Distribution of Rabbits on Schiermonnikoog

Research project Ecology and Evolution 2

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Abstract

Due to two diseases, Rabbit Haemorrhagic Disease (RHD) and Myxomatosis, the rabbit population in the Netherlands has been severely impacted. This has resulted in the Wild Rabbit becoming a red list species (threatened species). Wild rabbits play an important role in the ecosystems they inhabit, often being regarded as ecosystem engineers. On the island of Schiermonnikoog (an island, in the Dutch Wadden sea) the wild rabbit have taken to the dunes, regulating the expansion seaberries and hawthorns. The rabbit population on Schiermonnikoog (Schier) has also been struggling to recover since the outbreaks of RHD and Myxomatosis. Invasive feral cats on the island have not aided their recovery, often preying on the young and weak. To observe whether the rabbit population on Schier is recovering or not, we will be conducting various sampling methods used to approximate the rabbit abundance and observe their distribution on the island. These sampling methods consist of; rabbit pellet counts (RPC's), Mapping, Transects, Thermal imaging observations and wildlife camera observations.

Introduction

The wild rabbit has many functions within the ecosystem and is often regarded as an architect or ecosystem engineer (Gálvez et al. 2009). In dune environments, the rabbits dig holes, burrows and scrape the ground looking for roots to consume (Nierop et al. 1984). When doing this, they unearth calcium rich sand bringing it to the surface. Calcium is a vital element and crucial for regulating growth and development in plants (Hepler et al. 2005), as it regulates cell division, extension/elongation as well as homeostasis. Rabbits also selectively graze on the seedlings and the new shoots of hawthornes and seaberries, reducing their rate of expansion in the dunes (Kaetzke et al. 2003). By consistently grazing on the new growth of these bushes, they promote growth in unreachable areas of the tree, particularly in the crown. This creates bushes with few if any branches near the ground, and relatively high crowns, these pruned bushes then become ideal locations for entrances and exits of burrows, as they are completely hidden from above protecting them against birds of prey and larger mammalian predators (Bakker et al. 2005).

Since 1953, rabbit populations in the Netherlands have been declining largely due to two pathogenic viruses; Myxomatosis and Rabbit Haemorrhagic Disease (RHD) (Dekker et al., 2021). Myxomatosis was first seen in 1953 which largely obliterated the rabbit population post outbreak (Drees, 1992). RHD was first identified in 1988 (Siebenga, 1991), since then the disease has mutated, and in 2015 a new variant was discovered (IJzer et al., 2016), RDH2. The combination of Myxomatosis and RHD as well as other influences have resulted in a 68% reduction of dune rabbit populations in the Netherlands (Dekker et al., 2021) (measured between 1984 - 2018).

Schiermonnikoog, a small island located in the Wadden sea, was also heavily impacted by Myxomatosis and RHD, little is known about how the diseases arrived at Schiermonnikoog, but they were most likely transmitted by biting insects (mosquitos, horseflies and blackflies)(McColl et al., 2001). Schiermonnikoog consists of a small number of biomes; largely sand dunes, tidal flats, marshes and some small forest patches consisting of: pines, birch, hawthorns and seaberry trees (Pinus sylvestris, Betula pendula, Crataegus monogyna, Hippophae rhamnoides). Due to its isolation, biogeographical variability and its inherent boundedness, makes the island of Schiermonnikoog a fine research location to model population dynamics (DiNapoli & Leppard, 2018). Utilizing a combination of various sampling techniques its population dynamics can be fairly accurately modeled and predicted. However the centuries of isolation have lowered the diversity leaving its native biota vulnerable to invasive species (DiNapoli & Leppard, 2018).

Schiermonnikoog has been home to a small population of invasive feral cats since the 1980’s, of which some individuals have been shown to prey on native rabbits (Van der Ende, 2015). Although rabbits did not constitute a large percentage of their diet, it was decided that any rabbit consumed by the cats was one too many. The rabbits consumed by feral cats are most likely weak due to being exposed to one of the two diseases or are young. Potentially hindering the process of the native rabbits becoming resistances to the two viruses.

Young rabbits exposed to RHD two months after their birth can become resistant to RHD, remaining resistant to RHD for the rest of their lives, allowing them to pass it on to their offspring (should they have the chance to reproduce), strengthening the population (Neave et al., 2018)

Over the last two years these feral cats have been largely removed from the island, where 67 cats have been caught so far.

In order to find out whether the rabbit population is recovering from Myxomatosis and RHD as well as observing the effects of the removal of feral cats, long term data collection is necessary. Since 2016, rabbit pellet counts (RPC’s) have been completed in various locations on the island by Natuurmonumenten, and last year 6 new locations were added. These locations (plots) were chosen based on habitat suitability (Tellegen, 2011). In total 15 different plots were sampled on the island, where we conducted the various sampling techniques; RPC’s, mapping, thermal imaging observations and wildlife cameras. We also conducted transect routes but these were not done within the plots. Our research aims to find out which of the various sampling techniques works best to approximate rabbit abundance on Schier, as well as observing whether the distribution of rabbits has changed in relation to last year. Thus we posed the following questions;

research question

Which method works best to approximate rabbit abundance on Schiermonnikoog?

sub research question

Has the distribution of rabbits changed compared to last year?

Methods

In order to approximate the rabbit abundance on Schiermonnikoog, fifteen plots on the island were chosen, each measuring 50 meters by 75 meters. See image below.

Figure 1: Schiermonikoog and locations of the 15 plots.

A total of five methods were used; dropping counts, mapping rabbit signs (in the predetermined plots), transect survey, wildlife camera observations and thermal imaging observations, all methods were completed in May of 2024. To digitally note down rabbit sign, dropping counts and locations of the wildlife cameras Mergin Maps was utilized. Megin Maps is an app which allows users to upload a map of a location (they are surveying) and add multiple layers to it. This was a particularly useful tool for our research as we could quickly note down anything of importance whilst accurately marking it on the map (using precise gps coordinates) and instantly sharing it with all those involved in our project team.

Rabbit Pellet Counts

RPCS were performed in all of the plots. Each plot had 5 bamboo sticks driven into the ground which were located in all four corners and in the middle, marking the sample locations. A rope of 75cm was attached to the bamboo stick and pulled in a clockwise motion, creating a circle around the sample location. All the pellets (droppings) encountered were then counted (including hare droppings) and noted down in Mergin maps. A second round of dropping counts was completed two weeks after the first round, in all sample locations and plots. The initial dropping counts could be compared with last year's counts, if more rabbit droppings were observed this year than last year we could potentially conclude that the rabbit population is increasing or the contrary if we counted fewer. The second round of dropping counts gave an indication of how often the rabbits were present in the plots. See Figure below to see the different droppings observed in the plots.

Rabbit **Hare** **Goat**

Figure 2: the different droppings observed in the plots

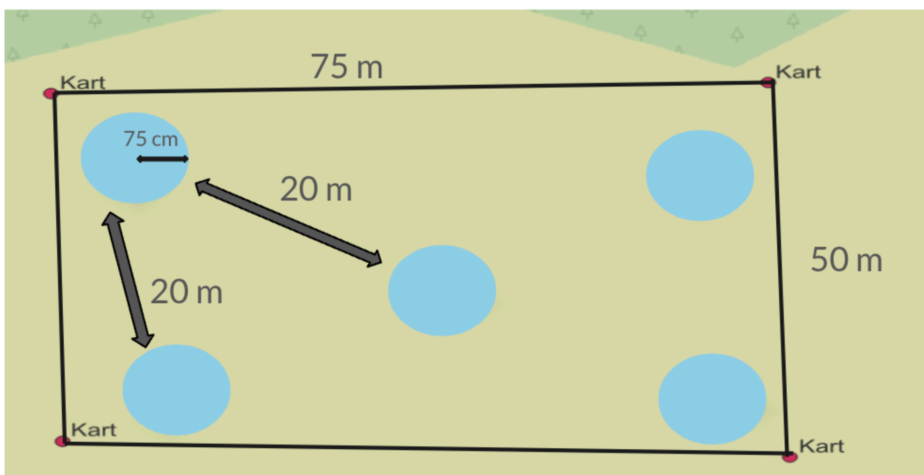


Figure 3: schematic of the RPCs

Mapping rabbit sign in the plots

Two measuring tapes of 50 m are put at the short ends of the plots and a rope of 75 m was placed at the long end of the plot. Giving us visual guidelines to adhere to, helping us to systematically walk the plot. We began 2m from a corner, looking both two meters to the left and two meters to right, (having a total of four meters between us). All latrines (places with more than 20 droppings), holes and digs (clearly made by rabbits) were recorded in Mergin maps. Once the 75 m rope was no longer clearly visible it was moved so that it could again be seen, being placed at the same distance on each tape measure.

See image below for Mergin maps depiction.

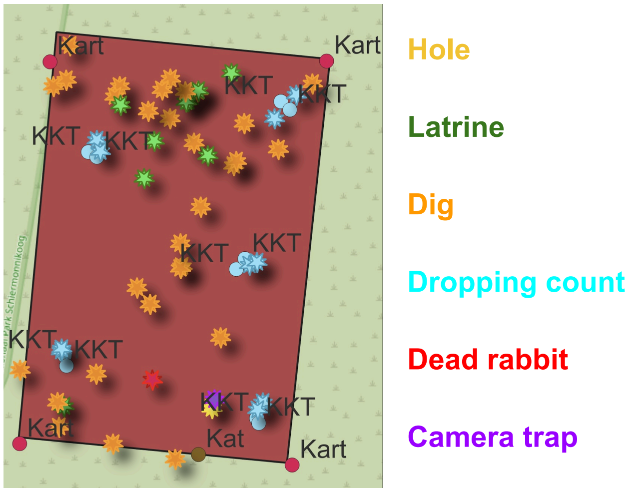


Figure 4: depiction of mapping results on Mergin maps (plot 5)

Transect survey

The transect route, is a standard route often driven by car, bike or walked, where every target species seen within the area of the spotlight is counted. As a spotlight we used a flashlight attached to the front of a bicycle. The transect is slowly completed to precisely count the target species, in our case rabbits. On Schiermonnikoog the transect route is done by bicycle as the bike allows access to all target regions of the island. The entire transect is 13.81 km, consisting of twelve shorter (sub) transects. See image below.

Figure 5: Complete transect route on Schiermonnikoog, consisting of 12 shorter transects.

