Behavioral response of reindeer (*Rangifer tarandus)* to acoustic stimuli

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Beteenderespons hos ren (Rangifer tarandus) till akustiska stimuli

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Abstract

Scare systems based on acoustic stimuli have been tested on several ungulates in recent years. The aim has been to investigate whether the method can be useful in situations where the animals must quickly be displaced from a specific site, for example, to prevent wildlife accidents. The method is based on inducing so-called anti-predator behaviors (flight and vigilance) by simulating predator presence via acoustic stimuli. However, there is a lack of research on how reindeer respond behaviorally to different acoustic stimuli, something that could be a useful method to keep animals away from critical infrastructure in the future. Therefore, the aim of this study was to investigate how reindeer react behaviorally to four acoustic stimuli: a predator (bear), white noise impulses (a wheezing sound), human voices, and sirens. A silent control was also included in the experiment to ensure that the reindeer were not disturbed by the equipment used for data collection. The experiment was conducted at three Sámi reindeer herding communities winter pastures in northern Sweden, with total seven study sites. The main questions before the study were: (1) How does the behavior change in reindeer when exposed to different acoustic stimuli? (2) What proportion of the observed reindeer react with a flight response as a result of being exposed to the different sounds? (3) Is there an appreciable difference between the four acoustic stimuli tested in the experiment when considering the two aforementioned questions?

In the results of this study, reindeer reacted most strongly to sounds from predator and the white noise impulses. The change in behavior was evident as the animals shifted from predominantly foraging before the sound started to predominantly running when the sound was played. A similar trend was observed when comparing the flight response to the different sounds. The flight response differed significantly between stimuli, 92.0%, fled in response to predator stimuli, followed by noise impulses at 81.9%, human voices at 75.8%, and sirens at 46.5%. Reindeer never exhibited a flight response when exposed to the silent control. Furthermore, all evaluated acoustic stimuli resulted in a reduced foraging behavior compared to the silent control, where reindeer primarily foraged throughout the entire observation period. These findings indicate that sounds from predators (bear) and noise impulses elicited the most pronounced behavioral changes in reindeer during the study. Therefore, these sounds could be useful in the future for effectively removing and keeping reindeer at a distance, particularly in critical areas where preventing wildlife accidents is crucial.

Keywords: reindeer, *Rangifer tarandus*, acoustic stimuli, behavioral response, flight response, induced fear

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Introduction

Infrastructure, like road and railway, has a negative impact on reindeer (*Rangifer tarandus*) because of the risk of animals getting injured or killed when in collision with a vehicle. In 2022, a total of 1 366 reindeer accidents on roads were registered according to statistics from the Swedish National Wildlife Accident Council (Nationella Viltolycksrådet 2023). Various measures to prevent vehicle-animal accidents are installed along roads in Sweden, including fences and bridges. The network constitutes varying degrees of barriers which interfere with wildlife and reindeer's natural migration path (Trafikverket 2021). Previous research has evaluated acoustic stimuli as a wildlife deterrence, where the aim was to induce fear by simulating predator presence to keep animals away from critical areas with human-wildlife conflicts. The method is based on using acoustic stimuli that can simulate the presence of danger (Bhardwaj et al. 2022; Widén et al. 2022). Similar research on reindeer, however, is insufficient.

1.1 Reindeer (*Rangifer tarandus*)

Reindeer is a migrating species well adapted to the varying seasonal conditions of the artic/sub-artic environment (Holand et al. 2022; Skarin et al. 2022). The migration from summer to winter pastures occurs due to reindeer adaption to varying conditions and avability of natural pastures (Pape and Löffler 2012), which can cover their need of forage with various quality and quantity over seasons (Holand et al. 2022; Pape & Löffler 2012). Reindeer have seasonal cycles in its metabolism and are adaped to these varying conditions (Pape and Löffler 2012). During the winter season, the nutritional needs of reindeer are reduced, and they primarily feed on lichens. In contrast, during the summer, they typically consume various forage plants that offer high digestibility and nutritional value (Holand et al. 2022; Skarin et al. 2022). Infrastructure and human activities may act as barriers to migration and cause disturbance and avoidance in the reindeer behavior (Anttonen et al. 2011). Also, transport infrastructure increase the risk of reindeer getting injured or killed (Trafikverket 2021).

Reindeer are a social specie that live in groups, with herd sizes varying throughout the seasons (Holand et al. 2022; Skarin et al. 2022). During winter, reindeer often live in smaller groups due to the higher competition for feed, while during migration they form larger herds (Holand et al. 2022). The dominant individuals are typically reproductive females with large antlers. These females often take on leadership roles within the group, leading and providing security for the herd (Skarin et al. 2022). Additionally, female reindeer with calves typically exhibit more frequent vigilance behavior compared to males (Reimers et al. 2021). Group living among reindeer offers several advantages, one of which is the shared responsibility for watching out for predators. This allows each individual to allocate more time and energy toward other behaviors such as foraging, rather than vigilant behavior (Reimers et al. 2021).

1.1.1 Reindeer husbandry in Sweden

The reindeer husbandry in Sweden is divided into 51 Sámi reindeer herding communities (Sametinget 2022). Due to variations in managmet practices there are three divisions: mountain, forest and concession reindeer herding communities (Sametinget 2022; Widmark 2006). Each community is an association with its own board that leads the reindeer herding within a specific geographical area (Sametinget 2022). The reindeer husbadry is based on the use of natural pastures and is adapted to the migration behavior of the animals. Therefore, the landuse of reindeer herding communities is often divided into two seasonal areas: winter pastures at costal areas and summer pastures at montain areas (Widmark 2006).

1.2 Previous studies regarding fear in reindeer

The behavioral response of reindeer to human approaching them on foot has, among others, been studied by Nieminen (2013) and Baskin & Hjältén (2001). Both studies investigated wild and semi-domesticated reindeer's response and compared the differences between herds. The results indicated that the behavior varied between wild and semi-domesticated reindeer, where wild reindeer exhibited a stronger vigilance and flight response (avoidance behavior) compared to semi-domesticated reindeer (Nieminen 2013; Baskin & Hjältén 2001). High predation pressure has been found to correlate with an increased flight distance compared to areas with low predation pressure. Also, an increase in group size reduced flight distance for the reindeer in the study (Baskin and Hjältén 2001). Supplementary feeding of semi-domesticated reindeer has been observed to result in a shorter flight distance compared to semi-domesticated reindeer that were not provided with additional feed. The reaction to provocation by human also differed between seasons, where the behavioral response was stronger during winter and autumn (Nieminen 2013).

Reindeer, among three other ungulates species, were studied to evaluate their behavioral response towards predators, in areas where predators were present and in predator-free areas (Berger 2007). Different sounds were broadcasted, including water sounds and predator sounds from wolves, tigers, and howler monkeys. The sounds were broadcasted for 25s and three behaviors were noted: vigilance, group clustering and immediate site abandonment. All three behavior responses analyzed in the study were more frequently exhibited by animals living in predator areas compared to predator-free areas. (Berger 2007).

1.2.1 Inducing fear without presence of an actual threat

Fear can be induced in animals by utilizing their different senses, and simulating predator presence which can induce anti-predator behaviors (Chamaillé-Jammes et al. 2014; Koehler et al. 1990). Fear can be induced through various means such as the olfactory system by adding urine from a predator (Chamaillé-Jammes et al. 2014), visual stimuli such as lights and moving objects, or through acoustic stimuli (Koehler et al. 1990). Using acoustic stimuli may be an effective method for keeping reindeer from undesired areas (Bhardwaj et al. 2022; Widén et al. 2022; Babińska-Werka et al. 2015; Berger 2007; Koehler et al. 1990).

One study by Bhardwaj et al. (2022) on moose (Alces alces) examined the effect of acoustic stimuli. The stimuli were divided into two categories, presumably threatening sounds which included human voice and dog barking, and presumably non-threatening sounds from birds (Boreal Owl and Black woodpecker). Moose exhibited the strongest behavioral response towards the human stimulus, with a 75% probability to leave the sight and waiting long periods before returning. The stimulus from a barking dog resulted in increased vigilance, and a 39% probability to leave the site. Moose left the site in 24% of the events when exposed to bird sounds. Throughout the course of the experiment, there was a noted habituation to all stimuli. However, the stimulus from humans still elicited the strongest behavioral reaction over time compared to the other stimuli tested (Bhardwaj et al. 2022).

Another study by Widén et al. (2022), examined the effect of acoustic stimuli from predator vocalization on five ungulate species (fallow deer, roe deer, red deer, moose and wild boar) to reduce crop damage. They evaluated predator sounds from dog, wolf and human and included non-predator sounds from birds (goose, owl and raven) as control. Predator vocalization induced stronger fear responses in all ungulate species compared to non-predator vocalization. Human voices gave the strongest behavioral reaction of the three different predator stimuli, followed by wolf, while dog gave the weakest response (Widén et al. 2022).

1.2.2 Tolerance and habituation

Tolerance is used to describe how strong intensisty of an disturbance that a individual can tolerate without giving a defined response (Bejder et al. 2009). Habituation on the other hand, refers to the process in which an individual´s responsiveness to a particular stimuli declines due to repeated exposure (Blumstein 2016; Blumstein 2014; Bejder et al. 2009) . When attempting to reduce a human-animal conflict through, for example acoustic stimuli, it's important to bear in mind that habituation can reduce its effectiveness (Blumstein 2016). However, habituation is a longterm process, and therefore, the measure of an individuals tolerance levels are more suitable for avoidance studies with short data collecting period. Also, evaluation of habituation is only approptiate for long-term experiments, with data collection of different exposure levels, that include the same individual over the whole experimental period (Bejder et al. 2009).

