CODE OF PRACTICE FOR THE CARE & HANDLING OF MINK: REVIEW OF SCIENTIFIC RESEARCH ON PRIORITY ISSUES

May 2012

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Excerpt from Scientists' Committee Terms of Reference

Background

It is widely accepted that animal welfare codes, guidelines, standards or legislation should take advantage of the best available knowledge. This knowledge is often generated from the scientific literature, hence the term "science-based".

In re-establishing a Code of Practice development process, NFACC recognized the need for a more formal means of integrating scientific input into the Code of Practice process. A Scientists' Committee review of priority animal welfare issues for the species being addressed will provide valuable information to the Code Development Committee in developing or revising a Code of Practice. As the Scientists' Committee report is publicly available, the transparency and credibility of the Code process and the recommendations within are enhanced.

For each Code of Practice being developed or revised, NFACC will identify a Scientists' Committee. This committee will consist of 4-6 scientists familiar with research on the care and management of the animals under consideration. NFACC will request one or two nominations from each of 1) Canadian Veterinary Medical Association, 2) Canadian Society of Animal Science, and 3) Canadian Chapter of the International Society for Applied Ethology.

Purpose & Goals

The Scientists' Committee will develop a report synthesizing the results of research relating to key animal welfare issues, as identified by the Scientists' Committee and the Code Development Committee. The report will be used by the Code Development Committee in drafting a Code of Practice for the species in question.

The full Terms of Reference for the Scientists' Committee can be found within the NFACC Development Process for Codes of Practice for the Care and Handling of Farm Animals, available at www.nfacc.ca/code-development-process#appendixc.

CODE OF PRACTICE FOR THE CARE AND HANDLING OF MINK (*Neovison vison*): REVIEW OF SCIENTIFIC RESEARCH ON PRIORITY ISSUES

Mink Code of Practice Scientists Committee
May 2012

INTRODUCTION

In many areas of fur animal research, there are few researchers working on few topics. In most cases, research is performed only on one or few farms using one colour type. This may mean that scientific conclusions cannot be attained in some cases. A large majority of the research is also performed in countries outside North America (particularly Scandinavian countries) and in some cases may not be transferable to North American practices.

Mink exists in many colour types; the most common on farms and in research are blacks, pastels and dark brown forms called ‘wild type’, ‘mahogany’ or ‘demi’. Colour type is given when mentioned in the research.

1. PHYSICAL ASPECTS OF HOUSING

CAGE SIZE AND STOCKING DENSITY

Conclusions:

1. **Adjusting the cage size alone without enriching the environment does not significantly improve the welfare of the mink, at least from floor areas 0.1m^2 to 1.05m^2 (1.08ft^2 to 11.30ft^2).**
2. **Stocking densities/group sizes of greater than two animals per cage in some cases can lead to increased aggression, lower weight gain and injuries that may lead to damaged pelts.**

Adult mink are generally kept individually in cages, whereas juvenile mink are often kept in male-female pairs until pelting. As reviewed below, cage sizes researched to date have a minimal impact on the welfare or productivity of the mink, unless the cages are extremely small.

Stocking density that is too high seems to cause increased aggression between grouped mink and damage to the pelts can occur, but this impact has not been well separated from group size. Group size and composition is discussed later in this report in the section on *Social Aspects of Housing.*

Table 1 presents the cage measurements and stocking densities found in the scientific literature reviewed for this section.

Cage size—effects on behaviour: Somewhat conflicting results have been found regarding the impact of cage size on various welfare measurements. On one hand, increased cage sizes combined with larger group sizes have been shown to lower the incidence of stereotypies (e.g. Jeppesen et al., 2000). Female kits housed with a male sibling in cages measuring 90cm L x 30cm W x 45cm H (35.5in L x 11.8in W x 17.7in H) showed higher amounts of stereotypies than female kits housed with the entire litter in a cage system consisting of three adjoining cages of this size. Cage size is often confounded with the complexity of the cage, i.e. connected cages. Cage size is also often manipulated in parallel with altered numbers of animals in the cage, further examples regarding manipulation of cage sizes and number of animals in the group can be found later in this report in the section regarding *Social Aspects of Housing*.

Hansen and Jeppesen (2000) compared 78 one- or two-year-old mink housed and raised in units of three conjoined cages of different sizes: 90cm L x 30cm W x 45cm H or 120cm L x 65cm W x 75cm H (35.5in L x 11.8in W x 17.7in H or 47.3in L x 25.6in W x 29.6in H). Swimming water was also provided for half of the mink in each type of housing. Stereotypies were significantly higher in the groups housed in small cages with no swimming water access. Stereotypies were also found to be significantly lower in climbing cages than in standard cages (measurements not given) (Lidfors et al., 2010). Stereotypies also increased with time in standard cages, while this change was not observed in climbing cages. Mink will also work for access to an empty compartment, but it is not as valuable to them as compartments containing enrichments (Cooper & Mason, 2000; Mason et al., 2001).

There are also several studies which suggest no detectable benefits or apparently negative effects of increasing cage size. Lindberg et al. (2007) found that an increase in cage size did not significantly affect behaviours or bite mark frequency in juvenile mink that were housed in pairs in either standard cages (90cm L x 30cm W x 45cm H [35.5in L x 11.8in W x 17.7in H]) or in climbing cages. Climbing cages consist of a standard mink cage with a smaller second floor (55cm L x 30cm W x 45cm H [21.7in L x 11.8in W x 17.7in H]) built on top of the cage, which increases the floor space available to the animal as well as increase the complexity of the cage. Hansen et al. (2007) investigated the impact of juvenile male-female pairs of wild type mink in single cages (90cm L x 30cm W x 45cm H [35.5in L x 11.8in W x 17.7in H]) and double cages (two connected cages of this size) and found no significant differences in the level of stereotypies, tail-chewing or social interactions in the different cages. Hansen et al. (1994) also found no significant behavioural differences in juvenile pastel mink housed in 3 different sizes of cage (1.05m^2, 0.27m^2 and 0.10m^2 [11.3ft^2, 2.9ft^2 and 1.1ft^2]) and concluded that an increase in the standard cage size cannot itself be considered to enhance the welfare of the animals. An increased level of stereotypies was even seen in large cages (Hansen et al., 1992). In this study, juvenile mink housed in male-female pairs in large cages (1.05m^2 [11.3ft^2]) performed more stereotypies than mink in standard (0.27m^2 [2.91ft^2]) or small (0.10m^2 [1.08ft^2]) cages. General activity is increased in large cages and stereotypies negatively correlate with levels of inactivity (European Commission, 2001). Thus, generally increased activity levels could explain such results. Mason and Latham (2004) suggest that "stereotypies are a warning sign of potential suffering, but should never be used as the sole index of welfare".

Cage size – effects on physiological and growth parameters: No significant difference was found in the concentration of fecal corticoid metabolites between adult female wild type mink given access to one cage measuring 90cm L x 30cm W x 45cm H (35.5in L x 11.8in W x 17.7in H), or two cages of this size (Hansen et al., 2007). The size of the cage was not found to significantly affect the number of eosinophil leucocytes or cortisol concentrations of pastel mink kits kept in male-female pairs when considering three cage sizes: 1.05m^2, 0.27m^2 and 0.10m^2 (11.3ft^2, 2.9ft^2 and 1.1ft2) (Hansen & Damgaard, 1991). Aulerich et al. (1991) also did not find any significant differences in neutrophil/lymphocyte ratio, eosinophils or cortisol concentrations between mink raised in either large (76.2cm L x 61.0cm W x 45.7cm H [30in L x 24in W x18in H]) or small (76.2cm L x 30.5cm W x 45.7cm H [30in L x 12in W x 18in H]) cages. Hansen et al. (1992) again found no significant effect on plasma cortisol concentrations but did find that juvenile mink pairs kept in large cages (1.05m^2 [11.3ft^2]) had significantly lower eosinophil counts than mink in standard (0.27m^2 [2.9ft^2]) or small (0.10m^2 [1.1ft^2]) cages, which suggested that mink in larger cages are under increased stress. It should be noted that eosinophil counts have not been well validated as an indicator of welfare of mink, particularly as an indicator of chronic stress, as it can be affected by a variety of factors. Conclusions based on these measures should be interpreted carefully (European Commission, 2001; Nimon & Broom, 1999).

Small changes in cage size do not significantly affect the weight gain of single-housed kits, unless the cages are extremely small (45cm L x 15cm W x 15cm H [17.7in L x 5.9in W x 5.9in H]) (European Commission, 2001).

Cage size recommendations from other countries: Most Scandinavian countries have standard cage measurements of 90cm L x 30cm W x 45cm H (35.5in L x 11.8in W x 17.7in H), with a nest box mounted outside (European Commission, 2001). Most farmers in European countries use the same cage for housing single females and males, whelping and nursing, and housing growing kits; this is not the case in Canada. Cages with a width of 20cm (7.9in) or less have recently been prohibited in Denmark and Norway. In the Netherlands, the legislated minimum cage size is 85cm L x 30cm W x 45cm H (33.5in L x 11.8in W x 17.7in H) with at least one nest box (Netherlands, 2003). In Italy and Argentina, the minimum cage size (not including the nest box) is 0.255m^2 (2.75ft^2) with a minimum height of 45cm (17.7in). Argentine recommended codes of practice also prohibit cages measuring less than 30cm (11.8in) wide or 70cm (27.6in) long (Argentine Federation for the Commercialization and Industrialization of Fauna, 2008). Norwegian legislation also states that the floor area should measure 0.255m^2 (2.75ft^2) with a minimum cage height of 45cm (17.7in) (Akre et al., 2008). New cages must have a depth of at least 90cm (35.5in), and the floor area must be 0.270m^2 (2.9ft^2), with an additional 0.085m^2 (0.9ft^2) for every animal above two. Chinese regulations for housing mink state that the total area for each breeding mink should not be less than 0.27m^2, and the activity area must not be less than 0.18m^2 (Chinese State Forestry Administration, 2006). Refer to Table 2 for a comparison of cage sizes across countries.

