_{1,\ 118}$ = 0.48, P = 0.48) and the weight loss of females (December-February) (cage type: $F_{1,\ 83}$ = 0.23, P = 0.63; number of cages: $F_{1,\ 83}$ = 0.69, P = 0.41).

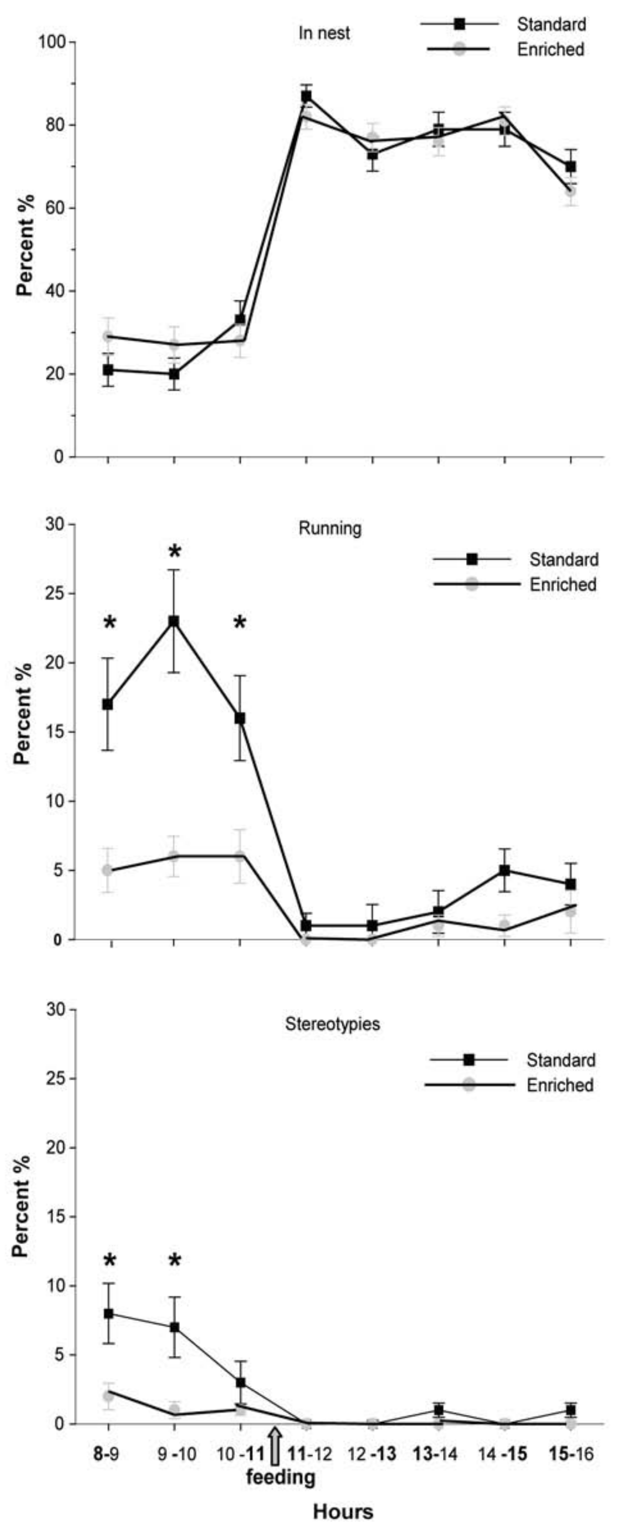
Rope replacements (ENR cages only)

In period III (with two animals per unit) and in period IV (with one female per unit) there was a significant difference in the wear of pull-ropes between minks with access to one or two cages. A lower number of pull-ropes were replaced for mink that had access to two cages (mean [+ SE]), period III: 47 (1.8) vs 42 (2.4), $F_{1,\ 66}$ = 8.0, P = 0.005; period IV: 45 (2.8) vs 37 (3.3), $F_{1,\ 66}$ = 26, P < 0.001). Individually housed females destroyed nearly as many pull-ropes during approximately 49 days in winter time (period IV) as were destroyed in the earlier period (III), when they were housed in pairs with a male for a longer period of time (65 days).

Straw consumption

Straw was replaced less often in mink in enriched than in standard cages (period III: ENR 2.7 (0.35) vs STD 5.1 (0.55), $\chi^2_{1,\ 125}$ = 49.0, P < 0.001; period IV: ENR 6.0 (0.60) vs STD 7.3 (0.62), $\chi^2_{1,\ 123}$ = 8.2, P = 0.004), and less often in mink with access to two cages than in mink with access to one cage (period III: two, 3.3 (0.39) vs one, 4.4 (0.53),

Figure 3



Duration (percentage) of specific behaviours, a) In nest, b) Running and c) Stereotypies in STD and ENR mink, as mean (+ SE) percentage of observation time. * P < 0.05.

