Feeding behaviour of juvenile mink housed in pairs or group in climbing cages

Utfodringsbeteende hos unga minkar uppfödda i par eller grupp i etageburar

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Sammanfattning

Minken är det vanligaste djuret för pälsproduktion i Sverige och de cirka 75 farmarna producerar tillsammans upp 1 000 000 pälsar varje år. Bakgrunden till denna studie är att nya regler för inhysning av minkar kommer träda i kraft under 2017 där de unga djuren inte längre får hållas i grupp. Syftet med denna studie var att undersöka skillnaderna i ätbeteende mellan djur som hölls i grupp med tre individer och de som hölls i par. Hur ofta och hur länge en mink äter samt eventuellt konkurrensbeteende kartlagdes också som en del i studien.

Studien gjordes på en konventionell minkfarm i Sverige. Totalt 30 minkar av färgtypen brun placerades direkt efter avvänjningen i antingen par (hona, hane) eller i grupp (två honor, en hane). Alla djur hölls i sina burar från 9 veckors ålder till ca 6 månaders ålder och inhystes i likadana burar med samma skötselrutiner. Minkarna var inhysta i etageburar med tillgång till en övervåning samt lya med strö. Utfodring skedde med ett färskt foder två gånger per dag genom att foder placerades på nätburens tak. Alla djur hade tillgång till miljöberikning i form av två hyllplan samt en kedja som hängde från nättaket ner i buren. Alla djur filmades under ett helt dygn i slutet av november 2013 och filmerna kodades sen för olika beteenden i Noldus Observer XT. Endast ett beteende i taget registrerades per djur, hane eller hona. Även utfodringstid samt när all mat var uppäten registrerades men utan att vara kopplat till ett specifikt djur. Beteenden som registrerades var ”äta”, ”vila i buren”, ”vistas i lyan”, ”aktiv i buren”, ”konkurrera om föda” samt ”social interaktion”.

Statistiska uträkningar gjordes med SAS Institute version 9.3. Durationer av beteenden analyserades för de olika könen med Students T-test och frekvenser av beteenden mellan olika kön gjordes med hjälp av Wilcoxon rank sum test. Signifikansnivån för p-värden sattes till < 0.05. De två honorna inhysta i grupp gick inte att skilja åt på individnivå utan ett medelvärde räknades ut av deras beteende.

Parhållna minkar vilade oftare ute i buren än grupphållna minkar ($p=0,03$). Detta var den enda skillnaden mellan inhysningssystemen. Skillnader i beteende mellan könen fanns för antalet registreringar där djuren åt, honor åt oftare än hanar ($p=0,01$) samt för antalet registreringar ”i lyan” där honor oftare besökte lyan än hanar ($p=0,01$). Oavsett inhysningssystem spenderade djuren mest tid i lyan.

I genomsnitt hade både grupp- och parhållna minkar tillgång till foder 13,3 timmar per dag men med stor spridning där emellan. Som längst hade parhållna djur tillgång till foder i 17,9 timmar och som kortast i 7,4 timmar. För grupphållna djur var längsta tillgången till foder 23,6 timmar och som kortast 7 timmar. Djuren observerades äta både tillsammans och enskilt i båda inhysningssystemen.

Slutsatsen var att det inte finns några skillnader i ätbeteende som kan härröras till de olika inhysningssystemen.

Summary

The mink is the most common animal for fur production in Sweden and around 75 farmers yearly produce 1 000 000 pelts. Backgrounds for this study is a new legislation for housing of mink from 2017. This new legislation states that young animals no longer can be kept in groups. The purpose of this study was to investigate differences in feeding behaviour

between minks kept in pair or groups of three animals. How often and for how long the minks eat were also analysed as a part of this study as well as competition over feed, if that is seen.

The study was made at a conventional mink farm in Sweden. A total number of 30 brown minks were placed in groups (one male, two females) or pair (one male and one female) after weaning. All animals was kept in the same type of cages with same management routines from 9 weeks of age to 6 months of age. All animas were kept in climbing cages with access to an upper floor and a nest with straw. Fresh feed was served twice a day and placed on the cage roof. All animals had access to enrichments in form of two shelves and a chain hanging from the cage roof. The animals were filmed during one day in the middle of November 2013 and the videos was later coded for different behaviours in Noldus Observer XT. Only one behaviour per animal was registered at a time and the behaviour was connected to either a male or female. Feeding time and the time when all feed was eaten was also registrated, but without connection to a specific animal. Behaviours registered was "eating", "resting in cage", "nest", "active in cage", competing over feed" and "social interaction".

Statistical analyses was made in SAS Institute version 9.3. Duration of behaviour was analysed for the different sexes with a Students T-test and frequencies of behaviours between sexes was made with a Wilcoxon rank sum test. Significance for p-values was set to <0.05. The two females in group housing were not possible to separate on individual level and a mean was calculated for females in group housing.

Pair housed mink rested more often in cage than group housed ($p=0.03$). This was the only difference between the different housings. Differences in behaviour between males and females was seen in frequency of eating, females ate more often than males ($p=0.01$) and for frequency of entering the nest, females visited the nest more often than males ($p=0.01$). Regardless housing system, minks spent most of their time in the nest.

Average time of feed available was 13.3 hours both for pair and group housed mink, with a large spread. The longest time pair housed animals had feed available was 17.9 hours and shortest time was 7.4 hours. Group housed animals had feed available for 23.6 hours at most and 7 hours at least. Animals was observed eating alone and together in both housing systems.

The conclusion is that there are no differences in feeding behaviour which can be connected to housing system.

Introduction

The mink (*Neovison vison*) is the most common fur animal in Sweden and the rest of the world (Berg and Hammarström, 2006; Gugołek *et al.,* 2013). Although Europe has its own wild mink species, the European mink, wild mink are not a natural part of the Swedish fauna. The first mink in Sweden were imported from North America for fur production purposes in late 1920s (Gerell, 1969; Dunstone, 1993). Today, Sweden have a feral population of mink spread all over the country and it is based upon animals that has escaped from farms or were set free by animal rights groups (Erlinge, 1969; Persson *et al.,* 2013).

Minks are kept in shadow houses and they are fed with a mixture of slaughter offal, grain and additives. Swedish legislation on mink for fur purpose states that only animals bred in captivity can be held as fur animals, stereotypic behaviours should be prevented, environments enriched and kits should not be housed alone (SJVFS 2013:16 Saknr L103). In 2010, half of the 46.5 million mink pelts produced worldwide were bred in Europe (Mononen *et al.*, 2012).

The Swedish board of agriculture has made a new legislation concerning mink which comes into effect in 2017. This new legislation is made to improve the animals welfare statues that minks should be housed in a cage with an upper floor, have access to enrichments in the cage and that group housing is banned (SJVFS 2012:14 Saknr L103, 2 kap. 4 §).

A former study at SLU (Swedish University of Agriculture) stated that there are small differences according to the animals' welfare between pair housed and group housed mink (Olofsson, Hansen and Lidfors, 2014). This study is a part of the previous one, but focusing on feeding and feeding behaviour of the mink.

Mink production in Sweden

Mink farming is only a small part of the Swedish animal production, with about 80 mink farmers in the whole country. Although the low number of farmers, there is approximately 180 000 female breeding mink, 35 000 male breeding mink and they produce around 1.000 000 pelts sold for 1000 million SEK (Sveriges Pälsdjursuppfödares Riksförbund, 2013). Pelts from all over the world are sold in large auction houses like Copenhagen Fur in Denmark (Dunstone, 1993).

Today minks live in cages in shadow houses in large farms. A shadow house consists of a roof, rows of cages on each side, have a passage way in the middle and are without walls. Animals in different cages are able to see each other through the cage mesh walls but not get in physical contact. Feeding routines varies between farms but usually the animals are given wet feed mixtures two or three times per day. Some farms have their own feed kitchen and others buy their feed. Pelleted feed for mink are not used in Sweden today.

Behaviour of the mink

Wild and feral mink

Wild mink use about 20 % of the day to travel and search for food (Dunstone, 1993). Wild mink live in solitary except during the breeding season (Dunstone, 1993) and are generally nocturnal (Gerell, 1969). Often several dens are used within their home range, but mink are not known for making their own dens (Dunstone, 1993). Male territories are larger than females and male and female mink are known to have overlapping territories (Marshall, 1936; Dunstone, 1993). Male and female mink sharing a den has also been observed, at least in wintertime during mating season (Marshall, 1936). The mink is naturally an opportunistic carnivore and eats a variety of other small animals such as rodents, fish, birds, eggs, frogs and crayfish (Gerell, 1969; Dunstone, 1993). Diet variation is also dependent on which habitat the mink inhabits with the largest variations discovered between habitats during summertime (Gerell, 1967). Type of prey often varies between seasons with fish being more common in wintertime and mammals and birds in summer time (Erlinge, 1969; Wise, Linn and Kennedy, 1981; Melero *et al.* 2008; Zschille *et al.*,

2012). Female mink are smaller than males and therefore known to be taking smaller prey (Birks and Dunstone, 1985).

Early spring is the onset of the minks breeding season and after approximately 50 days of gestation, an average of six kits are born (Dunstone, 1993). Multiple mating occurs in mink and even though only one litter is born per year, different male mink can therefore be contributing genetically (Marshall 1936; Thom *et al.,* 2003). Weaning in the nature is a gradual process which takes place until the pups are around 12 weeks old and they permanently move out of their mothers nest (Dunstone, 1993).

Farmed mink have in behavioural studies showed to be most active around feeding time and dusk and dawn (Hansen and Möller, 2008). Wild minks studied by García, Mateos and Arévalo (2009) in Spain showed similar activity patterns. Wild male and female mink have also been seen to have different circadian rhythm (Zschille, Stier and Roth, 2010).

