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IMPACT OF NOISE ON EUROPEAN MINK (*MUSTELA LUTREOLA*) BEHAVIOUR

MÜRA MÕJU EUROOPA NAARITSA (*MUSTELA LUTREOLA*) KÄITUMISELE

Final Thesis
Curriculum in Animal Science

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Antropogeenne müra põhjustab paljudel loomadel terviseprobleeme. Kasvava linnastumise tõttu on müra mõju elusorganismidele eriti aktuaalne teema. Eriti oluline on välja selgitada müra mõju ohustatud liikidele, nagu euroopa naaritsale, kelle loodusliku asurkonna ellujäämine sõltub tehiskeskkonna populatsiooni paljunemise edukusest, mida omakorda mõjutavad vangistuses olevad keskkonnatingimused. Käesoleva uuringu eesmärk oli välja selgitada, kas ja kuidas mõjutab avalikel üritustel tekkiv müra euroopa naaritsa käitumist ja aktiivsusmustreid. Uurimuses analüüsiti 14 isaslooma käitumist Tallinna loomaaias. Vaatlusperiood oli jagatud neljaks ööks enne üritust (kontrollperiood), kaheks ööks ürituse ajal (kõrge müra periood) ja neljaks ööks pärast üritust (taastumisperiood). Kõik analüüsid viidi läbi RStudio keskkonnas kasutades lineaarset segamudelit. Tulemused näitasid, et müra ajal võib jälgida märgatavat stereotüüpilise käitumise langust. Üleüldine aktiivsus oli kõige madalam päevadel peale müraepisoodi. Selle järgi saab järeldada, et euroopa naaritsa käitumine muutub kokkupuutel müraga ning mõjud on nii vahetud kui hilinenud. Saadud tulemused pakuvad aluse ja toimivad lähtepunktidena euroopa naaritsa tulevastele teadusuuringutele.			
Võtmesõnad: inimtekkeline heli, heaolu, liigikaitse, loomaaed			

Estonian University of Life Sciences

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Due to increasing urbanisation, the impact of noise on living organisms can be a major welfare issue. It has been shown that anthropogenic noise can cause health problems in many animals. Particularly important is to define the impact of noise to endangered species such as the European mink, whose wild population survival is highly influenced by the successful reproduction of the captive population, which in turn is influenced by the environmental conditions of artificial environment. The aim of this bachelor's thesis was to examine whether noise exposure during public events affects the behaviour and activity patterns of captive European mink. This research was conducted on 14 adult male European mink. The observation period was divided into four nights before the event (control period), two nights during the event (high noise period), and four nights following the event (recovery period). All analyses were performed within the RStudio environment, using a linear mixed model. The results indicated that stereotypic behaviour decreased significantly during noisy event. Total activity declined in the days after the event. Accordingly, the event had a significant delayed impact on the activity, and it suggests that noise exposure not only decreases movement in general, but it could also inhibit adaptive behaviour by temporarily suppressing stereotypical behaviours. The obtained results provide a foundation for future research on the European mink.

Keywords: anthropogenic sound, welfare, conservation, captivity

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GLOSSARY

ACTH — adrenocorticotropic hormone

AHD — acoustic harassment devices

ANOVA — analysis of variance

CCTV — closed-circuit television

DNA — deoxyribonucleic acid

FCM — faecal cortisol metabolite

FSH — follicle-stimulating hormone

IUCN — International Union for the Conservation of Nature and Natural Resources

LH — luteinising hormone

PTS — permanent threshold shift

ROS — reactive oxygen forms

SD — standard deviation

TTS — temporary threshold shifts

WHO — World Health Organization

INTRODUCTION

According to the World Health Organization, the occurrence of anthropogenic noise in aquatic and terrestrial ecosystems has made it one of the most dangerous forms of pollution (WHO, 2007). Construction and traffic are among the many human activities that produce loud sounds that are not a part of our communication systems. Anthropogenic noise has been shown to have negative effects on humans (Matheson *et al.*, 2003; Hammer *et al.*, 2014; Mohamed *et al.*, 2021), but it was only recently that it was realized that noise could also affect wildlife, which has led to several experimental studies (Francis *et al.* 2013; Harding *et al.*, 2019; Jerem *et al.*, 2020; Duquette *et al.*, 2021). It has now been established that high noise levels can adversely affect the well-being of both humans and other animals even with extremely brief periods of exposure (WHO, 2007; Kok *et al.*, 2023). Recent meta-analyses have demonstrated that noise pollution negatively affects a broad variety of taxonomic groups, including amphibians, arthropods, birds, fish, mammals, molluscs, and reptiles (Kunc & Schmidt, 2019; Duquette *et al.*, 2021). This demonstrates that a broad variety of animal species is affected by noise, which may have significant ecological consequences (Blickley *et al.*, 2010; Shannon *et al.*, 2016; Forney *et al.*, 2017; Wang *et al.*, 2022). Visitors, maintenance work and nearby events can all cause anthropogenic noises that are often heard in captive settings, such as zoos (Maia *et al.*, 2012; Kunc & Schmidt, 2019; Pelletier *et al.*, 2020; Salma *et al.*, 2024). Stress-related challenges may arise from the periodic exposure of these animals to intense or sudden sounds (Orban *et al.*, 2017; Pelletier *et al.*, 2020). While the effect of noise on wildlife has only recently begun to be studied systematically, a growing body of controlled experimental work has started to shed light on this phenomenon (Morgan & Tromborg, 2007). Unfortunately, geographical, and taxonomic biases remain, with most research concentrating on birds and aquatic mammals in North America and Europe, or on clades that are viewed as charismatic megafauna, including primates and ungulates (Melfi, 2009; Shannon *et al.*, 2016; Jerem & Mathews, 2020). This has created significant gaps in our knowledge regarding how less-studied groups, like for example small terrestrial carnivores, are impacted by noise pollution (Shannon *et al.*, 2016; Kunc & Schmidt, 2019).

The European mink (*Mustela lutreola*) is a small, semi-aquatic mammal. According to the IUCN Red List it is a critically endangered species, and despite conservation efforts their numbers are still declining in the present day (Maran *et al.*, 2016; IUCN, 2016).

Conservation efforts, such as captive breeding and reintroduction programs, have played a crucial role in maintaining and restoring mink populations (Amstislavsky *et al.*, 2008; Harrington *et al.*, 2014; Kiseleva, 2018). One of the many institutions actively involved in the conservation of this species is Tallinn Zoo, which houses the largest European mink captive population (100-120 animals) under controlled conditions, to support breeding and reintroduction (Kiik *et al.*, 2016).

These small carnivores contend with numerous challenges both in the wild and in captivity (Clubb & Mason, 2003; Mason & Rushen, 2006; Kroshko *et al.*, 2016). Among the factors influencing their behaviour and well-being, environmental noise has emerged as a concern, particularly in zoo settings where anthropogenic sounds are prevalent (Kight & Swaddle, 2011). For small carnivores such as the European mink, excessive noise may lead to modified behavioural patterns and cause stress (Ortiz-Jiménez *et al.*, 2021; 2022). Actions without stereotypical behaviour, also known as normal behaviours, vary across species and include actions animals naturally perform in the wild or under enriched conditions (Bracke *et al.*, 2006), whereas stereotypic actions are repeated, unchanging, and futile actions (Ridley, 1994).

As Ortiz-Jiménez *et al.* (2022) reported, the activity of male European mink decreases, and faecal cortisol metabolite (FCM) levels increase during exposure to human voice, suggesting increased stress. Therefore, it is expected that noisy events, such as the Ironman triathlon, conducted close to the Zoo area, could also have an impact on the behaviour of European mink by decreasing activity and increasing stress-related behaviours.

The results of this work will improve the understanding of the impact of noise on the behaviour of European mink in zoos. Behavioural data helps to identify potential welfare issues. Research was conducted using data, which were collected and provided to the author by Tallinn Zoo, and research was written using APA 7th edition reference system.

The interest in this topic was prompted by the author's deep interest in animal welfare and behavioural responses to environmental stressors. The primary objective of this thesis was to examine whether noise exposure during public events affects the behaviour and activity patterns of captive European mink. It is hypothesized that anthropogenic noise during events conducted nearby, influences activity level and the proportion of stress related behaviours, like stereotypy in the European mink.

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1. LITERATURE REVIEW

1.1. Impact of noise exposure on living organisms

1.1.1. Noise pollution as an environmental stressor

Chronic or frequent noise exposure can alter animal behaviour, physiology, and species interactions, potentially leading to community-level changes (Kok *et al.*, 2023). The term "noise" is used to describe unwanted sound that is either chronic or intermittent and can be classified by its frequency, intensity, frequency spectrum, and sound pressure shape over time (Burn, 2008). According to the World Health Organization (WHO), noise is the second highest environmental stressor from the public health perspective (WHO, 2007). Since the Industrial Revolution, there has been a marked increase in anthropogenic noise that significantly alters the acoustic environment, both in terms of sound exposure and geographical extent (Kok *et al.*, 2023). The rise in noise pollution has been driven by population growth, mechanization, infrastructure development and increasing demand for resources (Barber *et al.*, 2010). Anthropogenic noise, specifically, has been acknowledged as a major global pollutant that has considerable implications for human health (Matheson *et al.*, 2003; Hammer *et al.*, 2014; Mohamed *et al.*, 2021) and the behaviour, physiology and fitness of wildlife (Barber *et al.*, 2010, Templeton *et al.*, 2024). Research on this topic has increased over the past decade (Francis *et al.*, 2013; Harding *et al.*, 2019; Jerem *et al.*, 2020; Duquette *et al.*, 2021). However, the majority of research focuses on aquatic mammals and birds in North America and Europe (Paul & Mathews, 2020) or groups of charismatic species, such as primates and hoofed animals (Melfi, 2009), implying that geographical and taxonomic biases exist.

