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The Short-Term Impact of Military Jet Flight Activity on Semi-Domestic Reindeer in the Two Reindeer Districts Grovfjord and Tjeldøya

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Ecology

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Last, but not least, I want to extend a thank you to my family and friends for all your mental support along the way. Thank you for listening to me talking about my results and discussing with me, challenging my knowledge, and thank you for keeping me sane through it all. You have all been great motivators and I am grateful for each and every one of you.

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Abstract

Rangifer tarandus (hereby referred to as reindeer) are a migratory species with a diet changing throughout the year, and survival and reproduction depend on access to, and time for optimal grazing. Reindeer can be disturbed by anthropogenic activities, like aircraft activity, construction of roads and outdoor recreation. Such disturbances may change their migration route, delay their arrival at new grazing areas, increase grazing in less optimal areas or reduce time spent foraging.

A two-year study, starting in June 2021, experimentally tested the effects of jet flight activity on reindeer in two test and two control groups within the reindeer herding districts Grovfjord and Tjeldøya. Fieldwork in June 2021, September 2021 and September 2022 tested two models of jets, the F-16 and the new F-35, by registering the test reindeers' behaviour as aircrafts passed them. Control animals, i.e. animals that were not exposed to the jets, were also registered. Video cameras and binoculars were used to register the animals' reactions.

In Grovfjord, the majority of the test reindeer reacted clearly by either changing their behaviour or abruptly looking up while grazing (i.e. vigilance). At Tjeldøya, there was no difference between the number of test reindeer reacting clearly or not. The test animals overall showed a high level of vigilance in both districts. For both clear/unclear reaction and vigilance, none of the control animals in either district changed their behaviour over time. When analysing 60 seconds of "maximum overflight", control animals in Grovfjord show a high level of relaxed behaviour like lying and grazing, while the test animals show a high level of 'stressed' behaviour, like standing, walking and running. At Tjeldøya, results were unpredictable, with more 'walking' in the control group than anticipated. During the test period, reindeer on average stressed the most approximately 17-25 seconds into the minute and relaxed after that. An analysis including sound measurements showed that noise levels did not have a significant effect on the reindeer's reactions. Reindeer reactions were probably influenced by a mix of different factors, and not just the noise, such as movement, surroundings and more.

Content

1) <u>Introduction</u>

There has been an increase of activities of anthropogenic origin in reindeer ranges in Norway the last few decades, such as construction of cabins (Nellemann et al., 2010), windmills (Skarin et al., 2015; Skarin et al., 2018), power lines (Eftestøl et al., 2016), roads (Panzacchi et al., 2013), as well as recreational and cultural activities (Colman et al., 2012; Reimers et al., 2003). Disturbance from aviation has also increased, both in terms of passenger flights (Larsen & Farstad, 2018; Rideng & Denstadli, 1999) and military aircraft activity. "The world has never been as peaceful as today" has been said a lot the last years, and to some degree, is true, with less international wars and less deaths caused by war, as well as a shift from militarisation to democracy among the world's countries (OneEarthFuture, 2021; VisionofHumanity, u.å.; Vogt, 2019). Wars and conflicts still happen (NOU-15, 2007), which the invasion of Ukraine in February 2022 is a good example of, and being able to defend your country and airspace will always be a necessity.

Today, one of Norway's main tasks, on behalf of NATO, is the QRA – Quick Reaction Alert – mission, where we will have two F-35 jets on standby at all times. If someone tries to invade our or another NATO country's airspace, these two jets will be in the air within 15 minutes to identify the threats and where they came from (Forsvaret, 2022, u.å.-b). This mission has for the past decades been carried out in Bodø by the F-16 fleet, a jet model used from 1980 and until 2022, when the F-35 took over (Forsvaret, u.å.-a). The F-35 fleet performing the QRA mission will be stationed at Evenes Air Station, a "forward air station" at the border between Nordland and Troms & Finnmark. These new F-35 jets are faster and more powerful than the F-16 model, making them more effective at surveying the Norwegian airspace, and thus also protecting the Norwegian sovereignty (Forsvaret, u.å.-c). A consequence of these upgrades is that they generally make a lot more noise than the previous jets. Evenes Air Station is located within the reindeer district of Grovfjord, and close to other districts such as Tjeldøya and Frostisen (Tømmervik et al., 2018). It is thus necessary to investigate whether these jets possess a threat to the survival and reproduction of the reindeer in these districts.

Reindeer is one of the species considered to be the most affected by anthropogenic disturbances. 'Landscape of fear' is a concept used to visualize how fear of a predator can change how an animal uses an area to decrease its predation vulnerability (Laundre et al., 2010), and can be applied in relation to reindeer-anthropogenic interactions as well, although not in a predator-prey setting. Previous studies have shown that reindeer in many cases avoid areas they associate with danger, and that their vigilance increases when they know threats are nearby. Vistnes et al. found that reindeer avoid areas less than four kilometres from anthropogenic structures such as cabins, roads and power lines despite the habitat being optimal for foraging (Vistnes & Nellemann, 2001). This study was conducted during the calving season, where reindeer typically are extra cautious and vigilant as well. Reindeer are migratory and use much time walking from one site to another, between different habitats, finding the best grazing areas possible. Both wild and the semi-domestic reindeer can have up to eight seasonal grazing areas (Eira et al., 2022). Their diet differs throughout the year, and whereas they eat a variety of plants and herbs in the summer, they mainly eat lichen in the winter (Bergerud, 1972). Thus, they are highly dependent on large areas to roam, preferably continuously, as well as reaching the optimal grazing area at the right time. These factors make them vulnerable to both wild predators and anthropogenic disturbance that change their migration route and activity patterns. Avoiding them sufficiently can be crucial for survival.

As a way of surviving harsh winter conditions, reindeer have developed certain survival techniques. For instance, they have the ability to reduce activity rates depending on the season and store large fat reserves ahead of the winter season. They are also able to survive on nutrient-poor winter forage, like lichen, that is often limited. This pattern is necessary to maintain, and when human disturbances interrupt it, we reduce their chances of surviving the winter. Changed grazing patterns, even on a small scale, can also affect the performance and body weight of an individual (Reimers et al., 2003). According to Colman et al., heavier females have higher pregnancy rates, calve earlier and their calves are healthier than females with lighter weight (Colman et al., 2003). Thus, they are dependent on optimal grazing conditions during summer. Any kind of disturbances that occur might reduce their grazing time or make them graze in a suboptimal area (Reimers et al., 2003), which have negative consequences later.

If and how reindeer react to a certain disturbance, depends on the type and how much an individual or group perceives a stimuli as a threat. Short-term responses include increased heart rate and vigilance, getting visibly startled, and flight or fight responses (Harrington & Veitch, 1991), while long-term consequences include changes in area use, like avoidance (Johnson & Russell, 2014), and significant activity budget changes (Maier et al., 1998). In this case, disturbances caused by aircraft activity will firstly be short-term, such as vigilance and walking/running for short periods of time. The focus of this experiment will be on changes in behaviour while the flight occurs. Jet flights may over time produce longer lasting effects, but this will not be included in this study.

Reactions from jets in this study could be somewhat similar to fright and flight responses of reindeer when disturbed by vehicles or humans on foot. Reimers et al. researched snowmobiles' vs skiers' effect on reindeer, and found that despite the reindeer seeing snowmobiles from farther away than skiers, they moved farther distances and their energy loss was bigger when disturbed by skiers (Reimers et al., 2003). It was assumed that reindeer associated skiers with hunting and thus perceived them more of a threat than snowmobiles. Colman et al. and their paper about snow-kiters and skiers' effect on reindeer came to a somewhat similar conclusion (Colman et al., 2012). They found that the reindeer's fright response was longer for snow-kiters than it was for skiers, and it was the kite itself that induced the reaction coming in the sky and having a relatively large size. Due to the negative consequences that might come from getting distracted from grazing and using vital energy resources during fright and flight, it seems like reindeer consider the level of danger they are exposed to: they exhibit obvious fright or flight responses when they think their lives are in danger and they need to remove themselves from the situation.

In this study, I aimed to investigate how semi-domestic reindeer and their behaviour are affected by jet overflights. Based on results from previous studies, knowledge about the reindeer's behaviour and how the field work could be carried out, the focus was on short-term consequences towards the jet flights. An observational experiment, with field work in August and September 2022, was conducted in cooperation with the reindeer husbandry in the area and the National Armed Forces. Two test groups and two control groups were chosen and registered in the field using video cameras and binoculars. GPS trackers were also used, but not as a part of this study.

1.2) Hypotheses

The objectives of this study were to test how jet flight activity, both F-16 and F-35, affects reindeer behaviour, and whether noise level correlates with their reactions. Other variables, like season and group size, were also included in the analyses. The hypotheses were:

1) The reindeer will be frightened by jet overflights,
2) The fear response depends on the intensity of the source of fear.

To test for these hypotheses, five predictions were made:

A) The test reindeer respond to the aircraft activity by showing clear behaviour reactions, such as increasing amount of standing, running or walking, and vigilance, while control animals do not,
B) The test reindeer show a high level of vigilance, while the control animals do not,
C) The test reindeer exhibit more stressed behaviours, such as ‘walking’ and ‘running’, while the control reindeer are more relaxed, with more ‘lying’ and ‘grazing’ behaviour,
D) The test reindeer exhibit stressed behaviour for a relatively short amount of time, before “calming down” and returning to pre-stressed behaviour, while the control reindeer exhibit the same behaviour throughout the time analysed,
E) The noise level of the flights affects the intensity of the test reindeers’ responses and have a significant effect on the test reindeer’s behaviour.

2) Methods and materials

2.1) Study area

The study was conducted in two reindeer districts, Grovfjord and Tjeldøya, at the border between the two counties Nordland and Troms & Finnmark in the north of Norway. The jets came from Evenes Air Station, which is a part of Harstad/Narvik Airport, about ten minutes away.

Grovfjord is the biggest of the two districts, with an area of 1006 km^2 (Appendix A, Figure A1). One siida, with seven people divided into two families, work with and care for the same reindeer herd. In 2022, the total amount of reindeer was 377, 13% bulls, 63% cows and 24% calves (Skogan et al., 2022). Grovfjord consists of barren ground at the higher elevations, with deciduous forest at the lower elevations. Throughout the district, there are also areas with marshes and agricultural areas, as well as local settlement along the coast (NIBIO, u.å) (Appendix B, Figure B1 and Appendix C, Figure C1). The district has distinct seasonal grazing areas (Figure 1).

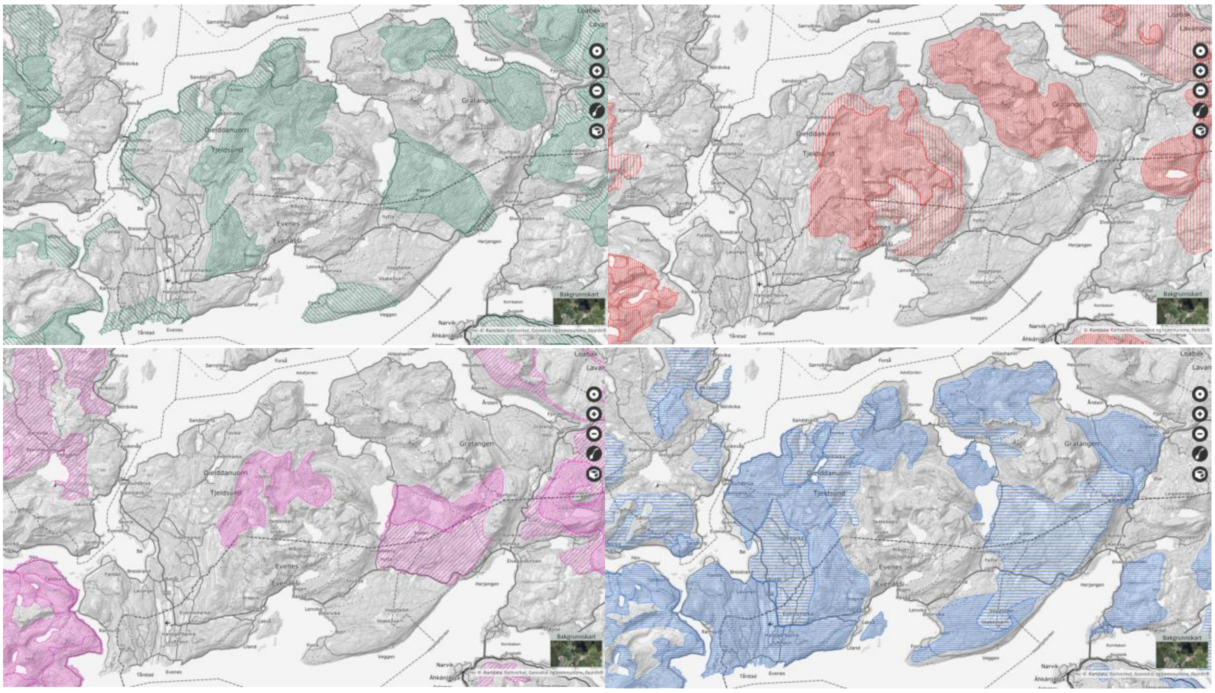

Figure 1: Seasonal grazing areas in Grovfjord. Green = spring, red = summer, purple = fall and blue = winter. Maps taken from kilden.nibio.no.

