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Use of Sound Stimuli to Elicit a Change in Moose (*Alces alces*) and Red Deer (*Cervus elaphus*) Behaviour

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Forest science

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"Being on top of the evolution pyramid, we humans have the responsibility of protecting the lesser beings, at least for our own good- to keep our earth safe and serene" *(Jayasankar & Selvakumar, 2016).*

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ABSTRACT

Over the years, a lot of different actions have been tested in order to prevent road and railway collisions with cervids. Amongst them, actions aiming to change animal behaviour. The aim of such actions has been to elicit a change in behaviour and to make the animals leave the area preliminary to prevent collisions. Cervids do naturally show anti-predator behaviour when something they connect with danger occurs. In this thesis, I wanted to study how moose (*Alces alces*) and red deer (*Cervus elaphus*) changed their behaviour when they were exposed to natural harmless sounds and sounds associated with predators. This was studied by exposing them to different sound stimuli through a motion-activated scare system (MASS) at winter feeding stations in South-Eastern Norway. The experiment was monitored with video cameras.

I investigated how different sound stimuli affected the proportion of the animals leaving the site, and the proportion of time they used for browsing and being vigilant. I compared the behaviour responses to the different sounds with normal behaviour at feeding stations. I found that the sound of a barking dog and a human voice elicited a change in behaviour for moose that in most cases made them leave the site. The more harmless sounds did not lead to such strong reactions. For the red deer the results were markedly weaker, and only the human stimulus lead to a significantly higher proportion of the animals leaving the site, compared with the normal behaviour. For both moose and red deer there were signs of habituation to the sounds within a relatively short time, though, red deer showed faster habituation than moose. The results confirm that the sound of a dog and a human can be efficient for eliciting a change in behaviour for moose, and thus be used in the further development of a technical system to prevent accidents with moose at the railway. For red deer other stimuli might be more efficient, due to the low response to the stimuli tested here.

SAMMENDRAG

Over tid har mange ulike tiltak mot hjorteviltpåkjørsler blitt undersøkt. Blant dem, tiltak som har som mål å endre atferden til dyrene. Målet med slike tiltak er å fremkalle en endring i atferd for å få dyrene til å midlertidig forlate et område. Hjortevilt viser naturlig en anti-predator atferd når de utsettes for noe som de forbinder med predatorer. I denne studien ønsket jeg å studere hvordan elg og hjort endrer sin atferd når de eksponeres for naturlige harmløse lyder og lyder som de assosierer med predatorer. Dette ble studert ved å eksponere dem for ulike lydstimuli gjennom et «bevegelsesaktivert skremme-system» (MASS) på fôringsstasjoner i Sørøst-Norge. Eksperimentet ble overvåket med viltkameraer.

Jeg undersøkte hvordan ulike lydstimuli påvirket andelen dyr som forlater fôringsstasjonen samt andelen av tiden de brukte til henholdsvis beiting og årvåkenhet. Jeg sammenliknet atferdsresponsen til de ulike lydstimuliene med dyrenes normalatferd på fôringsstasjonene. Jeg fant at lyden av losende hund og menneskestemme fremkalte en endring i atferd for elg som gjorde at de forlot fôringsstasjonen. De mer harmløse lydene førte ikke til en like sterk reaksjon. For hjort var resultatene markant svakere, og det var bare lyden av menneskestemme som førte til at en signifikant høyere andel av dyrene forlot fôringsstasjonen sammenliknet med normalatferden. For både elg og hjort var det tegn til habituering/tilvenning til lydene innen kort tid. Hjorten viste en raskere tilvenning enn elgen. Resultatene bekrefter at lyder som elgen kan assosiere med en predator kan være effektive for å fremkalle en endring i atferd, og dermed være interessant for den videre utviklingen av et teknisk system for å forebygge hjorteviltpåkjørsler på jernbanen. For hjort kan det i henhold til resultatene være at andre lydstimuli har en større effekt enn lydene testet i denne studien.

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1. INTRODUCTION

With the development of infrastructure, accidents between vehicles and vertebrates are an increasing issue worldwide (Jayasankar & Selvakumar, 2016; St Clair et al., 2019). Yearly, billions of vertebrates are vulnerable to accidents with vehicles (Seiler & Helldin, 2006). In boreal regions, such as Norway, the populations of moose (*Alces alces*), red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*) have increased over the last 70 years. In Norway, the growth in the populations had a peak around the year 2000. The growth is mainly due to the introduction of modern forestry and management with selective harvesting of calves and bulls (Hjeljord, 2008; Solberg et al., 2017). The growth in the populations also led to an increase in the number of road- and railway accidents with cervids. Road- and railway accidents with cervids increases at the same rate as the growth in populations of moose, red deer and roe deer (Solberg et al., 2009). On a large scale, population density has shown itself to be an important explanatory factor for the variation in road and railway accidents with cervids (Seiler, 2004), but other factors such as snow and temperature might be important locally (Solberg et al., 2009).

During the winter season 2019/2020, 8553 collisions between vehicles/trains and cervids were reported in Norway. This includes 1504 moose, 987 red deer and 6064 roe deer (SSB, 2020b). In Norway, road and railway accidents with moose and roe deer are most common in the counties Innlandet, Viken and Trøndelag, while accidents with red deer are most common north in the county Vestland (Sivertsen et al., 2010). The Norwegian Public Roads administration have estimated the annual socio-economic costs of accidents with cervids to around 600 million NOK (equivalent to 75 million euros) (Muskhaug et al., 2010; Tolletaten, 2021).

1.1 Actions to prevent accidents with cervids

Actions to prevent accidents with cervids seem to be resource-intensive, but to prevent injury is often better than repairing damages (Seiler & Bhardwaj, 2020). The actions that have been used to prevent accidents with cervids in Norway can be divided into four categories; (I) physical restrictions that keep cervids away from roads and railways (vegetation clearing, fencing), (II) reduction of the local density of cervids along roads and railways (diversionary feeding, reduction in populations), (III) actions to enhance behavioural changes in animals (scent-marking, wildlife mirrors), and (IV) strategies to change driver behaviour (warning signs, sight-clearing, speed reduction) (Rolandsen et al., 2017). Sivertsen et al. (2010) evaluated the various actions and found a statistical reduction in accidents for only one of the actions (sight-clearing). This shows that it is both challenging to develop effective actions against wildlife accidents in traffic, and to demonstrate whether they have an effect.

Based on the evaluation of different actions (Sivertsen et al., 2010), which mainly included physical restrictions aiming to keep cervids away from roads and railways, and strategies to change driver behaviour, it seems that other actions should be developed and tested to detect a greater effect.

1.2 Cervid behaviour and alternative actions

In winter, cervids typically have an energy-saving behaviour as their strategy. Getting access to food using as little energy as possible is the ideal strategy (Græsli et al., 2020). "Eat, but avoid being eaten" is a typical norm for cervid species in this period of the year, which make it necessary to have close interaction between the need of getting access to limited food resources and the anti-predator behaviour (Bjørneraas, 2012). Living in a "landscape of fear" requires that you are able to detect and escape from predators at the same time as obtaining food (Eisenberg, 2010). The presence of large carnivores usually leads to increased vigilance, change in use of habitat, activity patterns and size of group (Sand et al., 2016). These changes are also well known anti-predator strategies for cervids (Lingle & Pellis, 2002). With this information in mind, it seems reasonable that exposing cervids to stimuli that indicates fear and predators will elicit a behaviour change. Based on this assumption it could be interesting to investigate if it is possible to implement actions that directly can affect the behaviour of the animals. Such actions can also be implemented along the railway, where the collisions mostly depend on the behaviour of the animals. In this way, a collision could almost exclusively be prevented if the animals leave the track, which assumes that they have the opportunity to detect the train in time (Seiler & Olsson, 2017).

Different actions with light stimuli, aiming to affect both animals and vehicle drivers, have been tested. Wildlife warning reflectors, which produce a small light reflex that is supposed to alert animals when a car passes, have shown no or only short-term effects, because of habituation (Benten et al., 2019; Brieger et al., 2017; Seiler et al., 2017; Sivertsen et al., 2010). Habituation is a usual effect detected for cervids, meaning that the animals will become adapted to a disturbance after being exposed to it over a certain time (Reimers, 2018).

Actions involving different types of sound stimuli have also been tested. In a study in northern Norway, a combined optic- and acoustic system (DeerDeter450) was placed along the road, programmed to use high-frequent sounds and flashing lights when cars were present. This research showed that the combination of high-frequency sounds and flashing lights did not reduce vehicle collisions with moose (Sørensen, 2017). In Denmark, another study examined whether or not road-markings, that made sounds when cars passed over, affected fallow deer (*Dama dama*) to stay away from the road. The results showed a certain effect from start, but the effect decreased over time, indicating that the fallow deer became habituated to the sound (Ujvári et al., 2004). The habituation to sound may be related to the fact that the sounds were not threatening. Use of natural sounds, which should be familiar to the animals, may have stronger, longer-lasting effects (Babinska-Werka et al., 2015; Shimura et al., 2018).

Studies suggests that most mammals reacts to the sounds of their predators or predator-related sounds (Blumstein et al., 2007; Hettena et al., 2014). There is also shown that some animals have an innate anti-predator response to sounds of certain predators, even if the predators are absent (Makin et al., 2019). In Poland, during the period from 2008 – 2012, a study tested the use of a sound unit beside the railway tracks, which played natural sounds such as warning calls from jay birds (*Corvidae*) and the howl from a wolf (*Canis lupus*) before a train passed. Roe deer responded by leaving the railway tracks in 84 % of the cases, compared to 68 % when no sound was played. The study lasted for four years, and they could not detect signs of habituation during the study period (Babinska-Werka et al., 2015). Furthermore, moose in Sweden responded stronger to acoustic stimuli associated with fear or predation than sounds that were not related to fear (Lodnert, 2021). Moose left the site in 75 % and 39 % of the events when exposed to respectively the sound of a human voice and a barking dog. When exposed to the sound of birds the moose only left in 11 % of the events (Lodnert, 2021).

Behaviour experiments, such as the Swedish study (Lodnert, 2021) with different sound stimuli, might be important in the development of a technical system that can be used along the railway to prevent accidents with cervids. In long term, if the technical systems turn out to be efficient, they might be a cost-efficient replacement for railway fencing in addition to a reduced mortality effect (Seiler & Olsson, 2017). The desired effect from such systems is a temporary change in the behaviour of the cervids which make them react faster to arriving trains and disappear from the railway tracks.