Research has shown that noise pollution can cause stress responses and impairments in auditory processing, which can also interfere with cognitive processes in animals (Potvin, 2017). It has also been suggested that noise affects vocalization by covering and inhibiting animal sounds (Shannon *et al.*, 2016). Bottlenose dolphins (*Tursiops truncatus*) exposed to frequent noise exhibited increased whistle duration and amplitude, yet their cooperative task success decreased, indicating their impaired communication (Sørensen *et al.*, 2023). Noise pollution forces animals, particularly birds, to increase their minimum frequency of calls, while other vocal parameters such as amplitude and duration remain largely unchanged

(Duquette *et al.*, 2021). Call rate in *anuran* amphibians was reduced when frequently exposed to various sources of human-made airborne noise, such as airplane and road traffic noise, affecting mate selection and social behaviours (Zaffaroni-Caorsi *et al.*, 2022). Japanese pipistrelle bats (*Pipistrellus abramus*) showed reduced foraging activity near airports due to noise interference, which decreased the quantity of their feeding buzzes and altered echolocation by adjusting parameters such as pulse duration, peak frequency, and bandwidth (Wang *et al.*, 2022).

Moreover, noise does not only impact the auditory system but can also play a part in population decline (Blickley *et al.*, 2010). For example, communication difficulties from noise pollution can force marine mammals to migrate from their habitats, which may lead to increased stress and reduced foraging success (Forney *et al.*, 2017). Terrestrial mammals showed the same behaviour patterns as marine mammals. For example, the presence of mule deer (*Odocoileus hemionus*) in noisy areas was reduced due to noise's influence on habitat use (Kleist *et al.*, 2020).

1.1.2. Behavioural changes influenced by anthropogenic noise

Anthropogenic noise disrupts key animal behaviours related to predator defence, reproduction and, in some cases, feeding (Bruintjes & Radford, 2013). Birds in urban and natural gas field settings experienced altered predator–prey interactions and, in one instance, reduced hatching success, with noise amplitude affecting nesting behaviour (Francis *et al.*, 2009). In controlled and field studies, boat, ship, and compressor engine sounds reduced antipredator performance in a range of different species. For instance, Princess cichlids (*Neolamprologus brichardi*) exposed to boat noise showed less defensive behaviour towards predators, and European eels (*Anguilla anguilla*) exposed to ship noise were 50% less likely to startle and were 25% slower to react, increasing their vulnerability (Bruintjes & Radford, 2013). Disrupted feeding behaviour has been observed in shore crabs (*Carcinus maenas*), where ship noise delayed retreat from shelter, suggesting an increased risk of starvation (Wale *et al.*, 2013).

Diurnal species tend to exhibit more pronounced behavioural changes than nocturnal species (Queiroz *et al.*, 2018). For example, daytime activity in birds such as the great tits (*Parus major*) can decrease due to noise (Dominoni *et al.*, 2019). Moreover, elevated noise levels led to greater daytime activity and less vigilance and engagement among individuals during

nights following noisy days in nocturnal canids such as crab-eating foxes (*Cerdocyon thous*). Which can potentially lead to a reversal of the nocturnal habits of animals into daily ones, this change in habits can impact the welfare of captive animals by increasing their stress response (Marques *et al.*, 2024). With noise pollution becoming a growing ecological concern, it becomes important to examine how it impacts animals not only behaviourally but also physiologically.

1.1.3. Impact of noise on health

Exposure to noise may have both short-term and long-term effects on the auditory system. It can reduce hearing sensitivity for a short time or, in more severe cases, lead to permanent hearing damage, known as permanent threshold shifts (PTS) (Marler *et al.*, 1973; Blickley *et al.*, 2010). For human beings, noise levels above 70 dB(A) are considered dangerous for their well-being (WHO, 1999).

Due to the variety of species, finding a single noise level limit for all species is impossible. Different species can have different responses to noise based on intrinsic factors, such as body size and personality, as well as extrinsic factors, such as environmental context and prior exposure (Harding *et al.,* 2019). For example, it was proven that large birds hear lower frequencies better, whereas, small birds, like songbirds (*Oscen*), can better hear higher frequencies (Dooling *et al.*, 2000; Gleich *et al.*, 2005), showing that body size can influence the impact of noise (Engel *et al.*, 2024). Due to this, smaller species, which use higher-frequency signals, persist even in noisy areas, while larger birds with lower-frequency vocalizations tend to avoid them (Francis *et al.*, 2011). That is because variation in body size affects responses to environmental stressors due to fundamental differences in physiological mechanisms, morphology, and behaviour (Ortiz-Santaliestra *et al.*, 2006; Pörtner & Knust, 2007; Skinner, 2015; Harding *et al.*, 2019). A meta-analysis showed that noise pollution triggers responses across a wide range of animal groups, such as amphibians, arthropods, birds, fish, mammals, molluscs, and reptiles. Proving that noise sensitivity is widespread and not limited by evolutionary relationships (Kunc & Schmidt, 2019).

Noise can affect health; environmental noise increases the number of free radicals that can cause carcinogenic mutations (Samson *et al.*, 2005). Stress caused by noise can also increase the level of cochlear reactive oxygen forms (ROS), which damages DNA, proteins, and lipids (Ohlemiller *et al.*, 1999; Purnami & Manyakori, 2018). When mice (*Mus musculus*)

were exposed to loud prolonged sounds, 110 dB broadband noise, they experienced an increase of ROS levels that remained high for at least one to two hours after the event (Ohlemiller *et al.*, 1999). ROS-induced damage was also found in the adrenal glands (Frenzilli *et al.*, 2004) and the hearts (Lenzi *et al.*, 2003) of noise-stressed rats (*Rattus norvegicus*). Studies examining how environmental noise impacts genetics are still in their early stages (Guo *et al.*, 2017; Kok *et al.*, 2023; Templeton, 2024). Significant knowledge gaps remain, particularly regarding long-term exposure effects on nocturnal and crepuscular species (Jerem & Mathews, 2020).

1.1.4. Impact of noise on reproductive health

Chronic noise will cause the release of stress hormones, leading to altered corticosterone levels in birds, which can affect fitness and reproductive success (Kleist *et al.*, 2018). The effects of noise on animals can vary depending on factors such as exposure duration, with responses including increased stress hormonal production and elevated heart rates (Kight *et al.*, 2011; Broucek *et al.*, 2014). In carnivores, chronic stress in turn can lead to enhanced concentrations of adrenocorticotropic hormone (ACTH) and glucocorticoids (Young, 2004), which can result in the reduction of reproductive functions and suppression of the immune system (Kanitz, 2004).

In humans, female workers who were exposed to noise of approximately 85 dB during more than eight-hour shifts, did have menstrual disturbances, shortened gestation and their newborn children had lower birth weights (Nurminen *et al.*, 1995). In rodent species, such as mice (*Mus musculus*), the intensity and duration of noise was found to have a statistically significant effect on reproductive hormones (Nawrot *et al.*, 1980). Noise caused a significant decrease in the fertility of male rats. Rodents (*Mus musculus* and *Rattus norvegicus*) that were exposed to sound around 100 dB for 10–90 days had altered levels of both follicle-stimulating hormone (FSH) and luteinising hormone (LH) and lower serum testosterone (Fathollahi *et al.*, 2013; Dzhambov & Dimitrova, 2015). Severity of reduction in levels of testosterone depended on the duration of noise (Dzhambov & Dimitrova, 2015). When noise-exposed males mated with females, the pregnancy rate was clearly lower (16 females out of 24 became pregnant) compared to the control group (23 females out of 24 became pregnant). Moreover, the frequency of dead and/or absorbed foetuses in impregnated mates was 63% while the control group had 9% (Fathollahi *et al.*, 2013). Similar impact was also observed in other species, for example, it was found that environmental factors such as noise,

can cause the absence of ovarian cycles in female white rhinoceros (*Ceratotherium simum*). Authors suggested that it was also related to having higher variability in faecal corticoids, which coincides with increased stereotypical behaviour (Carlstead & Brown, 2005). However, more studies must be conducted in order to fully understand the impact of noise on reproductive systems of other animal groups.

1.2. Impact of noise on captive animals

Many species react to sound, indicating that it is not just a few of them that are highly sensitive, highlighting the need for effective methods to reduce noise pollution (Kunc & Schmidt, 2019). Noise has been shown to have a significant impact on animals in the wild, which indicates that there is a high probability that the impact of noise on captive animals is even larger. Because in the artificial environment animals have fewer ways to escape from negative stimuli, such as noise.

The primary cause of sound pollution within zoos is due to anthropogenic sources such as visitor interaction (Pelletier *et al.*, 2020; Salma *et al.*, 2024). Increasing visitor numbers, particularly during weekends and holidays, can lead to higher noise levels that can exceed WHO limits (Salma *et al.*, 2024). Since the 1970s, studies on captive animal welfare, assessing visitor effects including visual and olfactory cues, have increased (Williams *et al.*, 2023).

Especially in zoo settings, noise from human activities and visitor events can impact animal behaviour. Studies on orangutans (*Pongo pygmaeus*) (Birke, 2002) and white-crowned mangabeys (*Cercocebus atys lunulatus*) (Fragata, 2010) found that increased visitor noise and activity levels led to more visitor directed behaviours, which could be either affiliative or aggressive. Orangutans used paper sacks to cover their heads more during high visitor density periods, while infants held onto adults more frequently (Birke, 2002). Gorillas (*Gorilla gorilla*), exhibit increased restlessness and reduced resting time during noisy events (Bastian *et al.,* 2020). In contrast, when visitors were present, almost all observed felids, except the female Eurasian lynx (*Lynx lynx*) were significantly more inactive compared to the baseline period (Spiezio *et al.*, 2023). Reduced locomotion and increased inactivity due to visitor generated noise was also observed in pumas (*Puma concolor*) (Maia *et al.*, 2012).