During the four week research period the entire transect was cycled 6 times, cycled one hour after sunset (22:30 pm) when it wasn't raining. Rabbits much like people and cats do not like getting wet, and so remain in their burrows when it rains.

Wildlife camera observations

After mapping the plots, locations that looked active were observed using wildlife cameras, in our case we used the Bushnell Aggressor Trophy HD-camera. The cameras were primarily placed near the entrances leading to burrows made by rabbits. Once all burrow locations were viewed for 1 night (8:00 pm - 8:00 am), cameras were then placed on spots overlooking latrines. Using the wildlife cameras it was possible to determine if the burrow in the plot was actively being used by rabbits or if another animal had taken up residence in it. The wildlife cameras have three different settings: low, medium and high. Low is used when the target is presumed to be passing close by (0 - 4 m), medium is used at ranges 4- 9m and high is used at a distance of 9m and above. In our case we only used the cameras on the lowest setting when targeting burrows and on medium when targeting the latrines. See settings table below.

Parameter	Settings
Mode	Video
Format	Wide Screen
LED control	Low
Video size	1920x1080
Video length	10 seconds
Interval	02 seconds
Sensor level	Auto
NV Shutter	High

Table 1: Bushnell Agressor picture and video settings

Thermal imaging observations

Post mapping the plots, thermal imaging observations were completed for all plots with a high amount of activity. The amount of activity was concluded based on the results from mapping and the rabbit pellet counts. Plots that also produced a positive wildlife camera result were first observed with the thermal imaging camera. Observations were initiated an hour before sunrise around 4:30AM. The plots were broken down into four separate observations of 10 mins, at all

four sides of the plot (WNES), observing from slightly outside of the plot. Doing this with two people, one person would be observing through the thermal imaging camera, whilst the other person would be observing (second hand) through a live stream of what the camera was picking up, on a mobile phone. This could be done through the Stream vision app, a companion app of the Helios Thermal imaging camera where devices could be paired through wifi.
When walking to the observation points we walked around the outside of the plot to not disturb any rabbits potentially in the plot. See schematic below.

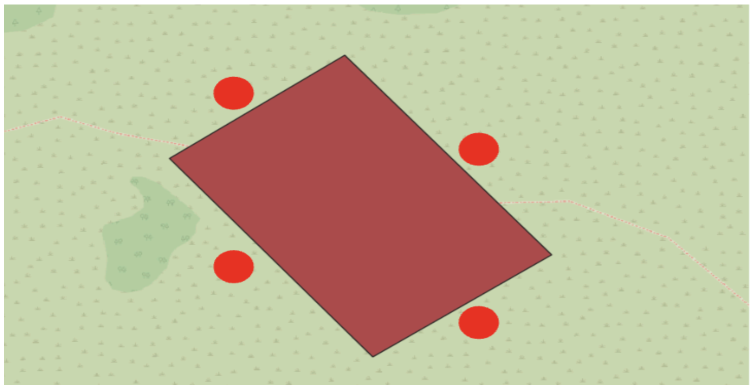


Figure 6: depicting the 4 locations on the four sides of the plot

Results

The project and data collection took place in April and May 2024. In all of the 15 plots dropping counts were performed twice, once at the start of the project and a second time after two weeks had passed. Mapping was also done once in every plot, with the exception of plots 8, 12 and 23 due to being located in a breeding area. Wildlife camera observations were done in plots 1, 2, 4, 5, 19, 20 and 21 as there was suspected to be rabbit activity in those locations. Thermal imaging camera observations were done in five plots with the highest likelihood of observing rabbits. These were plots 1, 4, 5, 19 and 20.

Rabbit Pellet Counts

With the pellet count method, an average of 8.92 pellets per plot was found over the first counting round and an average of 0.56 over the second counting round. Plots 7, 8 and 14 were contaminated by goats as those droppings can be difficult to separate from rabbit droppings. The counts sometimes went well above the average count per plot, with more than 100 droppings. Removal of these outliers changes the average droppings per plot for the first countings to 3.15 and for the second counting round to 0.68. During the first count period in 2024, plot 19 produced the highest average count per sample location, with an average of 15.4. During the second count period plot 1 produced the highest count per sample location, with an average of 6.6. In 2023, the first dropping count produced an average of 2.89 droppings per plot. The second count produced an average of 0.52 droppings per plot. During the first dropping count period in 2023 plot 4 produced the highest average sample count with 13.2 droppings counted in that location. During the second dropping count plot 20 produced the highest average with 5 droppings counted.

Figure 7

RPC 2023 7.1 **RPC 2024** 7.2

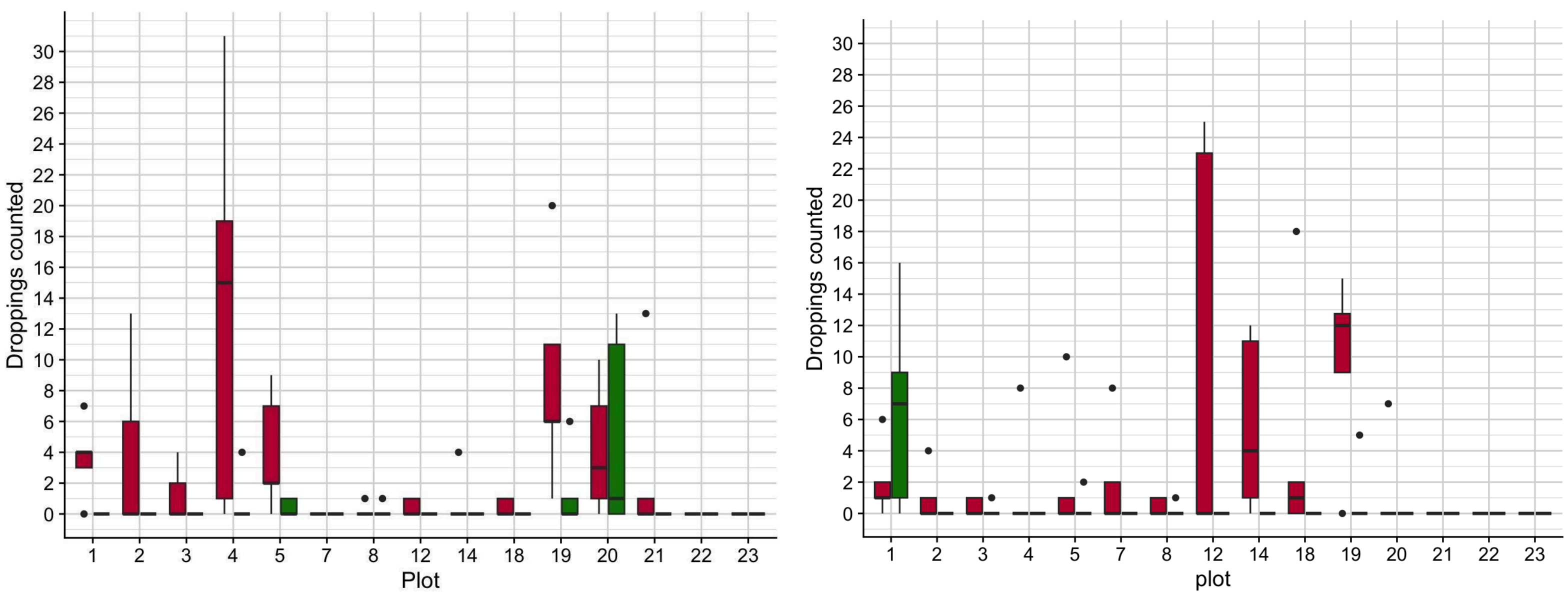


Figure 7: The average number of rabbit droppings per plot with red representing the first count and green representing the second count

Mapping method

With the mapping method plots 1, 2, 4, 5, 19, 20 and 21 were found to have rabbit activity. Holes and burrows were found in plots 4, 5, 19 and 20. An example of a mapped location, plot 5, is given in figure 8. The mapping results of the other plots can be found in the appendix. The results of the mapping have also been collected in a table, table 2. In this table the results from both the year 2023 as well as 2024 are shown.

Figure 8: Mapping results plot 5, located in the western part of Schiermonnikoog. On the left the results from 2023 (Huizinga & Mulder 2023) are shown and on the right the results from 2024 are shown.

Table 2

Location	Latrines	Holes
18	0	4
19	61	8
5	34	5
20	37	3
4	21	10
1	27	0
21	15	5
2	33	0
3	5	1
8	-	-
14	0	0
12	-	-
7	0	0
22	0	0
23	-	-

Table 2.1

Location	Latrines	Holes	Diggings
18	1	0	5
19	10	8	18
5	9	3	30
20	17	2	18
4	3	2	8
1	11	0	4
21	7	0	12
2	3	0	8
3	2	0	14
8	-	-	-
14	59	0	4
12	-	-	-
7	0	0	3
22	0	0	3
23	-	-	-

Table 2.2

Table 2: Table 2.1 and 2.2 show the mapping results of the research projects in 2023 and 2024 respectively. The locations are arranged from west to east on the island. Per location the number of latrines, holes and diggings are given

Transect route

The transect route was done six times. On average, during one transect route, we observed 12.8 rabbits. The number of rabbits counted was often higher in the transect sections on the western part of the island. In last year's transect route there was an average of 22 rabbits counted for one transect route. The average per section of the route can be found in figure 9. In 2023 rabbits were counted in sections 1, 3, 4, 7, 8, 9, 10, 11, 12. With the majority of the rabbits counted in section 11 (8.8 ± 3). In 2024 rabbits were counted in sections 1, 6, 7, 8, 10, 11. With the majority of the rabbits counted in section 10 (4.8 ± 2.3). Sections 2 and 5 produced no rabbit sightings in both years. Comparison between the transect sections from both 2023 and 2024 are depicted in figure 10 below.