In this thesis, I aim to find out how different types of sounds affects the behaviour of moose and red deer by studying their behaviour at feeding stations. The sounds in the study are natural and informative sounds, where some of them represent a predator, and others are harmless.

There is traditionally great concentrations of both moose and red deer at the winter feeding stations in the study area, and it is therefore interesting to examine if they have similar reactions to disturbances. The red deer is, compared to the moose, a newcomer in the area (Johnsen, 2012). Moose and red deer are organized in different ways socially. While the moose have a typically family-binding, where the calves follows the mother, the red deer can be organized in larger family groups of females (matrilinear groups) (Reimers, 2018). According to studies of cervid habitat use, there has been shown that moose are more tolerant to use habitats near human activity than red deer, because they browse in the forest where they are protected behind a shelter of vegetation, unlike the red deer, which prefers open grasslands as their browsing habitat (Lykkja et al., 2009). It is therefore conceivable that the red deer will have a stronger reaction to disturbances, such as sound stimuli, than the moose.

Based on the question of how moose and red deer reacts when being exposed to different types of sound stimuli, I have made the following hypothesis and predictions:

Hypothesis 1: The exposure for different sound stimuli elicits a difference in leaving response

> **Prediction 1:** Sounds associated with predation (human and dog) trigger more animals to leave the feeding station than natural harmless sounds (boreal owl and black woodpecker)
>
> **Prediction 2:** The leaving response to all sounds decreases with time (habituation)
>
> **Prediction 3:** Red deer has a stronger leaving response than moose

Hypothesis 2: The exposure for sound stimuli elicits a change in time used for browsing and being vigilant at feeding stations

> **Prediction 1:** Time used for browsing is decreased during and after being exposed to both sounds associated with predation and natural harmless sounds, with the strongest reduction with sounds associated with predation
>
> **Prediction 2:** Time used being vigilant is higher during and after being exposed to sounds associated with predation and natural harmless sounds than before
>
> **Prediction 3:** The behavioural response is stronger for red deer than for moose

2. METHODS

2.1 Study area

I collected data in Stor-Elvdal municipality in Innlandet county (Figure 1). This part of Norway has a typical inland climate with relatively low temperatures and low levels of precipitation (Dannevig, 2020). The municipality has a rich wildlife fauna, with the presence of all the four Norwegian cervid species and is especially known for the high density of moose. In 2020, 523 moose were shot in Stor-Elvdal municipality during the moose hunting season, only two other Norwegian municipalities had a higher number of moose shot (SSB, 2020a). The railway called Rørosbanen and the highway “Riksvei 3” passes through the valley, and several places along this railway and highway are every winter hotspots for train- and car accidents with cervids (Gundersen et al., 1998).

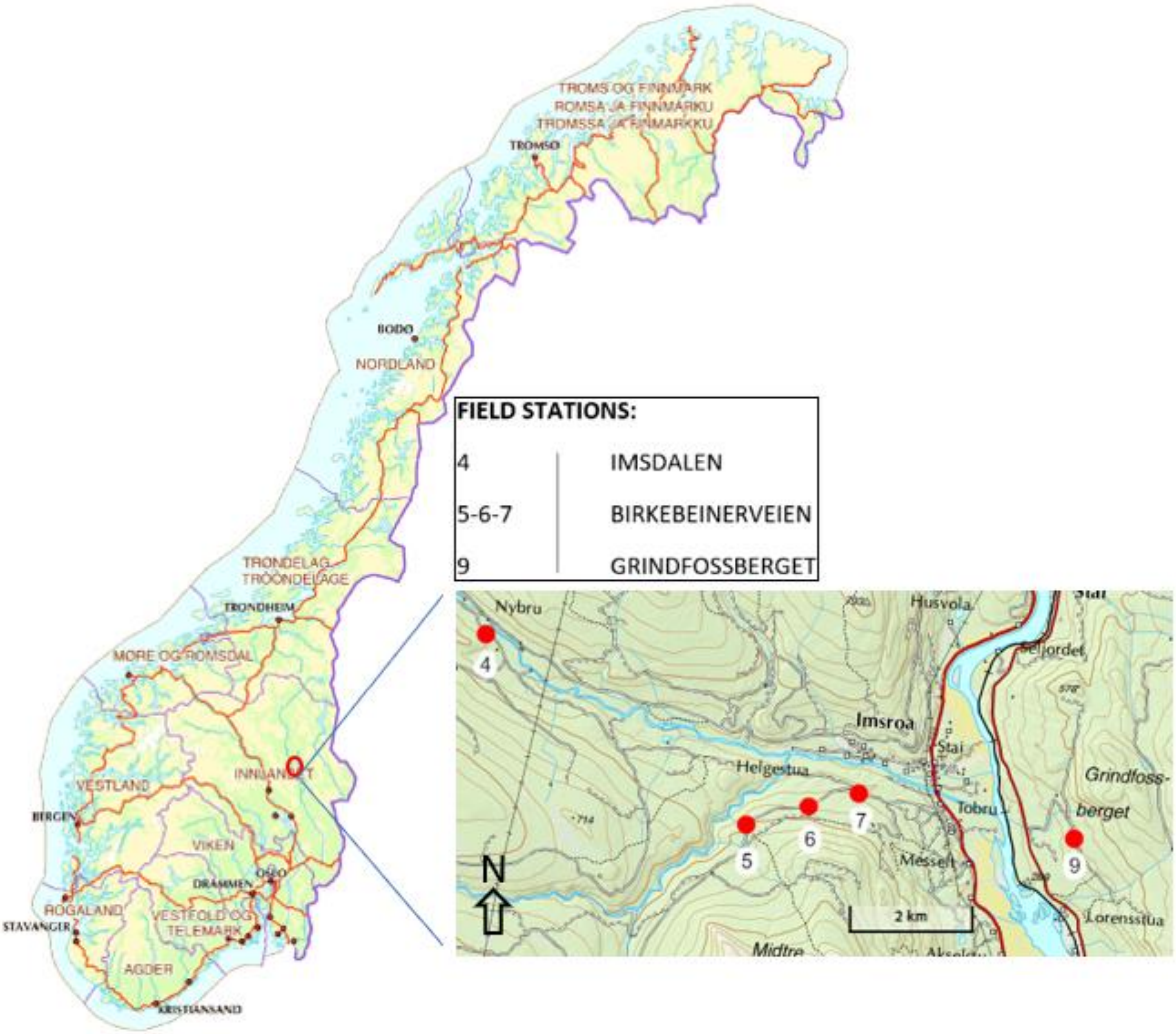


Figure 1. Location of the five study sites in Stor – Elvdal municipality, located in south - eastern Norway (*Norgeskart*, 2021).

2.1.1 Feeding stations

The Behaviour of moose and red deer were studied at five feeding stations in three different areas in the municipality (Figure 1). These feeding stations were already established as diversionary feeding stations to prevent traffic accidents with cervids during the winter season. The feeding stations were operated by local landowners, with economic support from the research project group. The feed consisted of ordinary silage bales, placed at the centre of the feeding stations. Four of the stations were located on the west side of the river Glomma and the last one at the east side (Figure 1). The criteria for the selection of stations were that they in minimum should be located one kilometre from the main road and the railway. There should also be one kilometre or more between the stations. The background for using the feeding stations in the study was the traditionally high densities of moose and red deer at these stations during the winter season.

2.2 Field season

During the field season, the aim was to observe the behaviour of moose and red deer at the feeding stations when they were exposed to different sound stimuli. Trying to achieve a sufficient period of observation, the fieldwork was carried out over a period of almost two months (from 28. February 2020 to 20. April 2020). Because of some technical issues, there was a period of 17 days (04.03 – 21.03) with no collection of data. The study was performed by observing behaviour with video cameras placed out at each station.

The practical fieldwork consisted of assembling the technical equipment at the stations and changing batteries and memory cards in the cameras during the field season. When assembling the technical equipment, three video cameras, covering a total of 114° view, were mounted at each station to cover an area as large as possible. The cameras were mounted in trees in the edge of the feeding station, directed against the silage bale.

To establish normal behaviour at feeding stations, we collected videos in a period before activating the sounds.

2.2.1 Motion Activated Scare System (MASS)

Description of MASS

The technical design and construction of the system, referred to as MASS, were done by technologists at the Norwegian University of Science and Technology (NTNU), following the design developed by Andreas Seiler at the Swedish University of Agricultural Sciences (SLU).

The cameras used in the study was of the type RECONYX Hyperfire 2 pro (RECONYX, Inc., Holmen, WI, USA). The internal trigger sensors in the cameras were overridden by an external passive infrared sensor (PIR) connected to the cameras. The PIR sensor was connected to and controlled the trigging of the motion-activated scare system (MASS). The MASS-units central part was constructed by a Raspberry Pi unit (Raspberry Pi Foundation, UK). The MASS was programmed with settings for which- and when sounds could be played. The cameras were set to record videos, controlled by the PIR sensor. The PIR sensor was triggered by movement in front of the sensor and sent signals both to the cameras to start recording and to the MASS to play a sound. When- and how many of these signals that could be sent between the PIR sensor and the cameras were controlled by the MASS (Figure 2). The MASS recorded all activities and alarms to an internal log.