Farmed mink

Both wild and farmed mink spend most of their time in the nest (Dunstone, 1993; Zschille, Stier and Roth, 2010; Malmkvist *et al.,* 2012). Bjælke, Hansen and Jeppesen (2000) found that farmed mink put a higher value to access to a nest compared to both swimming water and extra space. In a study by Malmkvist *et al.* (2003), female mink had a higher frequency of visits to the nest than males. The nest can also be used as a thermoregulatory factor, it protects the mink from draught and bedding material insulate the cold floor (Mononen *et al.,* 2012).

Mink breed seasonally once per year (Dunstone, 1993). Reproduction is highly connected to the female body condition and slim females give the best results, i.e. large litters (Boudreau *et al.,* 2014). Boudreau *et al.* (2014) also showed that the restrictedly fed animals had less DNA damage than *ad libitum* fed females. Kits are born in the late spring and pelted in November. Young animals are housed together in pairs or groups from weaning to pelting whereas breeding animals are housed alone from weaning to breeding. Weaning on farms normally takes place abruptly when the animals are around 6-8 weeks of age (Jeppesen *et al.,* 2000). Swedish legislation states that weaning should take place when kits are between 8 and 10 weeks old, with exceptions if the welfare of dams or kits are threatened (SJVFS 2013:16 Saknr L103, 2 kap. 2 §). Time of weaning at farms is made with consideration to both dams and kits. Mink dams with *ad libitum* access to feed adapt their feed and water intake to their milk production, the more kits in the litter, the more the dam will eat and drink. However, kits born in small litters have a higher weight at four weeks of age (Fink *et al.,* 2001) and the mortality rate is higher in litters with seven kits or more (Martino and Villar, 1990). Sex differences has been seen already under the suckling period, with male kits having a higher milk intake and gaining higher weights than female kits (Wamberg and Tauson, 1998). Mink kits start to eat solid food when they are around three weeks old (Brink *et al.,* 2004).

Brink *et al.* (2005) saw that mink usually started drinking water for the first time at the age of 33-44 days, but in another study (Brink and Jeppesen, 2004) only 23 % of the kits had started drinking at that age. Disturbed sexual behaviour has been observed for males weaned at seven weeks (Gilbert and Bailey, 1969) and weaning at the age of seven weeks compared to weaning at eleven weeks gave more tail-biting in females (Mason, 1994). Mink dams usually lose weight after weaning and the time right before weaning is the most

stressful for the dams (Sørensen *et al.,* 2011). Brink and Jeppesen (2004) made a similar conclusion when they studied the behaviour of mink dams with kits, stereotypic behaviour in dams increased at the end of the weaning period indicating poor welfare. Cage enrichments designed to help the dam get away from her kits can improve production results and decrease stereotypic behaviour in dams (Buob *et al.,* 2013).

Although minks are solitary animals in the wild (Dunstone, 1993), studies of farm animals have shown a higher frequency of stereotypies in animals housed alone (Jeppesen *et al*., 2000) and single housed animals more often chewed on their own tail than pairs or family housed mink (Hansen, Houbak and Malmkvist, 1998). Housing with another animal is often counted as a type of environmental enrichment (Hänninen *et al.,* 2008). Male and female differences in behaviour have also been found in a study of fear behaviour, where male mink were less frightful than females (Malmkvist and Hansen, 2002).

Digestive system and feeding behaviour

The mink digestion tract is short related to its body length, has no caecum and the feeds passage time through the digestive system is high (Kainer, 1954; Leoschke, 2011). Therefore, mink feed several times per day (Mustone *et al.,* 2006). Korhonen and Niemelä (1998) found that the mink males in their experiment fed up to 13 times per day on *ad libium* feeding. Malmkvist *et al.* (2003) found differences in eating behaviour between the sexes; females ate with a higher frequency and longer time than male mink. They believed that this could be explained by the females taking smaller bites and passing into and out of the nest more often than males. The same study also concluded that mink prefer familiar food compared to novel food.

In a study by Gugołek *et al.* (2013) the food transit time for farmed mink were about 200 minutes. Male mink had a longer passage time than females, probably due to their greater body size. Others have reported a passage time of 187 minutes (Bleavins and Aulerich, 1981) and 142 minutes (Sibbald *et al.,* 1962). Passage time seems to have increased, maybe due to breeding for larger and more efficient animals, since passage time for feed in wild mink are shorter (Gugołek *et al.,* 2013). Due to the short intestinal tract and high passage time the mink needs to feed several times per day.

Restricted feeding which is commonly used in winter time to avoid fat female breeding animals, is a factor that promotes stereotypic behaviour in mink (Blidsøe, Heller and Jeppesen, 1991; Daamgard *et al.,* 2004). *Ad libitum* feeding with feed less energy dens for female breeding animals during the wintertime instead of fastening was recommended by Daamgard *et al.* (2004) since this method did not enhance the prevalence of stereotypy. Fastening of animals is also a risk factor for development of fatty liver disease, especially for animals who previously have been fed with high intensity (Rouvinen-Watt *et al.,* 2012; Dick *et al.,* 2014). In a study by Mustonen *et al.* (2005) no proof of adaption to wintertime fastening as seen in many other carnivores could be found in mink. Instead, mink seem to change their behaviour when feed availability is short. Although studied in farmed mink, interpretations can be made that mink chose to predate more actively to increase feed intake rather than alter the metabolism (Mustonen *et al.,* 2005; Mustonen *et al.,* 2006).
Young mink are more likely to have gastrointestinal problems such as diarrhoea and blood-stained feaces and the risk is highest shortly after weaning. Feed quality seems to be a major factor for this problem (Rattenborg, Chriél and Dietz, 1999).

Minks left for 12 h without feed showed an increase in stereotypic behaviour (Hansen, Møller and Damgaard, 2011). Selecting female breeding animals by studying their residual feed intake and choosing animals with a low feed intake can also lead to lessen stereotypic activity as well as lowered feed costs (Daamgard *et al.*, 2012).

Mink feed usually consists of slaughter by-products, fish, cereals, fat and additives (Skrede and Nes, 1988). Some countries use pelleted feed for mink (Kumeno *et al.*, 1970; Dunstone, 1993), but only fresh feed is used in Sweden. According to Korhonen (2014), fish should be the major protein source for mink since animals fed on a high fish diet had more kits and a higher pelting weight compared to diets mostly containing of slaughter offal.
Protein is of great importance for fur growth and low protein levels gives a lowered pelt length and weight (Kumeno *et al.*, 1970; Zhang *et al.*, 2012). Since proteins are carnivores greatest source of energy, the levels of ME (metabolizable energy) protein should not be below 30 % to prevent mortality and to promote growth (Damgaard, Clausen and Dietz, 1998). Levels below 25 % ME from protein gave a mortality rate up to 20 % in one experiment in the study with growing male mink (Damgaard, Clausen and Dietz, 1998). Experiments with farmed mink have shown that mink can compensate a lack of specific macronutrients by compensatory eating of the wanted nutrient. In one of the studies, mink chose a diet where 35 % of ME came from proteins and 50 % from lipids (Mayntz *et al.*, 2009; Jensen *et al.*, 2014).

Mink digestibility for the different nutrients protein, fat and starch are reported to be high, all of them had a digestibility between 80-90 % (Ljøkjel *et al.*, 2004; Vhile *et al.*, 2005). Studies in feed utilization have proven that breeding can improve this trait in mink (Nielsen *et al.*, 2012). When trying to improve feed utilization through breeding, fertility must not be forgotten since the live weight of both male and female mink is correlated to fertility (Nielsen *et al.*, 2011; Boudreau *et al.*, 2014).

Abnormal behaviour

Abnormal behaviour is often a result of how well the animal is coping with its environment, and stereotypic behaviour is often regarded as an indicator of poor welfare (Broom, 1988). An improvement in animal welfare can be found when the animal gets a higher control over its environment (Broom, 1991). Abnormal behaviours shown by mink are locomotion stereotypies, fur chewing and tail-biting. Locomotion stereotypies are often seen in carnivores and can be described as moving of the upper body or head in repetitive patterns or moving in the same pattern in the cage (Dallaire *et al.*, 2011). Fur chewing is when an animal bites on its own or a cage mate's guard hair fur. Tail biting is when the manipulation of the fur is concentrated to the tail (Hansen *et al.*, 2007).

In a study by Axelsson, Aldén and Lidfors (2009) of female mink in wintertime at two Swedish farms, stereotypic behaviour was performed in roughly 10 % of the observed time. Stereotypies are more often seen in older breeding animals (Svendsen *et al.*, 2007; Hansen *et al.*, 2010) and before feeding (Hansen *et al.*, 2007; Axelsson, Aldén and Lidfors, 2009). Postponed feeding can lead to more animals performing fur chewing (Svendsen, Palme and Malmkvist, 2013). According to Jeppesen *et al.* (2000) animals housed in small cages generally show more stereotypic behaviours than animals with larger housing. Hansen *et al.* (2007) on the other hand found no such correlation between cage size and stereotypic behaviour. The variation in results in these studies may depend on different routines at the farms such as feeding time and other management factors.

Malmkvist *et al.* (2013) found that abnormal behaviour in farmed mink could be reduced by the presence of biting ropes, suggesting that some of the abnormal behaviour in mink is related to frustration over a lack of foraging.