Table 6 Frequencies of observed behavioural elements in percent of observations.

	Standard		Enriched	
	Male (n = 60)	Female (n = 60)	Male (n = 67)	Female (n = 67)
Period II				
Biting in cage wire	18[a]	9b	14[a]	8[b]
Climbing	1[a]	11[b]	0[a]	6[b]
Manipulate rope	-	-	9[a]	8[a]
Enter nest box	38[a]	44[a]	25[b]	30[b]
Social interactions	12[a]	8[ab]	6[b]	5[b]
Period III				
Biting in wire cage	10[a]	12[a]	12[a]	9[a]
Climbing	0[a]	13[b]	0[a]	7[c]
Manipulate rope	-	-	4[a]	9[b]
Enter nest box	60[a]	62[a]	58[a]	56[a]
Social interactions	10[a]	7[a]	5[a]	5[a]
Period IV				
Biting in cage wire	-	6[a]	-	4[a]
Climbing	-	7[a]	-	2[b]
Manipulate rope	-		-	4
Enter nest box	-	42[a]	-	49[a]

Significant differences: [abc] $P < 0.05$.

Table 7 Mean (± SD) percentage of cage units with feed refusals during periods II – IV.

	Standard		Enriched	
	1 cage	2 cages	1 cage	2 cages
Period II	52.7 (± 24.1)	53.6. (± 20.6)	54.8 (± 24.3)	54.2 (± 19.1)
Period III	51.2 (± 22.0)[a]	45.6 (± 30.7)[b]	56.7 (± 20.6)[a]	48.4 (± 26.7)[b]
Period IV	3.9 (± 5.9)[a]	3.6 (± 3.8)[b]	6.8 (± 7.3)[c]	4.2 (± 6.2)[d]

Significant differences: [abcd] $P < 0.05$.

Table 8 The number of mink with different degrees of tail chewing scored in period III.

	Standard		Enriched	
	1 cage	2 cages	1 cage	2 cages
Score 0	17[a]	15[a]	57[b]	55[b]
Score 1	15	12	9	4
Score 2	10	12	1	5
Score 3	11	16	0	1
Score 4	6	2	0	0
Total number of animals	59	57	67	67

Significant differences: [ab] $P < 0.05$.

$\chi^2_{1,\ 125} = 8.9$, $P = 0.003$; period IV: two, 5.9 (0.59) vs one, 7.3 (0.62), $\chi^2_{1,\ 123} = 9.1$, $P = 0.003$). No interaction between enrichment and number of cages was found during both periods (III and IV) with regard to straw consumption.

Feed refusals

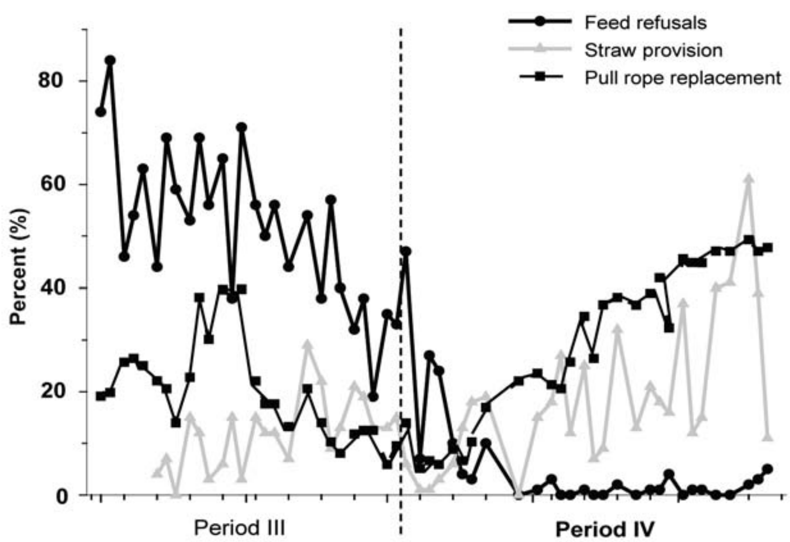
No significant differences were found in feed refusals between mink housed with access to one or two cages or between mink in traditional or enriched cages in period II (Table 7). In period III, however, mink with access to one cage left more feed than mink with access to two cages ($\chi^2_{1,\ 126} = 7.3$, $P = 0.007$), but with no difference between STD and ENR cages ($P = 0.15$). In period IV, similarly, more feed refusals were observed in mink with access to one cage than in mink with access to two cages ($\chi^2_{1,\ 124} = 4.7$, $P = 0.031$), and more feed was left in enriched than in standard cages ($\chi^2_{1,\ 124} = 6.4$, $P = 0.011$; Table 7). In addition, when females were kept alone, and feed ration became more restricted (see Figure 4; period IV), they ate more in standard than in enriched cages.

