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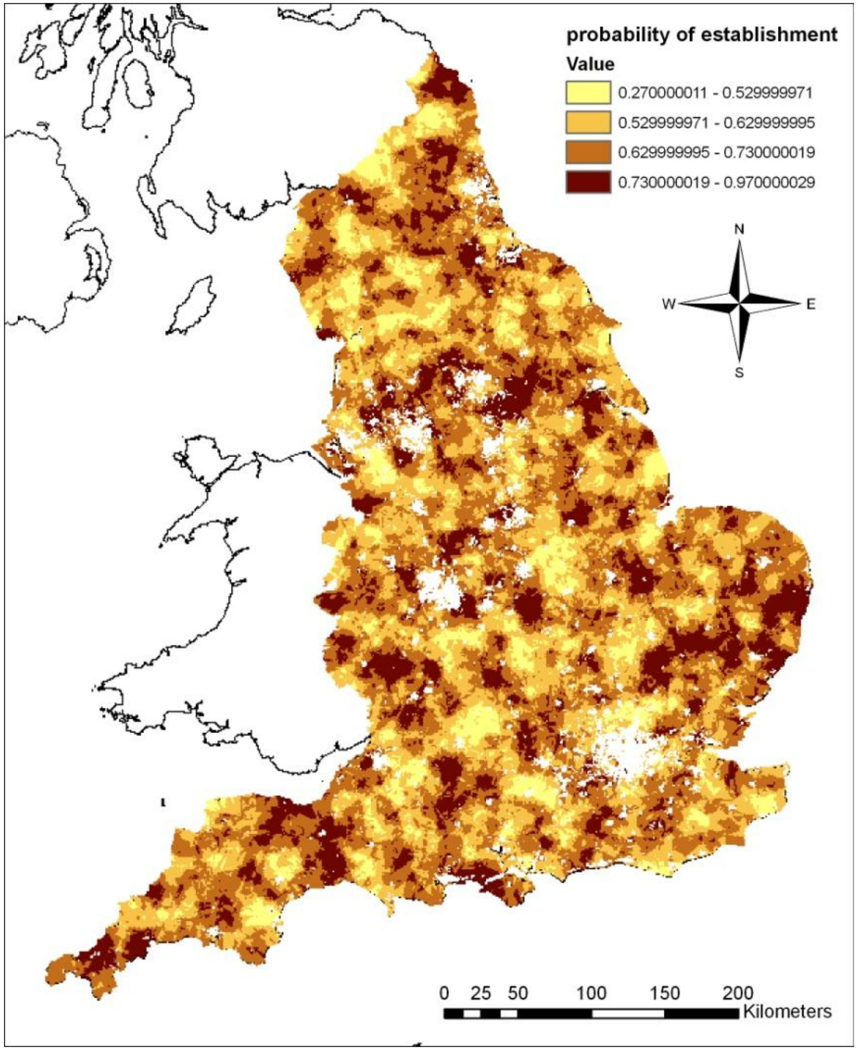
Predicting the establishment and spread of non-native species: n dimensions of uncertainty but only one map

No data? No idea? No problem!

James Aegerter, Pen Holland

Predictive modelling; Why & When

- Change
  - Landscape change
  - Policy change
  - Climate change
- Impact
  - Human/wildlife conflict
    - Agricultural damage
    - Zoonoses
  - Wildlife sustainability
- When
  - Future
  - Predict the current state
    - Distribution and dynamics poorly understood for most native species



Predictive modelling; What & Where

- Populations
  - Generic
    - Mammals
    - Non-native
    - Natives species
    - and Wild Boar
- Range of scenarios
  - Climate change
  - Policy change
  - Management

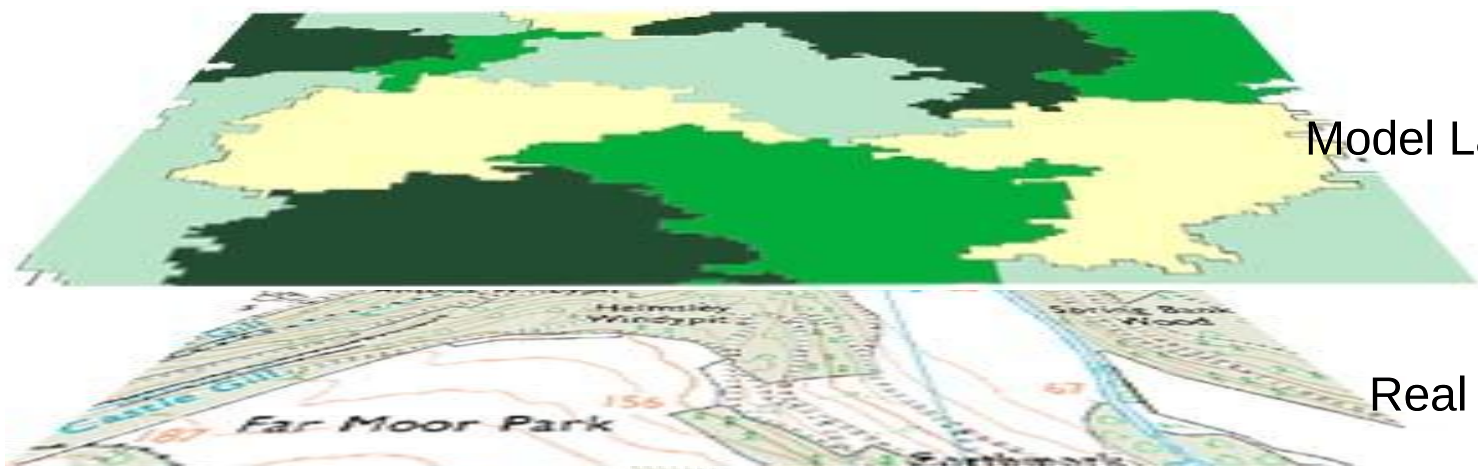
- Uncertainty
  - Reflect true state of knowledge
  - Measure of utility
  - Measure of risk policy formers are willing to bear
- Spatial
  - Variable resources
  - Density-dependence
  - Wildlife human interaction
    - Conflict
    - Management

Predictive modelling; How

- Real life scenarios need real life landscapes
- Model landscapes appropriate to the species under consideration

Many interacting issues and alternative methods

- Uncertainly
- Geometry
- Scale
- Resource
- Edges/boundaries/discontinuities
- Unexplored



