Identifying the “scaring away” pattern of wild boars from GPS trajectories in the Swiss Plateau

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Background and research goal

Wild boar (*Sus scrofa*) populations are currently spreading rapidly throughout Switzerland (Massei *et al.*, 2015). From an ecological point of view, this is a positive development, as native wild boars were almost eradicated in the 19th century. However, controversies are also returning with the wild boars. Wildlife damage is a major conflict between wildlife agencies and landowners (Gilsdorf *et al.*, 2003). Every day, a wild boar rummages through around 120 m^2 of forest, meadow or arable land in search of food and can cause substantial damage to agricultural crops (Keuling *et al.*, 2016). Wildlife depredation describes the damage to property caused by wildlife, which leads to economic loss to the owner (Gilsdorf *et al.*, 2003).

There are various approaches to keeping wild boar off agricultural land, such as electric fences and deterrent shooting (Suter & Eyholzer, 2010). However, the previous scaring devices are costly and time-consuming and can often not be used in nature conservation areas and hunting reserves. Based on the knowledge that the sense of hearing of wild boar plays an important role in the detection of enemies and consequently their flight behaviour (WSL, 2021), the Wildlife Management Research Group (WILMA) of the ZHAW tested an acoustic approach. They tracked several wild boars in the Swiss Plateau with GPS collars to test the effect of acoustic scare devices on specific crop fields. If an animal is startled by something, it has to choose between fight or flight, and wild boars often flee (Thurfjell, 2011).The effectiveness of the deterrence methods is determined based on the spatial movement pattern of the wild boars and not on the damage caused to arable crops. We would like to follow up on this research and use the collected WILMA data to analyse the effect of scare devices with the following research question:

- Can the movement pattern "scaring away" be derived from trajectories of wild boars exposed to scare devices?
- What is the noise exposure at which a wild boar scare was detected?
- How long do the scared wild boars stay away from the scaring site?

Methods

Study area and data

Data for our analysis were collected in the Canton of Bern (Fanel and Hagneck) and in the Canton of Fribourg (Cheyres) between 2014 and 2016. A total of 20 wild boar scare devices were placed at different locations and active during different time periods (Fig.1).

The devices played random sound combinations, composed of species-specific warning sounds, human voices or gunshots, in an interval of 10 to 20 minutes with a variability of about 40%. The scare devices are turned on and off by an integrated light sensor, activated by a sun position of approximately 6°. Since the weather can influence brightness and therefore the light sensor, we did not have the exact on and off times. We therefore assumed for our analyses that the "wild boar scare devices" were active at night from the beginning of dusk until the end of dawn.

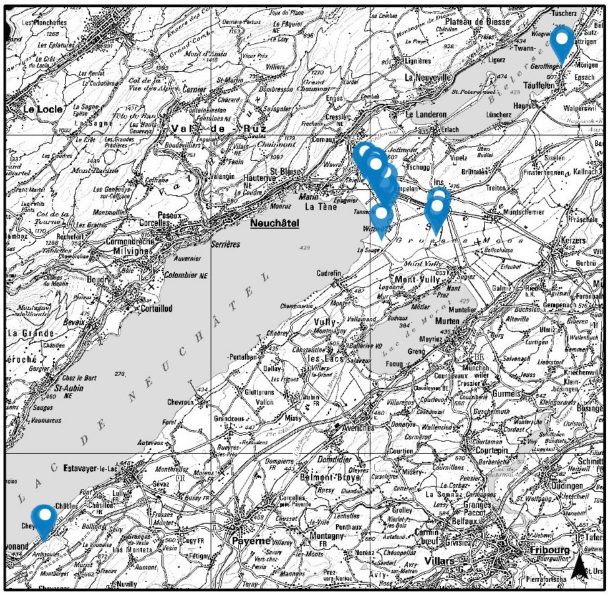

Fig. 1. Study area and scare devices (blue).

During the same time period, the movement patterns of 19 individual wild boars were recorded, by using GPS collars that transmitted their location every 15 min. Figure 2 gives an overview of the temporal distribution of the available movement data for each individual.

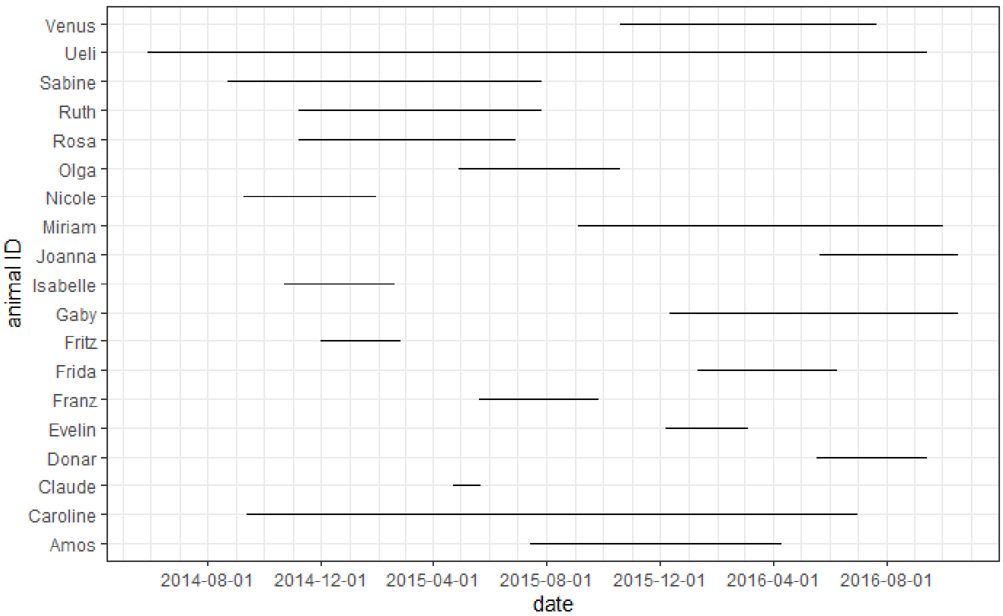

Fig. 2. Temporal trajectory of all observed wild boars over the period 2014 to 2016.

