UNIVERSITY OF COPENHAGEN
FACULTY OF SCIENCE

Mapping of grazing cattle using GPS collars

Grazing patterns in relation to habitats in a nature area on the island of Fanø

Mads Østergaard Brun (wzl230)

Nature Management

17/08-2022

Contents

1. Abstract

As a part of a larger study on the implementation of virtual fencing using Nofence© GPS collars for cattle on the island of Fanø, this study aims to analyze the grazing pressure of cattle on different habitats throughout the year, and to establish what might have an impact on the grazing pressure.

Using the positional data collected by the GPS collars, this study use the Graphical Modeler in QGIS to make several heatmaps, that visualize the grazing pressure in certain time frames. By analyzing vector layers derived from the model, an analysis of the presence of the cattle on specific habitats throughout the study period is made. This is compared to landscape and vegetation analysis made in QGIS, and observations from the study area made during a field study on the 1st and 2nd of August 2022.

Heatmaps was made for the full study period, for the period with supplementary feeding, and for the period without supplementary feeding. Furthermore, heatmaps was made for each month of the study period. Landscape analysis including topography analysis and vegetation analysis was also made. Tables describing the vegetation on the study area was made to help characterize the different habitats. Analysis of the observations within the habitats was made, to calculate a ratio of the observations and the habitat area, and to temporally describe the observation within the habitats.

The study found that the grazing pressure on the study site is highly affected by supplementary feeding, the structures in the landscape such as dense forest and ditches, and the layout of the habitats. When the cattle rely on the landscape to find food they use a variety of habitats, both nutrient rich meadows and salt marshes but also the nutrient poor dune-heath.

2. Introduction

Large herbivores as a conservation tool, have been used to increase biodiversity for many years, (Buttenschøn 2021; Rosenthal et al.2012). In recent years, there has been an increased awareness of the benefits of large grazers in large areas, and concepts such as rewilding has been proposed as a solution to the ongoing decline in biodiversity (Fløjgaard et al. 2021). The introduction of large grazers, however, imposes the need for physical fencing, which is both expensive in establishment and maintenance, while also being inflexible if for example the need for excluding an environmentally sensitive area or a need for a change in grazing pressure should arise. Physical fencing can also be problematic for the movement of wildlife such as deer (McKILLOP 2008). Various iterations of virtual fencing have been proposed as a solution to this problem.

Virtual fencing works by establishing an invisible virtual fence, which is made apparent to the grazers by auditory warnings and low energy electric impulses. These auditory warnings and electric impulses are administered by a collar, which also houses a GPS unit, along with batteries and small solar panels. The use of GPS to track the grazers, presents an opportunity to analyze the movements of the grazers, which can then be related to the landscape and to vegetation analyzes. The aim of this study is to analyze the grazing pressure of cattle on the different habitats throughout the year, and to establish what might have an impact on the grazing pressure.

3. Methods

3.1 Study area and context

This study took place on the central east coast of the island of Fanø, which is situated in the northern part of the Wadden Sea in the southwestern part of Denmark (Figure 1). The study area for this project is 51,5 hectare, and consists of salt marsh along the coast and a mosaic of dune-heath with grass- and heathland vegetation, improved grassland, meadows, bogs and small areas with deciduous and coniferous forest (Table 1 and Figure 2). The majority of the study area is comprised of dune-heath (Figure 2), salt marsh, meadow, not registered habitats and bog (Table 3).

Figure 1: An overview of where the study area is in Denmark. The study area is illustrated by the dashed red outline, by the eastern shore in the central part of the island of Fanø. Fanø is located in the northern part of the Wadden Sea, which is located in the southwestern part of Denmark.

Figure 2: Dune-heath from the study area with heather, cladonia, forbs and occasionally shore pine. The salt marsh can be seen in the background along with the Wadden Sea

A public dirt road runs through the area, and two summer houses is situated in the middle of the area. The area is grazed by 12 angus cattle (*Bos taurus*) aged 4 years or more, all approximately being the same size. The cattle were suited with a GPS collar fitted around the neck, which was used to track their movements and give auditory warnings and electric impulses when they came near and/or crossed the virtual fence. The collars used in this project is developed by the company Nofence©. This study is part of a larger study which began on 29 May 2021 and is planned to continue until 2025.

Table 1: A description of the different vegetation types in the study area. The 6 different habitats (Salt marsh, meadow, bog, dune heath with heather, dune grass dominated and improved grassland is described by the most dominating plant species.

Habitat	Dominating plant species
Salt marsh	Common reed (*Phragmites australis*), Creping bent (*Agrostis stolonifera*), Common coach (*Elytrigia repens*), Red fescue (*Festuca rubra*), Saltmarsh rush (*Juncus geradi*), Spear-leaved orache (*Atriplex prostrata*), Greater sea-spurreys (*Spergula media*) and Sea aster (*Tripolium vulgare*)
Meadow	Common bent (*Agrostis tenuis*) Yorkshire fog (*Holcus lanatus*), White clover (*Trifolium repens*), Trailing tormentil (*Potentilla anserine*), Creping buttercup (*Ranunculus repens*)
Bog	Common cotton-grass (*Eriohporum angustifolium*) Trailing tormentil (*Potentilla anserine*), Common reed (*Phragmites australis*) Marsh pennywort (*Hydrocotyle vulgaris*) Tormentil (*Potentilla erecta*)
Dune heath with heather	Heather (*Calluna vulgaris*), Sand sedge (*Carex arenaria*), Wawy hair-grass (*Deschampsia flexuosa*), Bog bilberry (*Vaccinium uligonosum*)
Dune grass dominated	Grey hair grass (*Corynephorus canescens*) Sand sedge (*Carex arenaria*), Reindeer lichen (*Cladonia sp.*)
Improved grassland	Yorkshire fog (*Holcus lanatus*), White clover (*Trifolium repens*),

3.2 Data source

The initial data for this study is collected from the 29th of May 2021 to the 7th August 2022. During this period, the collars continuously monitored the cattle's GPS position, but only logged data every 15 minutes or when an auditory warning or electric impulse was given. Furthermore, every 30 minutes a message with solar charge, activity etc. was logged. Status messages were sent on the most relevant changes, such as the collars transitioning from an inactive fence to an active fence (Aser et al. 2021). The different message types that are logged can be seen in Table 2.

Table 2: The different message types are described by their technical name, the frequency by which they are logged, and the number of observations within the study site during the period of 29th of May 2021 to 7th of August 2022, which is a total of 435 days. This study only uses the observations from 1st of January 2022 to 7th of August 2022, and only use the poll message type.

