Martin-Luther-University Halle-Wittenberg

Institute for Zoology

Modelling species-habitat relationships across scales for nature conservation

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Timeline

Time	Activity
Day 1	
09:15-09:30	Species identification exercise
09:30-09:50	From Aristotle to Humboldt
09:50-10:00	Break
10:00-10:45	Biodiversity; definitions and measures
10:45-11:00	Break
11:00-12:00	Exercise 1
Day 2	
09:15-09:45	Exercise 2A
09:45-10:00	Break
10:00-10:45	Exercise 2B
10:45-11:00	Break
11:00-11:40	Basic concepts: Niche *vs.* Habitat, Home range *vs.* Dispersal
11:40-12:00	Exercise 2C
Day 3	
09:15-09:45	Conservation in practice 1: Rewilding Europe
09:45-09:55	Break
09:55-10:30	Spatial and organizational scales in Ecology
10:30-10:45	Break
10:45-12:00	Exercise 3
Day 4	
09:15-09:45	Temporal dynamics and their impact on conservation decisions
09:45-10:00	Exercise 4A
10:00-10:10	Break
10:10-10:45	Conservation in practice 2: broad-scale policy frameworks
10:45-11:00	Break
11:00-12:00	Exercise 4B

Cover image: Climbing Maroon Peak in the Elk Mountains – one of the "Bells" and part of Colorado's noted 14,000 foot peaks which are famous for wild mountain goats (©Peter McBride).

Prologue

Welcome! My name is Elina Takola, and over the next few days, we'll be exploring the dynamics between species and their environments.

Course objectives

This course aims to introduce participants to the theory and practice of modelling species-habitat relationships, with an emphasis on spatial and ecological scales relevant to conservation planning. We'll explore how species interact with their environments, how these relationships vary across scales, and how such knowledge can be applied to real-world conservation problems.

About the course

This course blends history (because modern ecology didn't just appear out of nowhere), theory (to help us understand the "why" behind ecological patterns), and practice (so you can build hands-on experience with essential methods). The course will be conducted in English. The use of Large Language Models is prohibited.

Over the week, you'll have the chance to develop several important skills:

1. Analytical thinking and problem-solving; through exercises and data handling tasks
2. Communication; by engaging with your peers in discussions and collaborative work
3. Time management; as you'll be submitting a daily deliverable
4. Language skills; if English isn't your first language, this is a great opportunity to practice

The course will take place from Monday 16th of June to Thursday 19th of June 2025, from 09:15-12:00 in Hoher Weg 8 (Halle).

About me

I was born and raised in Greece, where I completed both my Bachelor's and Master's degrees in Forestry, specializing in wildlife conservation. My Master's thesis focused on species-habitat relationships in reptiles. In 2018, I moved to Germany to pursue a doctorate at the Friedrich Schiller University of Jena in the field of Behavioural Ecology. My PhD thesis was titled *"Scaling down the ecological niche concept from populations to individuals: an evidence synthesis approach."* After that, I moved to Leipzig for postdoctoral research and am currently leading the Biodiversity and Ecosystem Services (BIOECOS) group at the Helmholtz Centre for Environmental Research (UFZ). You can find me in LinkedIn, ResearchGate, Google Scholar or my personal website.

1. Preparation for the course

In the following text, you can find the tutorials by clicking on the hyperlinks. It is strongly recommended to use a PC or a laptop to complete the instructions in this section.

Step 1: Please download R/RStudio and create an account on GitHub.

Step 2: Once you set up a GitHub account, please first log in into your GitHub account and fork the repository of the course, by clicking on this link and clicking on the "Fork" button on the top right side of the repository page and then click on the "Create fork" button.

(You can find a video tutorial of Step 2 online.)

All the course material (data, solutions and the current document with active hyperlinks) are stored in this repository.

Please take some time to familiarise yourself with the RMarkdown tool, as you will need to use it daily. There is no need to download anything to use this tool, as it is already included in RStudio.

2. Course materials

2.1. Day 1 – Counting living things

Today's goals are to get acquainted with the historic roots of Ecology, the most influential figures and the concept of biodiversity. In addition, you will gain some hands-on experience on how to quantitatively estimate diversity of ecological communities.

Biodiversity includes the diversity of species, ecosystems and genetic variations within a species. There are three types of diversity; α (alpha), β (beta) and γ (gamma). Alpha diversity is the diversity of species in an area (usually calculated with Shannon's index). Beta diversity represents the difference between two communities or ecosystems (usually calculated with Bray-Curtis dissimilarity index). Gamma diversity represents the total diversity (number of species) across communities within an area.