In order to detect all encounters between tracked wild boars and active scare devices, the nearest active scare device was calculated for each wild boar timestamp using the Euclidean distance. Encounters, during which the wild boar came into close proximity to the scaring device (fewer than 400m) at a time the device was active, were categorized as trips. If there were missing gps data during the time of interest (between 18:00 and 09:45am) the trip was removed from the data.

Scaring away rate

This section describes our approach to analyse whether wild boars are scared away by the scaring devices and aims to identify each flight by its scaring pattern. A basic assumption of the work is that frightened animals record a fundamentally different movement after being frightened than before. Different variables were used to analyse whether the movements of wild boars were affected by a scaring device. All variables were standardized to values from 0 to 1 within a trip with the formula below.

$$standvar = \frac{var - min(var)}{max(var) - min(var)}$$

Hodges *et al.* (2014) analyzed the movement of fleeing hares and found that fleeing hares moved faster and straighter. To detect fast movement we included acceleration and average speed difference. Further, to tackle straight fleeing we calculated the sinuosity of the trajectory. Finally, we have to include operators considering the spatial relationship of the wild boar movement in relation to the scare device. We used a simple operator defining the proximity to the scare device and another operator containing information about the relative approaching rate of the wild boar to the scare device.

Proximity to scare device

The first variable used in the scare away pattern is the proximity to the scare device. For each GPS point the Euclidean distance to the scare device was calculated. It is assumed that the closer the wild boar is in relation to the scare device, the greater the probability that it will be scared off. Therefore, for identifying a potential scare effect small values are of interest.

$$Proximity = \sqrt{(w_x - s_x)^2 + (w_y - s_y)^2}$$

w: wild boar locations: scare device location

x: x-coordinate y: y-coordinate

Sinuosity

The term sinousity describes the windingness of a trajectory (Laube et al., 2007). Since sinuosity is usually calculated based on equal step sizes, the trajectories were transformed and then the sinuosity calculated with the “trajr” package. The sinuosity at each wild boar location is generated based on a trajectory of 4 points, the current point and the upcoming three point locations. The future 3 locations were taken because it is assumed that from the scare moment on the future trajectory is influenced. Low sinuosity values represent a straight trajectory while high values represent a winding trajectory. As a result, small sinuosity values should show the scare effect.

Standardised approaching rate

Laube et al. (2007) define the approaching rate as a measure that shows how intensively the moving object approaches or moves away from a target object. In our approach we used the standardised approaching rate, which expresses the fraction of the distance of the moving object travelled towards the target object and the total distance travelled during that interval, which was proposed by Laube et al. (2007). For each GPS point the approaching rate was calculated based on the current GPS location t and the location at time t+1. Therefore, the future standardised approaching rate was used in this project. High values represent a strong approachment, while low values represent a strong moving away from the target object. Since it is expected that frightened wild boars move away from the scare site, low values are interesting for the "scare-away" effect.

$$Approaching\ rate = \frac{p_{t0} - p_{t+1}}{\sqrt{(w_{x,t0} - w_{x,t+1})^2 + (w_{y,t0} - w_{y,t+1})^2}}$$

p: proximity w: wild boar location

x: x-coordinate y: y-coordinate

t: element at time

Average speed difference

In order to be sure that the rapid straight-line escape of the wild boar is due to the scaring, the change in average velocity should be included. First the speed at each GPS point was calculated by the distance to the previous point divided by the elapsed time. Then, the difference between the mean of the current and the two future speeds and the mean of the three previous speeds was calculated. Therefore, this variable shows the difference of the speed between two 45 minutes intervals, one representing the past and the other one the future speed. High values indicate a potential scare away effect, because it shows a shift from slow to high movement speed on a coarse time window.

$$Speed = \frac{\sqrt{(w_{x,t0} - w_{x,t-1})^2 + (w_{y,t0} - w_{y,t-1})^2}}{t_{t0} - t_{t-1}}$$

p: proximity w: wild boar location

x: x-coordinate y: y-coordinate

t: element at time

$$Average\ speed\ difference = \frac{(v_{t0} + v_{t+1} + v_{t+2}) - (v_{t-1} + v_{t-2} + v_{t-3})}{3}$$

v: speed t: element at time

Acceleration

Acceleration describes a rate of change of an object's velocity with respect to time. A simple computation of instantaneous acceleration examines the change of speed of two consecutive steps (Laube et al., 2007). Hereby, the difference of the speed at point t1 and t0 was calculated and divided by the elapsed time. High values represent an increase of speed at the current GPS point, which indicates a potential scare-effect. This is based on the assumption that the wild boar is searching for food with a low velocity and is moving away after the scare effect with a high velocity which results in a high acceleration at the location.

$$Acceleration = \frac{v_{t+1} - v_{t0}}{d_{t+1} - d_{t0}}$$

v: speed t: element at time

d: time

Identify scare-effect

By combining the five movement lifeline-context operators the scare away movement pattern can be defined. Each of the above mentioned operators was standardized from 0 to 1. The scare-effect is the sum of the above-mentioned operators by considering their positive or negative influence on the scaring away effect and is shown in the formula below. Scare effect values can theoretically vary from -3 to + 2, whereas high values indicate a higher probability of a scare away effect. Finally, a threshold has to be used to identify the GPS locations in which the wild boar was scared away by the scaring device. All locations with a scare-effect value higher than 1.4 were marked as “scaring away”. This threshold was taken based on visual interpretation of the results and should be looked at further in future studies. Appart of the scare device location no specific scare device data was included into the 'scare away' movement pattern, so that the movement pattern can be used in other application examples.

