What can we learn about 40 years of research on heathland management?

Thomas Neyens

UHasselt – CENSTAT/CMK
LIKONA

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A study of trends of invertebrate diversity and abundances in heathland in Limburg by using citizen science data

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Methodological research context

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- My research:
  - Spatial statistics in environmental studies
  - Citizen science
  - Development of statistical methods for opportunistic samples

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  - Uneven species detectability → less problematic in comparison study, when detectability is independent of observer's skills

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- Opportunistic samples lack a sampling protocol:
  - Unbalanced data through time → statistical analysis can resolve this
  - Unbalanced data in space → statistical analysis can resolve this
  - Uneven species detectability → less problematic in comparison study, when detectability is independent of observer's skills
  - Uneven sampling effort → biggest problem, difficult to correct for.

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Ecological research context

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- LIKONA (Limburgse Koepel voor Natuurstudie):
  - Monitoring fauna and flora in Limburg
  - Werkgroep Ongewervelden → extensive set of invertebrate data from 1980 – 2018:
    - Different observation techniques: pitfalls, fly nets, etc.
    - The whole of Limburg is covered

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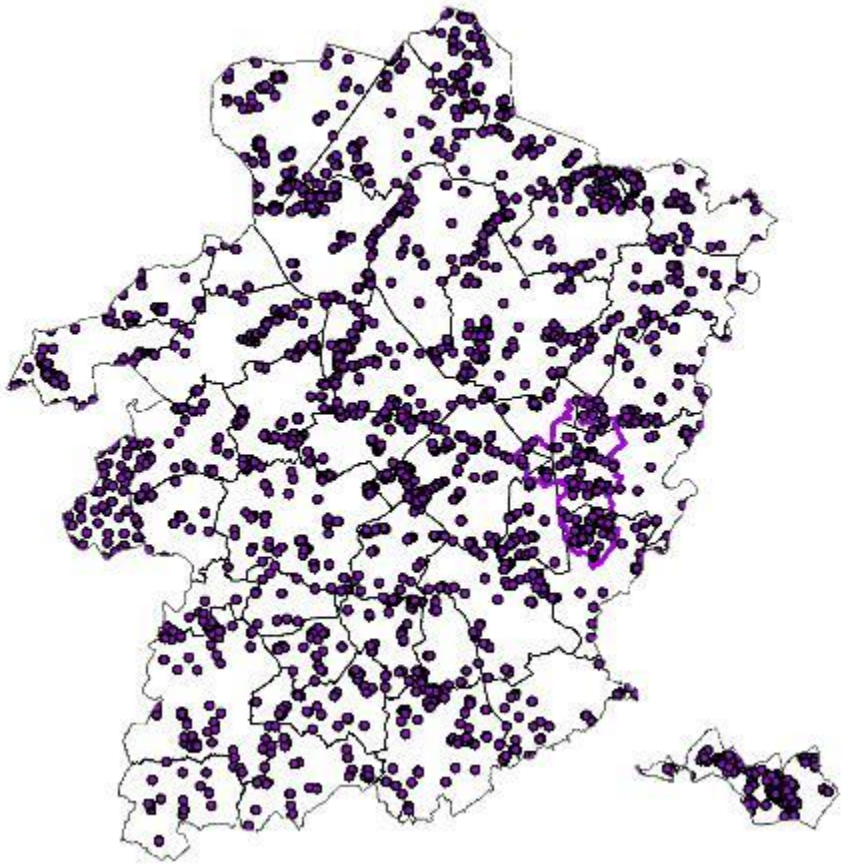
All sampling locations (all techniques)



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- Exploratory studies in 2017 suggested changes in heathland invertebrate numbers between the years before and after 2001.
  - Statistical methods not sophisticated
  - Data inconsistencies (taxonomic name changes, reporting bias, etc.)