Type	Frequnecy	No. of observations
client_warning	Occasionally	3.721
client_zap	Occasionally	295
poll	Every 15 minutes	511.621
seq	Every 30 minutes	159.320
status	Occasionally	749

This study analyze the GPS position of the cattle, only using the positional data from the poll messages that was logged every 15 minutes. This ensures that the positional data of the cattle is consistent. In the spring and summer of 2021, the virtual border was changed many times to slowly familiarize the cattle to the auditory signals, and in the autumn of 2021 the interval between the logging of positional data was temporarily changed. Due to the many changes in the virtual border and the temporary change in the logging interval, all of 2021 has been excluded in this study. The data period for analysis in this study is therefore from the 1st of January 2022 to the 7th of August 2022. By only using the poll data (Table 2) this ensures that there is temporal consistency in the data. The data was furthermore refined in QGIS, by removing duplicate geometries. The data used in the analysis is therefore spatially and temporally consistent.

Using the GPS collars, it is possible to monitor the whereabouts of the grazing animals when also logging the position. The interval between each positional logging, determines how precise the final analysis will be. The interval between the positional logging for this study was 15 minutes, which is considered sufficient to determine the habitat choice of the cattle. The precision of the positional data is also determined by the GPS signal, which can be affected by the landscape, vegetation, and the number of available satellites. The average amount of satellites for the positional data used in this study is 12,8, and 62% of the loggings was made with 4G LTE and the remaining 38% was made with 2G (Figure 14 and Figure 15 in appendix). This is considered to be sufficient for accurate positional data for this study.

All of the study area is within the virtual border and has been accessible for the cattle, except for a 1,7 hectare large area that has been excluded from the fence since May 2022 with the purpose of cutting hay (Figure 7). In the period between the 11th of November 2021 and the 20th of April 2022, there has been supplementary feeding of the cattle. This feeding was done with hay in four to five locations on the northwestern meadow (Figure 7).

3.3 Analysis with Graphical modeler

The bulk of the analysis was conducted in QGIS, using the Graphical Modeler to setup the processes. An overview of the processes in the model that was used, is represented in Figure 3. The model resulted in the following heatmaps: Full period, period without supplementary feeding, period with supplementary feeding and heatmaps for every month of the study period. The heatmaps was made by counting the number of observations within a 5 x 5 meter square grid of the entire study area. The model also resulted in vector layers that would be exported as XML-files and analyzed further in Excel. Tables was made in Excel to summarize the data and calculate the ratio between the number of observations and the area of the different habitats. Figures was also made in Excel to illustrate the grazing pressure on the different habitats throughout the study period.

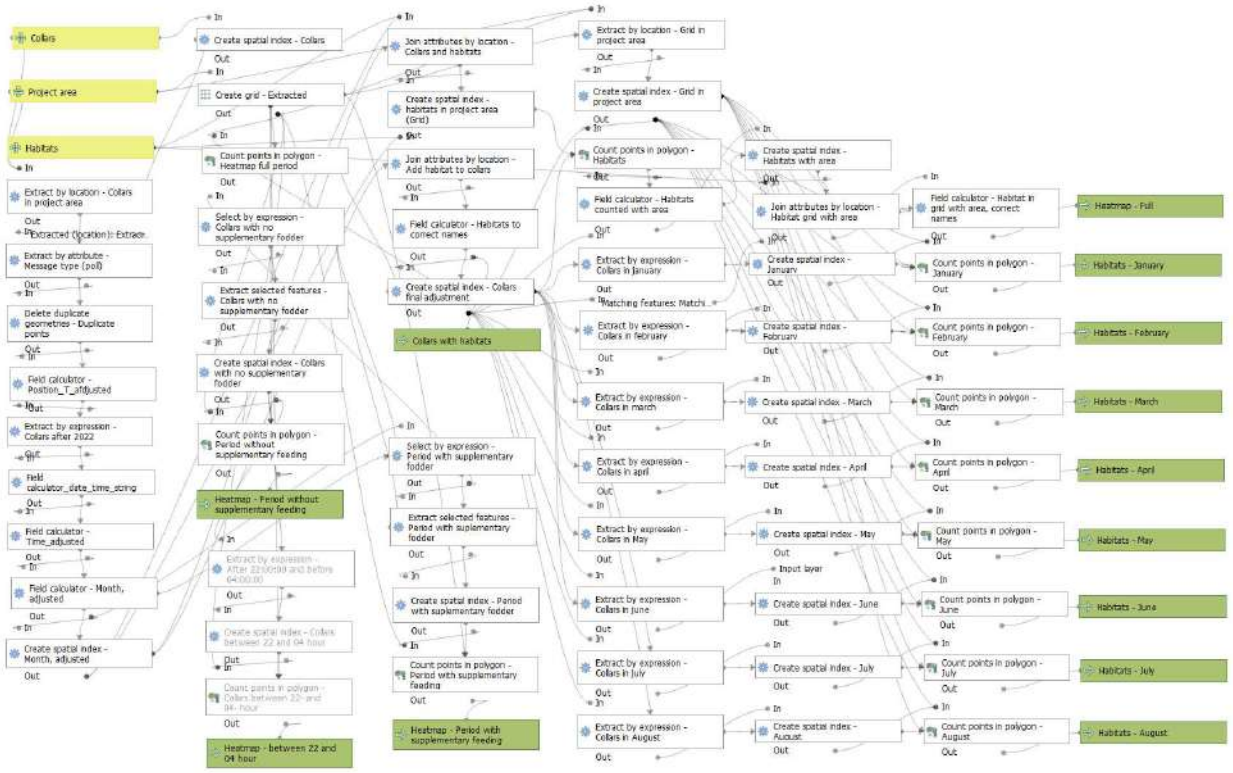

Figure 3: The Graphical modeler was used to analyze the data. The yellow boxes are the data-input, the white boxes are all the processes and calculations, and the green boxes are the output of the model.

Basic analyses of the terrain and vegetation was also conducted in QGIS using Digital Elevation Models (DEM) made by Dataforsyningen (Dataforsyningen). By subtracting the DEM of the surface with the DEM of the ground terrain, a map of bushes and trees, was made. The DEM of the terrain was also used to analyze the terrain, and to detect barriers such as ditches.