Behavioural responses to anthropogenic noise vary among species. For instance, raccoons (*Procyon lotor*), jackals (*Canis aureus*), tigers (*Panthera tigris altaica*) and Japanese cranes (*Grus japonensis*) were significantly more active when subjected to higher dB(A) levels and were less likely to be observed either resting or sleeping. Binturong (*Arctictis binturong*) and Amur leopards (*Panthera pardus orientalis*) were more likely to be inactive at higher dB(A), while porcupines (*Hystrix africaeustralis*) were significantly less active during exposure to higher dB(C) levels (Harley *et al.*, 2022). Loud anthropogenic noises led to increased behavioural signs of stress and elevated urinary or faecal glucocorticoid levels in captive giant pandas (*Ailuropoda melanoleuca*). The response of female giant pandas to noise was modulated by their reproductive condition, with greater sensitivity during estrus and lactation (Owen *et al.*, 2004). During higher anthropogenic noise Bornean sun bears (*Helarctos malayanus*) exhibit enhanced maternal care. Authors suggested that the increased maternal attentiveness is most likely to be linked with the mothers being more agitated by the presence of nearby activity, which led them to be more protective and attentive towards their cubs. Furthermore, on loud days there was a reduction in the percentage of time the mother spent feeding (Owen *et al.*, 2014).

It is thought that captive carnivores are particularly prone to exhibiting stereotypical behaviours compared to other animal groups (Mason & Rushen, 2006). Species with large home ranges, long daily travel distances, and extended chase distances during hunts are most susceptible to developing stereotypic route tracing, such as pacing (Clubb & Mason, 2003; Kroshko *et al.*, 2016). At lower dB(A) levels, the ocelot (*Leopardus pardalis*) showed significantly more abnormal behaviours, such as head twirling, and other stereotypic behaviours such as running repeatedly around the area of the enclosure. The ocelot was significantly less likely to be resting in the post-event period than during the event or pre-event (Monticelli *et al.*, 2022). Snow leopards (*Uncia uncia*) rested more and were less active during construction (Sulser *et al.*, 2008). Similar patterns have been observed in primates, where species with larger natural group sizes and longer day journey lengths show higher levels of stereotypic behaviours in captivity (Pomerantz *et al.*, 2013).

During exposure to construction noise heightened vigilance, increased locomotion, and stereotypical behaviours were observed in elephants (*Elephas maximus*), giraffes (*Giraffa camelopardalis*), and emus (*Dromaius novaehollandiae*) (Jakob-Hoff *et al.*, 2019). Giant pandas exhibited increased activity, stereotypic behaviour, and stress-related behaviours during the construction period. Cortisol levels in both observed pandas continued to increase

even after the demolition noises had ended, suggesting a delayed physiological response (Powell *et al.*, 2006). Mantled howler monkeys (*Alouatta palliata*) displayed increased physiological stress, when exposed to noise even at low levels (40 dB), such as construction noise, which was indicated by stress hormones in faecal samples, as well as behavioural changes such as increased vigilance and vocalization (Dias *et al.*, 2024). However, Bolivian gray titi monkeys (*Plecturocebus donacophilus*) exhibit less alarm calling and an ability to adapt to noise, demonstrating habituation to human activity noise (Hernani Lineros *et al.*, 2020).

Moreover, noise from public events has been linked to an increase in activity and a decrease in resting patterns in maned wolves (Monticelli *et al.*, 2022). The curassows' (*Cracinae*) resting frequencies were higher during the noisy event compared to the control conditions. Nevertheless, they were shorter and fragmented, and authors suggested that the rest had a lower quality despite the higher frequency of resting bouts (Monticelli *et al.*, 2022). In comparison, squirrel monkeys (*Saimiri sciureus*) were significantly more active during the event than in the pre-event period, while alpaca (*Lama pacos*) showed more resting behaviour during the event than in the pre-event period (Harley *et al.*, 2022). Fiordland penguins (*Eudyptes pachyrhynchus*) showed increased swimming and nesting behaviour during exposure to noise from music concerts, compared to their usual behaviour, while collared peccaries (*Pecari tajacu*) exhibited heightened vigilance (Fanning *et al.*, 2020).

The variation in behavioural responses when exposed to noise highlights the significance of considering factors such as noise source proximity, and the type of noise from visitor-generated to construction noise (Jakob-Hoff *et al.*, 2019).

1.3. Behaviour as an indicator of welfare in noisy environments

1.3.1. Importance of behaviour in assessing welfare

Welfare is viewed as the collective outcome of an animal's subjective experiences (Mellor & Beausoleil, 2015; Harvey *et al.*, 2022). It was shown that noise can change behaviour patterns in different species. Consequently, the question of whether these behavioural changes could be indicative of a threat to welfare arises. The European Union's animal welfare legislation is based on the Five Freedoms method as a foundational framework (European Commission, 2007). According to the Five Freedoms, animals must have freedom from: 1) thirst, hunger and malnutrition; 2) thermal and physical discomfort; 3) pain, injury

and disease; 4) fear and distress; 5) freedom to express normal behaviour (FAWC, 1993). The World Association of Zoos and Aquariums has approved the newer Five Domains Model as a framework for assessing welfare (Mellor *et al.*, 2015). The Five Domains Model is broken down into four physical or functional domains like nutrition, environment, health, and behavioural interaction (Mellor *et al.*, 2020), which form a fifth domain: the animal's mental state. This model is becoming more popular for assessing captive wildlife welfare in zoos and aquaria (Clegg *et al.*, 2015; Kagan *et al.*, 2015; Sherwen *et al.*, 2018; Ward *et al.*, 2020). The purpose of this method is to evaluate compromise in animal welfare. It was initially applied to animals used in research, teaching, and testing, and was refined by Mellor and Reid in 1994 to offer a more comprehensive, systematic, and detailed approach to assessing negative impacts on animal welfare. The handling of previous examples has demonstrated that noise has the potential to alter natural behaviours, which could jeopardize welfare by breaking the Five Freedoms and The Five Domains Model. However, in order to minimize the impact of noise on animal behaviour, researchers ought to accumulate comprehension of changes in behaviour in different species (Francis & Barber 2013; Kunc & Schmidt 2019).

1.3.2. Estimating mink behaviour through model species

In order to evaluate noise impact on European mink welfare, baseline behavioural patterns must be established (Pater *et al.*, 2009). The European mink, which is the focus of this study, displays a range of behavioural adaptations to potential threats (Ortiz-Jiménez *et al.*, 2021) and its behaviour is influenced by a variety of causes (Ortiz-Jiménez *et al.*, 2025). Molecular phylogenetic analyses have determined that the European polecat (*Mustela putorius*) is closely related to the European mink, leading some to question their separate species status (Davison *et al.*, 1999; Marmi *et al.*, 2004; López-Giráldez *et al.*, 2005). Moreover, history and genetic analysis support the proposition that ferrets (*Mustela furo*) were bred from the European polecats and from steppe polecats (*Mustela eversmannii*) (Davison *et al.,* 1999; Kurose *et al.*, 2000). Based on those two facts the research on ferrets can be used to better comprehend the natural behaviour of the European mink. Ferrets share critical physiological and behavioural traits that relate to noise sensitivity, making this surrogate species approach methodologically justified (Caro & O'Doherty, 1999). Even though European mink and ferrets are not exactly the same, knowledge of ferret behaviour can be used to help spot unusual reactions in European mink when they are exposed to loud noises. This is useful

because there is very little detailed and controlled information about how European mink normally behave.

Ferrets exhibit natural behaviours such as exploration, foraging, and den-living, with breeding seasons influenced by daylight (Vinke *et al.*, 2021). Researchers carried out tests to measure motor skills, social interactions, memory, and depressive-like behaviours in adult male ferrets to establish baseline behaviours. Behaviour outcomes were significantly influenced by age, with younger ferrets showing slight differences compared to older groups (Obasa *et al.*, 2022). Character of domestic ferrets can be described by four personality dimensions: Extraversion, Sociability, Attentiveness, and Neuroticism. Female ferrets were rated as overall less sociable than males, which could be related to a further finding that they are also more neurotic than males (Talbot *et al.*, 2021).

1.3.3. Stereotypical behaviour in European mink

One of the indicators of animal welfare is stereotypic behaviour. The term is used to describe behaviour patterns that are repetitive and invariant but have no clear purpose. Different species exhibit different stereotyped behaviours (Mason & Rushen 2006; Arney, 2018; Lewis *et al.*, 2022). Due to this, in order to assess impacts of noise on animal behaviour, researchers have to accumulate the recording and analysis of changes in behaviour in different species (Francis & Barber, 2013; Kunc & Schmidt, 2019).

To identify stereotypical behaviour in European mink, it could be helpful to examine the documented stereotypical behaviour of closely related species, such as American mink (*Neogale vison*). Mink stereotypical behaviours are diverse, with distinct triggers and treatments for each subtype. For example, scrabbling, a form of stereotypical behaviour, is uniquely directed towards nearby conspecifics and can be reduced by removing neighbours (Polanco *et al.,* 2018). Stereotypic behaviour in mink has moderate heritability and can be reduced through selective breeding. However, selecting for reduced stereotypic behaviour may lead to increased body weight, decreased litter size, as well as, removing mechanisms for coping with stress (Hansen *et al.*, 2009). Providing enriched nesting materials and chewable toys reduces stereotypic behaviour and improves nest building in American mink dams (Clark *et al.*, 2025). Mink without any apparent abnormal behaviour showed more investigative sniffing behaviour compared to mink with abnormal behaviours. Moreover,

providing access to a running wheel reduced almost all forms of stereotypic behaviour in the mink, the only exception being licking stereotypies (Malmkvist *et al.*, 2024).