Tjeldøya is a lot smaller than Grovfjord, with an area of 186 km^2 (Appendix A, Figure A1) and only one family working with the reindeer. Their total amount of reindeer in 2022 was 245, 19% bulls, 59% cows and 22% calves (Skogan et al., 2022). Most of the island is barren ground, with both deciduous and conifer forest along the coast (NIBIO, u.å) (Appendix B, Figure B2 and Appendix C, Figure C2). The district has a distinct year-round range, but the spring- and winter grazing areas are generally along the coast, while the summer grazing area is in the middle of the island (Figure 2).

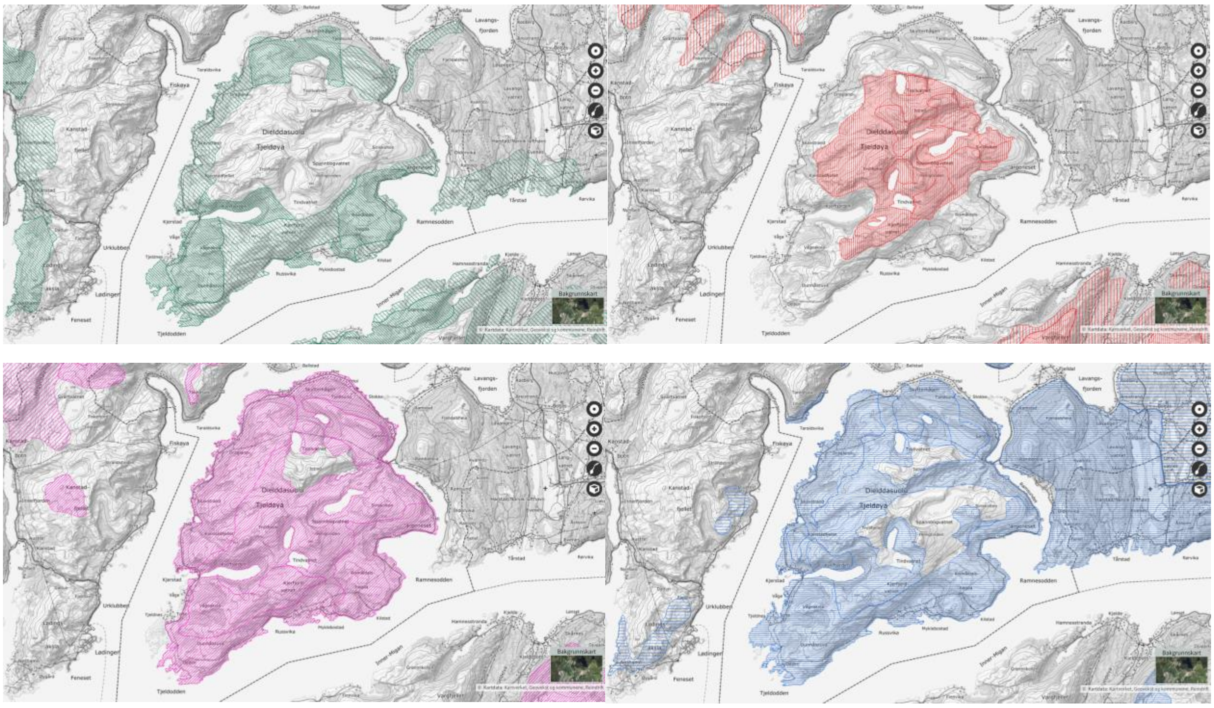

Figure 2: Seasonal grazing areas at Tjeldøya. Green = spring, red = summer, purple = fall and blue = winter. Maps taken from kilden.nibio.no.

Noise levels and thus, impact, is estimated to be biggest when the aircrafts take off (Tømmervik et al., 2018). The noise level from the jets might get as loud as 100 dB and louder by the airport and the closest areas. The district of Grovfjord, where Evenes Air Station is located, has important grazing resources both north, west and east of the airport. The area also has late winter grazing areas, early spring grazing areas, calving areas and important spring grazing areas along the coast that might get affected by the noise from jets at Evenes. Close to the airport, there are also migration routes for the reindeer (Appendix D, Figure D1). The take-off and landing zones for the jets are in set paths, and expected to be in areas that might influence important calving- and spring grazing areas at Tjeldøya as well. Mating areas and migration corridors might also be affected by noise (Appendix D, Figure D2).

2.2) Data collection

In the district of Grovfjord, fieldwork occurred in Storjorddalen, a valley surrounded by mountains on three sides (Figure 3). At the bottom of the valley, there were several rivers as well as a bushy, closed terrain with birch trees interspersed with more open marsh/wetland areas. Further up from the bottom of the valley, the terrain was flat with no trees, indicating that we were above the tree line (Appendix E, Figure E1).

In the district of Tjeldøya, fieldwork occurred at Trollfjellet the first day and at Spannbogan the second day (Figure 3). The terrain was more varied here than in Grovfjord: rugged terrain with steep mountain sides, flat plains, small lakes and marsh/wetland areas, as well as bushy areas with trees as well (Appendix E, Figure E2).

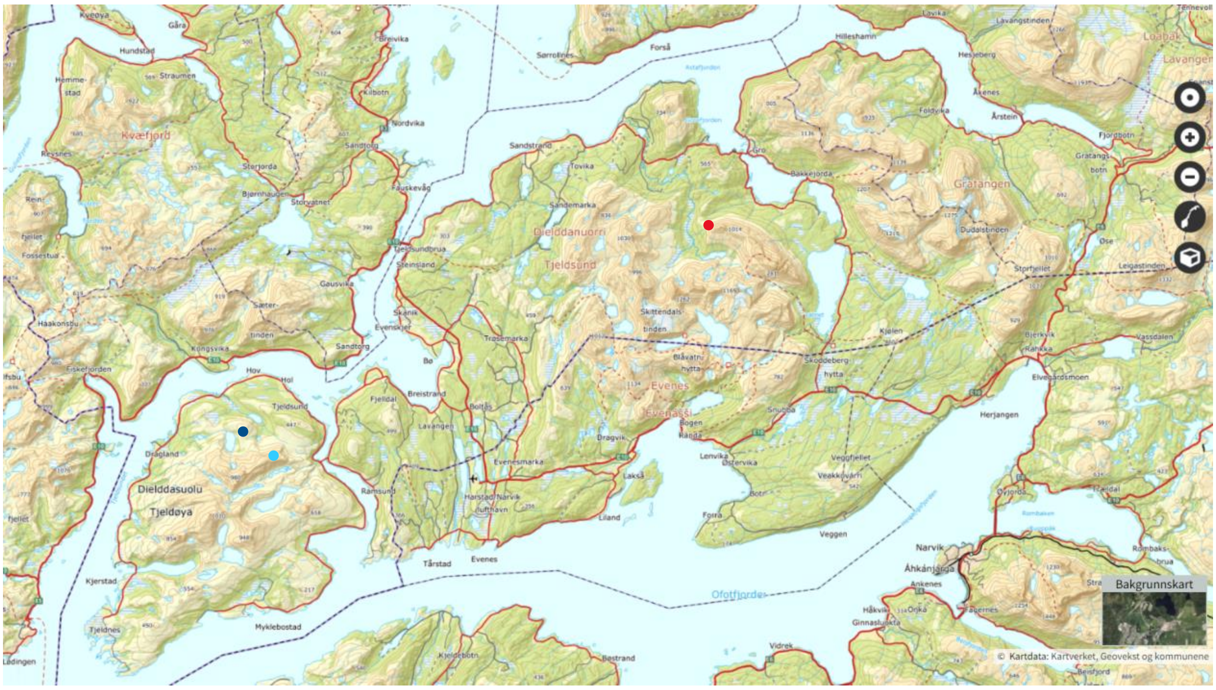

Figure 3: Approximate observation points of the observers at both Grovfjord and Tjeldøya. The red dot is the observation point of the observers on the 1st and 2nd of September 2022 and on the 23rd of June 2021, in Storjorddalen, Grovfjord. The dark blue dot is the observation point on the 1st of September 2022 at Trollfjellet, Tjeldøya. The light blue dot is the observation point on the 2nd of September 2022 at Spannbogan, Tjeldøya. The borders of the two districts are highlighted in Appendix 1.

In 2021, the fieldwork team consisted of Kjetil Flydal, Sindre Eftestøl and Sigurd Toverud from Naturrestaurering AS, and Magne Haukås and Adam Suleiman from Norconsult. In 2022, the team consisted of Kjetil Flydal, Sindre Eftestøl and Adam Suleiman, as well as Karen Creagh and Ole Tobias Rannestad from Naturrestaurering AS, Audun Skrindo from Forsvarsbygg and the author of the thesis, Ragnhild Aaberg Stenvik. Adam Suleiman measured the noise level using a sound level meter, while the rest of the team observed the animals.

During fieldwork, the first couple of days were used to localize reindeer, in cooperation with the reindeer owners, Anders Huva at Tjeldøya and the Nilsen family in Grovfjord. These days we went hiking to areas where we thought there might be reindeer, to see where we would get the highest chance of getting good observations of them. We then told the National Armed Forces about the approximate location of the reindeer. On the observation days, we hiked to our observation spots and used the time before the overflights to localize the exact positions of the reindeer. We updated the National Armed Forces and the pilots about the reindeer's positions, as well as how and where we wanted them to fly (i.e. height/elevation, power (speed) and compass direction). The reindeer owners also participated and agreed on the height of the flights and the routes (Figure 4), to make sure that the reindeer's wellbeing was prioritised.

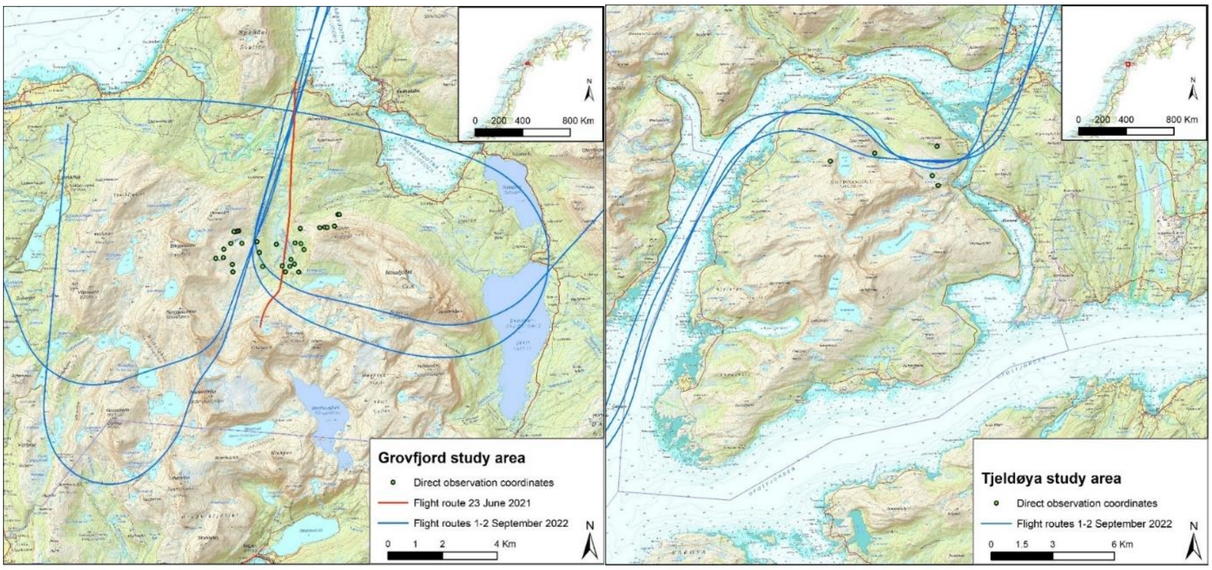

Figure 4: Study areas of Grovfjord (left) and Tjeldøya (right), the reindeer observation coordinates and the flight routes of the jet flights from both years. The aircraft routes for Tjeldøya in 2021 were not provided from the National Air Forces, so the exact routes of the jets when plotting in the reindeer coordinates were not available.

The jets were in the air on the 23rd of June 2021, 9th and 10th of September 2021 and on the 1st and 2nd of September 2022, and data was collected for each day. The 9th and 10th of September 2021 are not a part of the analysis, due to the weather conditions being so bad that it was difficult to see how the reindeer behaved and reacted.

In 2022, the F-35 jets passed the observation points 3-4 times between 10 am and noon, usually with around ten minutes between each overflight. Each observer had localized one herd that they were following through binoculars and/or video cameras during the overflights. On the 1st of September, the jets passed the observers in Grovfjord four times, while they passed Tjeldøya three times. On the 2nd of September, the jets passed both areas three times.

As the jets passed, the observers noted down how their herd reacted in a field registration form. The coordinate positions of the reindeer and observers, weather, terrain and other factors were recorded on the form.

The fieldwork in Grovfjord in 2021 was executed similarly to 2022. The 21st and 22nd of June were used to hike and locate reindeer herds, with the help of the reindeer owners. The plan for the two next days was to observe the reindeer as the F-16 jets passed them, but due to bad weather on the 22nd, the overflights were cancelled. On the 23rd, six overflights were completed according to plan. Both days, the herds were observed in Storjorddalen (Figure 4).

Figure 5: Picture taken from Storjorddalen, the observation spot in Grovfjord. Picture taken by Ragnhild Aaberg Stenvik.

Figure 6: Picture taken from Trollfjellet, one of the two observation spots at Tjeldøya. Picture taken by Karen Creagh.