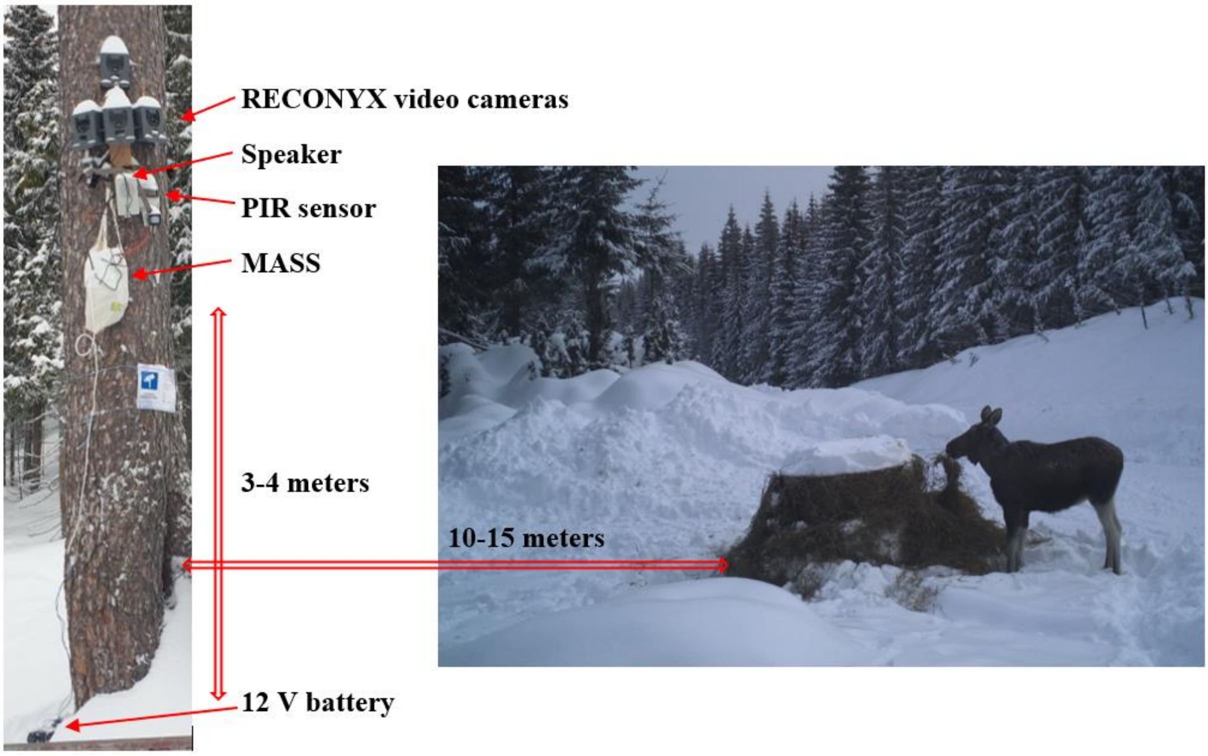


Figure 2. MASS system and location in relation to main silage bale at the feeding station.

Sound stimuli

The programming of the MASS was built up with a folder structure with 24 folders, one per hour throughout the day. We used five different sounds: two sounds associated with predation (human, dog), two natural harmless sounds (black woodpecker, boreal owl) and one blank sound (silent). The sounds were selected in cooperation with the parallel Swedish project (Lodnert, 2021). In Norway and Sweden, hunting is the main mortality cause for moose (Graesli et al., 2020; Solberg et al., 2000). In this way, human activity might have an important impact on the prey's anti-predator interaction, as humans in some areas are the main predators for moose (Ericsson et al., 2015). In this experiment, the sounds of a human voice and a barking dog (*Canis lupus familiaris*) were tested. Both sounds can be associated with hunting, for both moose and red deer.

Black woodpecker (*Dryocopus martius*) and boreal owl (*Aegolius funereus*) have a natural presence in the study area, and the system was programmed to play the sound of the black woodpecker in the day and the boreal owl at night. This was done to make the use of the sounds as natural as possible, as the black woodpecker is active in the daytime and the boreal owl at night. These sounds were tested as a control for behaviour change when cervids were exposed to sounds that basically should seem harmless. The blank/silent sound was an empty file without any kind of sound. This sound was used as a control towards the other sounds, and to evaluate whether the animals reacted to any eventual mechanical sounds from the system.

During the fieldwork period considerations were done whether technical adjustments were necessary. Because of a strong response from the animals during the first days in the field season, three new blank/silent sounds were added in the folders for each hour. In this way, the chance for playing a blank sound became higher than the chance for playing some of the other sounds. This was done as a precautionary action to prevent accidents with cervids, as the exposure of the sounds during the first days seemed to cause a higher movement rate towards the road and railway down in the bottom of the valley. A higher proportion of cervids in this area would increase the risk for accidents.

Programming and adjustments of the MASS

There was a limitation for how many triggers that could activate the cameras. The MASS was set to be triggered only once every 15 minutes. In this way, there could at maximum be played four sound-sequences per hour. This setting was made to avoid too many triggers, which could have led to an increase in animals not returning to the feeding stations. In the first period of the data collection period, from February 28th to March 4th, the delay setting with a 15-minute break in the triggers was by a mistake not activated. In this way, the system could be trigged almost continuous. This delay was correctly turned on for the next period.

When the PIR sensor was triggered, the three cameras started to record. The recording was programmed to last 60 seconds. 20 seconds after the recording started, a sound was played from the MASS. The sound was played for 20 seconds. By doing this, the video sequence could be divided into three parts for 20 seconds each; before, during and after a sound was played. This was done to observe the animal's behaviour before, during and after being exposed to sounds.

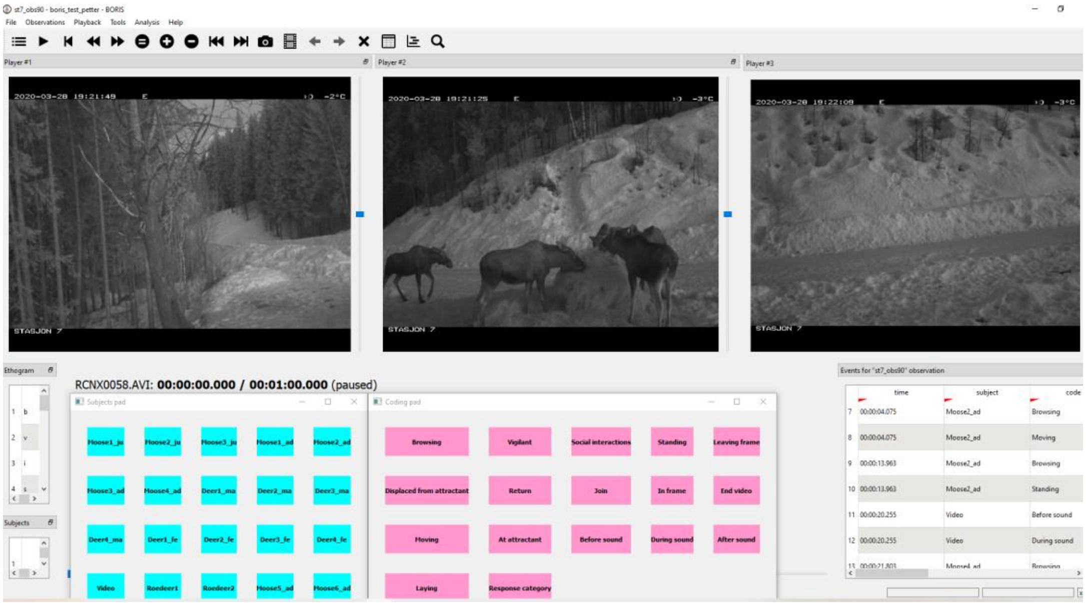
2.3 Data processing

The data consisted of videos collected with video cameras and log files that recorded date, time and type of sound when different sounds were played. The videos were sorted, and videos without the presence of cervids were excluded (trigged by vehicles, humans).

Because of few observations in station 5, 6 and 7, the observations in these stations were pooled. These stations were located in the same area, which made it possible to combine them as one station. In this way, the behavioural analysis for moose was based on data from three different locations: station 4, station 5, 6 & 7 and station 9. Data for red deer were collected only at station 9.

2.3.1 BORIS software

I used the software program BORIS (Behaviour Observation Research Interactive Software) to analyse the behaviour of moose and red deer shown in the videos. This program allows you to analyse two or more videos with several individuals at the same time and includes functions for creating ethograms and registering time per behaviour (Friard et al., 2016). In this way, the videos from the three cameras could be analysed simultaneously (Figure 3). I analysed the behaviour for each animal through the whole video sequence, as long as the animal was present in the video (before possibly leaving the frame). The same method was successfully used in the study by Lodnert (2021).



RCNX0058.AVI: **00:00:00.000 / 00:01:00.000** (paused)

	time	subject	code
7	00:00:04.075	Moose2_ad	Browsing
8	00:00:04.075	Moose2_ad	Moving
9	00:00:13.963	Moose2_ad	Browsing
10	00:00:13.963	Moose2_ad	Standing
11	00:00:20.255	Video	Before sound
12	00:00:20.255	Video	During sound
13	00:00:21.803	Moose4_ad	Browsing

Figure 3. Excerpts from the analysis program BORIS, with the three videos in top, subjects/individuals in the blue and behaviours in the pink boxes.

Before starting the behaviour analysis, I defined different behaviours in an ethogram. Within this project, behaviours were defined as state- or point- events. A state event referred to a behaviour event with a duration with a start and stop. A point event was a behaviour event registered just as a point, without any duration. Several behaviours were registered (Figure 2), but for the questions examined in this thesis, the behaviours *browsing*, *vigilant* and *leaving frame* were the relevant ones (Table 1).

Table 1. Definition of behaviours in BORIS.

Behaviour	**Definition**
Browsing (state)	The animal is standing near by the silage bale – browsing or chewing actively.
Vigilant (state)	Individual is vigilant – looking up and around and is observing surroundings.
Leaving frame (point)	Individual leaves the view of the video.

I also defined a set of independent variables which was registered for each video sequence. The independent variables used to answer the research questions were *sound*, *light, station-number, number of focus animals, the total number of animals* and *trial day* (Table 2).

Table 2. Independent variables defined in BORIS

Variable	**Definition**
Sound	blank, black woodpecker, boreal owl, dog, human
Light condition	daylight, dark, half-light
Station-number	ID for the station (4, 5, 6, 7, 9)
Total number of animals	Total number of moose and red deer observed in the camera field, including animals standing in the background for the silage bale.
Number of focus animals	The number of moose and red deer that were analysed in each video sequence. These animals were at the attractant and in the front of the group, their behaviour was often easy to register. They were present in the video from the start and at least until they are exposed to sound stimuli.

2.3.2 Control-study - defining normal behaviour

The video sequences from the period before the MASS was activated, were analysed in BORIS in the same way as the other video sequences. These behavioural analyses were later compared with the behaviour analysis from the videos with blank sound. This was done to control the technical equipment, checking that the MASS-unit did not make any kind of mechanic sounds or any other disturbances when blank sound was played, which could have disturbed the animals.