Figure 9

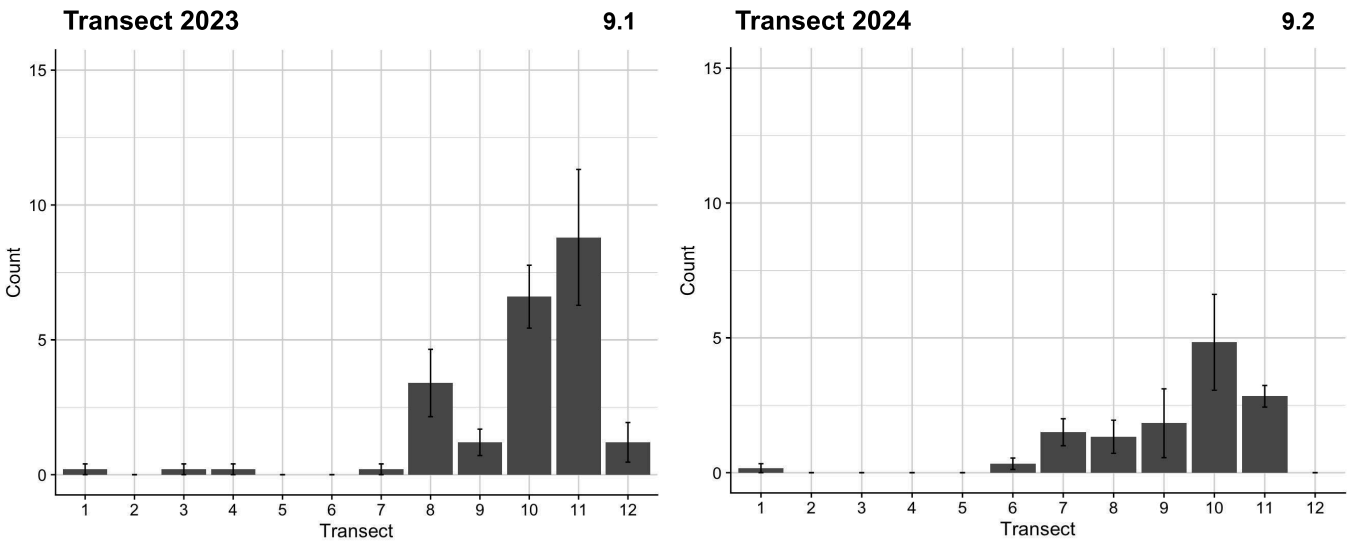


Figure 9: The average number of rabbits seen per section of the route. The route was completed five times in 2023 and six times in 2024

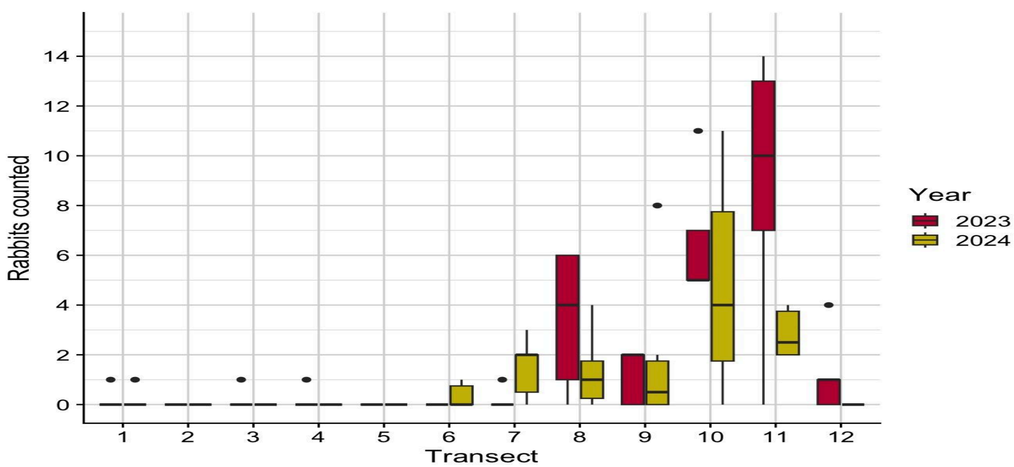


Figure 10: Comparison between the transect sections from both 2023 and 2024

Wildlife camera observations

As mentioned, wildlife camera observations were done in plots 1, 2, 4, 5, 19, 20 and 21. Using this method, only in plot 19 a rabbit was spotted. In plot 4 a rat was seen in what was thought to be a rabbit hole and in plot 2 a hare. The rabbit that was observed in plot 19 is shown in figure 11. In 2023 rabbits were found in plots 5 and 20, which are both near plot 19 on the western part of the island. An overview of the wildlife camera observations can be found in table 3.

Figure 11: Rabbit observed in a hole in plot 19.

Location	First observation, rabbits seen?	Second observation, rabbits seen?	Max. amount of individuals per camera trap	Setup date 1	Retrieval date 1	Setup date 2	Retrieval date 2
1	No			15-05-2024	16-05-2024		
2	No			15-05-2024	16-05-2024		
3							
4	No	No		7-5-2024	8-5-2024	8-5-2024	9-5-2024
5	No			8-5-2024	9-5-2024		
7							
8							
12							
14							
18							
19	Yes		1	9-5-2024	10-05-2024		
20	No			13-5-2024	14-5-2024		
21	No			7-5-2024	8-5-2024		
22							
23							

Table 3: Overview of the locations, setup- and retrieval dates and whether a rabbit was seen during and observation. It is also noted how many individual rabbits per camera trap were captured.

Thermal imaging observations

Thermal imaging observations were done in five plots: 1, 4, 5, 19 and 20. Rabbits were observed in plots 5, 19 and 20. The most active was plot 19 with a total sighting of 3 rabbits. There was an average number of 1.2 rabbits counted per plot. In table 4, the results of the thermal imaging camera observation of plot 19 can be found. In table 5, a short overview is given for every plot. The results with the total rabbits counted per side of the plot can be found in appendix.

Figure 12: Thermal imaging camera observation plot 19 on 10-05-2024, image taken from the east side of the plot

Side	Total rabbits counted	Maximum rabbits per individual observation
North	0	0
East	3	1
South	2	1
West	2	1
Total rabbits in the location	**3**	

Table 4: Overview of a thermal imaging camera observation done in plot 19 on 10-05-2024. Shown are the total rabbits counted on each of the four sides of the plot, as well as the maximum rabbits seen per side

Total rabbits in the location 2023	Location	Total rabbits in the location 2024
-	1	0
0	2	-
6	4	0
1	5	1

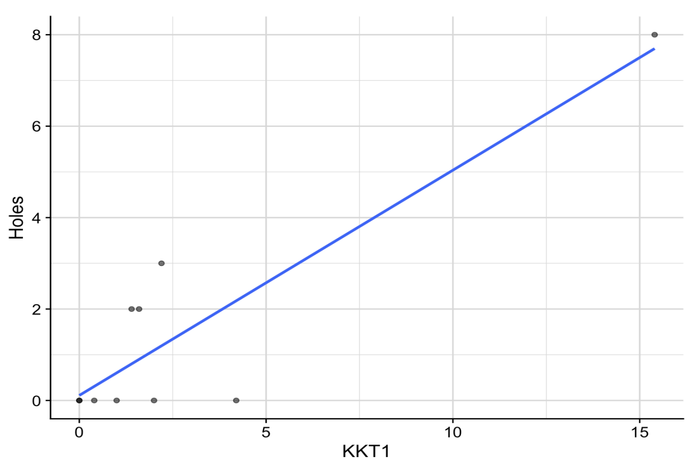
Table 5: Short overview of the number of rabbits observed using a thermal imaging camera per plot for both 2023 and 2024

Statistical analysis

A linear model is created with the first mean rabbit pellet count per plot (KKT1) as response variable and the number of holes as explanatory variable. The plots with goats and plots located in a breeding area are removed. A significant positive relationship is found in the model, the p-value being 0.000614 provided by the T1 Anova. The data is shown in figure 13.

Figure 13

13.1



13.2

```
lm(formula = (KKT1 ~ Holes), data = C)

Residuals:
    Min      1Q  Median      3Q     Max 
-3.0174 -1.6200 -0.2226  1.3274  3.7774 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)   0.4226     0.8357   0.506 0.626761    
Holes         1.5983     0.2937   5.443 0.000614 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.246 on 8 degrees of freedom
Multiple R-squared:  0.7874,	Adjusted R-squared:  0.7608 
F-statistic: 29.62 on 1 and 8 DF,  p-value: 0.0006139
```

Figure 13: This figure shows the linear model and the summary of the model. In figure 13.1 the linear model is shown using the first rabbit pellet count as response variable and the number of holes as explanatory variable. The KKT1 on the X-axis shows the mean of the first RPC. The number of holes is shown on the Y-axis. In figure 7.2 the summary of the linear model is shown

```
m1 <- lm((KKT1~Latrines) , data=C)
m2 <- lm((KKT2~Latrines) , data=C)
m3 <- lm((KKT1~Holes) , data=C)
m4 <- lm((KKT2~Holes) , data=C)
m5 <- lm((KKT1~Digs) , data=C)
m6<- lm((KKT2~Digs) , data=C)
```

Figure 14: Linear model data showing KKT as response variable and latrines, holes or diggings as explanatory variables

Further models were made with KKT as response variable and latrines or diggings as explanatory variables. As can be seen in figure 8, however, these did not produce significant results. When plotting them against each other utilizing a scatter plot, no relationships could be seen.

End Result

The results from 2024 of all five methods are combined into one figure, figure 8. The end results from 2023 are shown in the first figure of this section, which is figure 7. In both of these figures a heatmap is depicted showing the rabbit activity as well as the number of latrines, number of holes or burrows and the dropping counts. In 2024 the number of diggings is also shown. In both maps the green color represents low activity and red represents high activity.