1.3 The hypothesis of the behavioral response of reindeer to acoustic stimuli

The aim of this thesis is to investigate the behavioral response of reindeer to different acoustic stimuli and examine if sounds can be an effective tool for keeping reindeer from critical infrastructure. The four acoustic stimuli used in this study are: predator (bear), noise impulses, human voices and sirens. A silent control will also be used.

All four acoustic stimuli are predicted to elict a behavioral response in reindeer. However, the response is likely to vary in degree depending on the type of stimulus. The aim was to choose sounds that would hypothetically scare the reindeer away from the experiment site. Since reindeer has the brown bear as one of their large predators in Sweden (Støen et al. 2022), I considered it as a possible acoustic stimulus to scare the reindeer. Sounds from predators, like wolves and tigers, have previously been used to compare vigilance response in reindeer at locations with and without the presence of predators (Berger 2007). The noise impulses used in the experiment were an imitation of a truck's braking system, which makes a wheezing sound. I received a recommendation from one of the reindeer herders to test this specific sound. Human voices have previously been used in similar experiments on ungulates, where it has proven to be effective (Bhardwaj et al. 2022: Widén et al. 2022). Therefore, I thought it would be interesting to investigate their effect on reindeer as well. Different types of sirens may be used by reindeer herders when herding and moving the reindeer, and I wanted to investigate if they are an effective stimulus to induce behavioral responses.

Method

2.1 Study area

The study was conducted on free ranging, semi-domesticated reindeer in the mountain Sámi reindeer herding communities Ran, Gran and Svaipa at their winter pastures, in the northern part of Sweden. The winter pastures were located in Robertsfors municipality (Gran), Umeå municipality (Ran) and Vindelns municipality (Svaipa) (figure 1; appendix 1). All reindeer in the study were supplementally fed with silage, pellets or a combination by the two, by the reindeer herders. The reindeer herders chose suitable sites for each unit, however, the closest distance allowed between the units was 1km to make sure that reindeer did not get affected by nearby units. All sites were at relatively open locations surrounded by forest (figure 2; appendix 2), and had a varying degree of human activity. The sites in Ran had the highest human presence due to the units being placed along a local snowmobile trail, while Gran and Svaipa where more remote from human activities.

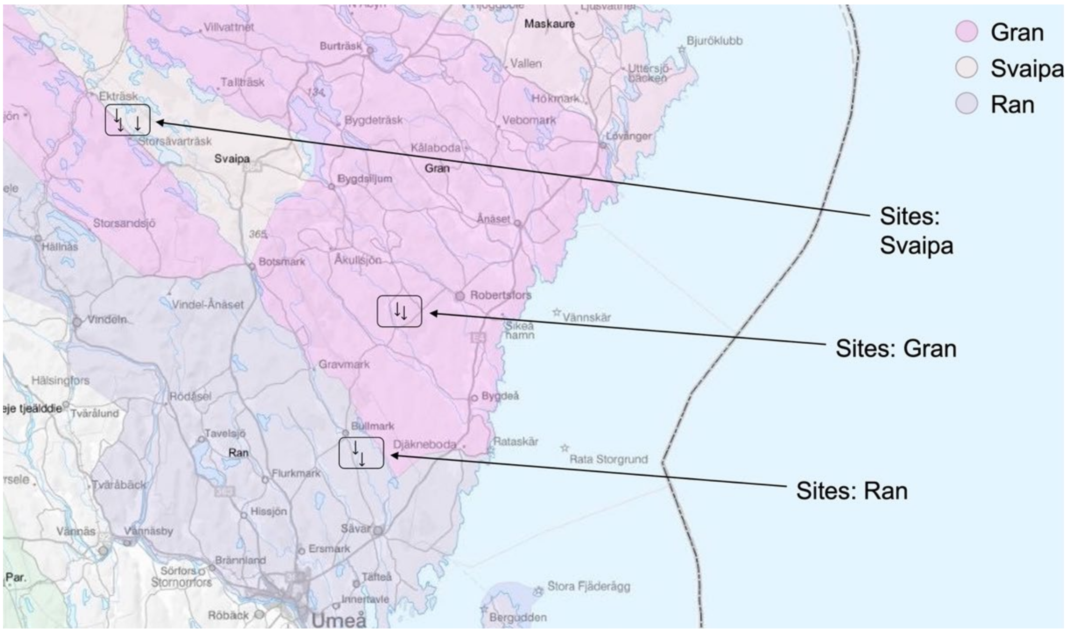

Figure 1. Map over the Sámi reindeer herding communities winter pastures, illustrating the locations of each site. For more detailed maps, see appendix 1.

Figure 2. Example picture, showing the location of the site Gran 1.

The experiment was conducted at seven different study sites (table 1), where all data were collected. However, not all seven sites were active throughout the entire study period. In the Sámi herding communities Gran and Ran, I had two sites at each herding community, while in Svaipa I had three different sites. The sites were chosen by the reindeer herders and placed where the reindeer were expected to pass by. At Gran and Ran, the units where stationary during the experiment, while at Svaipa one of the units were stationary and the other one was relocated once during the experiment due to movement of the reindeer.

Table 1. Information of each site: location, start- and end date, number of videos analyzed.

	Site ID	North	East	Start date	End date	$N_{Videos\ analyzed}$
Gran	Gran 1	7129051	769822	2023-02-07	2023-02-26	60
	Gran 2	7128803	770737	2023-02-13	2023-02-22	17
Ran	Ran 1	7108545	768615	2023-02-15	2023-02-21	43
	Ran 2	7109891	768421	2023-02-15	2023-02-22	6
Svaipa	Svaipa 1	7156814	734893	2023-02-08	2023-02-14	197
	Svaipa 2	7155036	736423	2023-02-08	2023-02-17	86
	Svaipa 3	7155387	737682	2023-02-14	2023-02-26	46
Total						455

There was a difference in the feeding strategies between the Sámi herding communities, resulting in variations between sites whether there was feed at the units to attract the reindeer or not. In Svaipa, silage and/or pellets were placed at the units to attract the reindeer. While at Ran and Gran, there was no feeding at the units, however the feed out locations of the reindeer were nearby the site areas. At all sites, animals were moving freely and would encounter the scaring devices by chance and unexpectidly.

2.2 Experimental setup

I used the ”Motion-Activated Scaring System” (MASS) to expose reindeer to acoustic stimuli and evaluate their behavioral response (figure 3). MASS are units developed at Grimsö Wildlife Reaserch Station, Swedish University of Agricultural Sciences, and used for experimental purposes (Seiler et al. 2022). The devices are activated by motion, and the aim is to play sounds that scare animals away from the site. When the unit is activated by motion, a built-in camera is programmed to record a video divided into three parts in order to capture behavioral responses (Seiler et al. 2022). In this study, the following programming was used: 12s of recording before the acoustic stimulus was displayed, 20s during the display of the acoustic stimulus, and 15s after the stimulus was displayed.

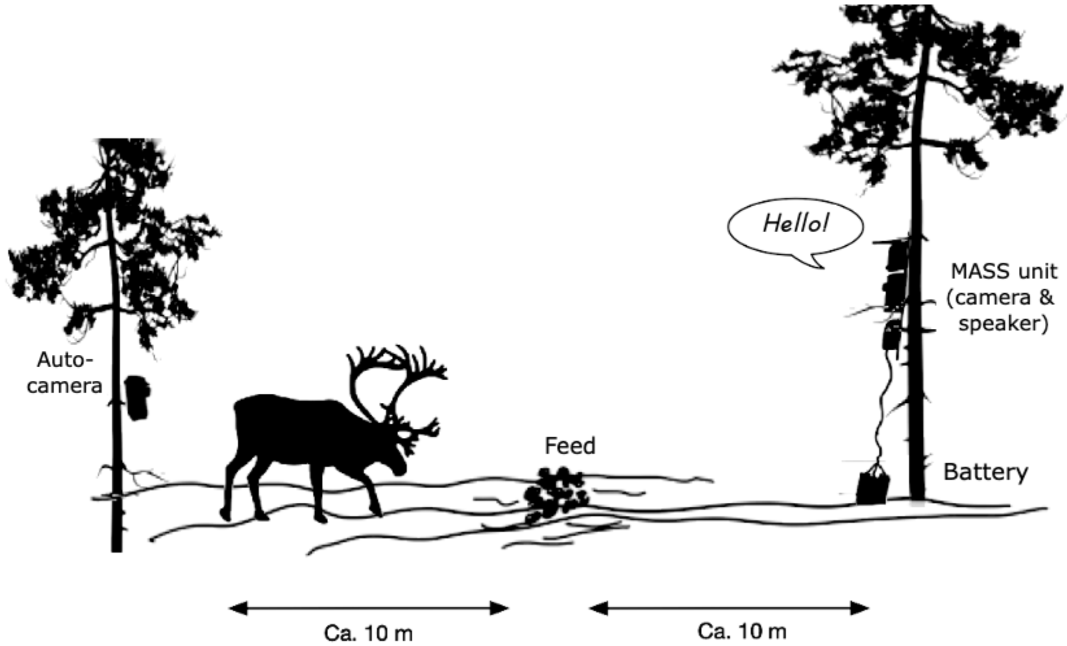

Figure 3. Illustration of the set-up from the test sites. Not all sites had feed near the unit due to differences in feeding strategies between the Sámi herding communities.

