Individual internship report

4th year

Using sensors for insect monitoring and conservation in rewilded landscapes

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2024-2025

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Using sensors for insect monitoring and conservation in rewilded landscapes :

Evaluation of the impact of different land uses on arthropod communities and vegetation

Abstract :

This internship was conducted during 15 weeks within the Ecoscience department of Aarhus University, Denmark, within the field of ecology. The objective was to assess changes in vegetation and their relationship with arthropod communities under different land uses, in a site with a rewilding project since 2023. Vegetation productivity was quantified using the Normalized Difference Vegetation Index (NDVI) from satellite data, while arthropod abundance and diversity were assessed using pitfall traps. Three groups of arthropods among the most abundant were studied in more detail, namely the Carabidae, the Silphidae, and the Araneae. Results showed that arthropod abundance and diversity varied according to habitat type, with 'arable' and 'grazed' habitats supporting higher abundances. Former arable lands that had been sown showed greater species richness than unsown ones, and also the greatest increase in NDVI since the rewilding project. Correlations between NDVI and arthropods were generally weak to moderate and varied by taxonomic group, but were consistently stronger for 2024 NDVI than for 2022, suggesting that vegetation changes since the start of the project are already influencing arthropod distributions. This work provides baseline data to evaluate the evolution of vegetation and arthropod communities at Saksfjed, as a recent site of rewilding.

Key words : Rewilding - arthropods - biodiversity - sensors – satellite – NDVI - productivity - land use – pitfall traps – Carabidae – Silphidae - Araneae

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I. Acknowledgements

First of all, I would like to thank my internship supervisor Jamie Alison for accepting my internship application and welcoming me to the Department of Ecosciences at Aarhus University under his supervision. I would also like to thank him for his trust, the time he gave me to help me, and his willingness to make me discover many things.

I would also express my appreciation to my academic supervisor, Mr Isselin, for his support and assistance, particularly when I encountered problems.

Then, my sincere thanks go to Helena Russello, whom I was able to assist on numerous occasions in the laboratory and in the field, and close to our pollinator friends.

Also, I am grateful to my other colleagues from the section for the integration, the shared lunches and their help whenever I needed it.

Finally, I am deeply thankful to my friends and colleagues Florian Tillon and Mathilde Sandron, with whom I visited the city and all of Denmark and who helped me a lot, as much to organize trips and visits as to answer my questions.

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IV. Introduction

A. Aarhus university as a host institution

As part of my fourth year at the Polytech Tours engineering school in urban planning and environment, I completed a 15-week research internship in the Department of Ecoscience at Aarhus University in Denmark from May to August 2025.

Aarhus University is one of Denmark's largest higher education institutions. Founded in 1928, it is located in the city of Aarhus, the country's second largest city on the east coast of Jutland, Denmark's large peninsula. The university is internationally recognised for the quality of its research programmes. It has approximately 40,000 students and attracts many international students. Also, it has thirty-two departments, in various areas and I'm integrating the Department of Ecoscience that is part of the Faculty of Technical Sciences. It is a research and teaching centre in the field of the environment and ecological sciences. Its aim is to study and understand terrestrial, aquatic and atmospheric ecosystems and to promote sustainable solutions to environmental challenges, including climate change, biodiversity loss and natural resource management. In addition, it participates in numerous national and European projects, particularly in relation to environmental monitoring and ecological modelling.

The department is structured into several research units according to field (see appendix 1 for the organisation chart). I am in the biodiversity section in the building where people work mainly on wildlife management and terrestrial ecology. I was integrated into its midst a team working specifically on the development of automated and intelligent systems for monitoring wildlife populations such as arthropods or pollinators. This allowed me to discover all aspects of the profession of ecological researcher.

B. Missions and objectives

In response to the erosion of biodiversity and the degradation of ecosystems linked to human activities, numerous ecological restoration initiatives are emerging. Among these, rewilding is becoming more common in Europe. Rewilding is defined as the passive management of ecological succession with the goal of restoring natural ecosystem processes and reducing the human control of landscapes (Pereira and Navarro, 2015). It is often carried out in formerly intensive agricultural land.

Therefore, it is important to assess the effectiveness of these projects and their real impact on biodiversity, particularly on insects and other arthropods, which are key players in terrestrial ecosystems and among the first victims of biodiversity decline. Furthermore, there is a wide variety of species, and they can be very sensitive to environmental changes, making them good ecological indicators. Their composition and abundance can reflect the effects of land use changes, making their study relevant for assessing the ecological health of this environment. This would enable us to determine if renaturation is an appropriate management method on formerly intensive agricultural land. Also, it would be interesting to observe if results differ from rewilding less intensively farmed land.

This is specifically what is being studied through the LRB23 project led by Jamie Alison at Saksfjed Vildmark, an emerging rewilding project in Lolland in Denmark on former agricultural lands. It is providing the opportunity to monitor the impacts of rewilding and generate rigorous baseline data on ground-dwelling invertebrates. My work is part of this project, in collaboration with the managers of Saksfjed Vildmark, to obtain data to observe and understand the evolution of the site in terms of vegetation and arthropods.

To do this, an indicator of interest is the Normalized Difference Vegetation Index (NDVI). It is a spectral index widely used in remote sensing to assess the presence of healthy green vegetation.

The objective was to use remote sensing data of NDVI and data from a sampling of arthropods to assess the effects of the rewilding project on vegetation and arthropod communities for different former land uses. In addition, it is interesting to determine whether there is a potential relationship between NDVI and the abundance and species richness of these arthropods.

To achieve this objective, this report will seek to answer the following questions. How does the composition and abundance of arthropods vary according to different land uses ? How is the vegetation affected by the rewilding project and according to different land uses ? Can a relationship be established between vegetation activity and the abundance of terrestrial arthropods ?

My mission consists of acquiring NDVI data from satellite imagery sites, formatting this data in a clear and readable manner with graphs and maps, and then analysing it. I also have a set of data from pitfall traps to process and analyse, particularly through graphs. In addition, communication work is required, including co-writing a blog post about this work in addition to the report.

Also, a parallel mission consists of assisting my supervisor Jamie Alison and one of his colleagues, Helena Russello, both in the laboratory to build field equipment such as automatic camera systems, and in the field to install these cameras, check that the equipment is working properly, and carry out pollinator surveys. Although these tasks are interesting and important, they are not all directly related to the subject of this report and will therefore not be presented.

This report is organized according to the scientific method. It includes a first section presenting the materials and methods used, followed by the results which will be presented. Finally, the results will be analysed and discussed considering current knowledge on the ecology of rewilding and the different responses of insects depending on their habitat. Each of these sections will be divided into three parts, beginning with the impact of different land uses on arthropod communities, followed by the impact of land use on vegetation using NDVI, and finally the relationship between arthropods and vegetation to see their potential correlation.

V. Materials and methods

A. The impact of different land uses on arthropod communities

The objective of this first part is to study the results of arthropod sampling from traps set up at the study site. This will enable us to analyse their composition and distribution according to different land uses.

1. Saksfjed Vildmark, site presentation

a) An important rewilding project on a coastal area

Saksfjed Wilderness is a large coastal area of 800 ha located in the southern part of Lolland, Denmark, owned by the Hempel Foundation. The site was dominated by farming and forestry until January 2023 when it was purchased by the Hempel Foundation, the current owners to develop one of Denmark's most ambitious rewilding projects. Rewilding can be defined simply as a scientific method for achieving a wilder nature. Now, the landscape composed mainly of meadows, forests and wetlands is evolving into a wilderness with open woodlands, flower-rich grasslands with scattered vegetation, wet meadows, and other wetlands. Also, the area is grazed by large herbivores with 51 Exmoor horses and 135 Galloway oxen. They are doing an important job for example by creating landscape variation and by keeping vulnerable habitats such as meadows, grassland, and wetlands open by grazing on vegetation protecting rare species of flowering plants and insects.

The site is protected under the Danish Natura 2000 law and has significant ecological potential. Especially for its location as an important stepping stone on the migration route of several species through Northern Europe. In fact, it is also classified as a Community Bird Protection Area and a Ramsar Site for wetlands. Also, 107 redlisted species have been spotted on the site creating an area with real environmental challenges.

The Wilderness is equally a laboratory for research, animal monitoring and baseline surveys ensuring its contribution to developing best practices for the benefit of everyone involved in nature restoration and biodiversity. Thus, knowledge is widely communicated through education, social media and activities to children, adults and decision-makers.

b) Different land uses

The study site comprises different environments and different land uses, depending on the management methods chosen. Before the rewilding project in 2023, the following land uses could be distinguished, which are represented in the map in Figure 1 below.

Coastal grasslands can be found on the southern coast of the site, characterised by treeless plains on sandy substrates, with herbaceous vegetation (grasses, creeping plants and salt-tolerant herbs) adapted to harsh maritime conditions such as wind, sea spray, salinity and poor soils.

Then, the fallow will be encountered in most of the Southern part of the site, it is agricultural land usually cultivated that is plowed and left unseeded for a season or more. Composed of ruderal plants (which grow on disturbed bare soil) and adventitious plants (formerly known as ‘weeds’), the vegetation is assumed to be much more diverse and spontaneous compared to arable land, depending on several factors such as the length of fallow time and past practices.

Another land use in Saksfjed is grazing, particularly in the eastern part of the site. The presence of grazing animals results in lower vegetation, which also depends on the number and type of animals and therefore the intensity of livestock farming.

Finally, the fields cultivated in 2023 are marked as arable and arable sown on the map below and are mainly located in the northern part of the site. In addition, this is intensive agriculture, using fertilisers, pesticides and heavy machinery to increase productivity and yield, at the expense of the surrounding biodiversity, and eradicating weeds between plantations. The most commonly sown crops were mainly wheat, barley and rape, so monocultures leaving little place for plant diversity.

It is also important to note the difference between the land uses “arable” and “arable sown”, which are marked as such on the map and will be used throughout this report. Both land uses were used as cultivated land before the rewilding project, but after the project, some of the former cultivated fields were sown with flower mixtures and are referred here as “arable sown”. The objective is to observe whether there is a real difference in terms of biodiversity on this land use compared to former cultivated fields that have not been sown, classified as ‘arable’. We will therefore take a closer look at these two land uses and compare them.

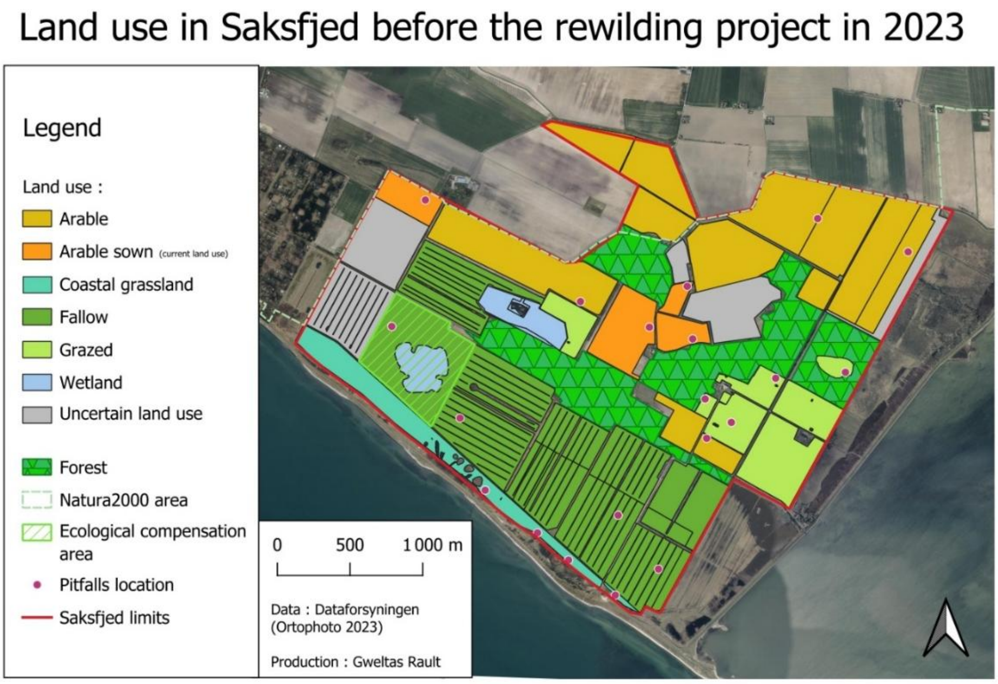

Figure 1: map of the different land uses in Saksfjed before the rewilding project in 2023.

