Assignment Academic Grant Writing Academic year 2022/2023

Name: Elise Nieuwenhuijze

Name supervisor: Jan Van Uytvanck

Major: FB

English title of project (max. 240 characters): Variation in v**egetation and vegetation structure and its relationship with spider diversity and abundance.**

Dutch title of project (max. 240 characters): Variatie in vegetatie vegetatiestructuur in relatie met spinnenbiodiversiteit en -abundantie

**Summary of the proposal in laymen’s terms** (max. 1500 characters):

Spider- and arthropod biodiversity in general, have been declining steadily for decades. Spiders are important predators in many ecosystems and play a critical role in regulating insect populations. To reverse this trend in nature reserves conservation management measures are needed. Livestock is used to manage large plots of land, not only as an easy and cheap alternative to more labour-intensive nature management, but primarily to restore ecological functions such as grazing, trampling, nutrient cycling and maintaining open vegetation types and landscapes with complex vegetation structures. If implemented properly grazing creates a heterogenous vegetation. Heterogeneity is considered a primary causal driver of biodiversity, yet the universal role of heterogeneity in structuring biodiversity is unclear. The aim of this research is to establish general insights on how spatial vegetation structure affects and relates to spider biodiversity on former agricultural land, using new remote sensing techniques to map spatial heterogeneity. The habitat-heterogeneity hypothesis states that an increase in habitat heterogeneity leads to an increase in species diversity, so I expect to see a positive correlation between biodiversity and the level of heterogeneity. In this research we focus on spiders living in a vegetation structure gradient, containing short grassland, tall herbs and scrub in three sites with a total of 30 plots in East-Flanders that have a development under low-intensity grazing management, exceeding 20 years. This research will give insight into the relationship between biodiversity and vegetation structure, and how to best implement nature management, particularly grazing.

**Indicate the state of the art** (max. 5000 characters):

Large grazing herbivores exert major influences on their habitat. In many semi-natural types of grassland, especially in Europe, the maintenance or reintroduction of large grazers is a widely applied management tool, aiming to preserve an open, species rich landscape (Ostermann, 1998). Grazing is an easy and cheap alternative to more labour-intensive nature management practices, and when implemented correctly, it is able to create a heterogeneous landscape with large variation in vegetation structure. Large grazers that are mostly used are cattle and horses. Recently attention is paid to the reintroducton of wild species such as Red deer, European bison and Elk.

The most important direct effect of grazers is the eating, trampling, fertilizing and damaging of plants or vegetations. Most grazers show selective foraging and have a preference for grasses. Plants usually have strategies to survive, they either tolerate it and are able to recover quickly or they have evasive strategies. Grazing changes the vegetation structure by creating open spaces that allow certain species to grow which would normally not be able to because of interspecific competition. Plant diversity will increase because of this, but grazing can also decrease plant diversity if the dominant species is tolerant against grazing and/or does not have the preference of grazers. This is why it is important to understand influences of large grazing herbivores on the biodiversity of various plants and animals. Effects of grazing on plant diversity are variable, with literature supporting positive as well as negative effects.

Spiders, which evolved from an arachnid ancestor during the Devonian period around 400 million years ago, are among the most common and abundant predators in terrestrial ecosystems (Nyffeler & Birkhofer, 2017). There is hardly any terrestrial area on this globe where spiders would be missing. “….Spiders exist in the most northern islands of the Arctic, the hottest and most arid of deserts, at the highest altitudes of any living organisms, in the depths of caves, in the intertidal zone of ocean shores, in bogs and ponds, on high, arid moorlands, sand dunes, and flood plains” (Turnbull 1973). They are so widespread because of their ability to survive under extreme conditions and to disperse by ballooning (Nyffeler & Birkhofer, 2017). Because of their ubiquity and abundance, spiders are potentially useful biological indicators of quality of natural habitats, or for determining how communities react to environmental changes or disturbance (Marc & Canard, 1997).

Spider and arthropod biodiversity has been declining globally for decades due to habitat loss, fragmentation, pollution, climate change, and other human activities (Cardoso et al., 2020). Changes in habitat diversity influence diversity of consumers including arthropods. Since all spiders are carnivorous and the main food source is insects (such as collembolans), but prey selection depends on prey availability (Birkhofer & Wolters, 2012).

Maintaining functional diversity is of ecological importance because it, by definition, is the component of diversity that influences ecosystem dynamics, stability, productivity, nutrient balance, and other aspects of ecosystem functioning. Functional biodiversity is important for resilience and adaptability of an ecosystem, it can help an ecosystem adapt to changing conditions.