A map of the habitat types was downloaded from Miljøgis (Miljøministeriet) and used in basic analyses of the landscape, and was also used in some of the processes in the model described above. The data used to determine the habitats, is municipal data of the habitats under § 3 in the Danish Nature Protection Act (Miljøministeriet, 2022). The municipal mapping of the habitats is not guaranteed to be updated, and when the habitats occur in a mosaic, this might not be represented by the data.

4 Results

4.1 Landscape analysis

The landscape analysis shows that the study area includes different habitats protected under the § 3 in the Danish Nature Protection Act, and some areas with former cultivated grassland and conifers forest not registered as protected habitats (Figure 4). The dune-heath is the most dominant habitat type, followed by salt marsh, meadow, and bog.

Figure 4: The nature types within and around the study area. The nature types within the study area are meadow, dunes with heath, bog and salt marsh. Lakes are also present outside the study area.

The study area was found to be relatively flat (Figure 5), especially in the areas with salt marsh and meadows. The dune landscape is more undulating, especially in contrast to the flat salt marsh and meadow. Several ditches can be seen in the area.

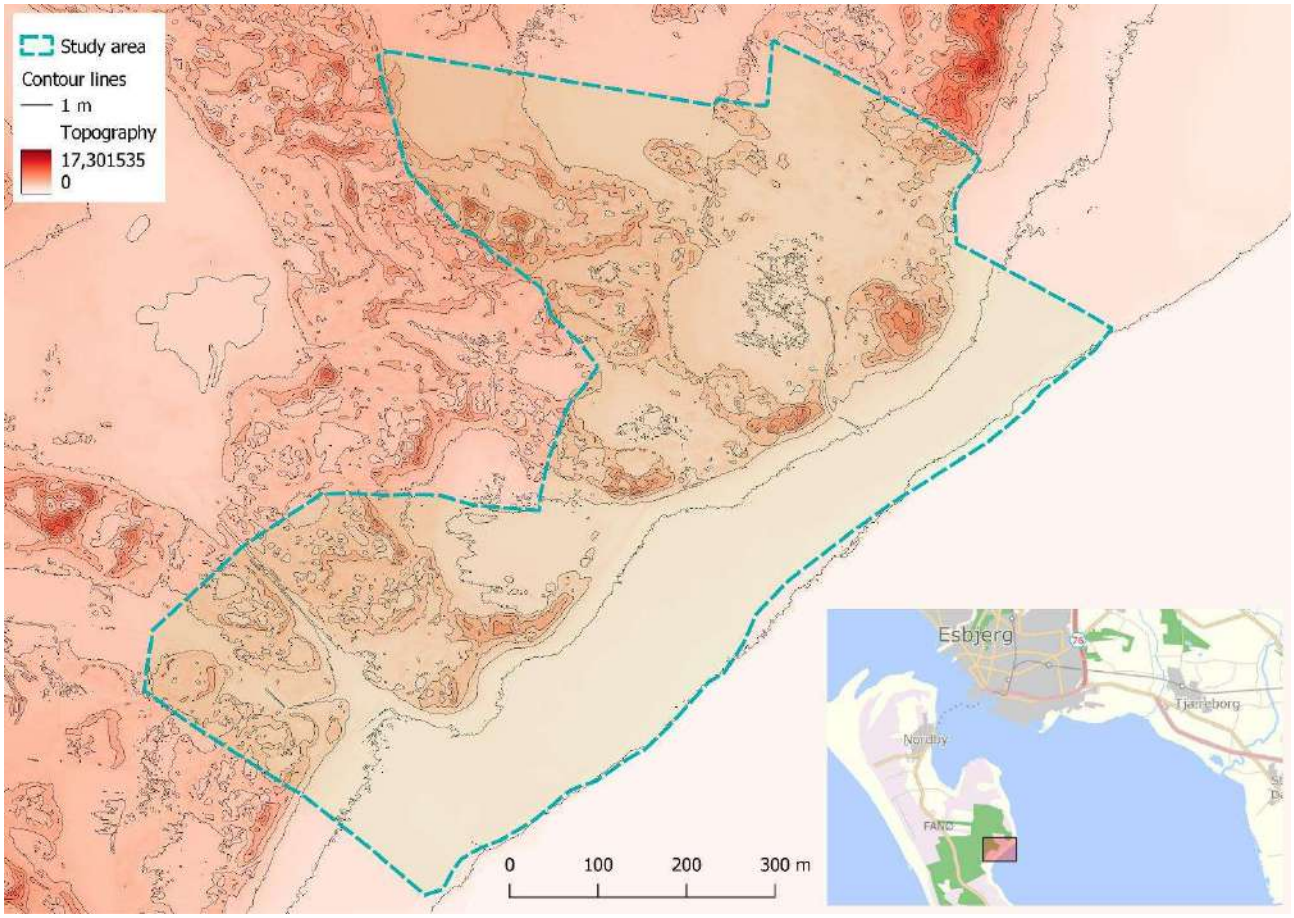

Figure 5: The topography of the terrain. Contour lines with a 1-meter interval is used to determine the outlines of the topography, and a red scale is used to visually describe the height of the terrain. Red colors resemble an increasingly higher topography. The blue dashed line is the outline of the study area.

The analysis of the occurrence of bushes and trees shows that the majority of the bushes and trees are present outside the protected habitats (Figure 6). These areas resemble forest and was found to hold little to no forbs and grasses (Field study on 1. August 2022). Scattered bushes and trees can be found on the dunes, and most of these was found to be Shore Pine (*Pinus contorta*) (field study on 1st August 2022).

Figure 6: Bushes and trees registered in and around the study area. Blue colors are the lowest vegetation, then comes green, yellow, and red as the tallest vegetation, in relation to the terrain. The grey dashed line is the outline of the study area.

4.2 Heatmaps

The heatmap of the full period shows that the cattle are utilizing most of the study area, besides the denser forest (Figure 7). The cattle move into the dense forest south of the northern meadow with the feeding sites, but never fully cover the entire forest patch. The cattle also stay out of a part of the dense forest in the south, where a ditch cuts through and around a forest patch, making a barrier that the cattle diverge around. The cattle also clearly stay in certain areas for longer periods of time. This is most obvious on the northwestern meadow around the feeding sites and in several spots on the dune-heath.