Stocking density–effects: As adult mink are generally housed individually outside of breeding, whelping and lactation, this section relates largely to juveniles from weaning to pelting. Raising two or three pastel juvenile male mink kits in a small cage (76.2cm L x 30.5cm W x 45.7cm H [30in L x 12in W x 18in H]) resulted in slightly more pelt blemishes compared to mink raised individually in either a small or large cage (76.2cm L x 61.0cm W x 45.7cm H [30in L x 24in W x18in H]). No differences between the groups of two or three were described, suggesting that the space per animal is not necessarily the causal factor of these blemishes (Aulerich et al., 1991). Hyperactivity, fighting and high pitched vocalization when feed was delivered also occurred in groups of two or three, whereas no mention was made of this behaviour in single-housed mink (Aulerich et al., 1991). These observations became less frequent as the trial progressed and again, no differences were described between groups of two or three animals (Aulerich et al., 1991). Experimental groups of scanbrown or wild type mink that were raised in litter groups with their mother in inter-connected cages at a stocking density greater than two animals per cage were found to have significantly more damaged pelts than the control male-female pairs (de Jonge, 1996). Mink housed in groups of three in a small cage also had significantly lower weight gains during the first six weeks of the trial than either mink raised in pairs in a small cage or individually in a large or small cage (Aulerich et al., 1991).

A significant difference was noted in the neutrophil/lymphocyte ratio between mink raised individually in a large cage and mink raised in a group of two in a small cage. This difference was only seen during one of four testing periods, suggesting minimal welfare implications. No other significant differences were found in the neutrophil/lymphocyte ratios, eosinophil leukocyte counts, or serum cortisol concentrations between housing mink individually in small or large cages or groups of two or three in small cages (76.2cm L x 30.5cm W x 45.7cm H [30in L x 12in W x 18in H]) (Aulerich et al., 1991). Further information about grouping mink can be found in the *Social Aspects of Housing* section.

Table 1: Reference table for cage size measurements used in the reviewed literature.

Reference	Cage dimensions		Cage height		Floor area		Cage volume		Number of animals per cage	Space allotment per animal		Country where work was completed
	L*W (cm)§	L*W (inches)§	cm§	inches§	m^{2}§	ft^{2}§	m^{3}§	ft^{3}§		m^{2}§	ft^{2}§	
Jeppesen et al., 2000	90*30	35.5*11.8	45	17.7	0.27	2.91	0.12	4.29	2	0.14	1.46	Denmark
	3 (90*30)	3(35.5*11.8)	45	17.7	0.81	8.73	3(0.12)	3(4.29)	3 - 7	0.27- 0.12	2.91 - 1.25	
Hansen & Jeppesen, 2000	3(90*30)	3(35.5*11.8)	45	17.7	3(0.27)	3(2.91)	3(0.12)	3 (4.29)	--	--	--	Denmark
	3(120*65)	3(47.3*25.6)	75	30.0	3(0.78)	3(8.40)	3(0.59)	3(20.84)	--	--	--	
Lindberg et al., 2007	90*30 + 55*30	35.5*11.8 +21.7*11.8	45 +45	17.7 + 17.7	0.425	4.58	0.20	7.06	2 or 4	0.21 or 0.11	2.29 or 1.15	Sweden
	90*30	35.5*11.8	45	17.7	0.26	2.80	0.12	4.29	2	0.13	1.40	
Hansen et al., 1992	--	--	--	--	1.05	11.30	--	--	2	0.53	5.65	Denmark
	--	--	--	--	0.27	2.91	--	--	2	0.14	1.46	
	--	--	--	--	0.10	1.08	--	--	2	0.05	0.54	
Hansen et al., 2007	1 or 2 (90*30)	1 or 2 (35.5*11.8)	45	17.7	0.27 or 0.54	2.91 or 5.81	0.12 or 2(0.12)	4.29 or 2(4.29)	2	0.14 or 0.27	1.46 or 2.91	Denmark
Hansen et al., 1994	--	--	--	--	1.05	11.30	--	--	2	0.53	5.65	Denmark
	--	--	--	--	0.27	2.91	--	--	2	0.14	1.46	
	--	--	--	--	0.10	1.08	--	--	2	0.05	0.54	
Hansen & Damgaard, 1991	110*96	43.3*37.8	76	29.9	1.05	11.30	0.80	28.3	2	0.53	5.65	Denmark
	90*30	35.5*11.8	45	17.7	0.27	2.91	0.12	4.29	2	0.14	1.46	
	35*30	13.8*11.8	45	17.7	0.10	1.08	0.05	1.67	2	0.05	0.54	
Aulerich et al., 1991	76.2*61	30*24	45.7	18	0.47	5.0	0.21	7.5	1	0.47	5.0	United States
	76.2*30.5	30*12	45.7	18	0.23	2.5	0.11	3.75	1	0.23	2.5	
	76.2*30.5	30*12	45.7	18	0.23	2.5	0.11	3.75	2	0.12	1.25	
	76.2*30.5	30*12	45.7	18	0.23	2.5	0.11	3.75	3	0.08	0.83	

§ Shaded areas represent a calculated or unit converted number based on authors' original work

-- indicates data were not available from source paper

Table 2: Reference table for cage size recommendations from other countries.

Country	Standard Cage Size		Recommended Cage Size		Minimum Cage Size		Prohibited Cage Size		Reference
	cm	inches§	cm or m^2	in or $ft^{2§}$	cm , m^2 or $m^{3§}$	in, ft^2 or $ft^{3§}$	cm	in§	
Argentina	--	--	--	--	0.255m^2* 45cm H; additional 0.085m^2 for each animal above two	2.745ft^2* 17.7in H; additional 0.92ft^2 for each animal above two	Less than 30cm W and/or 70cm L	Less than 11.8in W and/or 27.6in L	Argentine Federation for the Commercialization and Industrialization of Fauna, 2008
Canada	--	--	--	--	Individual males or females with litters: 0.21m^2, including nest box and 32cm H; All other single housed mink: 0.12m^2 and 32cm H	Individual males or females with litters: 2.26ft^2, including nest box and 13in H; All other single housed mink: 1.29ft^2 and 13in H	--	--	Agriculture Canada, 1988
China	--	--	--	--	0.27m^2 total area; 0.18m^2 activity area	2.91ft^2 total area; 1.94 ft^2 activity area	--	--	Chinese State Forestry Administration, 2006
Denmark	--	--	--	--	All animals: 30cm W *70cm L* 45cm H; Single adult animals: 0.255m^2 or 0.0638 m^2/kg free area; Single adult with pup(s): 0.255m^2; Up to two weaned kits: 0.255m^2 or 0.0319m^2/kg; additional 0.085m^2 for each animal above two after weaning	All animals: 11.8in W *27.6in L* 17.7 in H; Single adult animals: 2.745ft^2 or 0.687ft^2/kg free area; Single adult with pup(s): 2.745ft^2; Up to two weaned kits: 2.745ft^2 or 0.343ft^2/kg; additional 0.92ft^2 for each animal above two after weaning	20cm W	7.9in W	European Commission, 2001; Denmark, 2006

Country	Standard Cage Size		Recommended Cage Size		Minimum Cage Size		Prohibited Cage Size		Reference
	cm	inches§	cm or m^2	in or ft^{2}§	cm , m^2 or m^3§	in, ft^2 or ft^3§	cm	in§	
(Europe) European Fur Breeders Association	--	--	--	--	$0.255m^2$* 45cm H; additional $0.085m^2$ for each animal above two	$2.745ft^2$* 17.7in H; additional $0.92ft^2$ for each animal above two	Less than 30cm W and/or 70cm L	Less than 11.8in W and/or 27.6in L	Standing Committee of the European Convention for the Protection of Animals kept for Farming Purposes, 1999
Italy	--	--	--	--	$0.255m^2$ * 45cm H	$2.745ft^2$ * 17.7in H	--	--	European Commission, 2001
Netherlands	--	--	--	--	85cm L* 30cm W* 45cm H; additional 850 cm^2 for each animal above two	33.5in L * 11.8in W * 17.7in H; additional $0.92ft^2$ for each animal above two	--	--	Netherlands, 2003
Norway	--	--	$0.27m^2$; additional $0.085m^2$ for each animal above two and 90cm depth	$2.91ft^2$; additional 0.92 ft^2 for each animal above two and 35.5in depth	$0.255m^2$ * 45cm H	$2.745ft^2$ * 17.7in H	20cm W or less	7.9in W or less	European Commission, 2001; Akre et al., 2008
Scandinavian Countries	90cm L* 30cm W* 45cm H	35.5in L * 11.8in W* 17.7in H	--	--	--	--	--	--	European Commission, 2001
United States	--	--	--	--	Breeder pens: $2.77m^3$; Furring pens: $2.45m^3$, with additional $0.58m^3$ for each animal above two	Breeder pens: $2.49ft^3$; Furring pens: $2.20ft^3$, with additional $0.52ft^3$ for each animal above two	--	--	Fur Commission USA, 2010

§ Shaded areas represent a unit converted number based on authors original work

--indicates data were not available from source paper

Outstanding issues that are not addressed in current scientific literature:

Does the nest box placement (e.g. inside or outside the cage), and its impact on "free" cage space, affect the welfare of the animals?

Are climbing cages, with an upper compartment giving the cage twice the height, beneficial to welfare?

What are the relative merits of the types (transparent [a double wall of mesh] or opaque [e.g. solid plastic or steel]) of cage side-walls, i.e. those between adjacent cages?

How different are the current housing and management practices between Canada and Europe? In general, how translational are the European results to Canadian farms?

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ENVIRONMENTAL ENRICHMENT

Conclusions:

1. **Mink will work to access environmental enrichments and those with exposure to enrichments perform fewer stereotypies and appear to have improved welfare.**
2. **Types of enrichment that have proven effective are those that can be manipulated or variable novel objects (others are habituated to or destroyed very rapidly).**
3. **Open water and running wheels have also been shown to be valued by mink. These attract sustained use with minimal habituation—benefits that may also be applicable to other enrichments. However, removing open water once it has been provided causes frustration—a problem that may apply to other enrichments as well.**

Mink are receptive to environmental enrichments, but for some forms of enrichment, the effectiveness seems to be reduced once the novelty wears off. Enrichments introduced after stereotypies have developed may not decrease or eliminate them and should be used to prevent their development. Mink choose objects that can be manipulated over fixed objects, and also use an elevated resting place. Mink will work hard to access running wheels.

They will also work for access to open water, although there is some variation in use. Removal of open water from mink with access to it induces stress responses, suggesting that once it is supplied, environmental enrichment may need to be maintained.

