The role of population dynamics in ERAs to protect biodiversity

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Population-level dynamics

Population change is a consequence of changes in births, deaths and dispersal:

$$N_t = N_{t-1} + births - deaths + immigrants - emigrants$$

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Population-level dynamics

Given the complexity in births, deaths and dispersal

$$N_t = N_{t-1} + births - deaths + immigrants - emigrants$$

Any ERA should be proportionate and pragmatic to the technology being implemented (ACRE 2013; Report 3)

Plan

- Sensitivity (& Elasticity) Analysis
  - A net growth rate (λ) approach
- Trophic and complex species interactions
  - Linking performance and dynamics (ragwort-cinnabar moth)
- Rarity
  - Definitions
  - High Brown Fritillary (diffusive rarity)
  - Population dynamics consequences (low sample bias)
- Guidance for ERA

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Net-Growth Rate (λ) Analysis

Net growth rate – sensitivity analysis

Simple logistic population growth

$$\frac{dN(t)}{dt} = rN(t)\left(\frac{K - N(t)}{K}\right) - \mu N(t)$$

$$\frac{1}{N(t)}\frac{dN(t)}{dt} = r\left(\frac{K - N(t)}{K}\right) - \mu$$

$$\frac{1}{N(t)}\frac{dN(t)}{dt} = \frac{rK - rN(t)}{K} - \mu$$

$$\frac{1}{N(t)}\frac{dN(t)}{dt} = (r - \mu) - \frac{rN(t)}{K}$$

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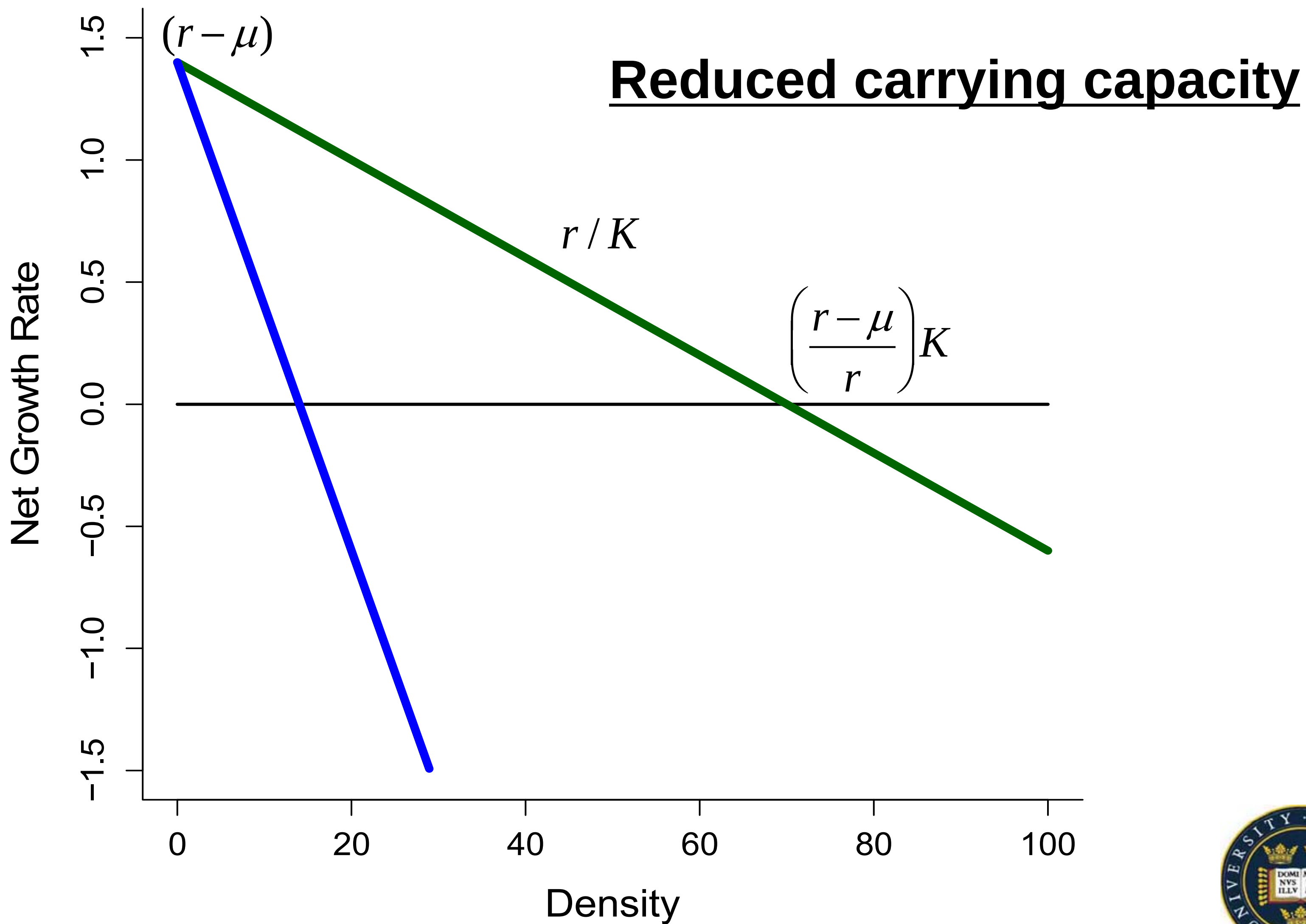
Net growth rate – sensitivity analysis