$$Scare\ effect = a + v - r - s - p$$

a: acceleration
v: average speed difference
s: sinuosity
r: standardised approaching rate
p: proximity to scare device

Scare device noise exposure at wild boar locations

To further improve the results the volume with which the wild boar perceives the noise emitted by the scare device was calculated alternatively. Due the scope of the project a simple formula was used to estimate the sound volume at a specific wild boar location. All data points at day time are assigned with the volume of -20dB, to indicate that it is not possible to have a sound effect. Further, the mean angle of the scare device was calculated based on the minimal and maximal orientation angle of the device. Then, the orientation of the device was classified into the four celestial directions based on the mean angle. After that the celestial directions of the wild boar locations in relation to the scare device was

calculated. Then, the directional volume was assigned based on a simple formula, if the speaker direction is the same as the wild boar direction (such as North and North), the speaker volume in direction at distance 1m is equal to the base volume. If speaker direction and the wild boar direction are neighboring cardinal points (such as North and East), the speaker volume in direction is set to 75% of the base volume (- 5dB). If the speaker direction and the wild boar direction are opposite cardinal points (such as North and South), the speaker volume in direction is set to 50% of the base volume (-10dB).
Using the thus defined directional volume at one meter distance, can be further used to determine the loudness at the wild boar location. Herby, the formula below was used, which takes as a baseline a volume decrease of 6 dB when the distance doubles (Tontechnick Rechner, 2021).

$$Volume\ at\ Location\ =\ L\ -\ |\ 20\ \cdot\ log(\frac{1}{1.581\cdot s})$$

L: speaker volume s: distance

Effect on return time

The duration of the scaring effects is an important criterion in the evaluation of scaring measures. The longer the effect lasts, the less damage to the scaring site can be expected. Additionally, we assumed that a higher scaring effect rate leads to a longer stay away from the scaring site (for each trip we used the maximal ‘scaring away’ effect). We calculated the time it took each animal to return to within 400m of a scaring device after the end of a trip and compared whether the number differed between trips, in which wild boars were scared away or not.

Results

A total of 113 unique trips from different wild boars were detected, which could possibly be scared away due to their location and time in relation to the scaring device. Only 70 trips from four wild boars (Olga, Ruth, Sabine and Ueli) matched our trip duration (15.75h) and contained the right amount of GPS points (#63) with the same sampling interval (15min). In 25 unique trips a scaring away effect was identified based on the movement pattern, which is roughly one third of the potential trips. Out of these trips 22 showed high enough noise exposition introduced by the scaring device to define a potential influence.

In the following sections we present some results of identified scare effects based on the "scare-away" movement pattern. A good example of a wild boar trip that was potentially frightened by a scaring device is that of the wild boar Sabine on June 9th, 2015, which is presented in more detail in the following pictures. Figure 3 shows the whole trajectory of the wild boar from 6 p.m. to 9.45 a.m of the next day. The black point represents the location of the scare device and the red point indicates the detected 'scare away' effect.

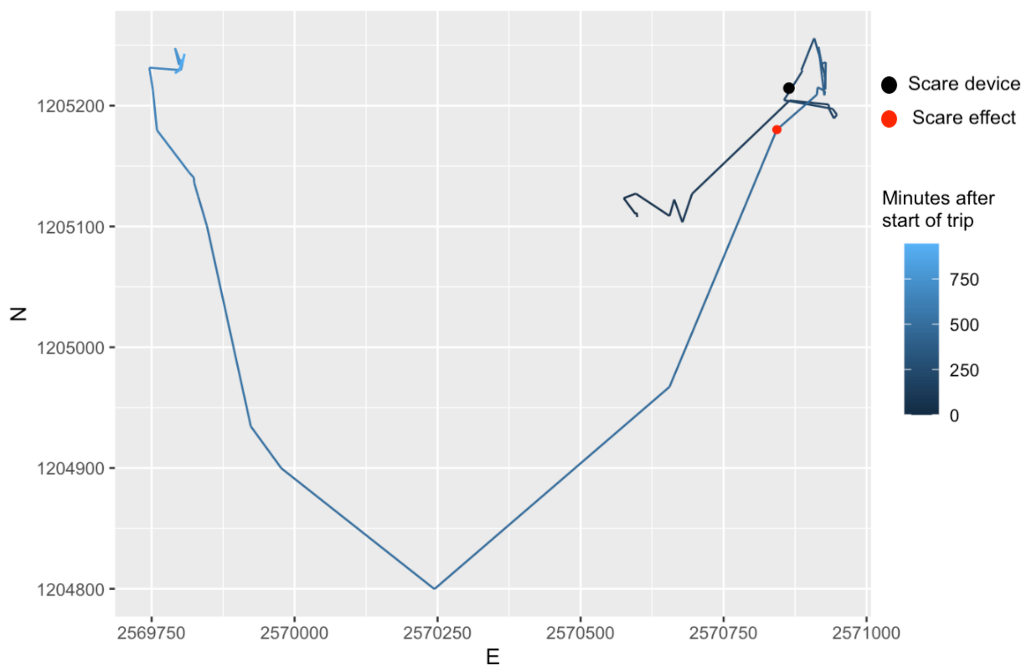

Fig 3. Wild boar trip of Sabine at 09.06.2015 with a detected scare effect from 6 p.m. to 9.45 a.m.