Behavioural effects of enrichments: Enrichments in cages, such as wire or plastic tubes, table-tennis balls and ropes resulted in less tail chewing, fewer stereotypies and reduced fecal corticoid metabolites in paired juvenile mink when compared to those kept in cages with no enrichments (Hansen et al., 2007; Hansen & Jeppesen, 2000; Hansen & Malmkvist, 2005). Wild type females kept individually during the winter months in enriched cages also performed significantly less stereotypies, were less active in their cage, had a lower frequency of tail-chewing and had lower concentrations of faecal corticoid metabolites than females kept individually in standard cages (Hansen et al., 2007). Half sapphire females that were kept in climbing cages after weaning performed significantly less stereotypies during the winter than those kept in standard cages, even though both types of cage were enriched with a net shelf, plastic cylinder and straw on the roof of the nest (Lidfors et al., 2010). Providing enrichments to black-cross adults after a stereotypic repertoire had already developed did not decrease or eliminate the level of stereotypies seen in one study (Axelsson et al., 2009), whereas in another study of the effects of enriching adult females, successful reduction was seen (Dallaire et al., 2011).

Enrichments as a refuge: When housed in pairs, wild type females used tubes (plastic and wire) attached to the ceiling of the cage more than males, and as such they are thought to act as a refuge for females from the bigger males (Hansen et al., 2007). Enrichments may also displace the attention of the male from the female to the items in the cage. Hansen et al. (2011) also found a higher use of the shelves by the females than by the males. As well, the attached tubes were used significantly more than loose tubes placed on the floor and the attached tubes were used especially at sunrise and up to expected feeding time when the mink were most active. After the males were removed at pelting, the individually housed females continued using the attached tubes and largely up to expected feeding time, indicating that fear of the male is not necessarily the main reason for the females' use of the attached tubes.

The use of shelves and cylinders as a refuge for the lactating dam has been investigated briefly as well. Jeppesen (2004) found that wild type dams' use of a wire shelf increased from week 4 to week 5 of lactation, but then decreased significantly over weeks 5, 6 and 7 of lactation from 13.2% to 8.5% to 4.8% respectively. The author suggests that the dam used the wire shelf as a place to withdraw from the kits, but as the kits' ability to enter the shelf in search of the dam increased, her ability to use the shelf to withdraw diminished. It was also found that lactating females prefer high-placed shelves more than low-placed shelves and that access to shelves reduced their stereotypic behaviour (Overgaard, 1998 as cited by Hansen & Møller, 2010). The inability of females to escape their kits in late lactation may cause an increase in stereotypies seen in the weeks before weaning, as well as increased aggression from the dam towards the kits (Jeppesen, 2004).

Type of enrichments preferred: When mink are not using a nest box, they prefer a resting place that is above floor level, such as a shelf (Hansen et al., 1994). Female black-cross colour type mink that were seven months old and individually housed in standard cages with a nest box used wire mesh shelves (10cm L x 30cm W [3.9in L x 11.8in W] placed 20cm [7.9in] above the cage floor) for resting, and also to look around outside the cage. Plastic cylinders placed loose on the cage floor were used significantly less than the wire shelves even though the cylinders were used for resting as well as active behaviours such as moving them around the cage (Axelsson et al., 2009). Plastic balls, also placed loose on the cage floor, were mainly carried into the nest box (Axelsson et al., 2009). Hansen et al. (2007) found that tubes and pull ropes were used extensively by paired juvenile mink, while table-tennis balls were not used. In this study, also one plastic and one wire tube were used, but both were attached to the cage ceiling, which prevented the mink from manipulating them to any extent but the mink in the enriched environment had permanent access to ropes to pull and chew.

Behavioural and physiological data were recorded following plastic balls being given to demi colour type and standard mink kept in male-female pairs in conventional Danish cages (Jeppesen & Falkenberg, 1990). No effect was found on the frequency of pelt-biting, eosinophil counts or cortisol concentration.

Animals with the balls spent less time in the nest and were more curious towards an observer and had a higher level of general activity. The level of stereotypies was significantly higher in females given playballs than females in the control group. The authors suggested that this increase was due to the overall increase in activity seen in animals provided with balls. The use of the playballs declined throughout the observation period and nearly ended on day 27, while the effects on general activity and curiosity of the mink remained.

Cooper and Mason (2000) used increasing door weights to determine the value of various enrichments to 6-month-old male and female wild type mink. The results indicated that mink value open water, hay for an alternate nest site and novel objects more than toys or platforms that were in turn valued more than an empty cage or loose wire cylinders.

Mason et al. (2001) also using increased door weights, further investigated the value of a variety of enrichments to mink as well as the impact of deprivation of certain enrichments. Mink valued open water the most highly, for example, they would push the heaviest weight to reach it. When the minks' access to the open water was denied, increases of urinary cortisol concentration occurred, which did not differ from the increase observed when the mink were deprived of food for 24 hours.

There was no significant increase in cortisol when access was blocked to an alternative nest site (deemed intermediate value) and an empty cage (deemed low value). Other work assessing strength of preference showed that scan brown mink would work hard (in terms of operant-responding, e.g. lever-pressing) to run in a running wheel (Hansen & Jensen, 2006). Mink also valued access to the running wheel and open water more than access to an empty water box. Mink also appear to require a longer period of time spent with access to a running wheel than with open water in order to reduce the motivation to use it (Hansen & Jensen, 2006). Access to open water as well as a running wheel did not affect the amount of wheel running performed by the mink, suggesting that the two types of enrichments do not substitute for each other (Hansen & Jensen, 2006). It appears that mink are highly motivated to perform some behaviours (such as swimming, head and foot dipping and wheel-running) that are impossible in a standard farm cage, and when able to do so they do not habituate – these activities stay rewarding for weeks or longer.

Although access to a running wheel prevents the development of stereotypies, there is some indication that wheel-running is another form of stereotypic behaviour (Hansen & Damgaard, 2009). Plasma cortisol concentration and behaviour (except stereotypy) did not differ between mink with and without access to a running wheel and females from a high stereotyping line had more turns in the wheel than those from a low stereotyping line (Hansen & Damgaard, 2009). More research is needed to assess the advantages (or lack thereof) of access to a running wheel.

The use of open water: As stated above, Mason et al. (2001) found that mink were highly motivated to access open water, and when deprived of it for 24 hours, showed urinary cortisol increases similar to those seen when deprived of food for 24 hours. Cooper & Mason (2000) and Mason et al. (2001) showed that mink will work for access to both open water and an empty compartment, but the empty compartment was not as valuable to them as compartments containing enrichments. Conversely, open water and an empty cage were not found to have a significantly different value to mink by Hansen and Jeppesen (2000). Great variation has been found with minks' use of water. In one study, mink housed in three standard cages (each 90cm L x 30cm W x 45cm H [35.5in L x 11.8in W x 17.7in H]) or three larger standard fox cages (120cm L x 65cm W x 70cm H [47.3in L x 25.6in W x 27.6in H]), with or without access to a water basin, were observed from nine to twelve months of age (Skovgaard et al., 1997). Results showed that 14 of 40 mink were not observed in the water at all, while one mink was observed in the water 11 times (Skovgaard et al., 1997). Mononen et al. (2008) found that 12 out of 18 scan glow colour type mink swam on all observation days, and all 18 mink were observed to swim on at least one day. Intra-individual consistency between the amount of time spent swimming and the number of swimming bouts from day to day, week to week, and year to year was also noted. Adult mink that had been provided with access to open water in the previous year swam more than adult mink that had not had access in the previous year and this difference decreased with time of exposure to the water bath (Mononen et al., 2008).

Research by the Mason lab, summarised by Vinke et al. (2008) indicated that all mink (n=58) used the open water when it was supplied without cost. This is significantly different than the results reported by Skovgaard et al. (1997), and may reflect genetic differences between the populations, and/or small differences in control housing or in the open water (with or without a sloping ramp into it for example) (Mason & Burn, 2011). Juveniles' use of open water has been correlated to their dams' use, which may also support the hypothesis that the motivation to swim has a genetic component (Mononen et al., 2008).

Mink with access to open water had a significantly higher level of activity than mink without access, but there was no significant difference in the level of stereotypies performed (Skovgaard et al., 1997). A long term experiment by Mononen et al. (2008) found that scan glow colour type mink with access to open water showed fewer stereotypies than those with access to a double cage but no open water, except when the experimental group was deprived of the open water.

A comprehensive review of the literature regarding the use of open water was prepared by Vinke et al. (2008). The authors concluded that the use of open water is most likely related to foraging behaviour. The absence of open water without prior experience has not consistently been found to alter the level of stereotypies, but the removal of open water from an animal with experience often causes short-term stress responses. It was also concluded that mink work hard for access to open water, but individuals differ in how much they value it. The authors also concluded that open water does not appear to be an innate need, but instead induces its own motivation via use and experience (a potential issue to consider for other enrichments as well).

Access to open water may potentially cause health problems in mink, as moisture and low temperatures are ideal for the development of pneumonia (Akre et al., 2008).

Outstanding issues that are not addressed in current scientific literature:

Are there economical, robust enrichments that sustain a mink's interest over weeks or months, for example through provision of food and water?

What are the effects of enrichment-removal? Is enriching juveniles, but not continuing this into adulthood worse than never enriching the animals at all?

Can enrichments induce competition or aggression between paired or group housed animals?

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NEST BOX REQUIREMENTS

Conclusions:

1. **The absence of a nest box greatly reduces the welfare and possibly the growth rate of mink.**
2. **An artificial nest or material that can be used to construct a nest improves kit growth and maternal responsiveness.**

Reduced welfare is indicated by all behavioural and physiological parameters in animals without access to a nest box. The use of a nest box with additional nesting material also improves the survival of kits in the neonatal period.

Behavioural and physiological effects of a nest box: Juvenile female pastel mink raised with access to a nest box performed fewer stereotypies from mid-September to late October than those without access to a nest box (Hansen et al., 1994). Mink placed in male-female pairs after weaning in cages without nest boxes have been found to have lower eosinophil counts, higher cortisol concentrations, and higher heterophil/lymphocyte ratios, indicating that these animals are subject to both chronic and acute stress more than those with nest boxes (Hansen & Damgaard, 1991; Hansen et al., 1992).

Production effects of a nest box: Paired juvenile pastel mink without nest boxes during the growing period had an increased feed intake that had no impact on weight development (Hansen et al., 1994). Hansen et al. (1992) similarly found that mink without nest boxes during the growing period consumed significantly more feed throughout the growth period and in this study, the mink without nest boxes also had a significantly lower growth rate than those with a nest box. The authors suggest that mink without a nest box have an increased energy requirement, in part for thermoregulation and in part due to the increase in stereotypies performed.