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➔ Build statistical models to improve the analysis

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Data cleaning

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Data cleaning

- Avoid inconsistencies in sampling effort
  - Focus on pitfall data

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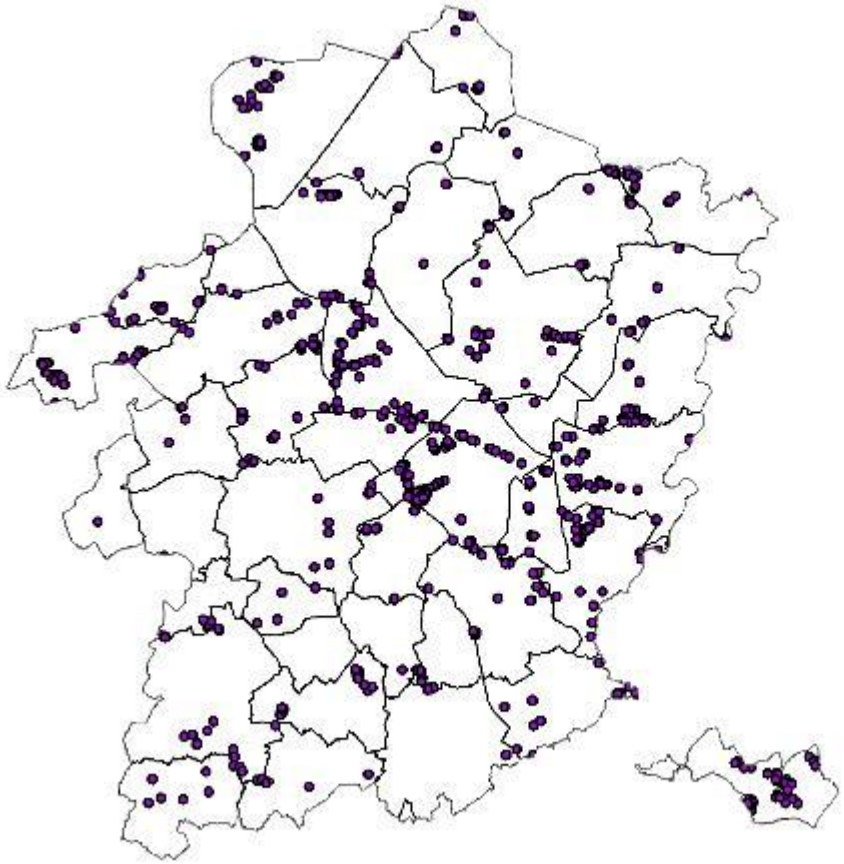
806 pitfall locations with GPS locations (1403 pitfall locations in total)



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Data cleaning

- Avoid inconsistencies in sampling effort
  - Focus on pitfall data
- Avoid differences in reporting precision between taxonomic groups
  - Focus on beetles and spiders

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- Avoid inconsistencies in sampling effort
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- Avoid seasonal effects
  - Only include data obtained in March 1-June 30

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  - Only include data with exact GPS coordinates and correct habitat information

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- “Avoid” temporal unbalance