Figure 4 shows the five movement lifeline-context operators which were scaled from 0 to 1, whereas acceleration and speed difference are expected to be close to 1 and the approaching rate, sinuosity and distance are expected to be close to 0, so that a scare effect can occur. After the wild boar was moving slowly with a high sinuosity in close proximity to the scare device for some time, suddenly a fast increase of speed and an instant straight moving away from the scare device was observed, which therefore was identified as a scare effect. Figure 5 and 6 show the movement behaviour from one hour before to one hour after the scare effect, in which a change of the movement behaviour before and after the 'scare away' effect can be observed clearly.

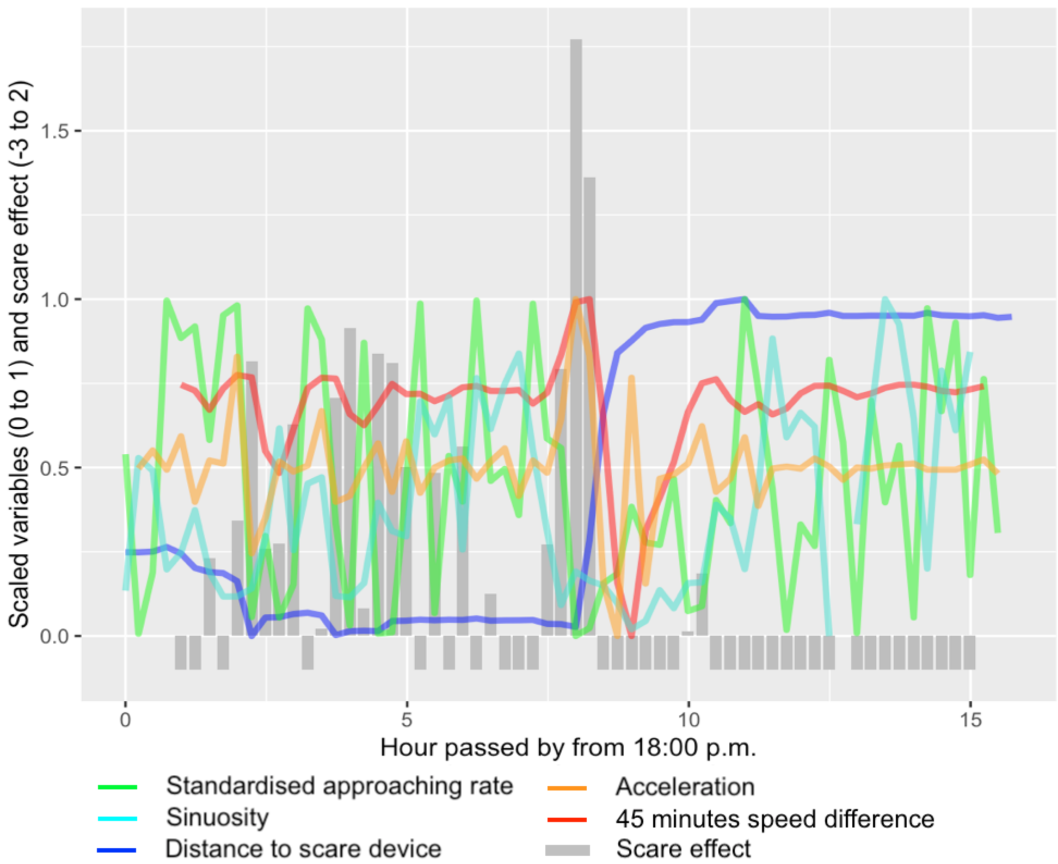

Fig 4. Scaled operators and the scare effect (grey) during the trip of Sabine from 09.06.2015 at 6 p.m. to 10.06.2015 at 4 a.m.