The site is also divided by several areas of forest in the middle. These areas of vegetation are important for wildlife, such as deer and birds. However, they were not selected for insect sampling and will therefore not be studied in this report, given that these environments change less rapidly than the selected land uses.

Also, there is an ecological compensation area in the western part of the site, where a wetland area has been developed, providing new habitats for migratory birds, amphibians and other species. This was established to offset a part of the impacts of the major project to link Germany and the island of Lolland in Denmark by bridge or tunnel. A partnership has been established between the project owner and the Hempel Foundation, this part corresponds to the compensation part of the "Avoid, Reduce, Compensate" sequence requiring the restoration of an area twice as large as the one impacted.

2. Methods for collecting and identifying arthropods.

Within the study site of Saksfjed, pitfall traps were placed to sample terrestrial arthropod populations. These are passive traps designed to capture terrestrial arthropods such as spiders and beetles that are active on the ground surface. They consist of a small plastic cup buried in the ground with a soil corer. With its rim at ground level, animals fall into a liquid containing water and a preservative and are unable to escape. To protect it from rain, a small roof is added on top.

This method is very inexpensive, allowing for multiple surveys over large areas, and remains effective in capturing many individuals and species. However, some more active and larger species are overrepresented, such as beetles, while others are underrepresented. These are more estimates of activity-density (W. McCravy, 2018).

The study on site was conducted by Cecilia as a field surveyor, in 2024 during 16 days from 27/08 to 11/09. This was requested by Jamie Alison as part of the LRB23 project. A total of 20 pitfall traps were placed, distributed using a random sampling protocol across the five land uses presented above, with four pitfall traps per land use. However, one of the pitfall traps in the coastal grassland area was flooded and its data is unusable, leaving only three traps for this area compared to four for the other areas.

Pitfall traps are one of the traditional methods used to sample terrestrial invertebrates. However, new methods are being developed, such as camera systems for insects, which are one of Jamie Alison's main areas of research. The main challenge is identifying species from photographs, as insects are small and highly diverse. To this end, the growing development of AI and deep learning are essential tools for identifying these insects. In addition, this method has the advantage of not being lethal to the animals. However, it also means that the same animal may be counted several times, making this method more suitable for detecting species than for estimating abundance, which will be more approximate.

3. Data and indices of ecological diversity

The data obtained from the pitfall traps was recorded in an Excel spreadsheet, which I then used as a basis for analysis. This spreadsheet contains the groups of arthropods sampled, mostly in the form of orders or families, with the number of captures in each of the 20 traps for each group.

Several groups were detailed down to the species level, namely the araneae, the beetle families ‘carabidae’ and ‘silphidae’, and the orthoptera. These groups, for which more detailed data is available, will be studied in greater detail in the rest of this report, except for orthoptera, which had too few specimens.

In order to analyse this data, there are several diversity indices in ecology that can be used to quantify the biological diversity of a community. First, there is species richness, which corresponds to the total number of species present in the sample studied from the pitfall trap, but this does not take into account the abundance of each species. For this, we can use specific diversity, which is calculated using the Shannon index, known as H'. This combines species richness and evenness, the latter representing the uniformity of abundances. Its value therefore increases with the number of species and species represented equally. The Shannon index is complementary with Piélou's J' evenness index, which only measures the homogeneity of abundances. Although there are other indices in ecology for analysing the distribution of these data, these are the main ones and provide us with important and sufficient information for this study.

B. Impact of land use on vegetation using NDVI

The objective of this section is to use NDVI as a vegetation index to observe changes in vegetation productivity in Saksfjed over recent years, particularly since the renaturation project began. This will enable us to see its impact on vegetation and compare it according to different land uses, some of which may be more affected than others. One objective in this part is to produce a map of NDVI for multiple time points across the Saksfjed area.

1. What is NDVI ?

a) NDVI definition

The Normalized Difference Vegetation Index (NDVI) is an indicator of the greenness of vegetation and thus closely linked to vegetation density and productivity[1] (Tucker & Sellers 1986).

[1] The rate of generation of biomass in an ecosystem, usually expressed in units of mass per volume (unit surface)

This index was proposed in the late 1960s (Kriegler et al., 1969) and first introduced by Compton J. Tucker, a researcher at NASA. It became more widely used with the development of remote sensing and the launch of Landsat satellites in 1972, followed by NOAA-AVHRR satellites in the 1980s. This is one of the most widely used indices in vegetation remote sensing.

The NDVI is derived from the red, near-infrared reflectance ratio with the following formula : NDVI=(NIR-RED)/ (NIR+RED)]. NIR and RED are the amounts of near-infrared and red light, respectively, reflected by the vegetation and captured by the sensor of the satellite. The formula is based on the fact that healthy vegetation reflects strongly in the near infrared and weakly in the red.

The NDVI vegetation index ranges from -1.0 to 1.0, where negative values mainly indicate clouds, water and snow, and values close to zero mainly indicate rocks and bare soil. Moderate values (0.2 to 0.3) represent shrubs and grasslands, while high values (0.6 to 0.8) indicate temperate and tropical forests.

b) NDVI uses

NDVI is a very useful index in many fields. It is mainly used in agriculture, particularly for monitoring crop growth, early detection of water or nutrient stress, and harvest planning. It is also useful for forest management, monitoring deforestation and reforestation, and in ecology for studying plant phenology and annual productivity cycles. Furthermore, this index is used for environmental monitoring, such as detecting droughts and fires, as well as in climatology for analysing large-scale climate indices on vegetation (Myneni et al. 1997).

Finally, NDVI is a very useful analytical tool in other areas of ecology, such as the correlation between plant productivity and the presence of wildlife, which is of particular interest to us in the context of this report. Indeed, it is used in wildlife management, highlighting how NDVI-based indices could be linked to animal distribution and abundance. For example, it is a strong predictor of red deer migration dates (Pettorelli et al., 2011). Moreover, it is not only studied on herbivores but also on other animals such as insects, since primary productivity influences the entire food web. Thus, positive relationships between NDVI and site-based beetle species richness and abundance were detected, as well as predictable differences in beetle composition in open canopy forests.

In conclusion, NDVI is a multifunctional indicator used in many sectors, including agriculture, environmental management, and life and earth sciences. It will be essential in this study to observe changes in vegetation productivity within different land uses in Saksfjed and to analyse whether or not there is a correlation with insects.

2. Remote Sensing Approaches and Satellite Selection

a) Remote sensing interest in ecology

Remote sensing is a discipline at the interface between ecology and earth observation. It has become a pillar of modern ecology due to its ability to obtain data for large areas with high temporal frequency, often with free or inexpensive access to data. This facilitates the monitoring of ecological dynamics, such as changes in land use and their impact before and after, habitat fragmentation, and seasonal variability in environments.

There are numerous remote sensing tools existing, the most commonly used in ecology being acoustic sensors, camera traps and airborne and satellite-borne sensors (Pettorelli et al., 2021). These make it easy to obtain a variety of data on fauna and flora.

We can differentiate between passive and active sensors. The passive sensors measure the energy reflected or emitted by the Earth's surface that originates from external sources (such as the sun). This is the case, for example, with the Sentinel-2 satellite, which we will discuss later. As for active sensors, they have their own source of radiation and measure the returning signal. This is the case, for example, with radar or LiDAR (Light Detection And Ranging), emitting a laser beam and measuring the timing and intensity of the returning signal, for building up a high-resolution three-dimensional image of the environment.

b) The different satellites

In recent years, scientists have realized how remote sensing can find a new application by providing accurate, inexpensive, and timely information related to Earth observation and in our case vegetation. Since then, numerous satellites have made it possible to generate continuous, global time series for this index. There are several generations of satellites, distinguished by their spatial, temporal and spectral resolution.

First, there was the NOAA/AVHRR satellite in the 1980s, with a low spatial resolution of approximately 1 km and a daily temporal resolution. Then, there was NASA's MODIS from 1999 to 2002, with a spatial resolution of 250 m to 1 km and a temporal resolution of 1 to 2 days. There were also the SPOT-VEGETATION and PROBA-V satellites by the European Space Agency (ESA) from 1998 to 2020, with a spatial resolution of approximately 1 km for SPOT-VGT and 300 m for PROBA-V, and a daily frequency. Then there are the Landsat satellites launched by NASA with the USGS (United States Geological Survey) since 1972. Although they provide access to data over a long time until the present day, they have a long periodicity of 16 days and a resolution of 30 m, which does not make them ideal candidates.

Finally, as part of the European Union's Copernicus programme, the Sentinel-2 mission with the Sentinel 2 L2A satellite launched in 2017 and the Sentinel 2 L1C satellite since 2015-2016 represents a major advance in vegetation observation. Their spatial resolution is 10 m, 20 m or 60 m depending on the bands, with a temporal resolution of every 5 days. For the calculation of the NDVI, we are only interested in bands B4 corresponding to RED and B8 corresponding to NIR, each with a resolution of 10 m. In addition, the Sentinel-2 satellite has data corrected by surface reflectance tools, enabling a reliable NDVI to be obtained that is comparable over time and space. Surface reflectance is an atmospheric correction applied to satellite images to estimate the actual reflectance of the Earth's surface, as it would be measured without the influence of the atmosphere (aerosols, water vapour, gases, variable atmospheric conditions, etc.). This correction allows for a more consistent calculation of the NDVI. Furthermore, it is not applied to the L1C version of Sentinel-2, which means that its data are less accurate, particularly if the atmosphere is variable. Therefore, Sentinel-2 is the most interesting choice for this work due to its ability to provide accurate, frequent NDVI data that is suitable for a local scale and atmospherically corrected.

3. NDVI data acquisition

a) *Obtaining satellite data*

In order to obtain Sentinel-2 NDVI data, the Sentinel hub – EO Browser platform was very useful. It was developed by Sinergise, a partner of ESA and the Copernicus project. It is also possible to access the same data via the Copernicus Browser platform developed by ESA, but its interface is less user-friendly and the data is more difficult to view directly.

On the website, I selected Sentinel-2 data for the desired date. I initially chose NDVI data from spring, so that the period would coincide with the orthophotos of the Saksfjed site that I was able to find. However, I then decided to use NDVI data for the summer period, during which vegetation, and therefore NDVI, is generally more stable than in spring, as it has often reached maturity. Also, I have tried to use data from around 1 August, give or take a week, as far as possible. In fact, not all NDVI data is easily usable, due to days when there are clouds over the study site when the satellite takes the photo, thus preventing access to all the data. A filter is available on the platform to select only days with less than a certain percentage of cloud cover. I used this filter for my initial research, then increased the cloud percentage if I couldn't find cloud-free data for the desired time range, to see if other dates would yield data with no clouds specifically over the study site. Next, the study area is delimited by a rectangle so that only this data can be accessed. The data can then be downloaded. I first tried to obtain the NDVI already calculated, but even after downloading it in GeoTiff format, I was unable to access the NDVI values with the raster obtained. So I downloaded the B4 (RED) and B8 (NIR) bands individually in order to calculate the NDVI directly on QGis, the GIS platform chosen for the rest of the calculations (version 3.34.12).

b) *Calculation of NDVI on QGis*

In QGIS, I imported these raster layers and calculated the NDVI in the raster calculator using the NDVI formula adapted to the corresponding bands, becoming: (B8-B4)/(B8+B4). To visualise the data, I changed the symbology by choosing 'single-band pseudo-colour' and a blue ribbon for negative values and green for positive values.

Next, I used the 'identify features' tool to find out the NDVI value of the raster pixels by clicking on them, targeting the NDVI value at the pitfalls. However, the pixel corresponding to the pitfall is sometimes on the border between pixels of different values (Figure 2), so it would not be very rigorous to just take this value. So, I created buffers with a radius of 5 metres around each pitfall and used the 'zonal statistics' tool to obtain the average value for each pixel. Increasing the radius of this circle should provide more homogeneous data for pitfall traps within the same land use. However, the main advantage of having the NDVI around pitfall traps is to be able to compare the data on sampled arthropods with the adjacent NDVI. To analyse the overall evolution of the NDVI on the study site and between different land uses, it is preferable to calculate the average NDVI within the total area of each land use. So, I did this using the 'zonal statistics' tool, which gave me data that was much more representative of the entire area. Finally, I was able to access the NDVI data by opening the Excel file created with the new layer from 'zonal statistics'. I did these steps for different years from 2015 to 2025, with 2015 and 2016 based on data from the Sentinel 2 L1C satellite, which was the first version. This gave me a table with the NDVI value for all pitfalls and all years when I was using the NDVI from around pitfalls and a table for the 5 land uses and all year.