It is possible to breed for less stereotypic animals, but there will be consequences in other traits such as size and breeding success due to genetic correlations (Hansen, Jeppesen and Berg, 2010; Meagher *et al.,* 2012). When a number of factors were investigated by Lagerkvist (1997), the highest profit was obtained at farms with the largest litter sizes and a large litter size did not influence pelt quality negatively. A large litter size is also positively correlated with stereotypic behaviour and stereotypic animals give birth to more kits (Jeppesen, Heller and Bildsøe, 2004). This correlation is probably due to the lower body weight of stereotypic animals.

A line bred for high stereotypic animals in a study by Svendsen *et al.* (2007) were more active and had a more confident temperament than the low stereotypic bred animals.

Environmental enrichments

Environmental enrichments have been found to reduce stereotypic behaviour in animals (Dallaire, Meagher and Mason, 2012; Campbell, Dallaire and Mason, 2013), but care must be taken that the enrichments given has a biological function to the animal to be a real improvement (Newberry, 1995). Typical environmental enrichments used for mink are chains, shelves, tubes and balls (Hansen *et al.,* 2007; Axelsson, Aldén and Lidfors, 2009; Buob *et al.,* 2013; Meagher *et al.,* 2014), but more chunky food can also be a type of environmental enrichment (Malmkvist *et al.,* 2013).

A large study by Meagher *et al.* (2014) with over 2000 mink in three commercial North American farms showed several positive effects of environmental enrichments for mink. A higher reproduction result was found in both males and females and enriched mink were easier to handle with a better temperament and lower extent of fur-chewing. A wide range of environmental enrichments were used in the study to be able to compare costs and benefits. Golf balls and plastic plumbing tubes were widely used by animals to a low cost (Meagher *et al.,* 2014).

Mink kits in highly enriched cages showed more play behaviour and less inactivity as young, but no difference in stereotypic behaviour could be found when highly enriched kits and kits from standard cages became older (Vinke *et al.,* 2004). A problem when assessing stereotypic behaviour in enriched cages is that animals sometimes become less active when given enrichments (Dallaire, Meagher and Mason, 2012). Meagher *et al.* (2013) suggested that this could be due to fear or boredom, but as stated before, wild mink spend most of their time in the nest (Dunstone, 1993; Zschille, Stier and Roth, 2010). Another study of Meagher and Mason (2012) showed that mink housed in non-enriched environments reacted with more investigating behaviour when presented with new stimuli than mink in enriched cages and came to the conclusion that non-enriched mink suffered from boredom due to housing environment.

Group and family housing of mink

Many studies on the welfare and production of group housed of mink have shown that pair housing is still to be recommended, even though group housed animals were housed in larger cages. These studies of group housed animals all consisted of 4 mink or more

(Pedersen *et al.*, 2004; Hänninen *et al.*, 2008). Fur damages such as bite marks are also more common in group housed mink (Hansen, Houbak and Malmkvist, 1998) and the number of bite marks increases over time (Hansen, Møller and Damgaard, 2014). Bite marks can appear both when mink are fighting and playing and more social behaviour in group housed mink can therefore lead to more bite marks (Hansen, Møller and Damgaard, 2014). Breeding for less bite marks in group housed mink has been done by Alemu *et al.* (2014) and it leads to an indirect breeding for less aggressive behaviour and therefore promoting a better animal welfare. There were also no correlation between aggressive animals and body size (Alemu *et al.*, 2014).

A study by Hansen and Daamgard (1991) found that there were differences in stress hormones between male and female mink kept in groups of three were only group members of the same sex were kept together. Their conclusion was that male mink are less stressed in a group housing environment compared to female mink. According to Dunstone (1993), wild female mink have smaller territory than males and a low tolerance of other mink within her home range.

Hänninen *et al.* (2008a) studied group housing for juvenile mink in combined cages with pair housing in a standard cage. Group housed animals had access to three standard cages and the groups consisted of three male and three female kits, which gave the same space access per mink as pair housed animals. As in former studies, group housed animals had more bite marks than pair housed, but these group housed minks had lower cortisol levels which indicates a less stressful environment. Pair housed animals also showed more stereotypic behaviour. Production results were poorer from group housed mink with smaller skins and a tendency for lower fur prices (Hänninen *et al.*, 2008a).

A large study of family housing of mink was made by Pedersen and Jeppesen (2001). Family housing can be described as when the kits stay with their mother until pelting and selection of new breeding animals, which normally takes place in November. The study consisted of hundred female breeding mink of pastel colour and one hundred of pearl colour. Half of the animals of each colour type lived alone after weaning in traditional cages and the other half stayed with their kits and had access to three row cages. The majority of family housed females suffered from teat damages, and fur damages were more common in family housed females. Stereotypic behaviour was more common in single housed female mink, but they had lower plasma-cortisol levels. Family housed mink in this experiment had access to three combined cages and therefore space should not have been a determining factor. Their result was that family housing promotes a good behavioural welfare for the adult female mink, but gives a reduction in production performance and physics (Pedersen and Jeppesen, 2001).

Hänninen *et al.* (2008b) studied family housing where the family housed animals had access to combined standard cages, with the number of combined cages corresponding to number of kits in the litter with a mean of two animals per cage. Number of kits per litter varied between five and nine. Fur damages were more common in family housed animals, but no aggressive behaviours was observed. Stereotypic behaviour was under 1 % in both housing systems and no kits performed stereotypies. There were indications of lessened stress in family housed animals according to adrenal function.

All these three studies (Hänninen *et al*., 2008a; Hänninen *et al.*, 2008b; Jeppesen, 2001) showed that both family housing and group housing of juvenile mink have a positive impact on behaviour but can effect production results negatively.

Aim

The aim of this study was to investigate if there are any differences in feeding behaviour between mink housed in climbing cages in pairs or in groups of three and to answer the question if it effects the minks feeding behaviour negatively to live in groups.

Following questions were analysed:

1) How often does mink eat in a 24 hour period?
2) For how long does the mink eat during a 24 hour period?
3) Are there more competition between individual mink when they are housed in group with three animals than in pairs?

Predictions

1) Mink eat several times per day
2) Eating durations are short and male mink eat for longer times than females
3) There are more competition between group housed mink than pair housed

Material and method

Behavioural study of farm mink

Housing and feeding

This study was carried out on a private mink farm in southwest of Sweden during July to November 2013. Cages were placed in shadow houses and therefore in contact with outdoor weather and a natural light cycle. The mink lived in conventional cages (80 x 30 x 45 cm) with a wooden nest box (approximately 22 x 30 x 18 cm) and had an extra upper floor (40 x 30 x 45 cm) which will be mandatory in Sweden from 2017. The mink could pass between the levels through a hole in the roof of the lower cage compartment and a hole in the upper compartment. Bedding material in the nest box consisted of straw placed on top of the nest box and minks themselves pulled it down to the nest box through the wire mesh top. Environmental enrichment were present in the form of a chain fasted in the cage roof and two shelves.

The routines on the farm was to feed fresh feed twice a day with a standard feeding machine leaving the feed on top of the cage roof, for feed ingredients see table 1 and feed analyse see table 2. The feeding machine resembles a small vehicle without a roof. At the back of the machine the feed is stored connected to tubes and the driver control portions given from the tubes. Farm practice was that 10-15 % of all cages should have feed left shortly before next feeding. This is a compromise between to make sure that all mink have enough feed and that they should be without feed for some time to increase their appetite. Since the studied period was late in the growing/furring period the animals was no longer fed *ad libitum* to avoid problems with fat livers. Water access was unlimited from a water dispenser in the back of the cage.

Feeding time varies depending on cage location in the farm but feeding interval between the two feedings for animals in this study was about 6 hours.

Individual feeding of cages were possible on the farm through a computer based program where residuals on the cages were registered and feed amounts was checked and calculated at an everyday basis. However, this was not in practice at the time of the study.

Table 1. Feed ingredients and percentage of feed as listed from the farmer for the studied time period

Feed	Percent of total kg feed
Chicken	25
Herring	24.2
Porridge	13
Cod	10
Potato	6.6
Oatmeal	5
Rumen	3.3
Fish silage	3
Corn gluten	3
Egg powder	3
Raw meat	2
Bran	1
Algae	0.4
Soybean oil	0.2

Table 2. Analysed content and metabolizable energy for the mink feed

Content	**Percent of total content**	**Metabolizable energy (ME)**
Dry substance	34.3	-
Ash	2.2	-
Crude protein	14.3	34.6 %
Fat	9	49.6 %
Carbohydrates	8.8	17.5 %

Animals and study design

A total of 30 wild coloured minks were used in the study. Six cages had pair housing with one male and one female and six cages had group housing with one male and two female. Thus, twelve minks lived in pairs and eighteen in a group of three.

The mink were filmed for 24 h in their caged at the end of the growing period in November 2013. Pair housed animals was filmed the 18th of November and group housed the 19th of November. They were filmed for 24 hours with one camera per two cages in infrared light during the dark hours and recorded by the Media Recorder (Noldus Information Technology, Wageningen, The Netherlands). The videos were coded for different mutually exclusive behaviours with Noldus Observer XT ®, version 11.0, (Noldus Information Technology, Wageningen, The Netherlands). Different letters were used to code for different behaviours e.g. the letter n was used when a mink entered the nest. Behaviours and their definitions are described in table 3. Each observation, except "feed available", was paired with a subject – male or female.

Females in group housing were not possible to identify at individual level and therefore only a mean is presented for behaviours of females in group housing.

Weather data from observation days were sunny and -2.5 degrees Celsius on the morning of 18th of November when pair housed mink were filmed and cloudy and + 7 degrees Celsius on the morning of 19th of November for the filming of group housed mink. Weather changes during the day were not registered.