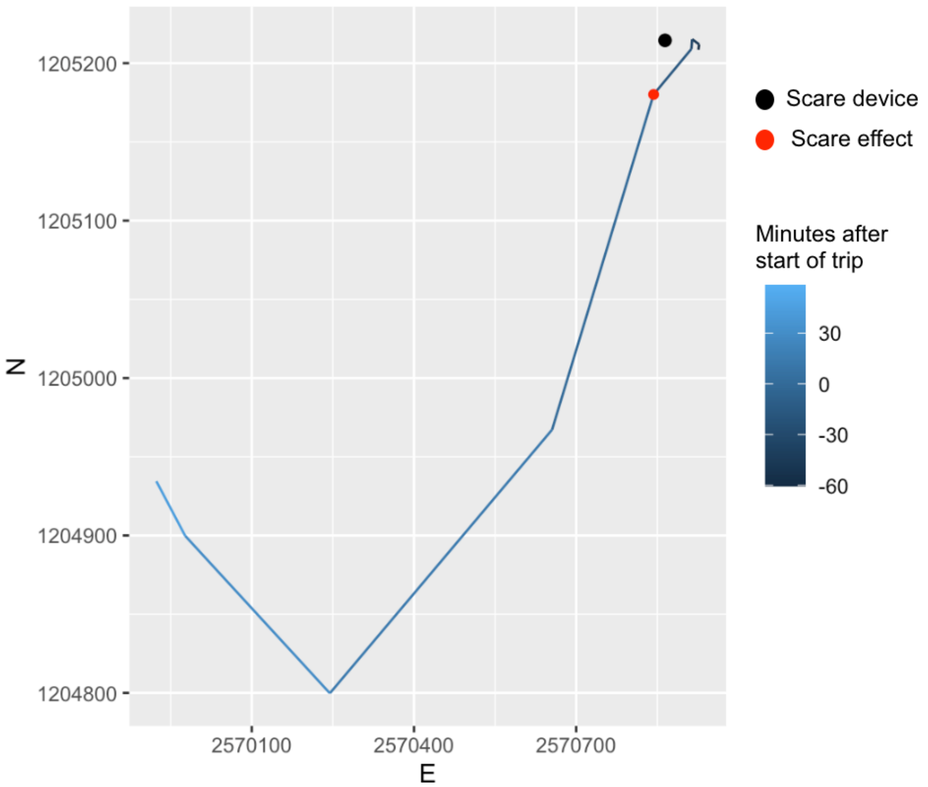

Fig 5. Wild boar trip of Sabine from 1h before to 1 after the detected scare effect.Scaled operators and the scare effect (grey) in the early morning of the 10.06.2015.

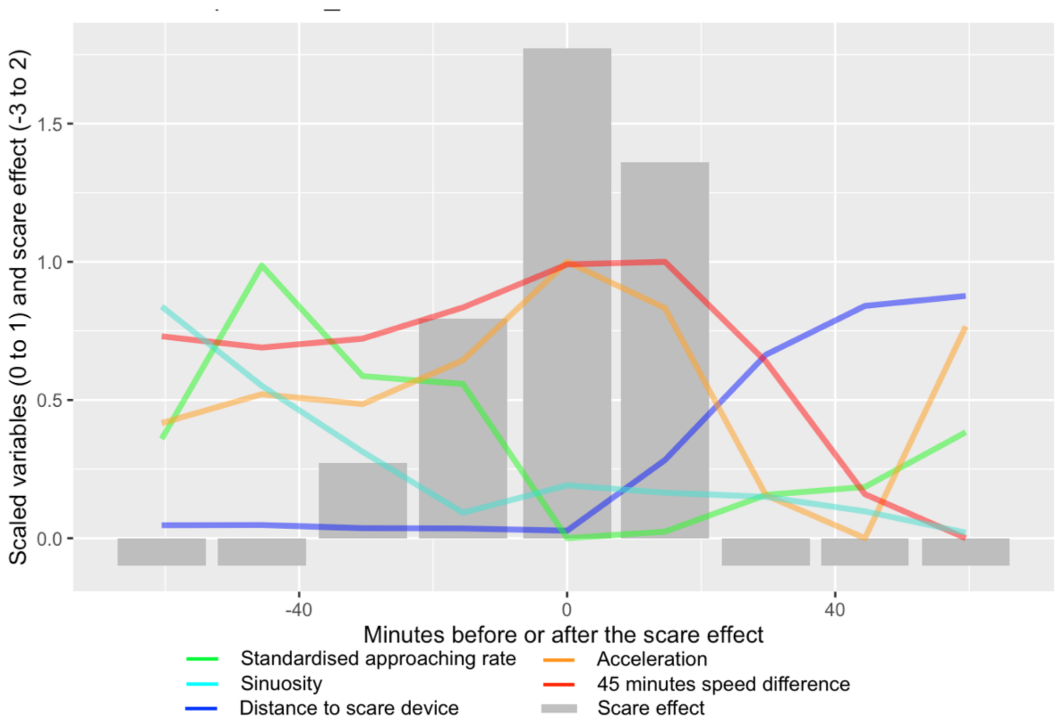

Fig 6. Scaled operators and the scare effect (grey) during the trip of Sabine the early morning of the 10.06.2015 from one hour before to one hour after the detected scare effect.

Figure 7 shows the scare effect determined by the movement pattern in relation to the volume at the wild boar location calculated by the distance, orientation and volume of the scare device in comparison to the location of the wild boar. Data points with high values of noise exposure and a 'scare away' effect have a high probability of a flewing behaviour introduced by the scare devices' sound effect. Since the temporal resolution of the wild boar tracking data is rather coarse, the volume of the scaring noise should only be viewed as a reference value. Therefore, we set 10 dB noise exposition as an additional threshold to exclude 'scare away' effects which are non related to the scare device because of too little influence of the scare device. Although a wild boar should not be scared by noise around 10 dB, we did not set this threshold higher, due to the low temporal resolution of the data, because the wild boar could have been closer between two consecutive data points. Due to this additional threshold 22 of 25 trips identified with a 'scaring away' effect are selected as the final result.