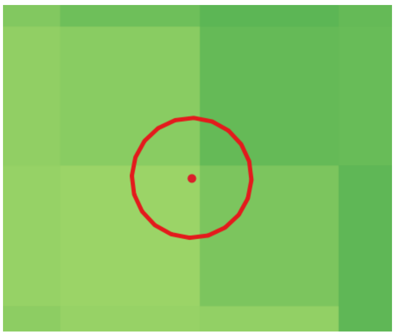

Figure 2: 5-metre buffer zone and NDVI pixels around a pitfall trap

C. Relationship between arthropods and vegetation

In this section, the NDVI data collected will be cross-referenced with data from arthropod sampling using pitfall traps. The aim is to determine whether there is a correlation between arthropods and the adjacent vegetation. The focus will be mainly on three groups of arthropods, namely the Carabidae and Silphidae, which are two families of beetles, and the order Araneae.

We can do this hypothesis that the number of arthropods will be higher if the NDVI is higher. This is because a higher NDVI value is linked to greater vegetation density and productivity, and therefore more food resources or habitats for arthropods.

1. Spearman's correlation test

I first wanted to see if there was a correlation between the total number of insects captured in the 20 pitfall traps in 2024 and the NDVI value within a 5m radius of each pitfall trap, also in 2024. Then, I used the individual data for Carabidae, Silphidae and Araneae to compare it with the NDVI around the pitfall traps.

To determine whether there is a real relationship between these two data sets other than visually, a statistical correlation test must be used. Given that the data are quantitative, we are looking for a relationship, there is one predictor and fewer than 50 variables (19 variables corresponding to pitfall traps), the most appropriate statistical test is Spearman's test. This test applies to discrete values that do not follow a normal distribution, which is indeed the case here.
To do this manually, I sort the insect sum data in ascending order, assigning them numbers from 1 to 19, which also changes the order of the associated NDVI values. Then, I assign numbers from 1 to 19 to the associated NDVI values, sorting them in ascending order. I then calculate the difference between the two ranks, square it, and calculate the sum of the 19 results. I can now apply the formula to obtain Spearman's coefficient (Figure 3). This correlation coefficient is called r and is ranging between -1 and 1. The closer it is to 1, the stronger is the correlation, so the NDVI value increases when the number of insects per pitfall increases. Conversely, the NDVI decreases when the number of insects increases for negative values.

$$= 1 - \frac{6\sum D^2}{n\left(n^2 - 1\right)}$$

Figure 3: Spearman correlation formula

Another faster way of calculating Spearman’s coefficient is by using XLSTAT software, which calculates it automatically simply by entering the initial data ranges.

2. Comparison of the correlation with the NDVI for 2022 and 2024

While it is interesting to observe the correlation, or lack thereof, between the pitfall arthropod data and the NDVI data in 2024, it may also be interesting to compare this same correlation but for NDVI data from two years earlier, so in 2022, in order to determine whether there is a stronger correlation or not. This will show whether the state of vegetation in 2022 before renaturation has a greater influence than the one of 2024 on the insect communities observed in 2024. Indeed, the composition of insect communities in 2024 may be influenced by vegetation conditions prior to rewilding. For example, some species are slow to colonise or disappear, so past vegetation (measured by NDVI 2022) could still influence their presence. The objective is therefore to study this time lag and delay for arthropod communities to adapt to the new vegetation. This is an exploratory temporal analysis cross-referenced with data from 2022. Furthermore, correlations with NDVI data from 2022 do not necessarily mean that vegetation in 2022 still impacts arthropods in 2024.

VI. Results

A. The impact of different land uses on arthropod communities

The groups to be studied in greater detail will be the Carabidae and Silphidae, two families of beetles, and the order Araneae. These groups are among those most abundant in pitfall traps and additional data is available for them, including identification down to species level. We will therefore study the data for all arthropods and then examine these groups in more detail. For each of the three groups, we will look at the abundance and the species richness. Specific richness corresponds to the number of different species, so it will be interesting to see which land uses have the highest number of species and to compare these results with the abundance seen previously. We will also pay particular attention to "arable" and "arable sown" land use to compare them and observe whether sowing has a real impact on the abundance and specific richness of these arthropod groups. Finally, we will look at the Shannon and Piélou indices, which provide us with additional information on whether or not the data is evenly distributed.

1. All arthropods

Given that the number of pitfall traps per land use is not equal (3 for coastal grassland and 4 for the others), it is not fair to add up the arthropod data for each land use in order to compare them. I therefore used the average number of arthropods in pitfalls traps for the same land use. In the following graph (Figure 4), the y-axis for each group of arthropods shows the sum of the average number of arthropods from pitfall traps for the same land use.

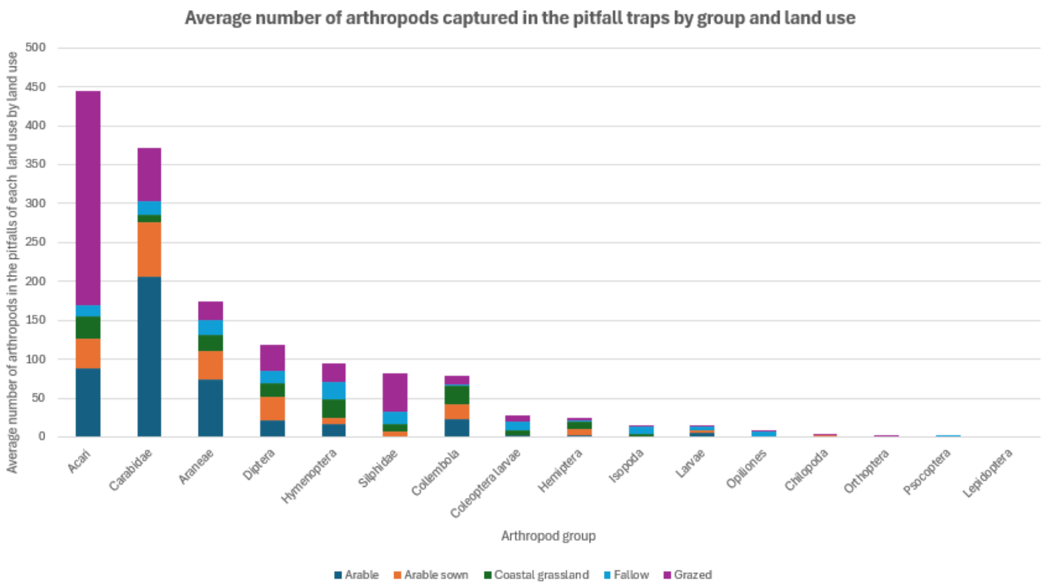

Figure 4:

Average number of different groups of arthropods captured in pitfall traps with the proportion of land uses in which they were found.

Here we can see that the most represented groups are, in order, Acari, Carabidae and Araneae which are mainly part of the epigean fauna. Also, some groups of flying insects are present in average quantities like Diptera and Hymenoptera and in small quantities for Hemiptera and Lepidoptera. Other groups are rarely present, such as Orthoptera, Chilopoda and Psocoptera.

In terms of distribution of the arthropods according to land use, we can notice that Acari are found mainly in "grazed" areas. Concerning Carabidae, Araneae and Silphidae, their distribution will be presented later. Also, Diptera and Hymenoptera are found in all land uses quite evenly.

The graph below (Figure 5) shows us in which land use the average number of arthropods captured in the pitfalls traps is higher, also providing us with the distribution of arthropod groups for each land use. We can see that the majority of arthropods were found in the 'arable' and 'grazed' areas, with an average of 442 and 500 individuals per pitfall trap, respectively. In appendix 2, we can see the distribution of those groups among the pitfall traps all over Saksfjed.

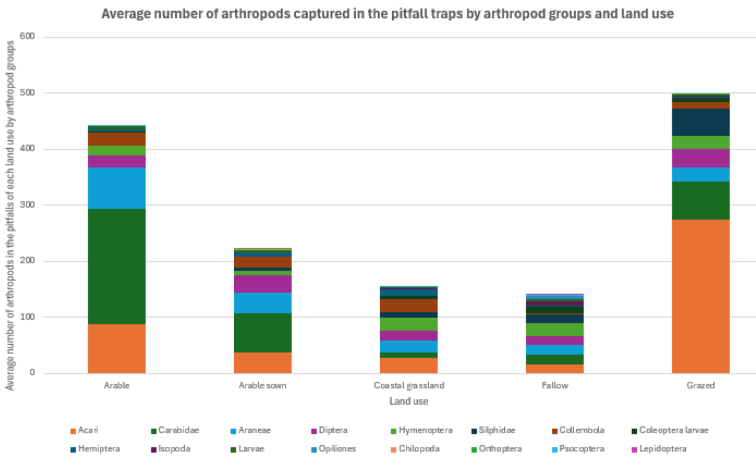

Figure 5 : Average number of arthropods captured in pitfall traps of a same land use for different land uses.

2. Carabidae

Let us now focus on a family of beetles, the Carabidae. They are fairly elongated and flattened in shape, with most species having small wings that are not particularly suited to flight and long legs for moving quickly. They are carnivorous, and some species are omnivorous with well-developed mandibles.

The graph below (Figure 6) shows the distribution of their abundance according to different land uses. We can see that Carabidae are most prevalent in 'arable', with an average of 205 individuals per pitfall trap, followed by 'arable sown' and 'grazed', with an average of around 70 individuals, and finally 'fallow' and 'coastal grassland', with an average of less than 18 individuals. Furthermore, these results are quite similar to those for the abundance of all arthropods, showing that this family carries significant weight and is fairly representative of the whole.

Next, Figure 7 shows that the highest average specific richness per pitfall is found in 'arable sown' areas, with an average of seven different species, followed by 'arable' areas, with an average of six. 'Coastal grasslands', on the other hand, have only about one species of Carabidae per pitfall on average.

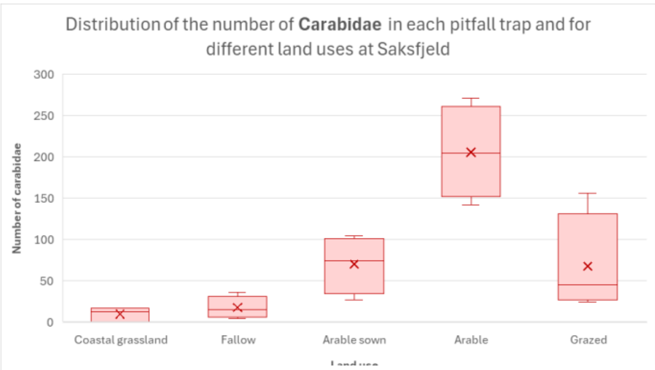

Figure 6: Distribution of the number of Carabidae in each pitfall trap and according to different land uses in Saksfjed.

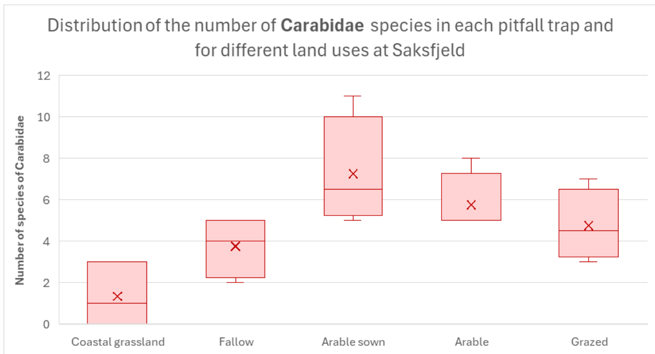

Figure 7: Distribution of the number of Carabidae species in each pitfall trap and according to different land uses in Saksfjed.

The table below (Figure 8) shows the Shannon and Piélou indices for Carabidae for each land use type. The Shannon index, which combines species richness and evenness, is highest for 'arable sown' with 1.51, followed by 'arable' with 1.20, and with 'coastal grassland' having the lowest index. These indices above 1 correspond to fairly species-rich environments, although their Pielou index is average at around 0.5, indicating that a few species are more prevalent than others.

	Arable	Arable sown	Coastal grassland	Fallow	Grazed
Shannon index H	1,20	1,51	0,29	1,21	1,10
Piélou index E	0,48	0,55	0,27	0,58	0,48

Figure 8: Shannon and Piélou indices of the distribution of Carabidae collected in pitfall traps for the 5 land uses. A high Shannon index will mean that there is a higher number of species or that the abundance for each species is distributed more equally. A higher Piélou index will mean that the abundance of the species is distributed more equally.

