Applied Animal Behaviour Science 158 (2014) 76–85

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

Bite marks in mink—Induced experimentally and as reflection of aggressive encounters between mink

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ARTICLE INFO

Article history:
Accepted 13 June 2014
Available online 21 June 2014

Keywords:
Welfare indicator
Group housing
Aggression
Mink

ABSTRACT

For many years, bite marks have been used as an indicator for aggression in mink production systems. However, the validity of bite marks as indicator of aggression has recently been questioned. We therefore tested the following hypotheses: (1) experimentally applied pressure to, or penetration of, the pelt during the growth phase of the winter coat will produce marks that can be recognized as bite marks at pelting, (2) bite marks applied experimentally by use of an artificial tooth or occurring due to social/aggressive interactions (bites) between mink are only visible if pressure/bite on the mink skin is applied during the active growth phase of the winter coat prior to time when matured, (3) bite marks will be easier to detect on dark mink than on mink with light coloured fur and (4) the number of bite marks accumulates and increases with time mink are housed in groups. The experimental mink were of the brown colour type ($N = 140$) and the white colour type ($N = 60$). Twenty brown and 20 white mink (housed in pairs since weaning) were housed individually at the age of 16 weeks. Every second week (at the age of 20, 22, 24, 25 and 28 weeks), four brown and four white mink were subjected to pressure by an artificial tooth. Before pressure was applied, each mink was anaesthetized and pain treated.

In order to investigate when bite marks from cage mates are inflicted and to what extend they accumulate over time, 120 brown and 40 white juvenile mink were placed in groups of four in climbing cages after weaning. Every second week (at the age of 20, 22, 24, 26 and 28 weeks) group housed mink were moved to single housing in standard cages in order to prevent further bites from cage mates.

At the age of 29 weeks, all mink were killed individually by CO_2 and the pelts were examined for bite marks.

The results showed that: (1) experimentally applied pressure on the skin can be recognized as bite marks in brown mink at pelting, (2) bite marks are easier to detect on brown mink than on white coloured mink ($P < 0.001$), (3) bite marks applied experimentally by use of an artificial tooth or occurring due to social/aggressive interactions (bites) between mink are only visible if pressure/bite on the mink skin is applied during the active growth phase of the winter coat prior to time when matured, and (4) the longer time mink are kept in groups, the more bite marks can be observed on the skin ($P < 0.001$).

The study has shown that bite marks are a valid and useful welfare indicator for quantifying the social tolerance of dark mink and consequently the risk for serious bite wounds.

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http://dx.doi.org/10.1016/j.applanim.2014.06.008
0168-1591/

1. Introduction

Group housing was approved by the European Convention, 1999 for perceived welfare reasons (CoE, 1999) and included in the Danish legislation in 2006. Since then, group housing of mink has become increasingly common because it increases the stocking density and thereby is more economic.

Group housing is, however, in conflict with the solitary and territorial lifestyle of mink, where the male territory may overlap that of several females in the wild (Dunstone, 1993). Therefore, adult mink have been housed singly and juveniles (less than 7 months) have in general been housed in male + female pairs, since the American mink (*Neovison vison*) was introduced in Scandinavia in the 1920s. The social tolerance between sexes still seems to be greater than within sex in group housed mink (Berg and Møller, 2010; Alemu et al., 2014). Therefore, group housing can be defined as housing more than one mink of the same sex in the same cage.

Aggression increases with the age of the kits which causes dispersal of the litter and establishment of individual territories (Dunstone, 1993). Mink has a strict annual production cycle entrained by the gradual shifts in day length and especially the vernal and autumn equinox. Decreasing day length initiates the growth and maturation of a heavy dense winter coat beginning around the autumn equinox and ends early November (Basset and Llewellyn, 1949; Blomstedt, 1989). The autumn equinox also seems to be the latest time of dispersal of juveniles (Dunstone, 1993). It can therefore be expected that the number of bite marks, wounds and other signs of aggression increase in group housed mink after the autumn equinox. This also seems to be the case in practice, based on mortality rate and treatment records, although no data on this seems to have been published yet.

For many years, bite marks have been used as an indicator of aggression in mink production systems (Pesso, 1968; Hansen and Damgaard, 1991; Damgaard and Hansen, 1996; Hansen et al., 1997; Mononen et al., 2000; Pedersen and Jeppesen, 2001; Hansen and Houbak, 2005; Hänninen et al., 2008a,b; Hansen and Jeppesen, 2008; Berg and Møller, 2010; Hansen and Møller, 2012). Bite marks, defined as dark spots on the leather side of the matured mink pelt has been used for a number of reasons: (1) bite marks are almost never seen in singly housed mink (Damgaard and Hansen, 1996; Pedersen and Jeppesen, 2001) and less frequent in pairwise than in group housed mink (Hansen and Damgaard, 1991), (2) bite marks correlate to the level of aggression and wounds observed (Hansen and Møller, 2012) and (3) bite marks are often seen in high numbers at the base of the tail (Photo 1) where severe bite wounds are also most frequent (Møller and Hansen, 2014 (Personal communication/results under publication)). Therefore, despite the widespread use of bite marks as indicator of aggression, it has neither been tested if bite marks can actually be caused by a bite from a cage mate, nor under which conditions bite marks develop.

