Matrix Population Models for Wildlife Conservation and Management

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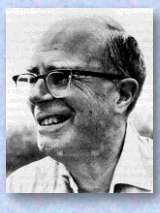
Lecture 12
Density Dependence



Robert MAY and David LACK, who contributed in very different fashions to our understanding of « Density-Dependence »

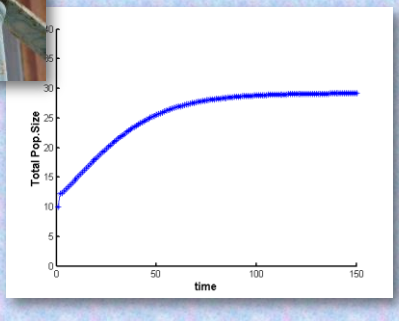
Matrix Models: Density-dependence

$$N_1(t+1) = \boxed{s_0(N_1(t) + N_2(t))\, f_1}\, N_1(t) + s_0 f_2\, N_2(t)$$

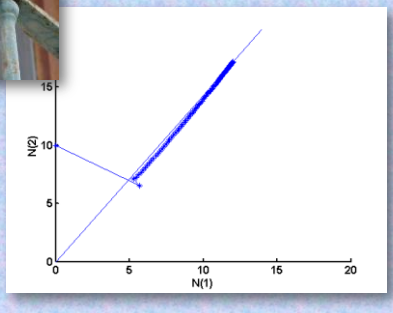
$$N_2(t+1) = q_1\, N_1(t) + q_2\, N_2(t)$$

e.g. $s_0(N_1(t) + N_2(t)) = 0.2 * \exp(-0.001\,(N_1(t) + N_2(t)))$

Trajectory over time
Asymptotic stabilization



Trajectory in the phase plane
Asymptotically stable age structure



Density-dependence and space
A Minimal Metapopulation Model

$$N_{t+1} = \text{R.D. } N_t = \begin{pmatrix} a(N_t)p & b\,(1-q) \\ a(N_t)(1-p) & b\,q \end{pmatrix} N_t$$

$a(N_t) = \exp(\, r\,(1 - N_t(1)/K)\,)$ (Source)
$b < 1$ (Sink)
$p < 1$ (migration, Source to Sink)
$q = 1$ (no migration from Sink to Source)

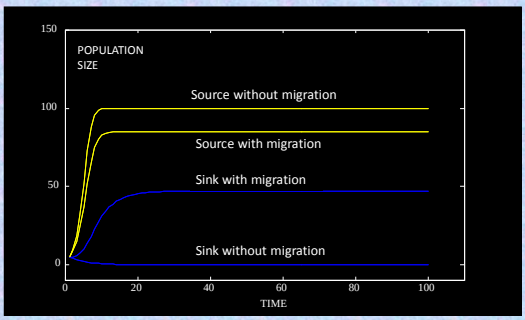
Density-dependence and space

A Minimal Metapopulation Model

$$N_{t+1} = R.D.\ N_t = \begin{pmatrix} a(N_t)p & 0 \\ a(N_t)(1-p) & b \end{pmatrix} N_t$$

$a(N_t) = \exp(\ r\ (1 - N_t(1)/K)\ )$ (Source)
$b < 1$ (Sink)
$p < 1$ (migration, Source to Sink)
$q = 1$ (no migration from Sink to Source)

Effect of migration from a Source to a Sink



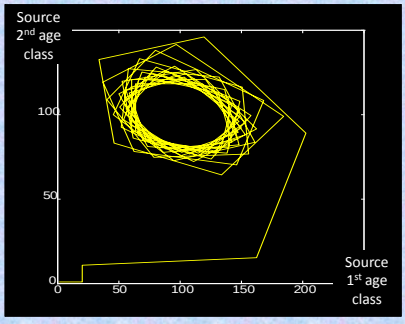
A diversity of behaviors

- Stages x ages etc…
- Dependence on total population size
- Dependence on some components:
  e.g., number of breeders
- Dependence of various parameters:
  e.g. probability of breeding

- Further complexity due to discrete time
  - stable equilibrium for low λ_{max}
  - periodic equilibrium for higher values
  - chaos for high values (exercise)
- … even more in multistate models

Source-sink

2 age classes, 2 sites



Estimating intensity of Density-Dependence

Issues resulting from uncertainty in population size estimates

Lebreton and Gimenez, JWM, 2013

- From series of population size estimates
  - Tricky
  - Strong risk of overestimation
  - State-space models promising
  - No fully standardized approach

- On traits (e.g. Capture-recapture data)
  - Straightforward
  - Conservative, i.e. tendency to underestimation

Modeling density-dependence often speculative rather than directly based on empirical evidence

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