Two extensions of the vanilla GLLVM

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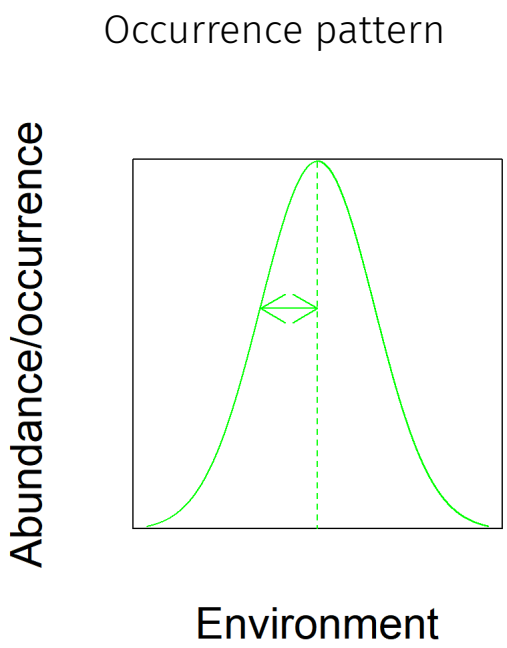
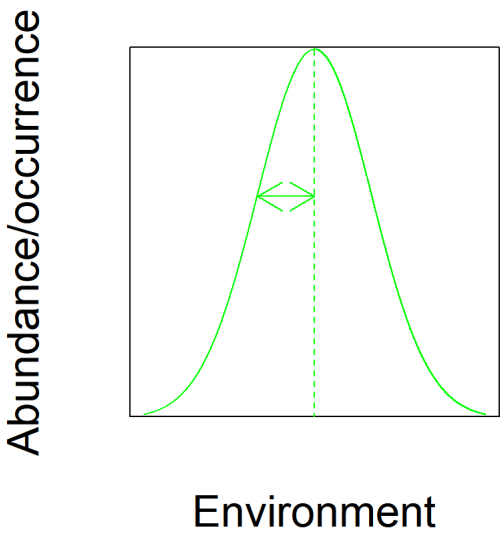
In the introduction…

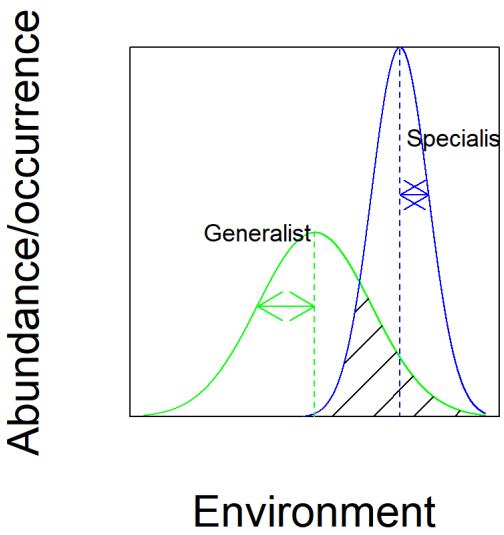


Why analyse multivariate data?