All observations were filmed with Nikon Coolpix P950 cameras with 83x optical zoom, making it possible to record the reindeer's reactions from a long distance, as well as examining details in the office at a later date. On the 1st of September 2022, three herds were filmed in Storjorddalen and one herd was filmed on Tjeldøya. On the 2nd of September, two herds were filmed in both locations. In June 2021, three herds were filmed, all in Grovfjord. In September 2021, two herds were filmed in Grovfjord and one at Tjeldøya, but none of these observations were used in the analysis. In addition to filming during the overflights, we also filmed their behaviour before and after, with the purpose of using these video clips as control data (a robust "Before-After-Control-Impact", or BACI-design (Christie et al., 2019)). That way, reindeer reactions during the overflights could be compared with their natural 'none disturbed' behaviour.

The noise level from the aircrafts was measured in June 2021 and September 2022. On the 1st of September, the noise level was measured by Adam Suleiman with a 'Casella Dbadge2' sound level meter from Brüel & Kjær. On both days, 'BK 2270' dosemeters were used by the other observers, with the same purpose. In June 2021, both the sound level meter and the dosemeters were used. This data allowed testing whether the noise levels influence the reindeer's reactions, and test correlations between the amount of noise and the reindeer herds' reactions.

2.3) Data preparation

All information was organized using an excel spreadsheet, including the observer's name, time of the overflights, date, herd size, response intensity (see below), direction of the overflight, aircraft elevation, terrain and the reindeer's coordinates for each overflight, among other details. Data was acquired by examining the videos, as well as going through the evaluation report from 2021 and the direct observation field-forms that were filled out while doing the fieldwork in 2022.

During the video analysis, a 'focal observation method' was used, which involved selecting a single focal reindeer and recording its behaviour during the overflights (Bosholn & Anciães, 2017). This approach enables a more detailed examination of behaviour, as only one individual is observed throughout the observation time interval. The same procedure was followed for the focal reindeer in the absence of overflights (i.e. control). For both the overflights (i.e. test) and control, all focal individuals were chosen randomly and were observed for one minute. When looking through the videos from before the overflights, the control videos, a one-minute section from the video was selected for an individual using dice, ensuring that there was at least a five-minute interval between each observation. For both the test and control observations, five behavioural activity categories were recorded: lying, grazing, standing, walking and running. These behaviours were registered from the moment the jets were audible on the video recordings and until one minute had passed. Sometimes, the video was cut short before the minute had passed. In that case, if they had been expressing the same behaviour for all the past seconds, the behaviour was assumed to continue the rest of the minute. Each activity was registered as many times as they occurred. If a reindeer started the minute grazing, started to run and then started grazing again, 'grazing' twice, and for how long they grazed each time was registered. The observers from 2022 also had recorded down the reindeer's pre-overflight behaviour in their field-forms.

With the help of shapefiles of the overflight routes, each of the reindeer coordinates were plotted in ArcGIS from the observations done in field. This was done for both September 2022, and June and September 2021 (Figure 4).

As a comment from the author, it is important to note that that when the results show 'count of observation', the number of reindeer was multiplied with the five activity categories in the analysis, showing a much higher number than the actual count. There were 38 focal reindeer in total, observed through video recordings, 30 in Grovfjord and 8 at Tjeldøya. Multiplied with the five, that were 190 'counts of observation', 150 in Grovfjord and 40 at Tjeldøya, as demonstrated in Figure 7. From here on, 'number of reindeer' is used rather than 'count of observation'. If it is not possible to read these numbers off from the figures in the 'results' section, they were taken directly from the excel spreadsheet.

2.4) Statistical analysis

The goal was to test how F16/F35 jets affect reindeer and their behaviour. A variety of statistical analyses were used in R version 4.2.0 (RCoreTeam, 2022). All analyses were done separately for the two study sites (i.e. Grovfjord and Tjeldøya), unless otherwise specified.

2.4a) Clear response, time spent and vigilance

The first step was to find out whether the general response of the reindeer was clear or not. A chi-square test was used for comparing the frequency of clear versus unclear responses. The observed frequency of clear responses with the expected frequency was then compared, assuming that the clear responses are equally likely as the not-clear responses. Before doing the test, a 'clear' response was defined as 'a clear change of behaviour', like starting to walk, run, raise up or abruptly raise their heads when grazing. “Clear response” was used as an umbrella term for every reaction that included behavioural changes in the reindeer.

The next step was to find out how much time the reindeer used on each of the five activities in seconds. A linear model was used to compare time spent on the reindeer’s responses (activities) while being exposed to overflights (test) or not (control). In this model, time spent (on each activity) was used as a response variable, while exposure (with two levels: control and test) and the activity (with five levels: lying, grazing, standing, walking and running) were used as fixed effect variables. To perform a post hoc test between the levels of activity, the ‘emmean’ package in R was used, which makes pairwise comparisons to determine the significance of differences between the various activity levels.

When looking through the videos, how long the reindeer showed vigilance (in seconds) during that minute was also recorded. Vigilance was defined as ‘abruptly looking up while grazing, laying or standing’. A linear model was used to compare time spent on vigilance between reindeer exposed to overflights and not (i.e. control vs test).

2.4b) Detailed minute analysis

To describe the progress of the reindeers’ reactions throughout the whole minute, aka what activity they were doing each second, a graph was produced. This made it possible to see at what period of the minute the reindeer generally were the most stressed, and how long it would take for them to eventually calm down. Again, for every reindeer, both the test and control animals, the activity they were doing in each second was used with the same categories as before; 1 – lying, 2 – grazing, 3 – standing, 4 – walking and 5 – running. In this analysis, a line plot function was used to compare each second of the minute for the test animals to each second of the minute for the control animals. The two resulting line plots (one for the test animals and one for the control animals) thus showed the average activities of all the individuals in each second.

2.4c) Noise level effects

The noise data was integrated into the vigilance analysis, using a linear model to find out the relationship between noise level and time spent on vigilance. The vigilance data was used as a response variable and the noise data as the fixed effect variable. The relationship between the noise level and the time spent on running was also tested, excluding the other four reactions (lying, grazing, standing and walking). The results for vigilance and running were approximately the same, so only the results for vigilance are presented here.

2.4d) Terrain, overflight direction, group size and seasonal effects

To investigate the impact of other variables such as terrain, overflight direction, group size and season, alternative models with and without the different variables were run, using the Akaike's Information Criteria (AIC) to select the best parsimonious model (Appendix J). The results, however, showed that the best model was the one excluding all four of the variables (Appendix K, Table K1 and K2). It was concluded that neither of them had a significant effect on the results, and thus were not included in the results.

3) Results

3.1) Clear/unclear response

The test reindeer showed clear responses to jet overflights, particularly in Grovfjord, with 22/26 reindeer responding clearly. Tjeldøya's test animals reacted differently, with four reindeer reacting clearly and four unclearly. None of the control animals, i.e. the reindeer that were never exposed to the overpasses, showed any clear responses at all, and this was the case in either district (Figure 7). With a p-level of < 0.05, there was a significant difference between the control animals and the test animals in both areas (Appendix F, Table F1).

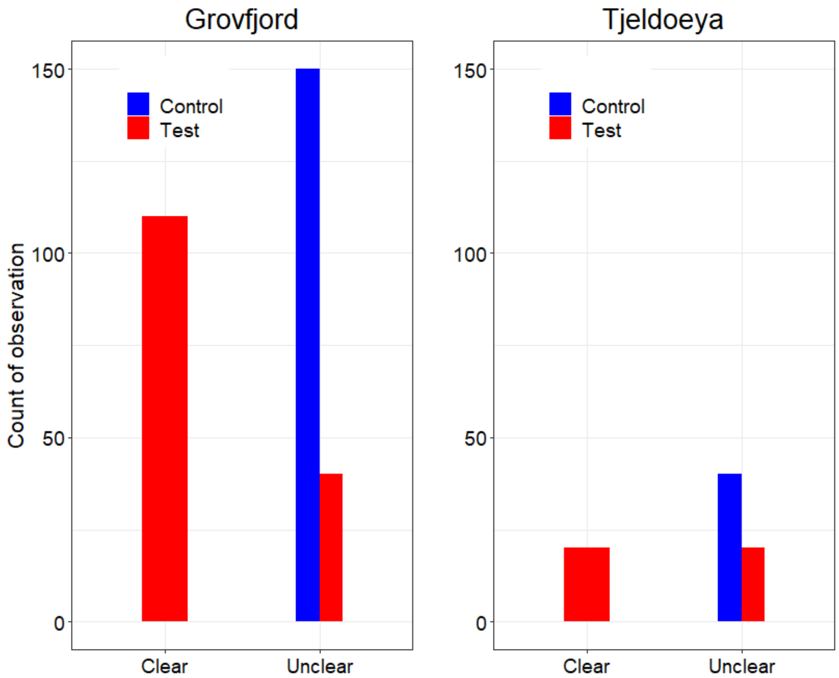

Figure 7: Response of the reindeer defined as "clear" or "unclear", for both areas. The blue bars show the control animals, which never showed any clear responses. The red bars show the test animals, which showed both clear and unclear responses.

3.2) Time spent on each activity

Grazing and lying down were more prominent among the control animals, while more reindeer were standing, walking and running in the test groups. This is visible, in particular, in Grovfjord, where there is a significant difference between the control animals and test animals for all the different response activities. For Tjeldøya, the result was more unpredictable (i.e. more walking among the controls), with less significant differences and more overlapping intervals (Figure 8). A table of the significant differences is shown in Appendix G, Table G1 and G2.

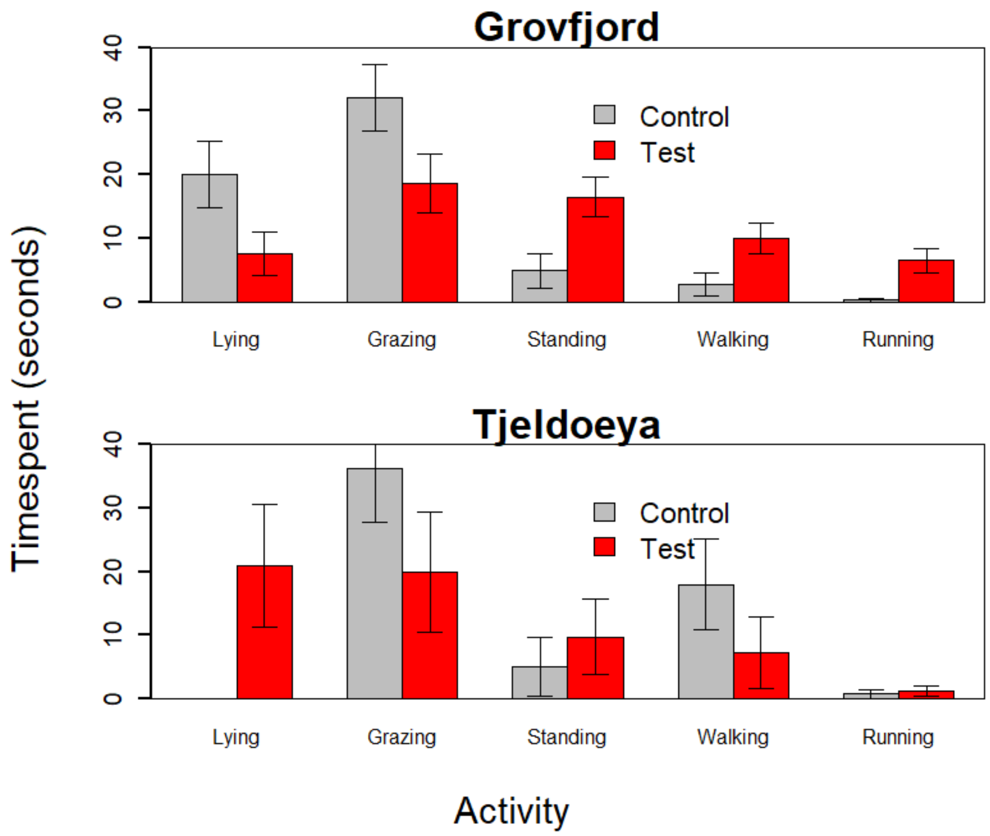

Figure 8: The relationship between the activities (i.e. lying, grazing, standing, walking and running) and the time spent (in seconds) on each activity, in both areas (test and control). When comparing the red and grey bars to each other in Grovfjord, their confidence intervals do not overlap, indicating that there is a significant difference between the test and control. In Tjeldøya, the confidence intervals overlap, and thus there was no significant difference.

3.3) Vigilance

The test reindeer spent more time (seconds) vigilant than the control animals. The trend was the same in both areas, with an average of 20 seconds spent on vigilance behaviour. The control animals at Tjeldøya, however, spent more time on vigilance than the control animals in Grovfjord (Figure 9). The significance level in this analysis was also set to 0.05, and a table of the significant differences can be found in Appendix H, Table H1 and H2.