3. Silphidae

Silphidae are a second family of beetles. These are scavengers, feeding on the carcasses of animals such as birds and rodents. They prefer environments rich in organic matter, often with denser vegetation. They can fly to better locate carcasses attracted by odours.

In Figure 9, we can see that Silphidae are most abundant in 'grazed' areas, with an average of 49 individuals per pitfall trap, compared to less than 20 for other land uses, although one pitfall trap in fallow land exceeded 50 individuals. Next, we can see in Figure 10 that the land use with the highest number of Silphidae species remains 'grazed'. We can also note that there are slightly more different species in arable sown than in arable.

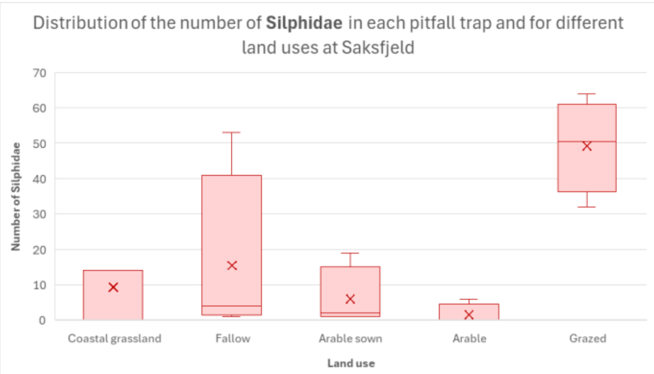

Figure 9: Distribution of the number of Silphidae in each pitfall trap and according to different land uses in Saksfjed.

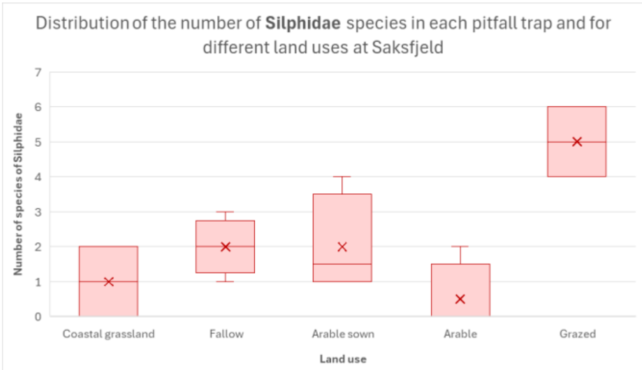

Figure 10: Distribution of the number of Silphidae species in each pitfall trap and according to different land uses in Saksfjed.

In Figure 11, we can see that the Shannon index is highest for grazed areas with 1.59, closely followed by arable sown areas with 1.32, which also show a high evenness of around 0.90. Conversely, arable soils have a specific diversity index that is less than half as high, at 0.64, due to the low abundance of Silphidae in this environment.

	Arable	Arable sown	Coastal grassland	Fallow	Grazed
Shannon index H	0,64	1,32	0,26	0,49	1,59
Piélou index E	0,92	0,95	0,37	0,45	0,89

Figure 11: Shannon and Piélou indexes of the distribution of Silphidae collected in pitfall traps for the 5 land uses.

Finally, the maps in appendices 3 and 4 show the distribution of the abundance and species richness of Carabidae and Silphidae all over Saksfjed to compare those two families of coleoptera easily.

4. Araneae

Finally, the third group of interest is the order Araneae. This is a very large order comprising more than 50,000 species. Spiders are predatory arthropods, generally feeding on insects using different hunting strategies. Some wait for their prey to become trapped in their webs, while others are more active, hunting by sight or lying in wait.

According to Figure 12, Araneae are found in all land uses in almost equal numbers, with an average of around 20 individuals per pitfall, except for "arable sown" and "arable", where the averages are slightly higher at 41 and 68 individuals respectively. The species richness (Figure 13) of Araneae is very homogeneous across the five land uses, with an average of between five and seven different species per pitfall. In particular, species richness is slightly lower for arable land, even though this land use had the highest abundance.

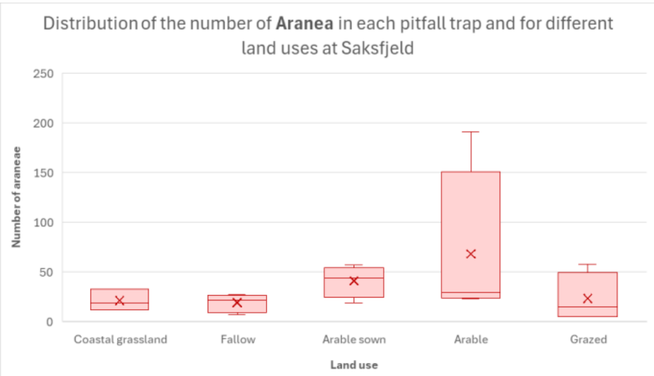

Figure 12: Distribution of the number of Araneae in each pitfall trap and according to different land uses in Saksfjed.

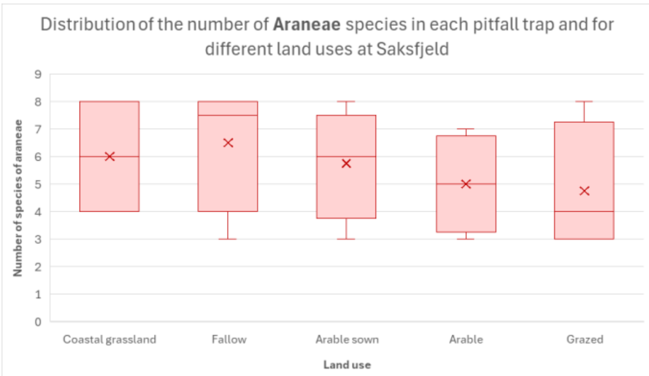

Figure 13 : Distribution of the number of Araneae species in each pitfall trap and according to different land uses in Saksfjed.

The table in Figure 14 shows a high species diversity of arachnids in 'fallow' and 'coastal grasslands', with an index of around 2.00, linked to a high degree of evenness in species distribution. For 'arable land', the Shannon index is lower at 0.81, even though this was the land use type with the highest abundance. In fact, the low Pielou index of 0.35, indicates that one species dominates the others.

	Arable	Arable sown	Coastal grassland	Fallow	Grazed
Shannon index H	0,81	1,05	1,90	2,10	1,40
Piélou index E	0,35	0,42	0,74	0,80	0,58

Figure14: Shannon and Piélou indices of the distribution of Araneae collected in pitfall traps for the 5 land uses

B. Impact of land use on vegetation using NDVI

1. NDVI evolution in Saksfjed according to different land use

a) General results

Now, we are interested in NDVI, specifically how vegetation has been affected by land use change since the rewilding project in Saksfjed, and whether certain land uses are more impacted than others.

To do this, after obtaining the table with NDVI data for each year for each land use, I was able to create various graphs allowing me to visualise and analyse this data.

The Figure 15 below shows the evolution of the NDVI at the Saksfjed site for the five land uses from 2015 to 2025. We can see quite significant variations from year to year, such as an overall increase in the NDVI in 2017 and a drop in the NDVI in 2018 and 2019. It can be seen that the land uses with the highest NDVI are 'coastal grassland' and 'grazed', while 'fallow' has average NDVI values, and 'arable' and 'arable sown' have the lowest NDVI values. It should be noted that before 2023 and the rewilding project, both were arable land. It was only in 2023, with the cessation of agriculture, that 'arable sown' became land simply sown with a mixture of flowers. It can then be seen that 'arable sown' has a higher NDVI than 'arable' in 2024 and 2025, which is consistent. There is also a general increase in NDVI in 2024 linked to the rewilding project and probably not to external factors, which is confirmed by very similar results in 2025.

The main finding is a radical change in NDVI for former arable land, which has more than doubled its NDVI from an average of between 0.200 and 0.300 to between 0.500 and 0.750. Finally, the data from 2015 to 2022 are also interesting to study, serving as a basis for assessing the real impact of the rewilding project. We can see an overall trend of slight increase in NDVI since 2015.

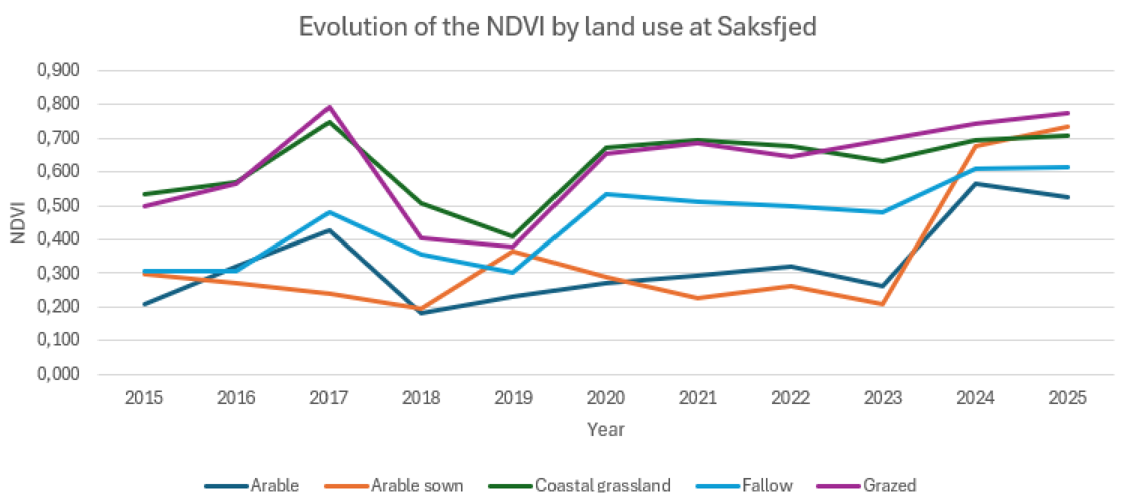

Figure 15 : Evolution of the NDVI by land use at Saksfjed from 2015 to 2025.

b) Approximate increase in NDVI using slope

It is now interesting to quantify the evolution of the NDVI using the NDVI trend coefficient. In order to compare the impact before and after the rewilding project, we will divide the analyses into two periods: 2015 to 2022 before the project, and 2023 to 2025 after the project. Given the short time since the project, these results should be viewed with caution and confirmed by monitoring over the next few years.

The trend coefficient expresses the rate of change in NDVI over time. This allows us to determine not only whether vegetation is improving or deteriorating, but also at what rate after the project. This change can be seen in the graph below (Figure 16).

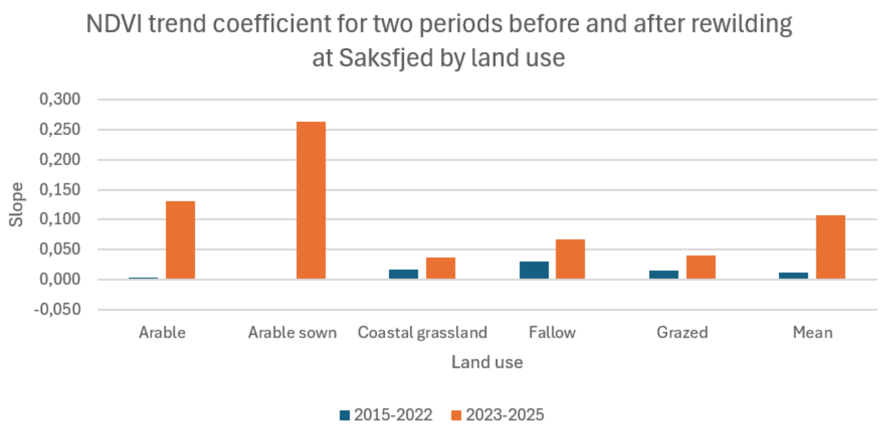

Figure 16 : Slope coefficients of the NDVI trend lines calculated for the pre-rewilding period (2015–2022) and post-rewilding period (2023–2025), presented for each land use type at Saksfjed. Positive values indicate an upward trend in NDVI, while negative values indicate a decrease in NDVI.

We can see a relatively small but positive change in NDVI from 2015 to 2022, which is strongest for non-arable land, particularly ‘fallow’, with an increase in NDVI of 0.030 per year. However, NDVI changes are more significant for the period after the rewilding project from 2023 to 2025, with the most notable changes occurring on ‘arable’, particularly with an increase of 0.0264 per year (over three years) for ‘arable sown’. Other land uses have more than doubled their annual NDVI increase for the period after rewilding. These results therefore confirm our observations in Figure 15 showing an increase in vegetation productivity from 2023 onwards, which is much greater for arable land.