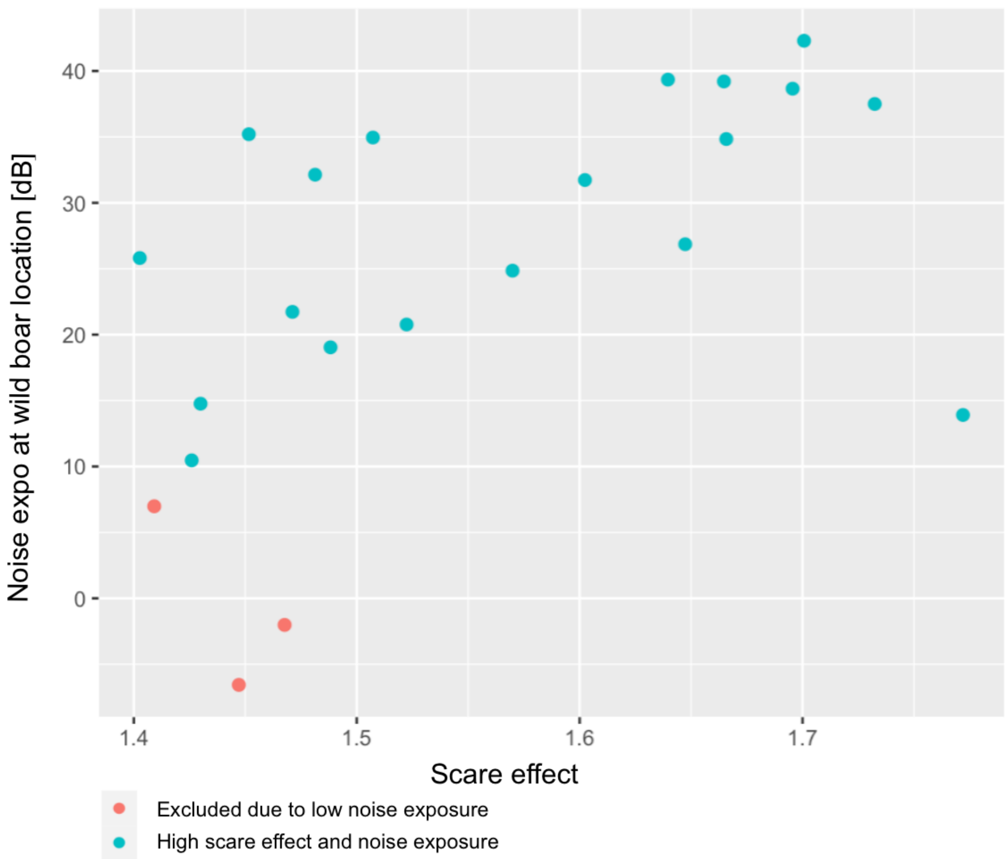

Fig. 7. Noise exposure of detected 'scare away' effects of wild boar trips.

Figure 8 summarizes our findings within this project in relation to different animals. For the wild boar named Olga 28 trips were found in which the animal was closer than 400 meters to a turned on scaring device. Out of these 28 trips at 18 trips the animal was at least once exposed to a scare noise volume of more than 20 dB, we extended the exposed sound volume to 20dB because it was calculated for the whole trip. Further, in 11 trips a 'scare away' effect of the movement behavior was found, in which 8 trips showed a 'scare away' effect and a high noise exposition. In the case of the wild boar Sabine, about 80% of the trips had a high noise exposure introduced by the scare device and one third had a 'scare away' effect and high noise exposure. Therefore, the scare device worked in terms of scaring away the wild boars Sabine and Olga at least in a short-term effect.

On the other hand, the wild boar Ueli was never exposed to high noise levels and no 'scare away' effect was detected. Either, the wild boar was just by randomness not going close to the scare device or the wild boar was not even accessing the area of high noise exposition because of the scaring device. Which would therefore mean that the device had no effect in scaring away but more over an effect of keeping away.

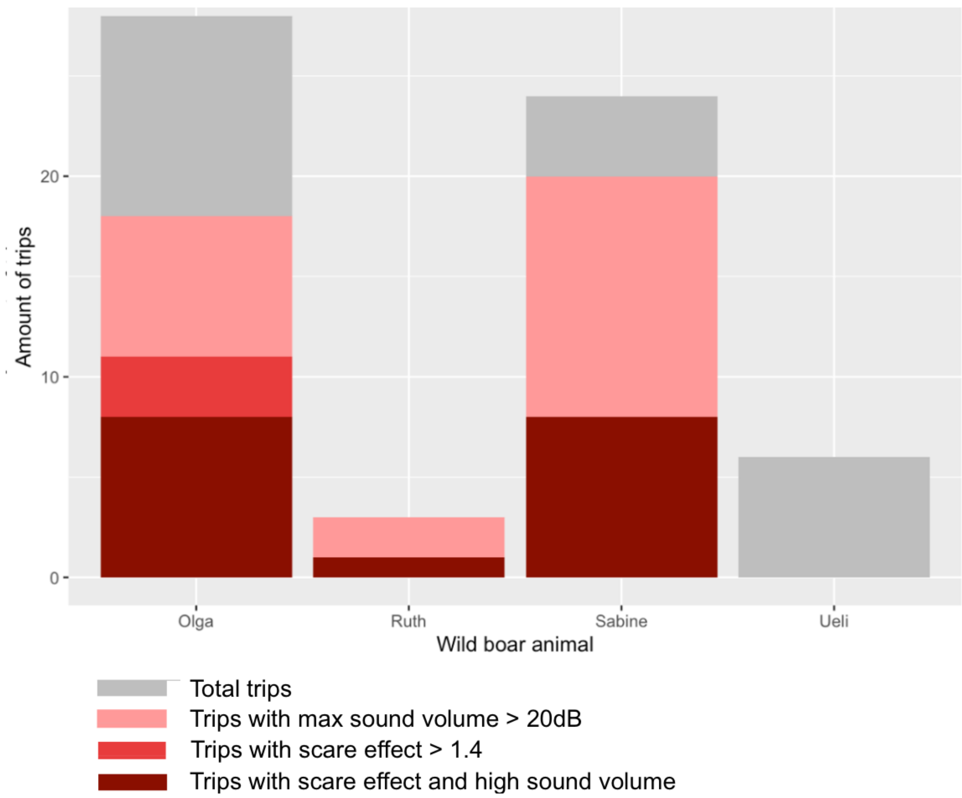

Fig 8. Trips in close proximity to a scare device and detected 'scare away' effects and noise exposition.

In a last step we analysed the effect a scare had on the return time of individuals to that specific scare. We calculated the mean (± SE) time in hours It took each animal to return to within 400m of the scare device after the end of the trip (see Fig. 9).