The validity of bite marks as indicators of aggression has recently been questioned by van Willingen et al. (2012), based on a lack of scar tissue or other traces of penetration of the skin in connection with the bite mark. Based on this, it was suggested that bite marks should instead be called blue spots, and that they could be caused by a spot-wise delay of maturation of hair follicles, in the priming of the winter coat. However, no support for a hypothesis of spot-wise delay of maturation of hair follicles was presented and no other causing agent for such a delay than bites was suggested. Nevertheless, the paper accentuated the need for a clarification of the causing agent of bite marks, especially in relation to the use of bite marks as an indicator of aggression.

Bite marks cannot be seen on the fur side of the pelt but as dark (black, brown or grey) spots on the bright leather side (inside) of the matured mink pelt. Bite marks can be recorded at pelting, after fleshing, when the leather side of the pelt has been scrapped for fat and subcutaneous tissue because the dark spots are in contrast to the bright leather side of the skin. The colours of bite marks do have some similarity with immature pelts, as suggested by van Willingen et al. (2012), although immature pelts involve either the neck area or the whole pelt and do not occur in spots.

As bite marks are typically observed in dark mink, it is reasonable to assume that bite marks are accumulations of the dark melanin grains in dark coloured mink. Such accumulations of melanin grains in the dermis might be the result of destruction of the hair follicles in the active (anagen) growth phases of the winter coat hairs. This could cause (the follicles to burst and) melanin granules (colour pigments) to be implanted in the dermis like a tattoo. Melanin grains could also be visible due to a spot-wise stop or delay of maturation of hair follicles, in which the winter coat does not prime before pelting. In any case, the only cause of visible melanin grains in otherwise prime/mature pelts that is consistent with the present knowledge seems to be bites applying a pressure high enough to cause the hair follicles to burst or stop priming.

A crucial point in such a clarification is if the physical pressure of a mink bite can cause a bite-mark. Therefore, a link between the pressure of an aggressive bite and a bite mark must be examined experimentally.

Our first hypothesis was to test whether experimentally applied pressure to, or penetration of, the pelt during the growth phase of the winter coat will produce marks that can be recognized as bite marks at pelting. Two sub-hypotheses follow from this. Hypothesis (2) Bite marks are only visible if pressure is applied during the active growth phase of the winter coat prior to maturation of the fur and hypothesis (3) Bite marks will be easier to detect on dark mink than on mink with light coloured fur. The objective, therefore, was to test if, and at what stages of the active growth phase of the winter coat it is possible to produce experimental bite marks in dark and light coloured mink pelts by applying pressure with artificial teeth.

Furthermore, we wanted to examine whether the number of bite marks actually accumulated and increased with time in group housing in the susceptible period between the autumn equinox and pelting. We therefore also tested the fourth hypothesis that the longer time into the growth phase of the winter coat mink are kept in groups, the more injuries and bite marks can be observed in the mink.

Photo 1. Bite marks on a female mink distributed primarily in the neck and at the base of the tail and a more diffuse distribution on the body. Neck, body, and tail region of scoring are indicated by a red line.

In order to relate bite marks to other welfare measurements we also measured the occurrence of fur chewing on the mink coat (Malmkvist and Hansen, 2001). Fur chewing has been related to boredom and under stimulation (Hansen et al., 1998), and we expected that prolonged group housing may reduce fur chewing due to enhanced social stimulation including aggression in a more dynamic and unstable social environment.

2. Materials and methods

The experimental mink were of the brown colour type ($N=140$) and the white colour type ($N=60$) and selected from litters of four kits or more in order to ensure that all kits had social experiences. The median date of birth was April 28th and the kits were weaned 8 weeks later. All mink were fed *ad libitum* at cage level once a day with fresh conventional wet mink feed from the local mink feed factory. All animals had permanent access to drinking water through a drinking nipple.

2.1. Investigation of bites applied experimentally

At weaning, 20 brown and 20 white mink (half males half females) were placed in non-sibling male + female pairs in standard cages (L: 0.90 m × W: 0.30 m × H: 0.45 m) with a nest box covered and bedded with straw. In order to prevent bite marks from cage mates, the 40 juvenile mink weaned pairwise were housed individually from August 20th (16 weeks of age) for the investigation of experimental bites. Every two weeks from September 19th to November 14th, four brown mink and four white mink were subjected to pressure by an artificial tooth (bitten) (Table 1).