Figure 8: Heat map showing the combined results of the five methods that were performed in 2023. The numbers in the circles represent the plot number. Box 1: Latrines, box 2: Holes or burrows, box 3: Total droppings in the first counting. The 12 transect sections are also depicted and in white the average rabbit observations per section are shown. Source: Huizinga, S. & Mulder, S. (2023)

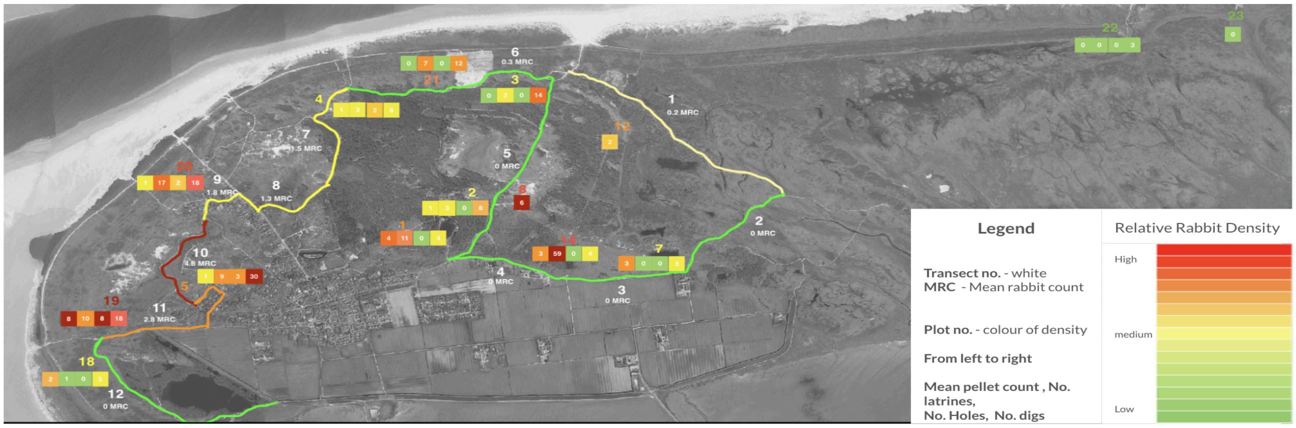


Figure 9: Heat map showing the combined results of the five methods that were performed in 2024. The numbers above the boxes represent the plot number. Box 1: Mean dropping count over the two rounds, box 2: Latrines, box 3: Holes or burrows, box 4: Diggings. The 12 transect sections are also depicted and in white the average rabbit observations per section are shown

Discussion

As previously mentioned, the average dropping count taken over all the plots was higher this year (2024) than it was last year in 2023. The average initial count per plot this year was 3.15 (with outliers removed) whereas last year it was 2.9. The average second count this year was 0.68 (with outliers removed) whereas last year it was 0.52. By looking at the dropping counts alone, we can see a slight increase in rabbit activity this year compared to last year. There can be multiple explanations for this. One explanation is that there are more rabbits this year and thus more droppings were counted. The amount of rainfall leading up to the counts could also affect the count (Iborra & Lumaret 1997), as rainfall can wash pellets away and also increases the degradation rate of the rabbit droppings. Dropping counts were a vital sampling method which gave a great indication of the amount of rabbit activity within the plot. However the dropping counts lack the ability to produce an actual number of rabbits per plot on their own, potentially with continued practice of the method on Schier, predictive models could be made allowing us to quantify the number of rabbits (Fernandez‐de‐Simon et al., 2011).

Mapping of the plots provided an in depth and insightful indication of the level of rabbit activity in the plot. Numbers of latrines, digs and holes could be compared allowing comparison of plots, allowing us to produce a ranking. This ranking was used to create an order of plots to be sampled with a wildlife camera and the thermal imaging camera where plots which ranked the highest (had the most activity) took priority.

The transect method was also proved to be an effective method to observe the distribution of rabbits on Scheir, supporting the observable differences between plots. The transect method is also being done in other dune habitats in the Netherlands (Van Strien et al., 2011b) and so results from this method are comparable between locations, and populations can be estimated.

Placing the wildlife cameras on holes produced little in terms of positive results, as it required the camera to be in the right place at the right time. To increase the reliability of the wildlife cameras a more systematic approach could be utilized, placing the cameras on holes and latrines for 12 hours at a time for a total of three times per location. Rabbit burrows have multiple entrances and exits (Kolb, 1985) and so even though we placed the cameras on the holes the rabbits could have chosen another path out of their burrow if they were suspicious of the camera.

Similarly, thermal imaging observations also required you to be in the right place at the right time. Thermal imaging observations did conclude multiple positive results, however these results could be further positively impacted by a more systematic approach. As completing the thermal imaging multiple times per location, gives you a greater chance to be a the right the place at the right time and therefore potentially yield more positive results creating better averages.

In conclusion, there was no one sampling method that produced the “best” results. It is the combination of all methods, performed in the correct order that produces the most accurate estimate for the rabbit abundance. The order of methods is as followed; dropping counts, mapping the plots, placing of trail cameras, thermal imaging camera observations and biking the transect route. As mentioned earlier, this is because the dropping counts and the mapping of the plots give a good indication of which plots contain the most rabbit signs. Utilizing this information, camera traps can then be placed on holes found when mapping the plots, to ensure that the burrow is being used by a rabbit. Once we know the burrow is being used by a rabbit we can then conduct thermal imaging sessions to estimate the number of rabbits in the plot. The transect route gives a good estimate of where the rabbits are most densely populated, helping to fortify the conclusions drawn from the dropping counts and the mapping of the plots, that the rabbit population density is highest in the west corner of the island.

That being said, if time was an issue and you wanted to rapidly find the rabbit distribution, you could either map the plots, only counting rabbit holes, or only do the RPC. We found that rabbit holes were linearly related to the RBC (utilising the statistical tests and plots mentioned earlier), concluding the same results in terms of distribution. Thus one or both of these methods could be considered the ‘best’ in terms of predicting rabbit abundance.

As for whether the rabbit distribution has changed compared to last year, we found that it had not. This was concluded by combining all the sampling results into a heat map as done in the previous year. This produced different counts per sampling method, and so potentially the number of rabbits is different this year than it was last year. However their relative distribution on Schiermonnikoog remains the same, they are most densely populated in the western side of the island.

This can be explained by the different habitat types in the different regions of the island. The western side of the island contains old dune habitat which in most places is well above the water table. The eastern side of the island consists largely of tidal (salt) marsh habitat with some newer dunes scattered throughout. Rabbits are heavily dependent on their burrows, their burrow depth providing insulation and protection from heat, cold, weather and predation (Morton, 2002). Building burrows on the eastern side of the island can only be done in a handful of locations, primarily on the few dunes that are present there, as otherwise their burrows would be at risk of flooding on spring tides and in periods of heavy rainfall, potentially drowning all the rabbits inside. See images below.

West side

East side

Furthermore, you can also see clear differences in the vegetation, again effecting the distribution of rabbits (Lombardi et al., 2003). The western side contains primarily typical short dune grasses; Violo Corynephoretum, Tortulo-Phleetum arenarii, Festuco-Galietum maritimi and Anthyllido-Silenetum nutantis (Yvonne et al, 1983.), as well as shrubs such as hawthorns and blackthorns. As already mentioned earlier, rabbits like to graze on new growth of grasses and the bushes (Bakker et al. 2005). Thus it seems they have a preference for these shorter grasses over the taller and salt tolerant grasses seen on the eastern side such as; Dune foot, Juncus-Suaeda-Limonium and Juncus-Artiplex-Festucs (Habtamu, 2006). However more specific research must be done to conclude this in a scientific manner rather than a purely observational manner.

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References

Bakker, E. S., Reiffers, R., Olff, H., & Gleichman, J. (2005). Experimental manipulation of predation risk and food quality: Effect on grazing behaviour in a central-place foraging herbivore. Oecologia, 146, 157–167.

Dekker, JJA & E Van Norren, 2021. Achteruitgang van haas en konijn sinds 1950. Oorzaken en beschermingsmogelijkheden. Rapport 2020.24. Zoogdiervereniging, Nijmegen.

Drees, J.M., 1992. Konijn, Oryctolagus cuniculus. In: S. Broekhuizen, B. Hoekstra, V. Van Laar, C. Smeenk & J.B.M. Thissen (red.). Atlas van de Nederlandse Zoogdieren. Stichting Uitgeverij KNNV, Utrecht.

DiNapoli, R. J., & Leppard, T. P. (2018). Islands as Model Environments. Journal Of Island And Coastal Archaeology/Journal Of Island & Coastal Archaeology, 13(2), 157–160. https://doi.org/10.1080/15564894.2017.1311285

Fernandez-de-Simon, J., Díaz-Ruiz, F., Villafuerte, R., Delibes-Mateos, M., & Ferreras, P. (2011). Assessing predictors of pellet persistence in European rabbits Oryctolagus cuniculus: towards reliable population estimates from pellet counts. Wildlife Biology, 17(3), 317–325. https://doi.org/10.2981/10-001

Gálvez, L., J. Belliure, and S. Rebollo. 2009. European rabbits as ecosystem engineers: warrens increase lizard density and diversity. Biodiversity and Conservation 18 (4): 869–885.

Hepler, P. K. (2005b). Calcium: A Central Regulator of Plant Growth and Development. ˜The œPlant Cell, 17(8), 2142–2155.
https://doi.org/10.1105/tpc.105.032508

Iborra, O. L. and J. P. Lumaret. 1997. Validity limits of the pellet group counts in wild rabbit (Oryctolagus cuniculus). *Mammalia* 61 (2): 205–218.

IJzer, J., Y.R.A. Van Zeeland, M.G.E. Montizaan, H.F. Egberink, P. König, I.M. van Geijlswijk, 2016. Introductie van een nieuw type virus in Nederland in 2015. Rabbit Haemorrhagic Disease Virus-2 (RHDV2): bij de konijnen af. Tijdschrift voor Diergeneeskunde 3: 24-29.

Kaetzke, P., Niedermeier, J., & Masseti, M. (2003). Oryctolagus cuniculus (Linné, 1758) – Europäisches Wildkaninchen. In J. Niethammer, & F. Krapp (Eds.), Handbuch der Säugetiere Europas. Band 3/II Hasentiere. Wiebelsheim: Aula-Verlag.

Kolb, H. H. (1985). The burrow structure of the European rabbit (Oryctolagus cuniculus L.). Journal Of Zoology, 206(2), 253–262. https://doi.org/10.1111/j.1469-7998.1985.tb05649.x

Lombardi, L., Fernández, N., Moreno, S., & Villafuerte, R. (2003). Habitat-Related Differences in Rabbit (Oryctolagus cuniculus) Abundance, Distribution, and Activity. *OUP Academic*. https://doi.org/10.1644/1545-1542(2003)084

Mahtani, K., Spencer, E. A., Brassey, J., & Heneghan, C. (2018). Catalogue of bias: observer bias. BMJ Evidence-based Medicine, 23(1), 23–24. https://doi.org/10.1136/ebmed-2017-110884

McColl, K. A., Merchant, J. C., Hardy, J., Cooke, B. D., Robinson, A., & Westbury, H. A. (2002). Evidence for insect transmission of rabbit haemorrhagic disease virus. *Epidemiology and infection*, *129*(3), 655–663. https://doi.org/10.1017/s0950268802007756

Morton, D. B. (2002). Behaviour of rabbits and rodents. In *CABI Publishing eBooks* (pp. 193–209). https://doi.org/10.1079/9780851996028.0193

Mulatu, H. (2006). Land covers change detection using Expert System and Hyperspectral imagery in the Islands of Schiermonnikoog, The Netherlands.