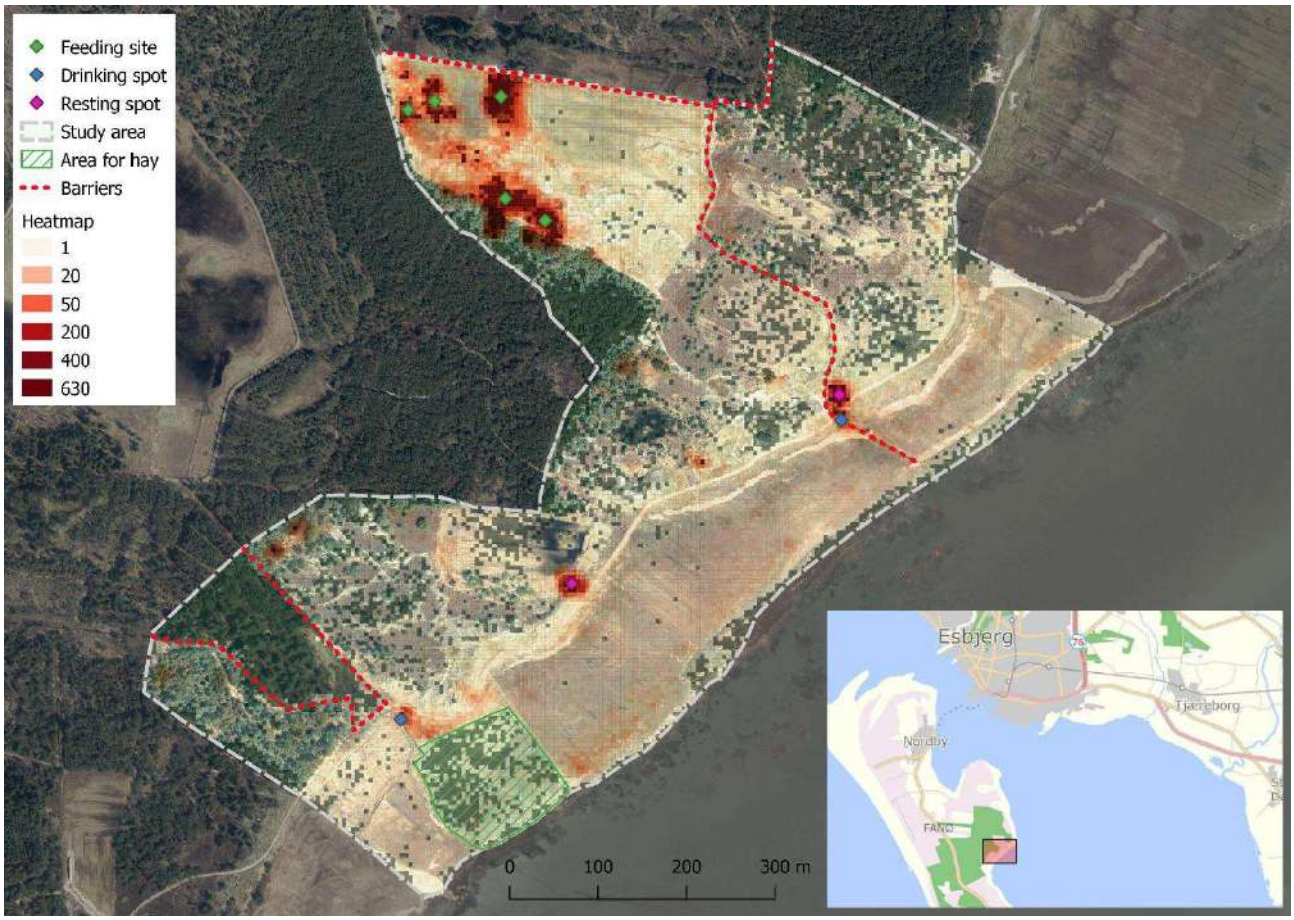

Figure 7: Heatmap of the full period, which is a total of 218 days. Increasingly red colors illustrate an increased amount of observations. Feeding sites, drinking spots, resting spots and barriers are visible on the map. The study area and an area, which during the study period was excluded from the virtual fence, is also visible on the map.

The analyses show that the cattle mainly stayed in the northwestern meadow in the period where the cattle received supplementary fodder. The exact location of where the fodder was placed, corresponds with the hotspots on the heatmap (Figure 8). When the cattle moved out of the feeding area, they mainly stayed in the dune areas next to the feeding area or along the road running through the study area, and only for very little time.