For whelping dams, a reduction in the size of the nest box volume helps to keep kits together when they are newborn and thus reduces kit chilling and mortality (Møller, 1990 cited by Malmkvist & Møller, 2010). If a nest box is not provided for a mother and young kits, kit mortality is increased and growth rate is lowered (European Commission, 2001). Mink housed in groups maximized the number of animals sleeping in one nest box, and larger nest boxes would likely be beneficial in such circumstances (de Jonge, 1996).

Nesting material: Nesting material used in the nest box may also be important to consider, as the number of total kits at birth and live kits at 3 to 4 weeks was also found to be significantly higher when the nesting material used was Easy Strø (a heat-treated, forage harvester wheat straw) when compared to wood shavings (Sønderup et al., 2009). Access to barley straw was seen to be beneficial for parturition progress as it is associated with reduced variation in inter-birth intervals during delivery (Malmkvist & Palme, 2008). An artificial nest made of plastic improved kit vitality and survival whether provided alone or with straw. This is thought to be due to the higher average and less variable temperature in nest boxes with an artificial nest. Kits raised in the nest boxes with an artificial nest and straw were on average heavier than kits raised with no additional nesting material (wood shavings only) (Malmkvist & Palme, 2008). Brown dams with an artificial nest and access to straw also retrieved their five-day-old kits placed away from the nest more quickly than dams with straw, an artificial nest, or wood shavings only. This kit retrieval test has been shown to relate to the level of kit loss, with dams that react slower tending to have higher kit loss (Malmkvist & Houbak, 2000).

Outstanding issues that are not addressed in current scientific literature:

Which nest box design do dams prefer, and which design optimises kit survival?

Is depriving juveniles from the nest box for 2-3 weeks at re-caging after weaning (to encourage the mink to defecate outside the nest box) stressful? Is there an alternative solution? A similar period of nest box deprivation is not practised on European farms, for example, and yet poor nest box hygiene is not reported as a major problem there.

How do the varieties of nest box types (e.g. "penthouse", "drop in", whelping/European-style nest boxes, open/covered top) compare in terms of adult welfare?

What is the optimal material for nest box construction; e.g. in terms of degree of insulation offered in the winter?

Do mink need bedding outside of the whelping period?

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2. SOCIAL ASPECTS OF HOUSING[1]

WEANING AGE

Conclusions:

1. **Weaning before 8 weeks of age causes a short-term increase of vocalizations and longer-term effects of tail biting and stereotypies, possibly indicating stress due to weaning. Early weaning may decrease reproductive performance if social isolation occurs at the same time. All responses to early weaning are exacerbated if the kits are housed individually at the time of weaning.**

2. **Weaning causes stress responses in the dam and weight loss is often seen following weaning.**

Kits can be weaned by removing the mother from the natal cage and keeping the litter intact for a length of time, or by removal of the kits from the natal cage, often in pairs (European Commission, 2001). Both early and late weaning can have negative impacts on the animals involved. Stocking density and cage size may be important factors in the problems with delayed weaning due to the increase in the size of the animals and therefore reduction of free space if the cage size remains the same.

Behavioural response to weaning: Many kits, regardless of age of weaning, vocalize in the first few days after weaning, and if they are housed next door to their mothers, may scratch at the barrier separating them from their mother (European Commission, 2001). Kits weaned into pairs or groups vocalized less in the first 15 hours after separation than kits weaned into isolation (Hansen et al., 1997).

Weaning age—effect on behaviour: Kits weaned at 6 weeks of age vocalise twice as much as those weaned at 8 to 10 weeks and spend more time in the nest box, a difference seen for the entire experimental period (Houbak & Jeppesen, 1987 as cited by the European Commission, 2001). Female wild type kits weaned at 7 weeks of age had a significantly higher incidence of tail-biting than those weaned at 11 weeks of age when measured at 6 months of age. When measured at 10 months of age, early-weaned kits of both sexes also tended to have more tail-biting (Mason, 1994). Bald tails (tails sucked or licked bald) were seen only at 10 months of age in kits weaned at 7 weeks of age (Mason, 1994). Over-grooming of the tail as described here is thought to be an indication of poor welfare.

Female kits weaned at 6 weeks and kept individually from 5 months of age in traditional cages showed significantly more stereotypies at 7 months of age than kits that were weaned at 8 or 10 weeks of age and then housed individually (Jeppesen et al., 2000). These differences were not apparent at 5 months of age, when the kits were still housed with siblings. At 9 months of age, the effect of weaning age on stereotypies declined. The level of activity or inactivity did not differ significantly with weaning age of the kits.

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[1] This section was formerly identified as *Animals in the Housing.*

Weaning age—effect on reproduction: In research conducted 5 decades ago, males weaned at 9 weeks were found to mate more successfully than those weaned at a younger age (Gilbert & Bailey, 1969).

In this study, both males and females weaned at 7 weeks or earlier responded abnormally during breeding, and no males weaned at 7 weeks or earlier bred successfully. Males weaned and raised singly from 6 weeks of age also had significantly fewer matings than males weaned at 6 weeks but maintained in groups (Bassett et al., 1959; Gilbert & Bailey, 1969). The negative impact of early weaning in combination with individual housing on mating success was also reported more recently by Hansen et al. (1997), where animals raised individually had poorer mating success than those raised in family housing or in pairs. Such drastic effects evidently do not apply to current mink on North American farms (where all are weaned before 7 weeks, and most mate fine), but these findings do raise the possibility that the incidence of males and females who do not mate could be reduced further by weaning later.

Later weaning in mink in Europe is generally combined with family housing, where the entire litter is maintained with the mother. The effects of this type of housing can be found in the following sub-section *Group/Family/Juvenile Housing*.

Impact of weaning on the dam: Weight loss was seen in standard type dams immediately following weaning, regardless of whether weaning occurred at 6 or 7 weeks (Sørensen et al., 2001). Insulin concentrations also declined after weaning, most probably due to low food consumption (Sørensen et al., 2001). These changes may be important in the appearance of the somewhat rare nursing sickness cases post-weaning (Sørensen et al., 2001).

Eosinophil counts were found to be significantly higher before weaning in dams that were weaned when the kits were 10 weeks old compared to those weaned when the kits were 6 or 8 weeks of age (Heller et al., 1988).

Outstanding issues that are not addressed in current scientific literature:

What are the relative health and welfare impacts on the kits of weaning at 6, 7 or 8 weeks, and does it depend on cage size and/or litter size?

How do current practices and genotypes of North American mink affect the short term and long term welfare with regard to weaning age?

Does weaning age affect defecation in the nest box?

What are the relative health and welfare impacts on the dam of weaning kits at 6, 7 or 8 weeks (e.g. stress, nursing sickness), and does it depend on cage size, litter size, her own body condition, and/or the opportunity to seek respite from the kits

What is the impact of leaving one kit with the dam?

Is the incidence of males and females who do not mate impacted by weaning age?

What is the impact of weaning age on "chewed kits" and severe injuries in kits and dams?

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GROUP/FAMILY/JUVENILE HOUSING

Conclusions:

1. **Individual housing of juvenile mink results in lower weight gain, increased stereotypies and possibly poorer mating success compared to pair housing.**
2. **Pair housing of juvenile mink helps to minimize the aggression between kits that is potentially seen in family and group housing.**
3. **In both family and group housing, increased aggression can lead to increased fur defects (wounds and bite marks).**
4. **Family and group housing reduces stereotypies and reduces feed intake, which in some cases also reduces growth.**
5. **Family housing causes an increase in fur and teat damage in the dam.**

Generally, mink kits are housed in mixed or same sex pairs of littermates after they are weaned from their mother. An alternative to this, which is used in some parts of Europe, is to house the entire litter together, with or without the dam. For the following section, family housing refers to housing the litter with the dam, group housing refers to housing juveniles together without the dam, and pair housing refers to two juvenile mink housed together (typically male/female pairs from the same litter unless otherwise specified).

While many studies indicate that increased aggression and food competition is present in group or family housed mink, this is not always seen. Possible differences that lead to these conflicting results may be mink temperaments, selection, stocking densities, the number of nest boxes, feeding levels and the nature of the control groups used (age of weaning for example) (European Commission, 2001). Nevertheless, it appears mink weaned at 6 weeks of age and raised alone have reduced welfare, whereas family housing generally does not show improved welfare above paired housing.

Housing systems—physical aspects: Groups are typically housed in vertically stacked cages. Groups in the stacked cages have been found to have a higher proportion of individuals with severe damages to the tail when compared to either the group housing in row cages or traditional cages (Pedersen et al., 2004). Stack housing is potentially more problematic than row housing, as there is only one feeding site and one nest box. This housing system in its current design is not recommended in the Netherlands (European Commission, 2001).

In family housing systems, nest boxes are generally provided in each cage, and as such, family groups have access to more than one nest box. Family groups have dirtier nest boxes than pairs, but usually do have one clean nest box (Hänninen et al., 2008b).

Single versus pair housing of kits: In terms of production, keeping mink individually allows easier control of feed rationing and individual weight gain as well as eliminating aggression between animals (Damgaard & Hansen, 1996). However pastel kits placed alone in September had a lower weight gain until pelting and were given slightly less feed than those maintained in male-female pairs (Møller, 1991). Housing kits individually can impact fur quality, where pastel mink kept in pairs were found to have a better pelt quality than individually housed mink (Damgaard & Hansen, 1996). Conversely, Møller (1991) found no quality differences of the pelt of pastel mink, despite the fact that animals housed alone had shorter pelts. Damage to the fur by chewing also did not vary between groups, in spite of pastel mink in pairs having more chewed fur on the back and that pair-housed animals were the only animals with fur chewed on their neck (Damgaard & Hansen, 1996). Alternatively, the frequency and degree of fur bites was found to be lower in pastel animals kept individually compared to those maintained in pairs (Møller, 1991). There was no difference in tail chewing between paired or individually housed pastel animals, showing that this type of damage is self-inflicted (Damgaard & Hansen, 1996; Møller, 1991).