Neave, M. J. & Hall, R. N. & Huang, N. & McColl, K. A. & Kerr, P. & Hoehn, M. & Taylor, J. & Strive, T. (2018). Robust Innate Immunity of Young Rabbits Mediates Resistance to Rabbit Hemorrhagic Disease Caused by Lagovirus Europaeus GI.1 But Not GI.2. Viruses, 10(9), 512. https://doi.org/10.3390/v10090512

Nierop, Y. D. B., & Van Der Meijden, E. (1984b). The influence of rabbit scrapes on dune vegetation. *Biological Conservation*, *30*(2), 133–146. https://doi.org/10.1016/0006-3207(84)90062-4

Siebenga, S., 1991. Virusziekte bij hazen (EBHS) en konijnen (VHS) nu ook in Nederland. De Nederlandse Jager 96: 4-6

Tellegen, C. (2011). Geef het konijn de ruimte op Schiermonnikoog [Masterthesis]. Wageningen University.

Van de Ende 2015, Ruimtelijke ecologie en prooi keuze van gezenderde verwilderde katten op Schiermonnikoog

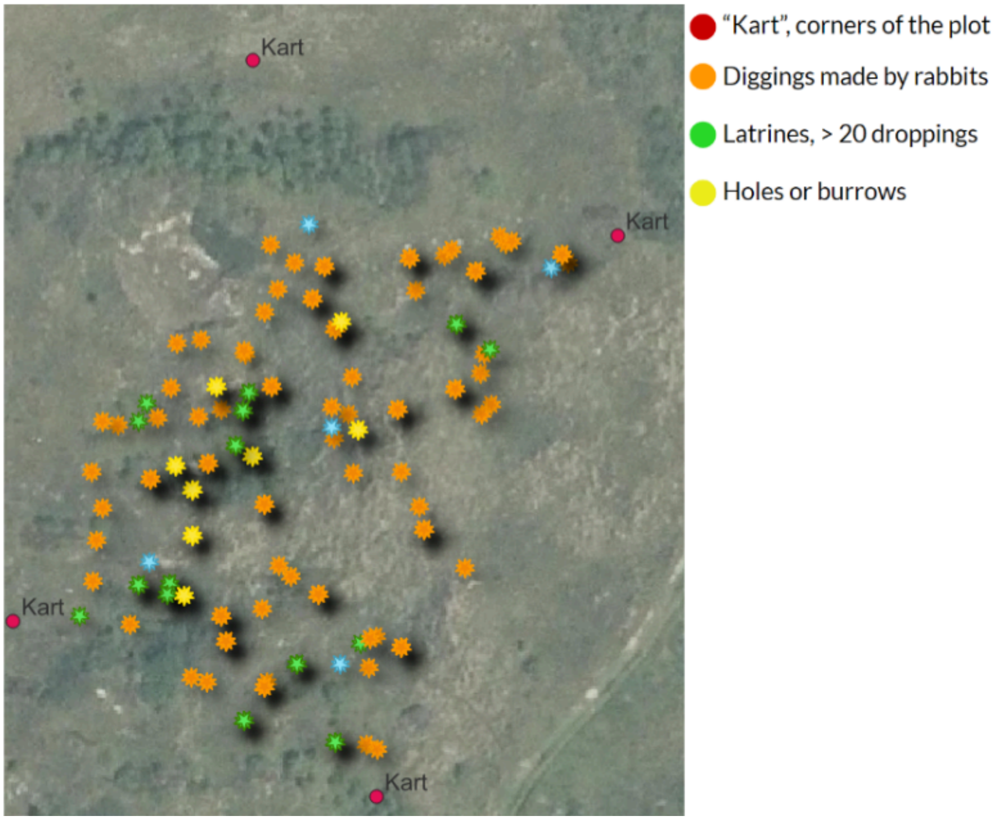
Van Strien, A. J., Dekker, J., Straver, M. E., Van Der Meij, T., Soldaat, L., Ehrenburg, A., & Van Loon, E. E. (2011). Occupancy dynamics of wild rabbits (Oryctolagus cuniculus) in the coastal dunes of the Netherlands with imperfect detection. Wildlife Research. https://doi.org/10.1071/wr11050

Appendix - Mapping

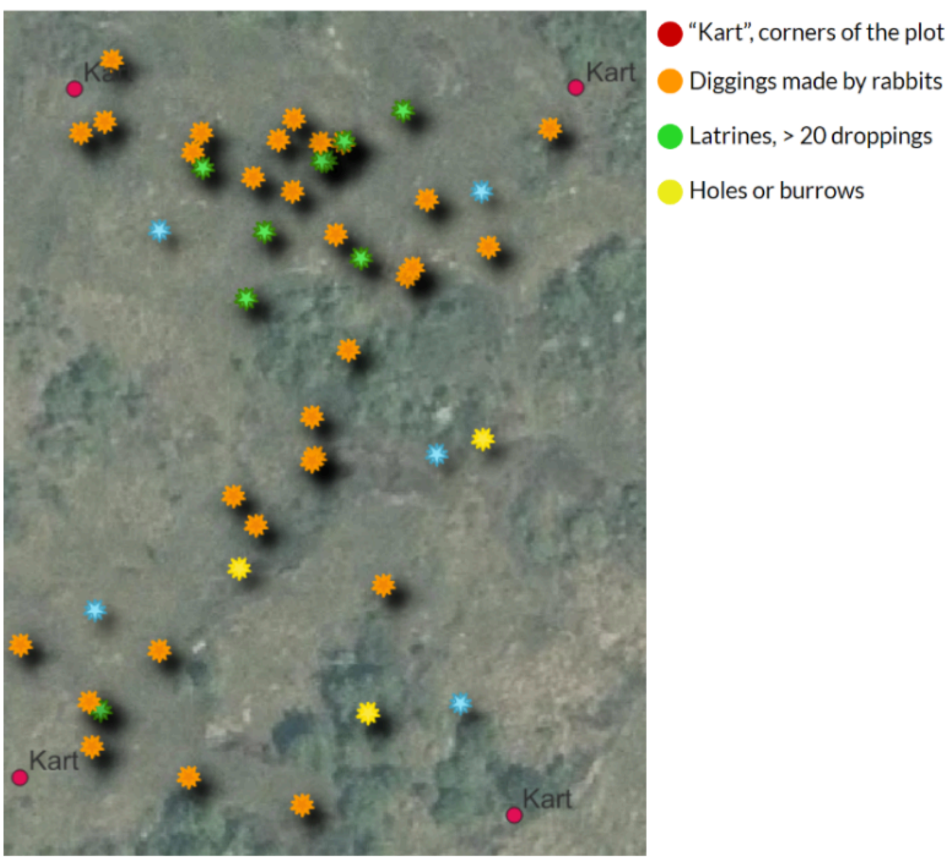
This appendix, appendix b, contains all results of the mapping method. This method is performed in 12 of the 15 plots, the exceptions being plots 8, 12 and 23. They were not mapped due to the disturbance during breeding season. The locations are shown in order from west to east on the island. Above every picture is noted what plot is shown.