Predictive modelling; How

- Modelling populations

Process modelling

- Species where little may be known

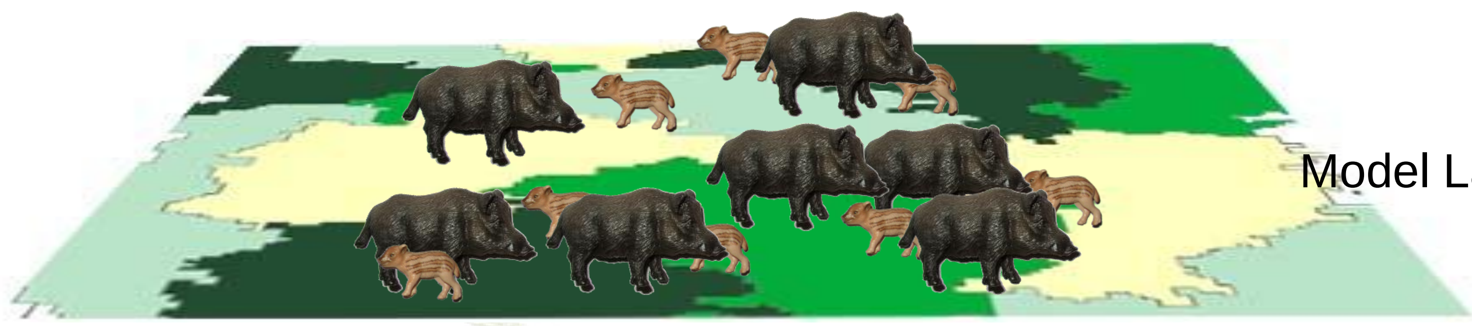
Generic

- Fundamental processes
- Small populations

Capture uncertainty

Allow us to produce robust models

- Choice of parameters
- Choice of alternative models



Model Landscape

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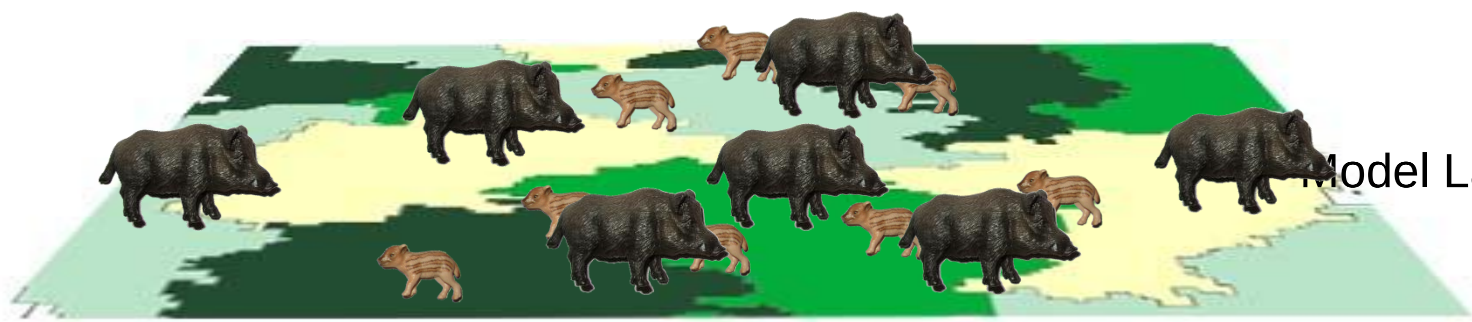
Predictive modelling; How

- Spatial
  Density dependence
  Movement



Model Landscape

Predictive modelling; How

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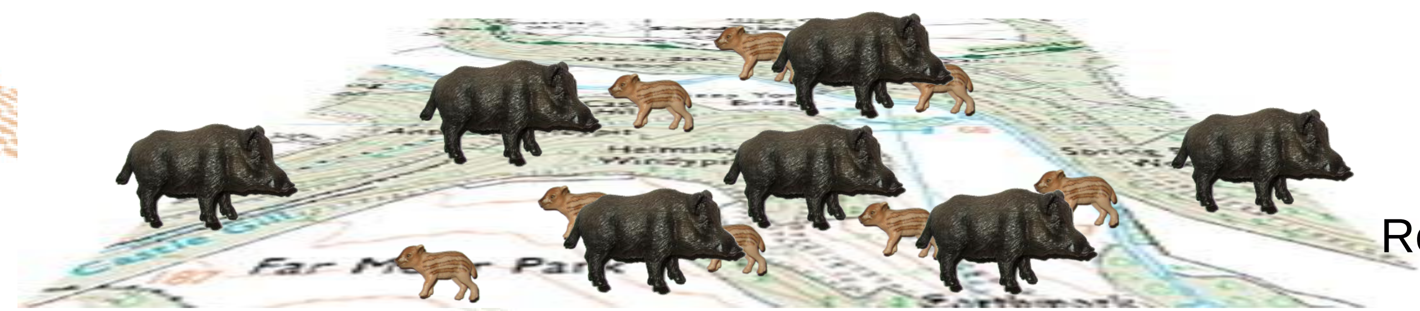
Density dependence

Population model

Movement

Resource



Real Landscape

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Modelling landscapes

- Most spatial data is inherently uncertain
  - Spatial
  - Conditional
  - quantitative
- Errors (and uncertainties?) decrease as scale increases
- Exclusive cells
  - >scale underlying data
  - LCM2000
- Structure of the landscape
  - rasters can bias movement
  - rasters affects the quality of gross representation

Modelling landscapes : shape / geometry

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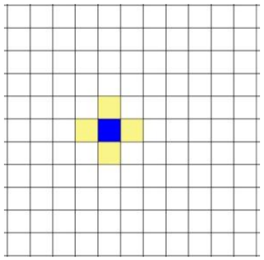
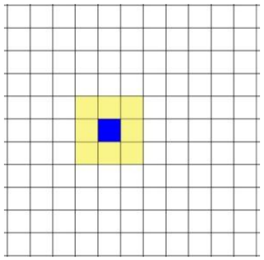
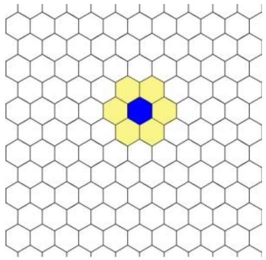