Shannon's Index

$$H = -\sum_{j=1}^{S} p_i \ln p_i$$

where

H = Shannon index

pi = proportion of individuals in *i*th species

s = number of species in a community

Bray-Curtis dissimilarity

between two sites j and k is

$$BC_{jk} = 1 - \frac{2C_{jk}}{S_j + S_k} = 1 - \frac{2\sum_{i=1}^{p} min(N_{ij}, N_{ik})}{\sum_{i=1}^{p}(N_{ij} + N_{ik})}$$

where

N_{ij} = number of specimens of species i at site j

N_{ik} = number of specimens of species i at site k

p = total number of species in the samples

2.1.1. Exercise 1

Imagine you're a Conservation Biologist working at the Helmholtz Centre for Environmental Research (UFZ) in Leipzig. Your project aims at comparing the biodiversity of the Carpathian Mountains in Eastern Europe with the Alps in Central Europe. Your goal is to extract insights that can help shape conservation strategies and promote sustainable land management within these important terrestrial ecosystems. Use the dataset from GitHub repository and calculate diversity indexes to estimate alpha (Shannon), beta (Bray-Curtis) and gamma diversity. Plot the results for each area in a bar plot. Mandatory: calculate the indices and visualize them. Optional: calculate the indices without using a pre-made function or an R package. Deliverable: submit an RMarkdown pdf with the code, results and plots.

2.1.2. Further reading

Jurasinski, G., Retzer, V. and Beierkuhnlein, C. (2009) 'Inventory, differentiation, and proportional diversity: A consistent terminology for quantifying species diversity', *Oecologia*, 159(1), pp. 15–26. doi:10.1007/s00442-008-1190-z.

Tuomisto, H. A consistent terminology for quantifying species diversity? Yes, it does exist. *Oecologia* **164**, 853–860 (2010). https://doi.org/10.1007/s00442-010-1812-0

Jurasinski, G., Retzer, V. and Beierkuhnlein, C. (2009) 'Inventory, differentiation, and proportional diversity: A consistent terminology for quantifying species diversity', *Oecologia*, 159(1), pp. 15–26. doi:10.1007/s00442-008-1190-z

https://www.medievalists.net/files/09012347.pdf / https://www.nps.gov/subjects/tek/index.htm

2.2. Day 2 – A day in the life of a field ecologist

Today's goals are to simulate data collection in the field, practice our species identification skills and learn about data management. After collecting our observations, we will calculate Margalef's index (alpha diversity), Sørensen index (complement of Bray-Curtis) and gamma diversity.

Sørensen Index

$$SI = (2 * EC)/(E1 + E2)$$

where

EC = total number of species in common between the sites

E1 = number of species in site 1

E2 = number of species in site 2

Margalef's index

$$d = \frac{S-1}{\ln N}$$

where

S = number of species

N = total number of individuals in the sample

2.2.1. Exercise 2

Imagine you are an Indiana-Jones-style field ecologist, aiming at protecting biodiversity in the area around the vast Saalezonian river. Today it's the first sunny day after a long time of rain, thus you have a unique opportunity to collect your data in the field. Grab your backpack, your data sheet (in the Appendix) and let's go! Deliverable: Rmarkdown pdf with code and plots.

A. Collect data from the field. What species do you see? Write them down in the Appendix.
B. Calculate alpha (Sørensen), beta (Margalef's) and gamma diversity and plot the results for each area in a figure.
C. Discuss: Can a polar bear live in Scotland? Why?

2.2.2. Further reading

McInerny, G.J. and Etienne, R.S. (2012), Pitch the niche – taking responsibility for the concepts we use in ecology and species distribution modelling. J. Biogeogr., 39: 2112-2118. https://doi.org/10.1111/jbi.12031

McInerny, G.J. and Etienne, R.S. (2012), Ditch the niche – is the niche a useful concept in ecology or species distribution modelling?. J. Biogeogr., 39: 2096-2102. https://doi.org/10.1111/jbi.12033

McInerny, G.J. and Etienne, R.S. (2012), Stitch the niche – a practical philosophy and visual schematic for the niche concept. J. Biogeogr., 39: 2103-2111. https://doi.org/10.1111/jbi.12032

Whittaker, R.H., Levin, S.A. and Root, R.B. (1973) 'Niche, habitat, and ecotope', *The American Naturalist*, 107(955), pp. 321–338. doi:10.1086/282837.

Alzate, A. & Onstein, R.E. (2022) Understanding the relationship between dispersal and range size. Ecology Letters, 25, 2303–2323. Available from: https://doi.org/10.1111/ele.14089

2.3. Day 3 – Solving ecological puzzles

Today's goals are to understand the importance of spatial and organizational scales in Ecology. We will talk about complexity, variability and the challenge of scales in conservation. We will scrutinize one of the biggest and currently ongoing ecological projects (Rewilding Europe) and analyse what should be considered when designing an action plan.

2.3.1. Exercise 3

Imagine you've just been hired as the lead biodiversity analyst for a national park system. Your challenge is to help decision-makers understand how much land needs protection to preserve the park's diversity of species. Calculate and plot the Species Accumulation Curve (SAC). What do you observe? Write your conclusions in a small report (~200 words) as pdfs.