Tail-chewing

The distribution of tail-chewing scores did not differ between sex ($\chi^2_1 = 0.02$, $P = 0.88$) and therefore scores for

Figure 4

Feed refusals, straw provision and replacement of pull-ropes (ENR single + double cages only) during period III (October 1 – December 4) and period IV (December 5 – February 23) in percentage of number of cage units.



males and females are pooled in Table 8. The frequency of mink without tail-chewing was not significantly different between single and double cages (STD: $\chi^2_1 = 0.09$, $P = 0.76$; ENR: $\chi^2_1 = 0.21$, $P = 0.64$). However, mink in standard cages showed significantly more tail-chewing than mink in enriched cages (single cage: $\chi^2_1 = 40.97$, $P < 0.001$; double cage: $\chi^2_1 = 38.97$, $P < 0.001$) and the tail-chewing was more severe for mink kept in the standard cages. Thirty-five mink in the traditional cages had fur-chewing on more than one cm of the tail compared to only one mink in the enriched cages ($\chi^2_1 = 37.63$, $P < 0.001$). The frequency of females with tail-chewing was examined again in February, at the end of the experiment, and again significantly more females in standard cages (79.7%) displayed tail-chewing compared with females in enriched cages (25.4%) ($\chi^2_1 = 36.9$, $P < 0.001$), and the number of cages still had no effect on the occurrence of tail-chewing ($\chi^2_1 = 0.28$, $P = 0.59$).

Physiology

The mean concentrations of faecal corticoid metabolites was significantly higher in females kept in traditional cages than those kept in enriched cages (98.5 ± 1.1 n mol kg^{-1} vs 73.7 ± 1.1 n mol kg^{-1}, respectively; $F_{1,4} = 7.55$, $P < 0.01$). There was no significant difference between females in single or double cages ($F_{1,4} = 0.39$, $P = 0.53$) and no interaction between cage type and number of cages ($F_{1,4} = 1.13$, $P = 0.28$). The time from collection until the freezing of the faeces sample did not affect the concentration ($F_{1,4} = 2.19$, $P = 0.14$).

Discussion

We found that mink kept in ENR cages performed significantly less tail-chewing, had fewer social interactions and used less straw than mink in STD cages during the growing season. Furthermore, females in enriched cages performed less stereotypies and had lower stress hormone levels than females in standard cages, during the winter period when the females were housed alone. Tail-chewing, stereotypies and elevated corticoid levels are all commonly used as indicators of reduced welfare in mink production (European Commission 2001). Thus, the enrichment of the production cages reduced these parameters and consequently increased the welfare of farmed mink. The positive results are achieved independently of the number of cages and confirm previous findings that concluded that environmental enrichments are more important for the welfare of mink than the size of the cage (Hansen 1988; Hansen *et al* 1994). The cage size and increased complexity (in terms of two connected cages; see Figure 1[b]) reduced the consumption of both straw and pull-ropes. This result indicates that increased cage size together with complexity may, to some extent, reduce motivation to use manipulatory objects.

During the late lactation period, both adult females and kits used the added enrichments (with the exception of the table-tennis ball), but otherwise no effects of enrichment were evident on behaviour during this period. This is in direct contrast to previous findings that showed access to shelves may reduce stereotypies in adult females during the late lactation period (Hansen 1990). However, in the present study the breeding females all originated from standard cages and they may have developed a stereotyped movement pattern prior to entering into the experiment. This may blur the potential treatment effects of enrichment on adult females, since already established stereotypies may be hard to deter (Mason 1993). In the growth period (July-December) the occurrence of stereotypies among pairs of mink (male and female) was very low, and our results support findings that stereotypies primarily occur during the winter period (Damgaard *et al* 2004). In the winter period, females selected for breeding are kept individually and slimmed in preparation for flushing and mating. The slimming procedure in the winter period was characterised by a marked reduction in feed refusals (Figure 4) and a 20-26% decrease in bodyweight. The results on bodyweight and leftovers indicate that access to double cages generally increased the demand for energy, with females in single ENR cages having the highest average bodyweight of all groups. The slimming procedure is known to increase activity and the occurrence of stereotypies (Damgaard *et al* 2004). During the winter period stereotypies and running behaviour occurred in the morning hours before feeding and stopped after feeding (see Figure 3), indicating that appetitive feeding motivation generally triggers the performance of stereotypies in mink, in accordance with previous findings (Bildsøe *et al* 1991; Damgaard *et al* 2004; Mason 2003). However, the performance of stereotypies and running behaviour was significantly lower in ENR mink than in STD mink, whereas the number of cages available had no effect on these behaviours. The result indicates that the presence of different kinds of occupation in the ENR cage might redirect, at least partly, the need for appetitive foraging motivation in mink.