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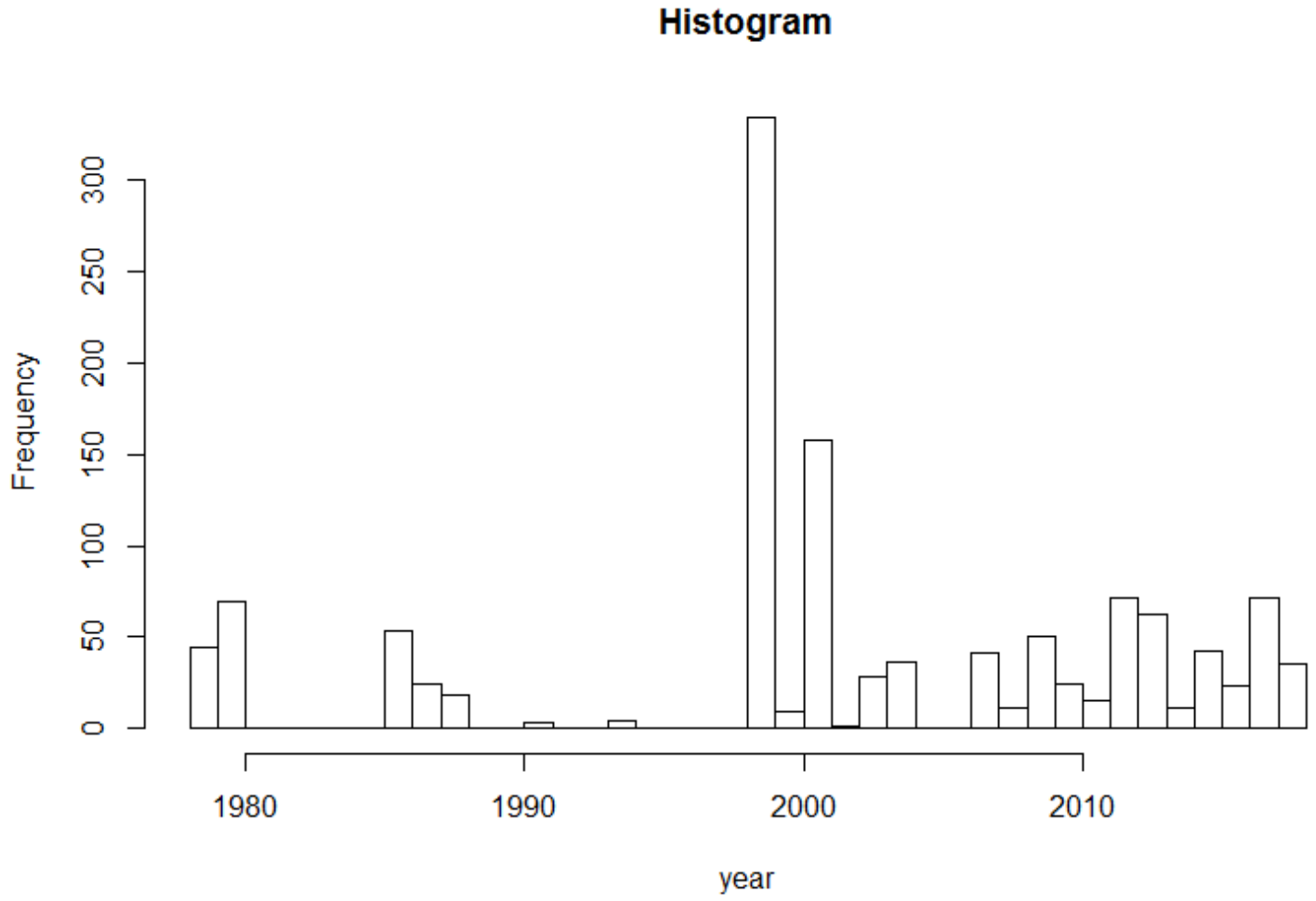
Pitfall sampling in heathland



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- Include only pitfalls that were re-collected within 30 days

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449 sampling events in dry heathland
239 sampling events in wet heathland

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Analysis plan

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- Analysis for:
  - Dry + wet, only dry, only wet
  - All species, vulnerable species, common species

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- Analysis for:
  - Dry + wet, only dry, only wet
  - All species, vulnerable species, common species
- Analysis of:
  - Abundance:
    - Numbers of captured animals per sampling event

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Analysis plan

- Analysis for:
  - Dry + wet, only dry, only wet
  - All species, vulnerable species, common species
- Analysis of:
  - Abundance:
    - Numbers of captured animals per sampling event
  - Diversity:
    - Hill 0: species richness
    - Hill 1: exp(Shannon-Wiener Index)
    - Hill 2: (Simpson's γ)$^{-1}$