Each mink was bitten nine times, using a machine pressing a metal tooth against a metal plate with a predefined pressure. Three series of three pressures were applied to each mink: (1) three pressures of 2 bars with a pointed metal tooth; (2) three pressures of 3 bars, with a pointed metal tooth and (3) one pressure of 1, 2 and 3 bars, respectively, with a blunt metal tooth. The six pressures with the pointed tooth were placed in a series on the right side of the mink starting at the right hip and towards the right foreleg. Similarly, the three pressures with the blunt tooth were placed in a series on the left side of the mink. Each pressure was placed on a fold of the pelt, whereby both the upper and lower layers of the pelt were potentially affected by the pressure. The range of pressures of 1, 2 and 3 bars were based on measurements of the strength of mink bites to a pressure gauge. The maximum of 3 bar pressure with the pointed tooth was chosen because only this was able to penetrate the mink skin. Before pressure was applied, each mink was anaesthetized with 5 mg/kg ketamin (Ketaminol® Vet., MSD Animal Health) and 0.1 mg/kg Medetomidinhydrochloride (Sedator, Novartis). After the pressures, the anaesthesia was terminated by injection of 0.25 mg/kg Atipamezole (Antisedan® Vet., Orion Pharma). A single injection of 2.2 mg/kg Flunizin (Finadyne® Vet., MSD Animal Health) was given which lasted 24 h and was deemed adequate post 'bite' analgesia. The experimental treatment was approved by the Danish Animal Experiments Inspectorate and complied with the Danish Laws concerning animal experimentation and care of experimental animals.

2.2. Investigation of separation to individual housing

In order to investigate when bite marks from cage mates are inflicted and to what extend they accumulate over time, 160 mink (120 brown and 40 white juvenile mink; half males and half females) were placed in groups of four non-siblings (two males + two females) after weaning. Each group was housed in a climbing cage (Photo 2) that consisted of a standard cage with nest box connected to a top cage (L: 0.70 m × W: 0.30 m × H: 0.45 m) through an

Table 1
Number and colour type of juvenile mink subjected to pressure at the dates specified.

Date in 2012	Week in 2012	Age in weeks	Pressure applied to	
			Brown juveniles	White juveniles
19/9	38	20	2 Males + 2 females	2 Males + 2 females
3/10	40	22	2 Males + 2 females	2 Males + 2 females
17/10	42	24	2 Males + 2 females	2 Males + 2 females
31/10	44	26	2 Males + 2 females	2 Males + 2 females
14/11	46	28	2 Males + 2 females	2 Males + 2 females
Total			10 Males + 10 females	10 Males + 10 females

Photo 2. Brown and white mink in climbing cages.

opening (0.20 m × 0.30 m) between the standard and the top cage. In order to investigate the effect of sex and colour type on the occurrence of bite marks in group housing, the juvenile mink were divided into three subgroups: A. 100 brown mink; B. 20 brown mink and 20 white mink housed in mixed sex and colour groups (one sex of each colour); C. 20 white mink. Every second weeks (at the age of 20, 22, 24, 26 and 28 weeks) mink from each subgroup were moved to single housing in standard cages (Table 2).

2.3. Post mortem examinations

On November 22nd, at the age of 29 weeks, all the mink were killed individually by CO_2 and labelled with an ID number in the nose. Unfortunately, 13 ID numbers were lost for the group housed mink during the pelting process and we were unable to identify those individuals which therefore were not included in the calculation of bite marks. The bodies were examined for injuries (damages to ear, eye, tail and legs), wounds (lesions in the cutis with involvement of subcutis, healed lesions), swellings of especially the skin on the tip of the tail and fur chewing (areas where the guard hairs or all hairs are missing). Wounds and fur chewing were registered on three areas on the body: *Neck* from the tip of the nose to the shoulder/foreleg; *Body* from the forelegs to 10 cm above the base of the tail; *Tail* from 10 cm above the base of the tail to the tip of the tail. We further distinguished between wounds placed on the tip of the tail and on the base/head of the tail. The size of wounds and fur chewing was scored on a scale from 0 to 9 (Table 3). Swelling on the tip of the tail was scored as wounds score 1.

2.4. Examination of bite marks

Two days after killing, the mink were pelted and subcutaneous tissue and fat on the leather side of the pelt were removed by a fleshing machine. After brushing off remaining saw-dust from the fleshing machine, the pelts were examined for bite marks, defined as dark spots on the bright leather side of the matured pelt. The number of bite marks was scored on a scale from 0 to 9 (Table 3) in the three areas of the pelt: Neck, Body and Tail. The sum of bite mark scores in the neck, body and tail was calculated as total bite marks.

Mink that died or had to be euthanized or moved to the infirmary during the experiment were registered throughout the experiment.