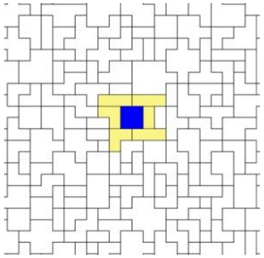
von Neumann



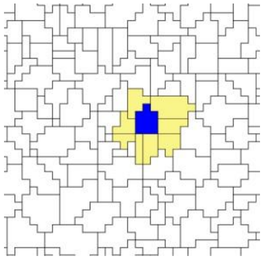
Moore



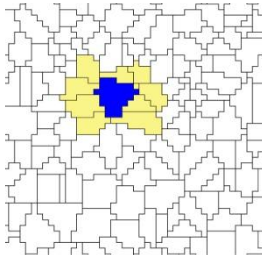
hexagonal



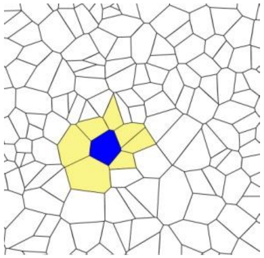
CG 4



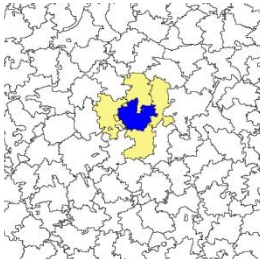
CG 9



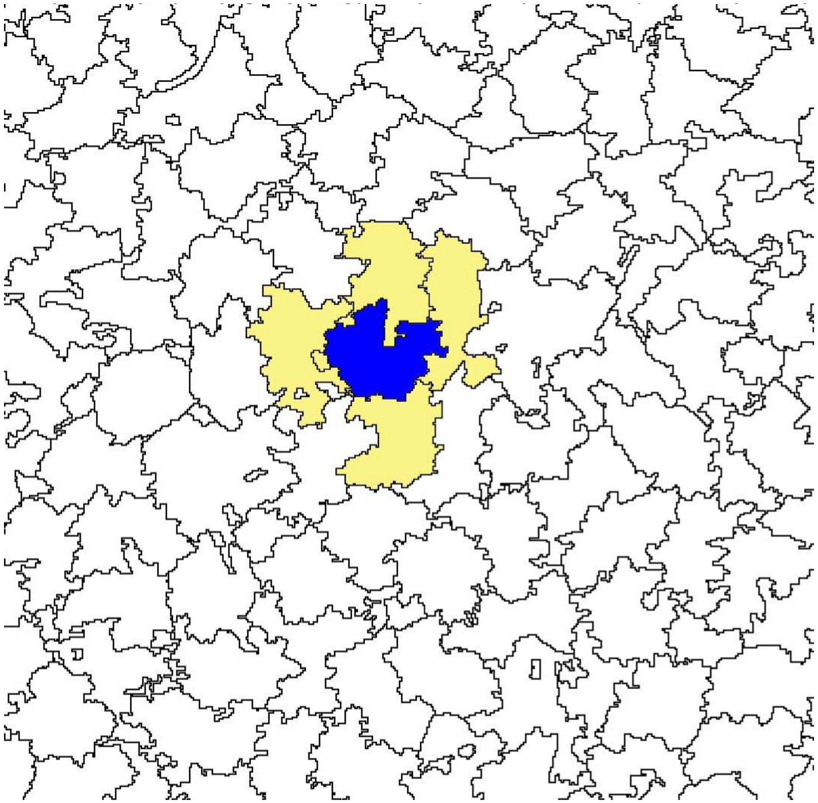
CG 16



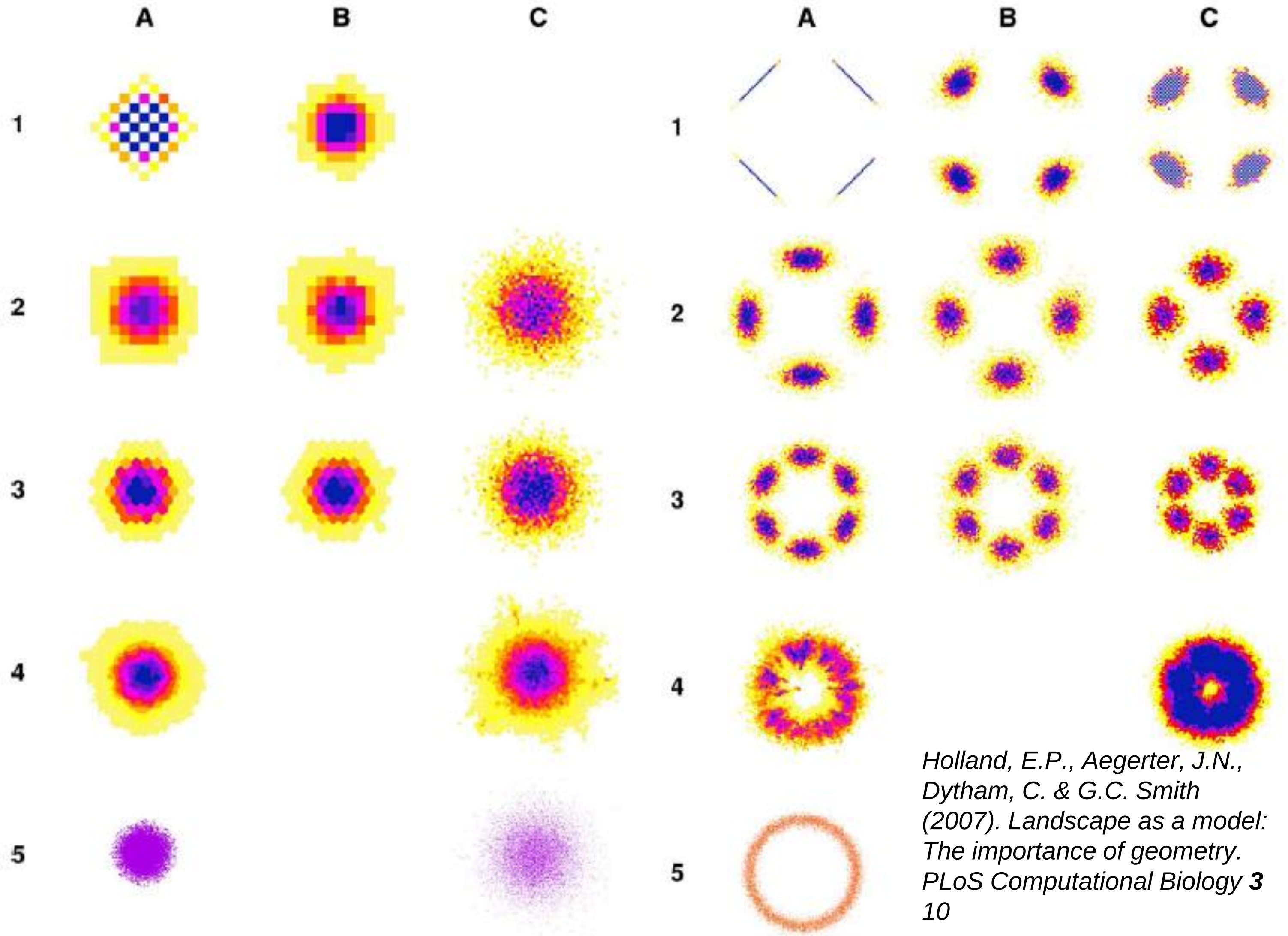
Dirichlet



habitat



Modelling landscapes: shape / geometry



Von Neumann

Moore

Hexagonal

Dirichlet

Vector

*Holland, E.P., Aegerter, J.N., Dytham, C. & G.C. Smith (2007). Landscape as a model: The importance of geometry. PLoS Computational Biology **3** 10*