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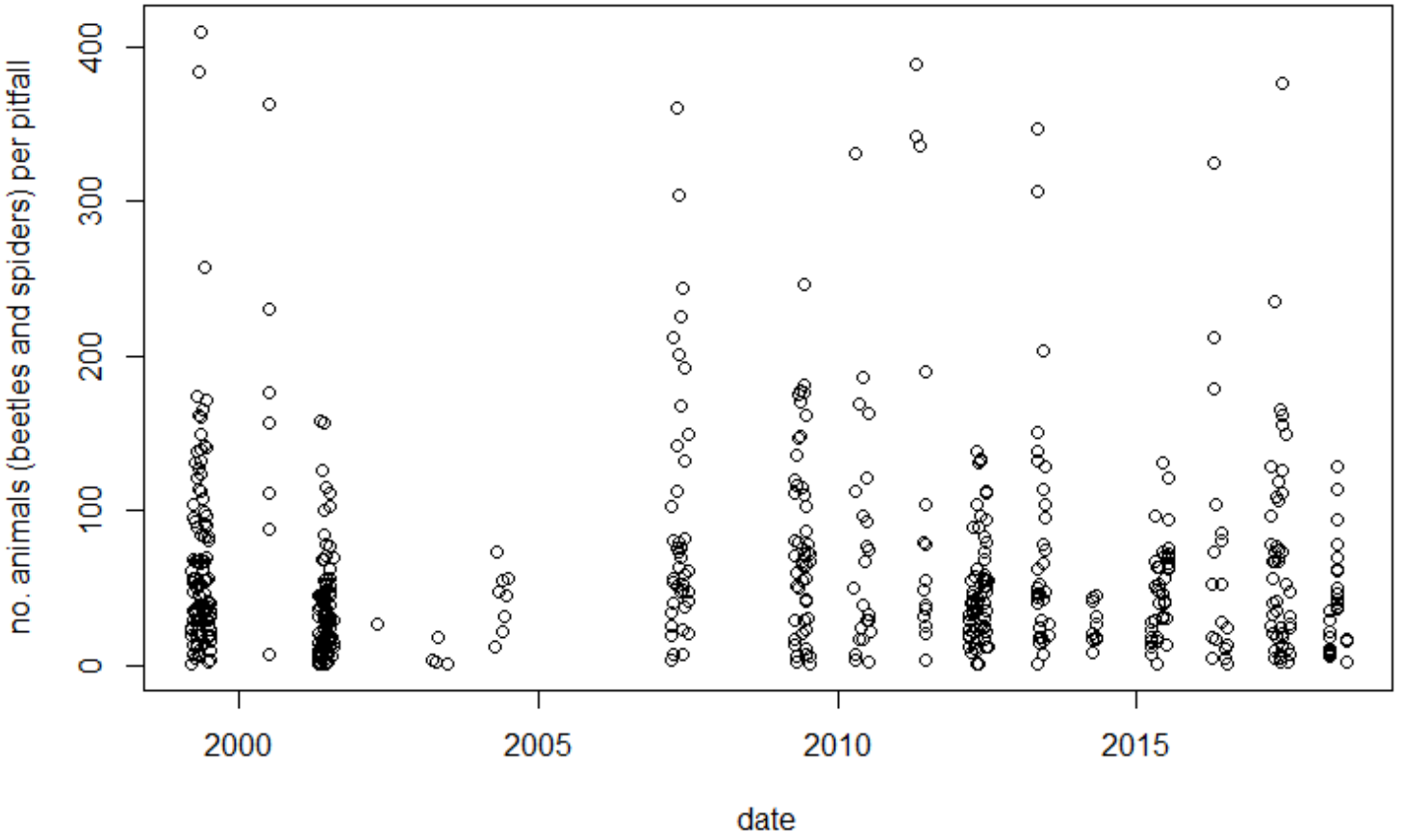
Example



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Methods

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- Abundance and Hill 0 are counts → Poisson distribution