In terms of welfare, as described in the *Weaning Age* section, kits weaned into isolation vocalize more than kits weaned into pairs or a group during the first 15 hours after separation (Hansen et al., 1997). Female kits kept individually from 5 months of age also showed significantly higher frequencies of stereotypies than animals kept under social housing conditions (pair housing or group housing) (Jeppesen et al., 2000). Likewise, kits housed individually from 6 weeks of age performed more stereotypies than those kept in pairs (paired mink were also weaned at 7-8 weeks) (Hansen et al., 1997) Kits raised in single animal housing were also found to be considerably more fearful of human contact, conspecifics and an unknown object than kits raised in pairs (Hansen et al., 1997). Mink raised in single housing in some instances cannot mate with other mink raised in single housing, whereas mink raised in family groups mate much more successfully (Hansen et al., 1997).

Single versus family housing of kits: It has been reported that kits raised in single animal cages weighed more and the males had longer pelts than those mink raised in family groups (Hansen et al., 1997). Conversely, Pedersen and Jeppesen (2001) stated that shorter pelts were found in single housed mink compared to family housed kits in both pastel and pearl type mink. Hansen et al. (1997) found no difference in fur quality between mink raised singly and those raised in family groups at live animal grading, but at pelt grading mink in the family housing had better pelt quality than single housed kits.

A highly significant difference in fur damage between kits raised individually and those raised in family groups was found by Hansen et al. (1998). Fur damage on the neck did not appear in kits raised individually and fur damage on the front part of the back was significantly higher in family groups than in kits raised individually. On the other hand, damage on the hind part of the back and on the tail was significantly higher in the single housed group than in the family group.

Pair versus family housing—effects on behaviour: Mink kept in pairs from weaning at 7-8 weeks or kits kept in family groups for approximately 4 months did not differ in the level of stereotypies (Hansen et al., 1997). Fur-chewing and tail-chewing incidences also did not differ between family housed and pair housed wild type mink kits (Hänninen et al., 2008b). Other studies with scanbrown and wild type mink found tail biting and tail sucking was strongly reduced in family housing compared to pair housing (2.6% versus 15%), but the family cages were also enriched, which may contribute to these results (discussed in this report in the section on *Physical Aspects of Housing*) (de Jonge, 1996). Both aggressive behaviour and social grooming were significantly lower in pair housed than family housed mink (Hansen et al., 1997). Furthermore, mink kits raised in a family group reacted significantly less fearfully to human contact than mink raised in male-female pairs while mink in the male-female pairs were less fearful than mink kept singly and mink in male-female pairs were also significantly less aware of the observer than mink in the other two groups (Hansen et al., 1997).

Pair versus family housing—effects on physiology: In one study, wild type kits in pair housing tended to have higher serum cortisol concentrations after adrenocorticotropic hormone (ACTH) administration than family housed kits, an effect that was stronger in female kit pairs than male kit pairs (Hänninen et al., 2008b). However, in a similar study Mononen et al. (2000) did not find significant differences in the serum cortisol concentration after ACTH administration between pair housed and family housed wild type kits.

Pair versus family housing—effects on production: Pelt quality is best when mink are kept in pairs (Hansen, 1998). Male wild type mink kits housed in family groups were found to have a lighter body weight in both September and at pelting in November when compared to males kept in male-female pairs (Hänninen et al., 2008b; Mononen et al., 2000). This difference was not found in females. Pelt length was not found to differ between groups of wild type mink (Hänninen et al., 2008b). In wild type and scanbrown kits, de Jonge (1996) found no difference in the size or quality of pelts in kits housed in family groups compared to male-female pairs, or in the growth rate of the kits when litter size was accounted for.

Fur defects (generally scars) occurred more often in family housed wild type and scanbrown males compared to pair housed males of the same colour types (de Jonge, 1996; Hänninen et al., 2008b; Mononen et al., 2000). Scars on the pelts were more prevalent in both male and female family housed wild type kits than in pair housed kits. Fur quality was found to be poorer in family housed female kits, but not male kits when compared to pair housed kits of the same sex (Mononen et al., 2000).

In September, feed intake was equal in both pair housed and family housed wild type mink (271 ± 3g versus 262 ± 7g feed per animal per day), while in November feed intake was lower in family housed animals compared to pair housed (209 ± 10g versus 248 ± 4g feed per animal per day) (Hänninen et al., 2008b). This difference may be due to the increased thermoregulatory benefits when the animals huddle in groups, but this is only one possible explanation.

Family housing—other effects on behaviour: Family housed animals chose mainly to be together, even if given the opportunity to avoid each other through access to several cages and nest boxes (de Jonge, 1996; Hänninen et al., 2008b). If given a choice between a small nest box that will fit just a single mink or a standard nest box, they will choose a standard nest box and sleep in groups (European Commission, 2001). Wild type mink also chose to spend more time together at lower temperatures, possibly for thermoregulatory benefits (Hänninen et al., 2008b). Mink spend less time together during weeks 10 to 13, which is about the age kits disperse in the wild.

Family housing—effect on the dam: Pastel and pearl type dams kept with their litters until September had fur damage more often than those kept individually (Pedersen & Jeppesen, 2001). Family housed dams also had fur damage at pelting in November on the neck, back and hips and tail with most of the damage occurring on the neck. No animals kept in single cages had fur damage, whereas 24% of the mink kept in family housing showed some fur damage to some part of the body (Pedersen & Jeppesen, 2001). Other results with wild type and scanbrown dams (de Jonge, 1996) revealed no difference in the physical condition or survival of dams kept in family groups in an enriched cage system compared to control dams kept in a traditional cage, either individually or with one young male.

A high percentage (82 to 93%) of family housed mink dams, of both pastel and pearl colour types, have been found to have swollen and/or bitten teats in September, whereas no teat damage of dams kept singly after weaning at 8 weeks was seen (Pedersen & Jeppesen, 2001). There was also a positive correlation found between the number of kits at weaning and the number of bitten teats on the dam, but not swollen teats.

Pearl and pastel type dams kept with their kits in family housing until the kits were 16 weeks of age had elevated cortisol concentrations when the kits were 16 weeks old compared to dams kept individually from 8 weeks of age (Pedersen & Jeppesen, 2001). This suggests that the dams were under more stress than those kept individually from 8 weeks. However, the handling of the mink prior to blood sampling often took longer for those animals kept in family housing; and because the handling was not recorded in the particular experiment, it cannot be ruled out as a confounding factor causing the observed differences.

A summary by Hansen (1998) of several studies surmised that females kept in groups are more stressed than if they are housed alone or in male-female pairs, whereas there is no indication that males are more stressed.

Pair versus group housing—effects on production: Pelt damage was compared between juvenile scanbrown mink housed in groups of 12 (6 males and 6 females) in large cages (80cm L x 195cm W x 40cm H [31.5in L x 76.8in W x 15.8in H]) equipped with shelves and cylinders and mink raised in pairs in standard cages (80cm L x 40cm W x 30cm H [31.5in L x 15.8in W x 11.8in H]) (Lindberg et al., 2005). This gave a space allowance of 0.13m^2 (1.40ft^2) per animal in the large group and 0.16m^2 (1.72ft^2) per animal in pairs in standard cages. A higher percentage of females (78% versus 48%), and a much higher percentage of males (76% versus 3%) that were group housed had some degree of pelt damage. Severe damage occurred more in group housed animals, particularly among females. Similar results were reported by Hänninen et al. (2008a), with juvenile wild type mink housed in groups of 6 (3 males and 3 females) tending to have more scars and more fur defects than those raised in male-female pairs. Groups of five pastel and pearl colour type kits raised in stacked cages (standard cage with a smaller cage on top) and litter groups in 3 connected traditional cages had more fur damage to the tail when compared to pair housed kits (Pedersen et al., 2004). The groups in row cages also had more individuals with severe damage to the tail when compared to paired systems. Animals had to be removed due to injuries or were fatally injured by cage mates in both the row system (11% of animals) and in the stacked system (9% of animals), whereas no animals were removed or fatally injured in the pair housed system.

Pair housed wild type animals had higher feed consumption than group housed wild type animals (Hänninen et al., 2008a). This likely relates to the heavier body weights seen in pair housed animals at pelting (Hänninen et al., 2008a). Pair housed males also tended to have a higher body mass in research by Lindberg et al. (2005), while a larger individual variation in body mass was seen in group housed males.

Pair versus group housing—effects on behaviour: Stereotypies occurred significantly more frequently in pair housed juveniles in November as compared to group housed (3 males and 3 females) animals. Pastel and pearl type kits kept in groups of five in a stacked cage system showed a higher frequency of surveillance, exploration and social interactions (agonistic behaviours in particular) and a lower frequency of sleeping than either kits housed in male-female pairs or in a row of three connected cages (Pedersen et al., 2004). The frequency of stereotypies, self-grooming and play did not differ among the groups. Neck biting and being neck bitten was rarely seen in the animals raised in stacked cages, and was seen more often in the group housed kits kept in a row of three connected cages than in traditional pair kept kits.

Outstanding issues that are not addressed in current scientific literature:

What is the impact of the different ways to pair house kits for the growing period (male-female, same sex and kits from the same or different litters)?

Should cage size vary for male versus female kits, since males end up with nearly twice the body weight?

Is splitting kits into singles in September “good” or “bad” for welfare?

What is the cause of, and how can “kits who chew kits” be prevented?

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3. NUTRITION CONCERNS

MANAGEMENT TO MAINTAIN IDEAL BODY CONDITION

Conclusions:

1. **Energy and protein requirements vary with the stage of production (e.g. lactation, growing or maintenance). Feeding practices should be adjusted in order to prevent over-conditioning and under-conditioning, especially when considering breeding animals.**

2. **Breeding animals have the highest welfare and productivity when they are maintained at an 'ideal' body condition score. Short term feed restriction is sufficient to realize the reproductive benefits of flushing.**

3. **Chronic feed restriction (e.g. over winter) has long term negative effects on behaviour, health and welfare of breeding animals. Selecting new breeders in August/September instead of November/December and adjusting their feed accordingly prevents them from being over-conditioned, which in turn removes the need to severely restrict their feed over winter.**

4. **Proper nutritional and body condition management will help to prevent or manage metabolic diseases such as nursing sickness, fatty liver and urolithiasis.**

5. **If melatonin implants are used, feed requirements are likely to increase.**

Proper body condition is important for the health and welfare of mink. Managing the body condition of mink requires changing the feeding strategy for animals in different stages of production. Mink are seasonal breeders and show great fluctuations in body weight in response to changes in the plane of nutrition (Rouvinen-Watt et al., 2005) as well as hormonal status (Mustonen et al., 2000). Body weights (and body fat deposits) are usually the highest in both males and females during late fall-early winter and the lowest during the summer months. These natural fluctuations in body weight, as well as varying demands (such as lactation and thermoregulation) during the production cycle make continuous monitoring of body condition an essential management tool (see Table 3 for body condition scores). Proper nutritional management with consideration of body condition will help to prevent over-conditioning and under-conditioning and reduce disorders such as nursing sickness and fatty liver syndrome.