Initially, a pre-study of one of the recordings was used to see which behaviours that could be observed. Behaviours of interest were then included in the observation scheme. The pre-study of the filmed material also included coding of approximately 12h of a 24 h film to learn the technique.

Table 3. Behaviours and their definitions

Behaviour	Definition
Nest	More than half the mink's body is in the nest box
Social interaction	All types of contact directed to another animal, not directed to feed. E.g. playing, grooming, fighting, resting together outside the nest box (if attention is directed at another animal)
Competition over feed	One or two animals disturbing or chasing away another when eating. Aggressions such as visible teeth visible
Eating	Animal is standing on hind legs with mouth close to or directly in contact with feeding place or when the animal is first standing on hind legs with mouth close to or directly in contact with feeding place and then goes down to cage floor to chew. Chewing movements visible.
Resting in cage	Mink lying outside the nest box, in the cage. Only little moving such as changing of body position occurs
Active	The animal is active in the cage either running, walking, grooming themselves, performing stereotypic behaviour or playing. All these performed alone without another animal present

Presences of feed on top of the cage were registered as a continuously behaviour with recording starting when the feeding machine portions the feed on top of the cage and stops when an animal finish eating and walks away with no more feed is visible on the cage roof.

Stereotypic behaviour in the studied mink material has previously been analysed by Olofsson, Hansen and Lidfors (2014) with only one female performing stereotypic behaviour in November. Since the stereotypic behaviour that was observed previously was of locomotion type, stereotypic behaviour was not recorded in this study.

Statistical analysis

All statistical analysis were performed with SAS Institute version 9.3. Duration of behaviours were analysed according to sex and a mean value was calculated for females in group housing. Students T-test (one-sided, null hypothesis) were run for behaviours "active in cage", "competing over feed", "eating", "nest "resting in cage" and "social interaction". Significance was noted for t-values < 0.05.

Wilcoxon rank sum test (one-sided, null hypothesis) were used to analyse frequencies of behaviours, these tests were also divided between the sexes and analysed for differences between sexes.

Significance were p-values < 0.05 are reported.

Results

Effects of housing

Pair housed mink performed a higher number of "resting in cage" than group housed mink. The differences in number of performed "resting in cage" were similar in both sexes where pair housed females performed it 8.8 times and group housed females 4.2 times per 24 h (Table 4) and pair housed males performed it 8.5 times and group housed males 4.5 times per 24 h (Table 5).

Although without significant differences between housings, females performed "eating" in pair housing with a mean of 23.5 times and in group housing with a mean of 25.7 times per 24h. The males performed "eating" in pair housing with a mean of 17.7 times and in group housing with mean 12.2 times per 24h.

Both male and female mink spent a high duration per 24 h in the "nest" (Figure 1 and 2). The second highest duration recorded was that the mink was "active in cage" and thereafter that it was "resting in cage" (Figure 1 and 2).The duration of "eating" and "social interaction" had a lower duration (Figure 1 and 2). Mean eating duration during the 24 h for males in pair housing was 30 minutes and for group housed it was 30 minutes. For females mean eating duration during 24 h in pair housing was 32 minutes and in group housing 27 minutes. There were no significant differences between pair and group housed mink in the duration of these behaviours.

Table 4. Effects of housing for frequencies of behaviours in female mink, one-sided tests

Behaviour	Housing	Mean	t-value	p-value	Standard Error of the mean
Nest	Pair	5.7	0.5	0.5	35.3
	Group	7.3			45.3
Social interaction	Pair	6.0	0.7	0.7	37.2
	Group	7.0			43.4
Eating	Pair	6.2	0.8	0.8	38.4
	Group	6.8			42.4
Resting in cage	Pair	8.8	0.05 *	0.03 *	54.6
	Group	4.2			26.0
Active in cage	Pair	7.2	0.6	0.6	44.6
	Group	5.8			36.0

Table 5. Effects of housing for frequencies of behaviours in male mink, one-sided tests

Behaviour	Housing	Mean	t-value	p-value	Standard Error of the mean
Nest	Pair	7.8	0.2	0.2	48.4
	Group	5.6			36.4
Social interaction	Pair	6.1	0.8	0.8	37.8
	Group	6.9			42.8
Eating	Pair	8.2	0.15	0.12	50.8
	Group	4.8			29.8
Resting in cage	Pair	8.5	0.09	0.06	55.3
	Group	4.5			27.9
Active in cage	Pair	7.5	0.2	0.2	46.5
	Group	5.5			34.1

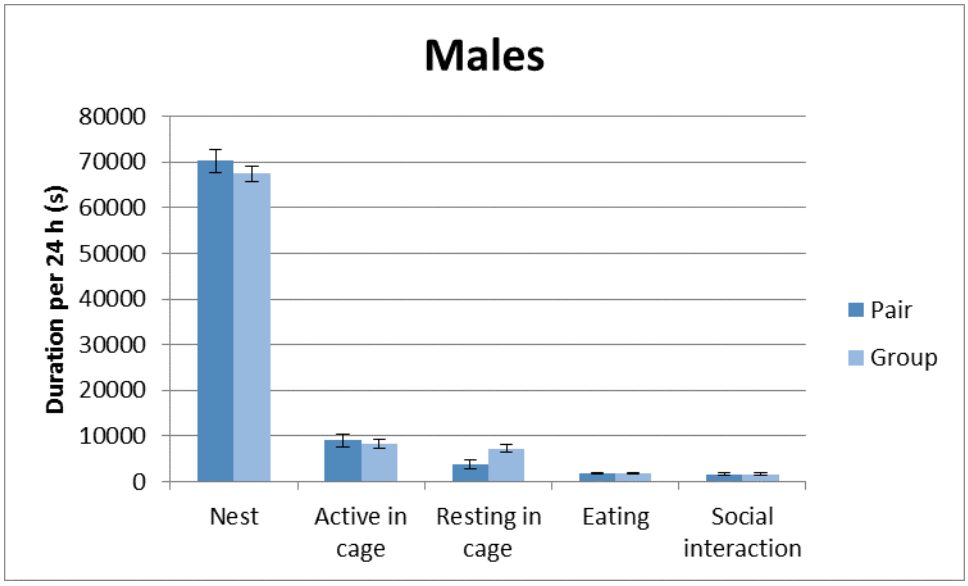

Figure 1. Duration in seconds per 24 h (±SE) to perform five pre-defined behaviours for male mink kept in either pair- or group housing

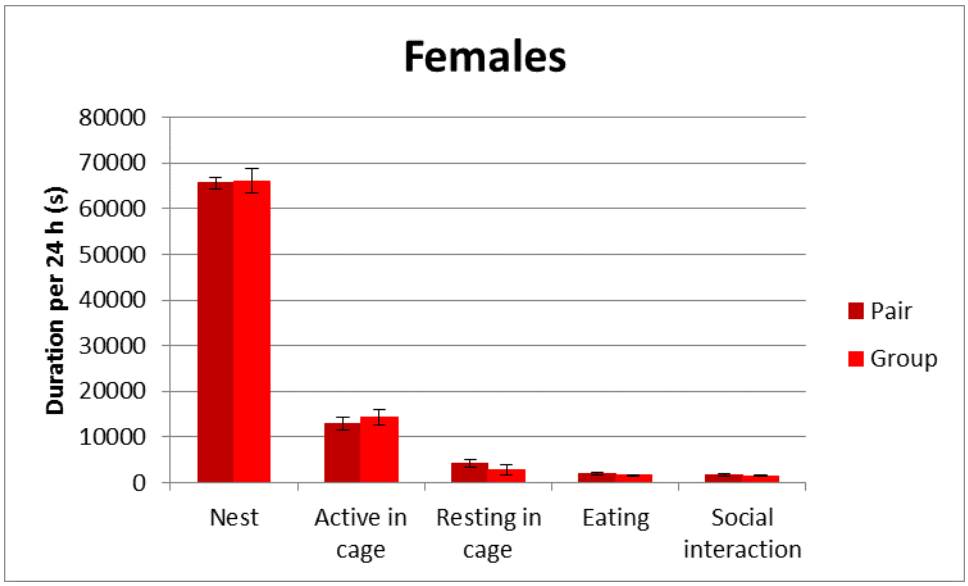

Figure 2. Duration in seconds per 24 h (±SE) to perform five pre-defined behaviours for female mink kept in either pair- or group housing

Effects of gender

Significant differences were found for effects of gender (Figure 3) in number of eating (one-sided t-value=0.01, p-value=0.01 and SE 156.5 for male mink and SE 273.5 for female mink). Females ate more often than male mink with mean number of eating for males 9.1 times and for females 15.9 (Figure 3) per 24h.

Female mink also had a higher number of visits to nest than male mink (two-sided t-value=0.02, p-value=0.01 and SE 159.2 for male mink and SE 273.3) (Figure 3). Number of visits to the nest per 24h was 15.8 for female and 9.2 for male mink. There were no significant differences between genders in number of recorded being active in cage, resting out in cage and social interaction (Figure 3).