1.4. Noise impact on mustelids

The preferred way to assess animal welfare is often by analysing their behaviour (Dawkins, 2004; Rutherford *et al.*, 2004; Wechsler, 2007; Arney, 2018). One of the most easily observed indicators of animal welfare is behaviour, as it provides information about the animal's needs, preferences, and internal states (Dawkins, 2004). For each species, normal and abnormal behaviour, as well as their durations differ. To gain a better understanding of the behavioural patterns of the European mink during noise exposure, previous research papers on this topic were reviewed. During this literature search process, it was discovered that there is a lack of studies regarding this topic, and it was chosen to examine the research papers on multiple species of the *Mustelidae* family. Consequently, this study takes the wider *Mustelidae* family as its reference point.

The *Mustelidae* family comprises 62 species spread across 23 genera and 8 subfamilies, can be found and is native worldwide except in Australasia and Antarctic. The European mink is part of the *Mustelinae* subfamily, which consists of 18 various species (Encyclopedia Britannica, 2025).

In the European pine marten (*Martes martes*) glucocorticoid stress hormone levels increased significantly with increased tourist pressure (Barja *et al.*, 2007). During higher dB(A) levels tayra (*Eira barbara*) were less likely to be inactive, while Asian small-clawed otters (*Aonyx cinereus*) showed no significant changes in their behaviour (Harley *et al.*, 2022).

Eurasian otters (*Lutra lutra*) showed behavioural changes, such as increased diving time and difficulty extracting food, in response to both low (1 kHz) and high (14 kHz) frequencies of sounds emitted by acoustic harassment devices (AHD). Even relatively low-intensity AHD sounds (40-80 dB) can affect otter behaviour, which is concerning given that commercial AHDs typically use much higher sound levels (Stepien *et al.*, 2024). In captivity, Asian small-clawed otters are impacted by human presence, and the absence of visitors leads to increased activity and social behaviour (Rossi *et al.*, 2020).

In controlled settings, European polecats, ferrets, and their hybrids responded to rustling noise with attention responses. The attention response has been employed as a method of determining alertness or environmental awareness in a behavioural sense. Polecats habituated rapidly to the noise stimulus, while ferrets maintained attention longer, and hybrids showed an intermediate pattern that depended on their previous experience of either indoor or outdoor housing. Ferrets have also been found to habituate more slowly to repeated auditory stimuli than polecats (Poole, 1972). Furthermore, ferrets demonstrated slower habituation to repeated auditory stimuli compared to polecats (Poole, 1972; Ma *et al.*, 2010).

Adult ferrets who were harmed by mild acoustic trauma developed long-term, frequency-specific impairments in their auditory behaviour and brainstem activity (Milinski, 2024). Gap-detection quantifies a listener's ability to detect a brief temporal separation between two marker stimuli, or an interval of silence embedded in an ongoing stimulus. Sensitivity to the presence of a gap is thought to be important for processing natural stimuli (Buss *et al.*, 2017). Using trained detection tasks, ferrets were tested to measure their behavioural responses to a rustling noise, assessing their ability to distinguish silent gaps or silence from noise, which could be influenced by tinnitus (Gold *et al.*, 2015). Tinnitus that is caused by noise can also disrupt sleep patterns in ferrets. Which is important when assessing the chronic effect of noise as it impacts the welfare in a longer period of time (Milinski, 2024). Domesticated ferrets generally have broader auditory filter widths than those of other mammals, averaging 21% of the signal frequency (Alves-Pinto *et al.*, 2016). Ferrets demonstrate poorer gap-detection sensitivity for low-frequency noise than for high-frequency or broadband stimuli like white noise (Gold *et al.*, 2015).

Adult female American mink has a broad hearing range from 1 kHz to above 70 kHz, with peak sensitivity at 8–10 kHz which indicates that mink can detect a wide range of frequencies, making them potentially sensitive to environmental noise disturbances. For example, noise can affect negatively mothers during delivery, impacting kit survival and welfare (Brandt *et al.*, 2013).

Human-related disturbances, trigger more extreme stress responses, compared to natural threats such as predator scents. Individuals that were exposed to anthropogenic noise, like noise from road traffic and human voices exhibited increased hiding adaptation behaviour, spending 18-25% more time concealed and reduced vigilance time by 30-40% compared to control conditions. Such adaptive behaviours are especially typical in female and juvenile

animals, demonstrating the intense effect of human disturbances (Ortiz-Jiménez *et al.*, 2021). Males spent more time on locomotor activity during noise exposure. Faecal cortisol metabolite levels slightly increased in mink exposed to short-duration/low-intensity road traffic noise and significantly increased in mink exposed to long-duration/high-intensity human voices. The authors suggested that human voices trigger more pronounced responses than road noise. Exposure to anthropogenic noises, especially human voices, also decreased the locomotor activity of European mink, with short-duration/low-intensity noises causing a more pronounced decrease than long-duration/high-intensity noises (Ortiz-Jiménez *et al.*, 2022).

Even though there have been reports of noise influence on the behaviour of the European mink, there are only a few studies on the general impact of noise on this specific species. Additionally, no studies have yet investigated the specific impact of public events on European mink. The lack of data makes it challenging to understand exactly what causes and what consequences noise related events have for this specific species. Due to this, further research in this area is required.

1.5. Measuring behaviour

Behaviour has a temporal component, it unfolds over time and is often complicated because patterns are difficult to represent with a single number or metric (Drummond, 1981; Bateson & Martin, 2021). Due to this, unlike usual systematic measurements with results in numerical form, measuring behaviour involves a qualitative approach. The qualitative research would define a set of behaviours such as aggressive, stereotypical, normal, etc. Following then with counting the occurrences of these behaviours observed in a specified time period (Bateson & Martin, 2021).

One of the most important tools in animal behaviour studies, is the ethogram, which Banks (1982) defines as a detailed catalogue of behaviours typical for a given species. An ethogram is created based on the analysis of the species' normal behaviour. When observing animals for a long time, it is important to pay attention to not only types of behaviours like normal or stereotypical behaviour but also to the durations of the behaviours, especially if the duration is extended (Ross, 2013; Arney, 2018). For instance, sleep is a natural behaviour, but by comparing the time spent sleeping throughout the day with the expected sleeping duration, we can assess welfare in different situations (Visser *et al.*, 2008). However,

ethograms are not available for most species and differ by species' age and sex (Ross, 2013; Arney, 2018).

The choice of sampling method is crucial in research design and depends on the aim and question of the research as well as the number of species studied (Setia, 2016; Berndt, 2020). In this research, animal behaviour was recorded using scan sampling as the primary method. Scan sampling involves the observer recording, at fixed intervals, the daily behaviour of every visible member of a group (Van Belle, 2017). Scan sampling can be a viable alternative for continuous sampling (Winchell & Kunz, 1993; Van Belle, 2017). Mainly because continuous recording requires uninterrupted monitoring and documentation of all behavioural events. When dealing with multiple individuals or long observation periods, continuous recording provides an exact record of behaviour but is more time consuming than scan sampling (Bateson & Martin, 2021; Tesar *et al.*, 2023). It has been shown that scan sampling with short intervals (1-15 minutes) can provide results comparable to continuous sampling for a range of behaviours in different species (Pullin *et al.*, 2017; Tesar *et al.*, 2023; Moest *et al.*, 2023). For example, a five-minute sampling interval accurately estimates lying, feeding, and standing behaviours for lambs (*Ovis aries*) (Pullin *et al.*, 2017). Additionally, a five-minute sampling interval gave similar results to continuous monitoring when used to measure the posture of newly weaned sows (*Suidae*) (Moest *et al.*, 2023). For broiler hens (*Gallus gallus domesticus*) the one-minute intervals were accurate for active, inactive, eating, and maintenance behaviours (Ross *et al.*, 2019). This indicates that scan sampling method allows the optimization of the observation process without significant loss of data quality, especially in zoological studies (Pullin *et al.*, 2017; Ross *et al.*, 2019; Tesar *et al.*, 2023; Moest *et al.*, 2023).

2. MATERIALS AND METHODS

2.1. Study subjects and enclosures

The study was conducted on 14 adult male European mink. These European mink were captive born at the Estonian Species Conservation Research Lab at Tallinn Zoological Gardens. Tallinn Zoo houses the world's largest captive population of European mink (n = 100 to 120 animals). Research facility is not open to the public. Observed animals were individually housed in enclosures (2m × 4m × 2m) and had a nest box (34 cm × 25 cm × 27 cm). Each unit is equipped with a water pool (85 cm × 65 cm × 50 cm), and enrichment items such as branches, tubes, and similar structures to stimulate natural behaviours. The enclosures are outdoors and exposed to natural weather conditions. The enclosures are cleaned and animals fed once in the mornings.

2.2. Animal observation

The behavioural observations were conducted over a 10-night period, from August 19th to August 29th, 2024. The observation period was divided into four nights preceding the noise event (control period), two nights during the event (high noise period), and four nights following the event (recovery period). The control period lasted from 19th to 23rd of August. The Ironman triathlon, which was conducted near Tallinn Zoo, lasted for 3 days from 23rd to 25th of august (2 nights for behavioural observation).

From 25th to 29th were observed nights following the event. In consideration of ethical guidelines for the use of animals in research the behaviour was recorded with CCTV cameras.

