Knufinke et al. "Temporal patterns of humans and ungulates at bridges – Co-existence or disturbance?"

Appendix 1 – Material and Methods

This an appendix to Knufinke, Helldin, Bhardwaj, Olsson: Temporal patterns of humans and ungulates at bridges – Co-existence or disturbance? In this appendix the results are described more in detail. This appendix includes further diagrams that are not included in the main report.

The monitored structures

The data that was analysed in the following report was collected as part of the TRIEKOL III project and none of the cameras was set up to specifically answer the questions that are part of this report. The data collection (photo trapping) took place in and around the following bridges in northern Sweden in the county of Norrbotten:

- One reindeer bridge over Haparandabanan railway at Sangijärvi

- Three minor bridges at Haparandabanan railway between Kalix and Haparanda:
  Harrioja: a narrow reindeer bridge over a motorway
  Kåtaträskvägen: a smaller railway bridge over a local road
  Sattaoja: a larger railway bridge/viaduct over a stream and a local road

- One reindeer bridge over road E10 at Mertainen

To have a small insight into southern Sweden's ungulates use of crossing structure the data gathered at one large underpass designed for large mammals near Borås in Västergötland was included in the analysis.

We analysed the data from the following periods:

Table 1: Summary of the surveillance periods of the structures

Bridge	Surveillance period	Periods that were excluded from the analysis
Harrioja	13.11.2018 - 11.05.2019	
Mertainen	15.11.2018 – 14.05.2019	
Sattaoja	14.11.2018 – 11.05.2019	
Sangijärvi	18.11.2018 - 11.05.2019	
Kåtaträskvägen	04.01.2019 – 11.05.2019	15.11.2018 - 03.01.2019
Borås	18.12.2018 - 30.07.2019	

We excluded the 15.11.2018 - 03.01.2019 period at Kåtaträskvägen from the analysis, because several cameras at the site were not fully functional due to errors in the timestamp.

We assumed that the general unknown malfunction and missed individuals due to the delay timer was the same error in humans and animals. In some parts of the following analysis the structures in Norrbotten (Sangijärvi, Harrioja, Kåtaträskvägen, Sattaoja and Mertainen) were analysed together despite their different design, construction method and purpose, as we suspected their other influencing factors to be similar. This enabled us to make a more profound analysis of the data.

Trail cameras

We used trail cameras produced by Browning (camera model: Spec Ops Advantage) in Norrbotten and trail cameras produced by Reconyx (Camera model: PC 900) in southern Sweden at Borås. The cameras were installed to sample the species, number of animals crossing and to reflect animal behaviour while using the area. The cameras were if possible, positioned to monitor the whole area were the animals could cross the structure. This included the crossing path and for structures that reach over a watercourse, also the watercourse. This was especially relevant in winter when the water could be frozen, but also at other times, due to animals swimming through or walking in the water.

The cameras were installed either on trees, on fencepoles of the wildlife mitigation fence or on poles that we set up for this purpose. The maintenance of the cameras was fulfilled every two months to ensure their full function. At every camera maintenance event the memory SD-card was exchanged, or the pictures were downloaded, and the batteries were checked and if necessary exchanged. Furthermore, at every maintenance visit the upcoming vegetation was cleared if these plants could mask an animal or trigger the cameras due to movements in the wind.

The relevant settings of the Browning trail cameras were set as in Table 3. We use central European wintertime (UTC +1) throughout the surveillance period to have a consistent timing.