2.5. Statistical analysis

The score of bite marks, wounds and fur chewing was subjected to analysis of variance using the Restricted Maximum Likelihood method in the mixed model procedure with multiple error terms (SAS Institute Inc., 1996). The model used for score of bite marks and score of wounds included week for inflicting experimental bites or for moving of the animals (weeks 38, 40, 42, 44 and 46), sex (male, female), colour type (brown, white) and interactions between these fixed effects. Cagemates were non-independent and fitted with animals nested within cage as random effect. Degrees of freedom were estimated with Sattherthwaite's specification in the model statement. The univariate procedure of SAS was used to determine the normality of distribution of each set of data. In addition, residuals were inspected to check that the assumptions of normal distribution and variance homogeneity were satisfactory. Separation of LSM for significant effects was done using two-tailed *T*-tests using the Tukey's options in the mixed procedure of SAS.

The Chi-square test was used for analyzing the number of mink with injuries and fur chewing. A probability level (P) of 0.05 was used as the limit for statistical significance in all tests. A probability level $0.05 < P < 0.10$ was reported as a tendency.

Table 2
Number and colour type of juvenile mink separated from group housing of two males and two females to single housing at the dates specified.

Date in 2012	Week in 2012	Age in weeks	A. 4 brown mink		B. 2 brown + 2 white mink		C. 4 white mink	
			Males	Females	Males	Females	Males	Females
19/9	38	20	10	10	4	4	2	2
3/10	40	22	10	10	4	4	2	2
17/10	42	24	10	10	4	4	2	2
31/10	44	26	10	10	4	4	2	2
14/11	46	28	10	10	4	4	2	2
Total	38–46	20–28	50	50	20	20	10	10

Table 3
Scores used for grading of (1) number of bite marks on the leather side of mink pelt after fleshing, (2) diameter (mm) of the wounds and (3) diameter (mm) of fur chewing on the body and on the tail.

Score	0	1	2	3	4	5	6	7	8	9
Bite marks, number	0	1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–45	>45
Wounds, diameter (mm)	0	<10	10–14	15–19	20–24	25–29	30–34	35–39	40–50	>50
Fur chewing body, diameter (mm)	0	<10	10–19	20–29	30–39	40–49	50–59	60–69	70–99	>100
Fur chewing tail, diameter (mm)	0	<10	10–19	20–29	30–39	40–49	a	b	c	d

Fur chewing on (a) more than 5 cm and less than ½ of the tail, (b) between ½ and 2/3 of the tail, (c) between 2/3 and almost the whole tail, and (d) the whole tail.

3. Results

3.1. Recognizing experimental bites as bite marks

The pressures applied experimentally to mink produced marks similar to bite marks that could be observed on the leather side of the pelt in brown mink (Photo 3). Not all pressures applied produced bite marks in all brown pelts, but all combinations of tooth and pressures were observed as bite marks in some of the pelts. Bite marks were more often observed where high pressure had been applied by both the pointed and the blunt tooth, while the pointed tooth more often resulted in bite marks than the blunt tooth when applied with the same pressure to brown mink (Fig. 1). From September to October (age 20–26 weeks), an increasing number of the pressures applied to brown mink resulted in visible bite marks while no bite marks were visible from the pressures applied at 28 weeks of age in November, regardless of the pressure or shape of the tooth.

The pressures applied to 28 weeks old brown mink in November could be observed as red spots in the leather side of the pelt (Fig. 2 and Photo 4).

None of the pressures applied to white mink could be observed as bite marks on the leather side of the pelt. However, red spots were observed in white mink in a pattern similar to the bite marks in brown mink (Fig. 3, Photo 5). Red spots were more often produced by the pointed tooth than by the blunt tooth. The higher the pressure applied, the more red spots were observed, and the frequency of red spots increased the later the pressure was applied. The pressure applied in November (age 28 weeks) produced red spots in exactly the same pattern in white and brown mink.

The total recognition of marks from the pressures applied (sum of bite marks and red spots) was not different between the two colour types ($F_{1,25} = 0.31$; $P = 0.58$) and there was no significant difference between sexes ($F_{1,25} = 0.08$; $P = 0.78$). The recognition of marks was significantly lower for pressures applied in September (age 20 weeks) than in October or November (22 weeks of age or older) ($P < 0.001$; Fig. 4).

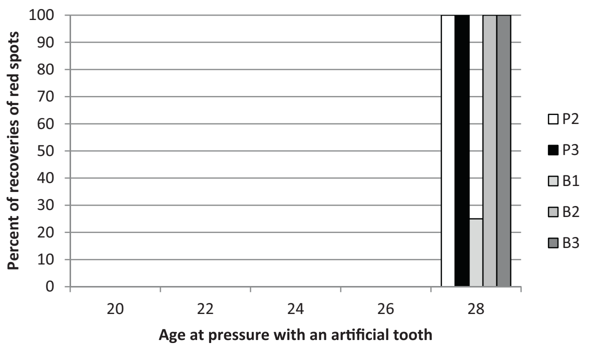

Fig. 2. Percent recoveries of red spots in brown mink after labelling with an artificial pointed tooth with two (P2) and three bars pressure (P3) and labelling with an artificial blunt tooth with one (B1), two (B2) and three bars pressure (B3) at the age of 20, 22, 24, 26 and 28 weeks.