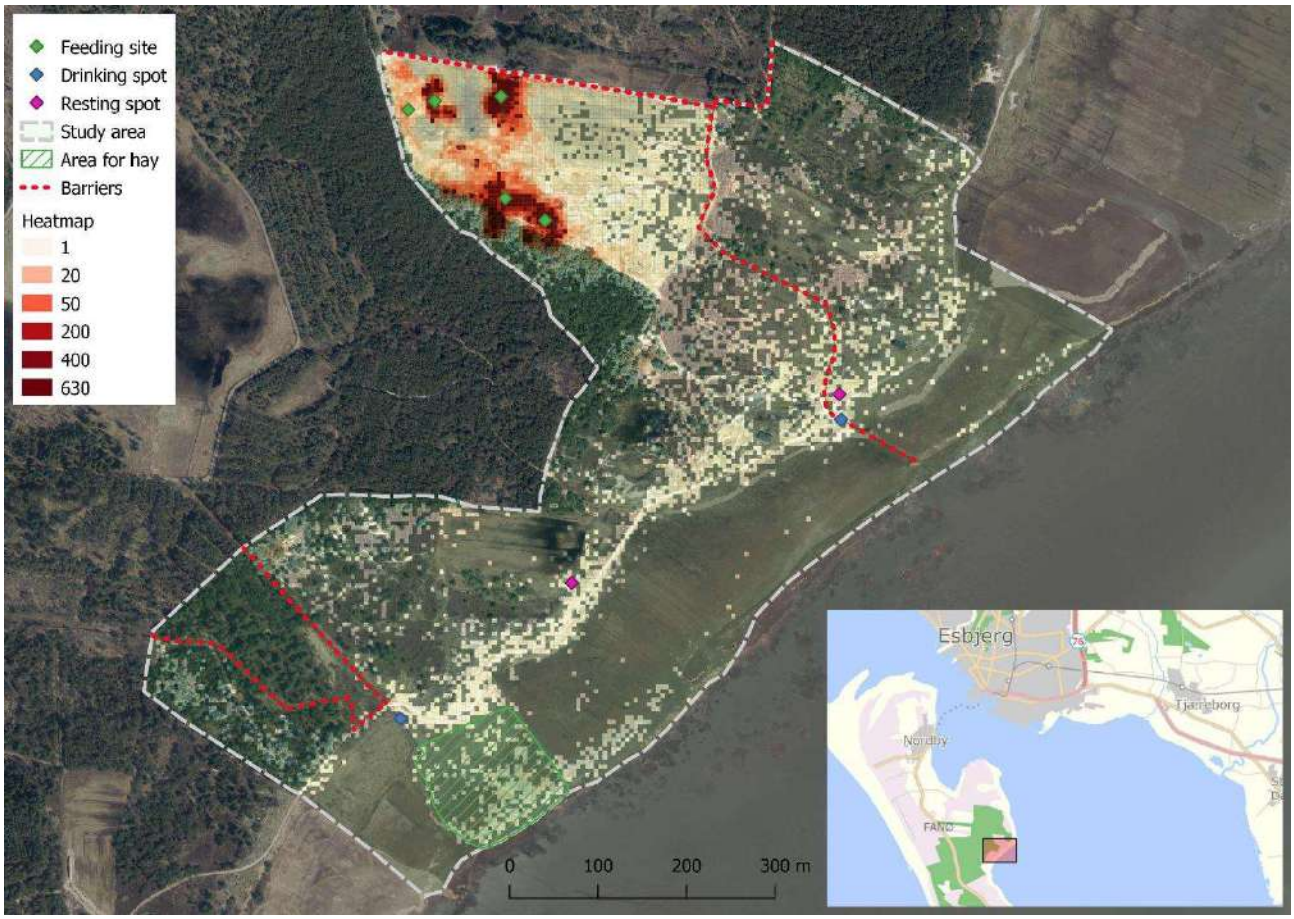

Figure 8: Heatmap of the period with supplementary feeding, which is a total of 109 days. Increasingly red colors illustrate an increased amount of observations. Feeding sites, drinking spots, resting spots and barriers are visible on the map. The study area and an area, which during the study period was excluded from the virtual fence, is also visible on the map.

In the period without supplementary feeding, there is observations of the cattle in almost all the study area. The cattle however stay out of the dense forest south of the northwestern meadow and the dense forest in the southwestern part of the study area, which is bounded by a ditch acting as a barrier (Figure 10). There are also very few observations of the cattle in the northern part of the dune-heath. The observations of the cattle almost fully cover the salt marsh, and there are widespread observations of the cattle in the dune-heath. There are two very visible hotspots in the dune-heath, just at the border of the salt marsh. During a field study in the area on the 1st and 2nd of august, these hotspots were identified as resting spots (Figure 9).

Figure 9: The Angus cattle resting in one of the resting spots within the study area. Notice the GPS collars around their neck (Photo: Rita M. Buttenschøn).

There are also two very visible hotspots in the northwestern meadow, where the cattle previously have received supplementary fodder. Next to one of the resting spots near the road is a nosepump where the cattle can drink freshwater. There is a visible hotspot around this nosepump. There is ditch running into the salt marsh in the southern part of the study area, which during the field study was determined as a drinking spot. This drinking spot also resulted in a visible hotspot on the heatmap (Figure 10). At the end of April, a

1,7 hectare large meadow in the southern part of the study area was virtually fenced off, because the meadow was needed for hay cutting.

Figure 10: Heatmap of the period without supplementary feeding, which is a total of 109 days. Increasingly red colors illustrate an increased amount of observations. Feeding sites, drinking spots, resting spots and barriers are visible on the map. The study area and an area, which during the study period was excluded from the virtual fence, is also visible on the map.

4.3 Observations in relation to the area

The meadow is the habitat with most observations per square meter, followed by dune-heath, salt marsh, not registered habitat and bog (Table 3).

Table 3: A table with all nature types, their area, number of observations and a ratio between area and observation. The basis for this table is observations of the poll message type, within the study site during the 1st of January 2022 to the 7th of August 2022.

Nature type	Area (m2)	No. of observations	Ratio (No. obs/sq m)
Meadow	73.707	58.905	0,80
Dune-heath	220.395	80.574	0,37
Bog	4.053	366	0,09
Salt marsh	158.847	36.535	0,23
Not registered	58.095	11.208	0,19
Total	515.097	187.588	

4.4 Heatmaps for each month

Heatmaps for each month, show the preferred habitat throughout the study period. In January there is only observations in the northwestern meadow and the nearest surrounding habitats, and a clear hotspot on the feeding sites. During February, March and April, the cattle increasingly move further out in the landscape, coinciding with the stop of supplementary feeding (Figure 11). During May, June, and July the cattle is observed more and more on the salt marsh and throughout the dune-heath. The hotspots where the cattle have been observed resting, and around the drinking spots are also visible in this period (Figure 12.