2.3.2. Further reading

Jackson, H.B. and Fahrig, L. (2015), Is research conducted at optimal scales?. Global Ecology and Biogeography, 24: 52-63. https://doi.org/10.1111/geb.12233

Estes, L., Elsen, P.R., Treuer, T. *et al.* The spatial and temporal domains of modern ecology. *Nat Ecol Evol* **2**, 819–826 (2018). https://doi.org/10.1038/s41559-018-0524-4

Levin, S.A. (1992), The Problem of Pattern and Scale in Ecology: The Robert H. MacArthur Award Lecture. Ecology, 73: 1943-1967. https://doi.org/10.2307/1941447

White, E.P. *et al.* (2010) 'Integrating spatial and temporal approaches to understanding species richness', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365(1558), pp. 3633–3643. doi:10.1098/rstb.2010.0280.

Chase, J.M., McGill, B.J., Thompson, P.L., Antão, L.H., Bates, A.E., Blowes, S.A., Dornelas, M., Gonzalez, A., Magurran, A.E., Supp, S.R., Winter, M., Bjorkman, A.D., Bruelheide, H., Byrnes, J.E.K., Cabral, J.S., Elahi, R., Gomez, C., Guzman, H.M., Isbell, F., Myers-Smith, I.H., Jones, H.P., Hines, J., Vellend, M., Waldock, C. and O'Connor, M. (2019), Species richness change across spatial scales. Oikos, 128: 1079-1091. https://doi.org/10.1111/oik.05968

2.4. Day 4 – Cross-scale dynamics in Ecology

Today's goals are to explore the importance of time and temporal dynamics in Ecology and to become familiar with policy frameworks. Natural systems are dynamic and constantly changing. Time has also different scales: which one should be considered?

2.4.1. Exercise 4

Imagine you are a scientist working at the German Federal Agency for Nature Conservation (BfN). You are invited to consult a group of policy makers in the German Bundestag (parliament) and discuss the prospects and challenges of re-introducing large mammals in European landscapes. As a preparation you are asked to do the following:

A. Discuss: Can wolves shape rivers? What do the evidence say?

B. Create a conservation action plan for the reintroduction of the European bison (*Bos bonasus*) in Germany. Think about the following: i) What are the requirements of the species? Are these requirements met by ecosystems in Germany? ii) What are the risks of this project? iii) Where will you find the individuals that will start the population? iv) Who might be affected by the reintroduction (stakeholder analysis)? v) How much will it cost?

2.4.2. Further reading

https://www.wwf.pl/sites/default/files/2019-09/Action%20Plan_Pucek%20et%20al..pdf

https://ebcc.wisent.org/wp-content/uploads/2022/07/European-bison-Status-Review.pdf

Appendix

BIODIVERSITY DATA FORM

GENERAL INFORMATION

Study area:

Latitude:

Longitude:

Temperature:

Canopy cover:

Soil type:

Land cover:

Observer:

Date:

Time:

Elevation:

Slope:

Aspect:

PLANTS

Species	Count	Details

ANIMALS

Species	Male	Female	Details

Accuracy Assessment Data Sheet

Site: Brown's Island | Date: 5-27

Recorder(s): [illegible]

Data collection time starts: [illegible]

GPS (circle): Garmin Trimble | Data collection time end:

Observation Levels:
1: Observed at sample pt (using coordinates)
2: Observed from 5-10 meters away
3: Observed from levee/ boardwalk closest to pt
4: Photo interpreted

Veg Classes:
1: Bolboschoenus maritimus
2: Scirpus americanus (S. Island)
3: Typha & S. americanus
4: S. americanus (N. Island)
5: S. americanus & Distichlis spicata (higher marsh)
6: Phragmites australis
7: Hydrocotyle spp.
8: Bare 9: Water, shadow

Cover Classes:
1: 0-2% cover
2: 2-5% cover
3: 5-25% cover
4: 25-50% cover
5: 50-75% cover
6: 75-95% cover
7: >95% cover

Fuzzy Categories (indicate level of match between ground & map):
1: Exact match - The associations are exactly the same.
2: Acceptable Error - mapped type has minor differences with type observed in the field; often species dominance or composition is very similar.
3: Understandable Error - mapped class does not match field point; types have structural or ecological similarity, or have similar species associates.
4: Vague Similarity - types seen in field and on map match in formation and structure, but species or ecological conditions are not similar.
5: Complete Error - classes have no conditions or structural similarity.

AA-ID	Obs. Level	GPS Acc.	Species Info (record spp. & cover class 1-7)																Fuzzy Cat.	Notes (include channel edge notes)
			[illegible]	[illegible]	Phau	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							
330	1	4.5	4	4	2	3	2	1	1	2									1	[illegible]
133	1	39		5						5									4	[illegible]
141	1	78	7			4		2		2									5	
115	1	8.4	6	4						4									4	[illegible]
475	1	[illegible]	3	7						3									2	[illegible]
[illegible]	1	4.5	7						2										5	[illegible]
[illegible]	1	[illegible]	2	7						2									2	[illegible]
136	1	[illegible]	2	3						3	1								2	[illegible]
109	1	3.5	1	[illegible]						1									3	[illegible]
392	1	29		[illegible]						1									3	[illegible]
162	1	4.5		6				1		3	2	3	2						5	[illegible]
197	1	[illegible]	1	5										9					2	[illegible]
[illegible]	1	[illegible]		7						4									1	

A real field data sheet (Lank et al. 2005).