2.2.1 Acoustic stimuli

The MASS-units were programed with four different types of sounds and a silent control; each sound had five different versions. The sounds used in the experiment were from a large predator (bear), siren, human voices and short (1 sec) impulses of white noise (will be refered to as noise in the following sections of this report). I divided the sounds into three different categories: threatening sounds which include large predator and human voices; artificial sound which include siren and noise; and lastly, silent control. Each acoustic stimuli had five slightly different versions of sound files, with the exception of the noise impulses, which only had four versions in total. The sound from humans consisted of five different voices, two female and three males, all five reading the same voice message. For the large predator, different versions of bear growling and breathing were used. Siren consisited of various versions of siren sounds.

The MASS-unit was programmed to randomly play one of the 24 sound files, 12s after motion was detected and the camera activated. Once the unit had been activated, there was a 30s delay before the unit could be activated again by motion. However, even though the files were played randomly, the overall exposure was approximately equal (table 9).

Two samples of the sound volumes were measured, one from a 1m distance to the unit and one from 10m. The decibel level ranged from 65-77dB when measured from 1m, and from 10m the decibel level ranged from 50-73dB. Human voice had the lowest decibel level, while the noise impulses had the highest for both distances.

2.3 Data collection

MASS units were active from the 7th of February 2023 to the 26th of February 2023 for the data collection. The units were active during the entire period, regardless of time of the day. The batteries and memory cards were changed every week. However, due to some sites being installed later for various reasons and issues with battery replacements for certain units, there are gaps in the data collection at some sites.

2.4 Behavioral analysis

The behavior analysis was performed using the open-access software BORIS (Friard and Gamba 2016). In each video, one focal individual was observed. In videos with more than one individual, the individual closest to the unit when the sound triggered was selected for the analysis. I created an ethogram (table 2) in BORIS with behaviors that were identified when analyzing the individual´s behaviors throughout the video. The time length spent on each behavior was rounded to the nearest second. The analysis was separated into three periods: “before”, “during” and “after” the acoustic stimulus was displayed.

Table 2. Ethogram of the behaviors quantified in BORIS.

Behavior	Description
Vigilant	Reindeer display alert behavior (observing surroundings, listening with ears up, concentrating on few directions).
Foraging behavior	Reindeer have head down and is eating or searching for food.
Walking	Reindeer walking in a slow pace.
Running	Reindeer runs or flees.
Other behavior	Reindeer performs undefined behavior, e.g., social behavior.
Not visible	Reindeer is not displayed on video or hidden, e.g. behind object or conspecific.

In addition to the behavioral analysis in BORIS, I also evaluated the individual's overall response to the acoustic stimuli. This analysis was based on a acoustic stimuli score (table 3) which only indicated how the reindeer reacted when the sound was displayed. The scoring ranging from 0-1 implied no flight reaction while 2-3 implied a flight reaction. The acoustic stimuli score was later also used to investigate flight response in the analysis, by converting the scores 0-1 = 0; no flight, and the scores 2-3 = 1; flight.

Table 3. Description of the acoustic stimuli score, used to evaluate the strongest reaction during the period when reindeer was exposed to acoustic stimuli.

Acoustic stimuli score	Flight response	Description
0	0	No response (i.e., no change in behavior compared to the period before the sound exposure).
1	0	Vigilance (listening and looking at its surroundings without exhibiting flight behavior).
2	1	Delayed flight (flight initiated after some time of vigilance).
3	1	Immediate flight (quick and abrupt flight, directly when exposed to the sound).

Three questions (table 4) were answered for the group response to the acoustic stimulus. For the group observation, all individuals were counted before, during and after the acoustic stimulus.

Table 4. Questions for the group analysis.

Question	**Definition**
How many individuals react with flight behavior?	Reindeer runs fast from site with at least 5 steps
How many individuals react with "controlled flight"?	Reindeer walks or runs "controlled" from the site, "controlled" = 3s or more of vigilance before moving or walking directly when sound starts
How many individuals leave the video frame?	How many reindeer leave the frame during and after the sound

2.5 Data variabels

The reindeer behavioral reaction to acoustic stimuli were examined by comparing a number of explanatory variables (table 5) and behavioral response variables (table 6). The variables of interest were analyzed in different tests in the statistical software JMP Pro version 17 (JMP Statistical Discovery 2023).

Table 5. Explanatory variables used in the evaluation of reindeer behavioral change in relation to acoustic stimuli.

Variable	Description
Period	Factor with three levels: before, during and after. A total of 47 second observation period divided into: 12s before exposure to acoustic stimuli or silent control, 20s during exposure to acoustic stimuli or silent control and 15s after exposure to acoustic stimuli or silent control.
Stimuli	Factor with four levels, one for each acoustic stimulus: predator, noise, human, siren and silent control. Different versions of the same stimuli were not distinguished.
Group size	Group size implies the number of individuals present during each period (before, during and after being exposed to acoustic stimuli).

Table 6. Behavioral responses used in the evaluation of reindeer behavioral change in relation to acoustic stimuli. For definitions of the variables: running, walking, vigilance, foraging, other behavior and visible or not visible see table 2, for acoustic stimuli score and flight response see table 3.

Variable	**Description**
Running	Proportion of time spent running while visible in the video. Giving a proportional variable, ranging from 0-1.
Walking	Proportion of time spent walking while visible in the video. Giving a proportional variable, ranging from 0-1.
Vigilance	Proportion of time spent vigilant while visible in the video. Giving a proportional variable, ranging from 0-1.
Foraging	Proportion of time spent foraging while visible in the video. Giving a proportional variable, ranging from 0-1.
Other behavior	Proportion of time spent on other behaviors while visible in the video. Giving a proportional variable, ranging from 0-1.
Visible or not visible	The time reindeer was visible or not visible to account for if reindeer left frame or was in background. Giving two proportional variables, visible = 0-1 and not visible 0-1. Visible includes all observed behaviors.
Acoustic stimuli score	The behavioral response of reindeer to the acoustic stimuli, scoring from 0-3 where 0 = no response and 3 = immediate flight.
Flight response	Flight or no flight, i.e. if reindeer perform flight response (acoustic stimuli score 2-3) or not (acoustic stimuli score 0-1).

2.5.1 Behavioral change when exposed to acoustic stimuli

The behavioral change in reindeer when exposed to acoustic stimuli where explored by creating a bar graph with 95% confidence interval. I used the data variables period, stimuli (table 5), running, walking, vigilance and foraging (table 6). The behavioral response variable “other behavior” was left out due to it being such a small portion of the overall behavior repertoire. The behavioral change in reindeer was then evaluated with a Students t-test to be able to compare if the change in behavior between periods (before-during and during-after) was significant.

To account for the time a reindeer was not able to be analyzed (i.e., when a reindeer was in background or out of frame), I created a table with the dependent data variables visible or not visible and stimuli. The analysis was conducted to examine whether there was a difference in the visibility of reindeer between the two periods: during and after being exposed to acoustic stimuli. I performed a Students t-test to evaluate if the differences between periods and stimuli were significant.

2.5.2 Flight response and acoustic stimuli score

To evaluate if there was a difference in flight response for the different stimuli, I created a contingency table and mosaic plot. The data variables used in the test were stimuli (table 5), flight response, running, walking, vigilance, foraging and other behavior (table 6). I also created a bar graph with the variation in behavior, depending on if the animal responded with flight response or not by using the same variables. To evaluate if there was a significant difference in flight response between stimuli, I created a Chi^2-test.

The variation in behavioral response when exposed to different stimuli was examined by comparing the data variables stimuli (table 5) and acoustic stimuli score (table 6). I created a mosaic plot in JMP where the proportions of acoustic stimuli score to each stimulus was presented.

2.5.3 Group response

The main group response to the four different stimuli was briefly examined by observing the average group size for the observation periods before, during and after the acoustic stimulus was displayed, and also the mean of total group size for all observations. The group response to acoustic stimuli was evaluated by creating a bar graph with 95% confidence interval. The data variables used were group size and stimuli (table 5). I also created a table with mean value and standard deviation, using the same variables, to present the difference in group size. To investigate if there were a significant difference between the observation periods (before, during and after exposure to sound), a Students t-test was created.

Result

In total, I collected 919 videos during the data collection period, of which 856 contained reindeer. The remaining videos consisted of footage of other wildlife or moments when the reindeer herders were present at the site. The final dataset, suitable for further analysis in BORIS, consisted of 455 videos from 3 Sámi herding communities and seven sites (table 7). In the following analyses, all sites were merged as no difference was detected in flight responses to each sound between the sites (Pearson $chi^2 > 8.41$, $p > 0.077$, $N > 54$).

Table 7. Distribution of observation for each stimulus between all seven sites.

	Predator	Noise	Human	Siren	Silence	**Total**
Gran 1	14	8	9	16	13	60
Gran 2	2	3	4	3	5	17
Ran 1	10	6	11	8	8	43
Ran 2	1	0	2	1	2	6
Svaipa 1	32	35	39	41	50	197
Svaipa 2	18	10	19	17	22	86
Svaipa 3	10	10	7	15	4	46
Total	87	72	91	101	104	**455**

3.1 Behavioral change when exposed to acoustic stimuli

For the silence control, foraging behavior was the most predominant behavior throughout the observation. During the period before reindeer were exposed to acoustic stimuli, the most frequent behavior was feeding. When exposed to any of the four acoustic stimuli, reindeer spent significantly less time feeding and more time being vigilant and running compared to being exposed to silent control (figure 4).