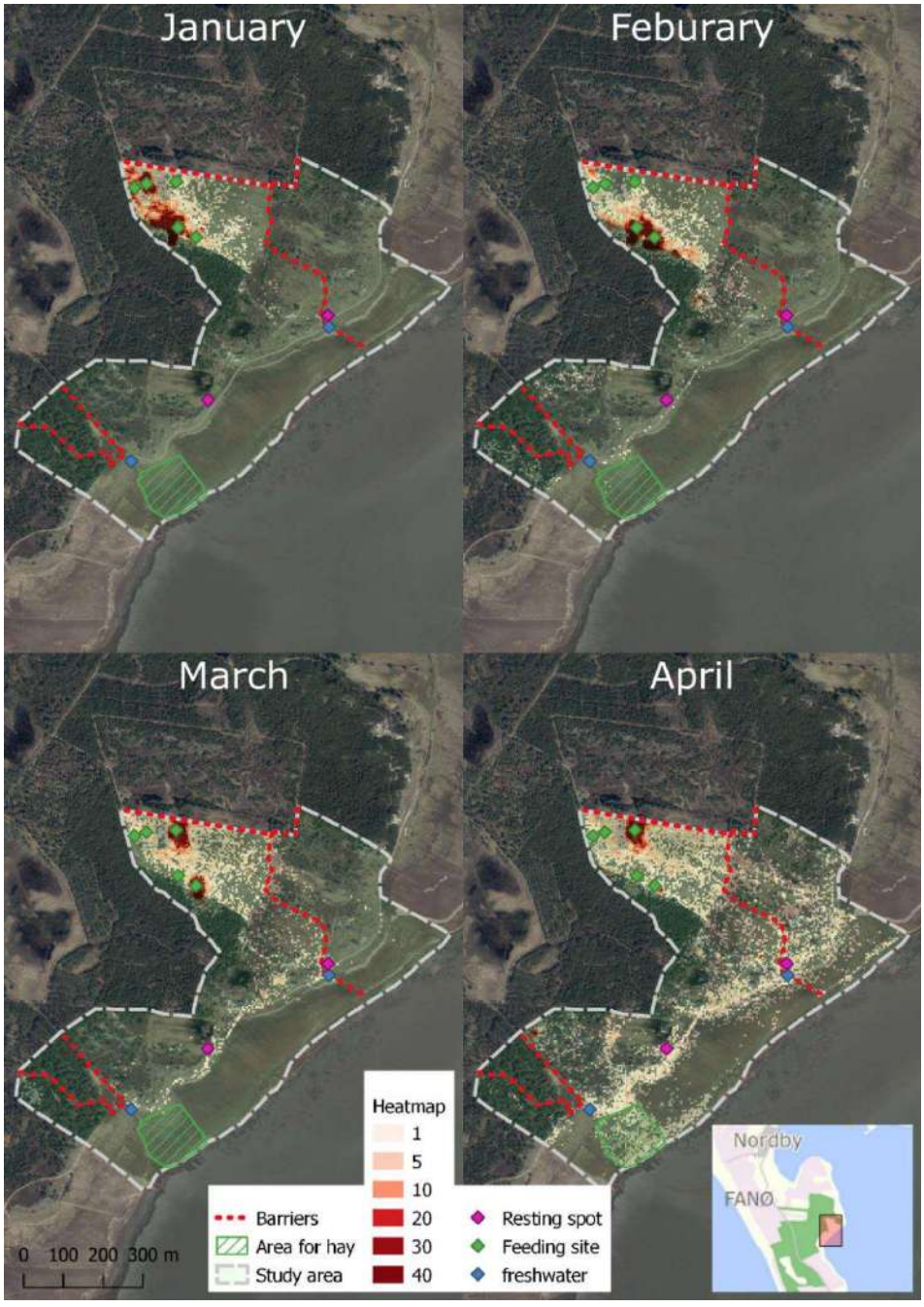

Figure 11: A heatmap for the month of January, February, March, and April of 2022. Increasingly red colors illustrates an increased amount of observations. Feeding sites, drinking spots, resting spots and barriers are visible on the map. The study area and an area, which during the study period was excluded from the virtual fence, is also visible on the map

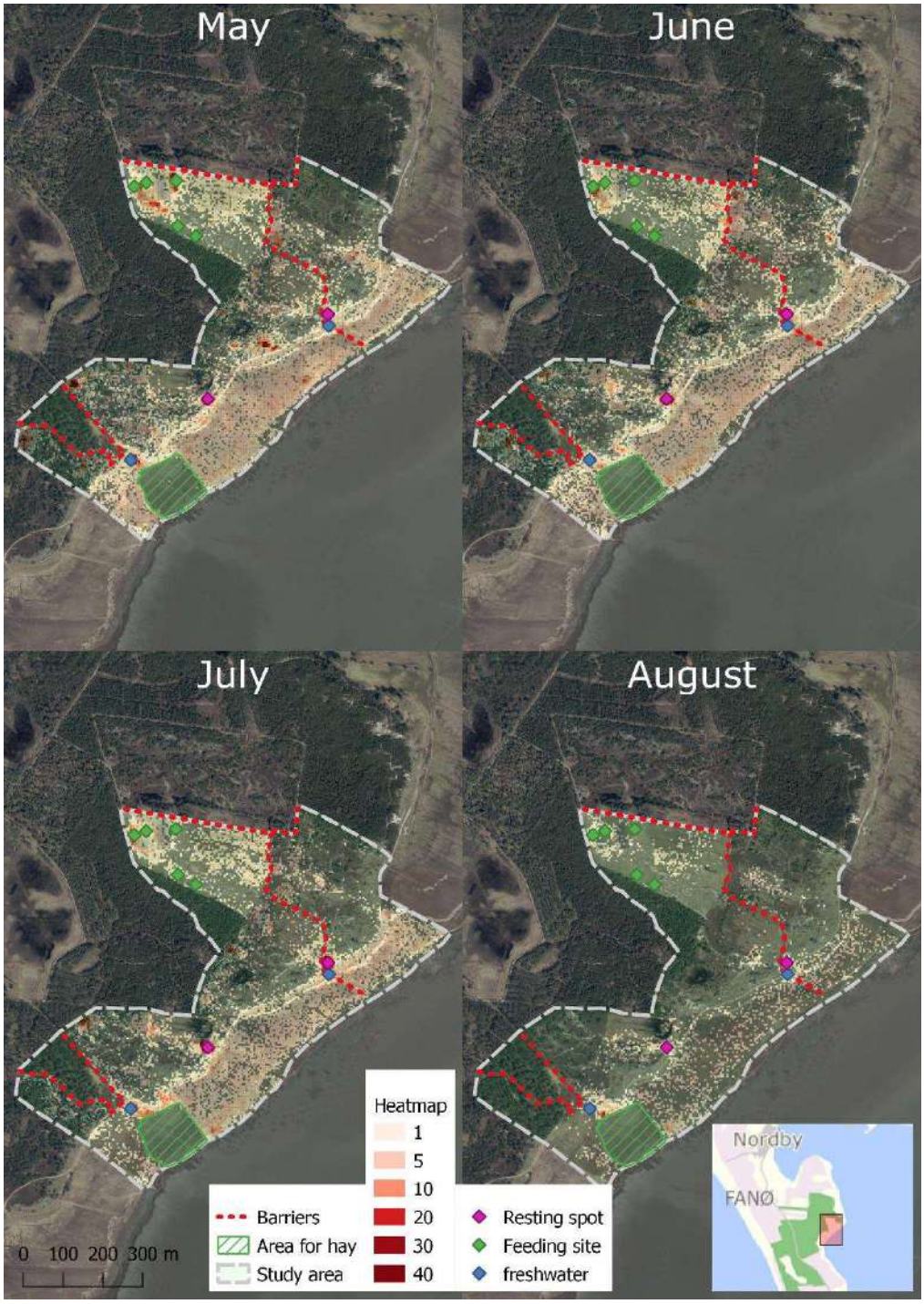

Figure 12: A heatmap for the month of May, June, July, and August of 2022. There are only observations for 7 days within August, which should be accounted for when interpreting the figure. Increasingly red colors illustrates an increased amount of observations. Feeding sites, drinking spots, resting spots and barriers are visible on the map. The study area and an area, which during the study period was excluded from the virtual fence, is also visible on the map

4.5 Observation per month within habitats

When looking at the number of observations on the different habitats within each month, the habitats that the majority of the observations have been made on is dune-heath, meadow and not protected habitats. From May, there is a more equal distribution of observations within the different habitats, where salt marsh is the preferred habitat (Figure 13).