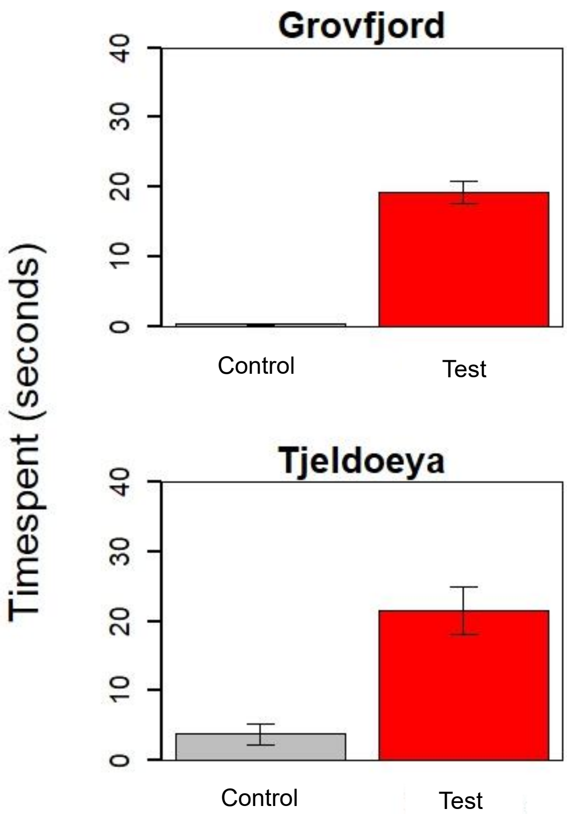

Figure 9: Level of vigilance in both the control and test animals, for both Grovfjord and Tjeldøya. The confidence intervals do not overlap in either district, indicating that there was a significant difference in vigilance between the control and test reindeer in both areas.

3.4) Detailed minute analysis

Combined for both districts, the average activity for the control reindeer was 2, meaning that they were mostly grazing the entire minute. There was more variation in the test period, with a peak around 18 to 25 seconds after start. At this point, the reindeer visibly got stressed and started moving, before they slowly calmed down again towards the end of the minute. Nevertheless, the average activity never got as low as it was at the beginning of the minute, and the minute for the test animals started with a higher number, indicating that these animals were generally more stressed than the control animals before the selected "minutes" began (Figure 10).

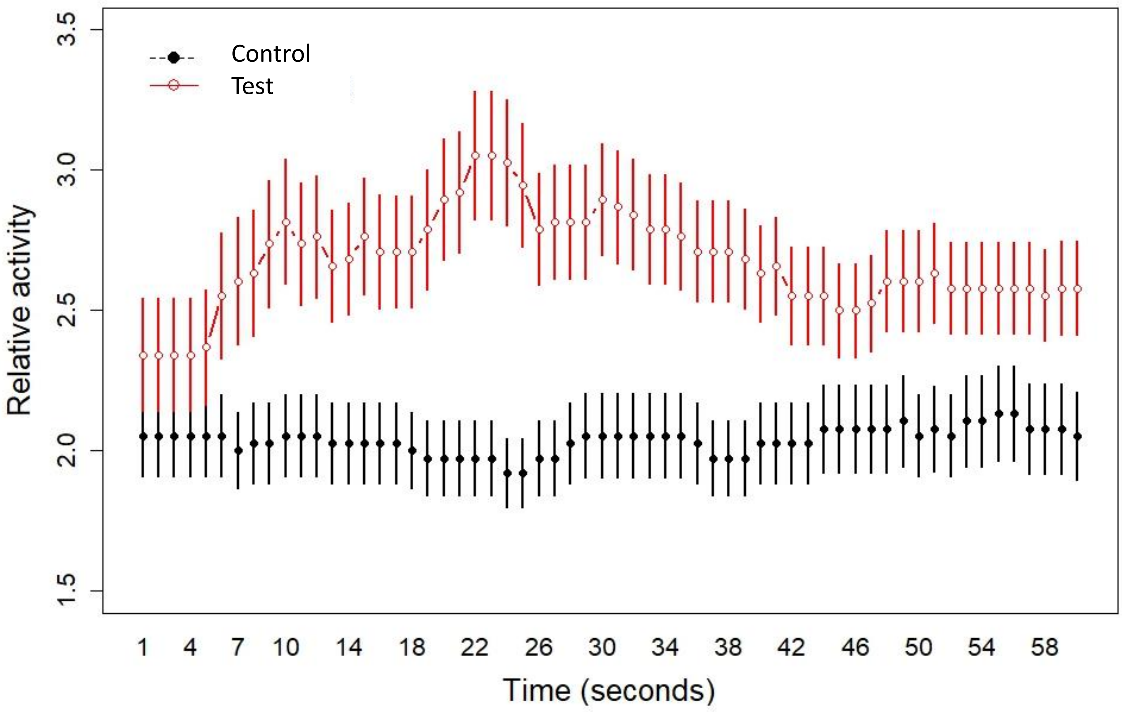

Figure 10: The relative/average activity of the test and control reindeer for each second throughout the whole minute, combined for each district. The numbers on the x-axis represent the seconds of a minute, while the numbers on the y-axis represent an activity (1 = lying, 2 = grazing, 3 = standing, 4 = walking and 5 = running).

3.5) Noise analysis

The correlation between noise level (in dB) and vigilance for the test reindeer in Grovfjord was slightly negative, indicating that when the noise level increased, the vigilance level decreased. At Tjeldøya, the trend was the opposite. The correlation was slightly positive: when the noise level increased, so did the vigilance level (Figure 11, Table 1-3). The significance level here was 0.05, and neither of these results were significant, as seen in Appendix I.

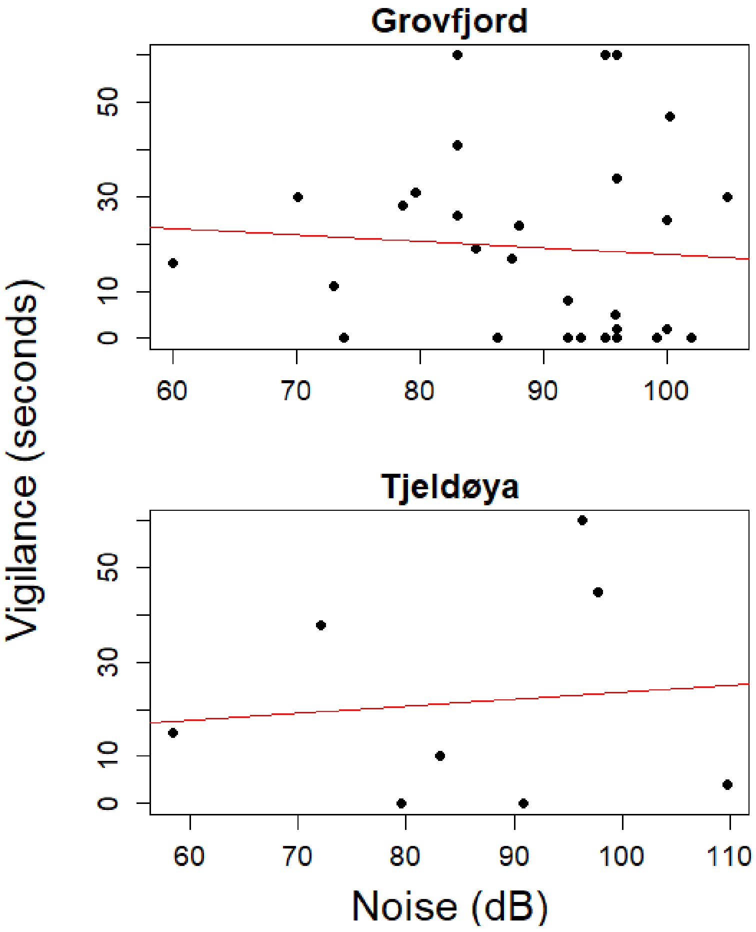

Figure 11: The correlation between the noise level (in dB) and the vigilance (in seconds) for test reindeer in both Grovfjord and Tjeldøya.

The noise level did not significantly affect the level of vigilance or running for the test reindeer, but there was a trend supporting an over-all behaviour change in the test animals, from the so-called 'inactive' activities (lying and grazing) to the 'active' ones (standing, walking and running) (Table 1-3). For instance, one of the test reindeer recorded on the 1st of September reacted by lying for the whole minute when the noise level was at the lowest (73.9 dB), the next minute (dB = 88) standing for 54 seconds, and then it stood, walked and ran during the two next overflights (Table 1). This happened more regularly in Grovfjord in 2022 than for Grovfjord 2021 and Tjeldøya 2022, with exceptions also in Grovfjord 2022 (Table 1-3). This result was not significant statistically, yet interesting enough to include here. Observations with no number were removed from the analysis, but were included in the tables to prevent confusion around the jump in time, thrust and noise level.

Table 1: Maximum noise level (LpAmax) and thrust of the aircrafts together with the test reindeer's reactions (in seconds) for Grovfjord in September 2022.

Observer	Date	Time	Thrust	LpAmax	Lay	Graze	Stand	Walk	Run	Vig.
Ragnhild	1/9	10:43	20	73.9	60	0	0	0	0	0
Ragnhild	1/9	10:50	60	88	6	0	54	0	0	24
Ragnhild	1/9	10:58	100	100.3	0	0	54	2	4	47
Ragnhild	1/9	11:12	150	104.9	0	0	11	40	9	30
Kjetil	1/9	10:43	20	60	0	44	16	0	0	16
Kjetil	1/9	10:50	60	73	0	49	11	0	0	11
Kjetil	1/9	10:58	100	81.9	-	-	-	-	-	-
Kjetil	1/9	11:12	150	87.5	0	0	17	33	0	17
Audun	1/9	10:43	20	78.6	5	0	28	13	13	28
Audun	1/9	10:50	60	86.3	0	0	40	8	12	0
Audun	1/9	10:58	100	99.2	0	0	26	14	20	0
Audun	1/9	11:12	150	100.2	-	-	-	-	-	-
Ragnhild	2/9	10:16	20	79.7	60	0	0	0	0	31
Ragnhild	2/9	10:26	60	95.8	0	0	42	14	4	5
Ragnhild	2/9	10:36	100	102	0	28	5	17	10	0
Kjetil	2/9	10:16	20	70.1	0	0	8	10	25	30
Kjetil	2/9	10:26	60	84.5	0	0	28	7	25	19
Kjetil	2/9	10:36	100	93	0	60	0	0	0	0

Table 2: Maximum noise level (LpAmax) and thrust of the aircrafts together with the test reindeer's reactions (in seconds) for Tjeldøya in September 2022.

Obs.	Date	Time	Thrust	LpAmax	Lay	Graze	Stand	Walk	Run	Vig.
Karen	1/9	10:11	22	58.4	0	0	15	45	0	15
Karen	1/9	10:18	60	72.1	38	0	16	0	6	38
Karen	1/9	10:29	100	96.3	60	0	0	0	0	60
Karen	2/9	10:03	22	65	60	0	0	0	0	10
Karen	2/9	10:12	60	79.5	9	4	47	0	0	45
Karen	2/9	10:18	100	90.9	0	43	0	13	4	4
Audun	2/9	10:03	22	83.1	-	-	-	-	-	-
Audun	2/9	10:12	60	97.8	0	60	0	0	0	0
Audun	2/9	10:18	100	109.7	0	60	0	0	0	0

Table 3: Maximum noise level (LpAmax) of the aircrafts together with the test reindeer's reactions (in seconds) for Grovfjord in June 2021.

Obs.	Date	Time	Thrust	LpAmax	Lay	Graze	Stand	Walk	Run	Vig.
Sigurd	23/6	11:04	-	79	0	0	6	9	45	26
Sigurd	23/6	11:10	-	-	-	-	-	-	-	-
Sigurd	23/6	11:19	-	112	0	0	33	10	17	60
Sigurd	23/6	11:36	-	107	8	0	22	30	0	25
Sigurd	23/6	11:42	-	99	0	52	8	0	0	8
Sigurd	23/6	11:45	-	103	0	9	0	51	0	2
Kjetil	23/6	11:04	-	77	29	0	19	12	0	60
Kjetil	23/6	11:10	-	85	60	0	0	0	0	60
Kjetil	23/6	11:19	-	91	0	26	34	0	0	34
Magne	23/6	11:04	-	89	0	0	31	19	10	41
Magne	23/6	11:10	-	91	0	60	0	0	0	0
Magne	23/6	11:19	-	85	0	60	0	0	0	2
Magne	23/6	11:36	-	94	0	60	0	0	0	2
Magne	23/6	11:42	-	89	0	60	0	0	0	0
Magne	23/6	11:45	-	98	0	50	0	10	0	0

4) Discussion

4.1) Unclear/clear response

As earlier mentioned, I defined ‘clear response’ as a ‘sudden change of behaviour’. When looking through the videos, there was a general clear response among the reindeer during the test period, particularly in Grovfjord (Figure 7). Most of the reindeer stopped what they were doing and were vigilant (28/38), and many showed a flight response as well, like running or walking (19/38). The length of the reactions varied, and while some reindeer spent the majority of the minute running, walking or being vigilant, others went back to their pre-disturbance behaviour after a few seconds. Some individuals did not react much at all, despite being exposed to overflights. There may be many reasons for this variety, which will be discussed below. The control animals, on the other hand, rarely reacted at all. There was no need for them to change their behaviour, as there were no overflights, and for the most part, they were either lying down/resting or grazing through the whole minute.

4.2) Activity vs time spent.

When looking at the graph for Grovfjord, the results were exactly as I expected. The control reindeer were more relaxed, with higher levels of laying and grazing, than the test reindeer that were exhibiting more standing, walking and running behaviour. This result indicates that the overflights generally made the reindeer more stressed and restless, while they were calmer and more relaxed when there were no jets passing over them. For Tjeldøya, the results were more unpredictable (Figure 8). For instance, we thought it was strange that so many reindeer were walking in the control areas, instead of lying down or grazing, as was the case in Grovfjord. There are several reasons why I think this could have happened. When looking through the videos, some of the clips were taken from so far away that it was hard to see their actual behaviour. It looked like they were walking, but there is a chance they could have been grazing instead. With more observations from Tjeldøya, the results would have been more reliable and predictable.