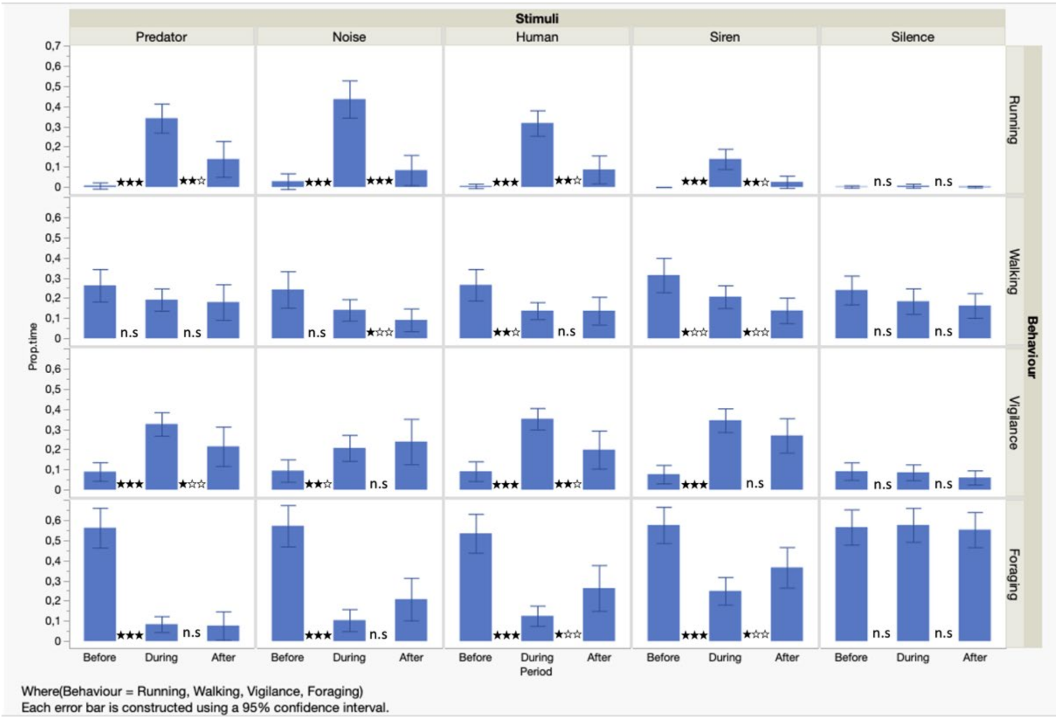

Figure 4. The mean proportion of time spent on the response variables running, walking, vigilance and foraging before, during and after exposure to acoustic stimuli. Means are compared by Students t-test and is presented with stars indicating significance levels, and n.s indicating no significant difference.

All four acoustic stimuli induced a behavioral change of varying degree in reindeer when being exposed to the sound, i.e, when comparing the before and during period. Reindeer exhibited the largest proportion of running (44%) when exposed to noise stimulus, followed by vigilance (21%) (figure 4). Both predator and human stimuli also induced running (34-32%) and vigilance (35-33%) as the most predominated behaviors (figure 4). Reindeer exhibited mostly vigilance (34%) and foraging behavior (25%) when sound from siren was displayed.

After the acoustic stimuli was displayed, reindeer behaved in different ways depending on which stimuli they had been exposed to. Animals exhibited vigilance as the predominant behavior when exposed to predator and noise stimuli (21-24%), meanwhile, foraging was the most common behavior after the exposure of human and siren stimuli (26-37%) (figure 4). Walking and running were performed more frequent after predator stimuli, while foraging behavior was the second most common behavior for noise stimuli (figure 4).

Acoustic stimuli from predator and noise produced the largest behavioral changes in reindeer in this experiment. When comparing how much time the reindeer have been visible in the before, during and after period (table 8), there is a difference between the four stimuli. In the period before being exposed to acoustic stimuli, the individuals were visible during almost the entire period for all sounds. Additionally, there was only a minor difference between the four stimuli in the period when reindeer being exposed to acoustic stimuli, with noise standing out slighty. However, there is a noticeable difference in the period after the reindeer have been exposed to the different stimuli. For both predator and noise, the proportion of visible reindeer drops from >89% to 62% (table 8). This indicates that the reindeer have, to some extent, fled from the unit in response to the acoustic stimuli and therefore were no longer visible in the same proportion as in the before period. For human stimulus, there was also a change in visibility, where 74% (table 8) of the proportion of reindeer remained visible after being exposed to the stimuli, compared to <96% in the periods before and during.

Table 8. The mean proportions of time reindeer were visible and not visible for each stimulus, presented for all the three periods: before exposed to acoustic stimuli, during exposed to acoustic stimuli and after exposed to acoustic stimuli. All differences between visible and non-visible are significant (t-test).

		Predator	Noise	Human	Siren	Silence
Period	**Visible**?					
Before	Visible	0,99	0,97	0,98	1,0	0,97
	Not visible	0,01	0,03	0,02	0,0	0,03
During	Visible	0,95	0,89	0,96	0,96	0,94
	Not visible	0,05	0,11	0,04	0,04	0,06
After	Visible	0,62	0,62	0,74	0,86	0,88
	Not visible	0,38	0,38	0,26	0,14	0,12

3.2 Flight response and acoustic stimuli score

The flight response differed between the four stimuli, with the silent control showing a 100% non-flight response (table 9). The predator stimulus had the highest proportion of flight response (92,0%), followed by the noise stimulus with the second highest proportion (81,9%). The flight response to human voices was also relatively high (75,8%), while nearly half of all observed reindeer in the experiment showed flight response to siren stimuli (table 9). The proportions of flight response for each stimulus are presented in figure 5.

Table 9. Contingency table for the distribution of flight or no flight responses of the individuals analyzed in BORIS.

	NFlight *Row %*	**N**No flight *Row %*	**Total** *Column %*
Predator	80 *92,0*	7 *8,0*	87 *19,1*
Noise	59 *81,9*	13 *18,1*	72 *15,8*
Human	69 *75,8*	22 *24,2*	91 *20,0*
Siren	47 *46,5*	54 *53,5*	101 *22,2*
Silence	0 *0,0*	104 *100,0*	104 *22,9*
Total	255 *56,0*	200 *44,0*	455 *100*

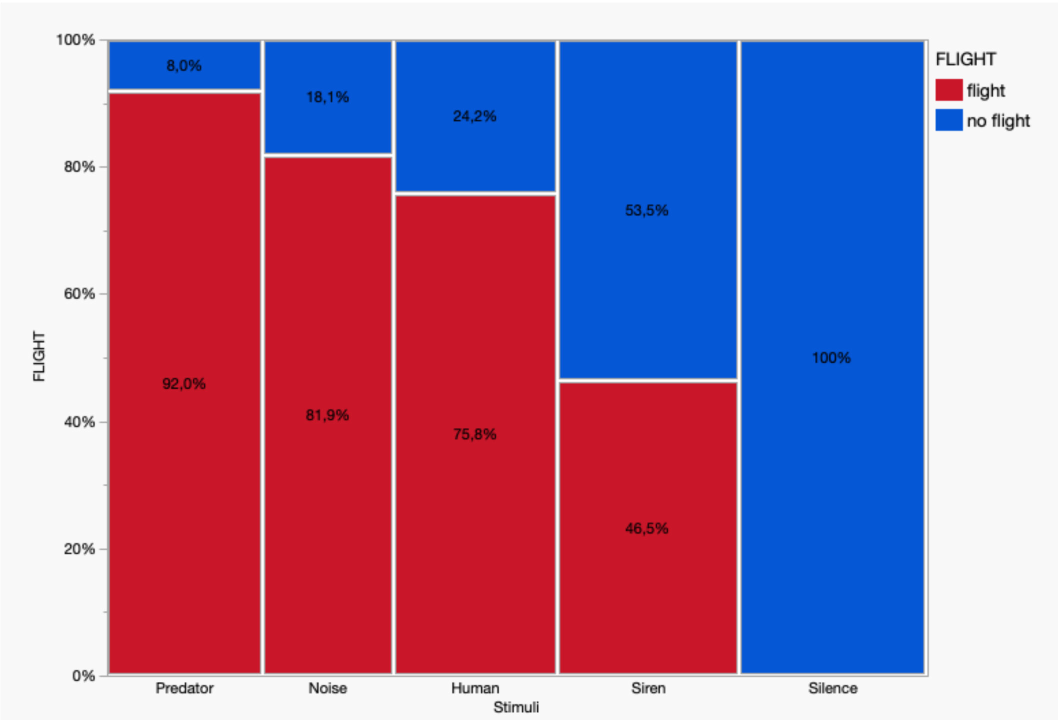

Figure 5. The flight response differed significantly among the acoustic stimuli (Chi^2 = 217,5; N = 455, P < 0,0001). No flight = no reaction or vigilance, flight = delayed flight or immediate flight.

The score of reindeer´s reaction to the four tested stimuli differed in the study. Immidiate flight response was considerably more common when reindeer were exposed to noise stimuli (66,7%), compared to the other three stimuli (>26,4%) (figure 6). Responding with a delayed flight was more common for predator, human and siren stimuli. However, only responding with vigilance where the most frequent response when exposed to siren stimuli. For the silence control, reindeer normally responded with no reaction and in a few cases vigilance was scored.