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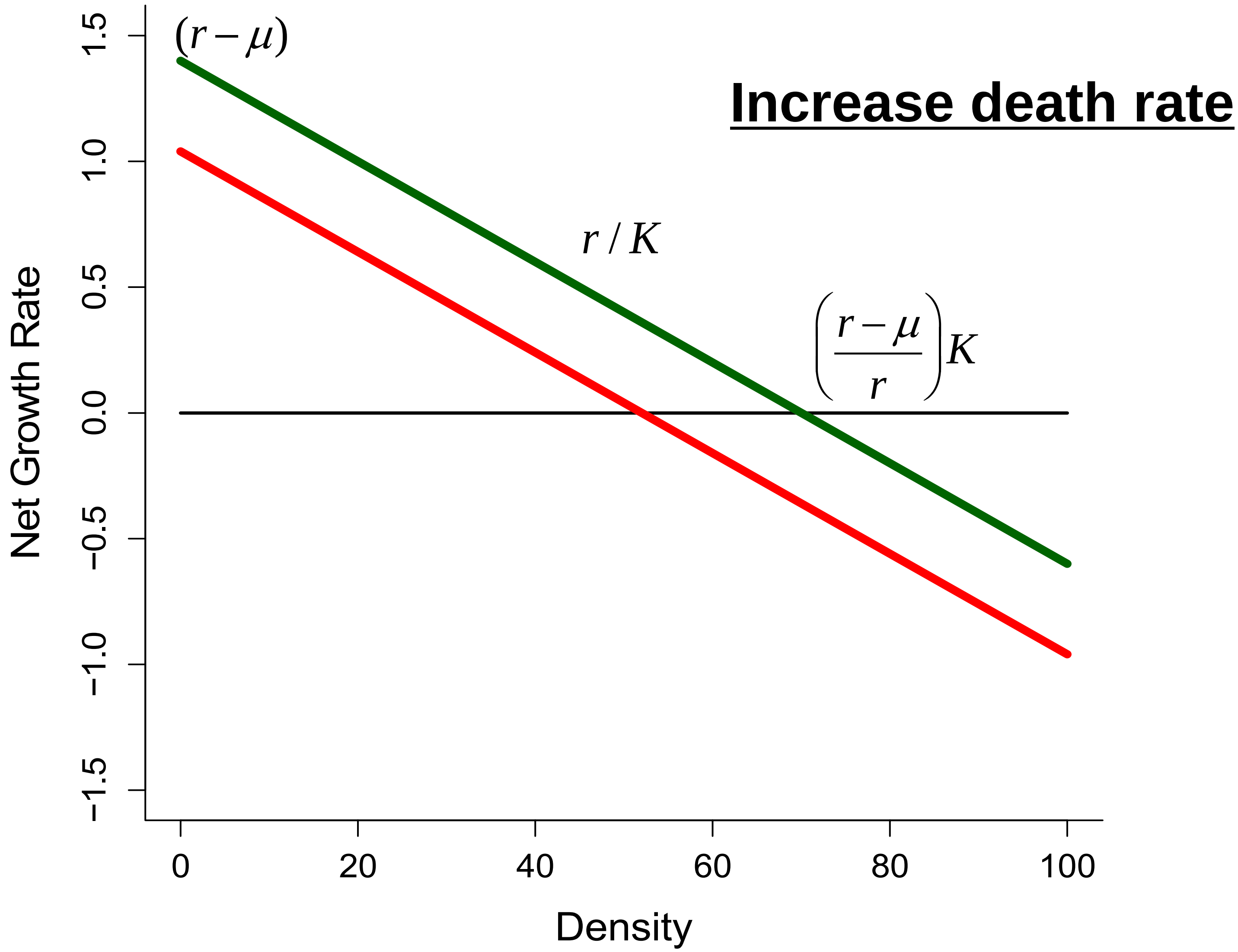