4.3) Vigilance

Vigilance is a natural behaviour for reindeer, and it is normal that they look up and scan the area occasionally for danger like predators. However, there is a cost associated with such vigilance behaviour. The more time reindeer use looking up and around, the less they use on foraging, thus increasing energy expenditure (Baskin & Hjältén, 2001) and decreasing productivity. This behaviour should be reserved for situations where it is necessary (Bøving &

Post, 1997), and reindeer and other ungulates often show varying degree of vigilance behaviour depending on their assessment of risk. For both Grovfjord and Tjeldøya, the test animals were much more vigilant than the control animals, indicating that they did perceive the jet flight activity as a threat. In many cases, the test reindeer's most common reaction to the jets was vigilance, whereas the control animals had nothing to be vigilant about, as the jets were absent. As seen in figure 9, the control animals at Tjeldøya showed a higher level of vigilance than the control animals in Grovfjord. This could be a coincidence with the same explanation as above; fewer observations and difficulties seeing what was happening through the cameras. They could also just be surveying the area due to natural vigilance behaviour.

4.4) Detailed minute analysis

When comparing the test animals to the controls, second by second, I could clearly see that there was a big difference in how the two groups of reindeer behaved. While the control reindeer mainly grazed (activity number 2) throughout the whole minute, the test individuals started the minute with a slightly relaxed behaviour (yet less relaxed than the control animals). They became more stressed and started walking or running around 17-25 seconds in, before the number began to reduce again. Harrison & Veitch reported similar behaviour in their caribou-jet flight research, where the caribou slowed down again relatively fast after they started running as a result of jet overflights (Harrington & Veitch, 1991). As seen in figure 10, the test animals started the minute in a more stressed state and were generally more restless. This could be explained by the fact that many of these individuals had already experienced consecutive overflights with only 5-10 minutes in-between, and still experienced a slightly elevated level of stress from previous overpasses. The test reindeer also never calmed down to a level as low as that of the control animals during the rest of the minute. When that is said, the highest average number was around 3.5, somewhere between standing and walking. So while a lot of reindeer in fact did react with an 'active' activity, like walking or running, a lot of the test animals did not react much at all, as we have already seen.

4.5) Noise effects

From the beginning, I expected the reactions of the test reindeer to be correlated with the noise level of the jet flights, rather than the sight of them. The range of frequencies an animal can hear is commonly referred to as hearing range. As of 2018, no studies had been conducted yet on the hearing of semi-domestic reindeer living in natural conditions (Tømmervik, H., 2018), but Flydal et al. investigated reindeer hearing in laboratories in 2001. The two male reindeer studied could detect sounds at 60 dB, corresponding to a normal conversation, at a sound frequency from 70 Hz and up to 38 kHz (Flydal et al., 2001). Their hearing range found in such studies implies that, with the exception of low frequencies, anthropogenic noise from sources such as engines, aircrafts and vehicular traffic are easily perceived (Reimers & Colman, 2009). The noise level range of jet flights has been measured several times before, reaching up to 120-130 dB (Harrington & Veitch, 1991; Reichman et al., 2018) at the most, with the highest noise levels in the frequency range of 1 kHz - 4 kHz (Harrington & Veitch, 1991). It is therefore logical to assume that the noise level of jet flights does influence the reindeer.

The noise analysis, however, showed that the noise level did not affect the level of vigilance, or the amount of running. Contrary to my initial beliefs, the trend was actually slightly negative in Grovfjord, with the vigilance level decreasing when the noise level increased. In Tjeldøya, the trend was slightly positive (Figure 11). Nevertheless, none of the results were significant (Appendix I), and the noise level thus did not have a significant effect on either vigilance or running.

I made three tables (Table 1-3) showing the over-all behaviour for the test reindeer, as observed in the videos, connected with changing noise levels. In Grovfjord in September 2022, the results were as expected: when the noise level was at the lowest, the reindeer spent most of the minute laying, grazing or standing (Table 1). The reindeer generally reacted more intensely as the thrust, and thus also the noise level, increased. Kjetil's observations both days were exceptions to this, and on the 1st of September, this could be due to the distance from the jet flight route. These animals were far away from where the planes flew and the noise level they were exposed to was lower than it was for the rest of the test animals, likely making their reactions less intense. Generally, these animals were also vigilant for a less amount of time than the other reindeer.

Karen's observations at Tjeldøya on the 2nd of September were as expected, with the reindeer's reactions becoming more intense as the noise level increased, whereas Audun's observations on the same day and Karen's observations the day before were not (Table 2). The reactions of the animals Karen was following became less intense with increased noise level, while Audun's animals did not really react at all, making the result from Tjeldøya less predictable.

All animals ran when the noise level was above 100 dB, with the exception of some of the reindeer in 2021 (Table 3). I suspect that, for 2021, due to the short amount of time in-between overflights (i.e., three minutes between the two last overflights), the animals got habituated to the noise. Previous studies about both wild and semi-domestic reindeer in Southern Norway (Reimers et al., 2010) and other ungulates (Weisenberger et al., 1996) have found that if stimuli are repeated, habituation may happen. There is a possibility that the reindeer did not perceive them as threatening or dangerous because they had just witnessed the same thing happen a few minutes before, as suggested in other studies (Reimers & Colman, 2009).

Additionally, I picked out one reindeer to follow throughout the whole minute. In big herds, however, one reindeer does not necessarily represent the general behaviour of the herd. Some animals were running, some were walking, and some did not react at all, and this happened in all the observations. Because the focal individuals were selected randomly, there is a chance that I picked the one reindeer that reacted differently from the others in the herd. Additionally, one individual could affect the whole herd's reaction if that animal is particularly timid. In conclusion, the different individuals in the herd are different in nature and behaviour and it is not always easy to conclude on why they react like they do.

4.6) Overflight direction, terrain, group size and seasonal effects.

After going through the data and looking through the videos, I speculated whether the variables overflight direction, terrain, group size and season could have had an effect on the result. We saw some trends when we were observing the animals, but did not know if they were significant or not. For instance, in Grovfjord, it seemed like the test reindeer reacted more intensely when the aircrafts flew southwards, over the mountains and down the valley, seeming to 'suddenly appear'. From the other direction, the reindeer would see the aircrafts from afar and seemingly not get startled as much. Similarly, there was a tendency that they reacted less when they were standing on the marsh, in open area, maybe due to a wider overview of the area. Reindeer in smaller groups also tended to react less, and we hypothesized that the reindeer observed in the spring would react more than the ones observed during fall, due to the calving season and thus an increased level of natural vigilance behaviour.

When we used AIC to find the best model, none of these variables proved to be statistically significant. On the contrary, a lot of previous scientific research says the opposite of what we found, and our observations might just be coincidental. Harrington found, in one of his studies, that the reindeer started running once they saw the aircrafts, and ran for a longer time

(Harrington, 2003). Their reactions were more intense and lasted longer if they could see and hear the disturbance from afar. In another study, Harrison and Veitch found that in open habitat, where reindeer would detect the aircrafts from afar, the reactions, as in the other research, would be more intense (Harrington & Veitch, 1991). Reindeer also have developed a group strategy to avoid predators, called ‘the many eyes’ effect (Manor & Saltz, 2003). The bigger the herd, the more eyes to detect threats. Bigger herds should, thus, react less intensely than smaller herds, which was not necessarily the case in our study. When it comes to seasonal effects; they did not make a significant difference on the results, but when looking at appendices J and K (Table K1 and K2), the models including season (and excluding the other variables) had lower AICs than the variables mentioned above, indicating that season had a bigger impact than others.

4.7) Other factors

One factor that could affect the result is the amount of data we had to exclude from the analysis. For instance, we had to exclude the observations from the fieldwork conducted at Tjeldøya in September 2021 due to bad weather conditions. When looking through the videos, it was hard to see how the reindeer responded. A lot of the videos had poor lighting, or the wind made it difficult to distinguish the jet flights from normal passenger flights. Several of the actual overflights had to be cancelled as well, because it was not justifiable to fly where we wanted them to fly, so the amount of data available was limited. Therefore, the results from Tjeldøya were not as extensive as we wish they could be.

Different ways of executing reindeer husbandry and the location of the districts might affect the way the different test animals react to jet overflights and should be taken into consideration when looking at the results. For instance, I was informed that Anders Huva, the owner of the Tjeldøya reindeer, feed his reindeer more than the Olsen family do with their reindeer in Grovfjord due to worse conditions of the grazing areas (K. Flydal, pers. Comm.). The district of Grovfjord also has more continuous area to roam in, and bigger seasonal grazing areas, which make them less dependent on human care. Both districts are close to Evenes Air Station, but the reindeer in Tjeldøya are also exposed to military activity in Ramsund, where there is a military base (Forsvaret, 2021), making them more exposed to these types of disturbances. Generally, it seems that the Tjeldøya reindeer are more used to disturbances of anthropogenic origin than the Grovfjord reindeer are.

In June 2021, a couple of the individuals I followed while looking through the videos were calves. This could have influenced the results, as calves can exhibit other types of behaviour than the adults. In another research with caribou and aircraft in the US and Canada, they found that calves react more to aircraft activity than older caribou, both during spring and fall (Calef et al., 1976). In spring, the calves would run to their mother, even when the mother did not react at all. Thus, a calf would not necessarily represent the herd's behaviour in a reliable way.

It is also important to note that, during the field work in June 2021, the jets were never supposed to fly lower than about 300 m. Due to miscommunication between the pilots and the observers, however, the jets flew 100 and 150 m above the reindeer, causing a much more severe disturbance than what was intended. Calef et al. found that a minimum altitude of 305 m (1000 feet) was required to avoid injuries and other harmful reactions of caribou (Calef et al., 1976). This was especially unfortunate when considering the time of the year, and that there were calves in the herds as well. Fieldwork was considered in June and January of 2022, too. Ultimately, the reindeer owners, as well as the observers, deemed both of these two periods to be too risky due to the reindeer's natural fragile state (Reimers et al., 2003).

After looking through the videos and analysing the results, it seemed like the test reindeer's reactions were not as intense and as bad as I initially assumed they would be. The reactions were clear, but overall I had expected their reactions to be worse. I had expected more of the reindeer to run and that they would run for a longer time. The reactions were not due to the noise levels alone either. My results are similar to those of other similar research, where moderate reactions have been the consensus. Harrington and Veitch found, in their study about short-term responses of jet flight activity on caribou in Labrador, Canada, that the caribou typically reacted with an initial startle response (Harrington & Veitch, 1991). Their heart rate (HR) increased, but they generally calmed down within a minute after the overflight had ended, despite their HR often being elevated for minutes after. Similarly, reindeer exposed to low-level F-16 jet flights and helicopter activity in Sørøya, Norway showed moderate reactions, with their most common reaction being increased vigilance and a brief startle response (Berntsen et al., 1996). For both of these studies, the amount of data was too small for the results to be reliable. Ten caribou were studied in Labrador and only seven in Sørøya, but due to technical difficulties, only one of the heart rate trackers worked throughout the whole study. These results were, thus, not as reliable as I wish they could be, and further prove that more research regarding jet flights' influence on reindeer is needed.

4.8) Implications for the future

The moderate reactions of the reindeer implies that this specific disturbance might not affect them as much as we feared. Despite several cases of flight responses and high levels of vigilance, the reindeer generally started grazing or resting soon after the initial response. However, the variety of responses from the reindeer indicates that a larger number of studies involving jet overflights is necessary to statistically conclude whether the noise level disturb them or not.

Future researchers should, in cooperation with the reindeer owners, aim to study the potential worst-case consequences of the overflights, as long as serious harm and injuries on the reindeer are avoided. Now that we have demonstrated that the test animals' reactions were moderate, future study designs might get more significant results if the fieldwork is conducted during the winter months, or during the calving season (as done in Grovfjord in September 2021). The impact of flying lower than 300 m or with more power could also be interesting to look into in future research.

If the military activity increases drastically, and it turns out that these disturbances result in more negative consequences than are justifiable, then it might be a good idea to introduce some mitigation measures to limit the negative impact that follows. These measures include staying away in periods where they are already vulnerable (i.e. during the winter- and calving season), never flying lower than 300 m above ground level and to avoid flight routes that might disturb their migration routes. On the other hand, with increased military activity, they might also become habituated, as my results show to a certain degree. In other words, future researchers need to be flexible and able to adjust their study design according to the results in the most recent previous studies.

When that is said, the reindeer owners know their animals best, and ultimately it is their decision whether they want to continue the research or not.

5) Conclusion

Prediction A was confirmed. The reindeer generally showed a clear response to the disturbances (i.e. military jet flight activity) they were exposed to. No ‘main’ source of influence was found statistically, indicating that there were several factors affecting the results.

Prediction B was partly confirmed. There was a significant difference between the test animals and the control animals when it comes to the time spent on each activity. In Grovfjord, the test animals exhibit more stressed behaviour, such as standing, walking and running, whereas the control animals were more relaxed, with more ‘lying’ and ‘grazing’ behaviour. In Tjeldøya, the test animals reacted more unpredictably, and there were generally more overlap between the test animals and control animals, indicating less significant difference.

Prediction C was confirmed. The test individuals were more vigilant, averaging approximately 20 seconds per minute of vigilance behaviour in total, for both Grovfjord and Tjeldøya. The control individuals were only vigilant for a couple of seconds per minute at most, although most of them exhibited no vigilance behaviour at all.