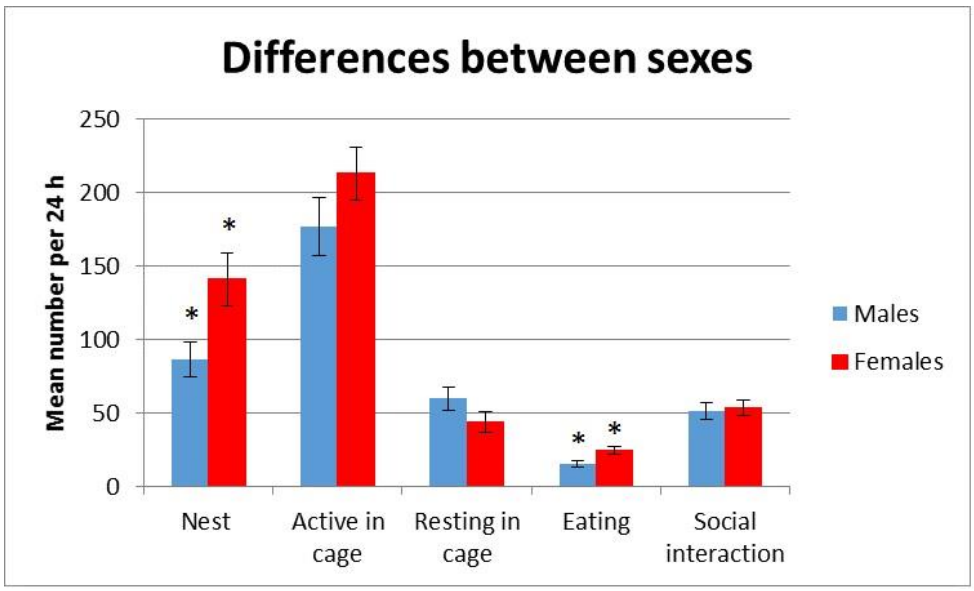

Figure 3. Mean number (±SE)of behaviours per 24 h for males and females in both group and pair housing

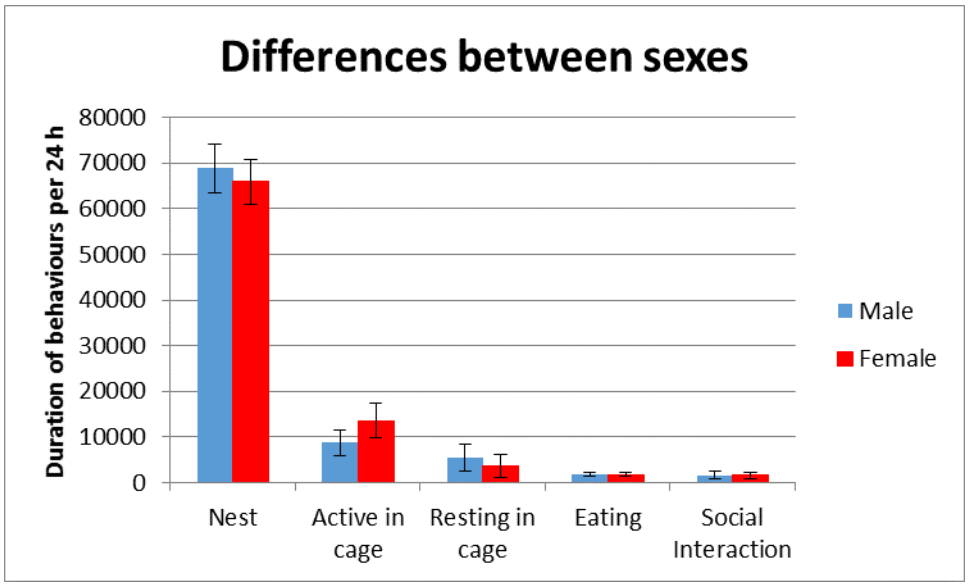

Figure 4. Mean duration (±SE) of behaviours per 24 hours for males and females in both group and pair housing

Feeding behaviour

Mink were seen eating both alone and together in both housing systems, but sometimes an animal went out to eat, took a bite and then went directly back to the nest. Then the animal came out again and the routine was repeated. Most of the times this behaviour was observed another mink was outside eating at the same time, but not always.

Mink were also seen eating or trying to eat although no feed was visibly available at the time, both in cages with two and three mink.

Mean time for feed being available was 13.3 h for pair housed and 13.3 h for group housed. However, the spread was large with a minimum time with feed available for 7.4 h and maximum 17.9 h for pair housed and a minimum time of 7 h and maximum of 23.6 h for group housed. Feed availability for all cages, see table 6.

Table 6. Total feed availability and longest interval without feed for individual cages

Cage number	**Total feed availability hh:mm**		**Longest interval without feed hh:mm**	
	Pair	Group	Pair	Group
1	11:03	10:12	10:00	11:13
2	07:43	10:08	13:25	11:25
3	17:54	23:37	05:10	00:23
4	10:57	17:18	06:40	06:43
5	16:55	11:10	07:00	12:11
6	15:25	07:07	07:50	12:09

One male in pair housing (Figure 4) was used as a model for at which times mink eat during 24 h. Most of the feed intake took place after feeding in the morning and few or no recordings were observed after feeding around 15.00. Mink tended to eat again at night, and all feed was eaten around midnight.

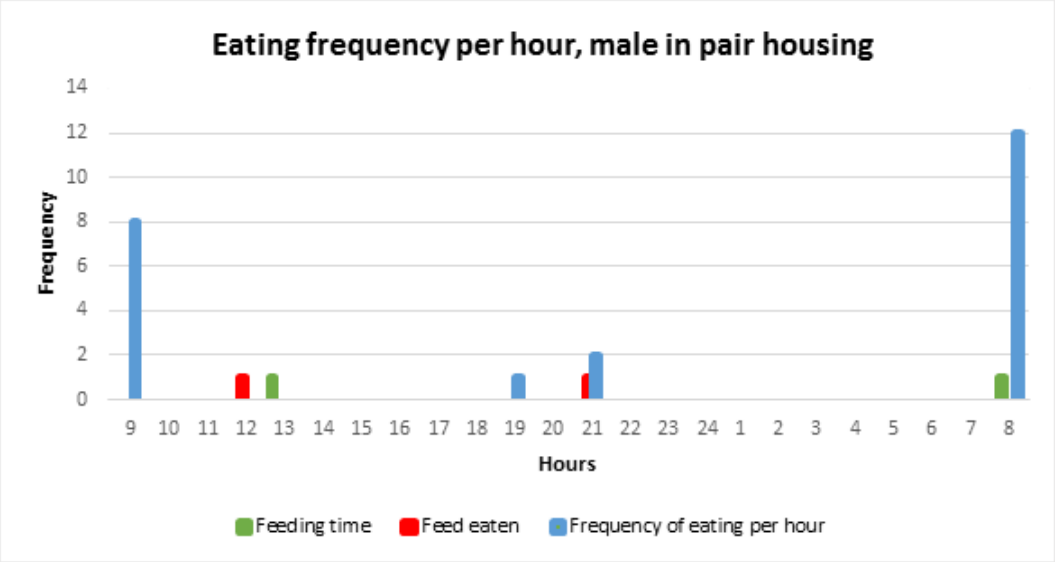

Figure 4. Number of eating bouts per hour, feeding time and when all feed was eaten for one male mink in pair housing

Figure 5 shows number of recordings of eating per hour for one male mink in group housing, but has fewer eating recordings per hour than figure 4. Most feed was eaten in the afternoon around 16.00 and there was no more feed left on the cage roof around midnight. Therefore there were no more recordings of eating until new feed was placed on the cage roof in the morning.

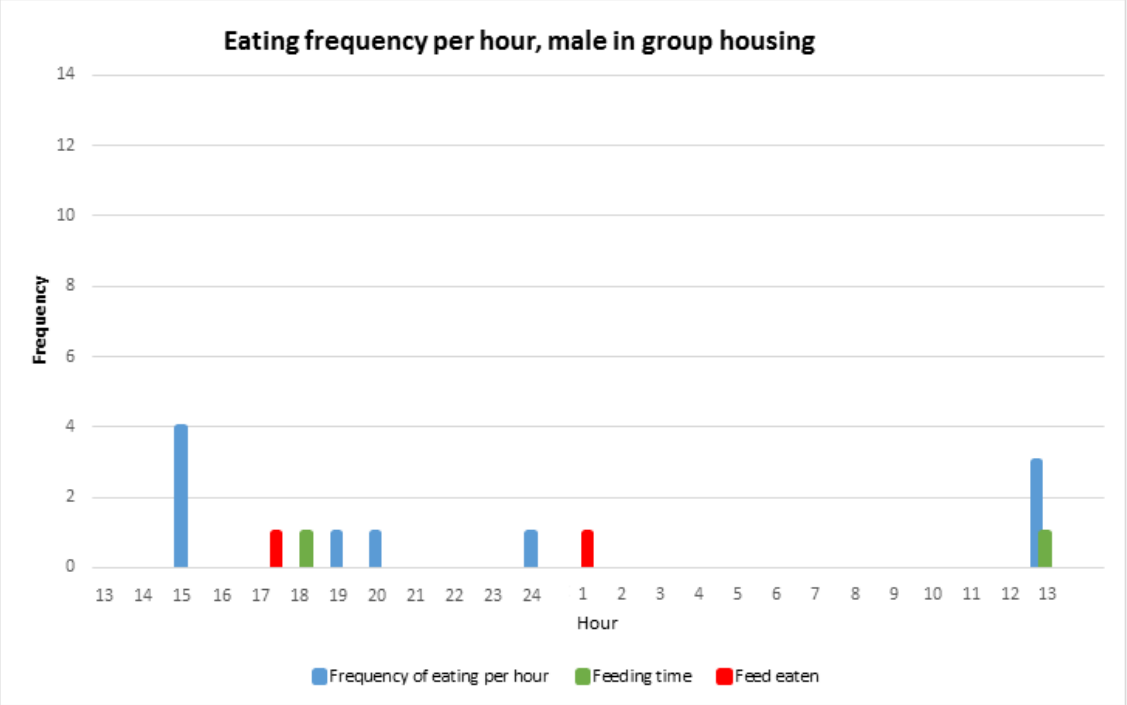

Figure 5. Number of eating bouts per hour, feeding time and when all feed was eaten for one male mink in group housing

Discussion

This study of feeding behaviour in pair and group housed mink are a part of a larger study by Olofsson, Hansen and Lidfors (2014) which investigated possible differences in welfare for mink housed in pairs or group. Their conclusion was that there were no differences in social interactions between the two groups, nor in weight gain. Bite marks on skins was more present in group housed animals.