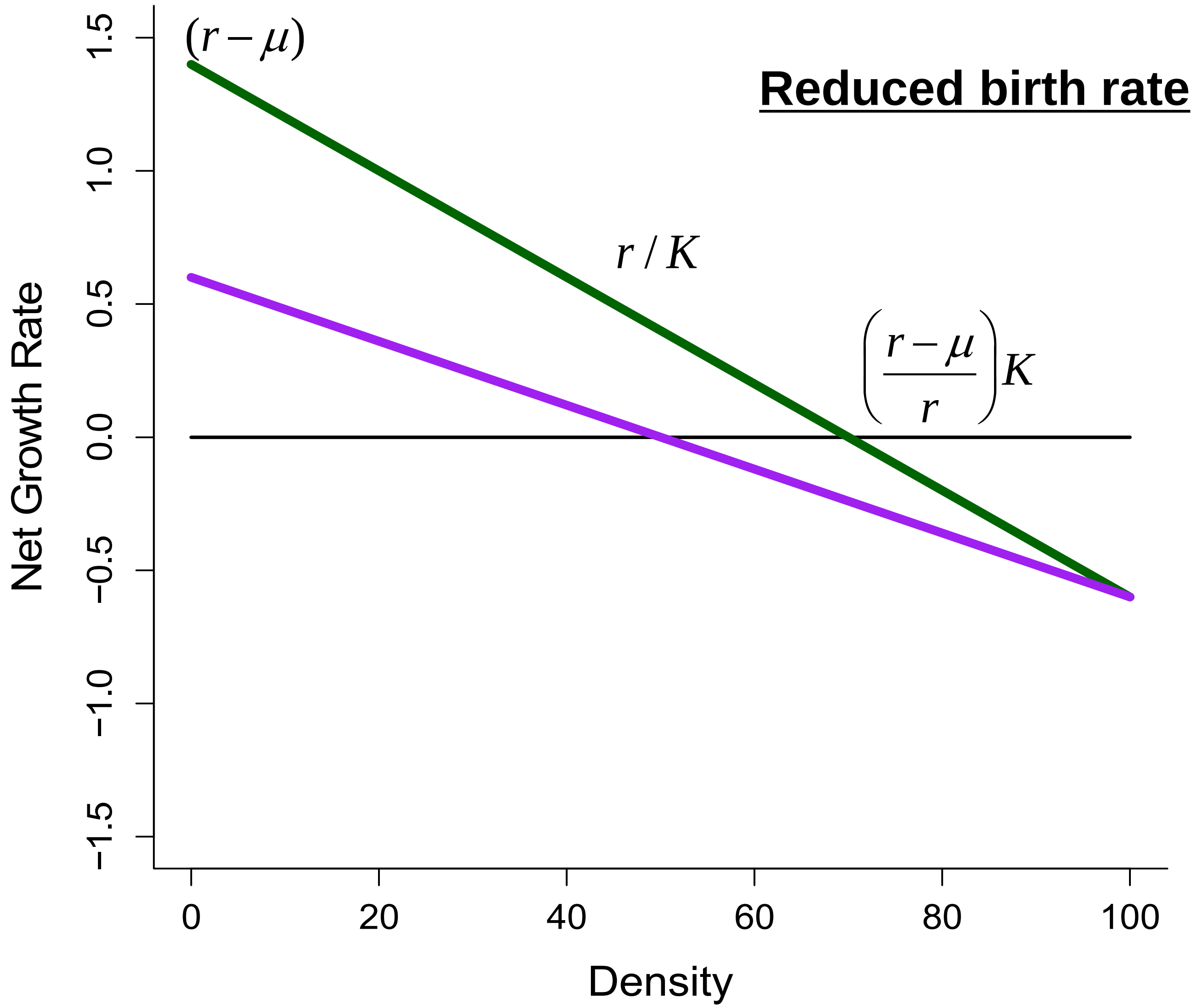
Net growth rate – sensitivity analysis