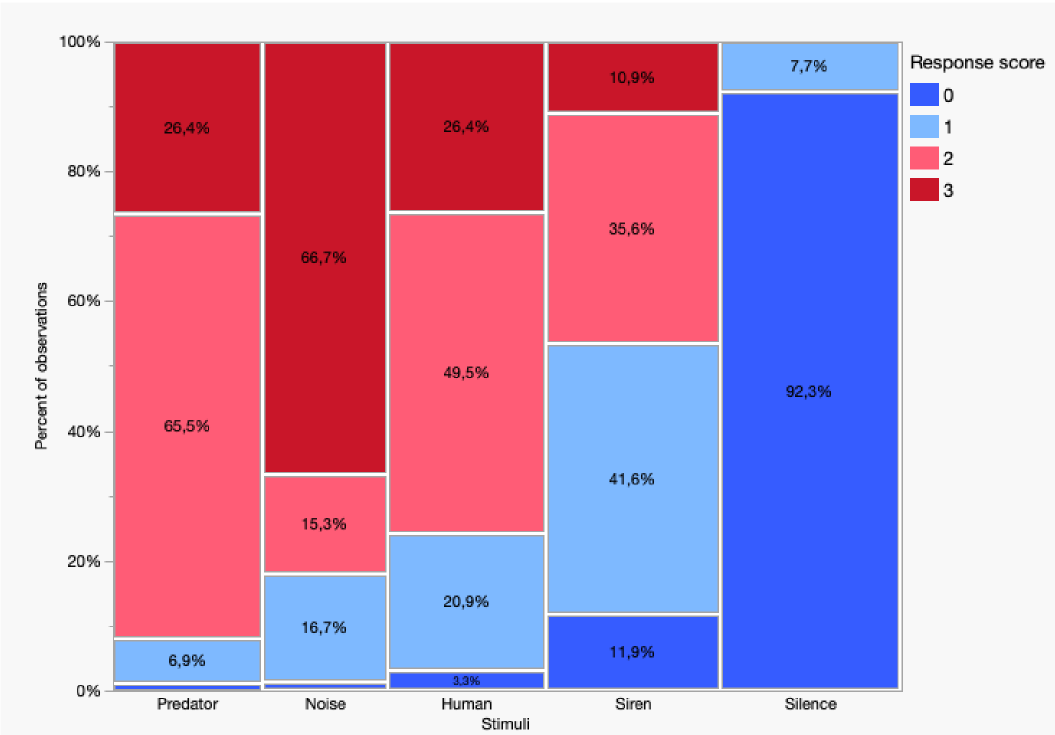

Figure 6. The percentage distribution of the acoustic stimuli score for each acoustic stimulus. 0 = no reaction, 1 = vigilance, 2 = delayed flight and 3 = immediate flight. Differences in scores between the sounds were significant (Chi^2 = 450,3; N = 455, P < 0,0001).

3.3 Group response based on group size and individual observations

The difference in average group size, when comparing the periods during and after reindeer were exposed to stimuli, can indicate how many individuals that left the site due to the sound. Exposure to predator and noise stimuli produced the greatest variation in average group size between these two periods, where the difference in reduced number of individuals ranged from 3,6-3,1 between the two periods (figure 7; table 10). Also, human stimuli had an effect in the average group size between these periods, where 2,1 individuals left the frame (figure 7; table 10).

Table 10. Average individuals in frame ± standard deviation and minimum, maximum of individuals for the three periods: before, during and after acoustic stimuli and total group size for the whole observation period.

	Before Avarage ± SD *Min, max*	**During** Avarage ± SD *Min, max*	**After** Avarage ± SD *Min, max*	**Total group size** Avarage ± SD *Min, max*
Predator	6,3 ± 5,5 *1, 21*	7,0 ± 6,4 *1, 29*	3,4 ± 4,9 *1, 24*	7,3 ± 7,0 *1, 41*
Noise	5,3 ± 5,0 *1, 21*	6,0 ± 5,6 *1, 21*	2,9 ± 4,1 *1, 19*	6,5 ± 6,1 *1, 35*
Human	6,3 ± 5,8 *1, 23*	6,4 ± 5,8 *1, 25*	4,3 ± 5,8 *1, 24*	7,1 ± 6,1 *1, 25*
Siren	6,9 ± 5,8 *1, 25*	6,8 ± 5,8 *1, 25*	5,9 ± 5,9 *1, 24*	7,4 ± 5,9 *1, 25*
Silence	6,8 ± 5,8 *1, 20*	6,9 ± 5,8 *1, 20*	6,7 ± 5,8 *1, 20*	7,5 ± 5,8 *1, 20*

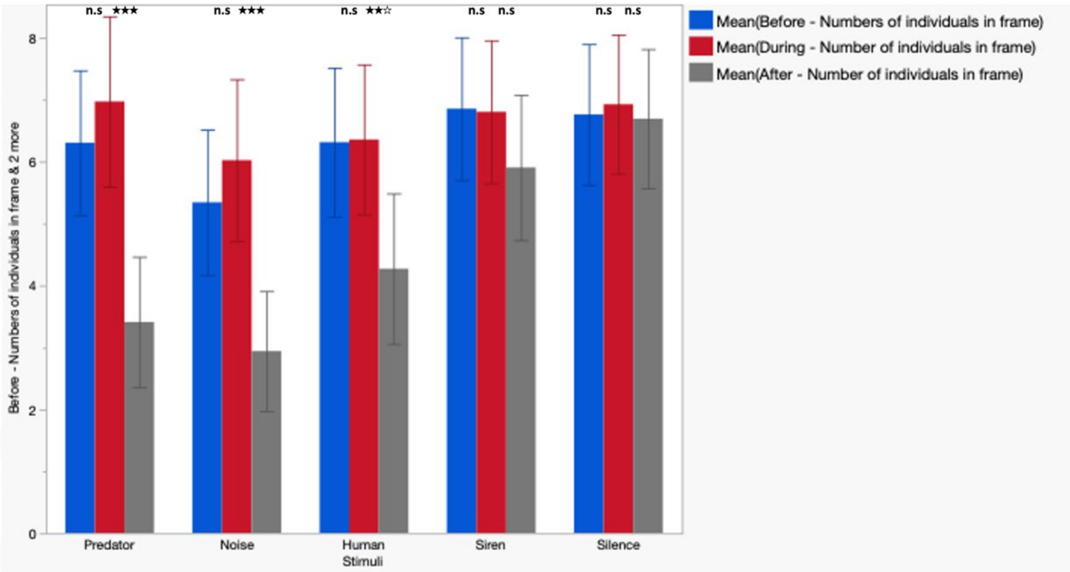

Figure 7. Average (± 95% C.I.) group size, i.e., numbers of individuals in frame during the three periods: before, during and after the display of the acoustic stimuli. Means are compared by Students t-test with stars indicating significance levels, n.s. indicating no significant difference.

When analyzed on group level, acoustic stimuli from predator and noise had the strongest effect on behavioral response in reindeer. In average, a total of 3,9 individuals in a group of total 7,3 individuals reacted with flight behavior when the sound from predators was played, while 4,0 individuals in a group of total 6,5 individuals had the same reaction to noise stimuli (table 10; table 11). Human stimuli were the third most effective, where 2,8 individuals in a group of 7,1 individuals reacted with flight behavior (table 10; table 11). There were few individuals that reacted with controlled flight behavior to all four stimuli, varying from 1,6 to 0,9, where predator had the highest response (table 11). The number of individuals who left the frame in response to acoustic stimuli were highest for predator 4,0 and noise 3,5, followed by human 2,5 (table 11). Acoustic stimuli from siren had the lowest impact on the behavioral response on group level, while silence control had no impact on the group response (table 11).

Table 11. Average behavioral response to acoustic stimuli on group level. "Reacts with flight behavior" refers to individuals that responded with immediate flight response or individuals that after a time of vigilance run from the unit. "Reacts with controlled flight" refers to individuals that immediate or after some vigilance walked from the unit. "Leave frame" includes only individuals that left the frame in response to acoustic stimuli.

	Reacts with flight behavior	**Reacts with controlled flight**	**Leave frame**
Predator	3,9 ± 5,3	1,6 ± 3,9	4,0 ± 5,7
Noise	4,0 ± 5,0	0,6 ± 2,6	3,5 ± 4,8
Human	2,8 ± 4,4	0,7 ± 1,7	2,5 ± 4,0
Siren	1,0 ± 2,8	0,9 ± 3,0	0,9 ± 2,3
Silence	0,0 ± 0,0	0,0 ± 0,0	0,0 ± 0,1

Discussion

4.1 Behavioral change when exposed to acoustic stimuli

As predicted, all four acoustic stimuli caused a significant change in behavior of the exposed reindeer and there was an evident increase in movement and vigilance to all tested sounds. Independent of stimuli type or silent control, reindeer spent the majority of time on performing foraging behavior in the period before the exposure period. For the silent control, there was no observed behavioral change, i.e. the reindeer continued with foraging behavior throughout the observation period (figure 4).

The strongest behavioral change when exposed to the stimuli was observed to the sounds from predator and the noise impulses. Most of the time during the exposure period of these sounds, reindeer exhibited a large proportion of running, followed by vigilance (figure 4). This can indicate a strong avoidance behavior, which also was expected in the hypothesis of the study. After the sound exposure, vigilance was the most practiced behavior for both stimuli (figure 4). Reindeer exhibited a reduced foraging behavior in both the periods during and after. However, the proportion of time spent on foraging in the after period was larger for the noise stimuli. This imply that the reindeer returned to "relaxed" behaviors, such as foraging, faster after the noise stimuli was displayed compared to when the predator stimuli was displayed.

