



METIER Graduate Training Course
“Ecological Modelling”
22 May – 2 June 2008, Leipzig & Bad Schandau (Germany)

Lecture 4: Spatial Models in Ecology

Part II: From metapopulation models, viability analysis and model-based decision-support

Karin Frank

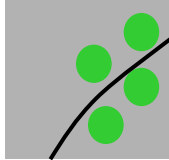
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Department of Ecological Modeling



Karin Frank; Lecture 4 „Spatial Models“ (Part II, Day 4)

I. Background

Important drivers of the loss of biodiversity: habitat loss and fragmentation



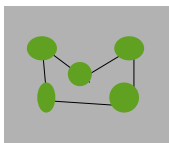
Driver:

Habitat loss →
Fragmentation →

Affected process:

Local extinction
Individual exchange/
colonization

One approach of conservation ecology:



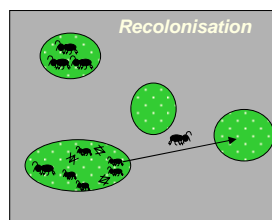
Connecting management
Establishing habitat networks

Underlying idea:
To compensate extinction by colonization

Effectiveness? → A principle question!

I. Background

One important concept of ecology:

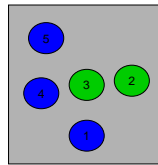


Metapopulation (Levins 1969) =
ensemble of populations living in isolated habitat remnants (patches)
with a certain risk of local extinction and the chance of becoming
recolonized by migrating individuals.

Questions of conservation ecology:
Conditions of persistence?
Role of the spatial structure of the habitat network?

II. Metapopulation models

The classical Levins model (1969)



Central assumptions: spatial homogeneity

- * infinite number of identical patches;
- * all patches equally connected to each other
- * patch states: either "occupied" (1) or "empty" (0)
- * metapopulation state: percentage p of occupied patches

The model

$$\frac{dp}{dt} = c \cdot p \cdot (1 - p) - v \cdot p$$

with c ... colonization rate
 v ... extinction rate

non-spatial

In order to understand persistence, make a stability analysis

Solving $\frac{dp}{dt} = 0$ leads to the equilibrium patch occupancy p^*

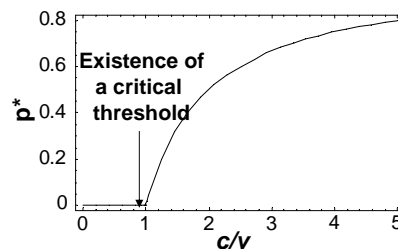
$$p^* = \max(0, 1 - (c/v)^{-1})$$

II. Metapopulation models

Analyzing the equilibrium occupancy p^*

$$p^* = \max(0, 1 - (c/v)^{-1})$$

p^* is completely determined by the ratio c/v .



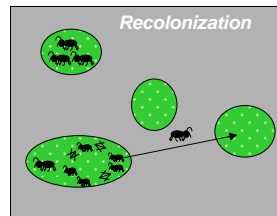
Definition of metapopulation persistence: $p^* > 0$.

Finding:

*A metapopulation only persists if $c/v > 1$,
i.e. colonization is faster than extinction.*

II. Metapopulation models

Include spatial structure



Add relevant sources of spatial heterogeneity:

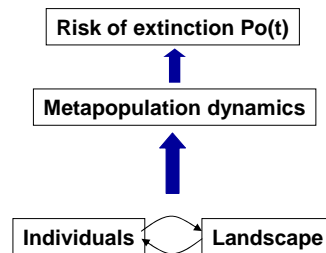
- finite number of patches
- patch size and shape
- patch configuration
- (pattern of connectedness)

Add stochasticity

A spatial model Variant I

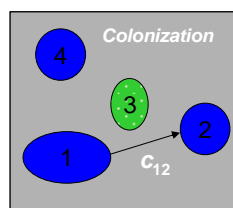
Individual-based
(cf. e.g. Woodhoopoe)

„All-in-one“



II. Metapopulation models

Include spatial structure



Add relevant sources of spatial heterogeneity:

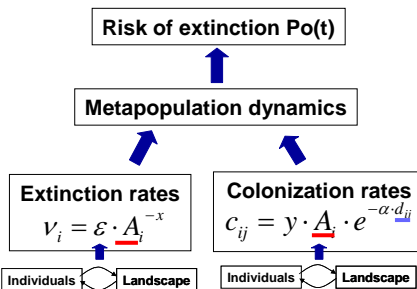
- finite number of patches
- patch size and shape
- patch configuration
- (pattern of connectedness)

Add stochasticity

A spatial model Variant II

Patch-based,
„modular“

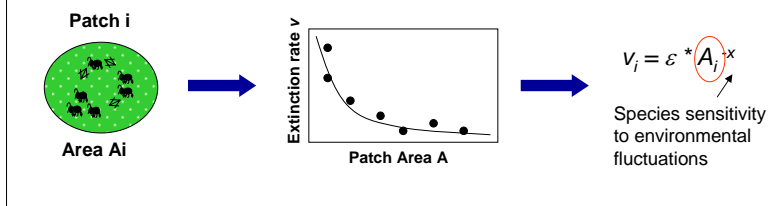
Hanski (1994),
Day & Possingham (1995),
Frank & Wissel (1994,1998)



II. Metapopulation models

The submodels for the rates are adequate

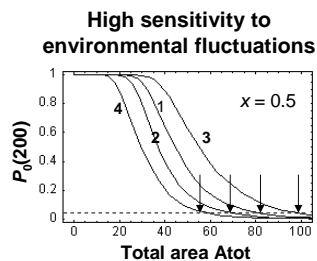
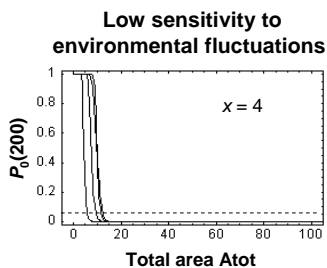
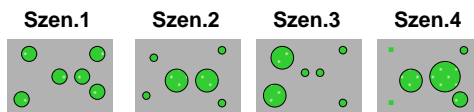
Various individual-based models for the local populations:



III. Potential: Metapopulation viability analyses

Question: Metapopulation persistence under habitat loss

Is it sufficient to assess the total amount A_{tot} of habitat in the metapopulation or is there a need to consider the spatial configuration as well?



Frank & Wissel (1998) *Landscape Ecology*; Frank (2003) *Biodiversity and Conservation*

III. Potential: Metapopulation viability analyses

Answer:

In all cases: existence of minimum total amounts of habitat A_{tot} needed for maintaining long-term metapopulation persistence

Species with

- **weak sensitivity to** environmental stochasticity ($x \gg 1$): Total amount A_{tot} is sufficient
- **high sensitivity to** environmental stochasticity ($x < 1$): Spatial configuration matters and has to be taken into account explicitly

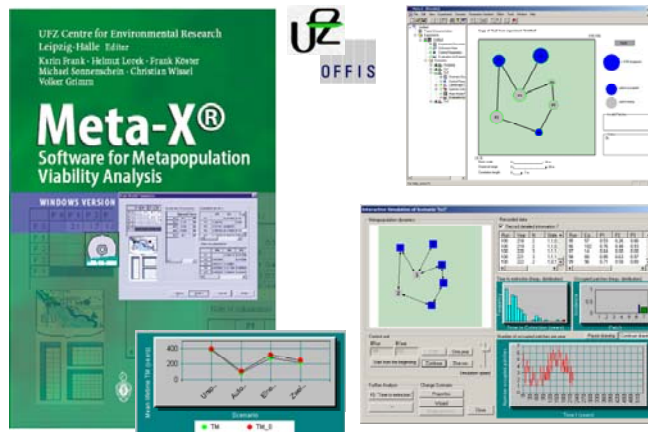
Existence of rules of thumb

BUT:

not universal, but for ecological classes of species

IV. From a spatial metapopulation model to a tool for decision-support

META-X Software for Metapopulation Viability Analysis



Designed for biodiversity conservation and landscape planning

Frank et al. (2003), Springer; cf. Grimm et al. (2004) *Biodiversity and Conservation* 13: 165 – 188