Shape / geometry? Conclusion

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Regular grids

Scale and representation are always confounded

Always have the potential for directional bias

- Bias is scale dependent
- Error increases with distance

Representation of irregular landscapes (extent and features) always with error

Irregular landscape models

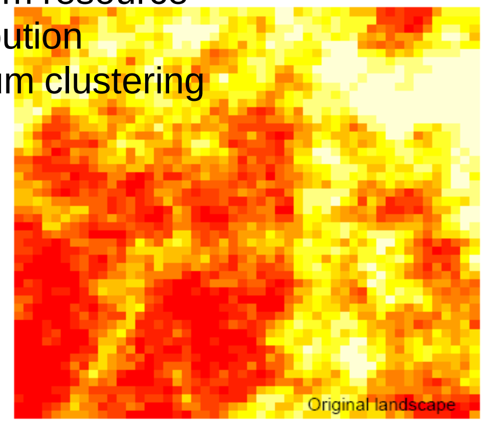
- Never show directional bias for movement
- No errors in representation

E.g. Landscape features can be retained at true scale

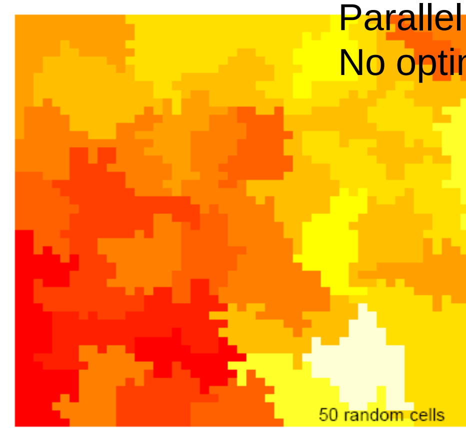
Modelling landscapes: Recipes

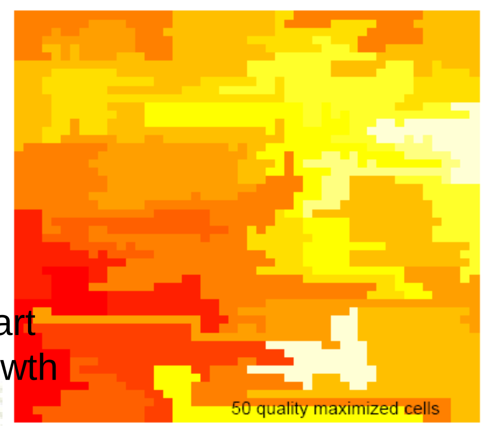
- Method to make the irregular cells
  - Randomisation
  - Aggregation sequence
  - Optimisation method
  - Scale
- Measurements
  - Mean
  - Variance
  - Spatial relationships

Uniform resource distribution
Medium clustering

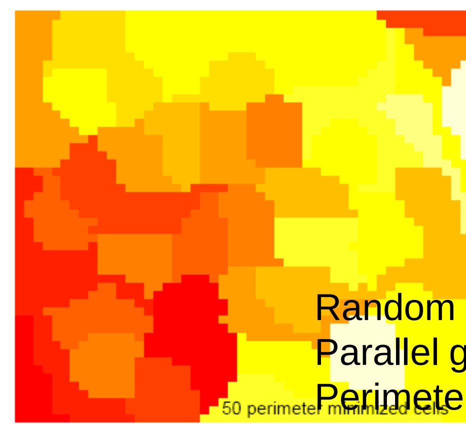


Random start
Parallel growth
No optimisation





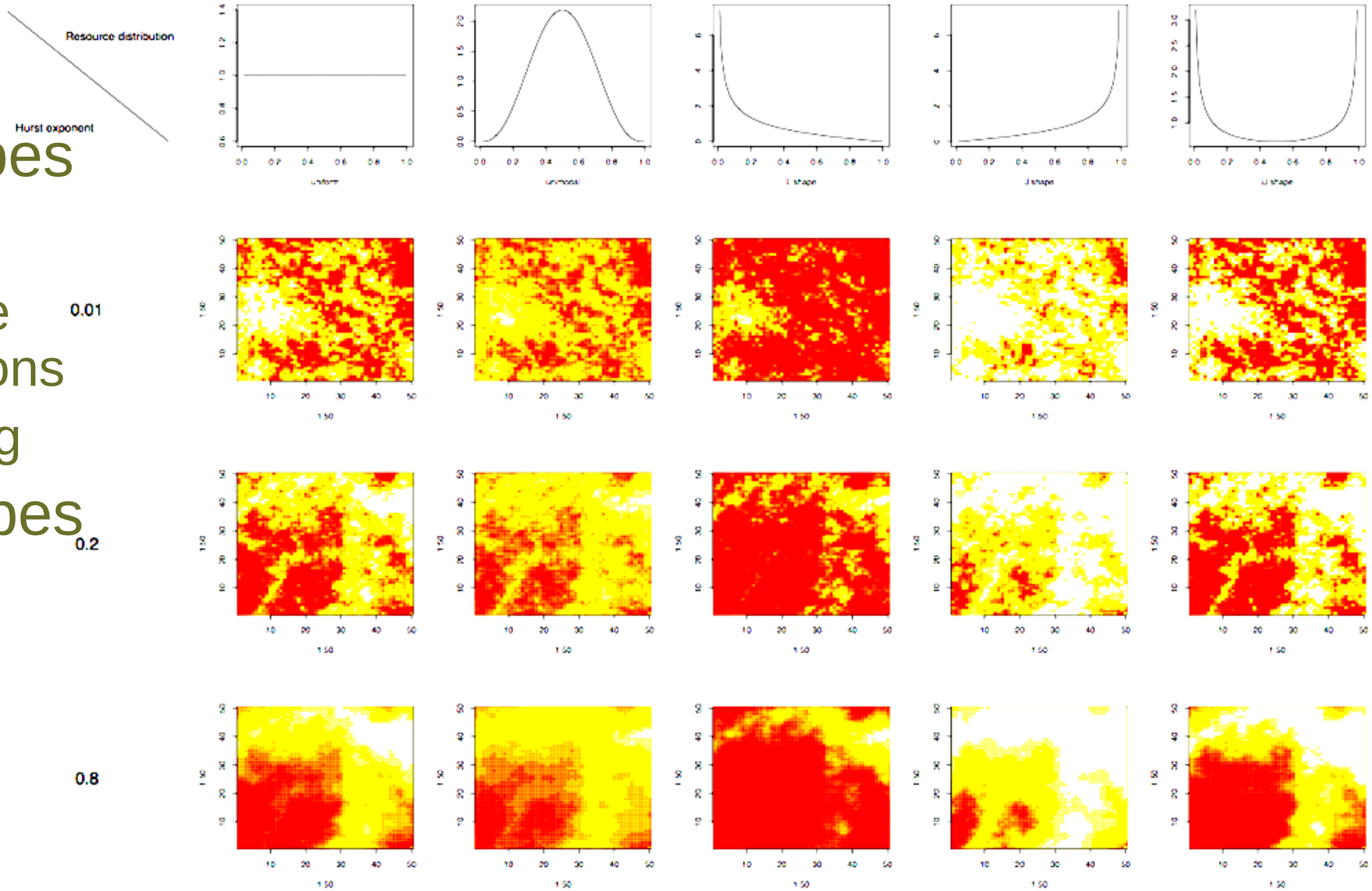
Random start
Parallel growth
Quality optimisation