The behavioral reaction towards the human voice was not as strong compared to predator and noise stimuli. During the period when reindeer were exposed to human voice, vigilance and flight were the most common responses. The distribution between the two behaviors was similar to the reaction for predator stimuli. However, reindeer returned to foraging behavior as the most frequent behavior after human stimuli was displayed (figure 4), compared to predator and noise stimuli where vigilance were the most frequent. This indicates that the reindeer returned faster to relaxed behaviors when exposed to human stimuli.

As predicted, stimulus from siren, out of the four stimuli, had the lowest effect on behavioral change in reindeer. During the period when sound was displayed, reindeer spent most time vigilant, followed by foraging (figure 4). In the period after the stimulus was displayed, reindeer returned to foraging as the most frequent behavior.

4.2 Flight response and acoustic stimuli score

Results from the analysis of flight response and acoustic stimuli score in this study implies that reindeer reacted with flight behavior to a varying extent, depending on stimuli. Flight response was for the most part exibited in reindeer when exposed to stimuli from predator (92,0%), noise impulses (81,9%) and human voices (75,8%) (figure 5; table 9). Usally, reindeer responded with immidiate flight to noise impulses, while delayed flight was a more common flight response to acoustic stimuli from predator and human (figure 6). The flight response for siren stimulus was just over half of all observations (figure 5), and reindeer mostly reacted with delayed flight when performing flight behavior (figure 6).

The flight response for human stimuli did not appear to be as strong for the reindeer in this study compared to similar studies made on other ungulate species (Bhardwaj et al. 2022; Widén et al. 2022). One explanation could be due to the fact that the reindeer in this study are semi-domesticated and exposed to more regular contact with humans in contrast to the wild ungulates studied by Bhardwaj et al. (2022) and Widén et al. (2022). It would be interesting to investigate if the result would have been different in wild reindeer, since they are not in contact with humans to the same extent. Previous studies on human interference and behavioral response strengthens the hypothesis that wild reindeer would react with stronger flight behavior compared to semi-domesticated reindeer, since wild reindeer exhibited stronger vigilance and flight response compared to the semi-domesticated reindeer (Nieminen 2013; Baskin & Hjältén 2001). Also, in Widén et al. (2022) study, the behavioral response of ungulates to acoustic stimuli from wolf (predator) and human was observed. In comparison to this study where sound from predator (bear) produced a stronger flight response compared to human voice, the ungulates in Widén et al. (2022) study performed stronger flight response towards human stimulus than to wolf stimulus. This also supports the hypothesis that the domestication process of reindeer has reduced their avoidance response towards human stimuli.

Also, all reindeer was supplementary feed to some extent during the study period, which could have an additional effect in their tolerance to human stimuli. In the study by Nieminen (2013), reindeer that were supplementary feed exhibited shorter flight distance compared to reindeer that was not feed, when observing the behavioral respons towards human approaching by foot.

The high proportion of immediate flight to noise stimulus, compared to the other three stimuli (predator, human and siren), are also of interest to discuss further. The noise sound distinguished from the other three sounds in acoustic stimuli score, as the noise stimuli started very sudden compared to the other stimuli. The sudden start resulted in a large proportion of immidiate flight response in comparison to the other stimuli, where the reindeer after some time of vigilance began to flee (delayed flight). This is also supported in Koehler et al. (1990), where sudden and unfimiliar sounds are refered to as effective to make mammals aviod areas. With this conclusion, it would be interesting to further investigate stimuli of similar sound structure as the noise impulses used in this study, to confirm that it's the sudden start that induces immediate flight in reindeer. The immediate flight response could be important if similar devices would be implemented in real situations, where the goal is to deter reindeer from a critical site.

Both the variables flight response and acoustic stimuli score indicated whether the animals reacted with flight behavior and to what extent when exposed to acoustic stimuli. However, they did not imply if the animals has left the site or how far they have fled. In some cases, the reindeer have reacted with an immediate flight response and then stopped running after a few meters. This may not be the desired effect if a similar method were to be used in a critical situation, where the aim is to get the reindeer to leave the site. The flight distance and flight response would need to be further investigated for each stimulus to make sure that they produce the desired effect, if they are to be implemented in the future.

4.3 Group response based on group size and individual observations

The results from the change in group size can give an indication of how large proportion of the group that reacted with flight response to each stimulus. To investigate the group response to each stimulus, the change in group size was combined with an individual analysis of all group members, where flight behavior and if individual left frame was noted. The group size remained the same throughout the whole observation for the silent control, this indicates a zero group response. The biggest change in group size was represented by predator and noise stimuli (table 10), and the strong group response for these stimuli is also supported by the individual observation on group level (table 11). Human stimuli had a slightly lower impact for the group response, followed by siren where on average only one group member exhibited flight response (table 10 & 11).

The group analysis of this study only gives a vague indication on how the different stimuli affect the flight behavior of the group. In order to give a more in-depth analysis on how the entire group of reindeer reacts to various stimuli, an individual analysis of all group members would have to be done for each video. If such analysis would be carried out, it would also be interesting to investigate whether the flight response to different stimuli is affected by group size. Especially since Baskin & Hjältén (2001) indicated for a reduced flight response in relation to increased group size when reindeer were exposed to human interference. Also, the effect on group response, depending in the age and gender distribution, would be interesting to investigate further. For example, females with calfs are usally more vigilant compared to males (Reimers et al. 2021), and this could have an effect on differet group´s reaction when exposed to acoustic stimuli.

4.4 Management implications and further questions

The main reason for conducting the study was to investigate if different acoustic stimuli could be an effective method to make reindeer alert and leave a specific site. In the future, this could be an important tool to reduce the number of reindeer-vehicles accidents.

The results from this study suggest that acoustic stimuli from predator (bear) and noise impulses are effective to make reindeer leave a specific area. Human voices are less effective; however, it may be used as a complement. A more sudden and intense voice message would perhaps induce a higher flight response in reindeer since the used human stimuli in the study did not result in as high flight response rate compared to noise and predator. The human voices used in this study were calm voice messages, in the future it would be interesting to evaluate a more intense talk, or maybe even a shouting message. I would not recommend using acoustic stimuli from siren if the method is implemented in real situations, due to it only inducing flight response in about half of all the observations.

It would also be beneficial to further investigate other stimuli, to have a wider repertoire of various sounds. For example, it appears that sounds that are very sudden could be extra effective, as the reindeer reacted with an immediate flight response to the noise stimulus in this study. Also, further investigation on acoustic stimuli from natural predators could be interesting in the future. A mixture of different sounds should be used, if implemented at critical areas, to reduce the risk of habituation and ascertain the effectiveness of the method. By this, I suggest that future studies should investigate more sounds that could influence the behavioral response in reindeer.

The feeding strategy in this study differed between sites, as feed was placed out at some units while other sites were free from feed. However, if the behavioral response of reindeer to the acoustic stimuli differed with different feeding strategies was not examined in the analysis for this study. In future studies, the effect of feed or no feed at the units would be interesting to investigate and evaluate if it influences the reindeer behavior.

In this study, three Sámi herding communities participated. In the study, no consideration was given to if the animal husbandry differed between the participating herding communities, yet there was no difference in flight response between them. Differences in management strategies between the Sámi herding communities could, however, have an effect on the reindeer´s behavioral reaction to tested acoustic stimuli. For instance, a varied human contact in the reindeer husbandry between herding communities may result in reindeer reacting differently to human stimuli. This is also supported by (Nieminen, 2013), where the flight distance toward human approach was shorter for reindeer which were fed with supplementary feed. Due to this, it is an important factor to investigate further in the future if the method should be implemented in real situations. Although no difference was proven between the three Sámi herding communities in this study, when comparing each site with flight response. There may be differences between other Sámi herding communities which could have an impact in future studies.

The habituation effect are an important factor to take into account if this method would be implemented in real situations. Habituation is a process which can occour when an animal is exposed to a particular stimulus repeatedly (Blumstein 2016; Blumstein 2014; Bejder et al. 2009). However, in studys like this one, there is not suitable to examine the habituation effect to the different stimuli. This is due to the short period of data collection (few weeks of active units) and lack of observations with recurring individuals. A measure of tolerance would, however, be suitable for this type of avoidance study to investigate how well the reindeer tolerate the different stimuli. The low proportion no-flight response towards stimuli from predator and the noise impulses could, for example, indicate a lower tolerance in reindeer compared to siren which gave a higher proportion of no-flight response. To be able to comment on the reindeer's actual tolerance levels to the tested acoustic stimuli in this study, and if the tolerance level changes over time, a analysis of the tolerance level would need to be carried out.

Also, in future studies, it would be of great importance to carry out similar studies with longer data collection periods and where individual differences can be evaluated. However, some form of marking or labeling (e.g. collars) of the reindeer would be needed to be able to perform individual evaluation and follow specific individuals. This is important to evaluate if habituation can occur in reindeer when exposed to acoustic stimuli over time, and to make sure that the method is suitable to use in real, critical, situations.