Occurrence pattern

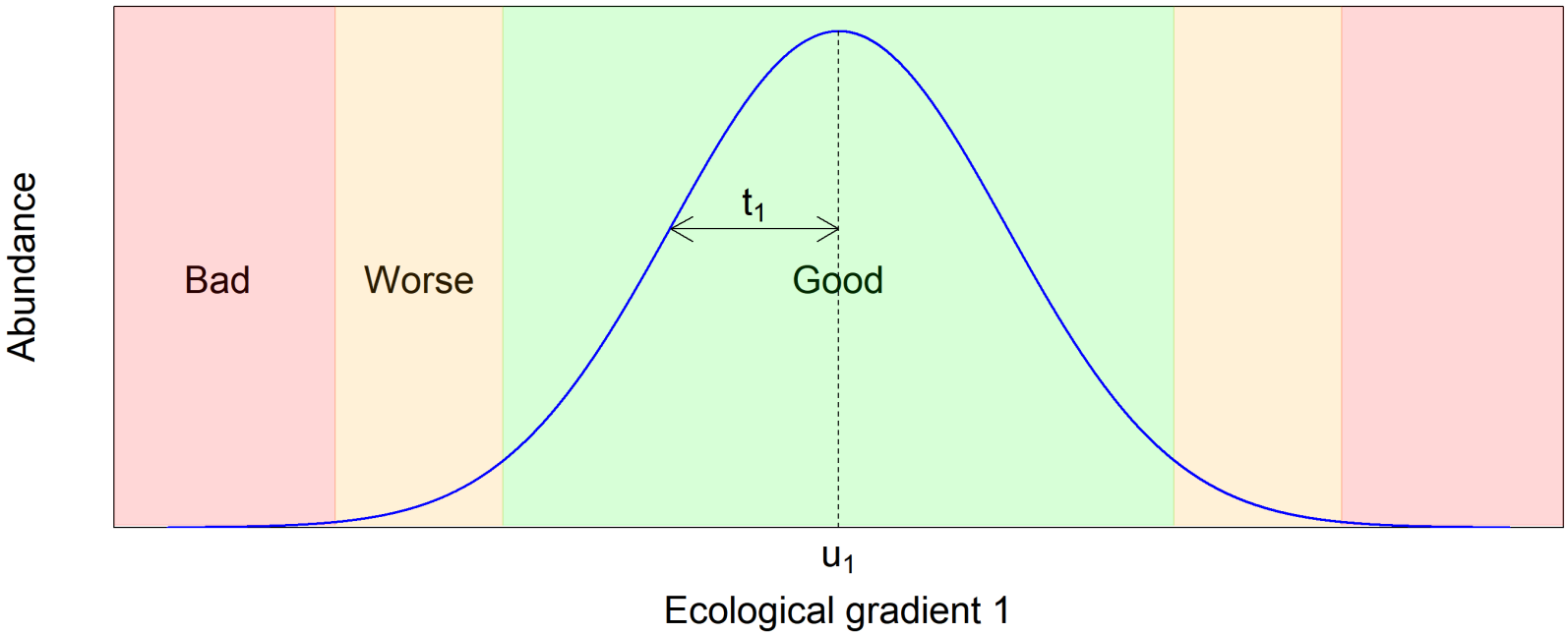


Co-occurrence pattern

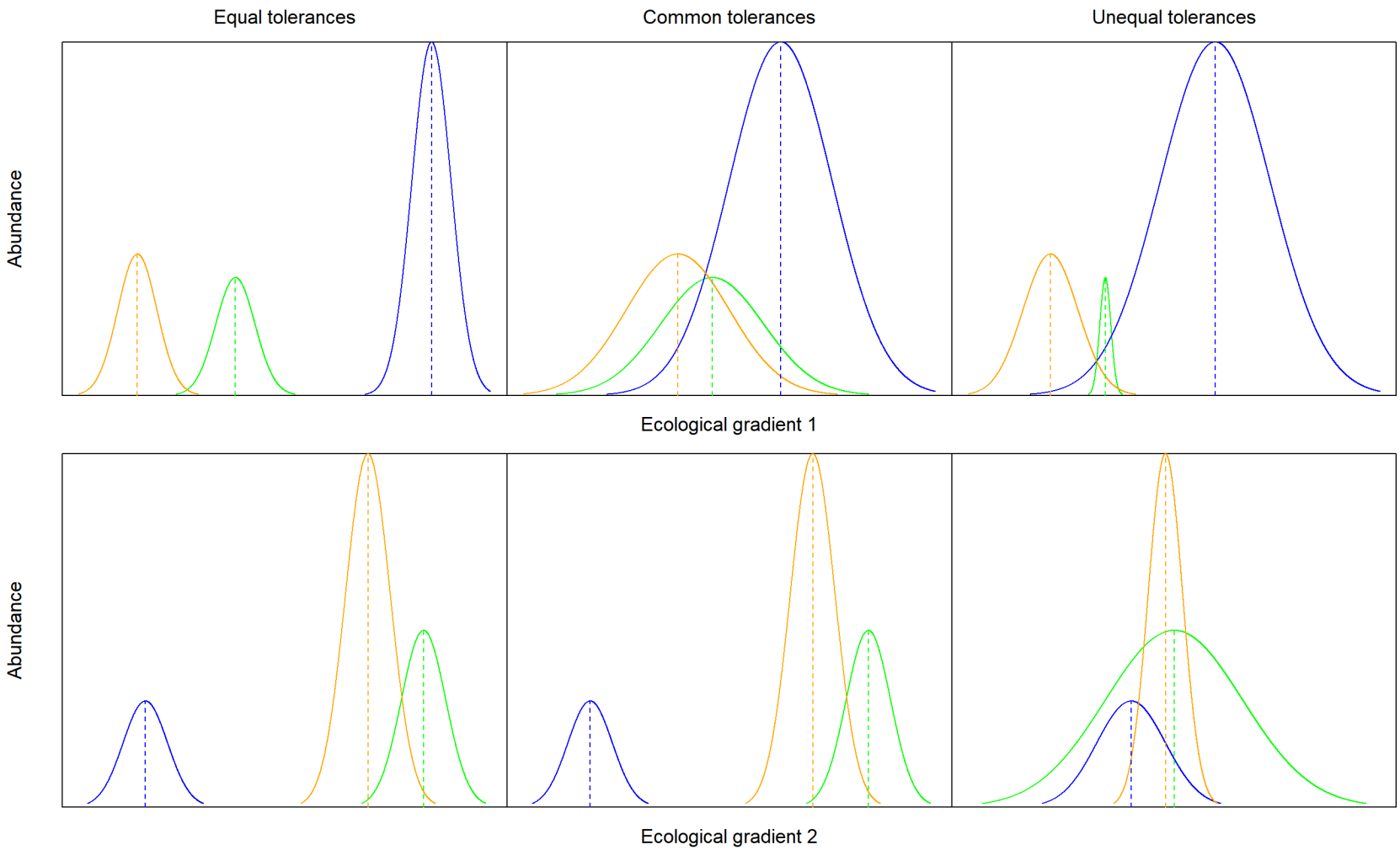


Motivation unimodal niches

- Shelford's law of tolerance (1931)
- Specialist or generalist
- e.g., `glm(y~x+I(x^2))`
- JSDMs and ordination often assume equal tolerances (or linear responses)

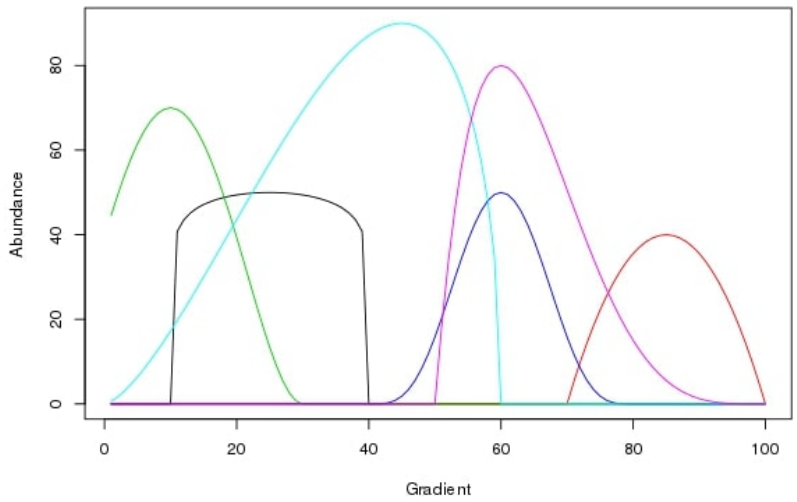


Tolerance models



Species response models

- Much discussion on "correct" response model
- e.g.,
  - Austin 1976, 1980, 2002, Austin et al. 1990, 1994
  - Oksanen and Minchin 2002
  - Jansen and Oksanen 2013
- In ordination: unimodal responses ter Braak 1987
- van der Veen et al. 2021
- Most complex ordination method to date



Quadratic GLLVM

- Linear coefficients $\boldsymbol{\theta}_j$
- Quadratic coefficients in Positive-definite diagonal matrix $\boldsymbol{D}_j$
  - Common tolerances $\boldsymbol{D}_j = \boldsymbol{D}$
  - Equal tolerances $\boldsymbol{D}_{jqq} = \boldsymbol{D}_{11}$

$$g(E(y_{ij}|\boldsymbol{\epsilon}_i)) = \beta_{0j} + \boldsymbol{\epsilon}_i^\top \boldsymbol{\theta}_j - \boldsymbol{\epsilon}_i^\top \boldsymbol{D}_j \boldsymbol{\epsilon}_i \tag{1}$$