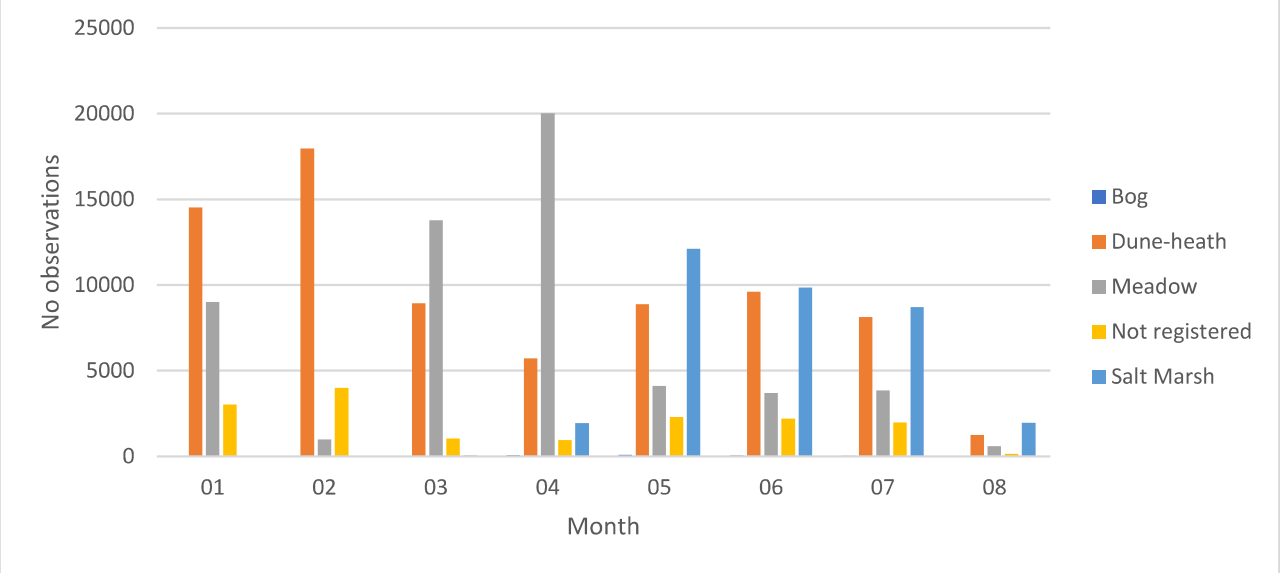

Figure 13: The number of observations on the different nature types within each month. On the x-axis the month of the year is shown, and on the y-axis the number of observations is shown. The different habitat types are illustrated by different colors. There are only observations for 7 days within month 08 (August), which should be accounted for when interpreting the figure.

5 Conclusion and discussion

The analysis showed that the grazing pressure on the study site is highly affected by supplementary feeding, the structures in the landscape such as dense forest and ditches, and the layout of the habitats. During the period where supplementary feeding is given to the cattle, they primarily stay in the vicinity of the feeding spots. As soon as the feeding stops, the cattle move out in the landscape where they graze a variety of habitats. During supplementary feeding, the results show that the cattle stay in the meadow and dune-heath most of the time, but it is important to note that the cattle most likely are not grazing these habitats, but instead eat the fodder they are given. This also results in an increased nutrient load on these specific areas.

Structures in the landscape can acts as a barrier for the cattle. This was apparent in the southern forest, where a ditch acted as a barrier, which seemed to almost prevent the cattle completely from grazing in the forest. For most of the time, the cattle also stayed out of the dense forest south of the feeding sites, although no barriers were present. This might be due to the low production in the forest, because of the nutrient poor soil combined with a limited amount of light reaching the forest floor, which makes the cattle choose other habitats for food.

To establish the seasonal change in the grazing patterns, individual heatmaps for every month was made. This showed that the cattle in general preferred the nutrient rich meadow. The heatmaps also showed that the cattle grazed the nutrient rich salt marsh, however they only began grazing this habitat in June which is likely due to the late growth of the vegetation and the wetness of the habitat which prevents them from walking in the marsh during winter and parts of spring and autumn. The dune-heath was found to be used by the cattle consistently throughout the year, which is surprising considering that the dune-heath is a nutrient poor habitat with low production. It is important to note however, that the cattle use the dune-heath for resting, which may cause them to spend time in this habitat without grazing it. The layout of the preferred feeding areas and sites for resting and drinking, can also result in observations in specific habitats. If the cattle wants to move between the nutrient rich meadow and the nutrient rich salt marsh, they will have to go through the dune-heath which will result in observations within this habitat.

In the period where the cattle only rely on the food they can find in the study area, the analysis show that they choose a variety of habitats to fulfill their needs. Habitats are used for grazing to varying extents, and some habitats are preferred for resting. Therefore, it seems that a varied outlay of habitats is needed to fully satisfy the grazing cattle.

To fully understand how the cattle use the landscape, further analysis is needed. The observations only show where the cattle is and when, but what exactly the cattle is doing can only be assumed. Manuel observations of what the cattle is doing at certain times could be made to understand this. Automated analysis of the distance between subsequent observations, and patterns of this, could give an indication on how active the cattle is which could be related to what they are doing. Optout of supplementary feeding during the winter, would also give a better understanding of the habitat choice of the cattle, should they rely only on the habitats for feeding. This could further on alter the landscape and the habitat choice during the rest of the seasons.

6 Bibliography

Dataforsyningen. (16. 08 2022). *Dataforsyningen*. Hentet fra Danmarks Højdemodel - Højdekurver: https://dataforsyningen.dk/data/926

Miljøministeriet. (16. 08 2022). *Miljøgis*. Hentet fra MiljøGIS - data om natur og miljø på webkort: https://mst.dk/service/miljoegis/

Buttenschøn, R.M. 2021. Effekt af rewilding på planterigdom, 46-59. I: Fløjgaard, C., Buttenschøn, R.M., Byriel, F.B., Clausen, K.K., Gottlieb, L., Kanstrup, N., Strandberg, B. & Ejrnæs, R. 2021. Biodiversitetseffekter af rewilding. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 124 s.

