(Spatial) Ecology and Evolution: Integrating Theory and Data

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OVERVIEW

. L1. Approaches to ecological modelling
. L2. Model parameterization and validation (stat)
. L3. Stochastic models of population dynamics (math)
. L4. Animal movement (math + stat)
. L5. Quantitative population genetics (math + stat)
. L6. Community ecology (stat)
mathematical biology group

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movements, populations, communities, genetics, evolution, bioinformatics
L1. Approaches to Ecological Modelling

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- L2. Model parameterization and validation
- L3. Stochastic models of population dynamics (math)
- L4. Animal movement (math + stat)
- L5. Quantitative population genetics (math + stat)
- L6. Community ecology (stat)
Approaches to ecological modelling

The forward approach: mathematical (mechanistic) modelling.
Aim: to understand causal relationships at the general level

The inverse approach: statistical (phenomenological) modelling.
Aim: to find out factors shaping empirical data
Empirical approaches for studying butterfly movements


Harmonic radar

Spatial mark-recapture

**Mechanism:** Flight speed, directional persistence, behaviour at edges, ...

**Pattern:** Movements in a mosaic of meadows, cultivated fields, and forests

How do the two branches of ecological modelling contribute to our knowledge about ecology?

- If individuals keep reproducing, populations will grow exponentially.

- Something must limit growth. Space? Resources?

- Let’s try a model with resource-dependent birth or death rate or interference competition.

- The models predict that the population does not grow beyond a carrying capacity.

- Let’s try a 2x2 factorial design: mites in small/big boxes, much/little food.

- Results of ANOVA: both food and space significant: more food or space gives more mites.

- Populations do not grow exponentially.

**Mathematical models**

**Hypotheses**

**Model predictions**

**Data**

**Theory**

**Experiments and observational studies**

**New Data**

**Statistical inference**

- Forward approach
- Inverse approach
Combining the forward and inverse approaches

One of the models fit the data best, but even that not perfectly. Let’s add a term for...

Statistical inference

New Data

Experiments and observational studies

Mathematical models

Let’s model the experiment with a resource-dependent birth or death rate or a model with interference competition

Predictions

Theory

If individuals keep reproducing, populations will grow exponentially

Populations do not grow exponentially

Something must limit growth. Space? Resources?

Let’s try a 2x2 factorial design: mites in small/big boxes, much/little food. Measure birth and death-rates over time.
Mathematical models and methods in ecological modelling

- **Mathematical models**
  - Individual-based models
  - Differential equations
- **Analytical methods**
  - Stability analysis
  - Theory of stochastic processes
  - Mean-field approximations
  - Many other kinds of analytical methods!
- **Numerical methods**
  - Numerical integration
  - Simulation methods
  - Many other kinds of numerical methods!
- **Model predictions, scenario comparisons, etc. etc.**

Many other kinds of models!
There are many kinds of mathematical models!

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Statistical models and methods in ecological modelling

Statistical models
- Generalized linear models
- Spatial statistics
- Ordinations
- Many other kinds of models!

Statistical methods: fitting models to data, hypothesis testing
- Maximum likelihood
- Bayesian inference
- Test-statistics and non-parametric methods
- Numerical optimization
- Analytical solutions
- MCMC methods
- ABC
- t-test, Spearman rank correlation, ...
- Permutation tests

Statistical inference of ecological data
There are many approaches to ecological modelling!

Think critically why you play with mathematical models! Just because you can (and you like it), or because that helps to learn about ecology?

Find your own modelling philosophy!

Markku has a data-driven modelling philosophy which he likes to summarise as 'whatever works'.