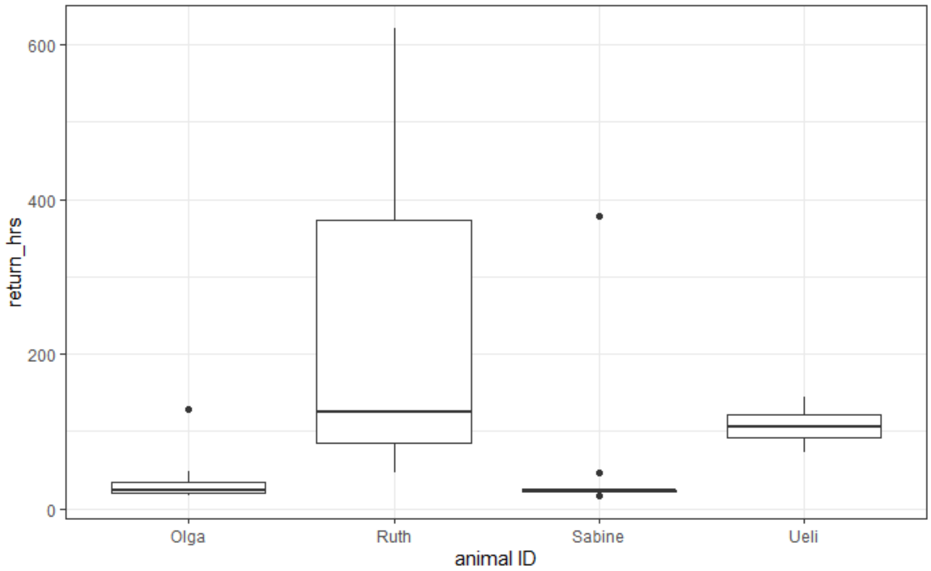

Fig 9. Shown is the mean (± SE) time [hours] until four individual wild boars returned within 400m of the scare device.

Animals that showed a scare effect did not return significantly later to within 400m of the scare effect (Wilcoxon rank sum test; W = 490, p-value = 0.57). The very small number of trips in which a scaring effect could be observed has to be noted and could explain why we did not observe a difference. We furthermore did not control for pseudo replication i.e. the fact that several trips from each animal were included in the analysis. A linear mixed model accounting for this (by using animal ID as a random effect) revealed similarly no significant difference between trips with or without a scare effect (Fig. 10). The residuals of the model, however, violated the assumptions of normality, which is why we decided to use the Wilcoxon rank sum test instead (see above).

After trips during which animals were not scared away, they return on average after 61.61 (SE=10.25) hours to within 400m of the scare device. The average return time for animals which were scared away is 27.35 (SE 3.13).

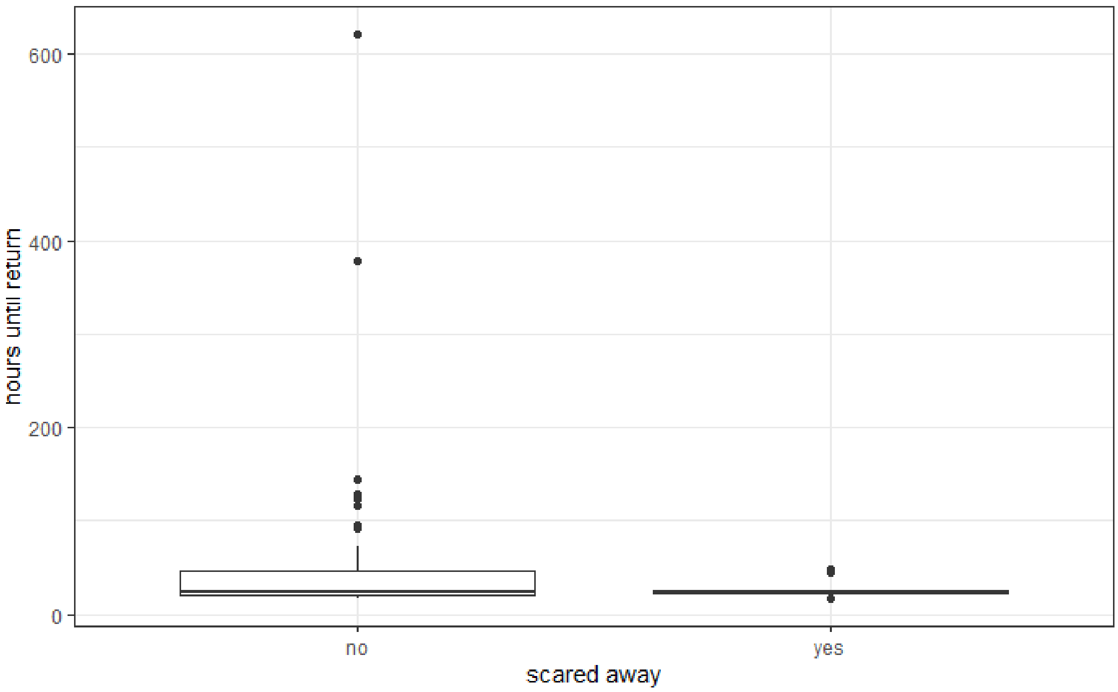

Fig 10. Boxplot showing the return time [hours] to within 400m of the scare device for trips during which a scare effect could be observed (TRUE) or not (FALSE). Black solid lines represent the median, while the limit of the box illustrate the first and third quartile of the raw data.

The standardized scare effect did also not correlate with the amount of time [hrs] it took animals to return to within 400m of the scaring device (spearman correlation test; rho -0.075, S= 49177, p-value = 0.55), see Fig. 11.