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- Abundance and Hill 0 are counts → Poisson distribution
- Problem with overdispersion → Negative binomial regression model
  - Can additionally capture (some) overdispersion caused by zero-inflation and spatial correlation

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$$Y_i \sim \text{NegBin}(\lambda_i, \alpha)$$

$$\log(\lambda_i) = \beta_0 + \beta_1 Date_i \qquad \text{For i} = 1, \ldots, \text{n}$$

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- Take sampling duration (pitfall in the field) into account

$$\log\left(\frac{\lambda_i}{duration_i}\right) = \beta_0 + \beta_1 Date_i$$

$$\log(\lambda_i) - \log(duration_i) = \beta_0 + \beta_1 Date_i$$

$$\log(\lambda_i) = \beta_0 + \beta_1 Date_i + \log(duration_i)$$

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Methods

Hill 1 and Hill 2 are continuous → Normal distribution (?)

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- Transform the data to achieve (semi-) normality and (semi-) homoscedasticity and fit a linear regression model

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$$\log\left(\frac{Y_i}{duration_i}\right) = \beta_0 + \beta_1 Date_i + \varepsilon_i$$

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For both analyses: Effects of outliers

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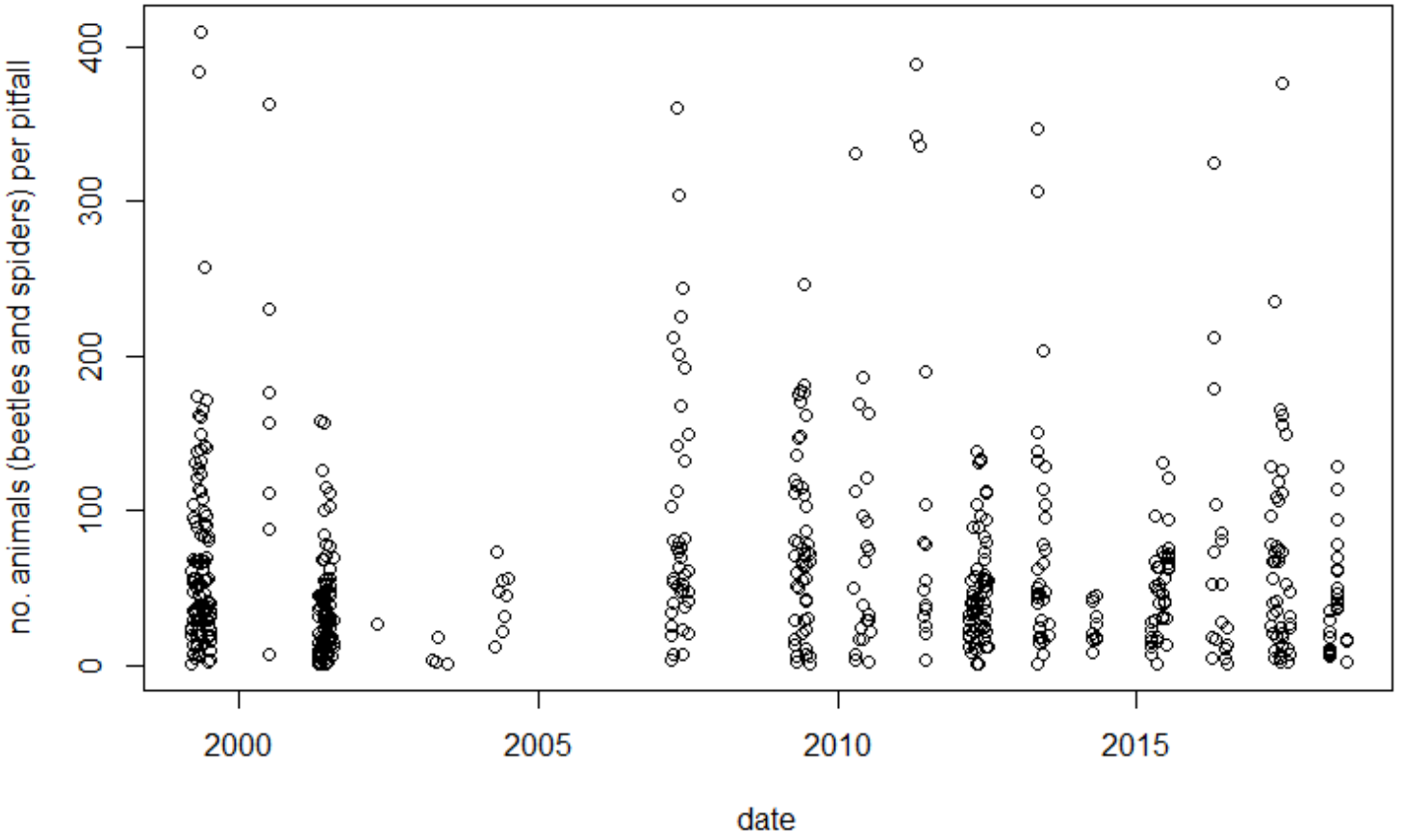
Outliers