Plot 18

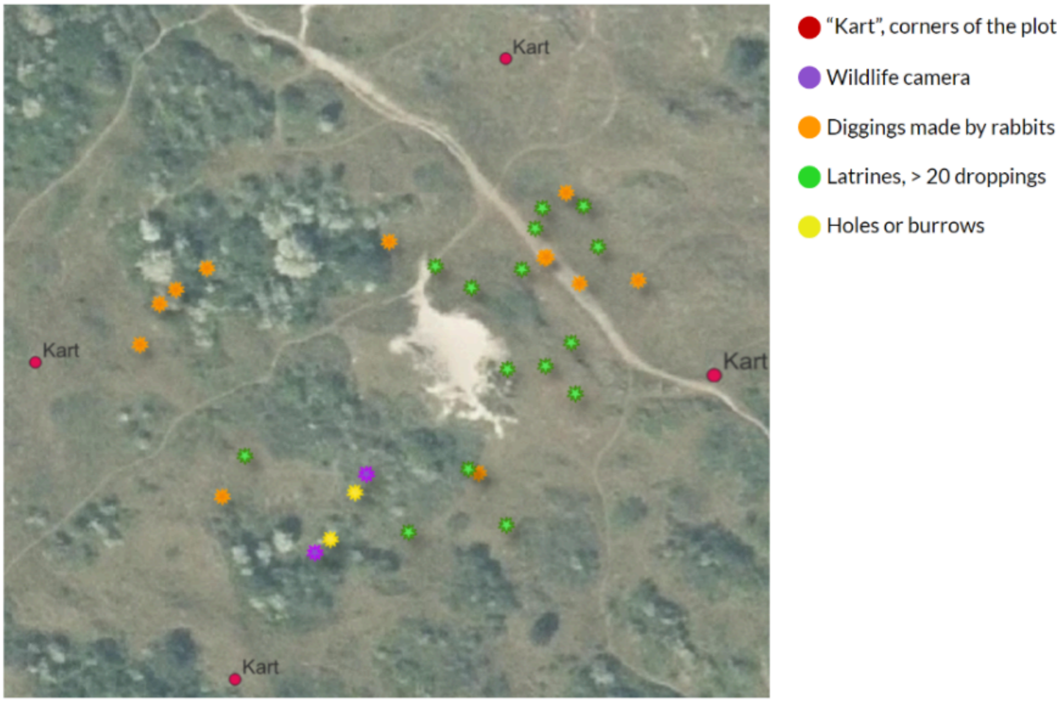
Plot 19



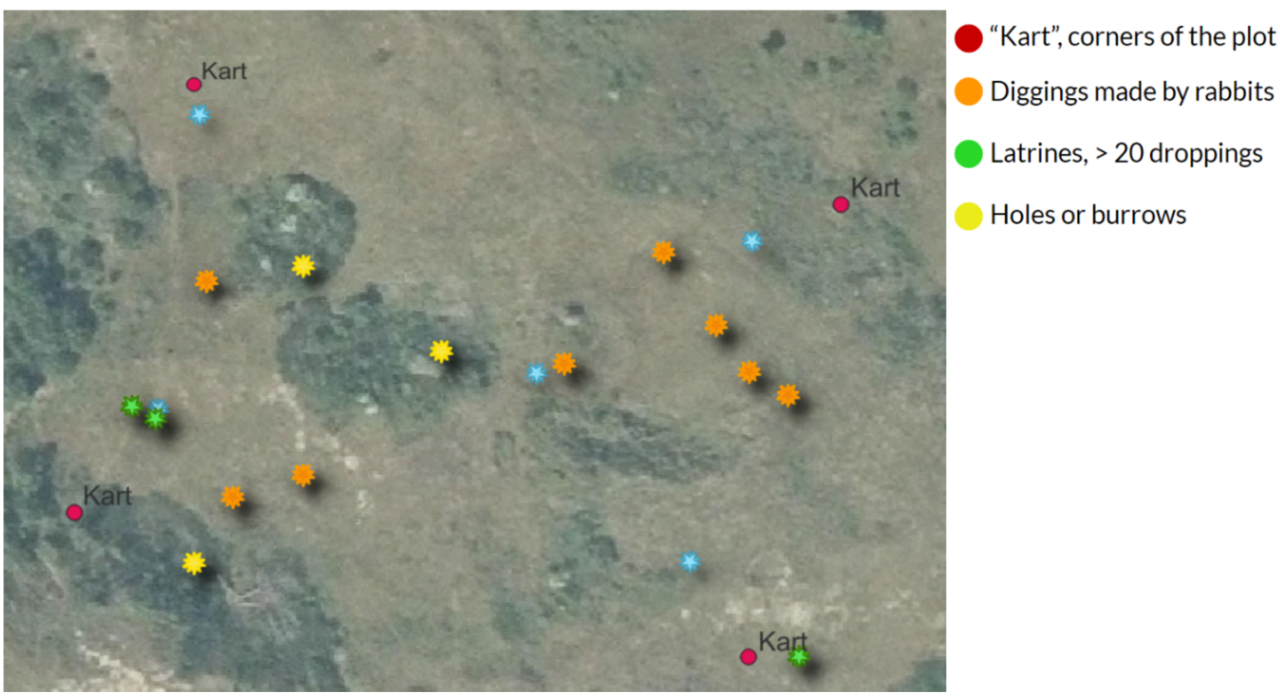
Plot 5



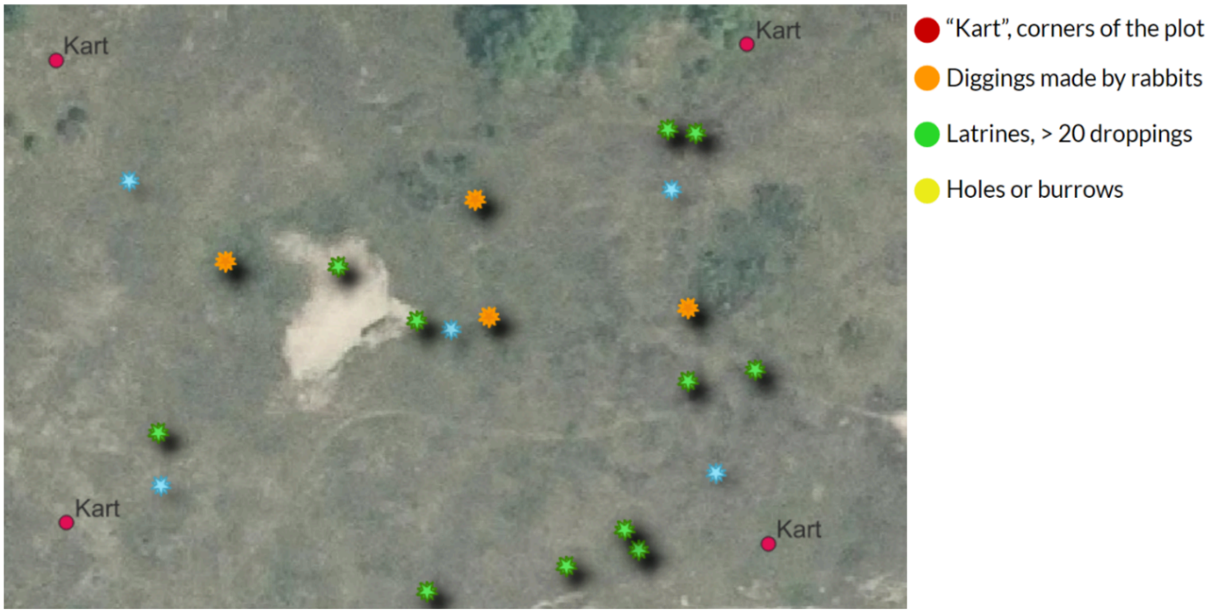
Plot 20



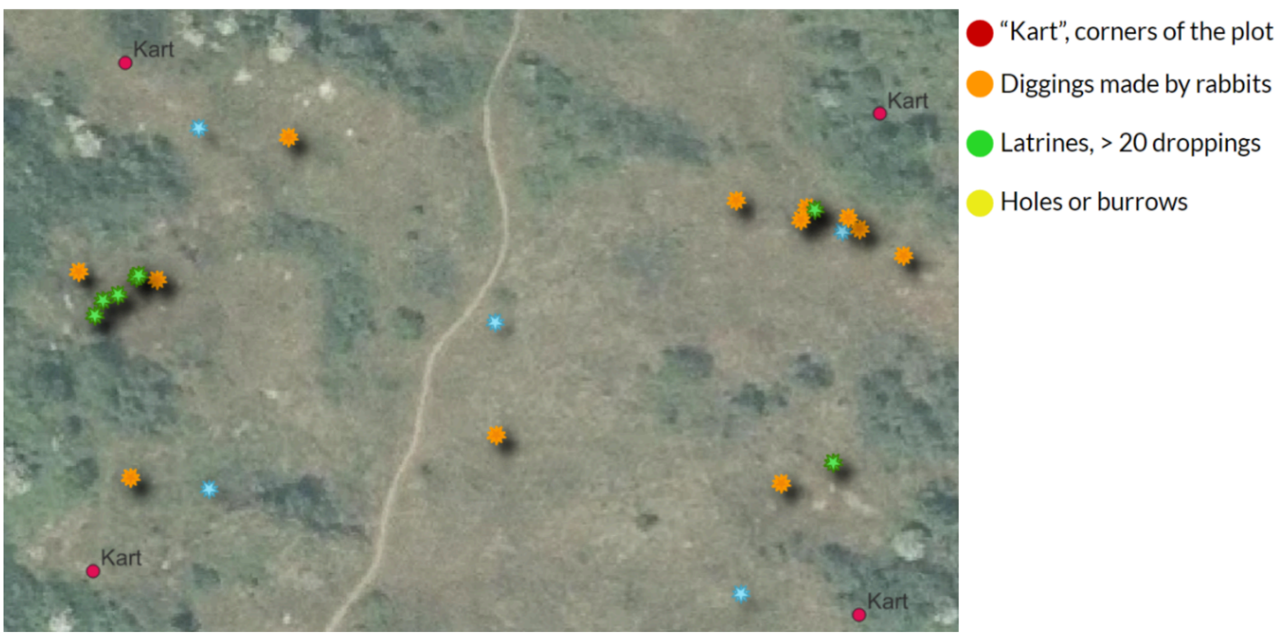
Plot 4



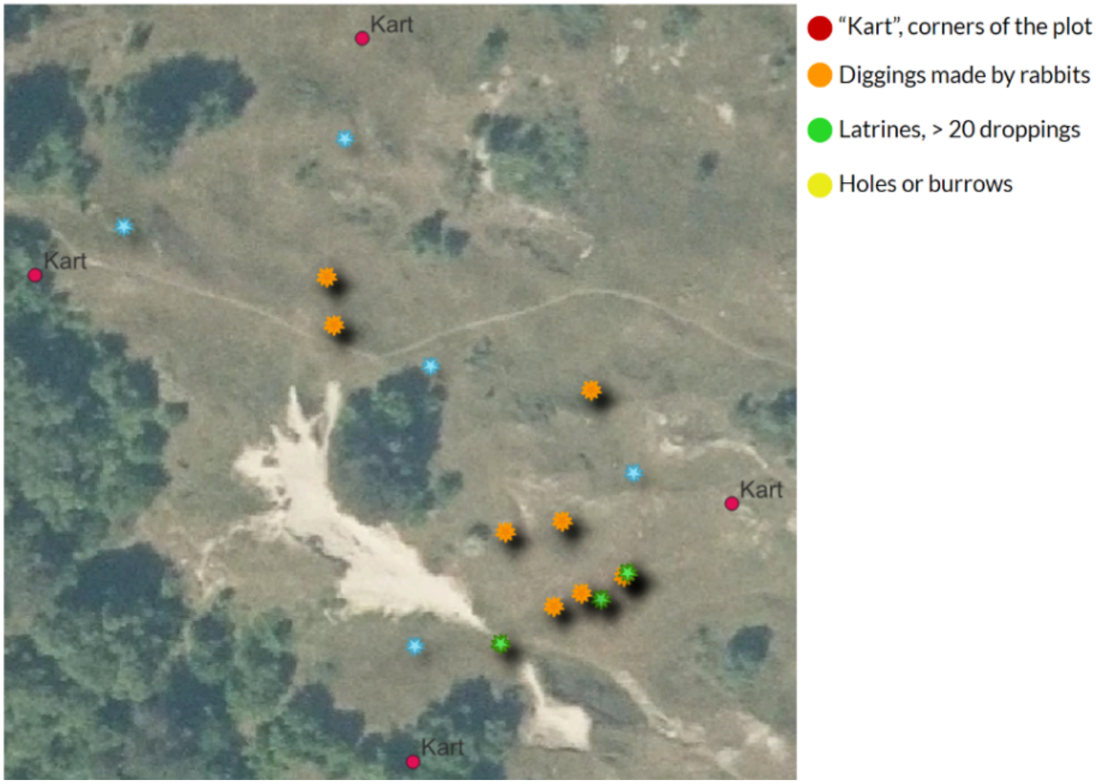
Plot 1



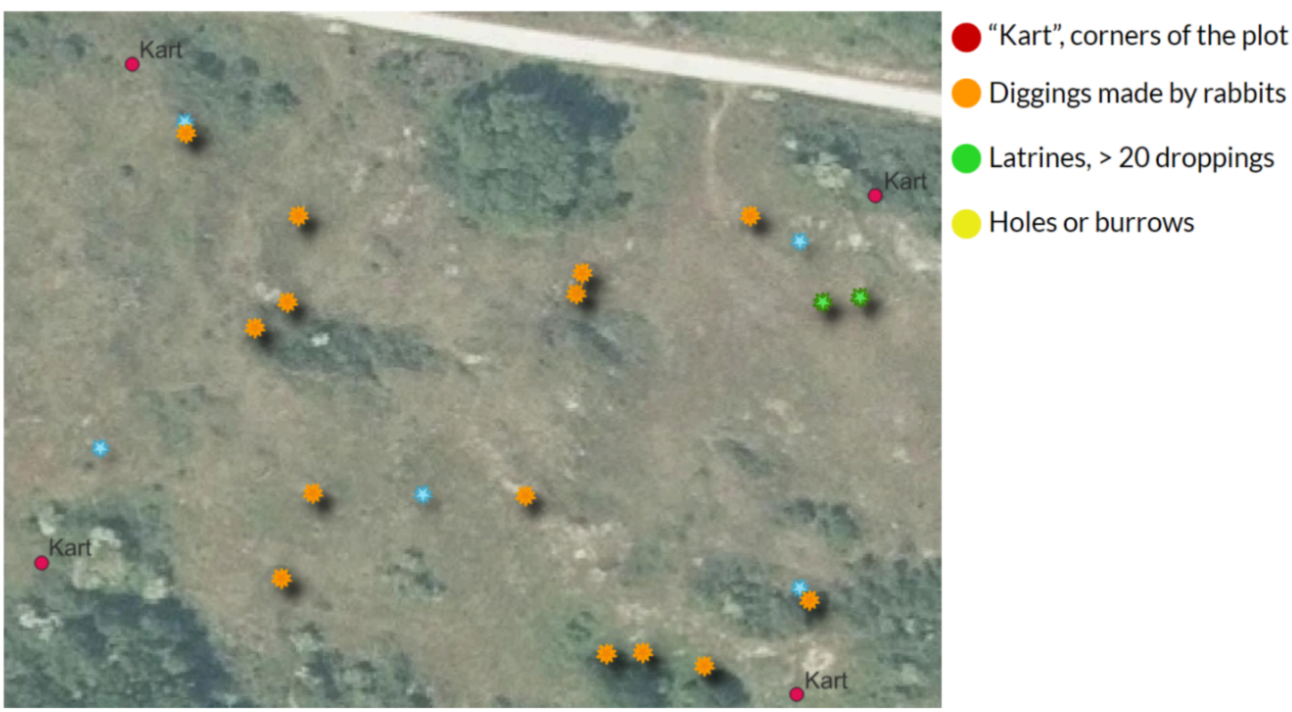
Plot 21



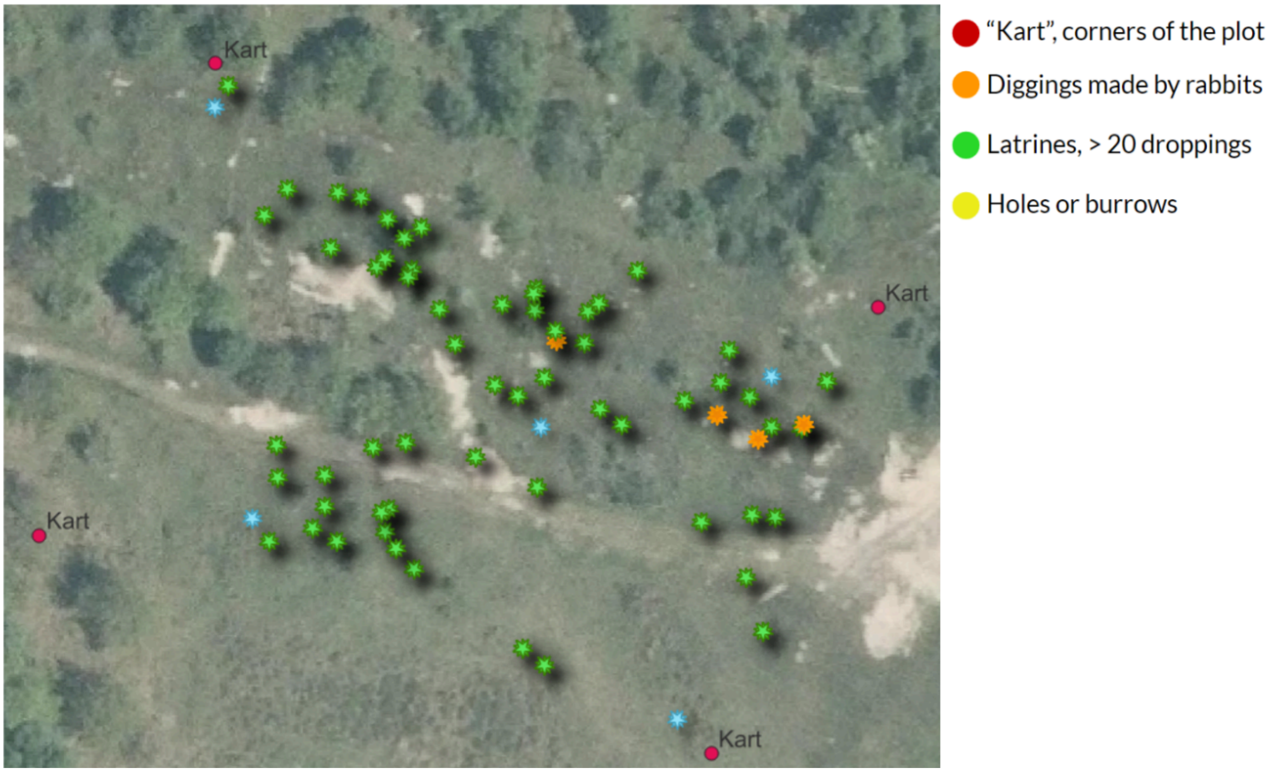
Plot 2


Kart
Kart
Kart
Kart
"Kart", corners of the plot
Diggings made by rabbits
Latrines, > 20 droppings
Holes or burrows

Plot 3


Kart
Kart
Kart
Kart
"Kart", corners of the plot
Diggings made by rabbits
Latrines, > 20 droppings
Holes or burrows

Plot 14



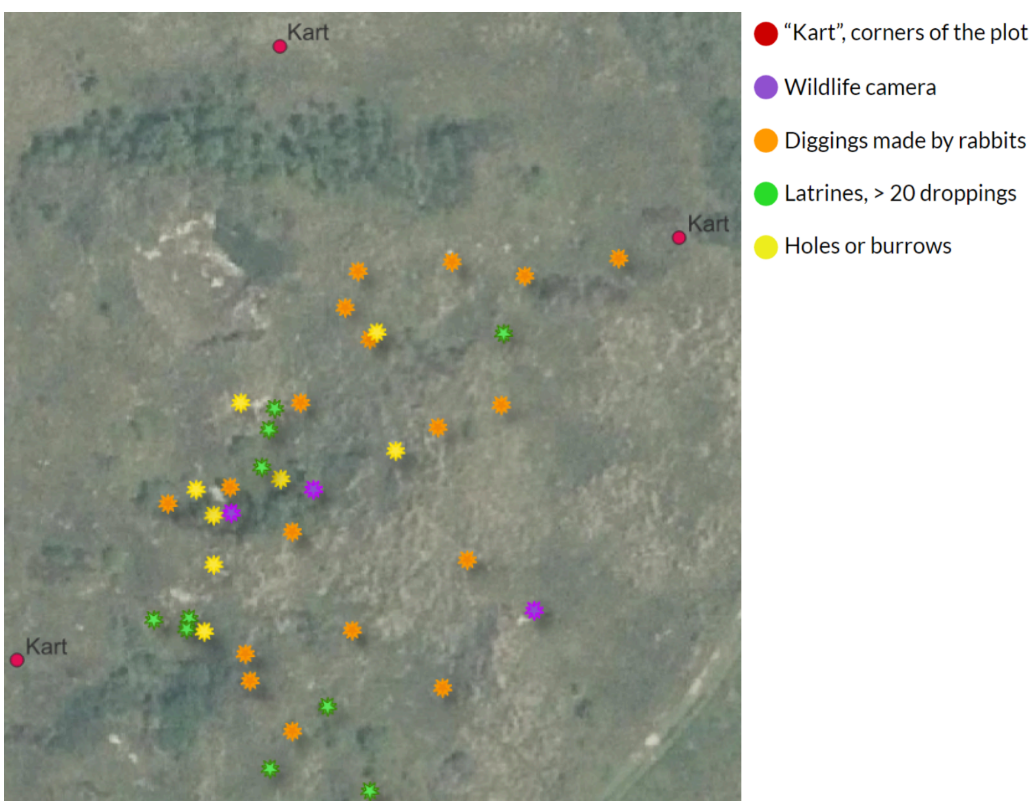
Plot 7

Plot 22

Appendix - Wildlife camera observations

This appendix, appendix a, contains all locations of the placement of the wildlife cameras. The three cameras that were used all had a number and the same SD-card was kept in each of the cameras in order to avoid any confusion or mistakes being made regarding the footage. The locations are shown in order from west to east on the island. Above every picture is noted what plot is shown and at what date the camera was placed.

Plot 19, 09-05-2024



Appendix - Thermal imaging camera observations

This appendix, appendix c, contains all thermal imaging camera observation results. The locations are shown in order from west to east on the island. Above every picture is noted what plot is shown and at what date the observation was done.