Prediction D was confirmed. Just like in previous research, the test reindeer exhibited ‘stressed’ (i.e. standing/running/walking) behaviour for only a few seconds, before they calmed down. The reactions typically peaked in intensity after about 20 seconds, and slowly decreased after that.

Prediction E was not confirmed, but more data is needed to reject the prediction, and thus also hypothesis 2. The noise level did not have a significant effect on vigilance or running behaviour. There were trends showing that the noise could be a factor in the over-all behaviour , but this was not proven statistically.

I think that my findings indicate that there is need for even more knowledge about jet flights' short-term influence on reindeer, which could be acquired through similar type of research. The results from this study show that the species reacts to the disturbances they are exposed to, but on such a moderate level that they are not affected for more than a couple of minutes at the time. The overflights did not cause any serious harm to the animals, and it would, thus, be justifiable and useful to continue the research, to assess potential risks and threats to the species.

Another part of the same reindeer-jet flight project has also started researching potential long-term consequences of the overflights. In this study, GPS trackers are used to investigate if the reindeer, for instance, avoid certain sites that they associate with danger, change their migration routes, or alter their behaviour in other ways that might change their activity budget significantly. More knowledge about long-term consequences, as well as the short-term, will probably result in a more reliable and statistically significant conclusion on jet activity's impact on reindeer.

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7) Appendices

Appendix A

Figure A1: The borders and the size of the two districts.

Red = Tjeldøya and blue = Grovfjord. Map taken from nibio.kilden.no.

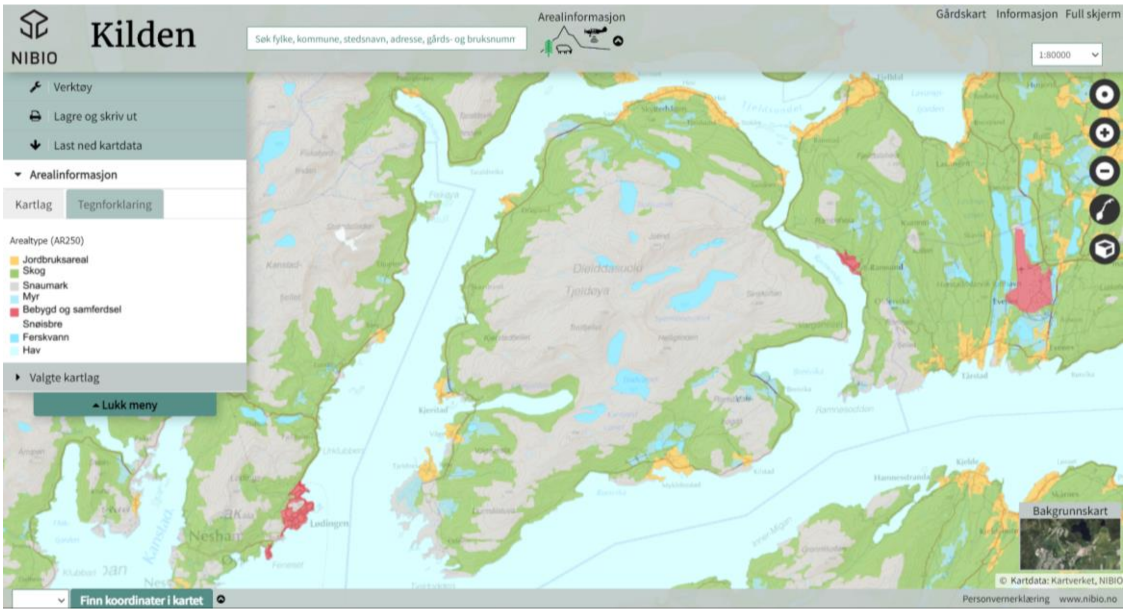
Appendix B

Figure B1: Map of the area type in the whole of Grovfjord.

Yellow/orange = agricultural area, green = forest, grey = barren ground/above treeline, blue = marsh, red = settlement, white = glacier, darker blue = fresh water/lakes and lighter blue = ocean. Map taken from nibio.kilden.no.

Figure B2: Map of the area types at the whole of Tjeldøya.

Yellow/orange = agricultural area, green = forest, grey = barren ground/above treeline, blue = marsh, red = settlement, white = glacier, darker blue = fresh water/lakes and lighter blue = ocean. Map taken from nibio.kilden.no.



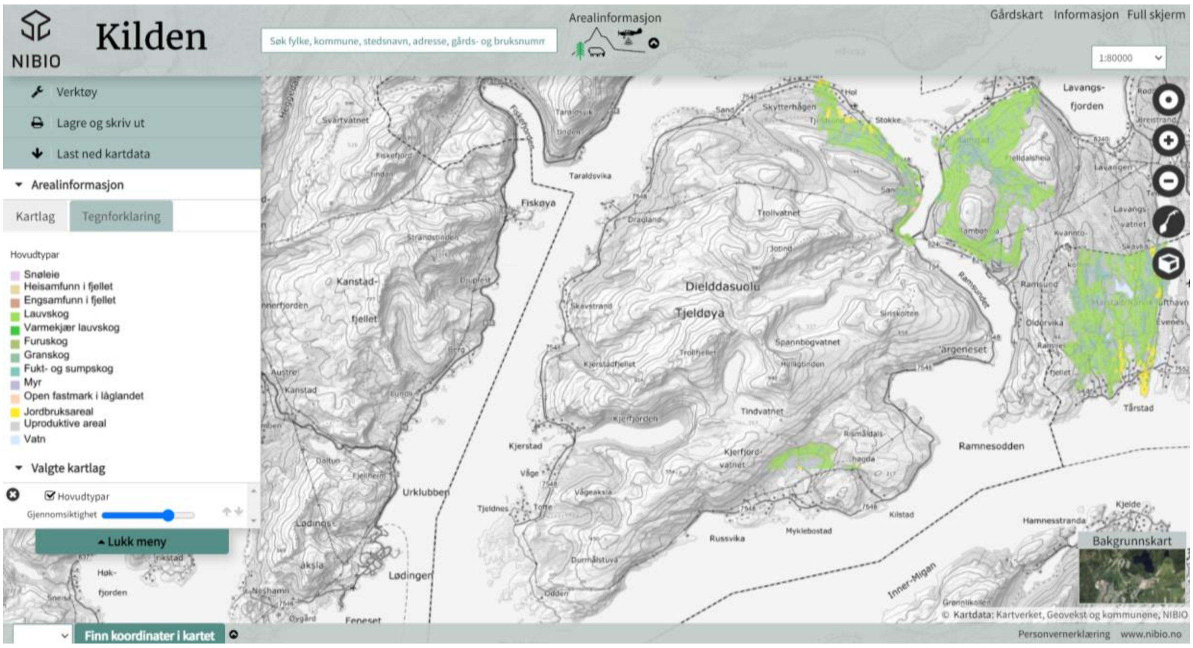
Appendix C

Figure C1: Map of the main types of vegetation in the district of Grovfjord.

The vegetation types represented here are agricultural area, different types of birch, pine and Norwegian spruce woods, as well as cultivated land.

Figure C2: Map of the main types of vegetation at Tjeldøya.

The vegetation types represented here are agricultural area, different types of birch, pine and Norwegian spruce woods, cultivated land and marshes.



Appendix D

Figure D1: Migration routes of the reindeer in Grovfjord.

Evenes Air Station is located within the blue circle. Map taken from kilden.nibio.no.

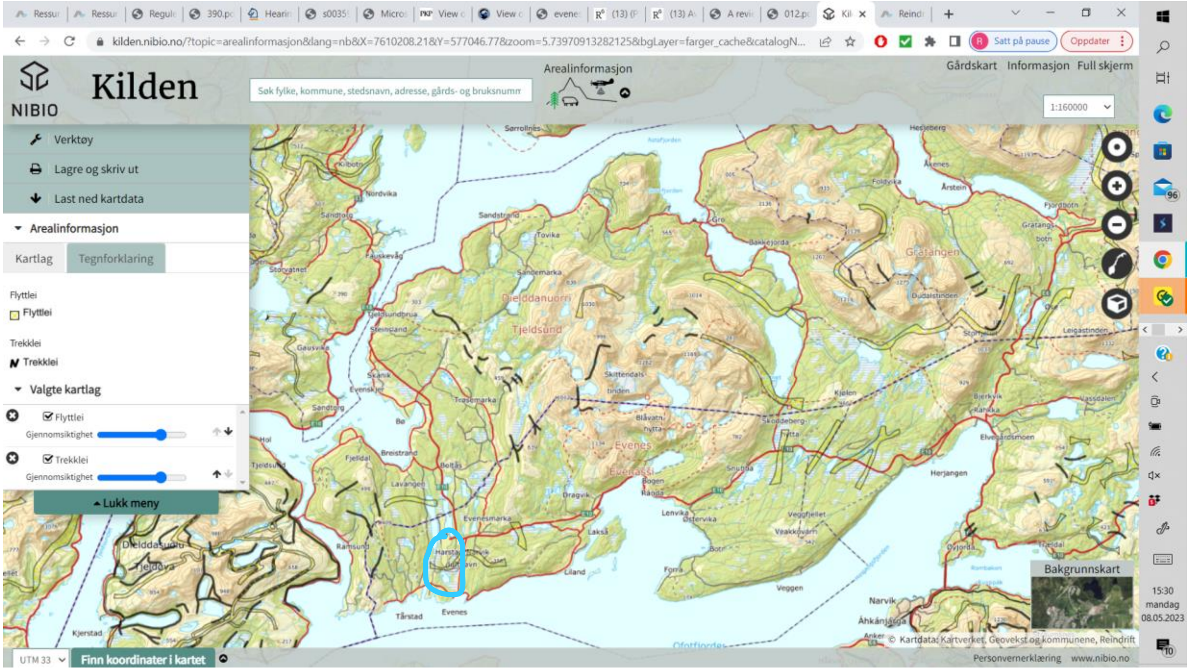
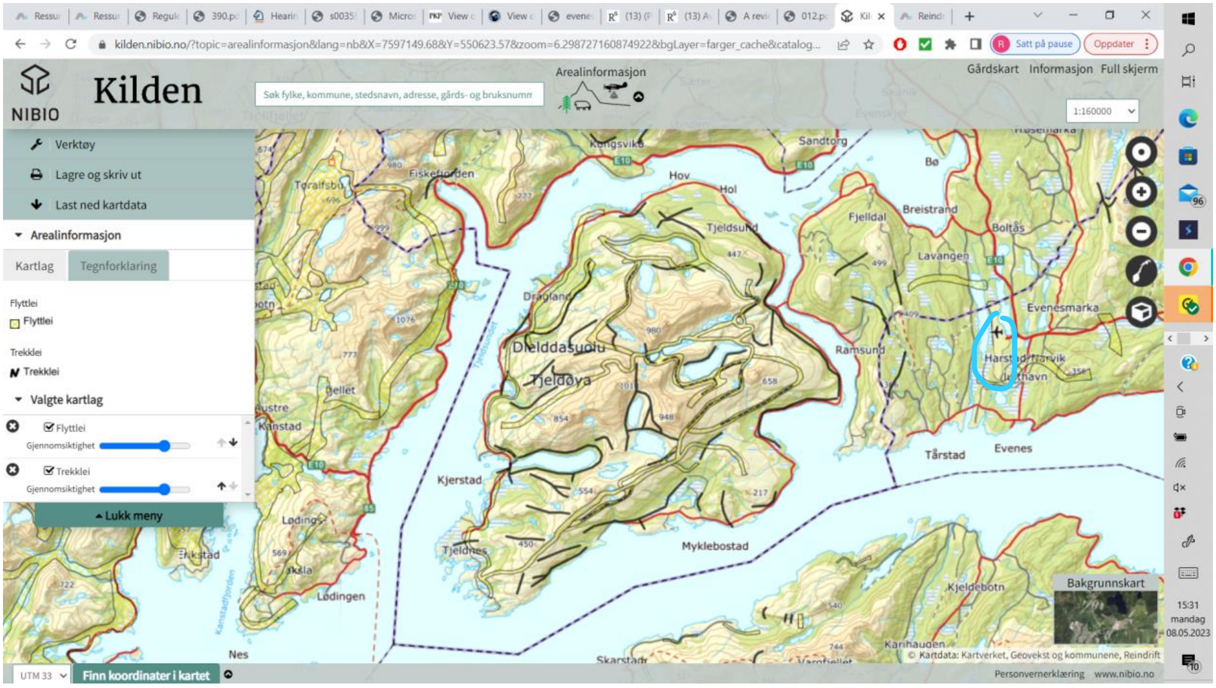


Figure D2: Migration routes of the reindeer at Tjeldøya.

Evenes Air Station is located within the blue circle. Map taken from kilden.nibio.no.



Appendix E

Figure E1: The terrain of the observation point in Grovfjord.

Green = forest, light blue with stripes = marsh, darker blue = lake, grey = barren ground and orange = agricultural area. Map taken from kilden.nibio.no.