The videos from the control period were analysed based on a selection of 10 videos each from station 4, 5, 6 and 7, and 14 videos from station 9. The reason for a larger selection for station 9, was that this station was the only station with the presence of red deer in the control period.

2.4 Analysis

2.4.1 Model variables

The model variables were based on the behaviour data from the video analysis in BORIS. The proportion of individuals leaving the site, and the proportion of time doing other kinds of behaviours were used as response variables in the models. The reason for using proportions was that all these variables were binomial, meaning that they represented either the proportion of individuals of all individuals that left the site or the proportion of time doing a behaviour divided by the time visible. The following variables were used in the models:

Response variables:

- **Proportion of animals leaving:** the proportion of animals leaving the site during or after they were exposed to sound stimuli (animals leaving before the exposure of sound were not analysed) → binomial variable (0-1)
- **Proportion of time spent browsing:** the proportion of time visible spent browsing for each 20- sec. period (before, during, after) → binomial variable (0-1)
- **Proportion of time being vigilant:** the proportion of time visible spent vigilant for each 20- sec. period (before, during, after) → binomial variable (0-1)

Explanatory variables:

- **Sound:** type of sound stimuli → categorical variable (blank, black woodpecker, boreal owl, dog, human)
- **Time period:** division of the video-sequences in periods → categorical variable (before, during, after)
- **Station-number:** the number/ID of the feeding stations → categorical variable (4 - 5,6 &7 - 9)
- **Light:** different light conditions, indicating time of day → categorical variable (daylight, half-light, dark)
- **Trial-day**: numbering of days from start to end of the experiment → numerical variable (1, 2, 3, 4, 5 …)
- **Number of focus animals:** number of animals (moose and red deer) analysed in each video-sequence → numerical variable (1, 2, 3, 4, 5 …)
- **Total number of animals:** total number of animals (moose and red deer) visible in the video-frame during the sequence → numerical variable (1, 2, 3, 4, 5 …)

2.4.2 Leaving site

To analyse the proportion of moose leaving the site with different sound stimuli, I used a general linear mixed model (GLMM) (Zuur et al., 2009). The model for moose consisted of a random effect, in this case the number (ID) of the feeding station, in addition to the other effects (variables). The random effect was used to control for multiple observations at the same stations. For red deer, I only had observations from one station (station 9), and the random effect was not needed for that species. Therefore, I used a general linear model (GLM) for red deer. I tested the models for both moose and red deer with several explanation environmental variables (*wind, trial-day, number of focus animals, total number of animals, proportion of juveniles*) in addition to the main variable *sound*. The response variable was a binomial variable, with the name *proportion of animals leaving the site*, with values between 0 and 1.

2.4.3 Time spent browsing and vigilant

To analyse the time spent doing the behaviours browsing and vigilant, a general linear mixed model (GLMM) was fitted for moose and a general linear model (GLM) for red deer. The variable *station-number* was included as a random effect in the GLMM for moose. The response variables in the models were *proportion of time spent browsing* and *proportion of time spent vigilant*, both binomial variables, with values between 0 and 1. There were separate models for the two response variables. I tested the models with the explanation variables *sound, time-period, light* and *trial day*, and also the interaction between *sound* and *time period*.

Statistics software and model selection

All the statistical analysis were done in the software Rstudio (RCoreTeam, 2020). I did separate analyses for moose and red deer. The video analysis from the control study were further analysed in Microsoft Excel with calculations of mean time spent for different behaviours in the two periods, and confidence intervals.

The selection of the best fitting model was done with AIC (Akaike Information Criterion) model selection, where the quality of each model, relative to the other models, were estimated (Leeuw, 2011). Based on the AIC model selection, models with a ΔAICc less than 2 were chosen as the best model(s). In some cases, it ended up with more than one model with ΔAICc less than 2. In these cases, the model with the lowest ΔAICc including the interaction between the variable's *sound* and *trial day* for the models with the *proportion of animals leaving the site*, and the interaction between *sound* and *time period* for the models for the proportion of time spent browsing/vigilant, were chosen.

3. RESULTS

3.1 Descriptive results

In total, 340 videos with moose and 321 videos with red deer were analysed. The database for the two species was almost the same in terms of the number of videos analysed for each species (Table 3 & 4).

Table 3. Total number of videos, number of videos with moose and videos with red deer analysed for the three study sites (station 4, station 5, 6 & 7, station 9).

Station number	Total number of videos (n)	Videos with moose (n)	Videos with red deer (n)
4	153	153	-
5/6/7	160	160	-
9	321	27	321

Table 4. Number of videos with moose and red deer divided to different sound stimulus.

Sound	n videos with moose	n videos with red deer
Blank	153	201
Black woodpecker	28	43
Boreal owl	84	30
Dog	13	-
Human	62	47

3.2 Defining normal behaviour

When comparing the videos from the control study with the videos with blank sound, it turned out to be no difference between the time used for the different behaviours, neither for moose nor for red deer (Figure 4 & 5). The videos with blank sound were therefore used as a control for the videos with other kinds of sounds further in the analyses.

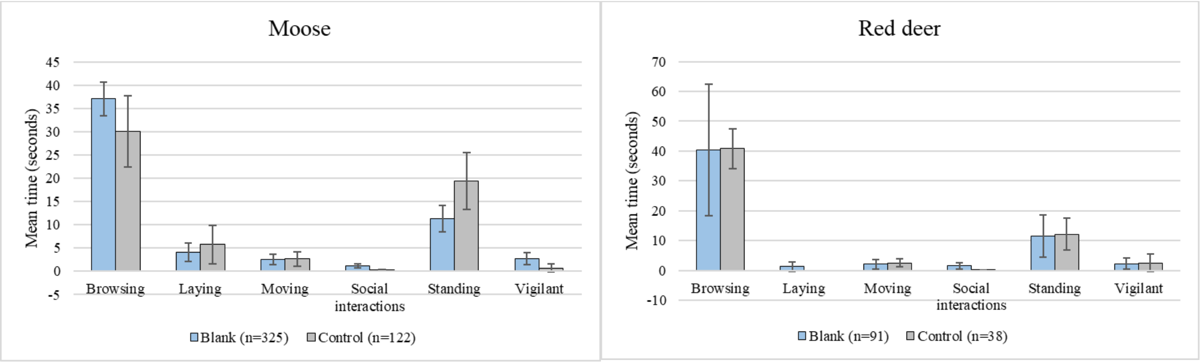


Figure 4 & 5. Mean time (± 95% confidence intervals) spent on different behaviours during a 60-second video sequence for moose (left graph) and red deer (right graph). Blue bars represent the sequences with blank sound during the experiment period (n= 153 for moose, n= 201 for red deer) and the grey bars represent the control period before the motion-activated scare system (MASS) was activated (n= 40 for moose, n= 14 for red deer).

3.3 Proportion of animals leaving the site

Moose

Based on the model selection, model 4 & 5 seemed to be the best explaining models (Table 5). Of these, model 5, including the interaction between *sound* and *trial day* was selected.

Table 5. AIC model selection with the best fitting models ranked from top (models with ΔAICc < 2 are the best fitting models).

Model variables	Model	AICc	ΔAICc	AICcWt
Sound+Light+Trial_day+(1|Station_nr)	4	411.4	0	0.63
Sound+Light+Trial_day+Sound*Trial_day+ (1|Station_nr)	5	412.84	1.44	0.3
Sound*Trial_day+(1|Station_nr)	6	415.77	4.37	0.07
Sound+Light+(1|Station_nr)	3	427.13	15.72	0
Sound+Light+N_tot+(1|Station_nr)	8	429.02	17.62	0
Sound+prop_of_juvenil+(1|Station_nr)	9	431.63	20.23	0
Sound+(1|Station_nr)	2	433.08	21.68	0
Sound+N_tot+(1|Station_nr)	7	433.75	22.35	0
#Null model	1	815.3	403.9	0

The moose left the area significant more when they were exposed to human stimulus (n=62) compared to dog stimulus (n=13, p=0.049), boreal owl stimulus (n=84, p<0.001), black woodpecker stimulus (n=28, p<0.001) and the blank sound (n=153, p<0.001) (Table 7). When exposed to the dog stimulus the moose left the area significantly more compared to the blank/silent sound (p<0.001), black woodpecker (p=0.007) and boreal owl (p=0.008). The black woodpecker stimulus only differed significantly from human (p<0.001) and dog (p=0.007). The blank/silent sound differed significantly from all stimuli except from the black woodpecker (p=0.99) (Table 6 & 7, Figure 6). There was no significant interaction between *trial day* and *proportion of moose leaving the site* when they were exposed to the sounds. It was, however, a significant effect of the *trial day*. This indicates that the proportion of moose leaving the site decreases with time, not for specific sounds, but as an effect of date (Table 6, Figure 7).

Table 6. Parameter estimates and fit statistics based on the GLMM for the proportion of moose leaving the site for the sound stimuli blank (n=153), black woodpecker (n=28), boreal owl (n=84), dog (n=13) and human (n=62), light-conditions dark (n=253), daylight (n=52), half-light (n=35) and for trial day (n=37). Random effect = station number.

	Estimate	Std. Error	Z-value	P-value
Intercept (Blank, Dark)	-2.15	1.12	-1.92	0.054
Black woodpecker	-2.17	3.48	-0.62	0.534
Boreal owl	1.91	1.01	1.89	0.058
Dog	5.57	1.58	3.53	< 0.001
Human	4.33	1.07	4.06	< 0.001
Daylight	-0.87	0.40	-2.19	0.029
Half-light	-0.71	0.40	-1.79	0.073
Trial_day	-0.13	0.05	-2.36	0.018
Black woodpecker*Trial_day	0.14	0.15	0.94	0.350
Boreal owl*Trial_day	0.04	0.06	0.71	0.481
Dog*Trial_day	-0.56	0.33	-1.71	0.088
Human*Trial_day	0.07	0.06	1.26	0.206

Table 7. Pairwise comparisons of the proportion of moose leaving the site for the sound stimuli blank (n=153), black woodpecker (n=28), boreal owl (n=84), dog (n=13) and human (n=62).