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For both analyses: Effects of outliers

→ Compare analyses based on data with and without outliers

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Results – all species

Legend
decrease in data with and without outliers
decrease in data with outliers
borderline increase (0.01 < p value < 0.05)
increase in data with and without outliers
increase in data with outliers

all species (beetles & spiders)	**wet + dry**	**dry**	**wet**
no. individuals			
Hill 0 --> species richness			
Hill 1 --> exp(Shannon-Wiener Index)			
Hill 2 --> (Simpson's gamma)^-1			
beetles	**wet + dry**	**dry**	**wet**
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Results – vuln. species

Legend
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borderline increase (0.01 < p value < 0.05)
increase in data with and without outliers
increase in data with outliers

all vulnerable species (beetles & spiders)	**wet + dry**	**dry**	**wet**
no. individuals			
Hill 0 --> species richness			
vulnerable beetles	**wet + dry**	**dry**	**wet**
no. individuals			
Hill 0 --> species richness			
vulnerable spiders	**wet + dry**	**dry**	**wet**
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Results – vuln. species

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increase in data with outliers

all vulnerable species (beetles & spiders)	**wet + dry**	**dry**	**wet**
no. individuals	no change		
Hill 0 --> species richness	no change		
vulnerable beetles	**wet + dry**	**dry**	**wet**
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Hill 0 --> species richness	no change		
vulnerable spiders	**wet + dry**	**dry**	**wet**
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increase in data with outliers

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Hill 0 --> species richness	no change	no change	
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vulnerable spiders	**wet + dry**	**dry**	**wet**
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Results – com. species

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increase in data with and without outliers
increase in data with outliers

all common species (beetles & spiders)	**wet + dry**	**dry**	**wet**
no. individuals			
Hill 0 --> species richness			
common beetles	**wet + dry**	**dry**	**wet**
no. individuals			
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common spiders	**wet + dry**	**dry**	**wet**
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Conclusion

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- In general, numbers seem to change (mostly decrease), diversity remains the same

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➔ Do animals move from dry to wet heathlands?

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Study limitations & future work

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- The trends are significant, but do not explain a lot of the variability in the data

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- Spatial correlation might affect results
  - Geostatistical models (current work)
  - Ecological covariates will be added to the data soon