4.5 Source of error

In this study, all behavioral analysis was made by the author of the report. Each video was analyzed with sound on, and the observer always knew which stimuli that would be displayed. The human factor when observing reindeer behavior may have been a bias for the result in this study. Even though I have worked objectively during the behavioral observations, there are still a risk that the human factor may have influenced the result. To avoid this risk in future studies, the videos could be observed in silent mode and with anonymous file names to evade the factor of the observer influencing the result.

Another source of error for this study was the experimental setup which differed between the sites. This was mainly because I did not have the opportunity to visit the sites before the data collection started, which resulted in a variation for how long distances that was visible in the videos recorded at the different sites. Due to this, the variable "not visible" probably differs between sites. I experienced when performing the observations, that reindeer left the screen more frequent at places with shorter visible distances compared to locations where the visibility distance where considerably longer. If a similar study is to be done in the future, I would recommend placing out distance markers at each location, to enable analyzes for flight distance and minimize the risk of variation between study sites that can impact the result.

Conclusion

In this study, I have concluded that acoustic stimuli can be an effective tool for eliciting flight responses in reindeer. The method could be used in the future to, at least temporarily, keep reindeer away from critical infrastructure such as roads and railways. However, it is important to conduct further studies to validate the approach and to prevent possible habituation for different stimuli.

References

Anttonen, M., Kumpula, J. & Colpaert, A. (2011). Range Selection by Semi-Domesticated Reindeer (Rangifer tarandus tarandus) in Relation to Infrastructure and Human Activity in the Boreal Forest Environment, Northern Finland. *Arctic* 64, 1–14. https://www.jstor.org/stable/23025661

Babińska-Werka, J., Krauze-Gryz, D., Wasilewski, M. & Jasińska, K. (2015). Effectiveness of an acoustic wildlife warning device using natural calls to reduce the risk of train collisions with animals. *Transportation Research Part D Environment*. 38, 6–14. https://doi.org/10.1016/j.trd.2015.04.021

Baskin, L.M. & Hjältén, J. (2001). FRIGHT AND FLIGHT BEHAVIOR OF REINDEER. *Alces*. 37 (2), 435–445. https://www.alcesjournal.org/index.php/alces/article/view/601

Bejder, L., Samuels, A. M. Y., Whitehead, H., Finn, H. & Allen, S. (2009). Impact assessment research: use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli. *Marine Ecology Progress Series*, 395, 177-185. https://doi.org/10.3354/meps07979

Berger, J., (2007). Carnivore Repatriation and Holarctic Prey: Narrowing the Deficit in Ecological Effectiveness. *Conservation Biology*. 21, 1105–1116. https://doi.org/10.1111/j.1523-1739.2007.00729.x

Bhardwaj, M., Lodnert, D., Olsson, M., Winsvold, A., Eilertsen, S.M., Kjellander, P. & Seiler, A. (2022). Inducing fear using acoustic stimuli—A behavioral experiment on moose (Alces alces) in Sweden. *Ecology Evolution*. 12, e9492. https://doi.org/10.1002/ece3.9492

Blumstein, D.T. (2016). Habituation and sensitization: new thoughts about old ideas. *Animal. Behaviour*. 120, 255–262. https://doi.org/10.1016/j.anbehav.2016.05.012

Blumstein D.T. (2014). Attention, habituation and antipredator behaviour: implications for urban birds. In: Gil, D. & Brumm, H. (eds.) *Avian Urban Ecology*. OUP Oxford. 41-53.

Chamaillé-Jammes, S., Malcuit, H., Le Saout, S. & Martin, J.-L. (2014). Innate threat-sensitive foraging: black-tailed deer remain more fearful of wolf than of the less dangerous black bear even after 100 years of wolf absence. *Oecologia*. 174, 1151–1158. https://doi.org/10.1007/s00442-013-2843-0

Friard, O. & Gamba, M. (2016). BORIS: a free, versatile open-source event-logging software for video/audio coding and live observations. *Methods in Ecology and Evolution.* 7, 1325–1330. https://doi.org/10.1111/2041-210X.12584

Holand, Ø., Mizin, I. & Weladji, R.B. (2022). Reindeer Rangifer tarandus (Linnaeus, 1758), In: Corlatti, L., Zachos, F.E. (eds.) *Terrestrial*

Cetartiodactyla, Handbook of the Mammals of Europe. Springer International Publishing, Cham, pp. 247–276. https://doi.org/10.1007/978-3-030-24475-0_24

Koehler, A.E., Marsh, R.E. & Salmon, T.P. (1990). Frightening methods and devices/stimuli to prevent mammal damage – a review. *Vertebrate Pest Conference*. 14, 168-173. https://digitalcommons.unl.edu/vpc14/50/

Nieminen, M. (2013). Response distances of wild forest reindeer (Rangifer tarandus fennicus Lönnb.) and semi-domestic reindeer (R. t. tarandus L.) to direct provocation by a human on foot/snowshoes. *Rangifer*. 33, 1–15. https://doi.org/10.7557/2.33.1.2614

Pape, R. & Löffler, J. (2012). Climate Change, Land Use Conflicts, Predation and Ecological Degradation as Challenges for Reindeer Husbandry in Northern Europe: What do We Really Know After Half a Century of Research? *AMBIO*. 41, 421–434. https://doi.org/10.1007/s13280-012-0257-6

Reimers, E., Eftestøl, S. & Colman, J.E. (2021). Vigilance in reindeer (Rangifer tarandus); evolutionary history, predation and human interference. *Polar Biology*. 44, 997–1007. https://doi.org/10.1007/s00300-021-02857-w

Sametinget (2022). *Rennäringen i Sverige*. https://www.sametinget.se/rennaring_sverige [2023-06-11]

Seiler, A., Winsvold, A., Olsson, M., Eilertsen, S.M. & Berndt, C. (2022). *VILTVARNING: Test av nya tekniska åtgärder för att minska antalet viltpåkörningar på järnväg.* Swedish University of Agricultural Sciences. https://doi.org/10.54612/a.7pbjcv25mc

Skarin, A., Kumpula, J., Tveraa, T. & Åhman, B. (2022). Reindeer behavioural ecology and use of pastures in pastoral livelihoods. In: Horstkotte, T., Holand, Ø., Kumpula, J. & Moen, J. (eds.) *Reindeer Husbandry and Global Environmental Change*. Routhledge. 63-72. http://doi.org/10.4324/9781003118565-6

JMP Statistical Discovery, (2023). *Home.* https://www.jmp.com/en_se/home.html [accessed 2023-05-05].

Støen, O.-G., Sivertsen, T.R., Tallian, A., Rauset, G.R., Kindberg, J., Persson, L.-T., Stokke, R., Skarin, A., Segerström, P. & Frank, J. (2022). Brown bear predation on semi-domesticated reindeer and depredation compensations. *Global Ecology Conservation*. 37, e02168. https://doi.org/10.1016/j.gecco.2022.e02168

Trafikverket, 2022. *Viltolyckor, barriärer och säkra passager för djur.* https://bransch.trafikverket.se/for-dig-i-branschen/miljo---for-dig-i-branschen/natur-kultur-och-landskap/viltolyckor-barriarer-och-sakra-passager-for-djur/ [accessed 2023-05-10]

Widén, A., Clinchy, M., Felton, A.M., Hofmeester, T.R., Kuijper, D.P.J., Singh, N.J., Widemo, F., Zanette, L.Y. & Cromsigt, J.P.G.M. (2022). Playbacks of predator vocalizations reduce crop damage by ungulates. *Agriculture, Ecosystem and Environment.* 328, 107853. https://doi.org/10.1016/j.agee.2022.107853

Widmark, C. (2006) Forestry and reindeer husbandry in Sweden – the development of a land use conflict. *Rangifer*, 26 (2), 43-54. https://res.slu.se/id/publ/26497

Populärvetenskaplig sammanfattning

Skrämselsystem baserade på akustiska stimuli har under senaste åren testats på flera olika klövdjursarter. Syftet har varit att undersöka om metoden kan vara användbar i situationer där djuren snabbt ska kunna avvärjas från platser, till exempel för att förhindra viltolykor. Metoden går ut att inducera så kallade anti-predatorbeteenden (flykt och vaksamhet), genom att simulera rovdjursnärvaro via akustiska stimuli. Fram tills idag saknas dock forskning på hur renar svarar beteendemässigt till olika akustiska stimulin, något som i framtiden kan vara en användbar metod för att hålla djur borta från kritisk infrastruktur. Syftet med den här studien var därför att undersöka hur renar reagerar beteendemässigt till fyra akustiska stimuli: rovdjur (björn), ett pysande ljust, människoröster samt sirener. Det ingick även en tyst kontroll i experimentet för att kontrollera att renarna inte stördes av den uppsatta utrustningen. De huvudsakliga frågorna inför studien var: (1) Hur ser beteendeförändringen ut hos ren när de utsätts för olika akustiska stimuli? (2) Hur stor andel av de observerade renarna reagerar med flyktrespons till följd av ljuden. (3) Finns det en påtaglig skillnad mellan de fyra testande ljuden, i beaktande till de två tidigarenämda frågorna?

I resultatet av studien framgick det att renar reagerade absolut starkast på ljud från rovdjur (björn) och det pysande ljudet, där beteendeförändringen gick från en övervägande andel av födosök innan ljudet började till en övervägande andel av flykt när ljudet spelades upp. Samma trend uppvisades även vid jämförelse av flyktrespons till följd av de olika ljuden, där 92,0% flydde till följd av stimuli från rovdjur, följt av pysljudet 81,9%, människa 75,8% och siren 46,5%. Det observerades ingen flyktrespons för tyst kontroll. Renarna visade ett reducerat födosöksbeteende till följd av samtliga akustiska stimuli, jämfört med tyst kontroll där renarna främst födosökte genom hela observationstillfället. Resultatet visar att ljud från rovdjur (björn) samt det pysande ljudet gav de absolut starkaste beteendeförändringarna för renarna i studien. Dessa ljud skulle kunna vara effektiva att använda i framtiden på kritiska platser där behov finns att effektivt avlägsna och hålla renar på avstånd, exempelvis för att förhindra viltolyckor.