Net growth rate – sensitivity analysis



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Linking performance and dynamics

Sensitivity analysis – trophic-interactions

$$\frac{dP(t)}{dt} = rP(t)\,f\,(P(t,\tau)) - aP(t)H(t)$$

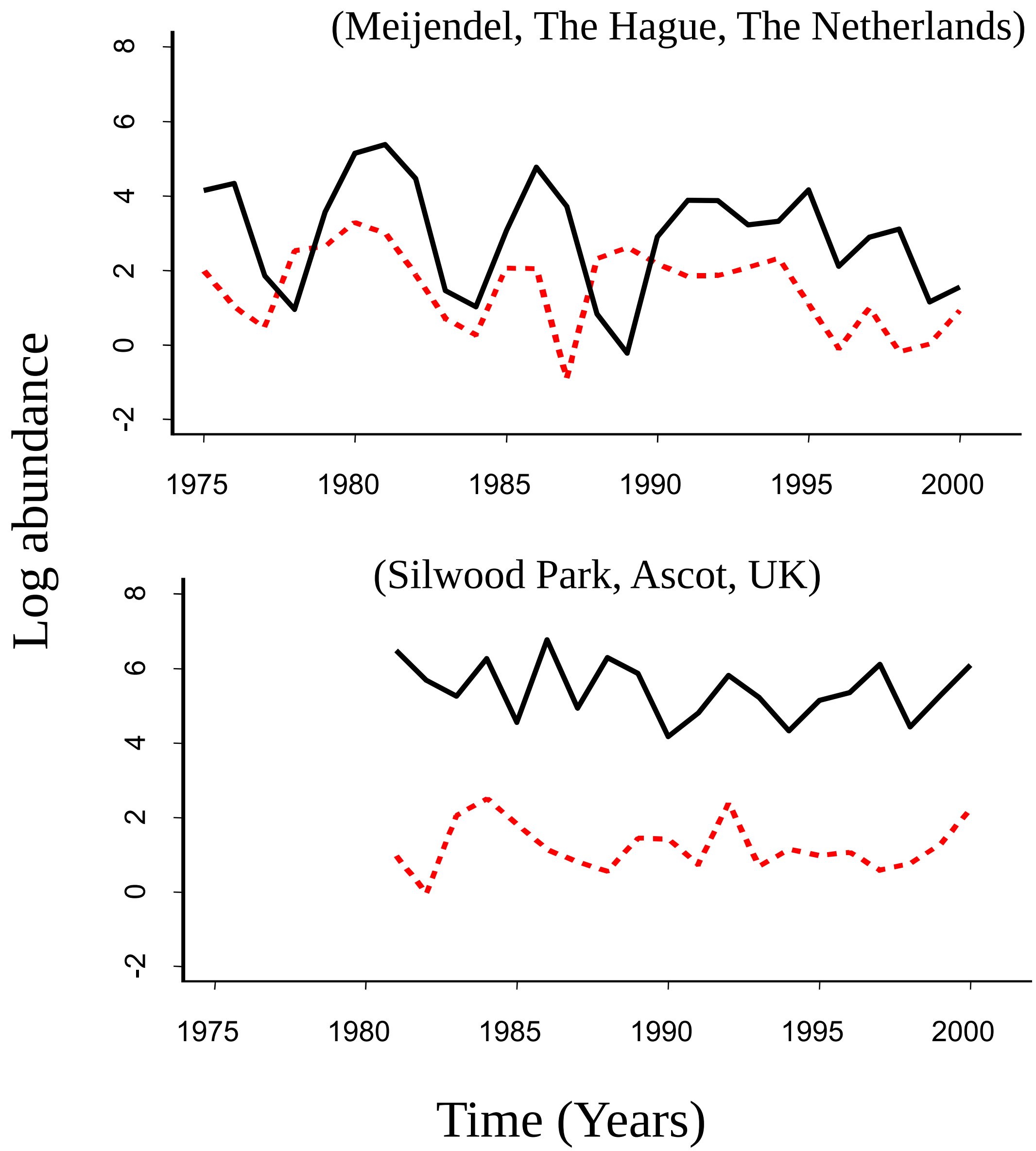
$$\frac{dH(t)}{dt} = caP(t)H(t) - uH(t)g(H(t,\tau))$$