2. Factors influencing NDVI

Now, we would like to look at the factors influencing the NDVI. This could help explain the various variations observed in the NDVI since 2015, such as the increase in the NDVI in 2017 and the decrease in the NDVI in 2018 and 2019 compared to the average. To do this, we can hypothesise that the main factors are the time of day, the date during the season and the weather (temperature and rainfall) over the past two months.

a) Time of day

The time of day could impact the NDVI, for example with different sunlight depending on the time or a difference in plant physiology. However, the Sentinel-2 satellite from which the NDVI data was collected passes at a fixed time every day in order to limit this effect. All photos were taken between 10:20 and 10:35 a.m. (Figure 17), which does not impact our NDVI data.

Time	10h20	10h32	10h23	10h32	10h25	10h35	10h35	10h35	10h35	10h35	10h27
Date	06-08	24-07	31-07	03-08	05-08	07-08	02-08	02-08	30-07	06-08	19-07
Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**

Figure 17 : Table showing the times and dates for which NDVI data was collected each year from 2015 to 2025.

b) Day during the season

As for the date during the season, I selected the most dates with usable data possible for three different years (2021, 2023 and 2024) in order to observe the evolution of the NDVI (see Appendix 2). Let's take the example of 2021 with the graph below (figure 18), representing the years before rewilding. For ‘fallow’, ‘grazed’ and ‘coastal grassland’, we observe fairly small changes in NDVI, making it difficult to determine a real trend. However, for arable land with 'arable' and 'arable sown', we can observe a drastic decrease in NDVI, which is therefore linked to agriculture corresponding to the harvest period. This can be observed for the years 2021 and 2023 but not 2024 due to the Saksfjed rewilding project, which began in 2023 and therefore marked the end of agriculture in this area. In addition, harvesting generally takes place from mid-July to early August, although it was carried out earlier in 2021. For more consistent NDVI data that is more accurately comparable, it is therefore useful to take dates for which the harvest was carried out for each year.

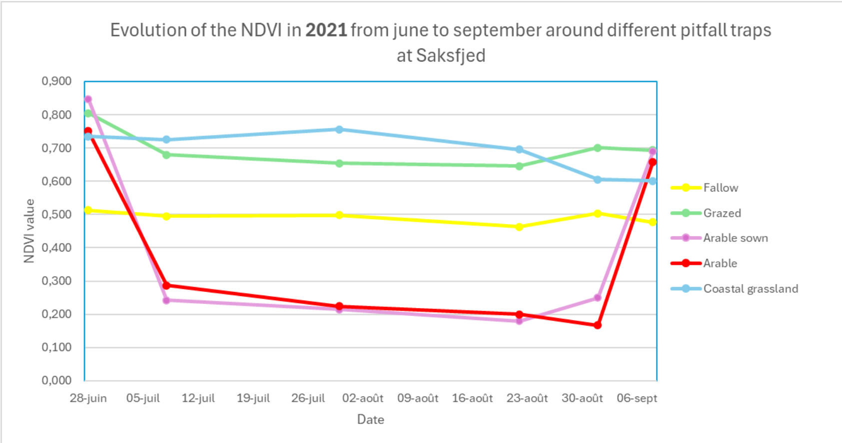

Figure 18 : Evolution of the NDVI in 2021 around pitfalls traps within a 5-meter radius from June to September. The average of the four pitfalls traps was calculated for each land use.

c) Temperature and rainfall

For the influence of weather, I first looked for data on the European 'weather and climate' website, but the closest weather station is in Copenhagen, 132 km from the study site, and rainfall data was not available before 2018. I therefore used temperature and rainfall data from the global website 'world clim' to compare them with the NDVI average for each of the selected dates per year. This website provides access to the average maximum and minimum temperatures per month, as well as total rainfall per month. The data is presented in raster form, allowing us to obtain data located precisely on the study site, but it does not come from a weather station and is therefore less accurate.

Given that the NDVI data was taken on dates around 1 August, it is interesting to choose temperature and rainfall data from one or two months earlier, i.e. June and July. However, we have to keep in mind that this is only to give a rough idea of NDVI link to rainfall and temperature. Is not entirely rigorous, particularly for dates taken later in August, as temperature and rainfall data for August are not available. Then, I obtain the graph below (Figure 19) to visually observe the relationship between temperature, precipitation and NDVI.

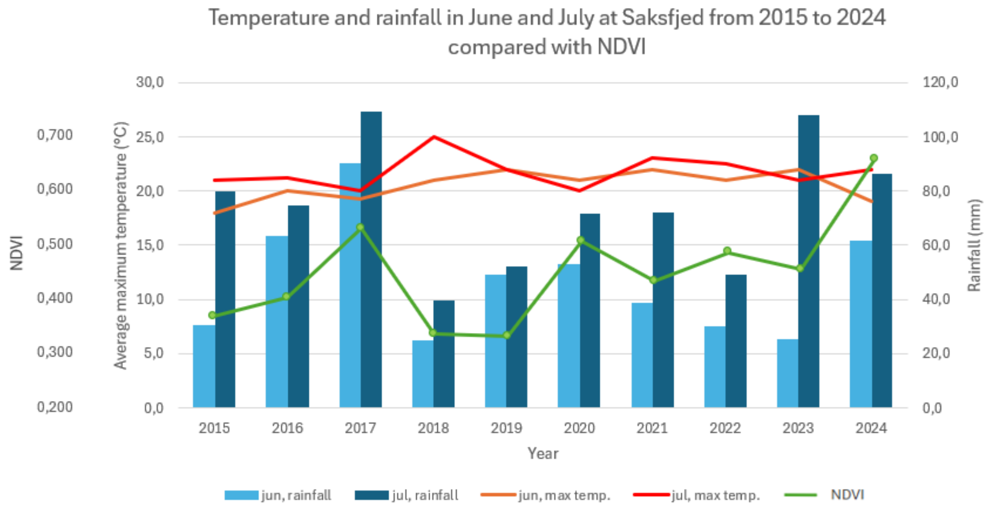

Figure 19 : Temperature and rainfall in June and July at Saksfjed from 2015 to 2024 (source : world clim) compared with NDVI. The NDVI data is coming from the mean of the NDVI from 5 meter radius around all pitfall traps.

Visually, we can see that the increase in NDVI in 2017 is most certainly linked to the very high rainfall in June and July. Similarly, the decrease in NDVI in 2018 and 2019 corresponds to higher temperatures and low rainfall, which probably explains this decrease in NDVI. However, the increase in rainfall in July 2023 did not lead to an increase in NDVI, which may call into question its influence. One hypothesis could be that the low rainfall in June had a greater impact on vegetation at that time than the rainfall in July.

C. Relationship between arthropods and vegetation

In this section, the aim is to determine if there is a correlation between arthropods and the adjacent vegetation. To do this, Spearman's correlation tests were carried out for each of the arthropod groups studied, first with abundance and then with species richness. We also wanted to compare the arthropod data from 2024 with the vegetation from that same year, as well as with the vegetation from two years earlier, to see which vegetation the arthropods are most receptive to. All the results are referred in the following table (Figure 20).

	Abundance				Species richness		
	Carabidae	Silphidae	Araneae	All arthropods	Carabidae	Silphidae	Araneae
r 2022	-0,312	0,270	-0,212	0,133	-0,609	0,109	-0,068
r 2024	-0,368	0,326	-0,472	-0,209	-0,346	0,302	-0,182
Delta	0,056	0,056	0,260	0,342	0,263	0,193	0,114

Figure20 : Table of Spearman's correlation coefficients for different groups of arthropods, abundance and species richness, and in comparison with the NDVI from 2022 and 2024.

1. Correlation with 2024

a) All arthropods

For all arthropods, we have a Spearman correlation coefficient of r = -0.209 for abundance with the NDVI of 2024, which corresponds to a very weak and negative correlation. This means that when the number of insects per pitfall increases, the NDVI value decreases very slightly.

In order to see if we obtain a more or less significant correlation, it is interesting to perform these correlation tests with only one group of insects and not all of them, in order to compare the results with the habitat and behaviour of these insects.

b) Carabidae

The Spearman correlation coefficient for Carabidae abundance and NDVI in 2024 is r = -0.368, which corresponds to a moderate negative correlation. Thus, there would be more Carabidae when there is less vegetation. Furthermore, the correlation coefficient obtained between the specific richness of Carabidae and the NDVI 5m around pitfalls in 2024 is -0.346, corresponding to a negative average correlation. This result is very similar to the one calculated for the abundance of Carabidae, which is -0.368.

Abundance	Carabidae species	Expected NDVI
511	Pterostichus melanarius	Medium to high
429	Calathus fuscipes	Low to medium
347	Harpalus rufipes	Low
69	Pterostichus niger	High
46	Poecilus versicolor	Low to medium

Figure 21 : Top 5 Carabidae species by abundance for all pitfall traps and an estimation of the NDVI preferences of each species based on their habitat and behavior (see appendice 6)

The table above (Figure 21) shows the five species of Carabidae with the highest abundances found in the 19 pitfall traps, along with their vegetation preferences and therefore the expected NDVI. We can see here that three species have much higher abundances and there is some heterogeneity in the expected NDVI values depending on the species, which therefore have different habitats and behaviours. Nevertheless, the species Calathus fuscipes and Harpalus rufipes, which are the second and third most abundant, represent 55% of the abundance of the five most prevalent species, and these prefer lower vegetation, which is consistent with the negative correlation coefficient found in the test.

c) Silphidae

The correlation coefficient r for Silphidae abundance with the NDVI in 2024 is 0.326, corresponding to a moderate positive correlation. Therefore, there would be more Silphidae when there is more vegetation. Furthermore, the coefficient with specific richness is 0.302, corresponding to a positive average correlation, very similar to the result with abundance, which was 0.326.

Abundance	Silphidae species	Expected NDVI
150	Silpha tristis	Medium to high
52	Nicrophorus vespilloides	High
50	Nicrophorus vespillo	Low to medium
32	Thanatophilus sinuatus	Low to medium
30	Nicrophorus investigator	Medium to high

Figure 22: Top 5 Silphidae species by abundance for all pitfall traps and an estimation of the NDVI preferences of each species based on their habitat and behavior (see appendice 6)

Looking at the five most common species in the 19 pitfalls traps (Figure 22), we observe that the two most abundant species prefer medium to high NDVI values. This is consistent with our correlation coefficient of 0.326.

d) Araneae

Spearman's correlation test for Araneae abundance and the year 2024 gives us a coefficient r of -0.472, corresponding to a moderate negative correlation. There are therefore more spiders where vegetation is sparser. Furthermore, the coefficient for specific richness is -0.182, which corresponds to a weak negative correlation. This is more than twice as weak as the correlation with abundance, which was -0.472. Thus, the vegetation in 2024 has a stronger effect on abundance than on the specific richness of Araneae.

Abundance	Araneae species	Expected NDVI
363	Oedothorax apicatus	Low
98	Lycosidae	Low to medium
85	Linyphiidae	Low to high
16	Trochosa terricola	Medium
13	Oedothorax fuscus	Low to medium

Figure 23 : Top 5 Araneae species by abundance for all pitfall traps and an estimation of the NDVI preferences of each species based on their habitat and behavior (see appendice 6)

When studying the most common species (Figure 23), we observe a majority of Oedothorax apicatus, which has a low expected NDVI, as do the following species in terms of abundance. This is therefore consistent with our result of a negative average correlation between NDVI and spider abundance.

2. Correlation with 2022

a) Comparison of the NDVI

In the graph below (Figure 24), we can compare the NDVI for 2022 and 2024 within a 5-metre radius of the pitfall traps. We can see that ‘arable sown’ had the largest increase in NDVI, almost tripling its value, while ‘arable’ also increased from 0.361 to 0.542. The NDVI of other land uses also increased slightly, except for ‘coastal grassland’, whose NDVI remained unchanged.

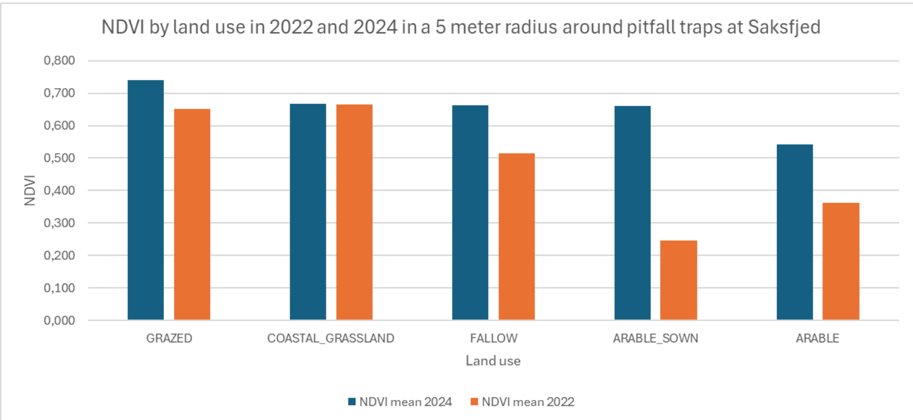

Figure 24 : Mean of the NDVI around the 20 pitfalls at Saksfjed in a 5-meter radius for 2022 and 2024 and for the 5 different land uses.

b) Carabidae

For Carabidae abundance, we obtain a correlation coefficient with the 2022 NDVI of -0.312, which corresponds to a moderate negative correlation. This correlation is slightly weaker than that with the NDVI for 2024, which was -0.368. Thus, Carabidae communities respond slightly more actively to the vegetation structure in 2024 compared to that in 2022.