We aim to gain new insights into the impact of grazing management on vatiation in vegetation structure and how this affects spider (functional) biodiversity. This will help create management plans that will benefit vegetation structure heterogeneity as well as arthropod, including spider, biodiversity.

**Describe the objectives of the research** (max. 3000 characters):

*Describe the envisaged research and the research hypothesis, why it is important to the field, what impact it could have, whether and how it is specifically unconventional and challenging.*

The development of cost-efficient monitoring tools to evaluate and predict landscape quality in terms of biodiversity is a major research objective at the Flemish Research Institute for Nature and Forest (INBO). The main focus in ecological monitoring is focused on flora, since use of flora is takes much time due to sample sorting and species identification. Moreover, the lack of any quantitative framework hampers the effective and efficient implementation of conservation actions essential to safeguard local (insect) biodiversity. And even if insights are available these are usually based on large, visible insects like pollinators.

Use of habitat quality indicators is needed to involve a wider range of invertebrates. Vegetation heterogeneity is one of these important indicators and is anticipated to drive insect interaction networks. Plant growth makes it difficult to establish experiments in which vegetation structure is manipulated in a relevant way and therefore a correlative approach is more appropriate here. We will establish general insights on how the multiple dimensions of spatial vegetation structure affects and drives the diversity of spiders. Focus will be on aboveground and plant-based arthropod interaction networks.

Since focus is on developing contemporary techniques that can be used to monitor landscape quality and diversity, new remote sensing techniques based on high resolution drone imagery will be used. These will be used to determine vertical and horizontal vegetation variation.

Grazing is one of the main drivers that determine vegetation structure, thus knowing how grazing -behaviour and -time influences vegetation structure heterogeneity is important. Since this vegetation heterogeneity, will influence spider and arthropod biodiversity. Understanding this influence can help determine management plans that benefit plant as well as spider (arthropod) biodiversity.

Objective 1: Determine relation of spiders with variation in vegetation structure

Hypothesis: Plots with the largest variation in vegetation structure will have the largest spider (functional) biodiversity.

Objective 2: Make link vegetation heterogeneity and grazing intensity

Hypothesis: A moderate grazing intensity will give the highest level of horizontal vegetation heterogeneity and thus give the largest spider biodiversity.

**Describe the methodology of the research** (max. 9000 characters):

*Be as detailed as necessary for a clear understanding of what you propose. Describe the different envisaged steps in your research, including the intermediate goals. Indicate how you will handle unforeseen circumstances, intermediate results and risks. Show where the proposed methodology is according to the state of the art and where it is novel.*

1. Study areas:

Study areas have already been selected as this research is a collaboration with the institute for nature and forest research (INBO). Ten study plots will be set up in each of the three study sites that have developed under low intensity grazing, for the last . These plots will shows five different types of vegetation variance, so that each type will have an duplicate to make the results more robust. Plots will be selected along a vegetation structure gradient, containing short grassland, tall herbs and scrub.

1. Sampling strategy:

Images will be taken by drones in blocks of 3 to 25 hectare depending on the specific terrain. Each plot will be a circular plot with a diameter of 6 meters. In each plot 5 subplots of 1m2 will be sampled.

Arthropods are collected through suction sampling. This can be combined with pitfall traps when necessary, because pitfall samples have more hunting and nocturnal spiders while suction samples have more web builders (Bali et al., 2019). Sampling time will be dependent on vegetation structure since it includes all vegetation surfaces. Suction sampling will be conducted twice a year: at the end of May/beginning of June and at the end of August/beginning of September.

1. WP1: Quantifying spatial structure

Aim: Create 2.5D canopy height models and integrate these with Normalized Difference Vegetation Index (NDVI) maps to determine vegetation structure variation.

Digital canopy models are obtained from drone flights performed by INBO in collaboration with ATO- Flemish government. These spatially overlapping aerial image sequences will then go through photogrammetric processing to map vegetation height. Structure from Motion (SfM) combines photogrammetry with computer visualisation (Westoby et al. 2012; Fonstad et al. 2013). Using a specialized software named AGIsoft, corresponding points are identified in overlapping images. These points are captured from different angles allowing for stereo-interpretation and generation of a 3D pointcloud. A top of canopy model can then be made from the three-dimensional vegetation model by finding the highest points of each area.

For vegetation heights below 25 centimetres, Normalise Difference Vegetation Index will be used. These are derived from false colour Near Infrared (NIR) images by analysing the variation of NIR reflectance values. Higher NDVI values indicate a higher density of vegetation or more productive vegetation. The resulting NDVI values for each pixel in the image can be used to generate a vegetation index map that indicates the areas of higher and lower vegetation density.

Risks: Operational risks will be low as the used datasets are available: drone photogrammetric point clouds to build the 2.5D models are available for each study site (INBO data) and NDVI-maps are publicly available.