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Appendix 1

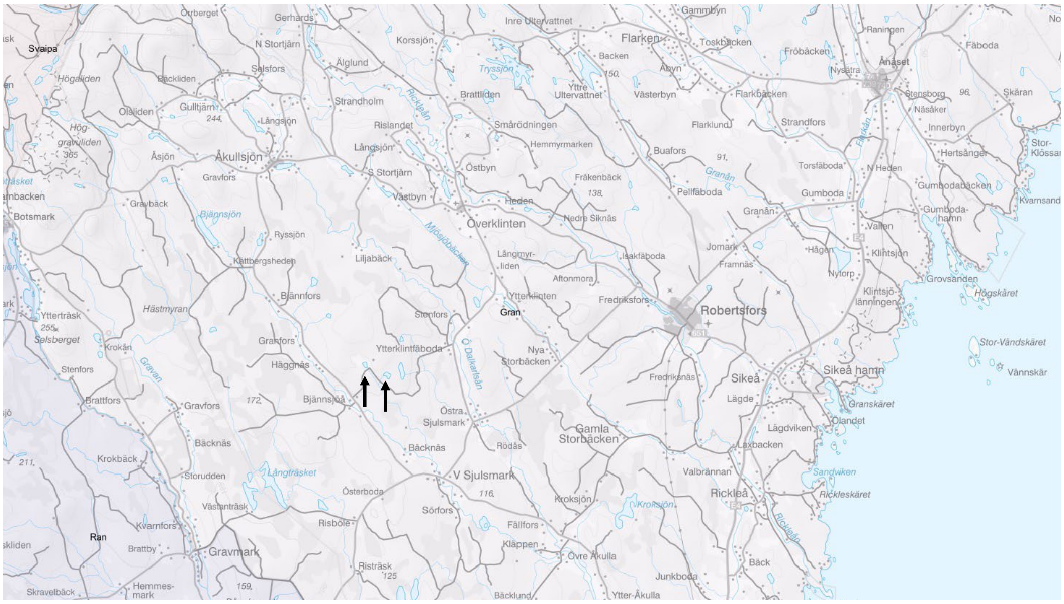

Figure 8. Map illustrating the locations of the two sites in Gran.

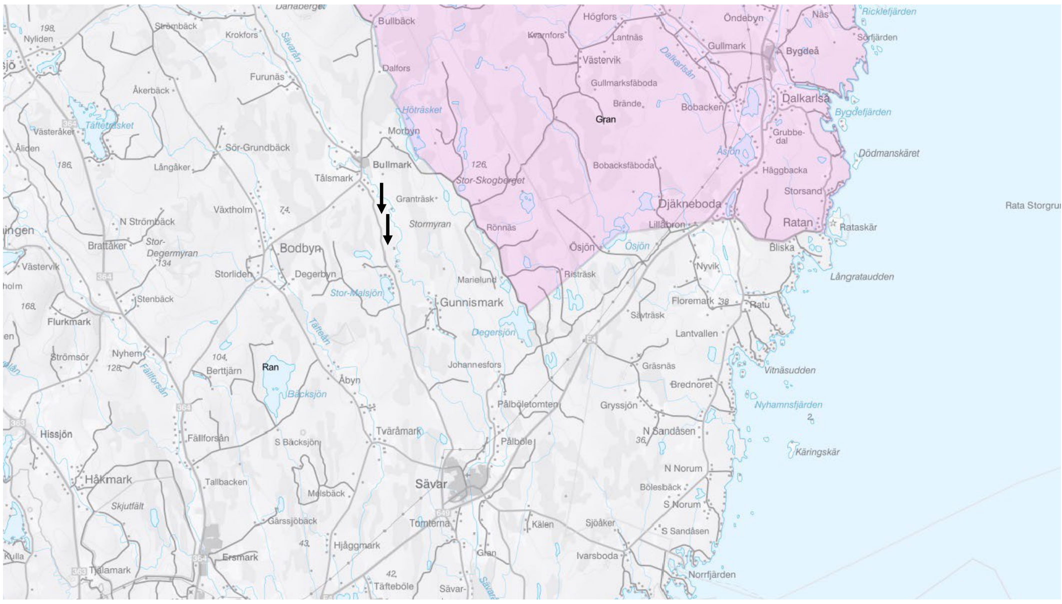

Figure 9. Map illustrating the locations of the two sites in Ran.

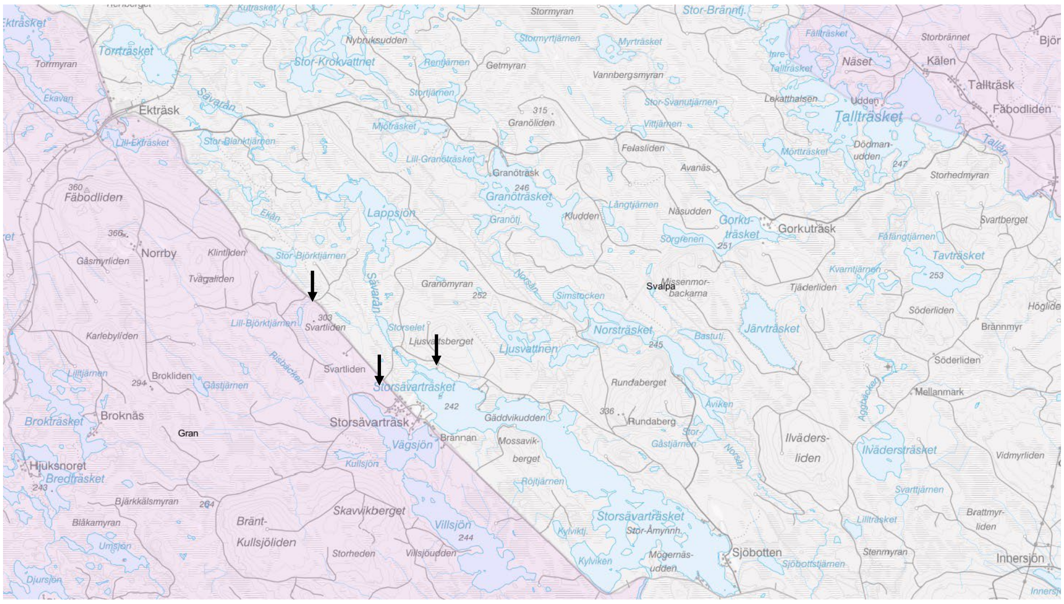

Figure 10. Map illustrating the locations of the three sites in Svaipa.

Appendix 2

Figure 11. Example picture, showing the location of the site Gran 2.

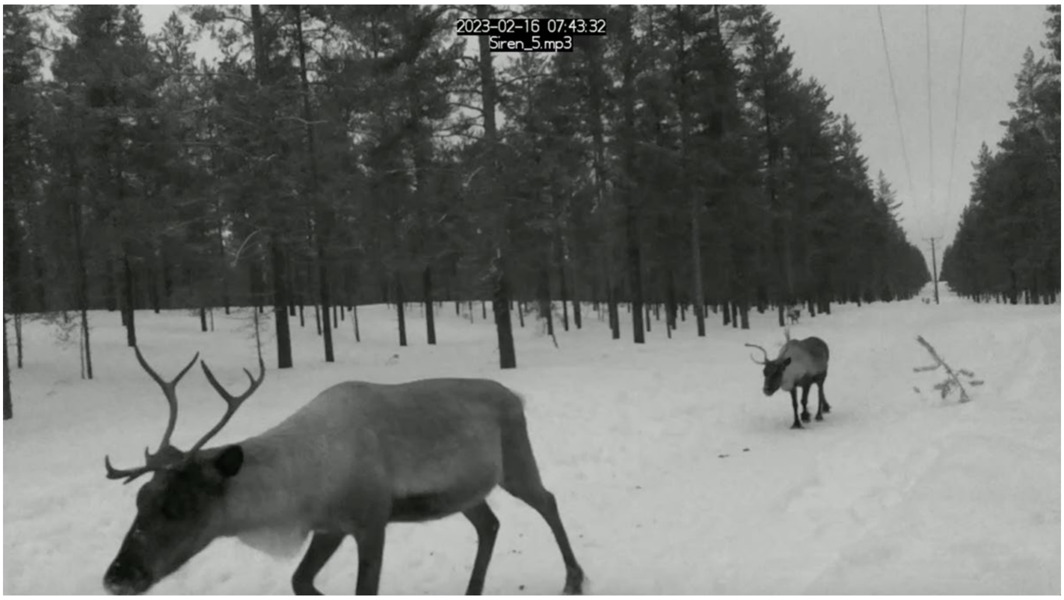

Figure 12. Example picture, showing the location of the site Ran 1.

Figure 13. Example picture, showing the location of the site Ran 2.

Figure 14. Example picture, showing the location of the site Svaipa 1.

Figure 15. Example picture, showing the location of the site Svaipa 2

Figure 16. Example picture, showing the location of the site Svaipa 3

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