			Estimate	Std. Error	Z-value	P-value
Black woodpecker	**vs.**	**Blank**	0.52	1.12	0.47	0.989
Boreal owl	**vs.**	**Blank**	2.57	0.49	5.27	<0.001
Dog	**vs.**	**Blank**	4.25	0.66	6.45	<0.001
Human	**vs.**	**Blank**	5.74	0.51	11.33	< 0.001
Boreal owl	**vs.**	**Black woodpecker**	2.05	1.04	1.96	0.257
Dog	**vs.**	**Black woodpecker**	3.73	1.12	3.32	0.007
Human	**vs.**	**Black woodpecker**	5.22	1.06	4.94	< 0.001
Dog	**vs.**	**Boreal owl**	1.68	0.51	3.27	0.008
Human	**vs.**	**Boreal owl**	3.17	0.30	10.67	< 0.001
Human	**vs.**	**Dog**	1.49	0.56	2.67	0.049

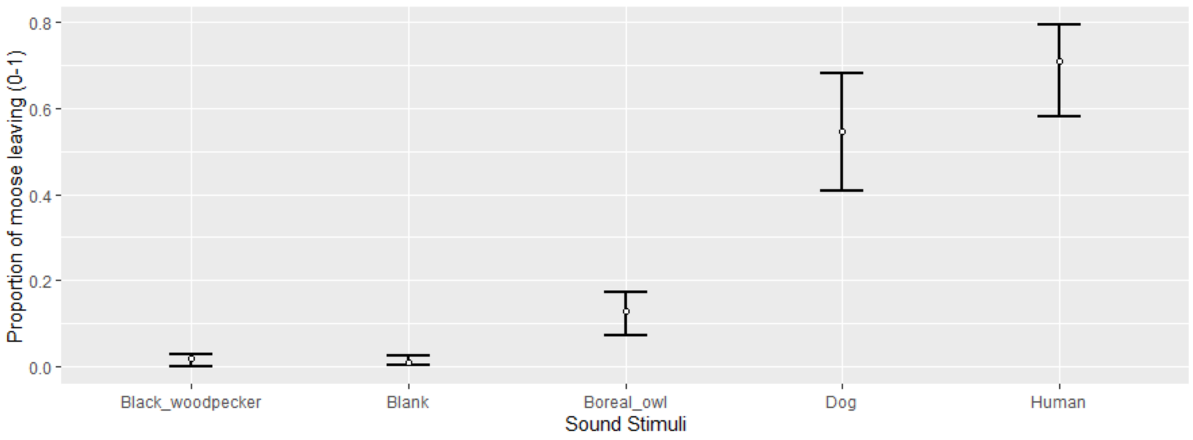


Figure 6. Mean proportion (± 95% confidence intervals) of focus animals leaving the site when being exposed to the sound stimuli black woodpecker (n=28), blank (n=153), boreal owl (n=84), dog (n=13) and human (n=62).

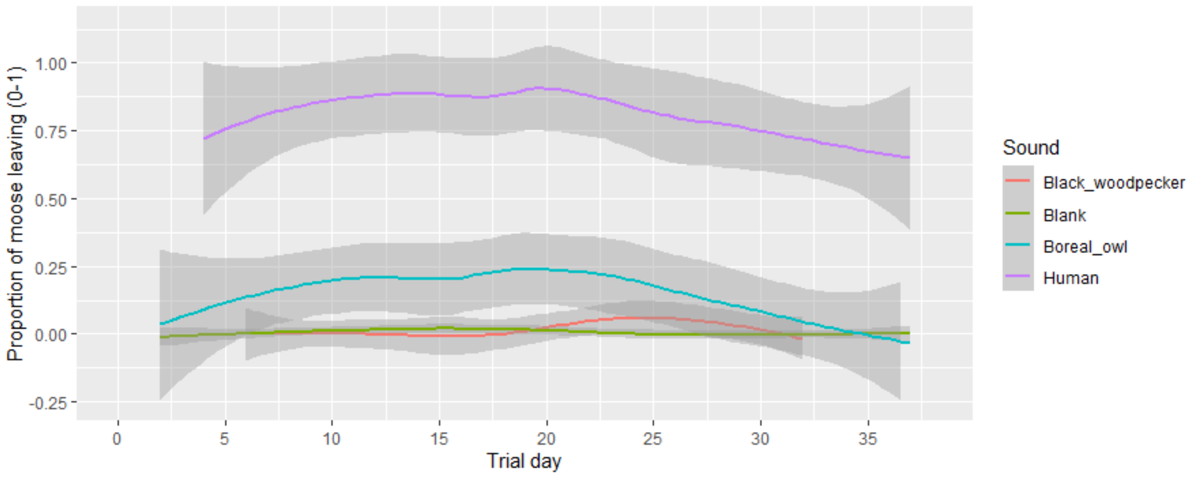


Figure 7. Proportion of moose leaving the site over trial day (n=37) for the sound stimuli black woodpecker (n=28), blank (n=153), boreal owl (n=84) and human (n=62). The dog stimulus is not included in the figure because it was only included in the experiment for a couple of days. The amount of data (n trial day = 5) is therefore not considered as large enough to visualize the effect of time for this stimulus.

Red deer

Based on the model selection, model 3, 5 & 6 seemed to be the best explaining models (Table 8). Model 5 with the lowest ΔAIC included the interaction between *sound* and *trial day* and was therefore chosen.

Table 8. AIC model selection with the best fitting models ranked from top (models with ΔAICc < 2 are the best fitting models).

Model variables	Model	AICc	ΔAICc	AICcWt
Sound+Sound*Trial_day	5	135.23	0.00	0.37
Sound+N_tot	6	136.88	1.65	0.16
Sound+Light+Trial_day	3	137.18	1.96	0.14
Sound	1	137.26	2.03	0.13
Sound+Light+Trial_day+Sound*Trial_day	4	137.67	2.44	0.11
Sound+Light	2	139.11	3.88	0.05
Sound+Light+N_tot	7	139.65	4.43	0.04

The red deer left the area significantly more when being exposed to human stimulus (n=47) compared to the blank sound (n=201, p=0.002). Between the other stimuli, there were no significant differences in the proportion of animals leaving the area (Table 10, Figure 8). It was a significant negative interaction between *trial day* and the *proportion of red deer leaving the site* when exposed to the human stimulus (Table 9, Figure 9).

Table 9. Parameter estimates and fit statistics based on the GLM for the proportion of red deer leaving site for the sound stimuli blank (n=201), black woodpecker (n=43), boreal owl (n=30) and human (n=47), and for trial day (n=25).

	Estimate	Std. Error	Z-value	P-value
Intercept (Blank)	-5.50	1.86	-2.95	0.003
Black woodpecker	3.33	3.23	1.03	0.303
Boreal owl	3.88	3.48	1.12	0.264
Human	8.29	2.71	3.06	0.002
Trial_day	0.06	0.11	0.50	0.615
Black woodpecker*Trial_day	-0.17	0.22	-0.80	0.423
Boreal owl*Trial_day	-0.19	0.24	-0.81	0.418
Human*Trial_day	-0.47	0.20	-2.38	0.018

Table 10. Pairwise comparisons of the proportion of red deer leaving the site for the sound stimuli blank (n=201), black woodpecker (n=43), boreal owl (n=30) and human (n=47).

			Estimate	Std. Error	Z-value	P-value
Black woodpecker	**vs.**	**Blank**	0.73	0.84	0.86	0.819
Boreal owl	**vs.**	**Blank**	1.04	0.85	1.22	0.603
Human	**vs.**	**Blank**	2.02	0.58	3.48	0.003
Boreal owl	**vs.**	**Black woodpecker**	0.31	1.01	0.31	0.990
Human	**vs.**	**Black woodpecker**	1.29	0.80	1.61	0.366
Human	**vs.**	**Boreal owl**	0.98	0.81	1.22	0.610

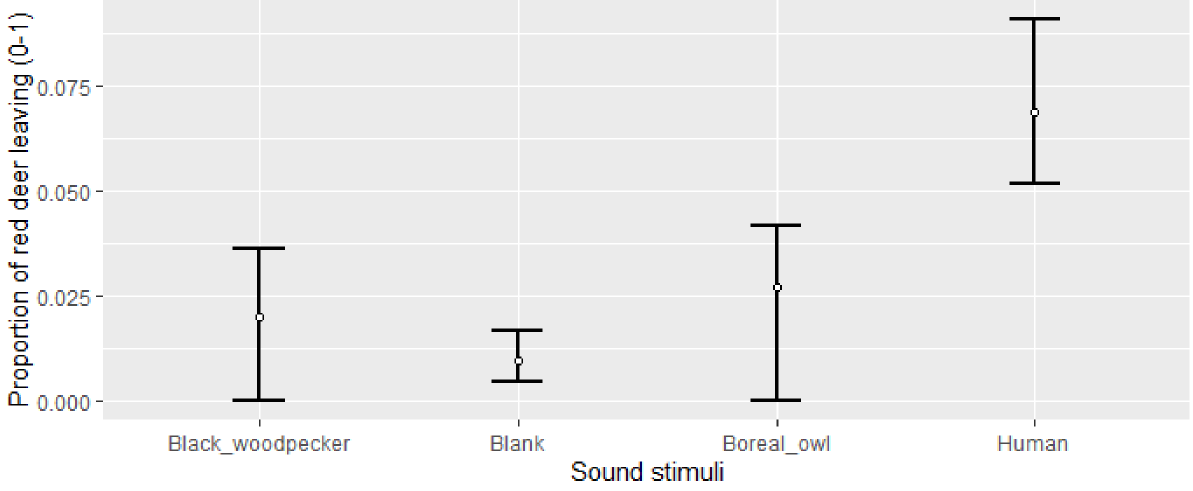


Figure 8. Mean proportion (± 95% confidence intervals) of focus animals leaving the site when exposed to the sound stimuli black woodpecker (n=43), blank (n=201), boreal owl (n=30) and human (n=47).