Sensitivity analysis – trophic-interactions

$$\begin{pmatrix} \lambda - rf'(P(t,\tau)) & aP(t) \\ -caH(t) & \lambda + ug'(H(t,\tau)) \end{pmatrix}$$

Cinnabar Moth – Ragwort Dynamics

Ragwort – Cinnabar Moth



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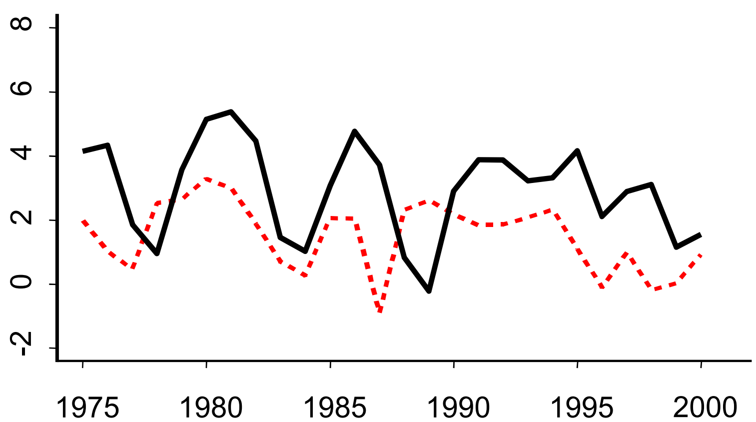
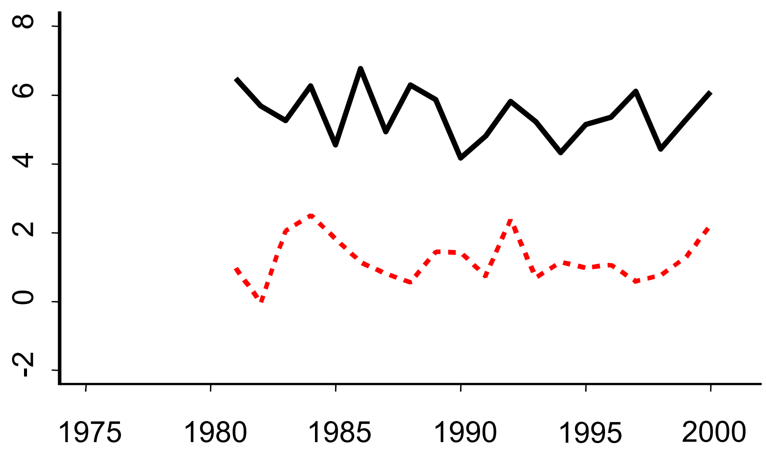
Moth dynamics in Meijendel =
moth population size (@ time t-1)
+ moth population size (@ time t-2)
+ plant population size (@ time t-2)



Plant dynamics in Meijendel =
plant population size (@ time t-1)
+ plant population size (@ time t-2)
+ moth population size (@ time t-1)

Moth dynamics in Silwood Park =
moth population size (@ time t-1)



Plant dynamics in Silwood Park = plant population size (@ time t-1)