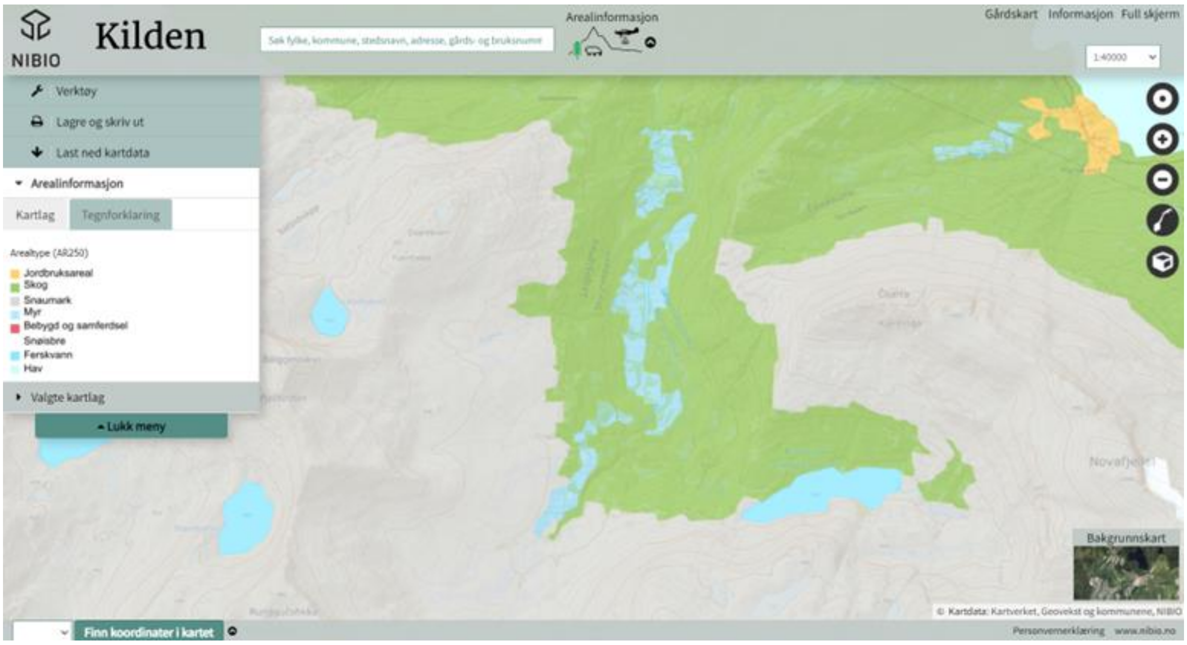
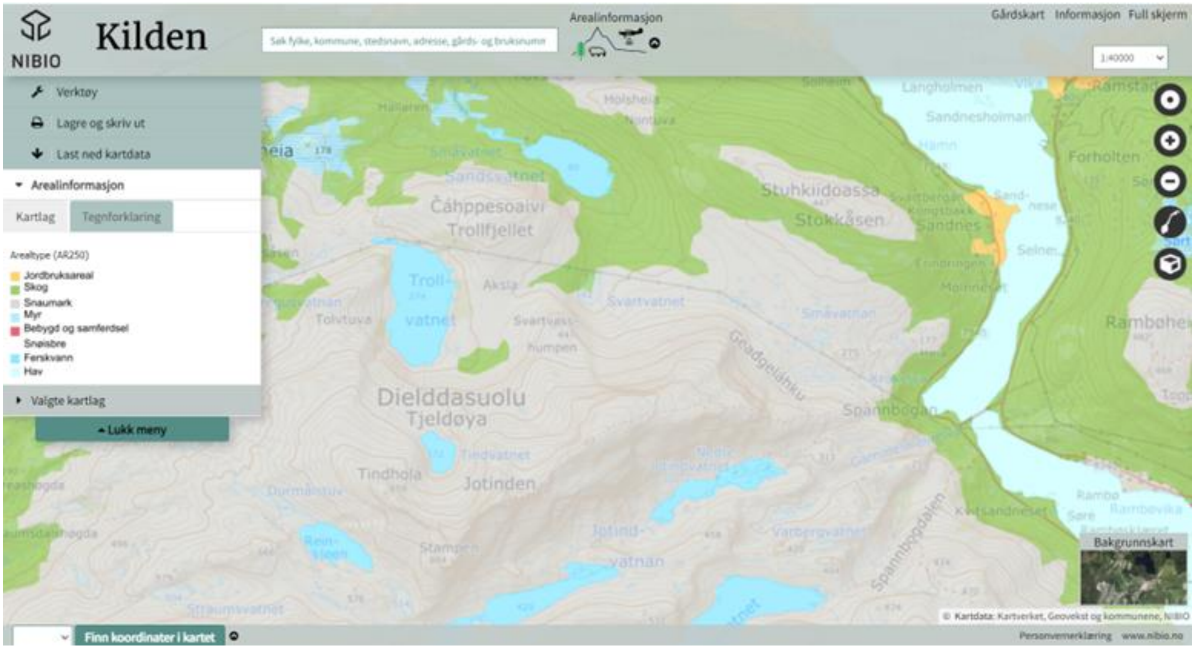


Figure E2: The terrain of the observation points at Tjeldøya.

Green = forest, blue with stripes = marsh, blue = lakes, grey = barren ground, light blue = ocean and orange = agricultural area. Map taken from kilden.nibio.no.



Appendix F

Table F1: Clear/unclear response.

The p-value, showing whether the difference in clear/unclear responses between control and test animals was significant or not. The p-value was less than 0.05, indicating a significant difference.

Area	p-value
Grovfjord	$< 2.2e^{-16}$
Tjeldøya	$9.306e^{-07}$

Appendix G

Table G1: Time spent on each response activity in Grovfjord.

An overview of the significant differences, as well as some other variables like standard error, between different activities in the time spent analysis. If the p-value between two activities is < 0.05, there is a significant difference between them. These numbers were copied directly from Rstudio.

contrast	estimate	SE	df	t-ratio	p-value
Lying Control - Grazing Control	-12.07	4.87	290	-2.480	0.2838
Lying Control - Standing Control	15.13	4.87	290	3.110	0.0627
Lying Control - Walking Control	17.20	4.87	290	3.535	0.0169
Lying Control - Running Control	19.73	4.87	290	4.055	0.0026
Lying Control - Lying Experiment	12.40	4.87	290	2.548	0.2477
Lying Control - Grazing Experiment	1.40	4.87	290	0.288	1.0000
Lying Control - Standing Experiment	3.57	4.87	290	0.733	0.9993
Lying Control - Walking Experiment	10.03	4.87	290	2.062	0.5560
Lying Control - Running Experiment	13.53	4.87	290	2.781	0.1478
Grazing Control - Standing Control	27.20	4.87	290	5.590	<.0001
Grazing Control - Walking Control	29.27	4.87	290	6.015	<.0001
Grazing Control - Running Control	31.80	4.87	290	6.535	<.0001
Grazing Control - Lying Experiment	24.47	4.87	290	5.028	<.0001
Grazing Control - Grazing Experiment	13.47	4.87	290	2.768	0.1527
Grazing Control - Standing Experiment	15.63	4.87	290	3.213	0.0466
Grazing Control - Walking Experiment	22.10	4.87	290	4.542	0.0003
Grazing Control - Running Experiment	25.60	4.87	290	5.261	<.0001
Standing Control - Walking Control	2.07	4.87	290	0.425	1.0000
Standing Control - Running Control	4.60	4.87	290	0.945	0.9948
Standing Control - Lying Experiment	-2.73	4.87	290	-0.562	0.9999
Standing Control - Grazing Experiment	-13.73	4.87	290	-2.822	0.1339
Standing Control - Standing Experiment	-11.57	4.87	290	-2.377	0.3436
Standing Control - Walking Experiment	-5.10	4.87	290	-1.048	0.9889
Standing Control - Running Experiment	-1.60	4.87	290	-0.329	1.0000
Walking Control - Running Control	2.53	4.87	290	0.521	1.0000

Walking Control - Lying Experiment	-4.80	4.87	290	-0.986	0.9928
Walking Control - Grazing Experiment	-15.80	4.87	290	-3.247	0.0420
Walking Control - Standing Experiment	-13.63	4.87	290	-2.802	0.1407
Walking Control - Walking Experiment	-7.17	4.87	290	-1.473	0.9018
Walking Control - Running Experiment	-3.67	4.87	290	-0.754	0.9991
Running Control - Lying Experiment	-7.33	4.87	290	-1.507	0.8886
Running Control - Grazing Experiment	-18.33	4.87	290	-3.768	0.0075
Running Control - Standing Experiment	-16.17	4.87	290	-3.322	0.0334
Running Control - Walking Experiment	-9.70	4.87	290	-1.993	0.6044
Running Control - Running Experiment	-6.20	4.87	290	-1.274	0.9586
Lying Experiment - Grazing Experiment	-11.00	4.87	290	-2.261	0.4181
Lying Experiment - Standing Experiment	-8.83	4.87	290	-1.815	0.7251
Lying Experiment - Walking Experiment	-2.37	4.87	290	-0.486	1.0000
Lying Experiment - Running Experiment	1.13	4.87	290	0.233	1.0000
Grazing Experiment - Standing Experiment	2.17	4.87	290	0.445	1.0000
Grazing Experiment - Walking Experiment	8.63	4.87	290	1.774	0.7509
Grazing Experiment - Running Experiment	12.13	4.87	290	2.494	0.2764
Standing Experiment - Walking Experiment	6.47	4.87	290	1.329	0.9462
Standing Experiment - Running Experiment	9.97	4.87	290	2.048	0.5657
Walking Experiment - Running Experiment	3.50	4.87	290	0.719	0.9994

Table G2: Time spent on each response activity at Tjeldøya.

An overview of the significant differences, as well as some other variables like standard error, between different activities in the time spent analysis. If the p-value between two activities is < 0.05, there is a significant difference between them. These numbers were copied directly from Rstudio.

contrast	**estimate**	**SE**	**df**	**t-ratio**	**p-value**
Lying Control - Grazing Control	-36.25	8.89	70	-4.077	0.0044
Lying Control - Standing Control	-5.00	8.89	70	-0.562	0.9999
Lying Control - Walking Control	-18.00	8.89	70	-2.025	0.5851
Lying Control - Running Control	-0.75	8.89	70	-0.084	1.0000
Lying Control - Lying Experiment	-20.88	8.89	70	-2.348	0.3726
Lying Control - Grazing Experiment	-19.88	8.89	70	-2.236	0.4433

Lying Control - Standing Experiment	-9.75	8.89	70	-1.097	0.9835
Lying Control - Walking Experiment	-7.25	8.89	70	-0.815	0.9981
Lying Control - Running Experiment	-1.25	8.89	70	-0.141	1.0000
Grazing Control - Standing Control	31.25	8.89	70	3.515	0.0251
Grazing Control - Walking Control	18.25	8.89	70	2.053	0.5660
Grazing Control - Running Control	35.50	8.89	70	3.993	0.0058
Grazing Control - Lying Experiment	15.38	8.89	70	1.729	0.7751
Grazing Control - Grazing Experiment	16.38	8.89	70	1.842	0.7067
Grazing Control - Standing Experiment	26.50	8.89	70	2.981	0.1036
Grazing Control - Walking Experiment	29.00	8.89	70	3.262	0.0508
Grazing Control - Running Experiment	35.00	8.89	70	3.937	0.0069
Standing Control - Walking Control	-13.00	8.89	70	-1.462	0.9021
Standing Control - Running Control	4.25	8.89	70	0.478	1.0000
Standing Control - Lying Experiment	-15.88	8.89	70	-1.786	0.7417
Standing Control - Grazing Experiment	-14.88	8.89	70	-1.673	0.8064
Standing Control - Standing Experiment	-4.75	8.89	70	-0.534	0.9999
Standing Control - Walking Experiment	-2.25	8.89	70	-0.253	1.0000
Standing Control - Running Experiment	3.75	8.89	70	0.422	1.0000
Walking Control - Running Control	17.25	8.89	70	1.940	0.6422
Walking Control - Lying Experiment	-2.88	8.89	70	-0.323	1.0000
Walking Control - Grazing Experiment	-1.88	8.89	70	-0.211	1.0000
Walking Control - Standing Experiment	8.25	8.89	70	0.928	0.9950
Walking Control - Walking Experiment	10.75	8.89	70	1.209	0.9685
Walking Control - Running Experiment	16.75	8.89	70	1.884	0.6795
Running Control - Lying Experiment	-20.12	8.89	70	-2.264	0.4251
Running Control - Grazing Experiment	-19.12	8.89	70	-2.151	0.4991
Running Control - Standing Experiment	-9.00	8.89	70	-1.012	0.9906
Running Control - Walking Experiment	-6.50	8.89	70	-0.731	0.9992
Running Control - Running Experiment	-0.50	8.89	70	-0.056	1.0000
Lying Experiment - Grazing Experiment	1.00	8.89	70	0.112	1.0000
Lying Experiment - Standing Experiment	11.12	8.89	70	1.251	0.9608
Lying Experiment - Walking Experiment	13.62	8.89	70	1.533	0.8743
Lying Experiment - Running Experiment	19.62	8.89	70	2.207	0.4617
Grazing Experiment - Standing Experiment	10.12	8.89	70	1.139	0.9787

Grazing Experiment - Walking Experiment	12.62	8.89	70	1.420	0.9168
Grazing Experiment - Running Experiment	18.62	8.89	70	2.095	0.5372
Standing Experiment - Walking Experiment	2.50	8.89	70	0.281	1.0000
Standing Experiment - Running Experiment	8.50	8.89	70	0.956	0.9937
Walking Experiment - Running Experiment	6.00	8.89	70	0.675	0.9996