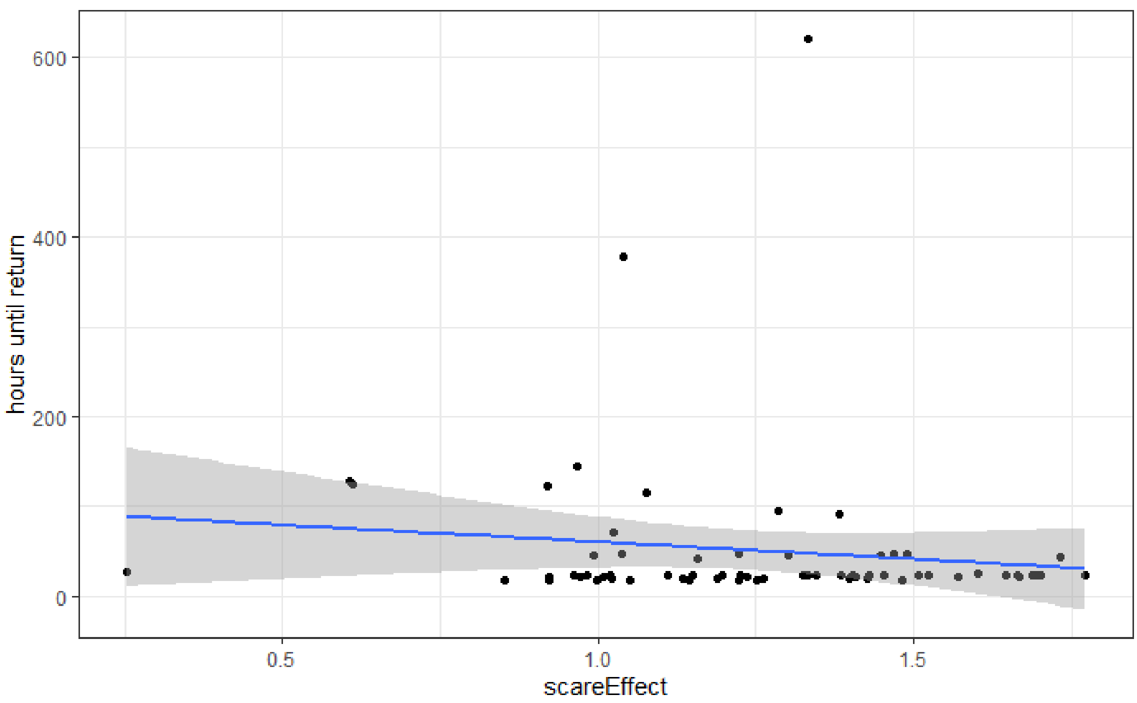

Fig 11. Correlation between the standardized 'scaring away' effect and the return time [6].

Discussion

In this project, a 'scare away' movement pattern was presented that can be used to evaluate acoustic scare devices. In general, few systematic definitions of movement patterns can be found in the literature (Dodge *et al.*, 2008). For the pattern 'scaring away', we could not find any comparative study that could be directly applied to wild boars. However, fleeing hares showed a faster and straighter movement (Hodges *et al.*, 2014), which was used to define the ‘scaring away’ movement pattern. As for calculating the scaring rate, we were oriented towards the work of Laube et al. (2007), who presented different movement lifeline-context operators. We implemented those operators who were fitting to our project scope. We used average speed difference and acceleration as operators to represent fast movement, sinuosity as operators identifying straight movement. Further proximity and approaching rater were used to include spatial information of the movement in relation to the scare device. The combination of these standardised operators represents the ‘scaring away’ movement pattern and contains a numeric value, indicating how strongly wild boar reacted to acoustic scare devices. Through visual interpretation we set a threshold of 1.4 for the ‘scaring away’ rate, whereas wild boar tracking points with a higher value were detected as potential ‘scare away’. This threshold is one limitation of the presented findings and should be further improved in future study to get best results in terms of finding ‘scare away’ effects.

70 twelve-hour trips were detected in which the respective wild animal was at least one time closer than 400 meters to an activated scare device. By applying the ‘scare away’ movement pattern 22 trips with a scare effect potentially triggered by the scare device were identified. Therefore, the scaring devices worked at least in some cases to ‘scare away’ a wild boar. However, a major limitation of our analyses was the fact that the exact time when the scaring devices emitted sounds (in between dusk and dawn) were not known. This meant that the exact timing of the "scaring away" could not be determined, we could only identify the windows, in which the scare devices were active and they might have scared away the near wild boars. Furthermore, the trajectories of the wild boars were based on GPS timestamps at an interval of every 15 minutes, which also leaves a lot of room for movement in between. Even if a "scaring away' effect is identified near an active scare device, we cannot be absolutely sure that the animal was not scared away by another event during these 15 minutes. Which is why we have found that for further analyses of the "scaring away" movement pattern, exact times of the sound emissions of the scaring devices are needed.

Equally relevant would be to investigate the "scaring rate" on additional individuals, as in our analysis only four individuals could be analysed, since no tracking data of other wild boars in close proximity to a turned on scare device was available. It would have been desirable to apply the 'scare away' movement pattern to a control group, e.g. the same animals at times when the scare devices were not active. Unfortunately, it was not possible for us to pursue this approach further within the framework of this semester work. We were only able to make comparisons between scared and non-scared individuals in the partial analysis of the wild boars' return times to the location. However, no significant difference could be found and due to the small sample size the results have to be taken with caution.

Furthermore, it should be taken into account that wild boar are extremely intelligent and adaptable (WLS, 2021), repeated encounters with scare devices without consequences could therefore result in a learning effect. Alternatively, it might be that the scaring device deter wild boars from even approaching them, which would be a success when it comes to deterring the animals, but mean that the effect could not be picked up by only analyzing the scare away patterns.

Literature

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