Observations were made at regular intervals, and each mink was manually scored. Considering that the European mink is a nocturnal animal, behavioural observations were conducted at the peak of its activity, between 19:00 and 07:00. This timeframe was selected to reduce interference from zookeepers, whose presence after 07:00 influences mink behaviour due to feeding anticipation.

Behavioural data were recorded using scan sampling at five-minute intervals (Bateson & Martin, 2021). This method involved documenting one specific behaviour per individual at each interval, allowing for a close examination of activity pattern and response to environmental changes. The observed behaviours were categorized into an ethogram (Table 1). Behaviours were divided into two main types, actions without stereotypical behaviour and stereotypical behaviour. When the animal was out of view, like in the nestbox or inactive, such as laying still in the hammock, it was considered to be 'not active'. When the animal was not visible direct behavioural analysis was not performed as it was not possible to reliably define and categorize animal's behaviour.

Table 1. Ethogram of behaviours recorded during the study

Behaviour	Definition
Not active	Cannot see the animal/ Inactive
Active/ Action without stereotypical behaviour	Animal: Eats/ Drinks/ Defecates/ Urinates/ Looks around the surroundings/ Walks/ Swims/ Digs/ Scratches/ Rubs/ Vocalizes at neighbour/ Sniffs/ Plays/ Climbs/ Jumps/ Runs
Stereotypical behaviour	Actions which are repeated, unchanging, and futile. Repetitively pacing back and forth across different locations, such as the topmost edge of the enclosure, enclosure's floor, etc.

2.3. Statistical analysis

For one night each individual was observed 12 hours in every 5 minutes, altogether 145 times. For each night scans where the animal was stereotypic and just active (without being stereotypic) were summarized. For analysis were used proportion in percentage of scans of active and stereotypic over all scans in one night. Average value for each animal for control period, during the event and after the event was calculated for stereotypic behaviour and for activity. Also, from all active scans (with stereotypic scans) proportion of scans when animal was stereotypic was analysed separately.

The four nights before the event were given the abbreviation A, for the two days during the event were given the abbreviation B, and the four nights after the event were given the abbreviation C. The mink were handled separately to get an overview of each animal's general activity. The percentage of activity of the mink during the noisy event (B) was calculated using the behavioural recording on two nights during the event. Furthermore, the proportion of scans when the animal conducted stereotypic behaviours was calculated over all active scans.

Linear mixed effect model was used to determine if proportion of behaviours varied significantly between different groups (before, during and after the event).

All analyses were carried out in R (Version 4.0.5 for Windows) within the RStudio environment (Version 2024.12.1+563 for Windows). Residuals were visually inspected using diagnostic plots, including residuals vs. fitted values (Bates *et al.*, 2015), and Q-Q plots (Almeida *et al.*, 2019). A linear mixed-effect model was fitted using the *lme4* package (Bates *et al.*, 2015), to analyse the effect of time period (pre-event, during the event and after the event) on the behaviour (activity and stereotypy). Groups were used in the model as the primary predictor. Animal's id was as random intercept to account for repeated measures on an individual mink. We examined the changes of proportion of total activity; proportion of stereotypic behaviour of total activity; proportion of activity without stereotypic behaviour and proportion of stereotypy without active behaviour between different groups (before the event, during the event and after the event). Graphics were made using *flexplot* (Fife, 2019).

2.4. Usage of artificial intelligence

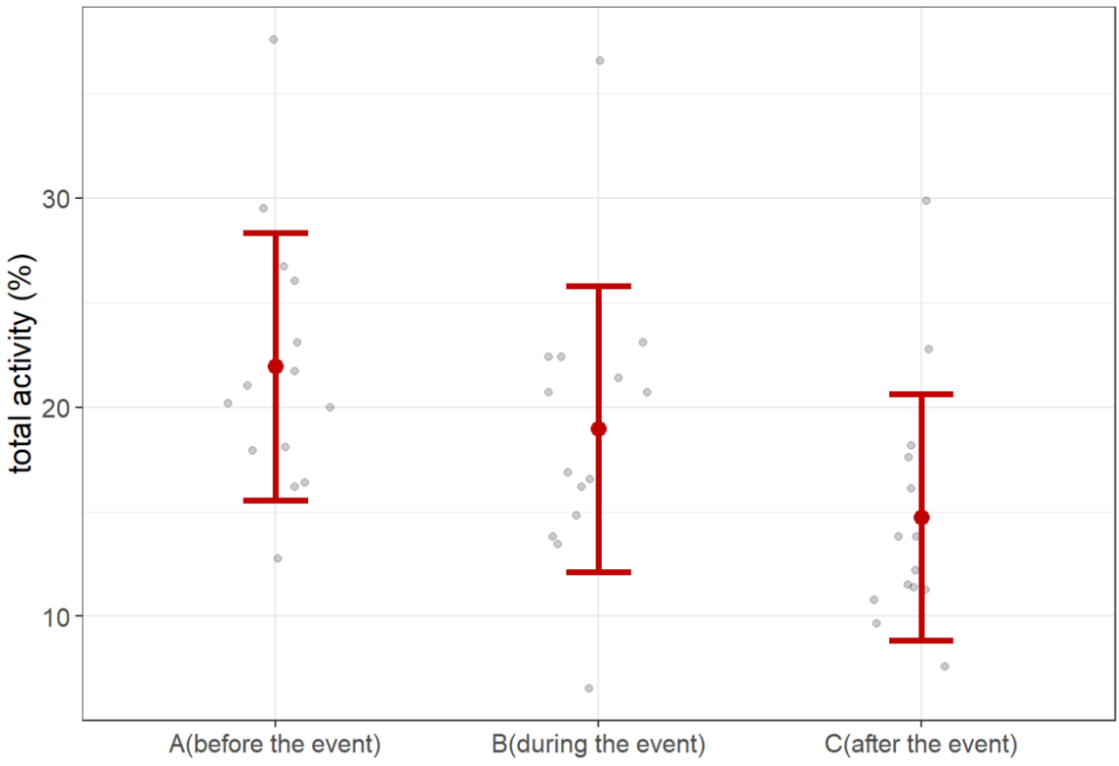
Two types of artificial intelligence tools were used, Grammarly (Grammarly, 2025) was used to check grammar, and reverso (reverso, 2025) was used to find synonyms.

3. RESULTS

The residuals vs. fitted values graphics and Q-Q plots revealed that all models fit relatively well with residuals being close to normally distributed and randomly scattered around zero with no significant outliers.

3.1. Impact of the event on the total activity

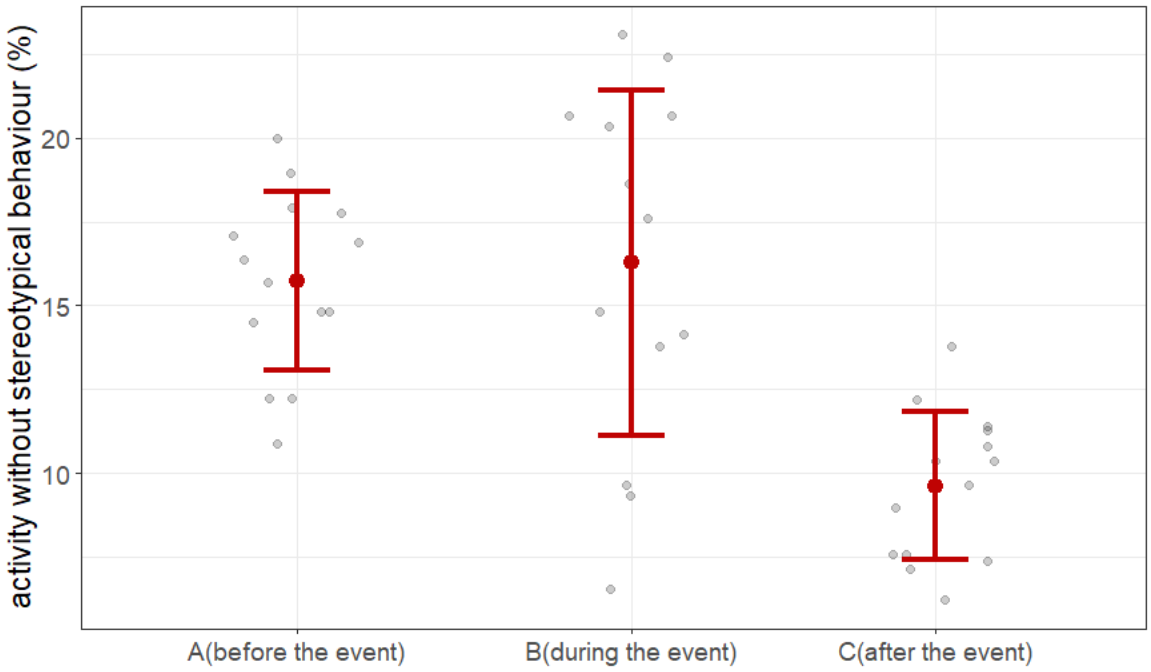
European mink had significantly lower activity after the Ironman event (C) (t=4.4; p=0.0001). The activity level during the event (B) did not significantly differ from the control time (before the event (A); p=0.08) but showed a downward trend (Graph 1).



Graph 1. Total activity changes over the observation period. Points show the mean of total activity. Error bars represent SD.