Table 2: Settings of the trail cameras

Setting	Setting in the beginning of the project	Changed settings in the further process of the project
Operation mode	Trail cam	--
Photo quality	medium	high
Photo delay	5 seconds	--
Multi-shot mode	5-shot-rapidfire	3-shot-rapidfire
Temperature unit	Celsius	--
Camera name	T*number of the camera*	--
Battery type	Lithium (winter period)	Alkaline (summer period)

Analysis of the data

Management of the trail camera pictures and analysis in excel

In the first instance the pictures of all cameras were cleaned from pictures showing only moving vegetation or other maloperations. Furthermore, photographs of humans were also deleted, due to the protection of the privacy of the photographed persons or their vehicles. This human use was registered in a Microsoft Excel file with information regarding the date, time and length of the disturbance. Additionally, we differentiated human related use into different categories: person (pedestrian or skier), car, snowmobile, lorry (truck), tractor, motorcycle, bicycle, dog (without a leash and a human), horseback rider, vehicle (undefinable vehicle) or other off-road-vehicle (quadbike). For all those categories we noted the number of individuals and how many dogs accompany them (either on a leash or near its owner). We also noted if this human activity was only taking place due to the camera management, i.e. one or several persons associated with the TRIEKOL project. If a person was arriving with a vehicle and got out of it, we counted this as two separate events, one person and one vehicle event. Possible periods of camera failure were also noted in a excel sheet. If only one of the reference cameras was out of function, we did not exclude this period from the analysis, because we expect the passage camera to record every crossing in the passage. In such a case, we assumed the other cameras to function as sufficient reference cameras.

After that cleaning, we renamed all the pictures to give them a unique identification consisting of the name of the crossing structure, the camera name, the abbreviation of the reference area or passage, the orientation that the camera had and a continuous number. This unique ID enabled us to collect all the pictures taken of one animal or a group of animals in a short time span and to summarize them in one animal event. This enabled us to further analyse the animal's behaviour and the duration of the use.

These animal events were created by collecting all pictures of one animal or one group of animals of the same species that triggered one or several of the same cameras in a short duration of time (<10 minutes) and behaved similar. The animals that did not behave similar where separated into two events. Differences in the behaviour were stated if one animal was crossing and the other was not or if one stayed in the sensitive area of the cameras and the other animal did not. If the animals triggered the cameras in a timespan longer than 10 minutes but were continuously recorded at least on one of the cameras, it was counted as one event. If animals appeared on the cameras multiple times but were not seen again for at least 10 minutes in between of those occasions, we divided them into two events. Individual signs, such as special fur patterns, antlers structure, collars or other unique features, were used to help defining events. We used these animal and human events in the analyses, rather than number of individual animals or number of humans, vehicles etc., because we compared the overall patterns of the events with that of number and found them similar. Furthermore, we believe events are more robust against variations. Otherwise differences in the number of animals using the structure in one event would gain more weight, influencing the further analysis.

We assumed that the ungulates were captured on all cameras they passed, when moving from one to another camera. However, the obligatory delay timer of the camera can result in missed animals if they are passing the cameras in the delayed timespan until the camera is able to take the next picture. Furthermore, we assumed that only one individual was present

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and detected, if an animal appears on one camera and less than 10 minutes later on another camera.

The animal events were sorted and recorded by their date, time and species. For the occasions with multiple species in one event/on the same pictures, these were saved for both species as separate animal events. In the further analysis this animal events were analysed together, despite the placing of the cameras, as a reference or a passage camera. We decided to clump the data together, because the reference cameras were in the direct surrounding of the passage (<50 meter to the passage itself) and we were able to use a bigger dataset due to this aggregation.

To analyse the animal and human use per month, weekday and hour this information was extracted. For that reason, the relevant columns were automatically copied and presented in the particular format. For each Group (Animals and Humans) and the particular timescale (hour, weekday, month) one pivot table was created. To visualize possible temporal pattern, we used bar plots visualizing the number of animal and human events per hour, weekday and month. To make this possible, we used each timing for both the x-axis and the y-axis values. The independent variable was there representing each different time value, whereas the dependent variable was representing the number of each of these time values, which are equal to a species or human event. The species/human activity was used as the legend/categories. Bar plots were constructed on the basis of these pivot tables. The analysis only covered the use of ungulates even though lagomorphs, carnivores and birds were also recorded using the surrounding and passage itself. Furthermore, since the reference cameras were in relatively close distance to the passage itself and we believed that both the reference area and the passage would be disturbed by human usage in a similar way, we analysed both datasets together. This enabled us to make a more sustained analysis.