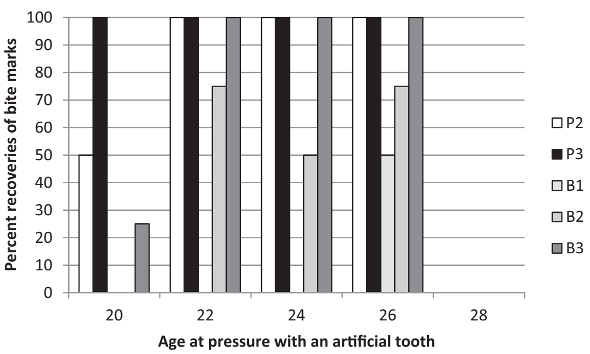

Fig. 1. Percent recoveries of bite marks in brown mink after labelling with an artificial pointed tooth with two (P2) and three bars pressure (P3) and labelling with an artificial blunt tooth with one (B1), two (B2) and three bars pressure (B3) at the age of 20, 22, 24, 26 and 28 weeks.

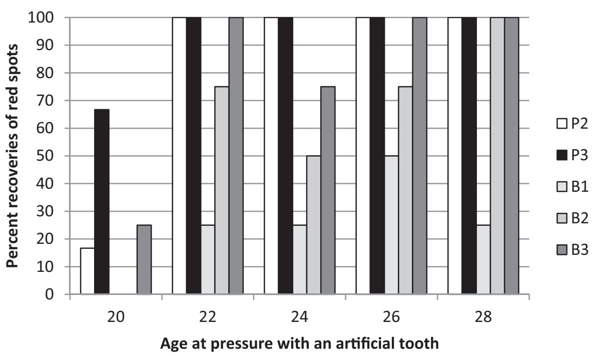

Fig. 3. Percent recoveries of red bite marks in white mink after labelling with an artificial pointed tooth with two (P2) and three bars pressure (P3) and labelling with an artificial blunt tooth with one (B1), two (B2) and three bars pressure (B3) at the age of 20, 22, 24, 26 and 28 weeks.

Photo 3. Brown mink with three bite marks after pointed tooth (P2 and P3) and two bite marks after blunt tooth (B2 and B3) inflicted at the age of 40 weeks.

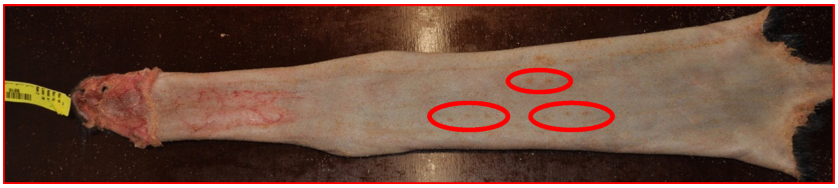

Photo 4. Brown mink with 2× three red spots after a pointed tooth (P2 and P3) and two red spots after a blunt tooth (B2 and B3).

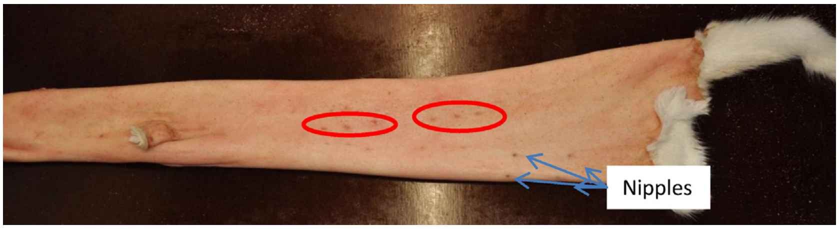

Photo 5. White mink with 2× three light bite marks after a pointed tooth (P2 and P3). The marks can be seen in both layers of the skin, as it was folded when pressure was applied. Four nipples can be seen on the belly.

3.2. Bite marks in group housed mink successively separated to individual housing

The number of bite marks differed significantly between colour types of group housed mink, as the total bite mark score was more than eight times higher in brown (7.47) than in white mink (0.91) ($F_{1,110}=35.55$; $P<0.001$) (Fig. 5). A significant interaction between weeks of separation and colour type ($F_{4,110}=4.00$; $P<0.005$) (Fig. 6) showed that the difference in total bite mark score between brown and white mink was non-significant for mink separated at the age of 20 weeks ($P=0.83$), tendency to higher score at the age of 22 weeks in brown mink ($P=0.08$) and significant more bite marks in brown mink in at the age of 24 ($P<0.05$), 26 and 28 weeks ($P<0.001$).

Because of difficulties in identifying bite marks in white mink, the effects of separation and sex could only be calculated for brown mink.