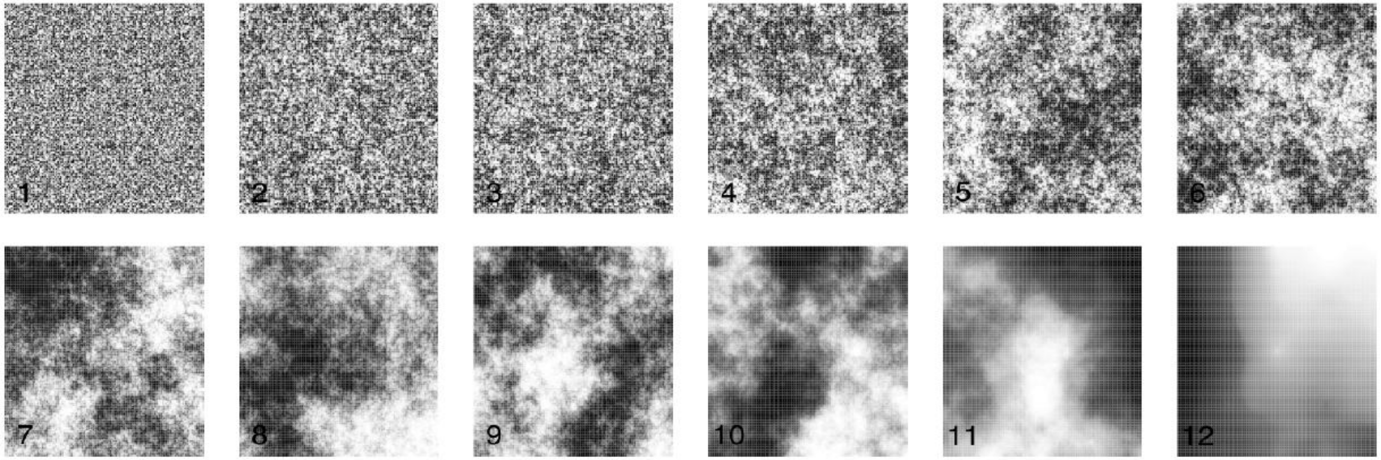


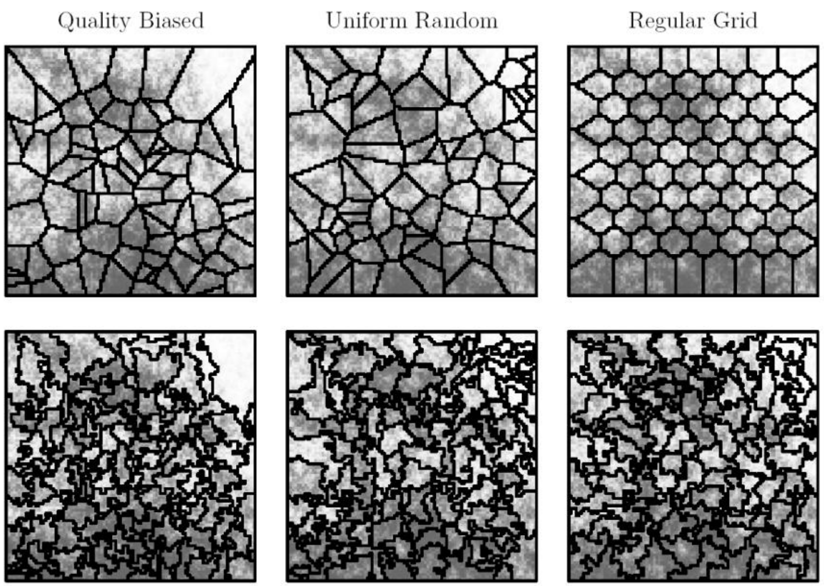
Random start
Parallel growth
Perimeter optimisation

Modelling landscapes

- Range of landscape types
  Simulated
  - Resource distributions
  - Clustering
- Real landscapes
  - n=1







Aggregation approach

Dirichilet
Poisson aggregation 1
Random aggregation
Perimeter minimisation 2
Quality maximisation 3
Quality homogenisation
X