The correlation coefficient with species richness obtained is -0.609, which corresponds to a high negative correlation. Thus, the weaker the vegetation in 2022, the more Carabidae species there are in 2024. This figure is about twice as high as the correlation coefficient for 2024 for species richness, which was -0.346, indicating a stronger impact of vegetation in 2022 than in 2024 on the species richness of Carabidae communities. It is also approximately twice as high as the correlation coefficient for abundance in 2022, which was -0.312, suggesting that species richness is more strongly linked to vegetation than abundance for vegetation in 2022.

c) Silphidae

For Silphidae abundance, the correlation coefficient with the 2022 NDVI is 0.270, corresponding to a weak positive correlation. This correlation is slightly lower than that with the 2024 NDVI, which was 0.326. Thus, Silphidae communities respond slightly more strongly to the 2024 vegetation structure compared to that of 2022.

The correlation coefficient between species richness and the 2022 vegetation is 0.109, corresponding to a weak positive correlation. This is about three times lower than the correlation between species richness and the 2024 vegetation, indicating a greater influence of the 2024 vegetation than that of 2022 on Silphidae communities. It is also more than twice as low as the correlation between abundance and 2022 vegetation, showing that the 2022 vegetation had a greater impact on abundance than on species richness for Silphidae in 2024.

d) Araneae

For Araneae abundance, the correlation coefficient with the 2022 NDVI is –0.212, corresponding to a weak negative correlation. This correlation is twice as weak as that with the 2024 NDVI, which was –0.472. Thus, Araneae communities respond more strongly to the 2024 vegetation structure compared to that of 2022.

The correlation coefficient for species richness and 2022 vegetation is –0.068, indicating no correlation between these two variables. Araneae therefore respond slightly more to the 2024 vegetation (coefficient of –0.182) compared to 2022 in terms of species richness. This is also much weaker than the correlation between abundance and 2022 vegetation (–0.212), showing that abundance is more strongly related than species richness to the 2022 vegetation for Araneae.

VII. Discussion

A. The impact of different land uses on arthropod communities

In this section, we aim to assess the effects of different land uses on the composition and abundance of arthropod communities.
Before examining the arthropod results obtained from the pitfall traps, it is important to recall that pitfall traps provide a good estimate of terrestrial arthropod populations but remain biased. They measure activity-density rather than absolute abundance (Spence & Niemelä, 1994). As a result, large and mobile species are overrepresented. Moreover, according to Knapp et al. (2020), on average, species recorded by pitfall traps were larger, more nocturnal, more carnivorous, less colourful, and had lower flight abilities.

1. Result analysis

a) All arthropods

Regarding the abundance of all sampled arthropods, Figure 4 shows that Acari were the most abundant group, particularly in 'grazed' areas. Indeed, according to a study conducted in subalpine pastures in Romania, intensively grazed grasslands had the highest levels of Acari abundance (Manu et al., 2023). This could be explained by an increase in soil moisture and temperature, linked to shorter vegetation, which favours decomposition and the reproduction of Acari as grazers and decomposers.

We also observed that Carabidae and Araneae were present in very high abundance. This seems logical, as these are mainly epigeic animals, meaning they move on the ground and are more likely to be caught in this type of trap. Conversely, flying insects such as Hymenoptera are probably underrepresented, but they are not the main target of this type of trap. For Hymenoptera, for example, pitfall traps are not suitable because they can escape more easily (Collett & Fisher, 2017). Likewise, other groups, such as Orthoptera, are rarely found, possibly because they are able to jump out of the trap.

We also found that total arthropod abundance was highest in both 'arable' and 'grazed' areas. For arable land, this may seem surprising, as these habitats are generally much less diverse. A recent study in the Netherlands (Litovska et al., 2025) concluded that arthropod abundance and diversity are often lower in croplands, especially when vegetation cover is lower. However, another study (Galli et al., 2025) noted that arable soils often show a dominance of epigeic species, which have the mobility and capacity to recolonise disturbed environments quickly, potentially explaining the high abundance observed. In addition, grazing can create heterogeneity in vegetation height and density, promoting the abundance and diversity of certain arthropods, particularly under light to moderate grazing (Goosey et al., 2019). Vegetation structure and disturbance are therefore factors that can influence abundance.

Furthermore, Figure 5 shows that 'arable' areas hosted more arthropods in terms of abundance than 'arable sown' areas. This is surprising, as the latter, which were sown as part of the rewilding project, normally have greater floral diversity, which is favourable to fauna. It would therefore be interesting to examine whether species diversity is indeed higher in 'arable sown' compared to 'arable' areas, thereby demonstrating one of the benefits of sowing wildflowers.

b) Carabidae

In Figure 6, we observed that Carabidae were most abundant in 'arable' land. This could be explained by the presence of crops and seeds attracting phytophagous insects as a food source. Carabidae also tolerate mechanical disturbances and prefer more open soils for hunting. However, it is interesting to note that species richness was slightly higher in 'arable sown' compared to 'arable', which could indicate a positive effect of wildflower sowing on Carabidae communities, whereas abundance was higher in 'arable' than in 'arable sown'. Moreover, the Shannon Index shows greater species diversity in 'arable sown' than in 'arable', due to slightly better evenness in species distribution and species richness. Thus, 'arable sown' areas are somewhat more ecologically valuable than unsown 'arable' fields for Carabidae due to their higher species diversity.

c) Silphidae

Silphidae were more abundant in 'grazed' areas in terms of both abundance and species richness. This family of necrophagous beetles is linked to the presence of decomposing organic matter, such as small carcasses. One hypothesis is that pastures provide higher animal mortality, in addition to dung attracting other animals. Indeed, research on burrowing arthropods (Goosey et al., 2019) suggests that the increased presence of Silphidae in 'grazed' areas could be due to a greater abundance of small mammal carcasses in grassland refuge areas (denser grass, low vegetation).

One might have expected to find greater species richness in some 'fallow' pitfalls with high abundance, which was not the case. This less-disturbed environment may be less diverse in terms of habitats suitable for other Silphidae species compared to ‘grazed’ areas, leaving more room for generalist Silphidae species.

d) Araneae

Figures 12 and 13 show that Araneae were present fairly evenly across all land uses, with slightly higher abundance in arable and arable sown areas. This could be explained by the fact that Araneae are hunters. Many species prefer more open, less vegetated environments where they can hunt their prey more easily. In addition, spiders are highly generalist and tolerant of all types of habitats, as long as they can find prey and suitable places to hide or build their webs, which may explain their presence across all habitats.

2. Limits and suggestions

Firstly, we studied two groups of predatory species (Carabidae and Araneae) and one necrophagous group (Silphidae). It would therefore be interesting to expand the detailed analysis to a greater diversity of groups, such as herbivores arthropods, in order to avoid drawing conclusions solely for predatory arthropods.

Moreover, we have seen that pitfall traps do not capture all species equally, favouring more active and larger species, which results in a species list that is not representative of the entire epigeic fauna.

To collect more species and cover a more complete spectrum of species traits, it is especially recommended to combine complementary sampling techniques, such as pitfall trapping and hand searching, in a single study (Knapp et al., 2020).

Furthermore, trap design, including its size, cover, solution, and the distance between traps can be factors influencing the sampled composition and the effectiveness of pitfall traps (Brown et al., 2016).

According to Boetzl et al. (2018), pitfall traps with guidance barriers were up to five times more effective than simple pitfall traps and produced samples that yielded more similar assemblage approximations. In contrast, pitfall traps with extended plastic rim plates not only performed poorly but also resulted in distinct carabid assemblages, with fewer individuals of small species and greater variation. It may therefore be worthwhile to change trap design, such as by adding barriers, to increase catches. However, this does not guarantee coverage of a wider range of species.

B. Impact of land use on vegetation using NDVI

The objective of this section is to assess the impact of the rewilding project and the different land uses on vegetation productivity.

1. NDVI evolution in Saksfjed

In Figure 15, we observed that NDVI increased between 2023 and 2024 due to the rewilding project launched in 2023. Although we might have expected a more significant increase with the rewilding project, these are still the early stages, and it takes time for vegetation to develop—not to mention that these environments are managed with grazing animals, which are essential for keeping habitats open.

This increase in NDVI is significant for former 'arable' lands, and even more so for those sown with wildflowers. The increase in 'arable' land could be explained by the greater potential for improvement, as these land uses had the lowest NDVI values before rewilding. Moreover, a study by Cramer et al. (2008) indicates that without sowing or restoration of soil conditions, natural colonisation can be very slow, particularly for semi-natural grassland species. Restoration can therefore help boost productivity in the early years. This partly explains the stronger NDVI increase in 'arable sown' areas, but it also raises the question of why the NDVI in unsown arable land evolved almost as rapidly. Another long-term study conducted in Great Britain on heathlands over 17 years found that introducing local seeds enables sustainable and effective restoration without eliminating existing vegetation cover, simply enriching the targeted floristic composition—confirming the NDVI increase in former arable lands that were sown.

2. Factors influencing NDVI

We also observed substantial NDVI variations across all land uses from year to year, mainly explained by rainfall and temperatures in the preceding months. Temperature quickly influences phenology and photosynthesis. Analyses such as Kempf (2023), at the European and north-temperate scale, show that thermal signals—such as spring warming—can trigger a visible "greening" in NDVI within the same month or the following month.

For rainfall, NDVI most strongly correlates with cumulative precipitation over 1–3 months in many contexts, according to Piedallu et al. (2019). This longer lag helps explain why the heavy rainfall in July 2023 (see Figure 19) had no real impact on NDVI.

Moreover, the dominant influence between rainfall and temperature varies depending on the ecosystem type and the season. For grasslands and crops, there is generally a stronger response to rainfall—especially when the soil is shallow—but the optimal lag often varies from 1 month to sometimes 2–3 months (Atzberger et al., 2013).

Finally, it would have been interesting to calculate the correlation coefficient between rainfall, temperature, and NDVI in order to quantify their influence and determine which month's weather data had the greatest impact in the context of this study. Additionally, to gain more comprehensive insights, it would also have been valuable to integrate weather data from further back in time, such as two or three months prior.

3. Limits and suggestions

As with any scientific study, there are limitations meaning that the data do not perfectly reflect reality. First, we have seen that NDVI values are affected by many factors, such as varying weather conditions between years, which influence NDVI to differing degrees. However, it is difficult to control for this to have more homogeneous weather conditions between years. One possibility would be to select data from a season other than summer with more stable weather conditions—but we specifically chose summer because it is the period when most vegetation reaches maturity in terms of growth.

Second, due to the presence of clouds on many of the satellite image dates, I had to use data from different days within the season for each year. This mainly affects 'arable' land, where crop harvesting generally takes place in July or even June, forcing me to select dates after the harvest had occurred.

Finally, an important limitation is that there are only two years of data following 2023, which is the year the rewilding project began. It is therefore still too early to draw firm conclusions about the project's effects, which need to be monitored over the long term.

C. Relationship between arthropods and vegetation

In this section, the objective was to determine whether there is a correlation between arthropods collected from pitfall traps and vegetation based on the 2024 NDVI. We also aimed to assess whether arthropod communities are more strongly correlated with the 2024 NDVI or with that of two years earlier, in 2022, before the rewilding project.