The total bite mark score, as well as the scores for bite marks in the neck, body, and tail region of brown mink increased significantly with the age at separation when separated at the age of 20–26 weeks ($F_{4,78}=9.6$; $P<0.001$) (Fig. 7). No bite marks were seen in the neck in juveniles separated at the age of 20 weeks and the score for bite

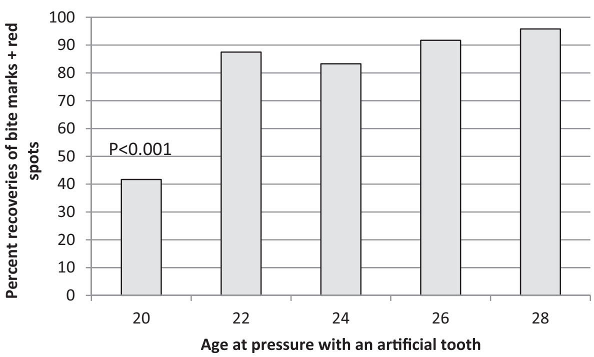

Fig. 4. Percentage of recovered bites (bite marks + red spots) applied at the age of 22, 24, 26 and 28 weeks.

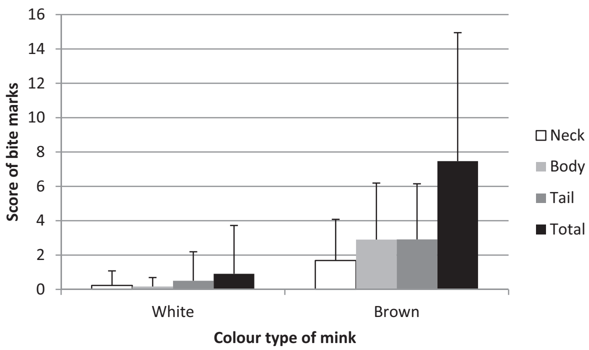

Fig. 5. The score of bite marks in brown and white juvenile mink in the neck, body and tail and summed to total ($P<0.001$).

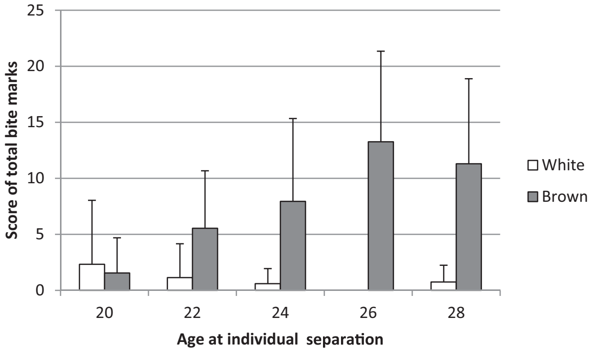

Fig. 6. The total score of bite marks in brown and white juvenile mink separated to individual housing at the age of 20, 22, 24, 26 and 28 weeks.

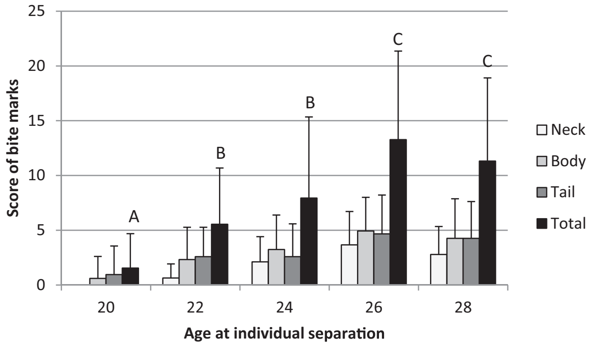

Fig. 7. Score of bite marks in brown juvenile mink moved to individual housing at the age of 20, 22, 24, 26 and 28 weeks. Bite marks are scored in the neck, body and tail and summed to total.

marks in the neck were low and not significantly different until separation at 24–26 weeks of age where the bite marks increased ($P<0.001$). Bite marks at the tail were seen at separation at the age of 20 weeks and increased at separation at the age of 22 weeks ($P=0.055$) and again at separation at 24 and 26 weeks of age ($P<0.05$).

The total bite mark score was not significantly different between sexes ($F_{1,78}=0.33$; $P>0.05$) (Fig. 8), neither was the bite mark score in the neck ($F_{1,78}=2.57$; $P>0.05$). There was a tendency to higher bite mark score on the body for males (3.44) than for females (2.24) ($F_{1,78}=3.63$; $P=0.06$) and a significantly higher bite mark score at the tail for

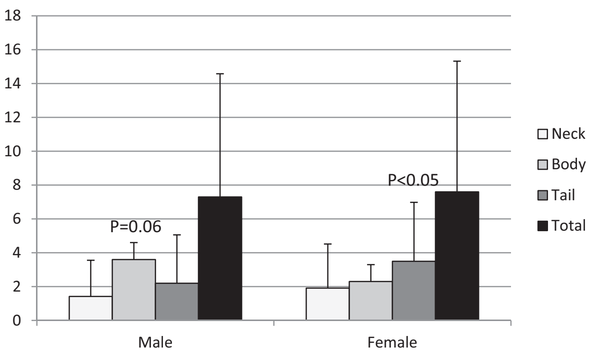

Fig. 8. Bite marks in brown juvenile male and female mink scored in the neck, body and tail and summed to total.