3.2. Impact of the event on activity without stereotypical behaviour

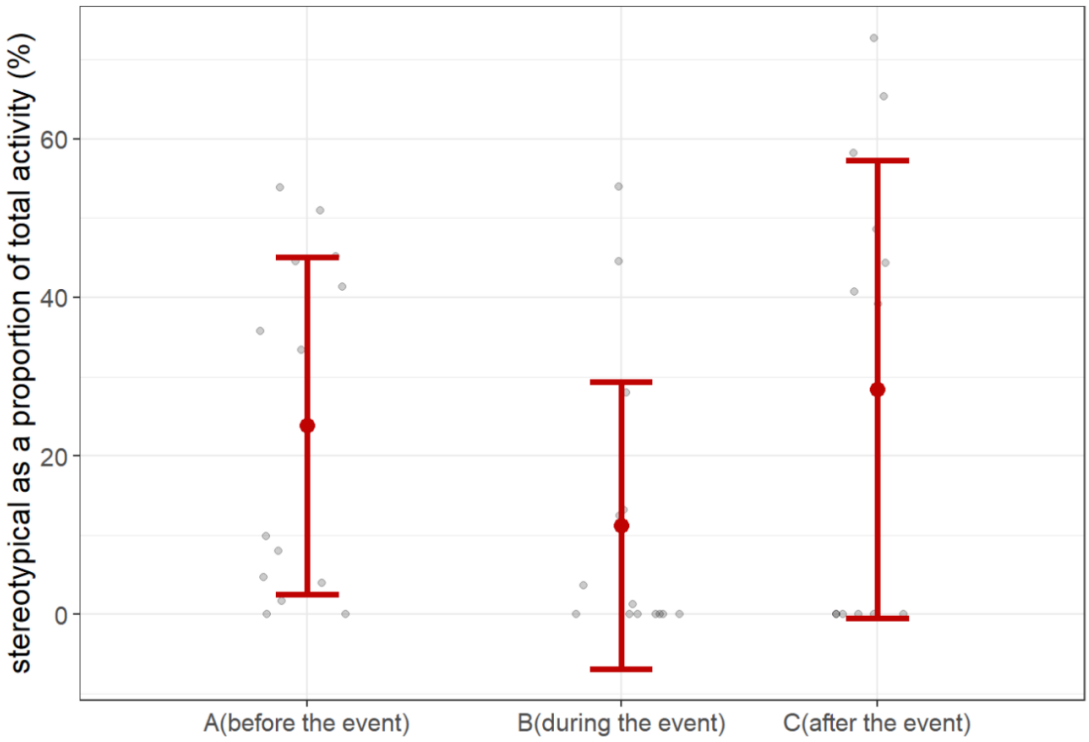
After the event the activity without stereotypic behaviour was significantly lower than in control period (before the event; t=-5.18; p<0.001; Graph 2). During the event the activity without stereotypic behaviour did not significantly differ from control period (p=0.6).



Graph 2. Changes in activity without stereotypic behaviour over the observation period. Points show the mean of total activity. Error bars represent SD.

3.3. Impact of the event on proportion of stereotypic behaviour from total activity

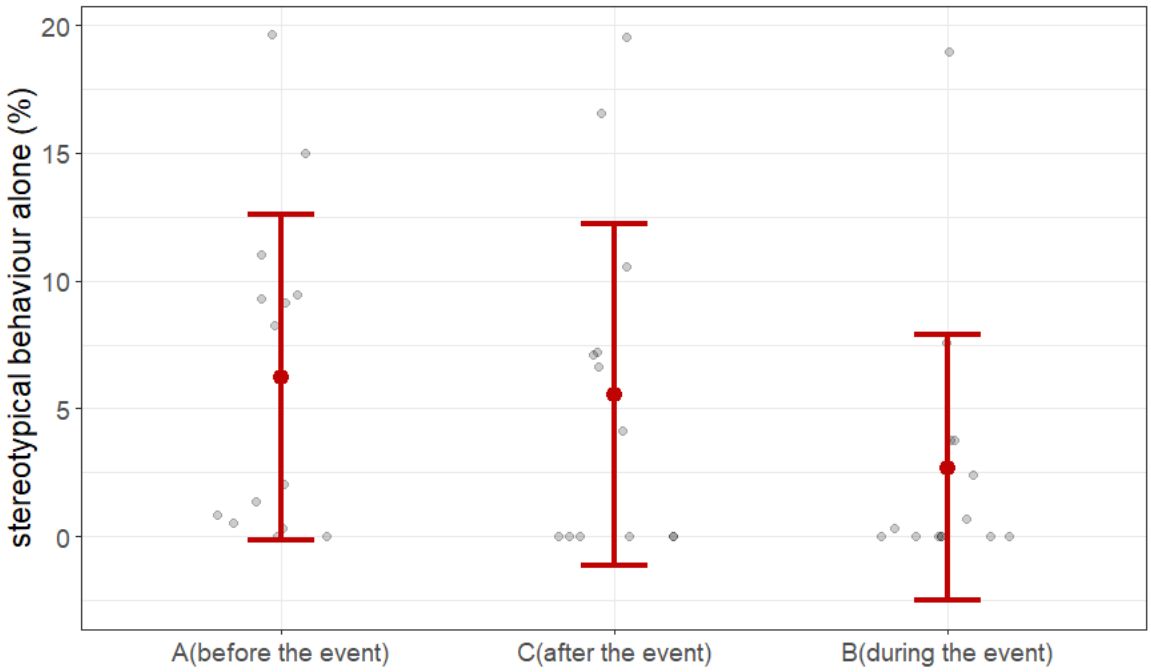
During the Ironman event the proportion of stereotypic behaviour from total activity (group B) was significantly lower comparing to the control period (before the event; t=-2.73; p=0.01; Graph 3). Group C did not significantly differ from the control period (p=0.44).



Graph 3. The proportion of stereotypic behaviour from total activity changes over the observation period. Points show the mean of total activity. Error bars represent SD.

3.4. Impact of the event on the stereotypical behaviour

Proportion of stereotypic behaviour from all scans was significantly lower during the event comparing to the control period (t=-3.44; p=0.002; Graph 4). After the event there was no significant difference how much mink were stereotyped (p=0.4).



Graph 4. Changes in stereotypic behaviour over the observation period. Points show the mean of total activity. Error bars represent SD.

4. DISCUSSION

This study analysed the impact of noise exposure on male European mink behaviour during three different periods: before, during, and after a noisy event. Therefore, this study aimed to evaluate the behavioural impact of the noisy event on the European mink, with a specific focus on total activity and the expression of stereotypical behaviour. Analysis revealed several significant findings that align with, and extend, existing research on anthropogenic disturbances in wild living and captive animals. The hypothesis was supported by some of the results, but others showed unexpected patterns that require further investigation.

The analysis of total activity (normal and stereotypical behaviour combined) demonstrated a clear pattern of decreasing activity across the experimental groups. The period after the event exhibited a substantial and statistically significant decline in activity compared to control conditions (before the event). While reduction of total activity during noise exposure was not statistically significant, considering the statistical significance of decrease of total activity after the event, it can still show a downward trend. This means that the effect of noise exposure was greater on the days following the event. Which might suggest a delayed response pattern. In essence, the effects of noise stressors may compound over time, with behavioural changes becoming more evident after the immediate stimulus has ceased (Samson *et al.*, 2006; Shannon *et al.*, 2016; Song *et al.*, 2025).

Similar results were found when analysing activity without stereotypical behaviour. After the event there was a statistically significant decrease in activity. This suggests that the event had a significant delayed impact on activity, and it supports the idea that noise exposure does not just reduce movement in general, it may specifically inhibit adaptive, exploratory, or routine behaviours (Bejder *et al.*, 2009: Kight *et al.,* 2012).

On the other hand, the proportion of stereotypical behaviour within total activity was significantly reduced during the event but returned to control conditions after the event. Similar results can be seen when stereotypical behaviour was analysed, from all scans.

The decrease in stereotypical behaviour during the event suggests that during noise exposure European mink tend to show less stereotypical behaviour. Which coincides with studies of Ortiz *et al.,* (2021; 2022). The relationship between stress and stereotypical behaviours is

evidently more complex than a simple positive correlation. The complexity and diversity of anthropogenic noise, which varies in duration, amplitude, and frequency, makes this particularly relevant (Mckenna *et al.* 2016).

When combined, these findings can suggest that stereotypical behaviours, typically associated with stress, actually decrease when exposed to anthropogenic noise, while overall activity decreases more significantly afterward. Stereotypical behaviours, which are often used to cope with chronic stress, may be suppressed when the animal is focused on assessing and responding to the immediate threat in this state (Mason, 1991; Mason & Latham, 2004). That is why, a plausible explanation is that noise triggers a freezing or vigilance response in European mink, temporarily suppressing stereotypical behaviours (Blanchard *et al.*, 2001; Koolhaas *et al.*, 2010).

While this study provides valuable insights into noise impact on European mink behaviour, certain limitations should be acknowledged. For instance, the power to detect significant differences may be limited by only observing one gender (male) and the small sample size (n=14). An increase in sample size tends to enhance statistical power, which means that more data is preferable when other conditions remain constant (Bateson & Martin, 2021). Moreover, expanding the observational period could have helped to determine whether the observed behavioural changes eventually return to baseline or if the changes are permanent. Though analysis of physiological parameters such as cortisol and heart rate were not conducted in this study, previous research on European mink has demonstrated increase in faecal cortisol metabolites following noise exposure (Ortiz-Jiménez *et al.*, 2022). This indicates that future research would be strengthened if more direct measures of physiological stress were integrated. Furthermore, in order to achieve more precise and deep comprehension of noise impact on European mink, accurate and consistent reporting of sound level metrics is required. Moreover, an interesting direction for future research could be analysing noise effects during European mink breeding and litter period, given that multiple studies on other species have shown that it has an impact.

CONCLUSION

The aim of the present study was to examine whether and how noise exposure during public events affects the behaviour and activity patterns of captive European mink. Based on previous research which indicated the vulnerability of many species, including *mustelids*, to acoustic stressors, it was proposed that noise would result in significant behavioural stress responses in European mink. The main focus was on analysing changes in general activity, stereotypical behaviour, and their proportion in the context of short-term noise exposure.