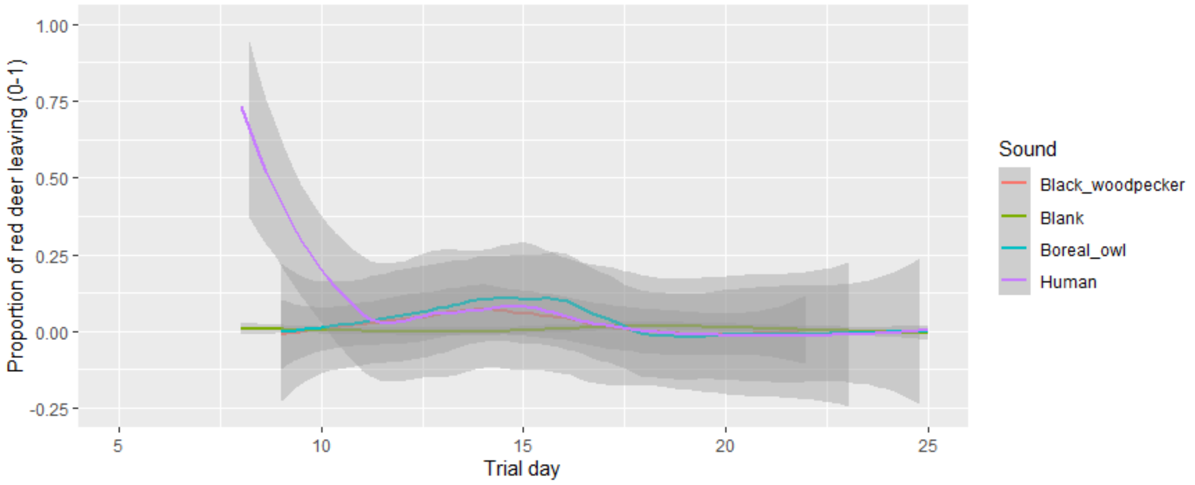


Figure 9. Proportion of red deer leaving the site over trial day (n=25) for the sound stimuli black woodpecker (n=43), blank (n=201), boreal owl (n=30) and human (n=47).

3.4 Proportion of time spent browsing

Moose

Based on the AIC model selection, model 5 was the best explaining model (Table 11).

Table 11. AIC model selection with the best fitting models ranked from top (models with ΔAICc < 2 are the best fitting models).

Model variables	Model	AICc	ΔAICc	AICcWt
Time_period+Sound+Trial_day+Light+ Time_period*Sound+(1|Station_nr)	5	2494.36	0.00	0.78
Time_period+Sound+Trial_day+ Time_period*Sound+(1|Station_nr)	4	2498.16	3.80	0.12
Time_period+Sound+Time_period*Sound + (1|Station_nr)	3	2498.31	3.95	0.11
Time_period+Sound+(1|Station_nr)	2	2696.96	202.59	0.00
#Null modell	1	3052.64	558.28	0.00

It was a significant decrease in time spent browsing between the period before and the period during exposure for the black woodpecker, boreal owl and human stimuli. During exposure for dog stimulus not all individuals used time for browsing (n=18 of 26 observations), however in the occasion they did browse, they spend 2.45 seconds, on average. When the moose were exposed to the stimulus black woodpecker and boreal owl, there were an increase in time spent browsing between the period during and after exposure (only significant for boreal owl). For the human and the dog stimuli there was no difference between the proportion of time spent browsing between the period during and after exposure. The blank sound did not cause a difference between any of the time periods (Figure 10, Table 12).

Table 12. Parameter estimates and fit statistics based on the GLMM for the proportion of time used per individual (moose) for browsing before (n=784), during (n=784) and after (n=784) being exposed to the sound stimuli blank (n=339), black woodpecker (n=38), boreal owl (n=228), dog (n=27) and human (n=152), light-conditions dark (n=566), daylight (n=117), half-light (n=101) and for trial day (n=37). Random effect = station number.

	Estimate	**Std. Error**	**Z-value**	**P-value**
Intercept (After, Blank, Dark)	0.69	0.16	4.24	<0.001
Before	-0.25	0.16	-1.56	0.120
During	-0.03	0.16	-0.15	0.878
Black woodpecker	-1.12	0.35	-3.17	0.002
Boreal owl	-1.52	0.19	-7.79	<0.001
Dog	-2.94	0.85	-3.46	<0.001
Human	-8.84	7.72	-1.15	0.252
Trial_day	-0.01	0.01	-0.95	0.344
Daylight	0.40	0.14	2.79	0.005
Half-light	0.31	0.15	2.08	0.037
Before*Black woodpecker	1.36	0.51	2.67	0.008
During*Black Woodpecker	-0.93	0.54	-1.73	0.083
Before*Boreal owl	1.45	0.26	5.54	<0.001
During*Boreal owl	-0.85	0.29	-2.90	<0.001
Before*Dog	3.74	0.97	3.84	<0.001
During*Dog	-2.15	1.89	-1.14	0.254
Before*Human	8.73	7.72	1.13	0.258
During*Human	3.91	7.75	0.51	0.614

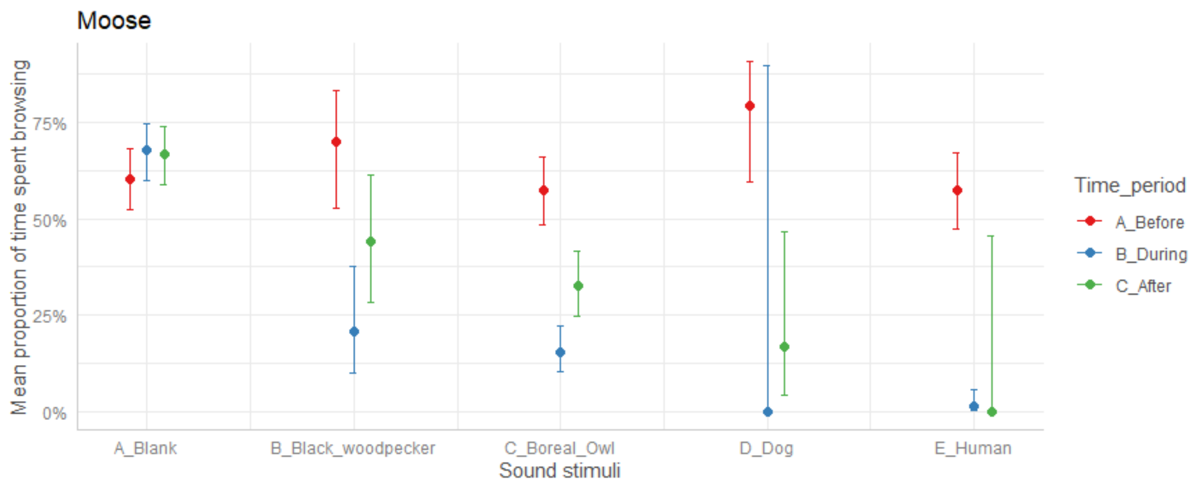


Figure 10. Mean proportion (± 95% confidence intervals) of time spent browsing per individual (moose) before (n=784), during (n=784) and after (n=784) being exposed to the sound stimuli blank (n=339), black woodpecker (n=38), boreal owl (n=228), dog (n=27) and human (n=152).

Red deer

Based on the AIC model selection, model 4 was the best explaining model (Table 13).

Table 13. AIC model selection with the best fitting models ranked from top (models with ΔAICc < 2 are the best fitting models).

	Model	AICc	ΔAICc	AICcWt
Time_period+Sound+Trial_day+Light+ Time_period*Sound	mod 4	2875.07	0.00	1
Time_period*Sound	mod 2	2944.51	69.44	0
Time_period*Sound	mod 5	2944.51	69.44	0
Time_period+Sound+Trial_day+ Time_period*Sound	mod 3	2947.08	72.01	0
Time_period+Sound	mod 1	2952.47	77.40	0

When exposed to the human stimulus the red deer spent significantly more time browsing before than during exposure of the sound. After the sound was played there was a significant increase in time spent browsing compared with during the sound was played. For the other sound stimuli, there were no significant differences in time spent browsing between the time periods before, during and after the sounds were played (Figure 11, Table 12).

Table 14. Parameter estimates and fit statistics based on the GLM for the proportion of time used per individual (red deer) for browsing before (n=772), during (n=772) and after (n=772) being exposed to the sound stimuli blank (n=495), black woodpecker (n=99), boreal owl (n=68) and human (n=109), light-conditions dark (n=312), daylight (n=419), half-light (n=41) and for trial day (n=25).

	Estimate	Std. Error	Z-value	P-value
Intercept (Before, Blank, Dark)	0.04	0.20	0.21	0.838
During	0.14	0.14	1.00	0.319
After	0.30	0.14	2.12	0.034
Black woodpecker	-0.39	0.23	-1.68	0.093
Boreal owl	-0.45	0.27	-1.68	0.092
Human	-0.29	0.22	-1.32	0.186
Trial_day	0.01	0.01	0.87	0.385
Daylight	0.82	0.10	8.06	<0.001
Half-light	0.36	0.20	1.79	0.073
During*Black woodpecker	-0.67	0.32	-2.08	0.038
After*Black woodpecker	-0.45	0.32	-1.39	0.165
During*Boreal owl	-0.26	0.37	-0.69	0.488
After*Boreal owl	0.18	0.37	0.48	0.629
During*Human	-1.23	0.32	-3.85	<0.001
After*Human	-0.63	0.31	-2.02	0.043

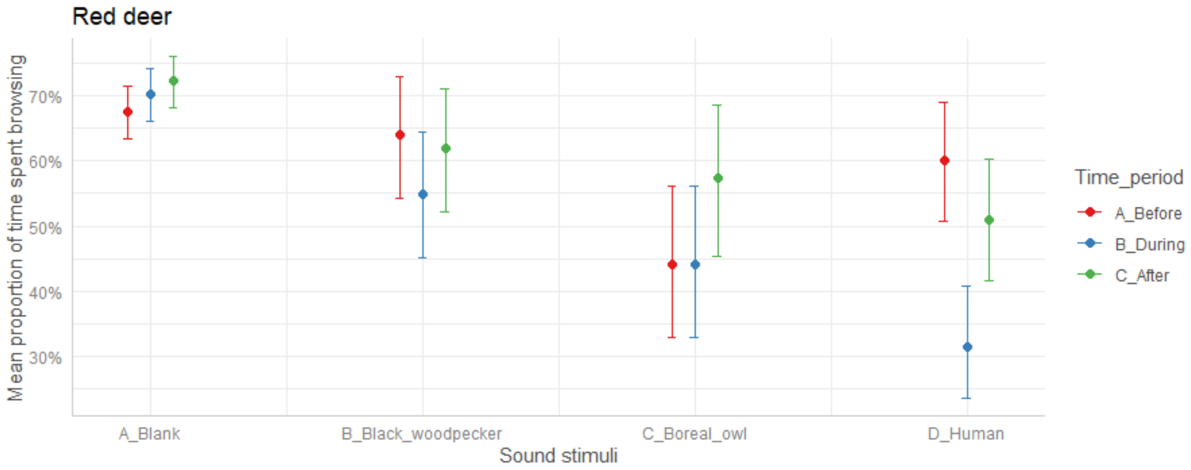


Figure 11. Mean proportion (± 95% confidence intervals) of time spent browsing per individual (red deer) before (n=772), during (n=772) and after (n=772) being exposed to the sound stimuli blank (n=495), black woodpecker (n=99), boreal owl (n=68) and human (n=109).