Photo 6. Healed wound (score 2) at the tip of the tail.

females (3.30) than for males (2.05) ($F_{1,78}=4.60$; $P<0.05$). The bite mark score in brown mink was not significant different between subgroups ($P>0.05$).

3.3. Excluded mink, wounds/swellings and fur chewing

During the experimental period, 20 of the group housed mink died or were excluded due to bite wounds while none of the experimentally bitten mink were excluded. One out of six mink was excluded before the autumn equinox (September 22nd) due to bite wounds while 10 out of 14 mink were excluded after the autumn equinox due to bite wounds.

At the post mortem examination at pelting, wounds at the base of the tail were observed once (score 2) and no wounds were observed on the body or in the neck. Forty-three mink had small wounds or swellings at the tip of the tail (mean score 0.31 ± 0.61) and more than 90% of the observed wounds were healed (Photo 6). Wounds or swellings were not affected by sex or colour type, and a gradual increase over time was not evident. No mink had ear or eye injuries but two mink had missed part of the tail (probably since birth).

The number of mink with any grade of fur chewing at the tail decreased significantly with time of separation to individual housing from almost half at the age of 16 weeks to almost none at the age of 28 weeks ($X^2{}_5=21.13$; $P<0.001$) (Table 4; Photo 7). Further, there was a tendency to decrease in the score of fur chewing ($F_{5,46.1}=2.11$;

Table 4
Percentage of mink with fur chewing at the tail and the mean score ± standard division for fur chewing according to the time the mink were moved to individual housing (week 34: separation for artificial bites; weeks 38, 40, 42, 44 and 46: separation of group housed mink).

Week in 2012	Age in weeks	*N*	Fur chewing at the tail	
			% Mink affected	Average score
34	16	40	47.5	1.02 ± 1.58
38	20	28	39.3	1.04 ± 1.90
40	22	33	31.2	0.27 ± 0.57
42	24	25	34.6	1.04 ± 2.01
44	26	24	16.7	0.46 ± 1.35
46	28	30	3.5	0.03 ± 0.18

Photo 7. Fur chewing (score 2) at the tip of the tail.

$P = 0.08$). Besides fur chewing on the tail, one mink had fur chewing in the neck (separated in week 40) and three on the body (separated in week 38 and 42). Fur chewing was not significantly affected by sex or colour type.

4. Discussion

4.1. Experimentally applied pressure produced bite marks

All combinations of tooth and pressures experimentally applied to mink produced marks on the leather side of the pelt similar to bite marks inflicted during the growth phase of the winter coat in brown mink. We therefore accept our first hypothesis that experimentally applied pressure to, or even penetration of, the skin during the growth phase of the winter coat will produce bite marks that can be recognized as such at pelting.

4.2. The moulting pattern of the winter coat affects the recognition of bite marks

The first pressures were applied in September (20 weeks of age) just before the autumn equinox, which is at the beginning of the active growth phase of the winter coat that ends in early November (Basset and Llewellyn, 1949; Blomstedt, 1989; Kondo and Nishiumi, 1991). The actual growth phase may vary 2–3 weeks due to variation between individual mink, location on the body and types of hair (Blomstedt, 1989; Kondo and Nishiumi, 1991). Therefore, only some of the mink may have had hair follicles in the active growth phase when the first pressures were applied in September. This may explain the low recovery rate of bite marks after applied pressures in September and give some support to our secondary hypothesis that bite marks are only visible if mink are bitten during the growth phase prior to maturation of the fur.

Pressures applied in November at the age of 28 weeks, which was after the active growth phase of the winter coat, were not recognizable as bite marks. We were, however, able to identify red or red-brown spots where the pressures had been applied, as we knew the position of the bites with the artificial teeth but they did not look like bite marks. The results show that pressures applied after the active growth phase of the winter coat were not recognizable as bite marks at pelting two weeks later. The most likely reason is that the coloured melanin grains are no longer present in the hair follicles to make a bite mark. However, a less likely explanation could be that it takes more than 2 weeks before bite marks become visible. No bite marks inflicted by the cage mate were observed in any of the experimentally bitten mink. As they were housed individually from August 20th (age of 16 weeks), this lack of bite marks from cage mates demonstrates that bite marks do not develop spontaneously during the growth phase of the winter coat in individually housed mink. Both results lend further support to our second hypothesis, that bite marks are only visible if mink are bitten during the active growth phase of the winter coat prior to maturation of the fur.

The moulting pattern of the winter coat occurring from tail to snout was also reflected in the number of bite marks in the tail and neck in group housed mink. Bite marks in the neck were not seen in mink separated to individual housing at the age of 20 weeks and occurred at a very low level until separation at the age of 26 weeks. In contrast, bite marks on the tail were seen in mink separated at the age of 20 weeks of age or later and increased with age of separation. The time difference in the occurrence and development of bite marks in the neck and on the tail coincide with a later start of the moulting process in the neck than on the tail.