In this study group housed male mink ate 12.2 times and female mink 25.7 times per 24 h, whereas pair housed males ate 17.7 times and females 23.5 times per 24 h. All these numbers, except males in pair housing, are higher than the up to 13 times per day reported by Korhonen and Niemelä (1998). The findings are in agreement with Malmkvist *et al.* (2003) which concluded that female mink ate more often than male. Number of times the mink eat are often correlated to duration, mink that eat many times has a shorter eating duration. Mean eating durations were shorter for females than males both in this study and that by Malmkvist *et al.* (2003).

The study by Malmkvist *et al.* (2003) included 48 animals of two different breeding lines and all animals were housed alone after weaning. The test was carried out over two days and behaviours were observed during 10 minutes after feeding. Design setup was well conducted but it would have been more interesting with a larger group of animals housed in standard conditions, i.e. in pairs. Another aspect to the study by Malmkvist *et al.* (2003) is that the time for an animal to get accustomed to novel feed was not investigated. Mink diets are changed several times during their life and resistance to novel feed might lower feed intake until the animals get accustomed to the new diet.

Malmkvist *et al.* (2010) saw in contrast to this study longer eating duration for female mink. Few studies have recorded eating frequency and duration of growing mink before, probably due to a lack of interest since growing mink most often are fed *ad libitum* or close to *ad libitum*.

There were no significant differences in eating duration per 24 hours between male and female mink. Both sexes in both housings spent approximately 30 minutes per day eating. Although there were no differences in total feeding time in this study, male mink kits are known to have a higher feed intake (Wamberg and Tauson, 1998). As discussed by Malmkvist *et al.* (2003), the larger feed intake by male mink might be due to differences in portion size where male mink take larger bites. This would agree with the behaviours seen in this study. Most of the observations related to eating took place after morning feeding of the minks. Only no or little feed intake could be seen after the afternoon feeding suggesting that this could be postponed. Mink tend to eat again during the night and in most of the cages all feed was eaten around midnight.

Competition around feed was seen a few times with no statistical significance between different housings or sexes. The behaviour when animals only took bites of the feed and then went in and out of the nest box can be signs of both gathering of feed and disturbance from cage mates. Most of the time this behaviour was observed when another mink were outside eating at the same time, but not always. Since there were no camera in the nest box, it is impossible to know if the animal was performing a normal gathering behaviour or if it was disturbed. At other times all animals in one cage, both group housed and pair, could be seen eating at the same time, suggesting no feed competition or disturbance at all.

Feeding duration can also be related to availability of feed since animals have been seen trying to eat without feed visible. This could be a sign of hunger or boredom. The mink in this study had usually access to feed for about 13 h and in some cages well below 12 h. Feed access below 12 h could not be recommended since other studies (Blidsøe *et al*., 1991; and Hansen *et al.*, 2011) showed an increase in stereotypic behaviour for animals on restricted feeding.

However, restricted feeding is often used by farmers to avoid fatty liver problems after the highest growing periods around August. This contradicts Mustonen *et al.* (2005), Rouvinen-Watt *et al.* (2012) and Dick *et al.* (2014) whose studies suggest that restricted feeding and both short-term and long-term fastening can induce liver problems in mink. However obesity and over fed animals are also reported as a source of the problem with fatty liver in mink (Dick *et al.,* 2014). Feeding breeding animals on a low energy-diet instead of restricted feeding where the animals can be given higher amounts was successfully tested by Damgaard *et al.* (2004). A large number of female siblings were fed with three different diets to test if stereotypies and production performance could be monitored by feeding strategies. Both parameters could be improved or maintained with a low-energy diet to breeding animals during the winter season.

The feed given to the mink in this study contained 34.6 % ME from protein, which is over the recommended minimum level of 30 % (Damgaard *et al.,* 1998). Metabolizable energy from fat was also close to 50 %, which is what minks themselves choose if given a choice (Mayntz *et al.,* 2009; Jensen *et al.,* 2014).

In this study mink behaviour changed relatively fast, except when sleeping. They run in and out of the nest, lie down for a short while and then jumped down to interact with their cage partner. Number of recordings of different behaviours might therefore not tell much about mink behaviour. Duration of each activity is a preferable way to describe how the mink spend their day.

Many studies of mink show that most of their time is spent in the nest (Dunstone, 1993; Zschille *et al.*, 2010; Malmkvist *et al.*, 2012), and this study came to the same result. Malmkvist *et al.* (2003) also came to the same conclusion as this study which is that females have more visits to the nest than males.

Although male mink generally are larger than females (Marshall, 1936; Dunstone, 1993) it could sometimes be hard to see the sex of the animal on the video. There were less visible differences in size between animals living in groups than in pairs and thus some animals might have been recorded with the wrong sex. A way to avoid this problem in the future can be to pair animals with different colours, such as wild coloured and pearl, or to mark one of the animals with an easy detectable colour marking like a white dot on the animals back.

Group housing of juvenile mink seems to be more preferable (Hänninen *et al.*, 2008a) than family housing with an adult female and kits (Pedersen and Jeppesen, 2001; Pedersen *et al.* 2004; Hänninen *et al.*, 2008b). However, these studies are not possible to compare directly to each other since housing conditions were very different. A well conducted study on group housing is by Pedersen *et al.* (2004) where two different types of group housing was compared to traditional housing in pairs. Stocking density was the same for all housing conditions but number of animals per cage varied with housing type. A female focal animal per cage was observed several times during a four month period and over 7000 observations was made of the focal animals in the different cages. Observers only recorded what the animal did at that precise moment of observation, i.e. only one behaviour was recorded per observation.

Stereotypic behaviour was not recorded in this study since a previous study on same material of mink (Olofsson *et al.*, 2014) only reported one case of stereotypic behaviour. Stereotypic behaviour is usually not seen in mink kits and only rarely in juvenile mink (Hansen *et al.*, 2010) and therefore it was considered unnecessary to include.

Continuous recordings during 24 hours is time consuming to study but also very useful. Registrations of feeding time and time when all feed is eaten gives a lot of extra information which is interesting when studying feeding behaviour.

In future studies, it would be interesting to have a camera in the nest box as well as the cage to be able to see if the mink are gathering feed or chewing when they go directly from eating to the nest box repeatedly. More studies will be needed on the subject of minks eating behaviour related to feeding time and cage mates to see how those factors can affect welfare and production performance. Effects of *ad libitum* and restricted feeding is another aspect that can be studied in relation to feeding behaviour.

Conclusion

Mink housed in climbing cages in groups of three did not show any great differences in feeding behaviour compared to those housed in pairs. Females tended to eat more often than males, regardless of number of animals per cage. Males on the other hand ate longer times than females. Therefore the new legislation with a ban of group housing will not have any effect on feeding behaviour in mink.

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Literature

Alemu, S. W., Bijma, P., Møller, S. H., Janss, L., Berg, P. Indirect genetic effects contribute substantially to heritable variation in aggression-related traits in group-housed mink (*Neovison vison*). Genetic Selection Evolution 46, 1-11.

Axelsson, H. M. K., Aldén, E., Lidfors, L. 2009. Behaviour in female mink housed in enriched standard cages during winter. Applied Animal Behavioural Science 121, 222-229.

Berg, C., Hammarström, M. 2006. The process of building a new governmental authority based on public demands for improved animal welfare. Livestock Science 103, 297-302.

Bjælke Hansen, C. P., Jeppesen, L. L. 2000. Short term behavioural consequences of denied access to environmental facilities in mink. Agricultural and Food Science in Finland 9, 149-155.

Bleavins, M. R., and R. J. Aulerich. 1981. Feed consumption and food passage time in mink (Mustela vison) and European ferrets (Mustela putorius furo). Lab. Anim. Sei. 31: 268-269.

Birks, J. D. S., Dunstone, N. 1985. Sex-related differences in the diet of the mink Mustela Vison. Holarctic Ecology, 8. 245-252.

Blidsøe, M., Heller, K. E., Jeppesen, L. L. 1991. Effects of immobility stress and food restriction on stereotypies in low and high stereotyping female ranch mink. Behavioural Processes 25, 179-189.

Boudreau. L., Benkel, B., Astakie, R., Rouvinen-Watt, K. 2014. Ideal body condition improves reproductive performance and influences genetic health in female mink. Animal Reproduction Science 145, 86-98.

Brink, A. L., Jeppesen, L. L. 2004. Behaviour of mink kits and dams (*Mustela vison*) in the lactation period. Canadian Journal of Animal Science 85, 7-12

Brink, A. L., Jeppesen, L. L., Heller, K. E. 2005. Behaviour in suckling mink kits under farm conditions: effects of accessibility of drinking water. Applied Animal Behaviour Science 89, 131–137.

Broom, D. M. 1988. The scientific assessment of animal welfare. Applied Animal Behavioural Science 20, 5-19

Broom, D. M. 1991. Assesing welfare and suffering. Behavioural Processes 25, 117-123.

Buob, M., Meagher, R., Dawson, R., Palme, P., Haley, D., Mason, G. 2013. Providing 'get-away bunks' and other enrichments to primiparous female mink improves their reproductive productivity. Applied Animal Behavioural Science 147, 194-204.

Campbell, D. L. M., Dallaire, J. A., Mason, G. J. 2013. Environmentally enriched rearing environments reduce repetitive preservation in caged mink, but increase spontaneous alternation. Behavioural Brain Research 239, 177-187.