Animals require nutrients for essential processes to maintain body weight and body function. Metabolizable energy is required to fuel metabolic processes (Rouvinen-Watt et al., 2005). The daily metabolizable energy requirement will vary according to the production cycle and environmental factors. Larger animals require more energy than small animals and animals that eat more require more energy to process that food. Animals that are more active, including those that perform stereotypies, also require more energy (Rouvinen-Watt et al., 2005). Feed restriction can trigger stereotypic behaviour, and a positive feedback cycle of unmet energy needs develops. Ambient temperature affects the amount of energy required to maintain body temperature with an additional 4 kcal per day required for each one degree drop in ambient temperature below 20°C (Rouvinen-Watt et al., 2005).

Protein must also be provided to replace essential compounds and support cellular regeneration (Rouvinen-Watt et al., 2005). Protein can be included in the diet at a minimum of 45% of the metabolizable energy and carbohydrates can be included up to 15% of the metabolizable energy in the winter and reproductive period without negative consequences on litter size or kit or female weights (Hejlesen & Clausen, 2000). Feed containing only 29% of the metabolizable energy from protein during the winter period appears to elevate the incidence of greasy kits in the late reproduction period.

Melatonin use: Melatonin has the potential to induce the growth of winter pelage in mink earlier in the season. Melatonin implants induced the moult of the summer pelage and growth of the winter pelage in adult standard dark female mink 6 weeks earlier than in control animals (Rose et al., 1984). These changes in fur growth are accompanied by changes in body weight and feed intake. Melatonin has this effect through induction of changes in the metabolism of lipids and carbohydrates that are necessary for the animals' survival during the winter (Nieminen et al., 2001).

Female mink kits implanted with melatonin in late July were significantly heavier than female controls in early September, while their weights were not significantly different in late September and October (Mustonen et al., 2000; Nieminen et al., 2001). Male kits implanted with melatonin were significantly heavier than male controls throughout the experimental period. Females implanted with melatonin had a significantly lower feed intake than controls in September, whereas implanted males had a significantly higher feed intake in early September. No difference was found in the feed intake of the males after September. These observations indicate that feed allowance should be increased in late summer and early fall in melatonin implanted mink to support the different growth pattern of these animals.

Feeding Strategies: As juvenile mink are generally pelted in November and fed ad libitum until then, certain feeding practices relate only to breeding animals. One of the biggest challenges faced on farms relative to managing body condition of breeding animals is over-conditioning. Over-conditioning often occurs in primiparious animals because breeder selection is done very close to pelting time, so the animals are being fed to produce a large size pelt. Mink selected for breeding at this time are typically over-conditioned for breeding purposes and must be slimmed down to maximize reproduction. Multiparous animals can also become over-conditioned during the summer/fall period if they are fed ad libitum. Energy intake can be reduced in late summer and early fall to prevent this over-conditioning by using a conditioning diet or by restricting energy intake.

Conditioning diet: A conditioning diet is ideally used to keep adult (multiparous) mink in proper body condition to ensure they are in optimal health at breeding. In conditioning diets, protein levels should be kept low and the amount of metabolizable energy coming from fat should be minimized to prevent over-conditioning (Rouvinen-Watt et al., 2005). The level of carbohydrates should be high, and a portion should come from digestible fibre sources to increase the "gut fill" and decrease stereotypies (Rouvinen-Watt et al., 2005).

During the conditioning period, the risk of metabolic and nutritional problems is low and a wide variety of ingredients can be included in diet. Cleanup of excess freezer inventory is not recommended as vitamins may be depleted and the levels of oxidized fats may be increased, which can increase metabolic stress on the mink (Rouvinen-Watt et al., 2005). Furring diets should also not be used during the conditioning period for adult breeders, as high levels of fat in these diets can cause over-conditioning and there may be insufficient levels of vitamins and minerals present (Rouvinen-Watt et al., 2005). Mink that are in good body condition should be fed levels that will supply adequate metabolizable energy to maintain that condition considering weather conditions.

Feed restriction: Feed is often restricted to slim down breeding females in preparation for flushing and mating in order to produce the maximum number of healthy kits. This is most often practiced with juveniles that were previously fed ad libitum for maximum pelt size. They are selected as breeders in November, and therefore are over-conditioned for reproduction. Feed energy intake is restricted to slim down over-conditioned mink by requiring them to use some of their body fat to supply energy for maintenance. It is important that mink are not underfed; body condition must be monitored and feeding levels increased if the animals are becoming thin, especially in cold weather and as the breeding season approaches (Rouvinen-Watt et al., 2005).

In order to minimize restricted feeding practices, an initial selection of juvenile mink to be retained for breeding should be made in late August or early September in order to allow conditioning of these breeders to begin. This helps prevent breeders from becoming too fat and eliminates the need to slim down animals that have put on excess fat (Rouvinen-Watt et al., 2005). Danish research has shown that breeder females that are excessively fat in November require very restrictive feeding in order to achieve ideal body condition at breeding time (February) (Clausen et al., 2007). These females also easily regained their previous heavy body weight and were difficult to maintain in ideal body condition. Excessive weight gain of breeders can be prevented by moderate dietary restriction during the autumnal body fat accumulation (Boudreau et al., 2011). Standard black females that were maintained in ideal body condition scores by about 20% diet restriction (moderate diet restriction [MDR]) from September through December gave birth to and weaned larger litters than their control sisters that were allowed to gain maximum body weight during the fall. Moderate maternal diet restriction during the fall also improved the viability of mink kits and significantly increased litter weights (Balderston & Rouvinen-Watt, 2011). The heavier litter weights were due to the decreased kit mortality in the MDR group, while individual kit growth did not differ.

Effects of restricted feeding—activity level: Primiparous brown breeding females fed a restricted diet from November to February in order to attain a weight loss of 25% were significantly more active both before and after feeding in February and March than females fed ad libitum (Houbak & Møller, 2000). Females that were active in at least one of six observations also had an estimated weight loss of 66g body weight more than females that were not observed to be active. In other results, no significant difference was found in activity levels between restrictively fed and ad libitum fed scanblack and scanbrown breeding females on January 9th, but from January 23rd to February 21st, restrictively fed animals had significantly higher levels of activity (Børsting et al., 1998). It is likely that the restricted dietary allowance increases feeding motivation of the mink, which in turn results in increased locomotor activity, most typically manifested as stereotypic behaviour. When reducing feed (energy) allowance, this increase in physical activity should be accounted for as it may accelerate body weight loss and lead to under-conditioned animals, especially during cold weather.

Mink fed a restricted diet for 10 to 15 weeks adapt their behaviour patterns to feed availability (Hansen & Møller, 2008). Activity is reduced in the morning hours, when feed is generally not available and mink increase their activity up to feeding time (Hansen & Møller, 2008). Conversely, mink which are fed ad libitum, adapt their activity to the sunrise as well as to the time of feeding (Hansen & Møller, 2008). Activity levels in the hour of feeding are high in all types of feeding programs, but when feeding was postponed, only the mink whose feed allowance was restricted increased their activity prior to the expected feeding time (Hansen & Møller, 2008). These results suggest that mink fed restrictively synchronize their behaviour to the expected feeding time whereas mink fed ad libitum may be stimulated by the actual feeding procedure.

Effects of restricted feeding—stereotypies: Restrictive feeding (feeding levels reduced from 150g/1140kJ to 100g/760kJ) increased the level of both normal activity and stereotypies in adult female mink that had been previously classified as either low stereotyping or high stereotyping (Bildsøe et al., 1991). After three weeks of being fed a full diet, normal activity returned to the previous levels, while the increased level of stereotypies remained. Børsting et al. (1998) found that on February 6th and 21st the frequency of stereotypies had increased compared to stereotypy frequency in January in restrictively fed scanblack and scanbrown animals, whereas in animals fed ad libitum, the frequency stayed the same. Significantly fewer wild type females (27% versus 53%) showed stereotypies when fed either a conventional diet or a diet with high barley content (lower fat and protein and higher carbohydrate content) ad libitum than females fed a restricted diet (Damgaard et al., 2004).

Significantly more brown females fed restrictively performed stereotypies after feeding in January than those fed a near ad libitum amount (Houbak & Møller, 2000). In addition, restrictively fed wild type females showed significantly higher levels of stereotypies before feeding compared to after feeding, whereas no significant difference was seen in the amount performed before or after feeding in animals fed ad libitum (Damgaard et al., 2004). When all groups were fed restrictively, the level of stereotypies was significantly higher before feeding and when all groups were fed ad libitum for nearly one month, no difference in the level of stereotypies before and after feeding was seen.

Mink fed a diet with increased barley content (lower fat and protein and higher carbohydrate content) lost weight over the winter period, but this was not accompanied with an increase in stereotypies. Decreasing the energy content of the diet without reducing the amount of feed therefore seems to be a way to regulate body weight of female mink without increasing the level of stereotypies (Damgaard et al., 2004). The volume of feed eaten appears to be important in controlling feelings of satiety and feeding motivation in the mink.

Females that were observed performing stereotypies in at least one of six observations also had an estimated weight loss of 147g more than those not performing stereotypies from November to February (Houbak & Møller, 2000). This weight loss is likely due to the energy spent on increased locomotor activity.

Effects of restricted feeding—production: There was no significant difference in pre-weaning body weight of kits whelped by scanblack and scanbrown dams fed restrictively (approximately 20% less) from mid-December until the end of January compared to kits whelped by dams fed ad libitum during this period (Børsting et al., 1998). Litter size (as measured the day after parturition and throughout lactation) and the number of stillborn kits were not affected by feeding regime. There was a significantly higher percentage of restrictively fed scanblack females that were barren compared to ad libitum fed females, leading to a lower number of kits per mated female in restrictively fed animals (Børsting et al., 1998). In scanbrown females, the percentage of barren females did not differ significantly between the two groups. Additional information on the reproductive implications of restricted feeding can be seen below.