4.3. Bite marks were easier to detect in brown mink than in white mink

Contrary to brown mink, none of the pressures applied experimentally to white mink could be recognized as bite marks. Instead, the experimental bites were recognized as red or brownish spots located systematically in the same position and proportion in the white mink as they were as bite marks or red spots in brown mink. A plausible reason for this could be that the bite marks were actually there, but due to the lack of contrast between the melanin grains forming the bite marks in light coloured mink and the mature bright leather side of the pelt, they were not visible. For group housed white mink successively separated to individual housing we found significantly fewer bite marks than in brown mink. This confirms our second hypothesis that bite marks will be easier to detect in dark mink than in mink with light coloured fur.

4.4. Bite marks reflected aggression

Play, aggression and/or sexual motivated behaviour can potentially be involved in the occurrence of bite marks. However, play behaviour is not increased in group housed mink compared to mink housed in pairs (Hansen et al., 1997; Pedersen et al., 2004) and sexual behaviour may primarily affect the occurrence of bite marks in the neck of the female. Consequently, the primary reason for bite marks on the body and tail may be aggressive interactions between mink (Hansen and Jeppesen, 2008).

We found no difference in total bite marks or in bite marks in the neck between sexes but males had more bite marks on the body than females and females had more bite marks on the tail than males. Females kept pairwise with a male had more bite marks than the male, probably due to the bigger size and social dominance of the male. Mink kept in groups, irrespective of sex, had more bite marks in the neck, body and tail than mink housed in pairs with the opposite sex (Hansen and Møller, 2012). The increased occurrence of bite marks in group housed mink may be due to the number of mink in the same cage, but also a lower social tolerance within sexes than between sexes may contribute to more aggression and bite marks in group housed mink (Berg and Møller, 2010).

4.5. Wounds and fur chewing in group housed mink

During the experiment, 7.9% of the group housed mink were found with severe wounds and consequently excluded from further participation in the experiment. In many papers on group housing, the causes of mortality are not clearly indicated, but mortality rates due to bite wounds in the growth period have been found to 2.1% (Møller, 2011), 10.0% (Pedersen et al., 2004) and 15.6% (Hansen and Møller, 2012). In comparison, mink housed in pairs have mortality rates due to bite wounds between 0 and 0.1% (Møller, 2011). The results confirm that group housing increased the risk of severe wounds and death due to increased aggression.

The majority of observations during the post mortem examination at pelting were minor healed wounds or swellings at the tip of the tail. It was not possible to relate that small wounds directly to the duration of time the mink had been housed in groups. The result indicates that other factors than aggression may be involved in the occurrence of small wounds on the tip of the tail.

Early separation of mink to individually housing increased the occurrence of fur chewing. Social deprivation has previously been found to increase fur chewing (Hansen et al., 1998). As an alternative to group housing, environmental enrichment (Hansen et al., 2007) and selection against fur chewing (Malmkvist and Hansen, 2001) have been shown to reduce fur chewing significantly in mink housed in pairs. Consequently, in relation to welfare neither individual housing nor group housing seems to be a better alternative to keeping juvenile mink in male-female pairs

4.6. Recognition of bite marks is restricted to a time window of about 5–7 weeks

The results of our investigations have some consequences for the use of bite marks as an indicator of aggression between mink in the same cage. First of all, the validity of bite marks as an indicator of bites is documented. Secondly, bites inflicted before or after the active growth phase of the hair follicles do not result in bite marks at pelting. The number of growing hairs in the winter pelt starts to increase in mid-September, is at its maximum in mid-October and ends in mid-November when the pelt is primed/matured (Blomstedt, 1989). Therefore, bite marks reflect social interactions between mink in a time window of about 5–7 weeks. This time window is in accordance with the period after the autumn equinox where the majority of the severe wounded mink were excluded due to bites, and an increasing number of bite marks were found in brown mink. This indicates three things: First, the autumn equinox is indeed a point in time after which aggression increases as indicated by bite marks. Secondly, bites are inflicted during the entire active growth period of the winter pelt. Thirdly, bite marks are inflicted by other mink in the cage. The number of bite marks at pelting thus represents the accumulated history of bites received during this period of about 5–7 weeks. We therefore accept our fourth hypothesis that the longer time into the growth phase of the winter coat mink are kept in groups, the more bite marks can be observed in the mink.

The temporal relationship between aggression and the time window for infliction of bite marks makes bite marks a valid and useful welfare indicator for quantifying the social tolerance of dark mink and consequently the risk for serious bite wounds.

Conflict of interest

There are no known conflicts of interest associated with this publication.

Acknowledgements

The project was financed by the Danish Ministry of Food, Agriculture and Fisheries and Aarhus University, Denmark (Grant No. 2012-17).

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