- species tolerances $\boldsymbol{t}_j = \frac{1}{\sqrt{(2\text{diag}(\boldsymbol{D}_j))}}$
- species optima $\boldsymbol{u}_j = \frac{\boldsymbol{\theta}_j}{2\text{diag}(\boldsymbol{D}_j)}$
- i.e. unconstrained quadratic (residual) ordination or JSDM with quadratic latent variables

Species associations

- Similarly calculate residual correlations
- Emphasizes "positive" associations for same $\boldsymbol{\theta}_j$ due to positive $\boldsymbol{D}_j$
- To better capture species co-occurrence patterns

Vignette quadratic model

How to use the quadratic response model?

Constrained ordination

Indirect versus direct gradient analysis

- Unconstrained ordination: indirect
- Constrained ordination: direct
  - e.g., CCA, RDA
- Difference: how to derive meaning?
- I.e. what represents the latent variable?

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FORUM

Are ordination and constrained ordination alternative or complementary strategies in general ecological studies?

Økland, Rune Halvorsen

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Økland 2004

Model-based constrained ordination

- Also known as Reduced Rank Regression Anderson 1951
- Reduced number of parameters

Multivariate GLM or stacked SDM

$$g(E(y_{ij}|\boldsymbol{x}_i)) = \beta_{0j} + \boldsymbol{x}_i^\top \boldsymbol{\beta}_j \tag{2}$$

- RRR: $\boldsymbol{\beta}_j = \boldsymbol{B}\boldsymbol{\theta}_j$
  - i.e. we have a model for the slope parameters
  - $\boldsymbol{B}$ is a matrix of slopes for d latent variables
  - Ordination axes or LV: $\boldsymbol{B}^\top \boldsymbol{x}_i$
  - $\boldsymbol{B}$ gives information on LV

Model-based constrained ordination

- Common issue: what if you only have few predictors?
- Random-effects to the rescue

$$g(E(y_{ij}|\boldsymbol{x}_i)) = \beta_{0j} + \boldsymbol{x}_i^\top \boldsymbol{B}\boldsymbol{\theta}_j + \boldsymbol{\epsilon}_i^\top \boldsymbol{\theta}_j \tag{3}$$

- Ordination axes or LV: $\boldsymbol{B}^\top \boldsymbol{x}_i + \boldsymbol{\epsilon}_i$
- So, RRR is a linear regression of LV without residual
- $\boldsymbol{B}$ gives information on LV
- $\boldsymbol{\epsilon}_i$ is unexplained variation in the ecological gradient

Vignette quadratic model

Model-based constrained ordination

Wrap-up

You now know:

1) What ecological gradient analysis is

2a) That JSDMs and ordination are both used to study co-occurrence patterns of species

2b) And that these are the same in terms of GLLVM implementation

3) How to use the `gllvm` R-package Niku et al. 2019

Bayesian Ordination and Regression

- For GLLVMs (ordination) with spatial effects
- Bayesian, with MCMC (i.e. can be **slow**)

Methods in Ecology and Evolution

British Ecological Society

Methods in Ecology and Evolution 2016, **7**, 744–750 doi: 10.1111/2041-210X.12514

APPLICATION

BORAL – Bayesian Ordination and Regression Analysis of Multivariate Abundance Data in R

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Hierarchical Modeling of Species

- For other cool GLLVM (JSDM) stuff
- Bayesian, with MCMC (i.e. can be **slow**)

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APPLICATION | Open Access

Joint species distribution modelling with the R-package Hmsc

Gleb Tikhonov, Øystein H. Opedal, Nerea Abrego, Aleksi Lehikoinen, Melinda M. J. de Jonge, Jari Oksanen, Otso Ovaskainen

First published: 25 December 2019 | https://doi.org/10.1111/2041-210X.13345 | Citations: 19

Let us know if you have any questions (twitter, e-mail, github)

Thanks!