The findings confirmed this hypothesis. The noise event resulted in a significant drop in total activity levels, and while the decline during the event wasn't statistically significant, the trend was still consistent. The most significant decline in overall activity was after the event. This effect was statistically significant and sustained by several models. This may indicate that European mink reacts to noise with delayed response patterns.

An intriguing trend was observed in the expression of stereotypic behaviour. It decreased noticeably during the event and then returned almost to the control level after the event. This is interesting because stereotypical behaviour, which is often associated with poor welfare, decreased during noise exposure itself. One potential explanation is that noise triggers a vigilance or freezing response in European mink.

In conclusion, this study demonstrates that noise exposure produces complex and sometimes counterintuitive effects on European mink behaviour. It is worth acknowledging that, as one of the first dedicated assessments of event noise impacts on European mink at Tallinn Zoo, this work represents only an initial step. Despite this, obtained results provide a foundation and act as a reference point for both European mink management and future research. These insights can help Tallinn Zoo develop animal welfare protocols and motivate a more detailed monitoring of behavioural health, especially during periods of increased visitor activity or construction.

ÜLDKOKKUVÕTE

MÜRA MÕJU EUROOPA NAARITSA (MUSTELA LUTREOLA) KÄITUMISELE

Käesoleva töö eesmärk oli uurida euroopa naaritsa käitumismuutusi ürituse ajal ehk, kas ja kuidas mõjutab avaliku ürituse müra euroopa naaritsa käitumist ja aktiivsuse mustreid. Võttes arvesse seda, et aastakümnete jooksul toimunud populatsiooni vähenemine on viinud selleni, et alates 2011. aastast on euroopa naarits kantud Rahvusvahelise Looduskaitseliidu punasesse nimestiku, (International Union for the Conservation of Nature and Natural Resources – IUCN Red List) kui äärmiselt ohustatud liik, on valitud teema äärmiselt oluline.

Antropogeense müra mõju elusorganismidele on viimastel aastakümnetel muutunud oluliseks uurimissuunaks. Selle töö teoreetilise osa kirjutamise käigus avastati, et müra mõju kärplastele ja veel täpsemalt euroopa naaritsale on uuritud äärmiselt vähe. Seega käesolev töö püüab peamiseid lünki kaardistada ja pakkuda ülevaadet varasematest teadusuuringutest müra mõjust erinevatele liikidele.

Esiteks käsitleti müra mõju elusorganismide käitumisele ja füsioloogiale. Erinevad allikad viitavad sellele, et korduv või krooniline müra võib kaasa tuua muutusi stressihormoonide tootmises, südamerütmis ning isegi geneetilistes protsessides. Teiseks toodi esile, et müra mõju väljendub nii vabas looduses kui ka tehistingimustes, nagu loomaias. Kuna varasemad uuringud on näidanud, et müra mõjutab looduslikke käitumismustreid ja suurendab stressile viitavat stereotüüpset käitumist, siis sai käitumise vaatlemisest selle töö võtmeosa. Seega üks eeldus töö praktilisel osal oli, et käitumine võib peegeldada looma heaolu.

Praktilises osas analüüsiti Tallinna loomaaias peetavate euroopa naaritsate käitumist kümne päeva vältel. Valimisse kuulus 14 isendit ning jälgiti nii üldist aktiivsust, stereotüüpset käitumist kui ka nende omavahelist suhet. Vaatlusperiood oli jagatud neljaks ööks enne üritust (kontrollperiood), kaheks ööks ürituse ajal (kõrge müra periood) ja neljaks ööks pärast üritust (taastumisperiood).

Arvestades loomade teadusuuringutes kasutamise eetikanorme, salvestati isendite käitumist valvekaameratega. Arvestades, et euroopa naarits on öise eluviisiga loom, toimusid käitumisvaatlused tema aktiivsuse tipp-perioodil, ajavahemikus 19:00–7:00. See ajavahemik

valiti ka seetõttu, et see võimaldas minimeerida loomaaia töötajate mõju, kelle kohalolek pärast kella 7:00 võib loomade käitumist mõjutada seoses toiduootusega. Käitumisandmed koguti viieminutiliste intervallidega, looma käitumine määratleti eelnevalt koostatud etogrammi põhjal. Neli ööd enne sündmust (kontrollperiood) tähistati tähega A, kaks ööd kõrge müra perioodiga - tähega B ning neli ööd pärast sündmust - tähega C.

Kõik analüüsid viidi läbi R-is (versioon 4.0.5 Windowsi jaoks) RStudio keskkonnas (versioon 2024.12.1+563 Windowsi jaoks). Jääke hinnati visuaalselt kasutades diagnostilisi graafikuid, sealhulgas jääkide vs. sobitatud väärtuste graafikuid ja kvantiil-kvantiil graafikuid. Lineaarne segamudel sobitati, kasutades *lme4* paketti, et analüüsida ajaperioodi (enne sündmust, sündmuse ajal ja pärast sündmust) mõju käitumisele (aktiivsus ja stereotüüpne käitumine). Looma ID-d kasutati juhusliku tegurina, et arvestada korduvate mõõtmistega.

Tulemused on kooskõlas teooriaga. Üldaktiivsus langes kõige märgatavamalt pärast müraepisoodi (grupp C), samas kui müra ajal (grupp B) vähenes statistiliselt oluliselt just stereotüüpne käitumine. See võib viidata sellele, et müra mõjul ei muutu loomade aktiivsustase mitte kohe, vaid hiljem. Samas stereotüüpse käitumise osakaal kogu käitumisest naases peale kõrget müra perioodi kontrolltasemele. See viitab, et euroopa naaritsad kipuvad müra mõjul olema veidi vähem aktiivsed ning näidata palju vähem stereotüüpset käitumist, mis omakorda tähendab, et stressi ja stereotüüpsete käitumismustrite vaheline seos on keerukas.

Tulevastes uuringutes tuleks kasuks füsioloogiliste markerite nagu näiteks kortisooli metaboliitide kaasamine. Lisaks ei ole mõõdetud antud uuringus sündmuste akustilist profiili (helitugevus, sagedus, kestus), mis aitaks tulevastes töödes paremini mõista põhjuslikkust. Üks huvitav tulevaste uuringute suund võiks olla müra mõju sigimisele ja pesakonnale. Käesoleva uurimuse piirangud ei luba teha väga põhjalikke järeldusi. Siiski, saadud andmete ja läbiviidud uurimistöö põhjal võib järeldada, et avalike ürituste müra mõjutab euroopa naaritsate käitumist, kuid selle ulatus ja muster sõltuvad tõenäoliselt mürakestusest, müra tüübist ja isendi omadustest.

Kokkuvõtteks viitavad tulemused selgelt, et euroopa naaritsa käitumine muutub kokkupuutel müraga ning mõjud võivad olla nii vahetud kui viivisega. Käitumisandmed toetasid eelnevalt kirjandusest leitud järeldusi, et müra võib vähendada aktiivsust,

moonutada käitumismustreid ja lühiajaliselt pärssida stereotüüpseid tegevusi. Oluline on märkida, et antud töö on esimene Tallinna Loomaaias tehtud uurimus, mis hindab ürituse müra mõju euroopa naaritsatele ja tegemist on taoliste uuringute alustamisel alles esimese sammuga. Saadud tulemused pakuvad aluse ja toimivad lähtepunktidena euroopa naaritsa tulevastele teadusuuringutele. Töö aitab paremini mõista, millised riskid kaasnevad loomaaia keskkonnas või läheduses oleva müraga. Need järeldused võivad aidata Tallinna Loomaial välja töötada loomade heaolu protokolle ja suunata põhjalikumalt jälgima loomade käitumisprobleeme, eriti suurenenud külastuste või ehitustööde ajal.

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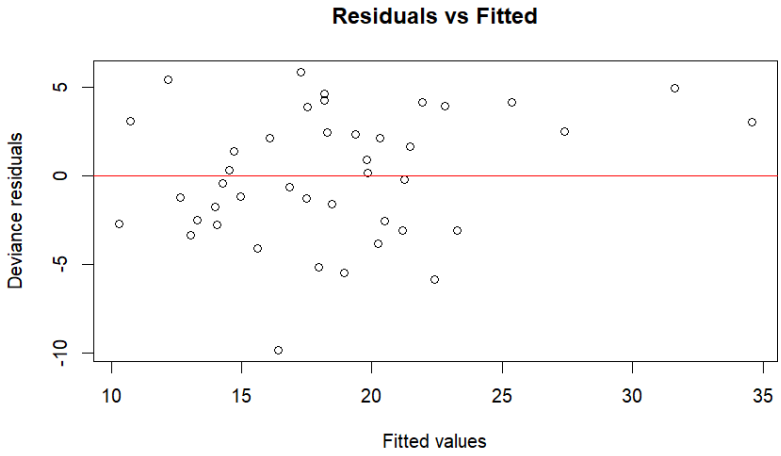
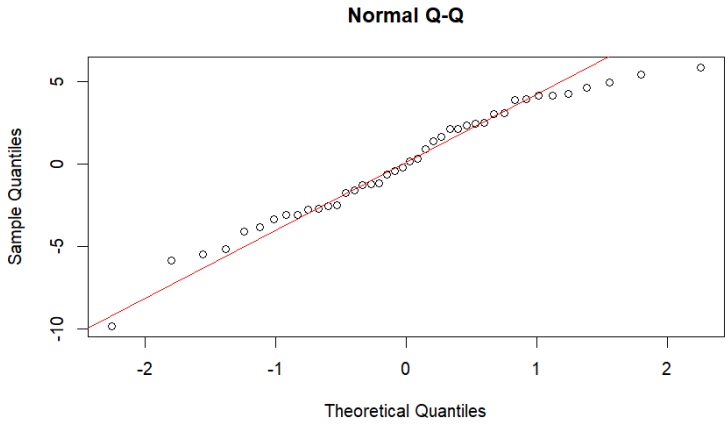
APPENDICES