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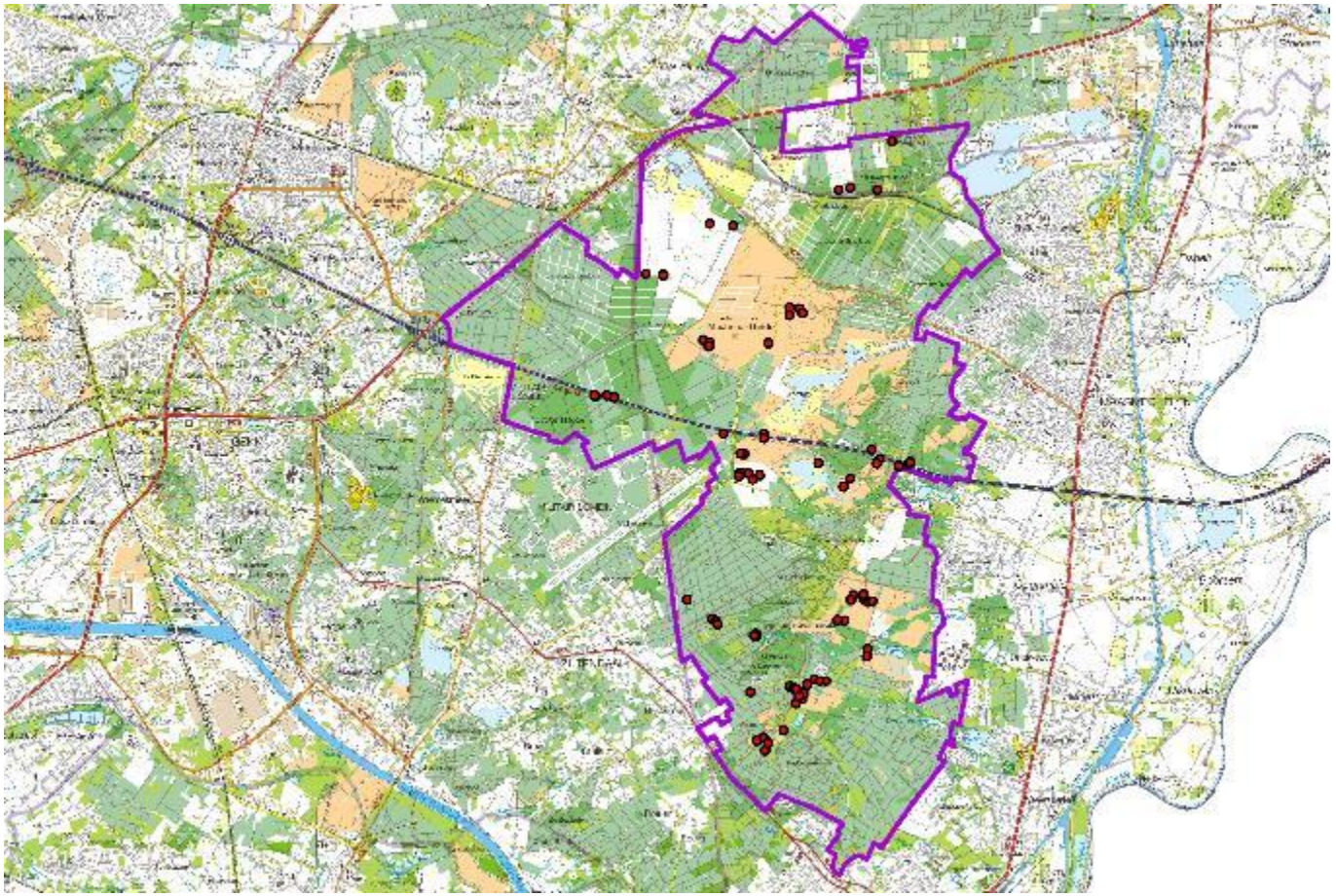
National Park



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Study limitations & future work

- The trends are significant, but do not explain a lot of the variability in the data
- Spatial correlation might affect results
  - Geostatistical models (current work)
  - Ecological covariates will be added to the data soon
- Preferential sampling might be an issue
  - However, investigations suggested that its effect is negligible.
  - It is good to model the sampling process and the outcome of interest simultaneously in a geostatistical context, but this is computationally demanding.

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Thank you!

A special “Thank you” to LIKONA – Werkgroep Ongewervelden

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