Appendix H

Table H1: Vigilance in Grovfjord

An overview of the significant differences, as well as some other variables like standard error, in the vigilance analysis. If the p-value is < 0.05, there is a significant difference. These numbers were copied directly from Rstudio.

contrast	**estimate**	**SE**	**df**	**t-ratio**	**p-value**
Lying Control - Grazing Control	0	3.61	290	0.000	1.0000
Lying Control - Standing Control	0	3.61	290	0.000	1.0000
Lying Control - Walking Control	0	3.61	290	0.000	1.0000
Lying Control - Running Control	0	3.61	290	0.000	1.0000
Lying Control - Lying Experiment	-19	3.61	290	-5.254	<.0001
Lying Control - Grazing Experiment	-19	3.61	290	-5.254	<.0001
Lying Control - Standing Experiment	-19	3.61	290	-5.254	<.0001
Lying Control - Walking Experiment	-19	3.61	290	-5.254	<.0001
Lying Control - Running Experiment	-19	3.61	290	-5.254	<.0001
Grazing Control - Standing Control	0	3.61	290	0.000	1.0000
Grazing Control - Walking Control	0	3.61	290	0.000	1.0000
Grazing Control - Running Control	0	3.61	290	0.000	1.0000
Grazing Control - Lying Experiment	-19	3.61	290	-5.254	<.0001
Grazing Control - Grazing Experiment	-19	3.61	290	-5.254	<.0001
Grazing Control - Standing Experiment	-19	3.61	290	-5.254	<.0001
Grazing Control - Walking Experiment	-19	3.61	290	-5.254	<.0001
Grazing Control - Running Experiment	-19	3.61	290	-5.254	<.0001
Standing Control - Walking Control	0	3.61	290	0.000	1.0000
Standing Control - Running Control	0	3.61	290	0.000	1.0000
Standing Control - Lying Experiment	-19	3.61	290	-5.254	<.0001
Standing Control - Grazing Experiment	-19	3.61	290	-5.254	<.0001
Standing Control - Standing Experiment	-19	3.61	290	-5.254	<.0001
Standing Control - Walking Experiment	-19	3.61	290	-5.254	<.0001
Standing Control - Running Experiment	-19	3.61	290	-5.254	<.0001
Walking Control - Running Control	0	3.61	290	0.000	1.0000
Walking Control - Lying Experiment	-19	3.61	290	-5.254	<.0001

Walking Control - Grazing Experiment	-19	3.61	290	-5.254	<.0001
Walking Control - Standing Experiment	-19	3.61	290	-5.254	<.0001
Walking Control - Walking Experiment	-19	3.61	290	-5.254	<.0001
Walking Control - Running Experiment	-19	3.61	290	-5.254	<.0001
Running Control - Lying Experiment	-19	3.61	290	-5.254	<.0001
Running Control - Grazing Experiment	-19	3.61	290	-5.254	<.0001
Running Control - Standing Experiment	-19	3.61	290	-5.254	<.0001
Running Control - Walking Experiment	-19	3.61	290	-5.254	<.0001
Running Control - Running Experiment	-19	3.61	290	-5.254	<.0001
Lying Experiment - Grazing Experiment	0	3.61	290	0.000	1.0000
Lying Experiment - Standing Experiment	0	3.61	290	0.000	1.0000
Lying Experiment - Walking Experiment	0	3.61	290	0.000	1.0000
Lying Experiment - Running Experiment	0	3.61	290	0.000	1.0000
Grazing Experiment - Standing Experiment	0	3.61	290	0.000	1.0000
Grazing Experiment - Walking Experiment	0	3.61	290	0.000	1.0000
Grazing Experiment - Running Experiment	0	3.61	290	0.000	1.0000
Standing Experiment - Walking Experiment	0	3.61	290	0.000	1.0000
Standing Experiment - Running Experiment	0	3.61	290	0.000	1.0000
Walking Experiment - Running Experiment	0	3.61	290	0.000	1.0000

Table H2: Vigilance at Tjeldøya

An overview of the significant differences, as well as some other variables like standard error, in the vigilance analysis. If the p-value is < 0.05, there is a significant difference. These numbers were copied directly from Rstudio.

contrast	estimate	SE	df	t-ratio	p-value
Lying Control - Grazing Control	0.0	8.96	70	0.000	1.0000
Lying Control - Standing Control	0.0	8.96	70	0.000	1.0000
Lying Control - Walking Control	0.0	8.96	70	0.000	1.0000
Lying Control - Running Control	0.0	8.96	70	0.000	1.0000
Lying Control - Lying Experiment	-17.8	8.96	70	-1.980	0.6153
Lying Control - Grazing Experiment	-17.8	8.96	70	-1.980	0.6153
Lying Control - Standing Experiment	-17.8	8.96	70	-1.980	0.6153
Lying Control - Walking Experiment	-17.8	8.96	70	-1.980	0.6153

Lying Control - Running Experiment	-17.8	8.96	70	-1.980	0.6153
Grazing Control - Standing Control	0.0	8.96	70	0.000	1.0000
Grazing Control - Walking Control	0.0	8.96	70	0.000	1.0000
Grazing Control - Running Control	0.0	8.96	70	0.000	1.0000
Grazing Control - Lying Experiment	-17.8	8.96	70	-1.980	0.6153
Grazing Control - Grazing Experiment	-17.8	8.96	70	-1.980	0.6153
Grazing Control - Standing Experiment	-17.8	8.96	70	-1.980	0.6153
Grazing Control - Walking Experiment	-17.8	8.96	70	-1.980	0.6153
Grazing Control - Running Experiment	-17.8	8.96	70	-1.980	0.6153
Standing Control - Walking Control	0.0	8.96	70	0.000	1.0000
Standing Control - Running Control	0.0	8.96	70	0.000	1.0000
Standing Control - Lying Experiment	-17.8	8.96	70	-1.980	0.6153
Standing Control - Grazing Experiment	-17.8	8.96	70	-1.980	0.6153
Standing Control - Standing Experiment	-17.8	8.96	70	-1.980	0.6153
Standing Control - Walking Experiment	-17.8	8.96	70	-1.980	0.6153
Standing Control - Running Experiment	-17.8	8.96	70	-1.980	0.6153
Walking Control - Running Control	0.0	8.96	70	0.000	1.0000
Walking Control - Lying Experiment	-17.8	8.96	70	-1.980	0.6153
Walking Control - Grazing Experiment	-17.8	8.96	70	-1.980	0.6153
Walking Control - Standing Experiment	-17.8	8.96	70	-1.980	0.6153
Walking Control - Walking Experiment	-17.8	8.96	70	-1.980	0.6153
Walking Control - Running Experiment	-17.8	8.96	70	-1.980	0.6153
Running Control - Lying Experiment	-17.8	8.96	70	-1.980	0.6153
Running Control - Grazing Experiment	-17.8	8.96	70	-1.980	0.6153
Running Control - Standing Experiment	-17.8	8.96	70	-1.980	0.6153
Running Control - Walking Experiment	-17.8	8.96	70	-1.980	0.6153
Running Control - Running Experiment	-17.8	8.96	70	-1.980	0.6153
Lying Experiment - Grazing Experiment	0.0	8.96	70	0.000	1.0000
Lying Experiment - Standing Experiment	0.0	8.96	70	0.000	1.0000
Lying Experiment - Walking Experiment	0.0	8.96	70	0.000	1.0000
Lying Experiment - Running Experiment	0.0	8.96	70	0.000	1.0000
Grazing Experiment - Standing Experiment	0.0	8.96	70	0.000	1.0000
Grazing Experiment - Walking Experiment	0.0	8.96	70	0.000	1.0000
Grazing Experiment - Running Experiment	0.0	8.96	70	0.000	1.0000

Standing Experiment - Walking Experiment	0.0	8.96	70	0.000	1.0000
Standing Experiment - Running Experiment	0.0	8.96	70	0.000	1.0000
Walking Experiment - Running Experiment	0.0	8.96	70	0.000	1.0000

Appendix I

Table I1: The noise analysis in Grovfjord

The negative estimate indicates a negative trend; vigilance slightly decreases when the noise level increases. P-value is more than 0.05, so the result is not significant.

	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	31.7854	13.6062	2.336	0.0208 *
Noise_dB	-0.1401	0.1513	-0.926	0.3557

Table I2: The noise analysis at Tjeldøya

The positive estimate indicates a positive trend; vigilance slightly increases when the noise level increases. P-value is more than 0.05, so the result is not significant.

	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	8.5381	20.0196	0.426	0.672
Noise_dB	0.1508	0.2293	0.657	0.515

Appendix J

Transcript from Rstudio showing the different models that were used in the AIC modeling, comparing overflight direction, group size, season and terrain.

Grovfjord:

```
#---- model selection for Grovfjord; season, groupsize, terrain and direction

names(directEC_G)

m1 <-lm(Timespent~RI*Type*Season+Groupsize+Direction+Terrain,data=directEC_G)
summary(m1)

m2 <-lm(Timespent~RI*Type*Season+Groupsize+Direction,data=directEC_G)
summary(m2)

m3 <-lm(Timespent~RI*Type*Season+Groupsize+Terrain,data=directEC_G)
summary(m3)

m4 <-lm(Timespent~RI*Type*Season+Direction+Terrain,data=directEC_G)
summary(m4)

m5 <-lm(Timespent~RI*Type*Season+Groupsize,data=directEC_G)
summary(m5)

m6 <-lm(Timespent~RI*Type*Season+Terrain,data=directEC_G)
summary(m6)

m7 <-lm(Timespent~RI*Type*Season+Direction,data=directEC_G)
summary(m7)

m8 <-lm(Timespent~RI*Type*Season,data=directEC_G)
summary(m8)

m9 <-lm(Timespent~RI*Type+Season,data=directEC_G)
summary(m9)

m10 <-lm(Timespent~RI+Type+Season,data=directEC_G)
summary(m10)

m11 <-lm(Timespent~RI*Type,data=directEC_G)
summary(m11)
```

```
m12 <-lm(Timespent~RI+Type,data=directEC_G)
summary(m12)

m13 <-lm(Timespent~Type,data=directEC_G)
summary(m13)

m14 <-lm(Timespent~RI,data=directEC_G)
summary(m14)

m15 <-lm(Timespent~1,data=directEC_G)
summary(m15)

AIC(m1,m2,m3,m4,m5,m6,m7,m8,m9,m10,m11,m12,m13,m14,m15)


## conclusion: modell 11 is the best (see Appendix K, Table K1)
m11 <-lm(Timespent~RI*Type,data=directEC_G)
summary(m11)


library(emmeans)
emmeans(m11,pairwise~RI*Type)
```

Tjeldøya:

```
#------ Model selection for Tjeldøya; groupsize, season, direction and terrain

m21 <-lm(Timespent~RI*Type*Season+Groupsize+Direction+Terrain,data=directEC_T)
summary(m21)

m22 <-lm(Timespent~RI*Type*Season+Groupsize+Direction,data=directEC_T)
summary(m22)

m23 <-lm(Timespent~RI*Type*Season+Groupsize+Terrain,data=directEC_T)
summary(m23)

m24 <-lm(Timespent~RI*Type*Season+Direction+Terrain,data=directEC_T)
summary(m24)
```

```
m25 <-lm(Timespent~RI*Type*Season+Groupsize,data=directEC_T)
summary(m25)

m26 <-lm(Timespent~RI*Type*Season+Terrain,data=directEC_T)
summary(m26)

m27 <-lm(Timespent~RI*Type*Season+Direction,data=directEC_T)
summary(m27)

m28 <-lm(Timespent~RI*Type*Season,data=directEC_T)
summary(m28)

m29 <-lm(Timespent~RI*Type+Season,data=directEC_T)
summary(m29)

m30 <-lm(Timespent~RI+Type+Season,data=directEC_T)
summary(m30)

m31 <-lm(Timespent~RI*Type,data=directEC_T)
summary(m31)

m32 <-lm(Timespent~RI+Type,data=directEC_T)
summary(m32)

m33 <-lm(Timespent~Type,data=directEC_T)
summary(m33)

m34 <-lm(Timespent~RI,data=directEC_T)
summary(m34)

m35 <-lm(Timespent~1,data=directEC_T)
summary(m35)


AIC(m21,m22,m23,m24,m25,m26,m27,m28,m29,m30,m31,m32,m33,m34,m35)


## conclusion: modell 31 is the best (see Appendix K, Table K2)
m31 <-lm(Timespent~RI*Type,data=directEC_T)
summary(m31)
```

Appendix K

Table K1: Terrain, direction, group size and season

The AIC for 15 models, some including the terrain,- direction,- season,- and group size data, and some not including them, in Grovfjord.

	df	AIC
m1	24	2639.213
m2	23	2637.216
m3	23	2637.213
m4	23	2637.214
m5	22	2635.216
m6	22	2635.214
m7	22	2635.217
m8	21	2633.217
m9	12	2626.962
m10	8	2642.423
m11	11	2624.968
m12	7	2640.429
m13	3	2675.821
m14	6	2638.436
m15	2	2673.827

Table K2: Terrain, direction, group size and season

The AIC of the same models as above, but at Tjeldøya.

	df	AIC
m21	15	706.8358
m22	14	704.8388
m23	14	704.8380
m24	14	704.8358
m25	13	702.8407
m26	13	702.8384
m27	13	702.8389

m28	12	700.8413
m29	12	700.8413
m30	8	704.1787
m31	11	698.8477
m32	7	702.1814
m33	3	712.2232
m34	6	700.1839
m35	2	710.2252

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