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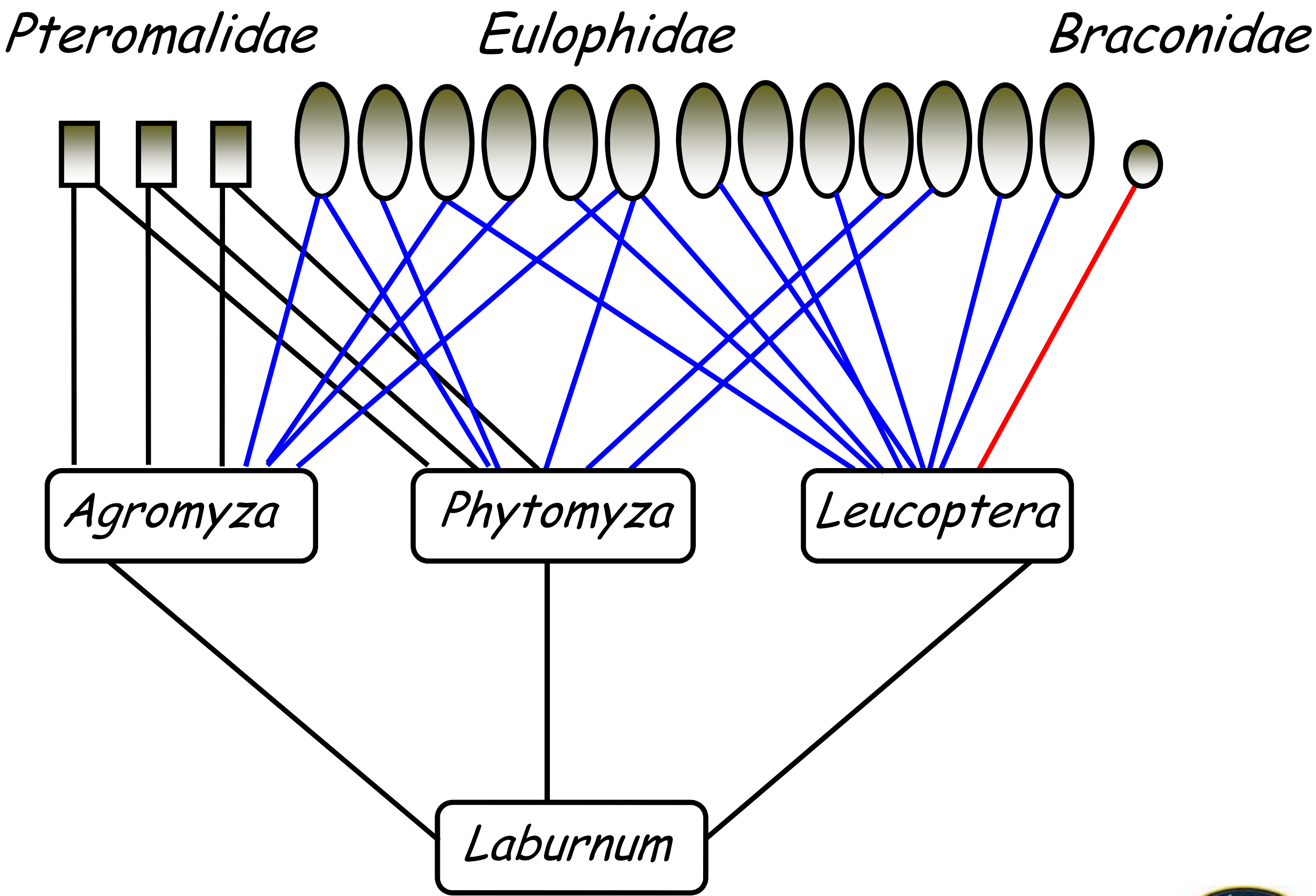
Complex species interactions



Rarity

Rarity

Geographic Distribution		Wide		Narrow	
Habitat Specificity		Broad	Restricted	Broad	Restricted
Local Population Size	Somewhere large	Common	Habitat Specialist		Endemics
	Everywhere small	Truly Sparse			Classic Rarity

Following Rabinowitz (1981) classification of rarity based on geographic distribution, population size and habitat specificity

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Example population-level models for rarity

$$\frac{dN(t)}{dt} = rN(t)\left(\frac{K - N(t)}{K}\right)\left(1 - \left(\frac{a+c}{N(t)+c}\right)\right) + \omega$$

$$N_i(T) = \int_0^T N_{i.0}\, g(N_i(x)) - f(N_i(x,\tau))N_i(x)\,dx$$

$$N_i(T+1) = \sigma_i\left(N_i(T) + v_{ij}\sum\left(N_i(T) - N_j(T)\right)\right)$$