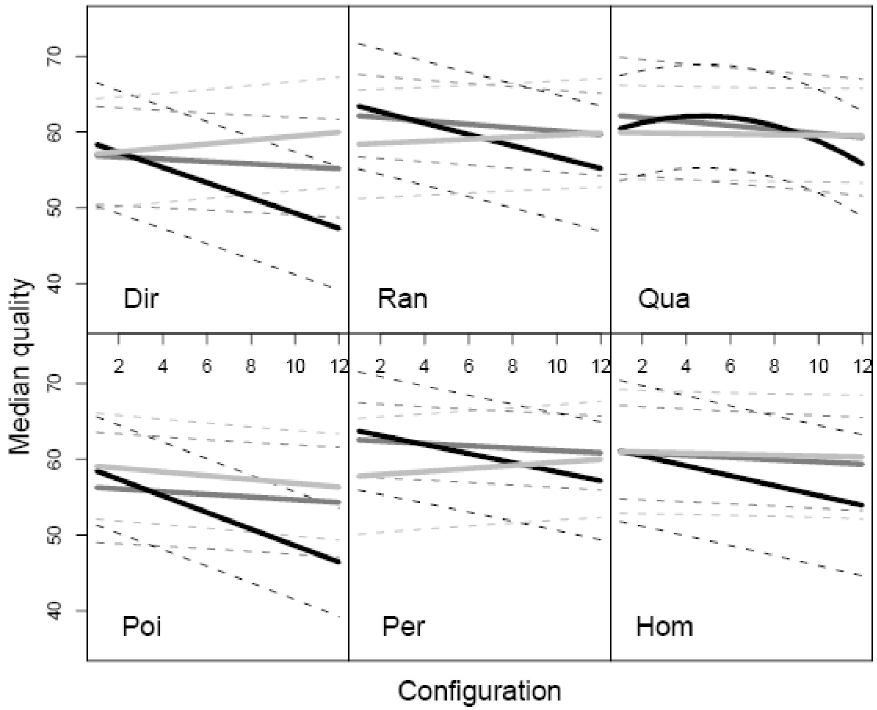
Seeding method

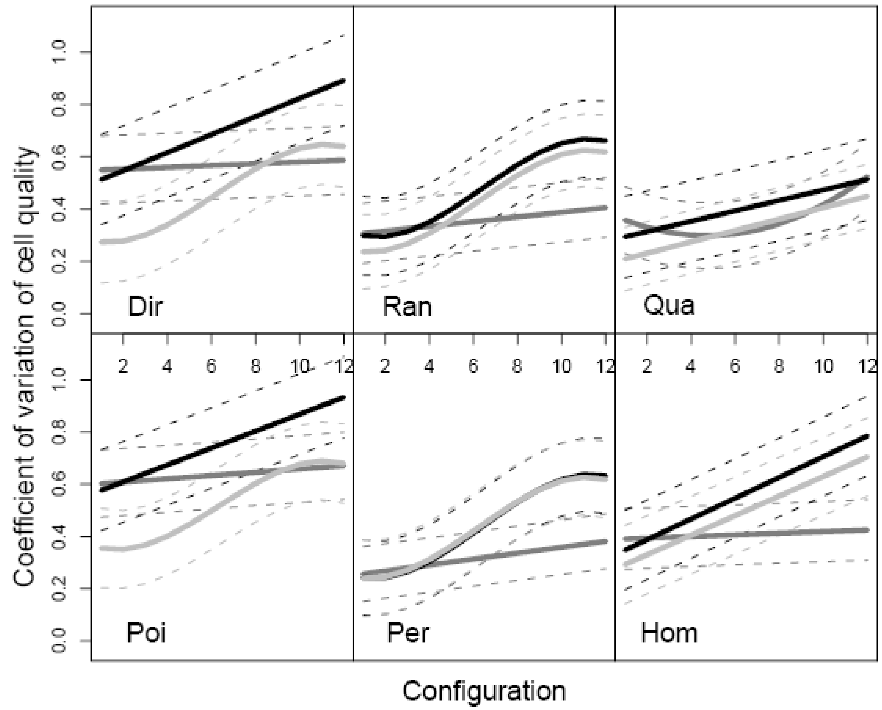
Random
Quality biased
Regular

Area
Quality
Perimeter
Neighbours
Connectivity
  Percolation threshold
  Percolation area
Heterogeneity/aggregation

Mean & CV

Comparison vs. underlying landscape
Inter-comparison





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Model landscapes

- Geometry
    - Squares are bad
    - Iterate
- Build approach
    - Recipes available
    - Always check absolute and comparative properties
- Uncertainty in attributes
    - Fuzzy
    - Iteration

Modelling populations

- Probabilistic (mix distribution) modelling
  - Flexible
  - Generic
  - Permits deeper hierarchies (if appropriate)
- Density-dependence
  - Model the effect
    - Without specifying the mechanism
    - Reducing population growth
    - Stimulating emigration
- Use the framework to determine the numerical = spatial scale for each of our spatial sub-units
- Uncertainty
  - Parameter quality
  - Parameter relevance
    - Eco-geography
    - Differential processes
  - Process model
  - Density dependence

Modelling populations

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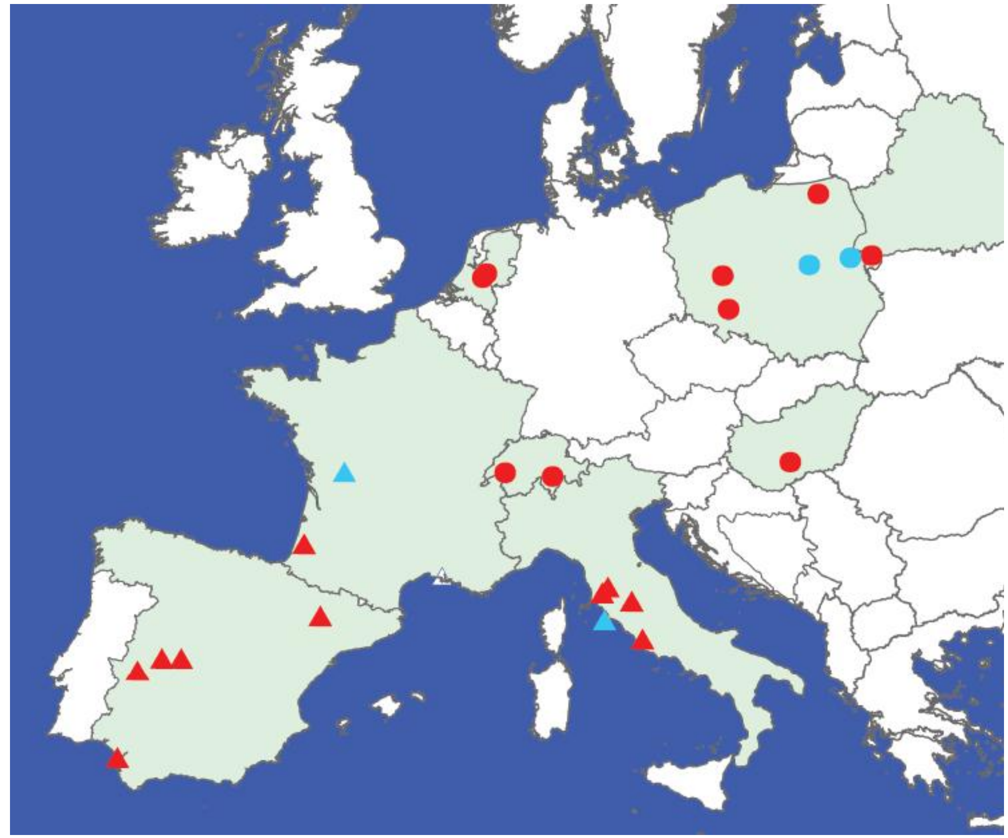
- Compare alternative models structures
  - Alternative hierarchical models
    - 1. Growth rate
    - 2. Reproductive rate - mortality
    - 3. (% ♀ reproducing x ♀ litter^{-1}) - % mortality
  - Alternative subsets of data