Dallaire, J. A., Meagher, R. K., Díez-León, M., Garner, J. P., Mason, G. J. 2011. Recurrent preservation correlates with abnormal repetitive locomotion in adult mink but is not reduced by environmental enrichment. Behavioural Brain Research 224, 213-222.

Dallaire, J. A., Meagher, R. K., Mason, G. J. 2012. Individual differences in stereotypic behaviour predict individual differences in the nature and degree of enrichment use in caged American mink. Applied Animal Behaviour Science 142, 98-108.

Damgaard, B. M., Clausen, T. N., Dietz, H. H. 1998. Effect of dietary protein levels on growth performance, mortality rate and clinical blood parameters in mink (*Mustela vison*). Acta Agric. Scand. Sect. A. Animal Science 48, 38-48.

Damgaard, B. M., Hansen, S. W., Børsting, C. F., Møller, S. H. 2004. Effects of different feeding strategies during the winter period on behaviour and performance in mink females (*Mustela vison*). Applied Animal Behavioural Science 89, 163-180.

Daamgard, B. M., Dalgaard, T. S., Larsen, T., Hedemann, M. S., Hansen, S. W. 2012. The effects of feed restriction on physical activity, body weight, physiology, heamatology and immunology in female mink. Research in Veterinary Science 93, 936-942.

Dick, M. F., Hurford, J., Lei, S., Mustonen, A-M., Nieminen, P., Rouvinen-Watt, K. 2014. High feeding intensity increases the severity of fatty liver in the American mink (*Neovison vison*) with potential ameliorating role for long-chain n-3 polyunsaturated fatty acids. Acta Veterinara Scandinavica 56:5, 1-9.

Erlinge, S. 1968. Food Habits of the Otter Lutra lutra L. and the Mink Mustela vison Schreber in a Trout Water in Southern Sweden. Oikos 20, 1-7.

Fink, R., Tauson, A-H., Bislev Hansen, K., Wamberg, S., Kristensen, N. B. 2001. Energy intake and milk production in mink (MUSTELA vison)-effect of litter size. Archiv für Tierernaehrung 55, 221-242,

García, P., Mateos, I., Arévalo, V. 2009. Diurnal activity of the American Mink (Neovison vison) in Central Spain. Hystrix - Italian Journal of Mammalogy Vol 20, 1. 61-68.

Gerell, R. 1967. Food selection in relation to habitat in mink (Mustela vison Schreber) in Sweden. Oikos 18, 233-246.

Gerell, R. 1969. Activity Patterns of the Mink Mustela vison Schreber in Southern Sweden. Oikos 20, 451-460.

Gilbert, F. F., Bailey, E. D. 1969. The effect of early weaning on the sexual behaviour and reproductive success of ranch mink. Journal of Mammalogy, 50. 742-747.

Gugołek, A., Zalewski, D., Strychalski, J., Konstantynowicz, M. 2013. Food transit time, nutrient digestibility and nitrogen retention in farmed and feral American mink (*Neovison vison*) – a comparative analysis. . Anim. Physiol. a. Anim. Nutr. 97. 1030-1035.

Hansen, S. W., Daamgard, B. M. 1991. Stress physiological, haematological and clinical-chemical status of farm mink placed in groups or singly. Acta Agriculturae Scandinavica 41. 355-366.

Hansen, S. W., Houbak, B., Malmkvist, J. 1998. Development and possible causes of fur damage in farm mink – significance of social environment. Acta Agriculturae Scandinavica Sect A Animal Science 48, 58-64.

Hansen, S. W., Malmkvist, J., Palme, R., Damgaard, B. M. 2007. Do double cages and access to occupational materials improve the welfare of farmed mink? Animal Welfare 16, 63-76.

Hansen, S. W., Møller, S. H., Damgaard, B. M. 2014. Bite marks in mink – induced experimentally and as reflection of aggressive encounters between mink. Applied Animal Behavioural Science 158, 76-85.

Hansen, B. K., Jeppesen, L. L., Berg, P. 2010. Stereotypic behaviour in farm mink (*Neovison vison*) can be reduced by selection. Journal of Animal Breeding Genetics 127, 64-73.

Hansen, S. W., Møller, S. H. 2008. Diurnal activity patterns of farm mink (Mustela vison) subjected to different feeding routines. Applied Animal Behaviour Science 111. 146-157.

Hansen, S. W., Møller, S. H., Damgaard, B. M. 2011. Feed restriction and tubes for environmental enrichment in growing mink – consequences for behaviour and welfare. Applied Animal Behavioural Science 134, 139-200.

Hänningen, S., Ahola, L., Pykkönen, T., Korhonen, H. T., Mononen, J. 2008a. Group housing in row cages: an alternative housing system for juvenile mink. Animal 2:12, 1809-1817.

Hänninen, S., Mononen, J., Harjunpää, S., Pyykönen, T., Sepponen, J., Ahola, L. 2008b. Effects of family housing on some behavioural and physiological parameters of juvenile farmed mink (*Mustela vison*). Applied Animal Behavioural Science 109, 384-395.

Jensen, K., Simpson, S. J., Nielsen, V. H., Hunt, J., Raubenheimer, D., Mayntz, D. 2014. Nutrient-specific compensatory feeding in a mammalian carnivore, the mink, *Neovison vison.* Brittish Journal if Nutrition 112, 1226-1233.

Jeppesen, L. L., Heller, K. E., Dalsgaard, T. 2000. Effects of early weaning and housing conditions on the development of stereotypies in farmed mink. Applied Animal Behaviour Science 68, 85-92.

Jeppesen, L. L., Heller, K. E., Bildsøe, M. 2004. Stereotypies in female farm mink (*Mustela vison*) may be genetically transmitted and associated with higher fertility due to effects on body weight. Applied Animal Behaviour Science 86, 137-143.

Kainer, R. A. 1954. The gross anatomy of the digestive system of the mink. American Journal of Veterinarian Research, 15. 82-97.

Korhonen, H., Niemelä, P. 1998. Effect of *ad libitum* and restrictive feeding on seasonal weight changes in captive minks (*Mustela vison*). Journal of Animal Physiology and animal nutrition 79. 269-280.

Korhonen, H. 2014. Effect of slaughter-house offal and fish levels on production performance in mink and blue fox. Open Journal of Animal Science 4, 237-243.

Kumeno, F., Itoyama, K., Hasegawa, J., Aoki, S. 1970. Effect of protein and fat levels in complete pelleted diets on the growth of mink kits. Journal of Animal Science, 31. 894-899.

Lagerkvist, G. 1997. Economic profit from increased litter size, body weight and pelt quality in mink (*Mustela vison*). Acta Agri. Scand. Sect. A, Animal Science 47, 57-63.

Leoschke, W. L. 2001. Nutrition and nutritiolan physiology of the mink – A historical perspective. United States of America, Trafford**.** 1-425.

Lidström, L. 2011. Pälsfarmning på övertid – Burhållning av minkar kan inte förenas med djurskyddslagen. Minirapport om minkar, Djurens Rätt. Urban Print. Älvsjö, Sweden.

Malmkvist, J., Hansen, S. W. 2002. Generalization of fear in farm mink, *Mustela vison*, genetically selected for behaviour towards humans. Animal Behaviour 64, 487-501.

Malmkvist, J., Herskin, M. S., Christensen, J. W. 2003. Behavioural responses of farm mink towards familiar and novel food. Behavioural Processes 61, 123-130.

Malmkvist, J., Brix, B., Henningsen, K., Wiborg, O. 2012. Hippocampal neurogenesis increase with stereotypic behavior in mink (*Neovison vison*). Behavioural Brain Research 229, 359-364.

Malmkvist, J., Palme, R., Svendsen, P. M., Hansen, S. W. 2013. Additional foraging elements reduce abnormal behaviour fur-chewing and sterotypic behaviour in farmed mink (*Neovison vison*). Applied Animal Science 149, 77-86.

Marshall, W. H. 1936. A Study of the Winter Activities of the Mink. Journal of Mammalogy 17, 382-392.

Martino, P. E., Villar, J. A. 1990. A survey on perinatal mortality in young mink. Veterinary Research Communications 14, 199-205.

Mason, G. 1994. Tail-biting in mink (*Mustela vison*) is influenced by the age at removal from the mother. Animal Welfare 3, 305-311.

Mayntz, D., Hunnicke Nielse, V., Sørensen, A., Toft, S., Raubenheimer, D., Hejlese, C., Simpson, S. J. 2009. Balancing of protein and lipid intake by a mammalian carnivore, the mink, *Mustela vison. Animal Behaviour 77, 349-355.*

Meagher, R., Bechard, A., Palme, R., Díez-León, M., Hunter, D. B., Mason, G. 2012. Decreased litter size in inactive female mink (*Neovison vison*): Mediating variables and implications of overall productivity. Canadian Journal of Animal Science 92, 131-141.

Meagher, R. K., Mason, G. J. Environmental enrichment reduces signs of boredom in caged mink. , PLoS ONE 7, 1-10.

Meagher, R. K., Campbell, D. L. M., Dallaire, J. A., Díez-León, M., Palme, R., Mason, G. J. 2013. Sleeping tight or hiding in fright? The welfare implications of different subtypes of inactivity in mink. Applied Animal Behaviour Science 144, 138-146.

Meagher, R. K., Dallaire, J. A., Campbell, D. L., Ross, M., Møller, S. H., Hansen, S. W., Díez-León, M., Palme, R., Mason, G. J. 2014. Benefits of a Ball and Chain: Simple Environmental Enrichments Improve Welfare and Reproductive Success in Farmed American Mink (Neovison vison). PLOS One 9. 1-14.