The most common location in which mink manipulated/bit at the pull-ropes and wires was while they were in the tubes (see Figure 2[b]). The wear of pull-ropes increased significantly during period IV (Figure 4), when the females were kept alone and experienced feed restriction. Having the possibility of manipulating the rope with teeth and claws may lower the minks' motivation for locomotive appetitive behaviour and thereby reduce the development of stereotypic behaviour. Furthermore, both the frequency of mink with tail-chewing and the severity of the resultant fur damage were significantly lowered in mink kept in ENR cages. Tail-chewing and stereotypies are both abnormal behaviours with a suggested association with the lack of an opportunity to engage in species-specific behaviours ie exploration (Wemelsfelder 1993; Hansen *et al* 1998). We assume that the rope had an occupational effect, acting partly as a chewing object and partly as a novel object to which the behaviour could be directed. This assumption is supported by the frequent replacement of the ropes and reduced straw consumption. In contrast, mink did not use the other unchewable play objects permanently present in the cage (the table-tennis balls), which confirms the lack of interest in play balls previously observed during a smaller part of the growth season (Jeppesen & Falkenberg 1990). Furthermore, the positive effect of the enrichments on welfare is supported by lower concentrations of faecal corticoid metabolites (11, 17-dioxoandrostanes) for mink in enriched compared to mink in standard cages.

Mink in enriched environments used the tubes for rest and consequently reduced their use of the nest box and activity out in the cage in period II and IV, whereas the number of cages and the birth environment had no general effect on behaviour. However, in period II access to one cage increased the use of the nest box, and in period III both the enriched birth environments and access to one cage increased the use of the nest box and decreased the activity out in cage. Experiments with rats have indicated that experiences with enriched environments may increase the ability to adapt or to cope with stressful situations (Fernandez-Teruel *et al* 2002). However, when the mink shifted between having access to one and two cages we found there was no effect of birth environment (standard or enriched). Furthermore, the activity out in the cage(s) was not affected whether the mink were either deprived or enriched with access to two cages and only in one out of four shifts did we find that the mink increased their use of the nest box when shifted from two cages to one. The welfare implications of being in the nest box more or less, or active in the cage more or less, may be difficult to interpret. However, we expected that if mink were frustrated, due to being deprived access to two cages, the activity out in the cage would increase, since such an effect has been shown in other studies where mink were deprived access to a nest box (Hansen *et al* 1994). However the activity did not increase and the number of cages (single vs double) did not affect the abnormal behaviour or the corticoid metabolite concentration. The mink in ENR double cages ate more and had a reduced consumption of straw and ropes than the mink in ENR single cages. We assume that these effects are primarily brought about by increased cage complexity due to the connection of two ENR cages, including an increased possibility of spatial separation of mink in the same cage.

It has been advocated that mink should be kept in pairs (male and female) during the growing period. When access to tubes was granted, females used them more than males and were also less active in the cage and used the nest box more. Access to tubes may give females the chance to escape from the bigger and more dominant males, thereby acting as a place of refuge. Furthermore the occupational materials in the ENR cages may distract the attention of the male from the female. Previously, it has been shown that denying access to the nest box increases social interaction between mink pairs and the performance of stereotypic behaviour (Hansen *et al* 1994). We found that males in ENR cages initiated fewer social interactions with females, than males in STD cages. However, differentiation of social interaction were not carried out in the present study, therefore social interactions include behaviours such as aggression and play, which may have different impacts on welfare. Females climbed significantly more on the cage wire than males, which we propose is a direct result of their smaller size and the fact that they were required to climb on the cage wire to reach the food on the cage ceiling. However, since the females in STD cages climbed more often than those in ENR cages, the lack of access to an elevated resting position or a 'safe area' in the tubes may also have increased the climbing. A previous study has shown that carnivores prefer an elevated resting place (Hansen *et al* 1994).

Animal welfare implications

The study has shown that mink exposed to the tested enrichments showed decreased stereotypies, tail-chewing, social interactions and physiological stress levels compared to mink in standard cages. In contrast these parameters were not affected by a doubling of the cage size. The results indicate that further improvement to welfare of the mink is possible through introduction of cage enrichments that are better adjusted to motivate the mink and increase environmental variability/complexity. In particular, the pull-ropes were used extensively as occupational material by the mink. It may, however, be problematic to implement this type of pull-rope in mink production, due to the time-consuming nature of replacing the little strands of rope. Therefore, there is a need for further development of enrichment devices, eg finding a suitable material which is more able to resist the tearing, chewing and biting activity of the mink while still maintaining its interest and requiring less maintenance/interference from the caretaker.

Acknowledgements

The authors want to thank the Danish Fur Breeders' Association for funding this research and the anonymous referees for their constructive criticism of this manuscript.

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