We calculated the number of crossings per day of each month and per day at one bridge to get some more comparable values. To calculate the number of days we used the "=Tage" function in Excel. This function calculates the time in between to dates; this means that the first day is counted, the end date is not counted. However, this is no big problem, because the trail cameras were always installed and managed in the mid of the day.

To analyse if human presence in or near the passage influenced the frequency of animal use of the passage, we estimated the timespan between an animal event and the previous event of the same species. We estimated the timespan between an animal event with previous human presence likewise. To estimate this timing an extra column "Date.Time" with the format "DD.MM.YYYY HH:MM" was added by copying the date and time. To estimate this timespan in excel, we produced an extra binary column "Human" with the possible values "yes" and "no". This column simplified the analysis of the different human activities by summarizing them. The activities for the column "Human" were filled in manually. Two extra columns "previous animal use" and "previous human use" were added and we used excel-formulas to estimate the timespan to the foregoing event. The rows were formatted to "[hh]:mm" to be able to show hours higher than 24 hours.
The timespan was estimated using the combined excel formula :
=WENNNV(WENNS(UND($I2 = "Moose"; $J1 ="Yes");$E2-$E1);"")
and
=WENNNV(WENNS(UND($I2 = "Reindeer"; $J1 ="Yes");$E2-$E1);"")
for the column previous human event and
=WENNNV(WENNS(UND($I2 = "Reindeer"; $I1 ="Reindeer");$E2-$E1);"")

and

=WENNNV(WENNS(UND($I2 = "Moose"; $I1 ="Moose");$E2-$E1);"")

for the column with previous animal events.

In this case "I" was used as the species column, "J" as the human column and "E" as the Date.Time column. From these values the Minimum, Maximum, Mean and Variance were calculated via excel formulas (=Min; =Max; =Mittelwert; =Var.P). To test the overall timing, we combined all time to data for each Reindeer and Moose. We used an F-test in Excel to check if the variances were even. Due to the result of the F-test we used a T-test for uneven variances, to compare the means of both groups. Both the F-test and the T-test were calculated via excel formulas.

Data analysis in R

The further statistical analysis of the data was executed in the R-Studio and R-Commander interfaces. Before we started the analysis in R, we added another column in each excel table "Count" with the value one for each row in the excel table. We used this to enable the analysis of animal events and not the number of photographed animals. After adding the count column, we imported the data for each data frame and summarized each timing category (hour, weekday, month).

To analyse the temporal patterns of events we used generalized linear models for the dataset of all Norrbotten structures combined and for each structure separately. We used a generalized linear model to calculate the response of the animals' and humans' events count to the hour, weekday and month in one model for each. The number of animal events was used as a response variable and the time category was used as an explanatory variable.

We used a Poisson-regression, due to the existing count data. We calculated each ungulate species response but summarized all human activities for this analysis. To analyse a possible reaction of the animals' temporal patterns to the human use, we divided the human use into two periods, based on the results of the diurnal human use. The first period was the period of low human use from 21:00 to 08:59 o'clock and high human from 09:00 to 20:59 o'clock. This human use category values were added manually to the existing dataset. The interaction of human use periods and animal temporal pattern was tested with a generalized linear model using an interaction of the animals temporal use and the human use category, with the following formula:

GLM.17 <- glm(All_Moose.Count ~ All_Moose.Human_use_category + All_Moose.Weekday + (All_Moose.Human_use_category * All_Moose.Weekday), family=poisson(log),

  data=All_Moose_Weekday_HumanUse)

As another possibility to explore usage patterns we also used dendrograms. The usage was clustered by combining the time periods with similar number of events. We used the following formula to produce the dendrograms:

plot(hclust(dist(model.matrix(~-1 + Gesamtergebnis, All_Norbotton_Human_Month), method= "manhattan") , method= "ward.D"), labels = Month_11._05., main= "Cluster dendrogram for monthly human events in Norrbotten", xlab= "Number of human events per month", sub="Method=ward; Distance=city-block")