Severe feed restriction can increase mortality rates due to starvation from over-slimming. Crude mortality rates during the winter have been calculated at 0.17% (Møller, 2011). An examination of all dead mink on six Danish mink farms involving almost 10,000 females and over 50,000 kits indicated that 20 breeder animals died during the winter, mainly from enteritis, respiratory disease and starvation (Dietz et al., 2000 as cited by Møller, 2011). Winter mortality rates from feed deprivation and starvation have not been investigated in North America.

Effects of restricted feeding—incidence of sticky kits: 'Sticky' or 'wet' kits is used to describe when kits develop a greasy, sticky exudate on the skin, particularly the neck, tail and claws as well as a red and swollen perianal region (Clausen & Dietz, 2004). Yellowish-white diarrhoea is common, as is mewing, distressed behaviour. While the etiology of sticky kits is not completely understood, feed restriction of the dam is known to affect the incidence. The proportion of sticky kits was found to be significantly higher when the dam was fed restrictively to attain a 25% reduction in body weight from November to February (Møller & Chriél, 2000). There was also an increased incidence of sticky kits when feed allowance was restricted in late gestation.

Reproductive implications relating to body condition score and feeding strategy: Both over- and under-conditioning will reduce breeding success. The best breeding performance occurs when mink are in "ideal" body condition (see Table 3 for body condition scores) (Rouvinen-Watt et al., 2005). A short period of restricted feeding (14 days) followed by ad libitum feeding (5 days) is sufficient to obtain the positive reproductive effects of flushing if mink are not over-conditioned (Møller, 1999 as cited by Akre et al., 2008). In general, body condition scores should be 2 in late February, 3 in late March and 4 in late April in order to attain the best whelping results without getting the dams too thin during the winter or too fat before whelping (Danish Agricultural Advisory Centre, 2008). Females with a body condition score of 2 in late February have been found to have the most living kits (Bækgaard et al., 2008). Females with a body condition score of 3 in late March also had significantly more kits alive after 3 days than females that had a body condition score of 4 or 5. Females scoring a 4 in late April had the most living kits on average, and females with a body condition score of 5 in late April had significantly more dead kits per litter than females scoring a 3 or 4 (Bækgaard et al., 2008). Females that had a lower body condition score in late April than late March also had significantly fewer living kits when compared to females maintaining or increasing body condition (Bækgaard et al., 2008).

It has also been found that brown females fed an increased energy allowance during the implantation period (March 21 to April 10) had significantly larger litter sizes than females fed at maintenance feed levels, whereas black mink showed no significant differences in litter sizes when fed at the two levels of energy allowance (Møller, 2008). Increasing the feed allowance during the prenatal period (April 11 to April 30) also decreased the number of barren females and increased the litter size at birth.

Males should also be in ideal condition at the beginning of the breeding season and should be fed a high quality diet. Body condition should be monitored closely to ensure the males do not lose weight. Males that are not pelted after breeding should then be returned to maintenance feeding levels (Rouvinen-Watt et al., 2005).

Body condition of the female also impacts kit mortality. Litter size at weaning can be improved by selection, through both litter size and kit survival. Unfortunately, the heritability is low and it is unfavourably correlated to body weight (Hansen & Berg, 2008). Continuous selection for high body weight at live grading may lead to a decrease in the number of kits at weaning due to reduced litter sizes and reduced kit survival (Hansen & Berg, 2008). Correlations between the number of live born kits and the body condition of females has been reported, with females scored as obese or very obese having more dead kits than those scored as heavy or ideal (Bækgaard et al., 2007). This correlation was found when the body condition score of the female was measured in March, April and at parturition, but not in January and February. Furthermore, wild type, pearl and white females that had an increase of two or more body condition scores from February to March had fewer live born kits and more dead kits in their litters (Bækgaard et al., 2007). However, being too slim is not good for breeding outcomes either. Females that had a lower body condition score in April than in March also had significantly fewer live born kits than females that maintained or increased their body condition. In addition, if females lost two or more condition scores from March to April, they had a significantly higher number of dead kits (Bækgaard et al., 2007). It is evident that a moderate increase in body condition during gestation is desirable for optimum reproduction, whereas marked increases or decreases in condition may be detrimental to litter size and kit viability.

Diseases and disorders related to feed, feeding strategy and body condition—nursing sickness: Nursing sickness is a complex metabolic syndrome associated with severe disturbances in the blood sugar and electrolyte balance (Hunter & Barker, 1996; Rouvinen-Watt, 2003). It is characterized by excessive breakdown of body tissue and dehydration to meet the demands of lactation. Nursing sickness typically occurs during late lactation or after weaning. Older females with large litters and the highest demand for nutrient mobilization for lactation are most at risk. While the precise cause is unknown, it has been thought that genetic, management, nutritional and environmental factors are involved in the occurrence of nursing sickness (Clausen et al., 1992). More recently, Rouvinen-Watt (2003) has proposed that the cause of nursing sickness may be the inability to maintain glucose homeostasis (i.e. acquired insulin resistance). As milk contains high levels of n-3 fatty acids, it is possible that as the demands of lactation increase, these fatty acids become deficient (Rouvinen-Watt, 2003). The deficiency of n-3 fatty acids may result in reduced insulin signaling and the occurrence of hyperglycemia (excessive blood sugar).

Symptoms of nursing sickness include decreased feed consumption, weight loss, lethargy, emaciation and dehydration. Animals that die of nursing sickness are consistently found to have marked dehydration (Schneider et al., 1992). This may be due to reduced kidney function as a result of extremely high blood glucose concentration (Rouvinen-Watt, 2003). Females are usually affected around day 42 of lactation, with death occurring around day 46 (Rouvinen-Watt et al., 2005; Schneider et al., 1992). Nursing sickness is more common in older females, females with large litters, and females that have lost greater than 30% of their body weight during lactation. Females that had mild to severe cases of nursing sickness lost significantly more weight (35.2%) during lactation when compared to healthy females that lost 22.7% of body weight (Wamberg et al., 1992).

Mink dams with abnormalities in regulation of blood sugar early in the breeding season were more likely to have reproductive failure and become ill, while females that successfully raised large litters were more likely to develop hyperglycemia only during pregnancy and lactation (Hynes & Rouvinen-Watt, 2007). Disruptions in glucose homeostasis may be occurring throughout the reproductive cycle of the mink, and are most likely influenced by factors such as genetics, management and feeding practices (Hynes & Rouvinen-Watt, 2007). Females that are thin or obese during gestation are less able to adequately regulate their blood sugar levels (Hynes & Rouvinen-Watt, 2007). A diet with high-quality polyunsaturated fatty acids and a high carbohydrate level appears to help the lactating dam maintain normal blood glucose concentrations (Hynes & Rouvinen-Watt, 2007). The incidence and severity of nursing sickness can be reduced through proper nutritional management of the breeding and lactating female. Female breeders should be maintained at a moderate body condition throughout the year and obesity and emaciation should be avoided to reduce the likelihood of nursing sickness (Rouvinen-Watt, 2003).

A lack of sodium has traditionally been thought to be involved in the development of nursing sickness as it is common for affected animals to have extremely low urinary sodium concentrations (Clausen et al., 1996). Hansen et al. (1996) used loop diuretics to conclude that salt deficiency is a consequence and not a cause of nursing sickness. Extra sodium in the diet can reduce nursing sickness by 33%, possibly by increasing the water intake of the mink and thereby improving kidney function (Rouvinen-Watt, 2003). Increased dietary salt must therefore be accompanied by ad libitum water and/or increased dietary water (European Commission, 2001). Dietary supplementation of 0.42-0.50g NaCl per 100 kcal is recommended (Clausen & Damgaard, 2002). Levels exceeding this can be harmful to young kits, as their capacity to concentrate urine and excrete sodium is limited.

Diseases and disorders related to feed, feeding strategy and body condition—fatty liver: Fatty liver is a condition that occurs when excess fat accumulates in the liver or when something interferes with the liver's ability to metabolize fat (Rouvinen-Watt et al., 2005). During the production cycle, the risk of development of fatty liver may be elevated due to excessive fattening during the fall, excessive feed restriction prior to breeding, stress during pregnancy and mid-late lactation, and rapid mobilization of body fat reserves for milk production (Hunter & Barker, 1996; Rouvinen-Watt et al., 2005, 2010). Standard black mink fasted for as few as three days begin to lose weight and the fat content in the liver increases (Rouvinen-Watt et al., 2010). A rapid decrease of the proportion of n-3 polyunsaturated fatty acids in the liver is seen during food deprivation, which may trigger an inflammatory response in the liver and contribute to the progression of fatty liver disease (Rouvinen-Watt et al., 2010).

Fatty liver incidence increases if excess dietary energy is derived from fat, or if dietary fat of poor quality is fed (Rouvinen-Watt et al., 2005). If dietary protein is reduced to 20% of metabolizable energy and fat supplies 60% of the metabolizable energy, the incidence of fatty liver is also significantly increased (Damgaard et al., 1994 as cited by Rouvinen-Watt, 2000). Recommended levels of protein vary with stage of production: 30% of metabolizable energy coming from protein is required by growing/furring mink, 35% of metabolizable energy should be derived from protein during breeding and pregnancy, and 40% during lactation (Rouvinen-

Watt, 2005). Dietary protein fed at too low a level for the stage of production will hinder the liver's ability to mobilize fat (triglycerides) and pass it into the circulation in the form of very low density lipoprotein (VLDL) cholesterol (Rouvinen-Watt et al., 2010).

Diseases and disorders related to feed, feeding strategy and body condition—urolithiasis (urinary calculi): The normal pH range for mink's urine is 6.3-7.5, which makes it prone to struvite (ammonium-magnesium-phosphate) crystal formation (Rouvinen-Watt, 2000). The only sign of a problem may be sudden death of apparently healthy animals (Rouvinen-Watt et al., 2005). The stones may be present in the kidneys, bladder or urethra, and can cause irritation resulting in inflammation of these organs. If the urethra becomes blocked, the animal will not be able to pass urine and can die. Urolithiasis is most often seen in heavy, fast growing males after weaning. The most common cause of urolithiasis is infection of the urinary tract by urea-decomposing bacteria (Zellen, 1996). The bacteria may originate from the feed or other environmental sources, or they may be bacteria normally found in the urinary or intestinal tract (Zellen, 1996). Dietary protein levels in excess of the recommended amount for the level of production lead to an unnecessary increase in urea formation, which is involved in the formation of struvite stones (Rouvinen-Watt et al., 2005). Meat-based diets that are high in the sulphur-containing amino acids such as methionine help to lower the pH of the urine, which reduces the formation of struvite crystals. In comparison, plant-based proteins are alkaline and will increase the pH of the urine, increasing the risk of struvite stones. There is some indication that the addition of ingredients such as sodium chloride or ammonium chloride to the diet of mink helps to prevent the development of urinary calculi by lowering the pH of the urine and/or increasing water intake. For example, a daily addition of 0.35% ammonium chloride to the diet reduced the urinary pH of mink kits to around 6.0 (Clausen, 2001). Sodium chloride added at 0.68g/100kcal to the diet of male black mink kits from 10 to 12 weeks of age increased the water intake and urine production but also reduced the body weight gain (Clausen & Sandbøl, 2008). Risk of urolithiasis is also increased due to dehydration during hot weather in the summer, limited water availability during the winter, and the use of dry pelleted feeds (Zellen, 1996). Increased water consumption should be encouraged as this dilutes the urine and reduces the precipitation of minerals (i.e. formation of stones).