Melero, Y., Palazón, S., Bonesi, L., Gosàlbez, J. 2008. Feeding habits of three sympatric mammals in NE Spain: the American mink, the spottet genet, and the Eurasian otter. Acta Theriologica 53, 263-273.

Mononen, J., Møller, S. H., Hansen, S. W., Hovland, A. L., Koistionen, T., Lidford, L., Malmkvist, K., Vinke, C. M., Ahola, L. 2012. The development of on-farm welfare assessment protocols for foxes and mink: The WelFur project. Animal Welfare 21, 363-371.

Mustonen, A-M., Pyykönen, T., Aho, J., Nieminen, P. 2006. Hyperthermia and increased physical activity in the fasting American mink *Mustela vison*. Journal of Experimental Zoology 305 A, 489-498.

Mustonen, A-M., Pyykönen, T., Paakkonen, T., Ryökkynen, A., Asikainen, J., Aho, J., Mononen, J., Nieminen, P. 2005. Adaptions to fastening in the American mink (*Mustela vison*): carbohydrate and lipid metabolism. Comparative Biochemistry and Physiology Part A 140, 195-202.

Nielsen, V. H., Møller, S. H., Hansen, B. K., Berg, P. 2011. Response to selection and genotype-environment interaction in mink (*Neovison vison*) selected on ad libitum and restricted feeding. Canadian Journal of Animal Science 91, 231-237.

Nielsen, V. H., Møller, S. H., Hansen, B. K., Berg, P. 2012. Genetic parameters and effect of selection for body weight in lines of mink (*Neovison vison*) on ad libitum and restricted feeding. Acta Agriculturae Scand Section A 62, 24-28.

Newberry, R. C. 1995. Environmental enrichment: Increasing the biological relevance of captive environments. Applied Animal Behaviour Science 44, 229-243.

Olofsson, L., Hansen, S. W., Lidfors, L. 2014. Utvärdering av välfärden hos växande minkar hållna i grupp och parvis i etageburar. Slutrapport till Jordbruksverket.

Pedersen, V., Jeppesen, L. L. 2001. Effects of family housing on behaviour, plasma cortisol and performance in adult female mink (*Mustela vison*). Acta Agric. Scand Sect A Animal Science 51, 77-88.

Pedersen, V., Jeppesen, L. L., Jeppesen, N. 2004. Effect of group housing systems of behaviours and production performances in farmed juvenile mink (Mustela vison). Applied Animal Behavioural Science 88, 89-100.

Persson, S., Rotander, A., van Baveln, B., Brunström, B., Bäcklin, B. M., Magnusson, U. 2013. Influence of age, season, body condition and geographical area on concentrations of chlorinated and brominated contaminants in wild mink (Neovison vison) in Sweden. Chemosphere 90, 1664-1671.

Rattenborg, E., Chriél, M., Dietz, H. H. 1999. Influence of farm, feed-producer and season on incidence of gastrointestinal disorders in Danish farm mink. Preventive Veterinary Medicine 38, 231-237.

Rouvinen-Watt, K., Harris, L., Dick, M., Pal, C., Lei, S., Mustonen, A-M., Nieminen, P. 2012. Role of hepatic *de novo* lipogenesis in the development of fasting-induced fatty liver in the American mink (*Neovison vison*). Brittish Journal of Nutrition 108, 1360-1370.

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Skrede, A., Nes, I. F. 1988. Slaughterhouse by-products preserved by *Lactobacillus plantarum* fermentation as feed for mink and foxes. Animal Feed Science 20, 287-298.

Sibbald, I. R., Sinclair, D. G., Evans, E. V., Smith. D. L. T. 1962. The rate of passage of feed through the digestive tract of the mink. Canadian Journal of Biochemistry and Physiology, 40(10). 1391-1394.

Svendsen, P. M., Hansen, B. K., Malmkvist, J., Hansen, S. W., Palme, R., Jeppesen, L. L. 2007. Selection against stereotypic behaviour may have contradictory consequences for the welfare of farm mink (*Mustela vison*). Applied Animal Behavioural Science 107, 110-119.

Svendsen, P. M., Palme, R., Malmvist, J. 2013. Novelty exploration, baseline cortisol level and fur-chewing in farm mink with different intensities of stereotypic behaviour. Applied Animal Behavioural Science, 147. 172-178.

Sørensen, B., Clausen, T. N., Wamberg, S., Hansen, O. 2001. Physiological changes in mink (*Mustela vison*) dams subject to weaning at different times during lactation. Acta Agricultural Scandinave Section A, Animal Science 51, 148-154.

Thom, M. D., MacDonald, D. W., Mason, G. J., Pedersen, V., Johnson, P. J. 2003. Female American mink, Mustela vison, mate multiply in a free-choice environment. Animal Behaviour 67, 975-984.

Vhile, S. G., A. Skrede, A., Ahlstrøm, Ø., Hove, K. 2005. Comparative apparent total tract digestibility of major nutrients and amino acids in dogs (*Canis familiaris*), blue foxes *(Alopex lagopus*) and mink (*Mustela vison*). Animal Science, 81. 141-148.

Vinke, C. M., Bos Van Den, R., Spruijt, B. M. 2004. Anticipatory activity and stereotypical behaviour in American mink (*Mustela vison*) in three housing systems differing in the amount of enrichments. Applied Animal Behavioural Science 89, 145-161.

Wamberg, S., Tauson, A-H. 1998. Daily milk intake and body water turnover in suckling mink (*Mustela vison*) kits. Comparative Biochemistry and Physiology Part A 119, 931–939.

Wise, M. H., Linn, I. J., Kennedy, C. R. 1981. A comparison of the feeding biology of Mink *Mustela vison* and otter *Lutra lutra. Journal of Zoology 195, 81-213.*

Zhng, H. H., Jiang, Q. K., Sun, W. L., Xu, C., Cong, B., Yang, F. H., Li, G. Y. 2013. Effects of different dietary protein levels and DL-methionine supplementation on hair growth and pelt quality in mink (*Neovison vison*). Journal of Animal Physiology and animal nutrition 97. 1036-1042.

Zschille, J., Stier, N., Roth, M. 2010. Gender differences in activity patterns of American Mink *Neovison vison* in Germany. European Journal of Wildlife Research 56, 187-194.

Zschille, J., Stier, N., Roth, M., Mayer, R. 2012. Feeding habits of invasive American mink (*Neovison vison*) in northern Germany – potential implications for fishery and waterfowl. Acta Theriol 59, 25-34.

Appendix 1

Visualization of recorded behaviours in a time line for group housed mink. Each animal´s behaviours are recorded mutually exclusive. Feed status is a state-stop event without subject.


Relative Time
12:00:00,83 (HH:mm:ss,ff)
Results <Missing Subject>
Feed status
Feed avaible
Results Male
Behaviour
Nest
Social interaction
Easting
Active in cage
Resting in cage
Results Female II
Behaviour
Nest
Social interaction
Easting
Active in cage
Resting in cage
Results Female
Behaviour
Nest
Social interaction
Easting
Active in cage
Resting in cage


Relative Time
11:53:49,97 (HH:mm:ss,ff)
Results <Missing Subject>
Feed status
Feed avaible
Results Male
Behaviour
Nest
Social interaction
Easting
Active in cage
Resting in cage
Results Female II
Behaviour
Nest
Social interaction
Easting
Active in cage
Resting in cage
Results Female
Behaviour
Nest
Social interaction
Easting
Active in cage
Resting in cage


Relative Time
11:55:10,60 (HH:mm:ss,ff)
Results <Missing Subject>
Feed status
Feed avaible
Results Male
Behaviour
Nest
Social interaction
Easting
Active in cage
Resting in cage
Results Female II
Behaviour
Nest
Social interaction
Easting
Active in cage
Resting in cage
Results Female
Behaviour
Nest
Social interaction
Easting
Active in cage
Resting in cage


Relative Time
12:00:00,46 (HH:mm:ss,ff)
Results <Missing Subject>
Feed status
Feed avaible
Results Male
Behaviour
<Initial Behaviour>
Nest
Social interaction
Easting
Active in cage
Resting in cage
Results Female II
Behaviour
<Initial Behaviour>
Nest
Social interaction
Easting
Active in cage
Resting in cage
Behaviour
<Initial Behaviour>
Nest
Social interaction

Appendix 2

Visualization of recorded behaviours in a time line for pair housed mink. Each animal´s behaviours are recorded mutually exclusive. Feed status is a state-stop event without subject.


Relative Time
12:01:36,82 (HH:mm:ss,ff)
Results <Missing Subject>
Feed status
Feed avaible
Results Male
Behavior
<Initial Behavior>
Nest
Social interaction
Eating
Active in cage
Resting in cage
Results Female
Behavior
<Initial Behavior>
Nest
Social interaction
Eating
Active in cage
Resting in cage


Relative Time
12:04:49 (HH:mm:ss)
Results <Missing Subject>
Feed status
Feed avaible
Results Male
Behavior
<Initial Behavior>
Nest
Social interaction
Eating
Active in cage
Resting in cage
Results Female
Behavior
<Initial Behavior>
Nest
Social interaction
Eating
Active in cage
Resting in cage


Relative Time
12:01:38,15 (HH:mm:ss,ff)
Results <Missing Subject>
Feed status
Feed avaible
Results Male
Behavior
<Initial Behavior>
Nest
Social interaction
Eating
Active in cage
Resting in cage
Competing over feed
Results Female
Behavior
<Initial Behavior>
Nest
Social interaction
Eating
Active in cage
Resting in cage

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