Hunted
Non-hunted

Modelling populations

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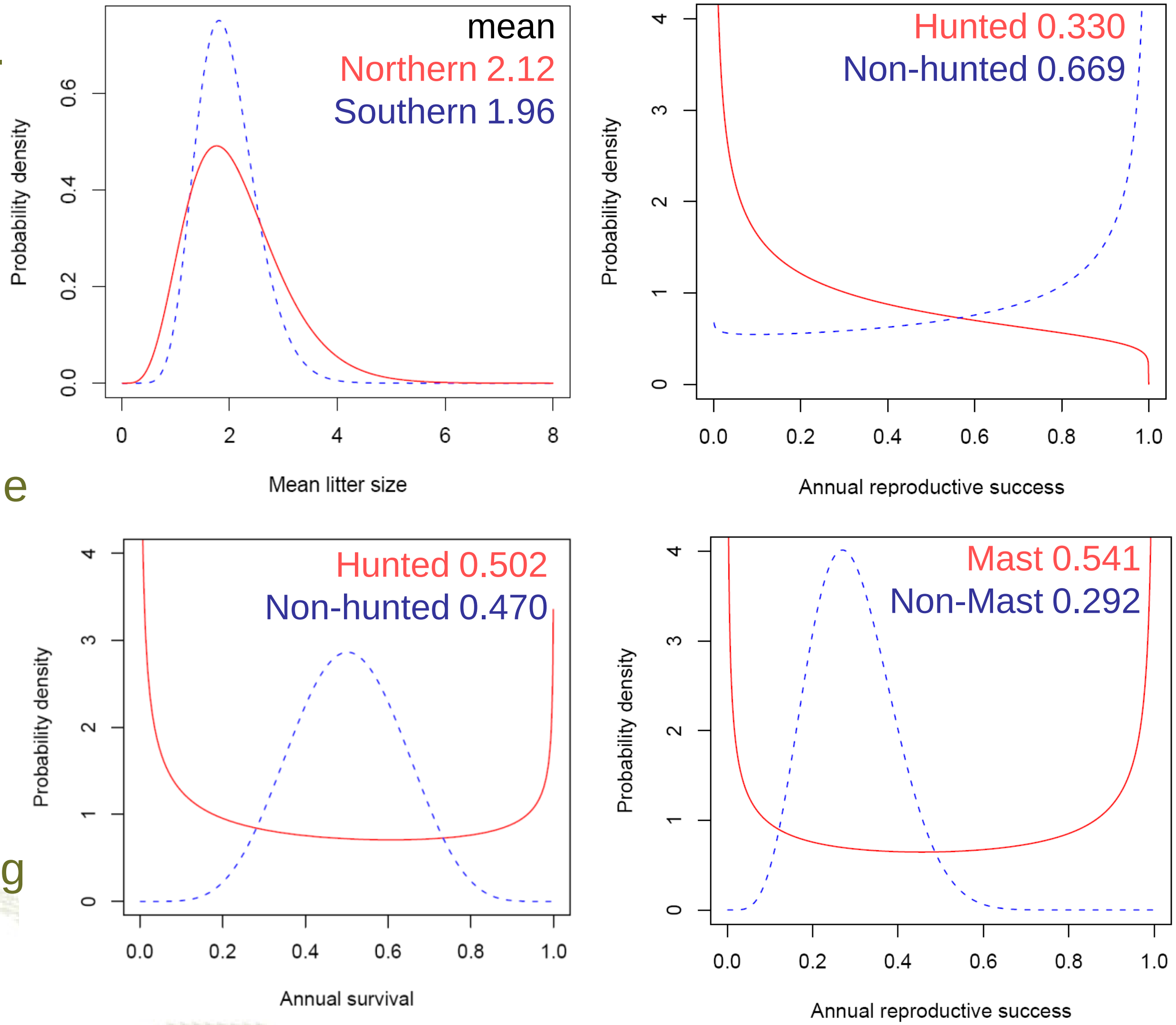
- Probabilistic modelling (non-spatial)
  - Representing parameters
    - All the data
    - Compare subsets of the data
    - Fit using maximum likelihood
- Uncertainty
    - Bootstrapping

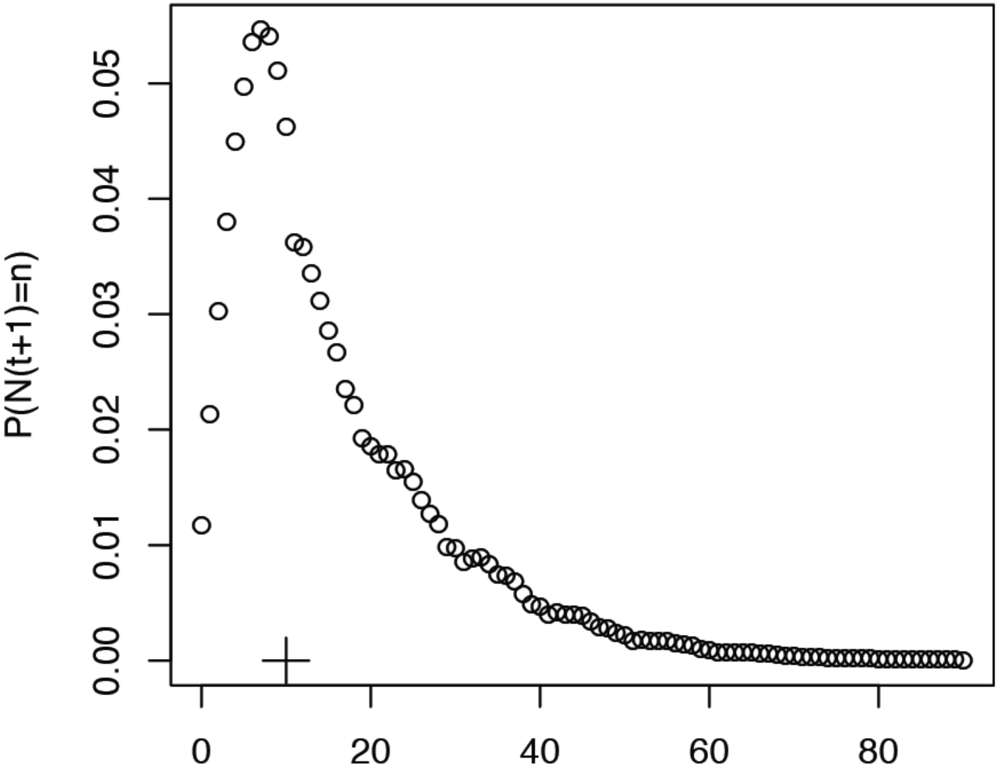


Modelling populations

- Probabilistic modelling (non-spatial)
  - Chance of n_{t+1} given n_t
    - Calculated for integer n
    - Output can reflect all interactions between components
    - No arguments about sequence of processes