1. Result analysis

a) All arthropods

From the table of Spearman's correlation coefficients (Figure 20), we observed a very weak negative correlation between total arthropod abundance and the 2024 NDVI, and a similarly weak but positive correlation with the 2022 NDVI. Given that NDVI values were lower in 2022, this means that the particularly strong vegetation increase in former arable lands sown with flowers made the correlation turn negative. This result is surprising because it suggests that arthropods are more abundant in 2024 when vegetation is less dense. This contradicts our initial hypothesis that more insects would be found where the NDVI value is higher. One possible explanation is that more than half of the sampled arthropod abundance prefers open habitats with less vegetation. However, it is important to remember that pitfall traps measure activity–density, i.e., mostly surface-active individuals. Therefore, when vegetation becomes denser, many arthropods may move less on the surface. Another possibility is that other factors may be more influential than vegetation in determining insect abundance, and these were not considered here—for example, disturbances such as grazing animals, soil quality and structure, soil moisture, vegetation type, etc. Furthermore, this weak correlation suggests diversity in NDVI preferences among different arthropod groups, meaning that the sum of their abundances is only weakly correlated with NDVI.

b) Carabidae

For Carabidae, the correlation with 2024 NDVI was moderate and negative. This is likely due to the species Calathus fuscipes and Harpalus rufipes, which are the second and third most abundant species (Figure 21), together representing 55% of the abundance of the five most common species, and both preferring lower vegetation—thus explaining the negative correlation coefficient.

More surprising is that the correlation with species richness was twice as high with the 2022 NDVI than with that of 2024. This was the only case where a stronger correlation was found with the 2022 NDVI. Thus, Carabidae richness was twice as strongly correlated with the lower vegetation of 2022 compared to 2024. This could be explained by the fact that many generalist Carabidae species, especially in northern Europe, are thermophilic and heliophilic, preferring open habitats with short vegetation and lower NDVI values such as those in 2022. This greater diversity of open habitats is therefore linked to a higher number of Carabidae species. Moreover, it is well established that temperate open habitats (grasslands, extensive crops) support high Carabidae species richness (Kotze et al., 2011).

c) *Silphidae*

For Silphidae, we found moderate positive correlations, which were weaker for 2022 than for 2024. As Silphidae tend to prefer habitats with slightly higher NDVI values, it is consistent that they are more strongly correlated with the 2024 NDVI than with that of 2022.

d) *Araneae*

For Araneae, we observed moderate negative correlations, stronger for abundance and with the 2024 NDVI. Like Carabidae, Araneae are generally more abundant in areas with lower vegetation. However, their stronger correlation with the higher vegetation of 2024 is surprising. One hypothesis is that Araneae can quickly recolonise new habitats, which might explain the stronger correlation with the 2024 vegetation.

2. Limits and suggestions

For the three arthropod groups studied, the correlation is stronger for 2024 than for 2022. This may suggest that the rewilding project is already having some effect on arthropod populations, or that most of the selected groups are capable of recolonising habitats relatively quickly. To be certain, it would have been interesting to perform correlation tests on other arthropod groups that may be less mobile.

There are also limitations to the Spearman correlation test used. First, the sample size of 19 (corresponding to the number of traps) results in relatively low statistical power. Modest correlations may fail to reach significance, and those observed may be unstable and strongly influenced by a few extreme values. Second, Spearman's method is based only on ranks, which means it loses information about the distribution and quantitative nature of the variables. Finally, even when a correlation is observed, it does not demonstrate that NDVI is causing the variation in abundance, as this could instead be due to other factors such as microclimate or predation pressure.

VIII. Conclusion

This internship was part of the ecological monitoring of a rewilding project initiated in 2023 at the Saksfjed site in Denmark. The aim was to assess vegetation changes through NDVI and its relationship with arthropods, as well as the impact of different land uses, particularly on various arthropod groups.

First, analysis of the pitfall trap data revealed higher arthropod abundance in 'arable' and 'grazed' habitats, the latter largely due to the strong presence of Acari. In addition, former arable lands that were sown showed greater species diversity for the three groups studied compared to unsown ones, highlighting the ecological value of sowing. NDVI data from 2015 to 2025 indicated an increase in vegetation productivity following the rewilding project in 2023, particularly marked in former arable lands, especially those sown with flowers. Meteorological factors (temperature and precipitation) were found to influence NDVI with a lag of up to three months. Finally, correlations between NDVI and sampled arthropods were variable—often weak to moderate depending on the groups and their habitat preferences for more or less open environments. Correlations were stronger between arthropod data and the 2024 NDVI than with that of 2022, suggesting that the 2024 vegetation had a greater influence on arthropod distribution than the vegetation of 2022.

This work is part of a longer-term project and therefore serves as a basis and as preliminary analyses for research that will be continued. I was able to observe initial results from this rewilding project, without yet being able to draw general conclusions about the impact of such projects, as it only began recently. Continued monitoring of arthropods and NDVI will therefore be essential in the coming years, not only to assess the short-term impacts of the project but also its longer-term effects.

To complement this work, it would have been relevant to develop a program in R to automatically extract NDVI data and calculate NDVI values. This would facilitate NDVI monitoring in the coming years. However, due to time constraints, this was not possible, and the choice was made to focus more on fieldwork.

Finally, this internship enabled me to acquire knowledge related to ecology and the rewilding of natural sites. I also gained skills in remote sensing (from extracting NDVI data to processing it), statistical analysis and scientific writing. I further developed organisational skills, the ability to work independently, and skills in science communication through the co-writing of a blog post. Moreover, this internship allowed me to gain a better understanding of the work of an ecological researcher, prompting reflection on my future career path. I participated in meetings, notably with the research team, and took part in a wide range of tasks—for example, assembling cameras in the laboratory and conducting numerous field trips that gave me the opportunity to discover several sites of ecological interest in Denmark and learn how insect sampling protocols are implemented in the field.

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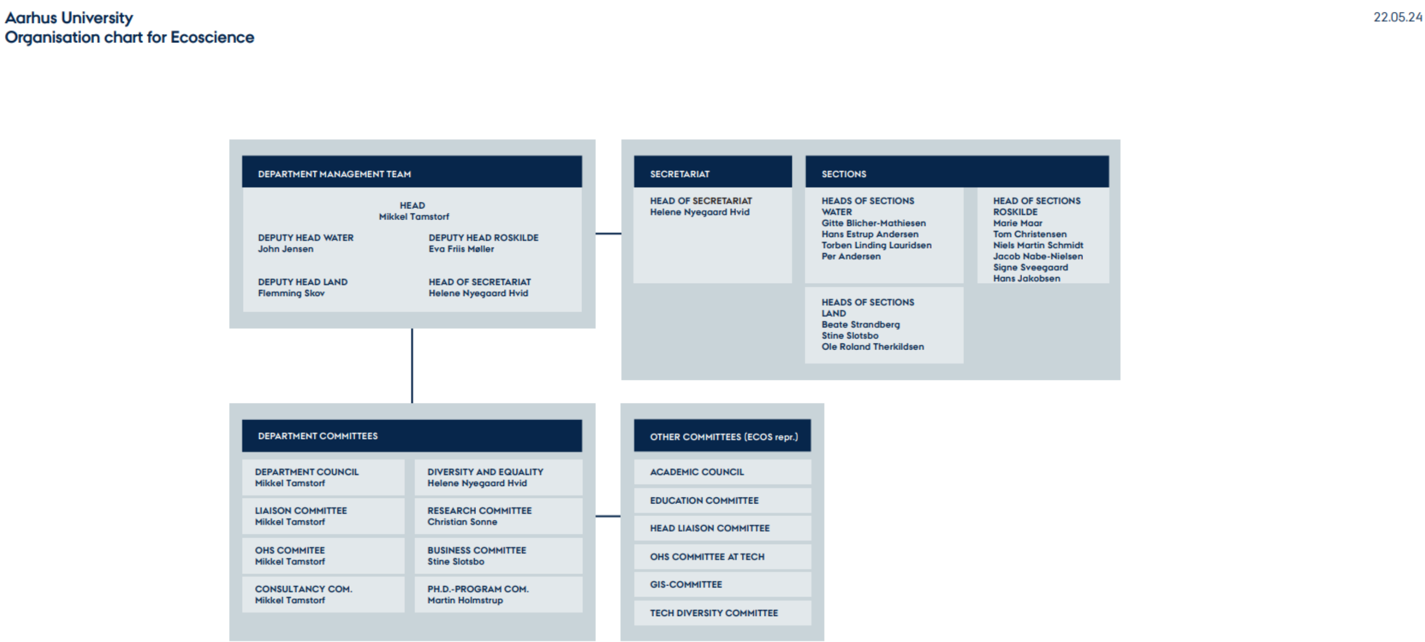
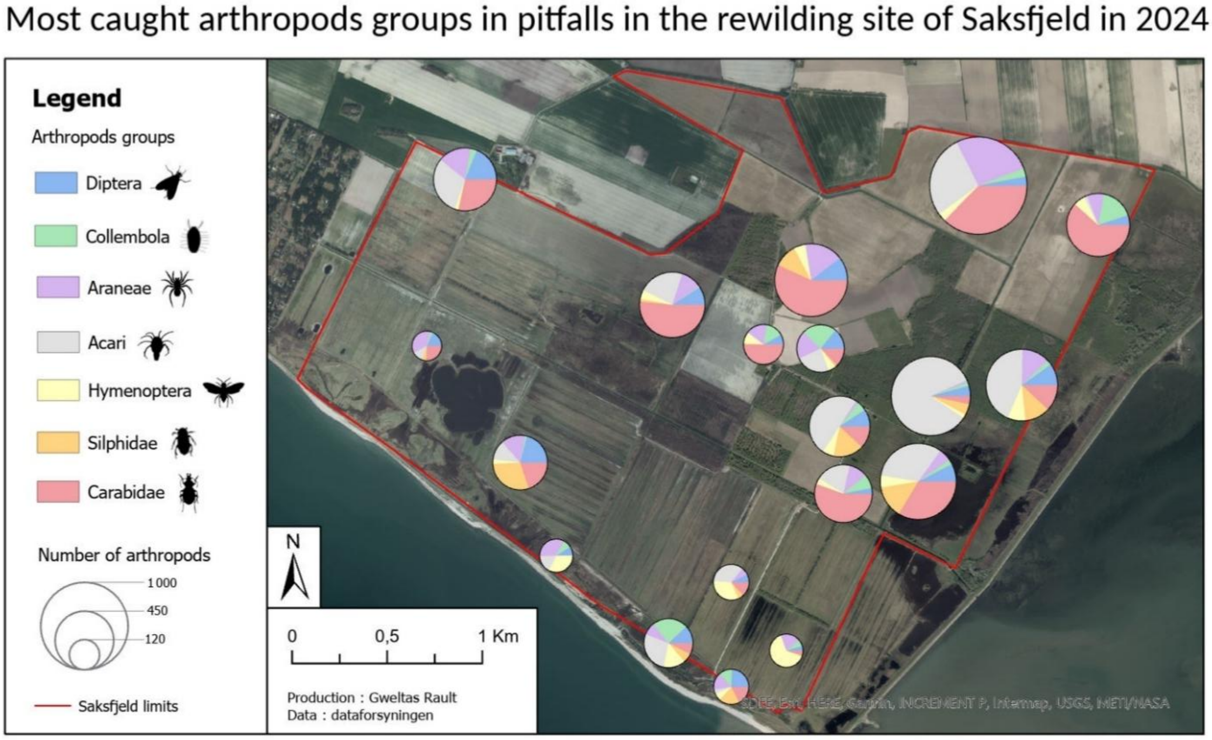
X. Appendices