1. WP2: Determining biodiversity and the relationship of spiders with the vegetation structure

Aim: Linking structural diversity to spider diversity.

Methods: Vegetation structure heterogeneity of each subplot (obtained in WP1) will be used to relate them to spider biodiversity. Suction sampling will be conducted on 30 plots and 150 subplots in 3 study sites. Spiders will be identified at species level. Biodiversity, biomass and functional biodiversity will be determined.

Biodiversity:

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Biomass:

Body length will be measured using ImageJ (Schneider et al., 2012) and then regression models from Penell et al. (2018) will be used to determine body mass based on body length.

Functional diversity:

Functional biodiversity is used to determine the overall biodiversity as having different functional groups is important for ecosystem functioning. Spiders don’t have a large range of functions as all spiders are predators. Specimens will be divided in groups based on: hunting strategy (free hunters and web builders), habitat (representing general spatial niche) and body size (reflecting the ability to handle prey of different sizes).

Statistics:

Generalized linear mixed models will be used to correlate (functional) biodiversity and biomass to vegetation heterogeneity within a plot. we would fit a GLMM that incorporates the fixed effect of vegetation heterogeneity and the random effect of location to account for the correlation among data points within each location. The model would also include any relevant confounding variables as covariates. After fitting the GLMM, we would examine the correlation between spider biodiversity and vegetation heterogeneity.

Risks: Scientific and operational risks are rather low for the used methods. Identification however might take a lot of time.

1. WP3: Make a link to grazing intensity

Aim: Determine if there is a correlation between the amount of time cattle spends grazing in a certain area and what the vegetation looks like (structure, heterogeneity and variation)

Methods from Turner et al. (2000) were used as a foundation to build this methodology. GPS collars can be used to determine the grazing behaviour of cattle in the study areas. The size of the plots used will be dependent on the roaming area of cattle. The paddock will be separated into blocks of equal size. GPS collars will be fitted on 8 cows. These collars will note the x, y and z coordinates every 5 minutes (GPS fix interval) for 7 days. Utilization per cell is indicated by number of locations (GPS fixes) within cell multiplied by GPS fix interval. Cell utilization was determined for period and expressed as a percentage of total paddock occupancy time.

The collars will also be fit with dual axis motion sensors that record animal movement, and are sensitive to horizontal and vertical movements of the head and neck. They record activity in movement counts (255 counts maximum) that are stored with other information when GPS position fix is taken, then are reset to zero. The activity sampling window will be set to 4 min.

Cows will be observed on four occasions, each lasting up to 8 consecutive hours. At each GPS location fix, the general behavior of each cow during the preceding 5 min will be classified as active (grazing) or inactive (standing or lying). Counts from horizontal and vertical activity sensors are summed for respective 4-min observation windows and data is then analyzed for differences between collars and observed activity per period.

This GPS data can then be used to determine habitats preferences and grazing time. This can then be correlated to the map that shows vegetation structure variation to determine how the different grazing times affect the vegetation structure and heterogeneity.

Statistics:

Vegetation heterogeneity and grazing time of each block will be determined as mentioned in WP1 and WP3 respectively.

Risks: Use of electrical devices like GPS collars can lead to some technical difficulties. A risk is incomplete data collection, collars incomplete data collection included failure of the collar to initiate and collect data, collar malfunction during collection and inability to download data. However, GPS collars have been used in many experiments without problems, so I the risks to be rather low.

**Provide a work plan, i.e. the different work packages and a detailed timetable** (max. 3000 characters):

*Describe the different work packages (WP) the proposed research work will be divided in. Indicate for each WP the time that it is expected to take. You might use a table or another type of scheme to clarify the work plan.*



**References used in the proposal**

*Only list the publications that have been cited in the text (give full bibliographic references).*

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10. Cardoso, P., Barton, P. S., Birkhofer, K., Chichorro, F., Deacon, C., Fartmann, T., Fukushima, C. S., Gaigher, R., Habel, J. C., Hallmann, C. A., Hill, M. R., Hochkirch, A., Kwak, M. L., Mammola, S., Noriega, J. A., Orfinger, A. B., Pedraza, F., Pryke, J. S., De Oliveira Roque, F., . . . Samways, M. J. (2020). Scientists’ warning to humanity on insect extinctions. Biological Conservation, 242, 108426. <https://doi.org/10.1016/j.biocon.2020.108426>
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12. Birkhofer, K., & Wolters, V. (2012). The global relationship between climate, net primary production and the diet of spiders. Global Ecology and Biogeography, 21(2), 100–108. <https://doi.org/10.1111/j.1466-8238.2011.00654.x>