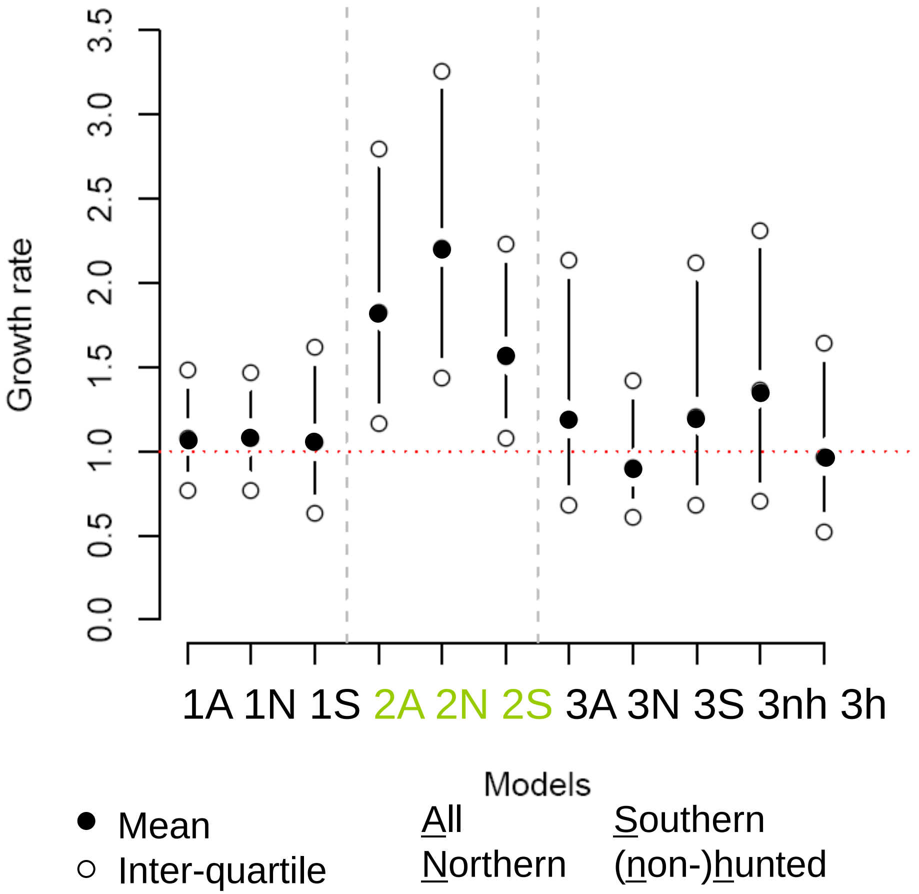
$$M_3(x, N_t, \theta_3) = \sum_{l=0}^{\infty} \sum_{c=0}^{N_t} \sum_{s=0}^{N_t} \mathcal{GP}(l, k_\nu, \theta_\nu) \mathcal{BB}(c, a_f, b_f) \mathcal{BB}(s, a_\phi, b_\phi) \delta(lc + s, x),$$

where $\delta(lc + s, x) = 1$ if $lc + s = x$ and 0 otherwise.



Modelling populations

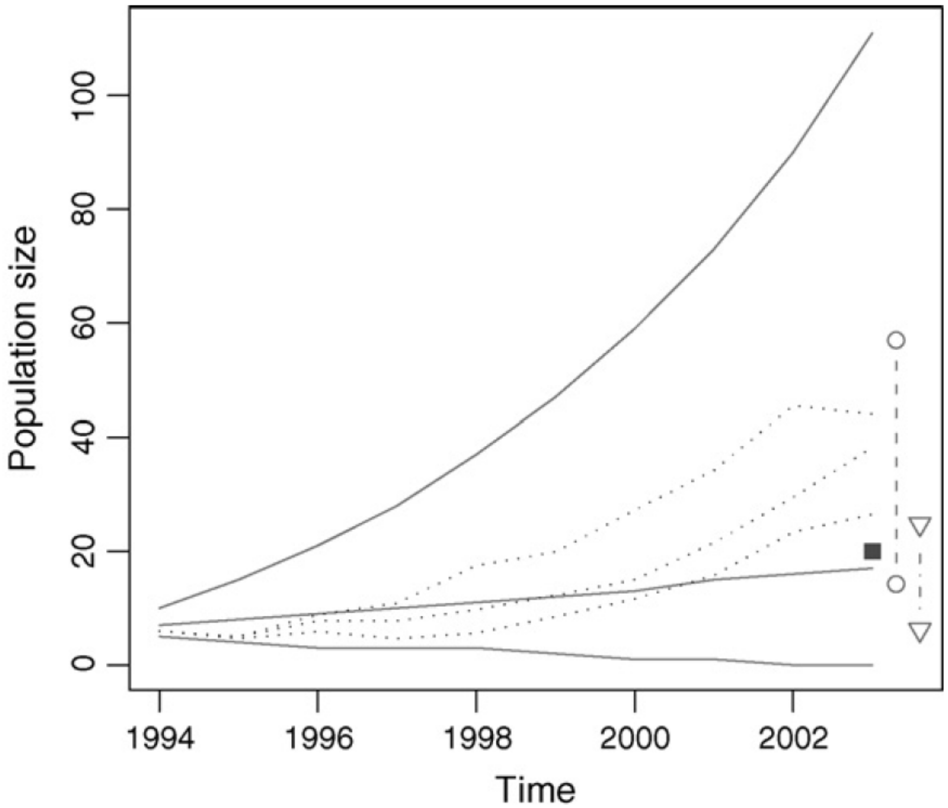
- Model selection
  - Validation data
    - Information theoretic approaches
  - No validation data
    - Kullback-Liebler distances between pairs + common sense
- Modelling under climate change
  - Ignore assumption: future = Mediterranean
  - Mast year frequency
  - Socio/economic context crucial (hunting)



Holland E.P., Burrow J. & Aegerter J.N. Predictive population modelling with uncertain data: a meta-analysis of European Wild Boar (2009) Ecol. Mod. 230 1203-1217

Validation?

- Uncertain starting conditions
- One data point



A vision forward…

- OSMastermap™
    - A spatial data source without inherent errors?
- Assisting in designing wildlife sampling strategies
- Predicting disease dynamics and management
- Conservation

Acknowledegments

Dr. Graham Smith (fera)

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