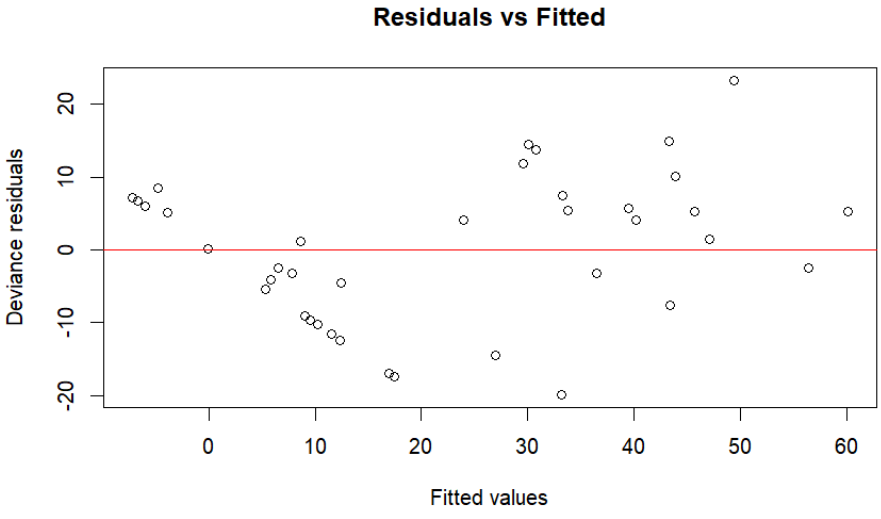
Appendix 1. Residuals vs. fitted values for total activity



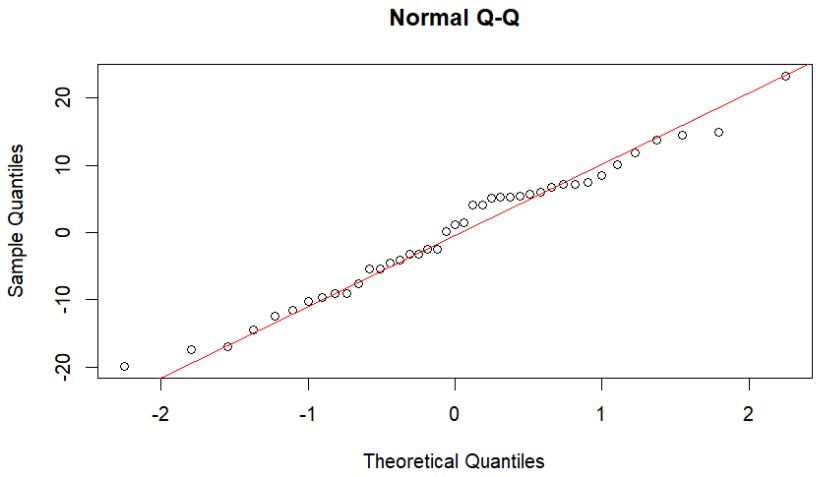
Appendix 2. Q-Q plots for total activity



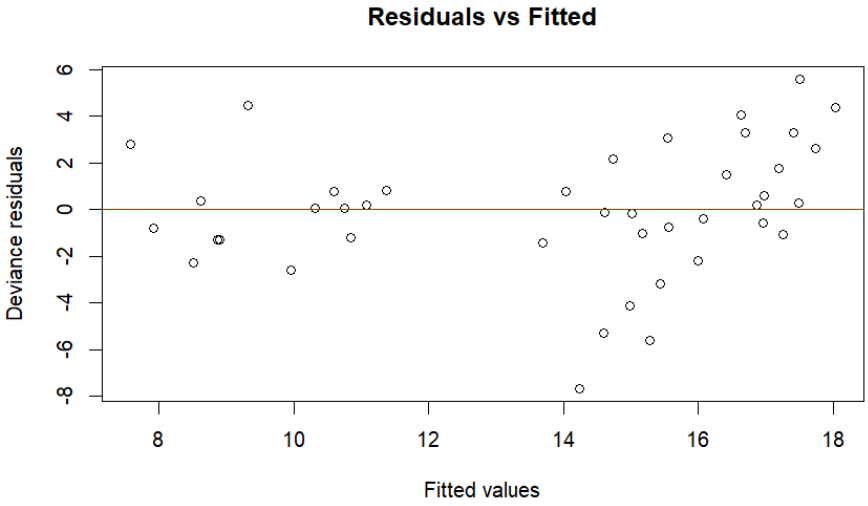
Appendix 3. Residuals vs. fitted values for stereotypical as a proportion of total activity



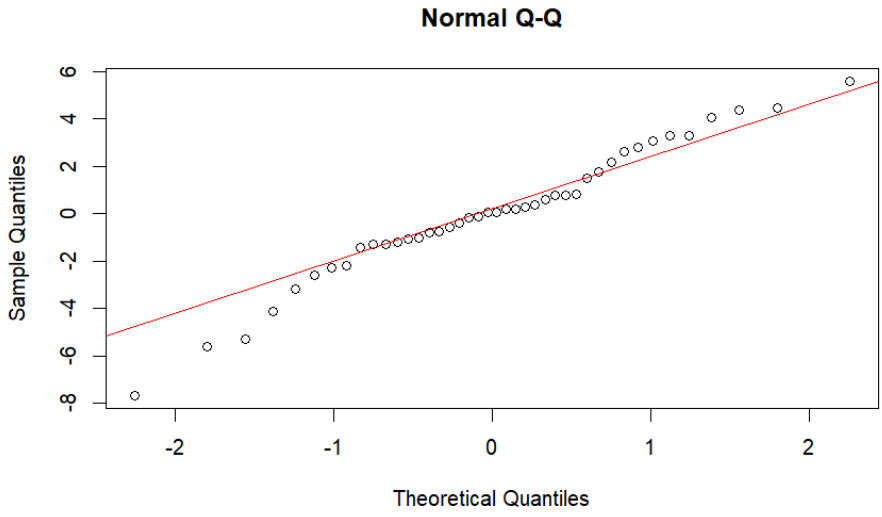
Appendix 4. Q-Q plots for stereotypical as a proportion of total activity



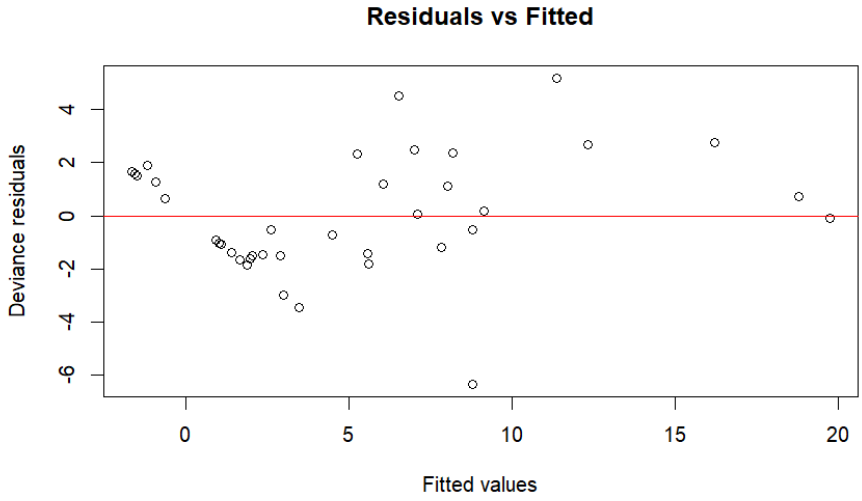
Appendix 5. Residuals vs. fitted values for activity without stereotypical behaviour



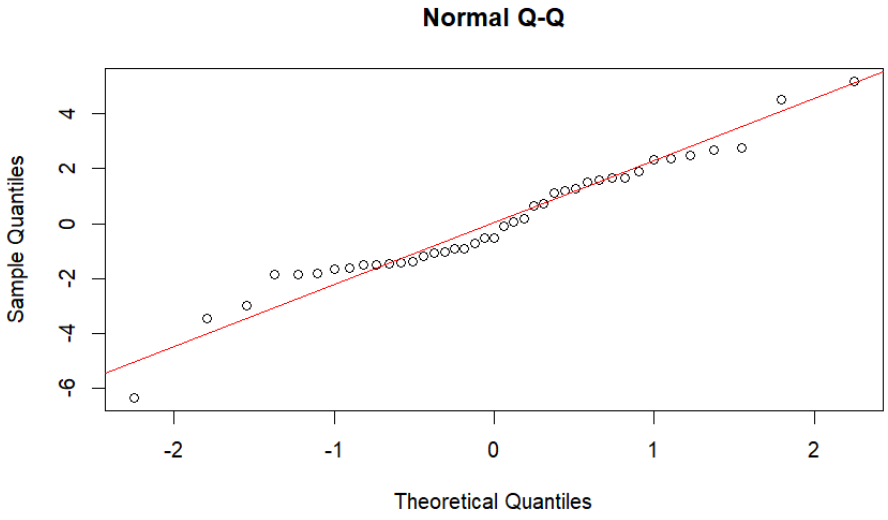
Appendix 6. Q-Q plots for activity without stereotypical behaviour



Appendix 7. Residuals vs. fitted values for stereotypical behaviour alone



Appendix 8. Q-Q plots for stereotypical behaviour alone



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