3.5 Proportion of time spent vigilant

Moose

Based on the AIC model selection, model 3 & 4 were the best explaining models (Table 15). Model 4, with the lowest ΔAIC, included the interaction between *time period* and *sound* and was therefore chosen.

Table 15. AIC model selection with the best fitting models ranked from top (models with ΔAICc < 2 are the best fitting models).

Model variables	Model	AICc	ΔAICc	AICcWt
Time_period+Sound+Trial_day+ Time_period*Sound+(1|Station_nr)	4	1289.16	0.00	0.56
Time_period+Sound+Time_period*Sound + (1|Station_nr)	3	1289.99	0.82	0.37
Time_period+Sound+Trial_day+Light+ Time_period*Sound+(1|Station_nr)	5	1293.50	4.34	0.06
Time_period+Sound+(1|Station_nr)	2	1341.89	52.73	0.00
#Null modell	1	1916.53	627.37	0.00

Time spent vigilant increased from the period before to the period during exposure for the black woodpecker, boreal owl, dog and human sounds. The moose did usually not use time for vigilance before exposure of the black woodpecker stimulus (n=5 of 38 observations), the dog stimulus (n=2 of 27 observations) and the human stimulus (n=3 of 152 observations), which affected the confidence intervals in the graph (Figure 12). Between the period during and after the sounds were played, time spent vigilant decreased for the black woodpecker and the boreal owl. When the human sound was played there was an increase in vigilant time after the exposure (Figure 12, Table 13).

Table 16. Parameter estimates and fit statistics based on the GLMM for the proportion of time used per individual (moose) for vigilance before (n=784), during (n=784) and after (n=784) being exposed to the sound stimuli blank (n=339), black woodpecker (n=38), boreal owl (n=228), dog (n=27) and human (n=152), trial day (n=37). Random effect = station number.

	Estimate	Std. Error	Z-value	P-value
Intercept (After, Blank)	-2.93	0.32	-9.26	<0.001
Before	-0.72	0.47	-1.53	0.127
During	0.10	0.38	0.25	0.802
Black woodpecker	2.12	0.46	4.62	<0.001
Boreal owl	2.76	0.31	8.87	<0.001
Dog	2.36	0.64	3.71	<0.001
Human	2.99	0.39	7.65	<0.001
Trial_day	-0.01	0.01	-1.36	0.174
Before*Black woodpecker	-10.22	29.18	-0.35	0.726
During*Black woodpecker	1.03	0.62	1.66	0.097
Before*Boreal owl	-3.24	0.77	-4.23	<0.001
During*Boreal owl	0.67	0.43	1.64	0.102
Before*Dog	-6.01	7.53	-0.80	0.425
During*Dog	-0.02	0.78	-0.02	0.981
Before*Human	-9.85	15.27	-0.65	0.519
During*Human	-1.77	0.53	-3.37	<0.001

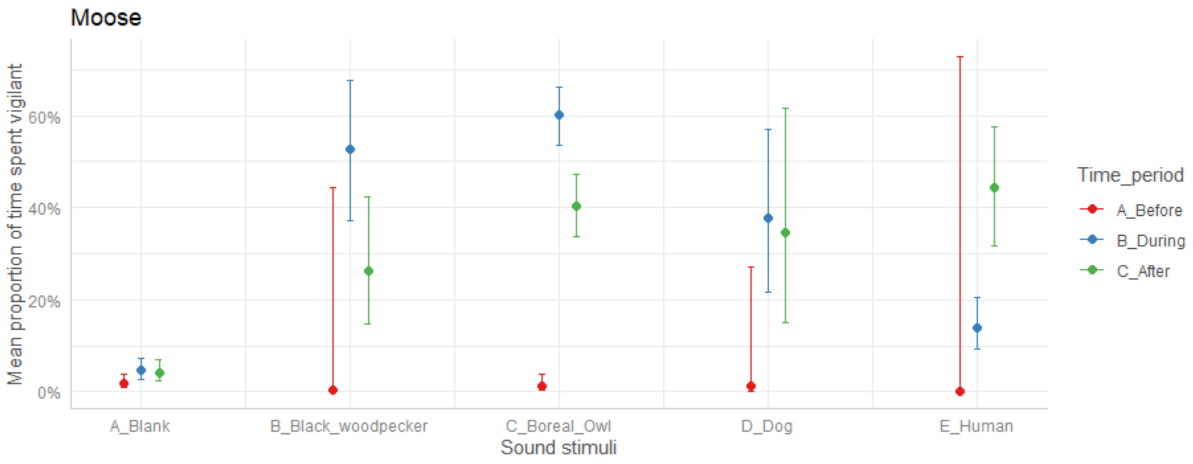


Figure 12. Mean proportion (± 95% confidence intervals) of time spent vigilant per individual (moose) before (n=784), during (n=784) and after (n=784) being exposed to the sound stimuli blank (n=339), black woodpecker (n=38), boreal owl (n=228), dog (n=27) and human (n=152).

Red deer

Based on the AIC model selection, model 2 & 5 were the best explaining models (Table 17). Model 2 included the interaction between *time period* and *sound* and was therefore chosen.

Table 17. AIC model selection with the best fitting models ranked from top (models with ΔAICc < 2 are the best fitting models).

Model variables	Model	AICc	ΔAICc	AICcWt
Time_period+Sound+Time_period*Sound	2	756.02	0.00	0.48
Time_period*Sound	5	756.02	0.00	0.48
Time_period+Sound+Trial_day+ Time_period*Sound	3	761.56	5.54	0.03
Time_period+Sound	1	766.88	10.86	0.00
Time_period+Sound+Trial_day+Light +Time_period*Sound	4	767.17	11.15	0.00

It was an increase in time spent vigilant between the period before and during exposure of sound for all stimuli, except for blank sound. The red deer did usually not use time for vigilance before exposure of the black woodpecker stimulus (n=1 of 100 observations), the boreal owl stimulus (n=4 of 69 observations) and the human stimulus (n=7 of 108 observations), which affected the confidence intervals in the graph (Figure 13). In the same way, there was a significant decrease in time spent vigilant between the period during and after exposure of all the sounds, except for blank/silent sound. The largest differences between the time periods were seen for the human stimulus. It was no difference between the time periods for the blank/silent sound (Figure 13, Table 14).

Table 18. Parameter estimates and fit statistics based on the GLM for the proportion of time used per individual (red deer) for browsing before (n=772), during (n=772) and after (n=772) being exposed to the sound stimuli blank (n=495), black woodpecker (n=99), boreal owl (n=68) and human (n=109).

	Estimate	Std.Error	Z-value	P-value
Intercept (Before, Blank)	-4.31	0.39	-10.96	<0.001
During	0.59	0.49	1.20	0.232
After	0.32	0.52	0.62	0.533
Black woodpecker	-1.88	2.25	-0.84	0.403
Boreal owl	-0.38	1.34	-0.28	0.776
Human	0.07	0.90	0.08	0.939
During*Black woodpecker	4.89	2.28	2.14	0.032
After*Black woodpecker	3.10	2.30	1.74	0.082
During*Boreal owl	3.49	1.39	2.51	0.012
After*Boreal owl	2.43	1.43	1.70	0.089
During*Human	3.63	0.97	3.75	<0.001
After*Human	2.50	0.99	2.52	0.012

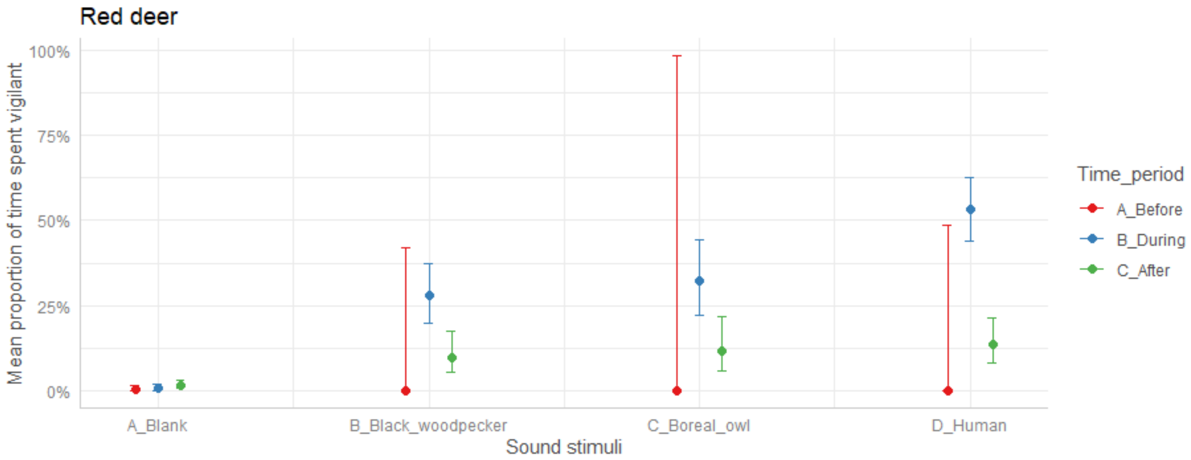


Figure 13. Mean proportion (± 95% confidence intervals) of time spent vigilant per individual (red deer) before (n=772), during (n=772) and after (n=772) being exposed to the sound stimuli blank (n=495), black woodpecker (n=99), boreal owl (n=68) and human (n=109).