Table 3: Body condition scoring of mink using a five-point scale (Rouvinen-Watt & Armstrong, 2002).

Body Condition Score	Description
Score 1 Very thin	- The mink has an emaciated appearance with decreased muscle mass. - The animal has a thin neck and a clearly V-shaped body. - There is no body fat and the stomach is sunk in. - Shoulder and hip bones can be seen and the ribs are easily felt.
Score 2 Thin	- The mink has a thin neck and a V-shaped waistline. - There is no subcutaneous body fat layer. - The shoulder and hip bones and the ribs can be easily felt.
Score 3 Ideal	- The mink has a slender neck and a straight body shape. - There is a slight amount of subcutaneous body fat. - The shoulder and hip bones and the ribs can be easily felt.
Score 4 Heavy	- The mink has a thicker neck and a pear shaped body. - The ribs are difficult to feel. - The shoulder and hip bones are covered by a moderate fat layer. - An abdominal fat pad is present.
Score 5 Obese	- The mink has a thick neck with a slight brisket and a full body shape. - The ribs are very difficult to feel. - The shoulder and hip bones are covered by a moderate to thick fat layer. - A fat pad is present in the abdomen and the tail. - Fat deposits can be seen in the limbs and the face.

Outstanding issues that are not addressed in current scientific literature:

What is the mortality rate of breeding mink during the winter?

What is the best way to select breeders early and house/feed them accordingly without harming reproductive performance?

Does melatonin administration impact the welfare or behaviour of mink?

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4. EUTHANASIA

HUMANE METHODS OF EUTHANASIA

Conclusions:

1. **Carbon dioxide inhalation is considered a suitable method of euthanasia, yet mink find it aversive. If it is used, concentrations of 100% are effective.**

2. **Euthanasia by carbon monoxide in concentrations of 4% or greater is also acceptable and has been recommended because it causes mink to lose consciousness quickly. Carbon monoxide does have increased risks in terms of human safety.**

Animals raised for fur are generally removed from their cage and immediately euthanized on farm. Although handling (i.e. catching and restraint) causes stress, this can be minimized by euthanizing animals at or near their home cage (American Veterinary Medical Association [AVMA] 2007). The criterion for choice of method of euthanasia must be a rapid loss of consciousness with minimal discomfort to the animal (AVMA, 2007; Canadian Council on Animal Care [CCAC], 2010). Unconsciousness is essential because it indicates that the cerebral cortex is non-functional and therefore painful effects cannot be experienced (AVMA, 2007).

Euthanasia by inhalant agents: Euthanasia with inhalant agents takes some time because a certain concentration of the gas must be reached in the alveoli (AVMA, 2007). The suitability of the agent is dependent on the distress experienced between the time inhalation of the agent begins and the time the animal loses consciousness. Inhalant agents are generally not recommended for newborn animals, as they have high resistance to hypoxia (AVMA, 2007). Carbon monoxide is also difficult to detect by humans and other animals, hence the safety risks with using this gas are increased (CCAC, 1993).

Carbon dioxide (CO_2) at concentrations of 100% is considered to be the most acceptable gas for euthanasia of mink by the AVMA (2007), whereas the CCAC (2010) states that CO_2 is not acceptable for euthanasia of mink. CCAC (1993) stated that CO_2 is not effective in killing diving mammals that have adaptations for a relatively oxygen-free environment, and that 100% CO_2 is required to kill mink. Exposure to 100% CO_2 resulted in loss of consciousness in an average of 18.8±3.9 seconds and the total course of euthanasia using CO_2 lasted on average 152.9±10.4 seconds (Hansen et al., 1991). This rapid loss of consciousness suggests that although mink find CO_2 aversive (see below), concentrations of 100% are suitable for euthanasia.

Exposure to CO_2 concentration of ≥80% has been studied recently (Korhonen et al., 2011) and was also found to be effective at euthanizing mink. The average time to death was 4 to 6 minutes, but the time to loss of consciousness was not described (Korhonen et al., 2011). When 70% of CO_2 was used, pastel animals placed in a 60cm x 30cm x 35cm (23.6in x 11.8in x 13.8in) pre-filled box survived at least 15 minutes and lost consciousness significantly later than those exposed to 100% CO_2 (Hansen et al., 1991). It is therefore possible that concentrations of 80% CO_2 also delay the loss of consciousness significantly. If animals are first stunned by 70% CO_2, they should be killed by 100% CO_2 or by other means (AVMA, 2007). Animals euthanized with cylindrical CO_2 at 80% have been found to fall/lie down sooner than animals euthanized with either cylindrical CO or filtered exhaust CO, as well (Korhonen et al., 2011).

Although CO_2 is an accepted method of euthanasia, it is an aversive substance and mink will avoid contact with it if possible (Cooper et al., 1998). Wild type mink exposed to 80% CO_2 responded by withdrawing and coughing, and would not endure this contact in order to interact with a novel object. When the chamber was filled with air, the mink rapidly entered it and spent a large portion of the 10-minute test interacting with a novel object. Conversely, when the chamber was filled with 80% CO_2, none of the subjects reached the novel object and only one of eight mink tested entered the chamber before immediately retreating (Cooper et al., 1998).

Exposure to 100% CO_2 resulted in loss of consciousness significantly quicker than both 4% carbon monoxide (CO) and 100% nitrogen (N_2), which caused loss of consciousness at 64.2±14.3 and 76.4±37.9 seconds, respectively. The total course of euthanasia was 152.9±10.4 seconds for CO_2, 215.1±44.8 seconds for CO, and 134.1±43.8 seconds for N_2 (Hansen et al., 1991). As the standard deviations are quite large, the safety margin must be considerable in order to ensure death of all the animals before they are removed from the chamber. The authors suggest minimum times of 5 minutes for CO_2 and N_2 and 6.5 minutes for CO (Hansen et al., 1991). N_2 is considered to be the least suitable inhalant agent because the time to loss of consciousness is much longer compared to CO_2 and CO (Hansen et al., 1991).

While it has not been researched in mink, work in poultry suggests that employing a biphasic approach to stunning animals using low concentrations of gas (40% CO_2, 30% O_2, 30% N_2), followed by 80% CO_2 in air somewhat eliminates vigorous behavioural responses seen with anoxic controlled atmosphere (gas) stunning, while exacerbating respiratory responses (McKeegan et al., 2007). The authors argue that the respiratory discomfort seen with the biphasic approach, which is unpleasant, is preferable to vigorous wing flapping and potential associated injury that occurs while the birds are conscious during controlled atmosphere stunning.

Carbon monoxide at a concentration of 4% is also considered suitable as a method of euthanasia and in some countries it is recommended because consciousness is lost after a short period of exposure, and excitation does not occur (AVMA, 2007; European Commission, 2001). Results from Korhonen et al. (2011) suggest that 4 to 6% CO was effective in causing death of the animal within a reasonable time frame of 3 to 6 minutes. Carbon monoxide concentrations of 1.2-3% were too low, as mink either did not die or took a long time to die. Behaviours that were typically observed before death were restlessness, hyperventilation, incoordination of movements and recumbency (Korhonen et al., 2011).

Raj and Mason (1999) reported that wild type mink experiencing argon-induced hypoxia spent significantly less time in a reward chamber than those allowed access to the chamber with no argon. After leaving the argon atmosphere, the mink appeared to hyperventilate, but returned to the argon atmosphere repeatedly. Argon is an odourless, tasteless gas and does not itself appear to be aversive, yet prolonged exposure causes reduced blood oxygen levels. It is suggested that bradycardia resulting from exposure to argon would be similar to the bradycardia that occurs during diving (Raj & Mason, 1999). As mink are capable of detecting this hypoxic state, it is likely that gaseous methods of euthanasia do cause mink some level of distress. Handling the mink may also induce bradycardia, which may also affect the minks' response to hypoxia (Raj & Mason, 1999).

Source of gas: According to the AVMA (2007), compressed CO_2 gas in cylinders is the only recommended source because the inflow to the chamber can be precisely regulated. Studies in laboratory rodents have shown that the best practice is to first place the animals into the chamber and then introduce 100% CO_2, although both pre-fill and rising concentrations can cause distress and pain (CCAC, 2010; Hawkins et al., 2006).

In Finland, mink are usually killed with exhaust CO produced by a feeding machine or a commercial killing machine (e.g. 5.5 HP engine Jasopels, Denmark) (Korhonen, 2010). The CO concentration has been reported at 6.5% to 9.4% in the feeding machine and 2.4% to 6.8% in the killing machine. Korhonen et al. (2011) suggests that both engine-produced gases and gases compressed in cylinders can be used to effectively kill mink. However, carbon monoxide from a gasoline combustion engine can produce irritation and discomfort due to impurities that are contained in the gas, therefore the use of unfiltered gas is inadvisable (CCAC, 1993). Regulations in the European Union, which are to be implemented in 2013, impose control on the quality of gas used for euthanasia and require it to be suitably cooled, filtered and free from irritating components (Korhonen, 2010).

Confirmation of death: The death of each animal must be confirmed, generally through the cessation of vital signs. An animal can be considered dead when cardiac and respiratory movements as well as reflex movements have ceased (CCAC, 2010).

Outstanding issues that are not addressed in current scientific literature:

What is the best practice regarding filling the chamber with CO for euthanasia (pre-fill or increasing concentration)?

What is the length of time until animals lose consciousness on farm and how is this affected by box size and number of animals in the box?

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