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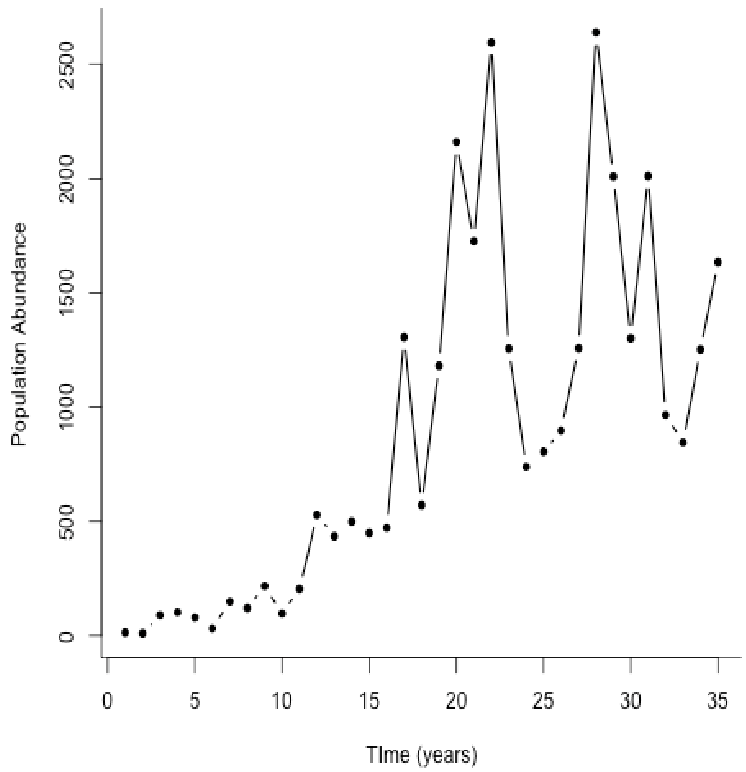
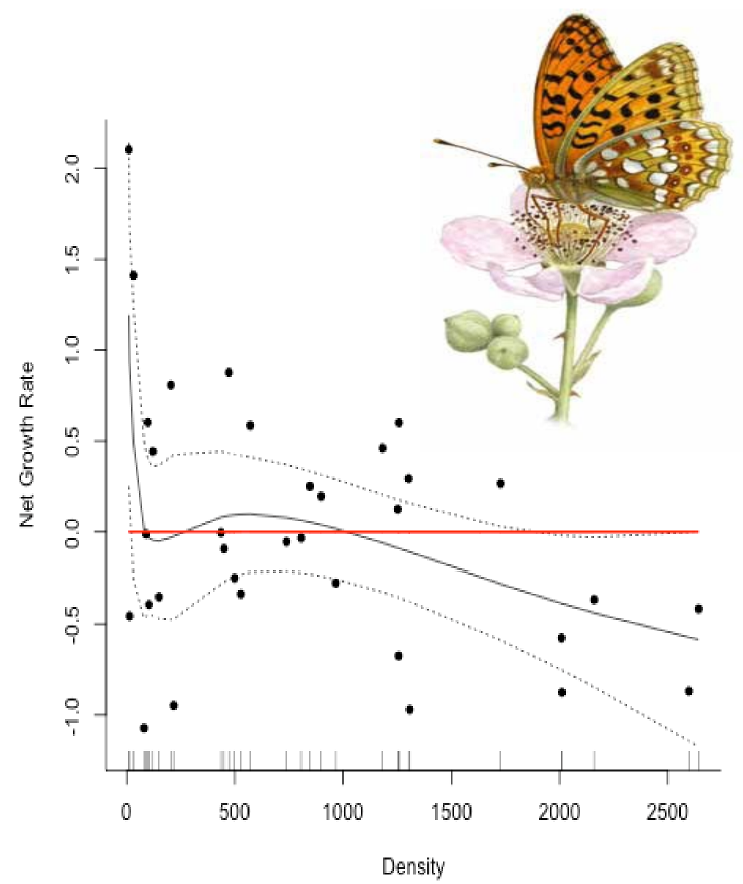
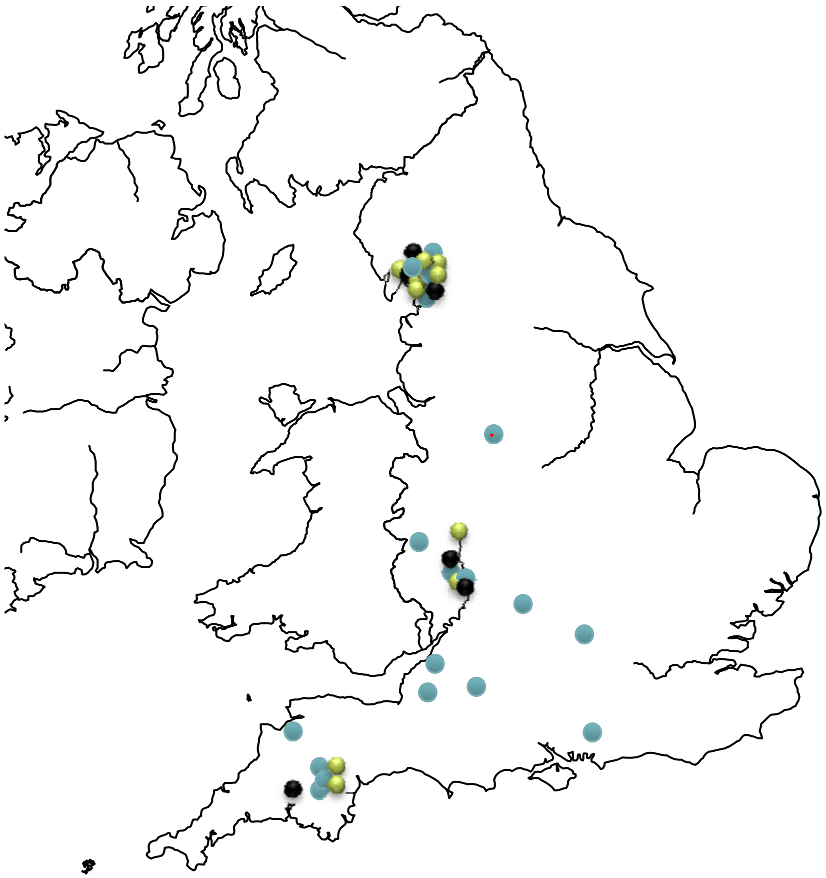
High Brown Fritillary