4.DISCUSSION

Moose left the site significantly more often when they were exposed to sounds associated with predation (human and dog) compared to the natural harmless and blank/silent sounds, which are in line with my hypothesis and prediction (H1, P1). The proportion of red deer leaving the site after being exposed to the sound stimuli differed a lot from the proportion of moose leaving the site. The red deer turned out to rarely leave the site, apart from the human stimulus that made a significantly larger proportion of animals to leave the site compared to the blank sound. This also supports the hypothesis (H1, P1). The leaving response decreased with time for red deer being exposed to the human stimulus. The other sound stimuli did not show a significant decrease in leaving response with time. These results partly support hypothesis 1 and prediction 2 for red deer, but not for moose. The moose had a stronger leaving response than the red deer, which is the opposite of my prediction (H1, P3).

For moose, time used browsing decreased during and after being exposed to both natural harmless sounds and sounds associated with predation, with the strongest reduction with sounds associated with predation, which are in line with my prediction (H2, P1). For red deer, the only significant reduction in time spent browsing was during exposure for human stimulus, which only partly support my prediction (H2, P1). There was a significant increase in time being vigilant during and after being exposed to the sound stimuli human and boreal owl for moose and human for red deer, compared to the time being vigilant before they were exposed to the same stimuli. This partly supports the prediction (H2, P2). Also for this hypothesis, the moose had a stronger response to the exposure of sound stimuli, which doesn’t support my prediction (H2, P3).

4.1 Behaviour response to sound stimuli

My results are in line with the parallel study from Sweden, which also showed that a larger proportion of moose left the site after being exposed to human and dog stimuli (Lodnert, 2021). The same patterns are shown in the two studies, with a larger reaction to the sounds associated with predation than the natural harmless sounds. Other wildlife deterrent studies have also shown a pattern where animals react stronger to devices playing sounds associated with natural predators than other kinds of sounds (Babinska-Werka et al., 2015; Koehler, 1990). A change in behaviour when animals are exposed to a disturbance associated with the “human super predator” seems to be a common pattern for several species (Smith et al., 2017). It is therefore not a surprising result in this study.

The strongest response (decrease) in time spent browsing and being vigilant was shown with the human- and partly with the dog stimulus. This corresponds to the results for the proportion of moose leaving the site, where the same pattern with the strongest response to dog and human stimuli were shown. A possible factor that could have influenced the results is the fact that browsing is the main cause for the presence of the moose and the red deer at these sites. With the energy-saving strategy in mind, it is conceivable that ensuring access to energy have a higher priority than the anti-predator behaviour (Lima & Dill, 1990).

The two natural harmless sounds, black woodpecker and boreal owl had the same impact on the proportion of animals leaving the site, both for moose and red deer (Table 7 & 10). For moose, the boreal owl led to a significantly higher proportion of individuals leaving the site compared to the blank sound. This difference can be explained by the fact that the boreal owl only was played at night when the highest proportions of moose were present at the feeding stations throughout the day. Both the boreal owl and the black woodpecker should be perceived as natural sounds for the moose and the red deer in the study area. The settings that made the black woodpecker play in the daytime and the boreal owl at night, should enhance this naturalness. The volume settings for the sounds are an uncertainty that may have affected the behaviour reaction beyond the sound itself.

4.2 Species differences

The small proportion of red deer leaving the site was a surprising result, which rejected my hypothesis for this test, suggesting that the red deer should have a stronger reaction to the acoustic stimuli than the moose. The red deer is a relatively newly established species in the study area, and during the last years, there has been an increase in the population and the occurrence at feeding stations during winter seasons (Johnsen, 2012). During the hunting season 2020/2021 there was shot 54 red deer in Stor-Elvdal municipality. By comparison, there was shot only 4 red deer during the season 2000/2001 (SSB, 2021). This indicates an increase in the relatively newly established population of red deer in the municipality. The red deer have been hunted over a considerably shorter period than the moose in the municipality, which for decades has been one of the municipalities with the highest number of moose shot during the hunting season (SSB, 2020a). This might be one of the explanations for the higher response to the human and dog stimuli for moose than for red deer, as these sounds for the moose probably are associated with hunting to a greater extent than for the red deer.

Living in herds is an anti-predator behaviour, often known under the name “safety in numbers”, used to increase the possibility to detect predators in time (Foster, 2017). Among cervids, such strategies are usually most common for reindeer, who lives in open landscapes (Bjørneraas, 2012). Studies have shown that time spent vigilant decreases with group size (Lima & Dill, 1990). This can be one of the explanations for the lower response to the sounds for the red deer than the moose, taken in account that the red deer occurred in larger groups at the feeding stations. To gain the benefits with a herd strategy, the animals are dependent on certain individuals taking the responsibility to be vigilant and keep an eye (sentinels) for predators (Lima & Dill, 1990). If a group of individuals who normally does not live in larger groups, starts to appear in herds, the importance for certain individuals keeping an extra eye for predators, might not be established among the animals. In this way, we might see a sort of mismatch between the choice of herd strategy and how the strategy works, considering that the red deer do normally not occur in such large groups as they did at the feeding stations. It is also possible that they considered the sounds not to pose a danger because they appeared in a sort of herd. This might be some of the explanations for the low response for the red deer, compared with the moose.

Another factor that should be considered is the placing of the sound-unit (MASS) at the feeding station for red deer (station 9). At this station, the system was placed some meters further away (approximately 10 meters) from the silage bale than at the other stations, due to lack of trees for mounting the MASS. In addition, station 9 was more open, with a greater distance to the forest and more exposed to wind than the other stations. This may have muted the volume of the sounds and thus led to lower response. It should however be mentioned that moose at this station had the same response as moose at the other stations (a large proportion of them left when they were exposed to the human sound). We did not measure the volume of the systems in dB from the centre of the feeding stations. This might have shown a difference between the feeding stations.

4.3 Habituation

Connected to disturbances for wildlife, habituation is a well-known effect (Benten et al., 2019; Koehler, 1990; Smith et al., 2000; VerCauteren et al., 2005). My results show a significant interaction with a lower proportion of red deer leaving the site when they were exposed to the human sound with increasing trial day. For moose, there were shown no significant interaction between trial day and the sounds, but a significant correlation. In this way, there was seen a decrease in the proportion of animals leaving the site with increasing trial day as a general pattern for all sounds. This may be explained by the time of year, which is an important factor for cervids during the last months in the winter (Neumann et al., 2011). The energy reserves were low at the start of the study period (late February), but even lower at the end of the period (late April). Based on this it will cost them more energy to react to the sounds later in the winter than earlier. A study found that the moose has the lowest heart rate and body temperature in March, indicating that this is the toughest period for the moose during winter. This energy-saving strategy is called hypermetabolism. (Græsli et al., 2020). Whether this makes the animals less aware of disturbances has not been examined in scientific studies, but it is conceivable that it might have an effect. It is also uncertain whether moose and red deer at winter feeding stations enter hypermetabolism since the feeding station gives them rich access to food, but it should be considered when exposing cervids to such stimuli in winter at other places.

It has been shown that natural sounds with some kind of understandable information for the animals have a more long-term effect than other kinds of acoustic stimuli (Koehler, 1990). This may be because cervids normally will show anti-predator behaviour to sounds associated with fear (Stankowich, 2008).

Habituation was an expected effect in this study. The short study period may be one of the explanations for the partly weak results for habituation in this study (Figure 7 & 9), compared with others. The study was conducted for less than two months, with a period without any sound exposure in the middle of the period. The comparable study from Sweden, conducted for 50 days, showed a clearer sign of habituation among moose (Lodnert, 2021). Previous studies reported the same patterns with a habituation effect within a relatively short time (Koehler, 1990; Smith et al., 2000). My results showed a fast habituating effect for red deer (Figure 8), which suggests that red deer get habituated to disturbances within a short time.

Babinska-Werka et al. (2015) refer an unpublished study from Kowalczyk, where they explained decreasing response to acoustic stimuli with time at feeding stations with the fact that the warning sounds at feeding stations never will lead to a danger to emerge, unlike with similar experiments along the railway, where a train always will emerge after a sound has been played. This supports the results from Babinska-Werka et al. (2015) performed along the railway, where no signs of habituation were seen during the five years the study was performed. Other studies also suggests that the habituation effect can be reduced and avoided if the sounds are followed by a real danger (Bomford & O'Brien, 1990).

False triggers caused by weather conditions, cars etc. may also contribute to habituation. The moose and the red deer will often not stay far from the feeding station in winter, and can in that way be affected and habituated to the sounds also when they aren’t present at the feeding stations (VerCauteren et al., 2005).

4.4 Relevance for management

This study is a part of a project where the aim is to develop a technical system to prevent wildlife accidents at the railway. There is little doubt that further research is needed in order to develop a technical system that can be implemented along the railway. Many studies state that habituation is a usual effect when exposing wildlife to different kinds of stimuli. When implementing a system at the railway this effect might however change, as the sounds then will be followed by real danger. This effect was discussed in the earlier mentioned study from Kowalczyk, cited in Babinska-Werka et al. (2015). When moving the sound stimuli from a static environment as a feeding station to an environment where real dangers occur (i.e., at the railway), the effect of habituation might decrease or disappear, which was stated in Babinska-Werka et al. (2015), where no habituation was shown. It seems reasonable to suggest that a form of sensitization might be expected when implementing a such system along the railway or when linking it to trains. Sensitization is the opposite of habituation and involves an enhanced response by repeated or enhanced exposure to disturbances (Reimers, 2018).

Combining different sounds have also been suggested and studied by others, and this has shown to reduce and delay habituation (Biedenweg et al., 2011; Koehler, 1990). This could be the next step in the path to examine if a combination of sounds could be more efficient for eliciting a change in behaviour for red deer.

For further research, I recommend finding a way to register climate data during the fieldwork period. This is explained by the fact that increasing snow depth and decreasing temperatures have shown to increase the risk for accidents with cervids (Gundersen & Andreassen, 1998). It would therefore be interesting to investigate whether these factors in any way influence the response to acoustic stimuli. Measuring the decibel levels of the stimuli at the different feeding stations are also recommended to make sure there are no big differences between the different stations.

4.5 Conclusions

This study aimed to examine whether sound stimuli could affect the behaviour of moose and red deer in a way that changes their behaviour to preliminary leave the area. The results for the human and dog stimuli show that these stimuli elicit the desired change in behaviour for a large proportion of moose, but not for red deer. This indicates that other stimuli than those tested here might have a better effect for the red deer. The fact that the dog and human stimuli seem to elicit a change in behaviour for a large proportion of moose makes it interesting to further investigate the possibilities for using such sounds in the development of a technical system to prevent accidents with cervids at the railway.

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