Location 19, 10-05-2024

Side	Total rabbits counted	Maximum rabbits per individual observation
North	0	0
East	3	1
South	2	1
West	2	1
Total rabbits in the location	**3**	

Location 5, 09-05-2024

Side	Total rabbits counted	Maximum rabbits per individual observation
North	1	1
East	1	1
South	0	0
West	1	1
Total rabbits in the location	**1**	

Location 20, 14-05-2024

Side	Total rabbits counted	Maximum rabbits per individual observation
North	0	0
East	1	1
South	1	1
West	0	0
Total rabbits in the location	**1**	

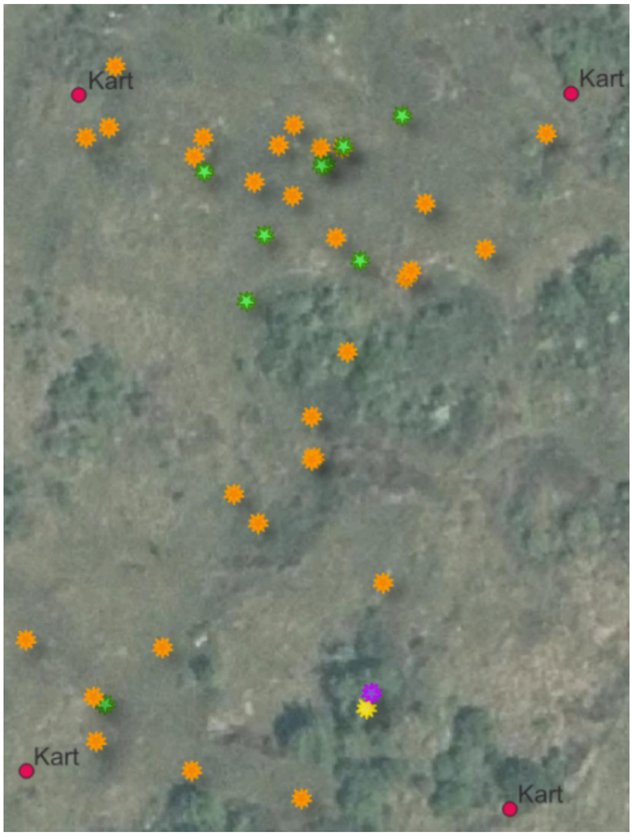
Location 4, 23-05-2024

Side	Total rabbits counted	Maximum rabbits per individual observation
North	0	0
East	0	0
South	0	0
West	0	0
Total rabbits in the location	**0**	

Location 1, 16-05-2024

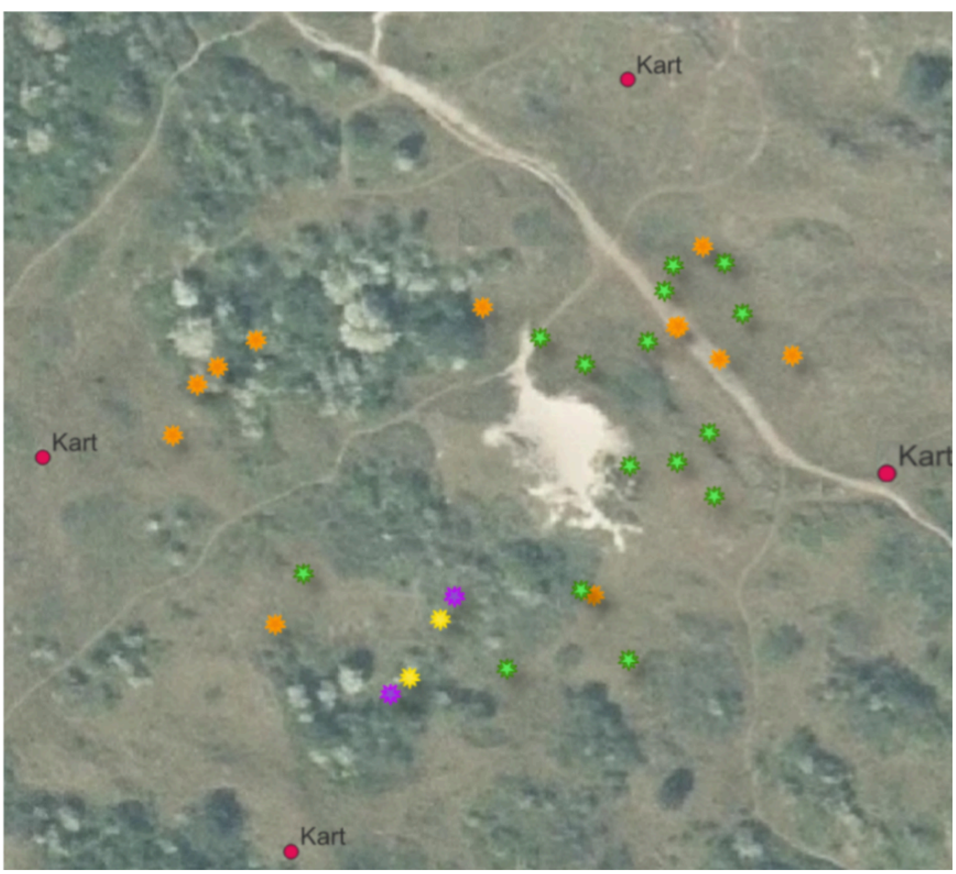
Side	Total rabbits counted	Maximum rabbits per individual observation
North	0	0
East	0	0
South	0	0
West	0	0
Total rabbits in the location	**0**	

Plot 5, 08-05-2024



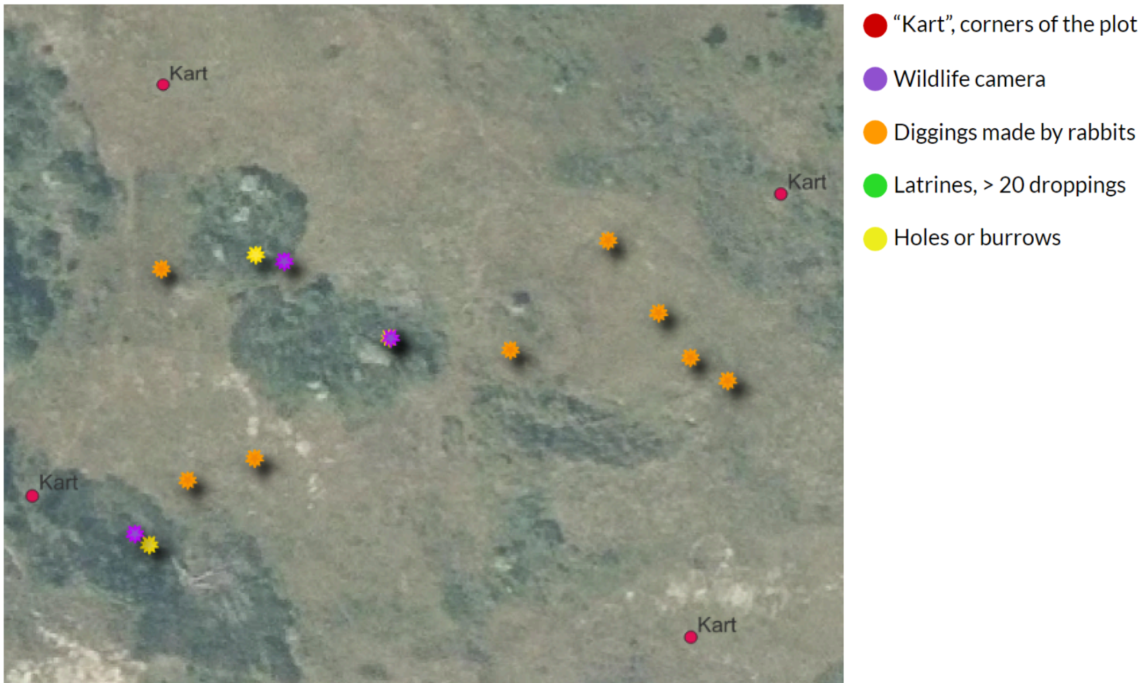
"Kart", corners of the plot
Wildlife camera
Diggings made by rabbits
Latrines, > 20 droppings
Holes or burrows

Plot 20, 13-05-2024

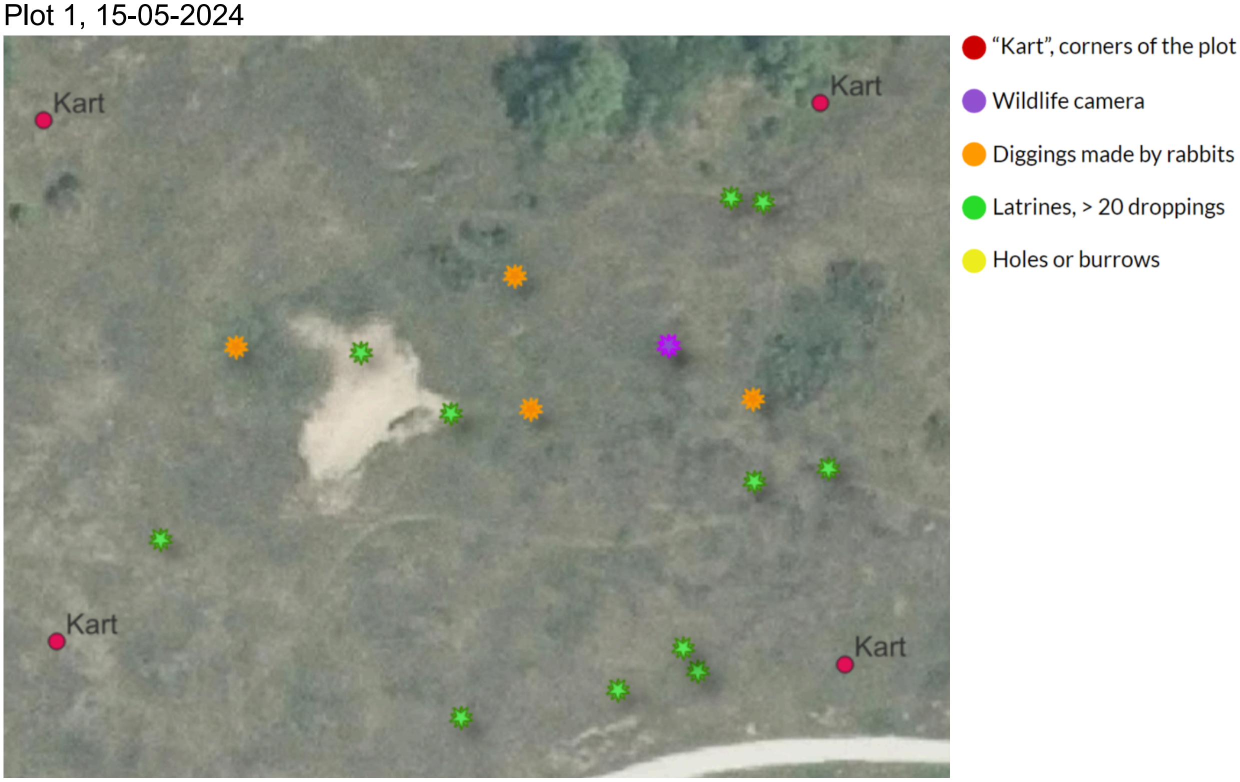


"Kart", corners of the plot
Wildlife camera
Diggings made by rabbits
Latrines, > 20 droppings
Holes or burrows

Plot 4, 07-05-2024 and 08-05-2024



Plot 1, 15-05-2024



Plot 21, 07-05-2024

Plot 2, 15-05-2024