Fløjgaard, C., Buttenschøn, R.M., Byriel, F.B., Clausen, K.K., Gottlieb, L., Kanstrup, N., Strandberg, B. & Ejrnæs, R. 2021. Biodiversitetseffekter af rewilding. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 124 s.

Rosenthal, G., Schrautzer, J. Eichberg, C. 2012. Low-intensity grazing with domestic herbivores: A tool for maintaining and restoring plant diversity in temperate Europe. Tuexenia, 32, 167-205.

Aaser, M. F., Staahltoft, S. K., Korsgaard, A. H., Trige-Esbensen, A., Alstrup, A. K. O., Sonne, C., Pertoldi, C., Bruhn, D., Frikke, J. & Linder, A. C. (2022). Is Virtual Fencing an Effective Way of Enclosing Cattle? Personality, Herd Behaviour and Welfare. Animals, 12(7), 842.

McKILLOP, I. & Sibly, Richard. (2008). Animal behaviour at electric fences and implications for management. Mammal Review. 18. 91 - 103. 10.1111/j.1365-2907.1988.tb00078.x.

7 Appendix

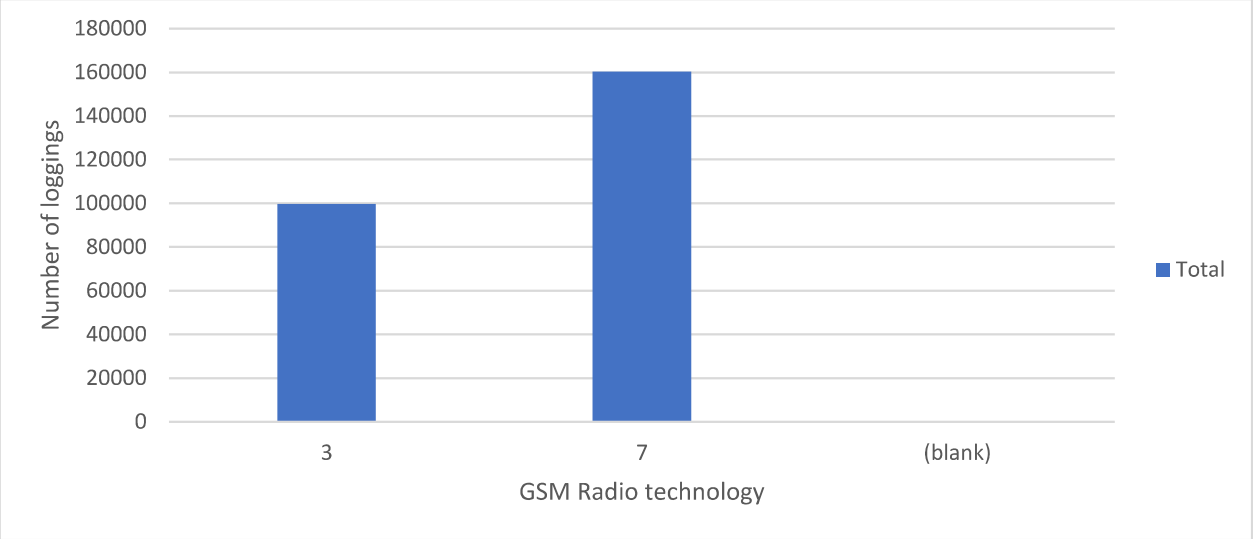

Figure 14: The number of loggings within each type of acces technology. Acces technolgy 3 is 2G and acces technology 7 is 4G LTE. The basis for this figure is poll observations within the study area from 29th May 2021 to 7th August 2022.

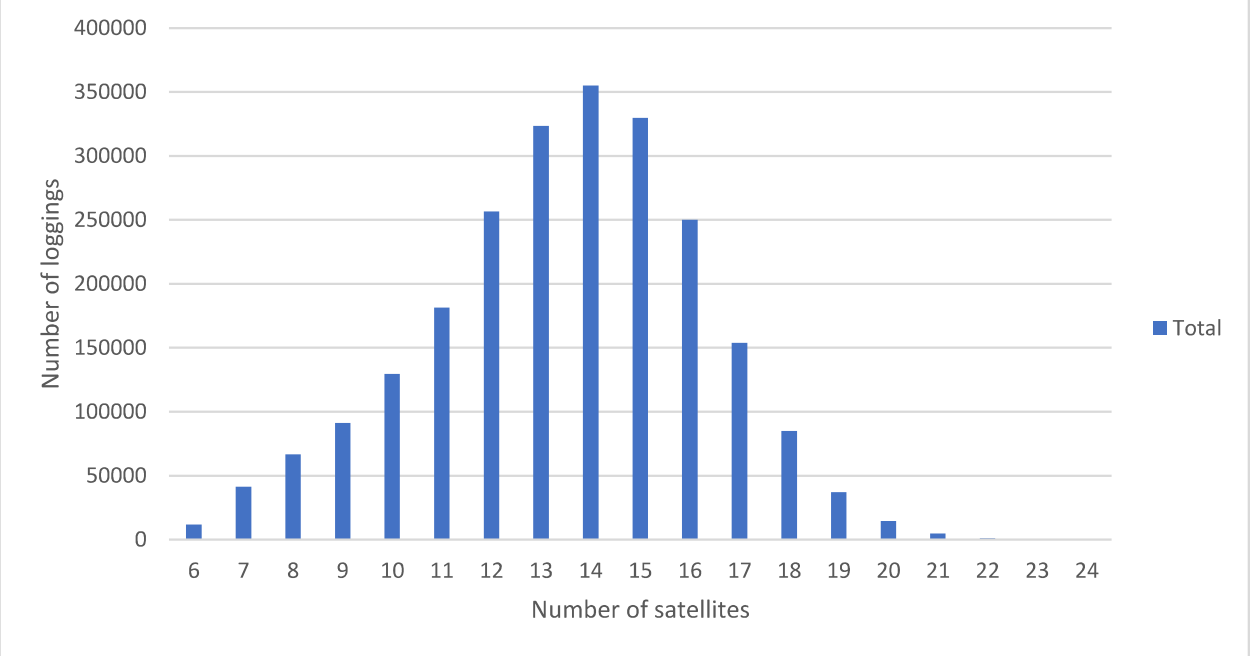

Figure 15: The number of positional loggings and the amount of satellites that was available. The basis for this figure is poll observations within the study area from 29th May 2021 to 7th August 2022.