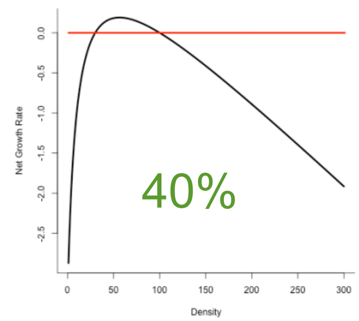




High Brown Fritillary

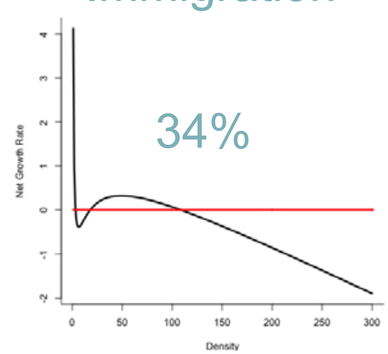


Allee Effect



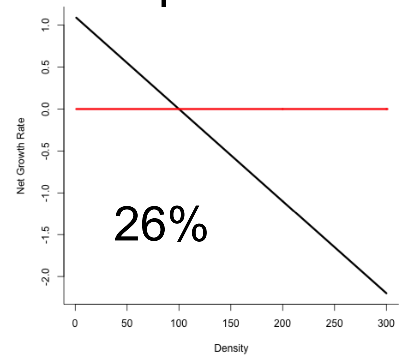
40%

Allee Effect & Immigration



34%

Density Dependence



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Rarity: consequences for ERAs?

- Low sample bias
  - Affects demographic processes; detection of biodiversity shifts.
- Ecological constraints
  - Affects bias in population level processes; detection of biodiversity shifts.
- Evolutionary constraints
  - e.g. frequency dependence might favour reproductive modes to buffer environmental variability.

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Points for Thought

- NGR analysis allow ALL demographic and population processes to be integrated….
- …however, rapidly complicated. So…
- ..in an ERA
  - Objective function (define goals)….maximize (minimize) with respect to constraints (ecological, biological, economic)
  - Adaptive management
- … so that we have ***<u>proportionate responses to technologies</u>***

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Questions?