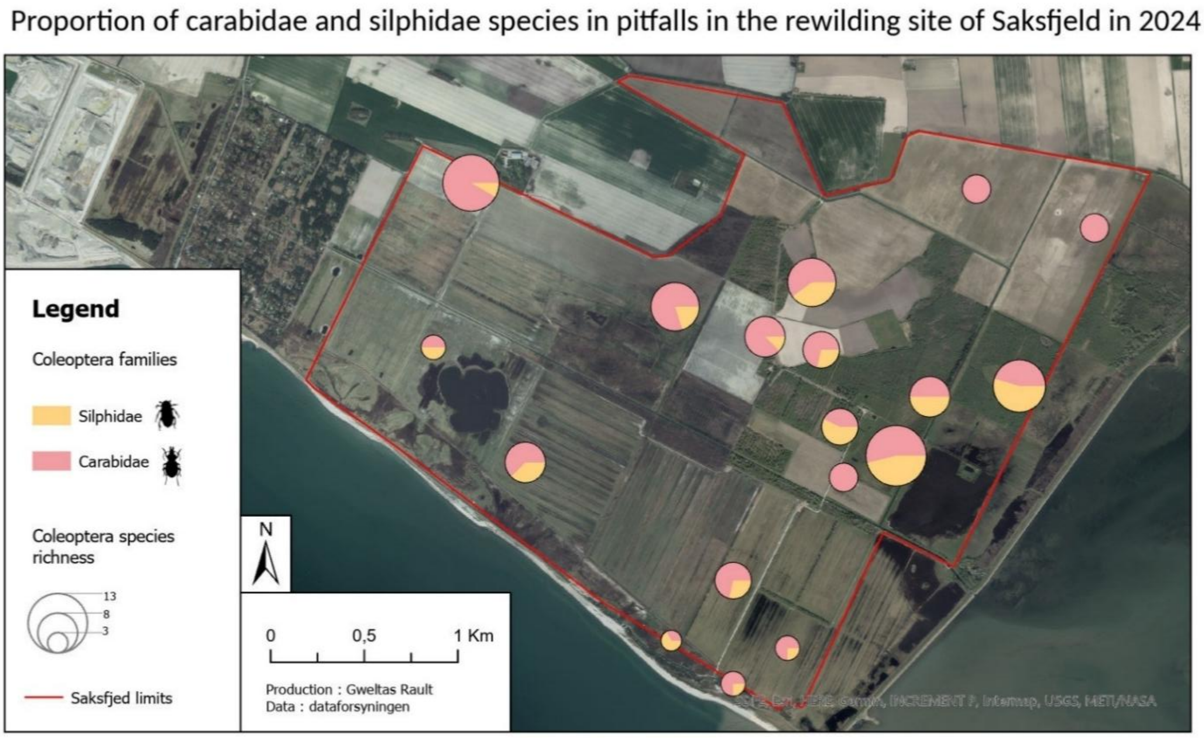
Appendix 1 : Organisation chart of Ecoscience department



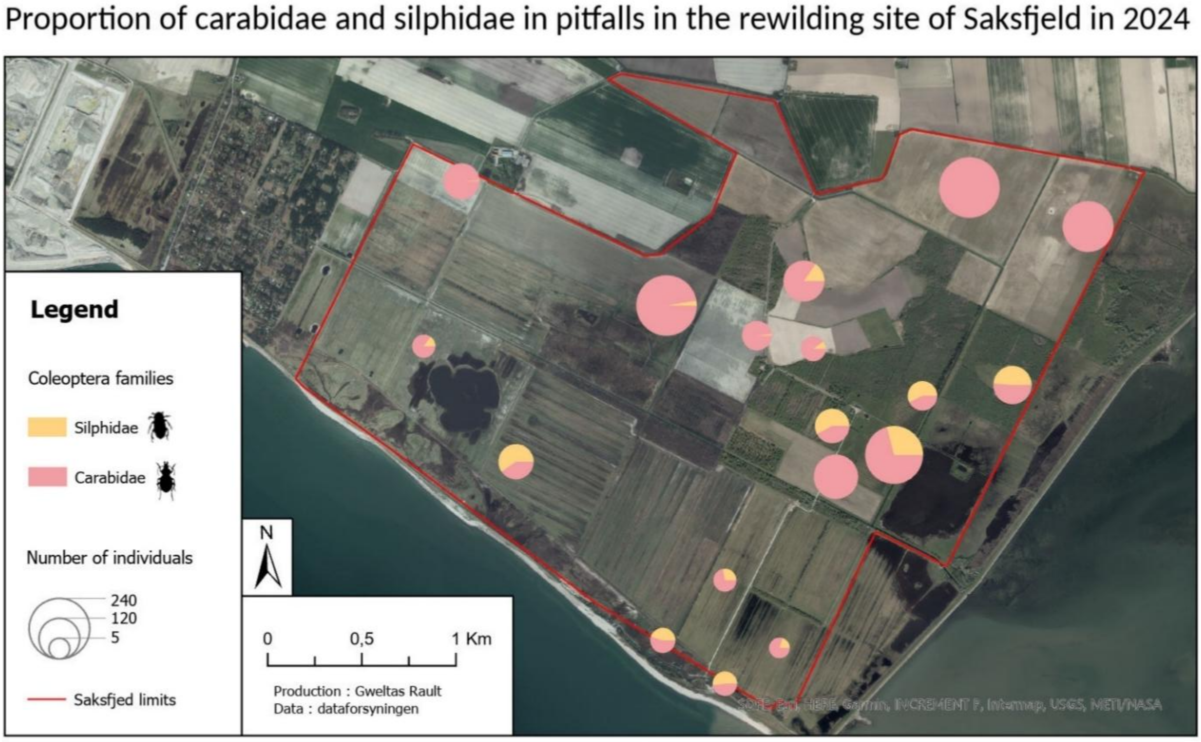
Appendix 2 : Map of the distribution of the main arthropod groups in Saksfjed in 2024



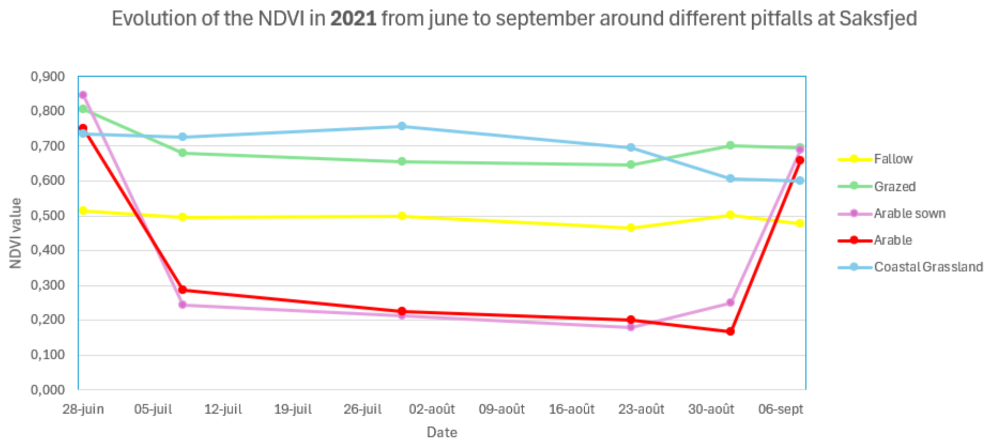
Appendix 3 : Map of the distribution of Carabidae and Silphidae in Saksfjeld in 2024

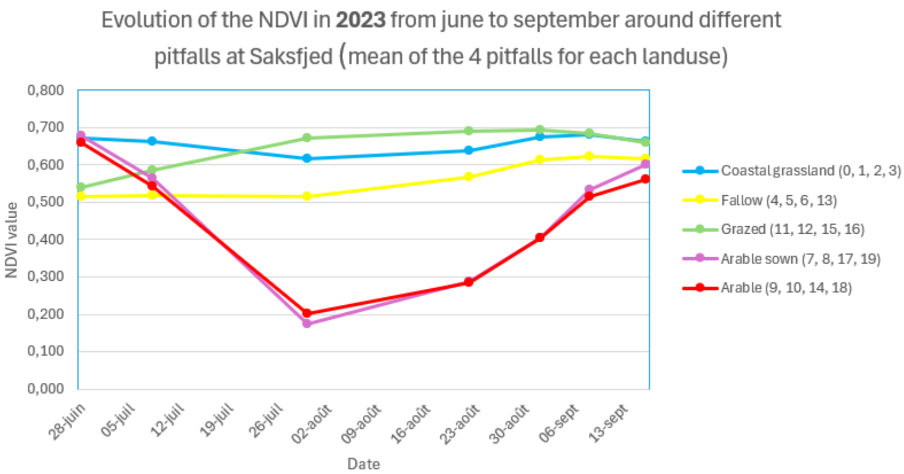


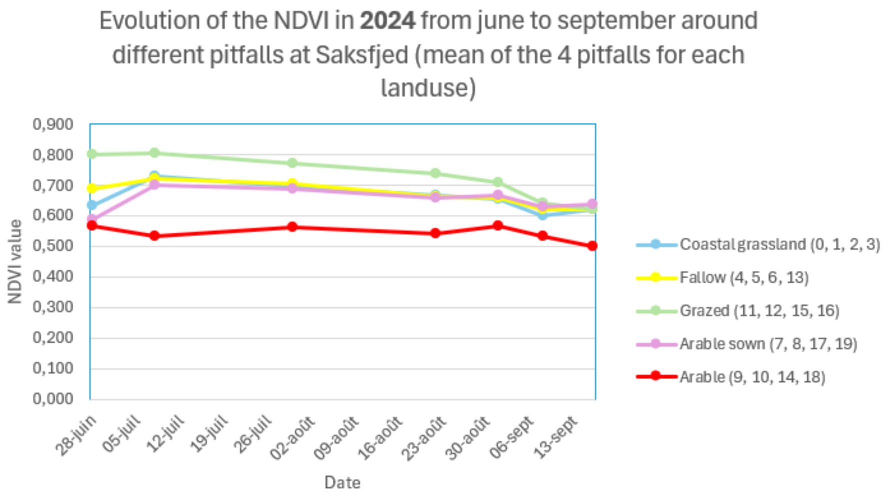
Appendix 4 : Map of the distribution of the species richness of the Carabidae and Silphidae at Saksfjed in 2024



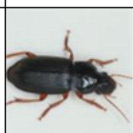
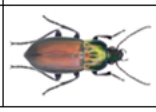
Appendices 5 : Evolution of the NDVI over the season for the years 2021, 2023, and 2024







Appendices 6 : Explanatory tables of the habitat and expected NVI of the 5 most abundant species for the groups of Carabidae, Silphidae, and Araneae

Abundance	Carabidae species	Expected NDVI	Habitat	Photo	Source
511	Pterostichus melanarius	Medium to high	It is able to tolerate wet environments with a wide ranges of temperatures , The beetle can inhabit habitats including forests, meadows, urban areas, feeds on insects, invertebrates, and plants and arable land		wikipedia
429	Calathus fuscipes	Low to medium	It is a eurytop species, which means that it can be found on a wide variety of soils. However, it is mainly found in open areas, especially on dry, sandy or clayey soils that are more or less rich in humus, such as meadows, pastures and cultivated land.		naturbasen
347	Harpalus rufipes	Low	It prefers open ground, especially where the soil is very clayey or loamy, also in cultivated fields, gardens and the like. feed at night, gnawing on seeds (pine, larch, spruce...), caryopses (wheat...) or achenes (strawberry...)		naturbasen and wikipedia
69	Pterostichus niger	High	It is a forest generalist that is found as soon as there is a fairly stable forest climate in the soil. This could be in a dense broom stand, in a garden, or in an old, untouched deciduous forest. Like many other soil bugs, it is quite fond of moisture, and the easiest way to encounter it during the day is to turn over stones, lift fallen branches or remove bark.		naturbasen
46	Poecilus versicolor	Low to medium	It is found everywhere in the open countryside, but preferably in quite dry places. Too much vegetation seems to keep it away.		naturbasen

Abundance	Silphidae species	Approximation of expected NDVI	Habitat	Photo	Source
150	Silpha tristis	Medium to high	Found primarily in open habitats, dense herbaceous vegetation		naturbasen
52	Nicrophorus vespilloides	Medium to high	Found primarily in forests, but also open to semi-open environments. Looking for carrions		naturbasen
50	Nicrophorus vespillo	Medium	It is found in almost all terrestrial biotopes, but rarely in dark forest stands. It is most commonly found attached to carrion, but is sometimes also found in rotten mushrooms or manure.		naturbasen
32	Thanatophilus sinuatus	Medium	Found in both forest and open habitats.		naturbasen
30	Nicrophorus investigator	Medium to high	Primarily associated with forests. It is only rarely found on open ground.		naturbasen

Abundance	Araneae species	Expected NDVI	Habitat	Photo	Source
363	Oedothorax apicatus	Low	The species is a frequent aeronaut that occurs in most habitats. It is characteristic of open disturbed habitats such as disturbed grasslands, agricultural fields and river shingles. In moss, grass and sparse vegetation.		naturespot and treatment.plazi
98	Lycosidae (family)	Low to medium	These spiders are found in many types of habitats: from coastal to inland. These include wooded land, coastal and wet forest, alpine meadows and suburban gardens. They disperse by air and this has made them very adaptable. They live rather solitarily and hunt alone, either by chasing their prey for short distances or, above all, by ambushing them.		wikipedia
85	Linyphiidae (family)	Low to high	Variable in its habitats, including moss, small vegetation, meadows, clear forest undergrowth .		
16	Trochosa terricola	Medium	It is found in woodland, grassland, heathland and industrial sites and is often encountered under stones and logs, but overall it shows a preference for drier, heath-like conditions		wikipedia
13	Oedothorax fuscus	Low to medium	A common aeronaut, this spider found in a variety of grassland (including lawns), arable, recently burnt heathland and wetland habitats.		naturespot