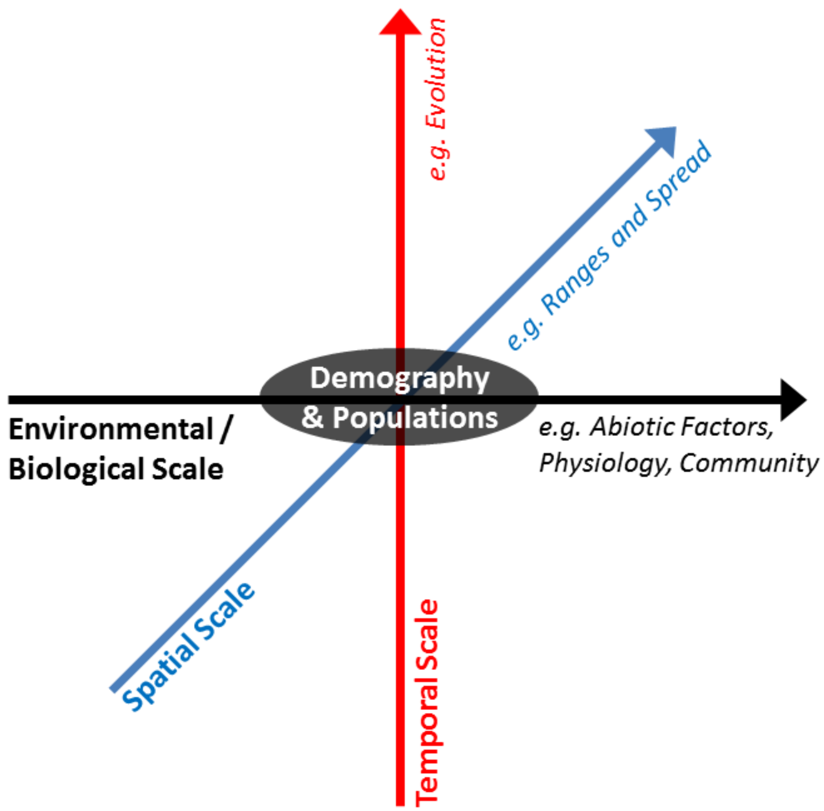
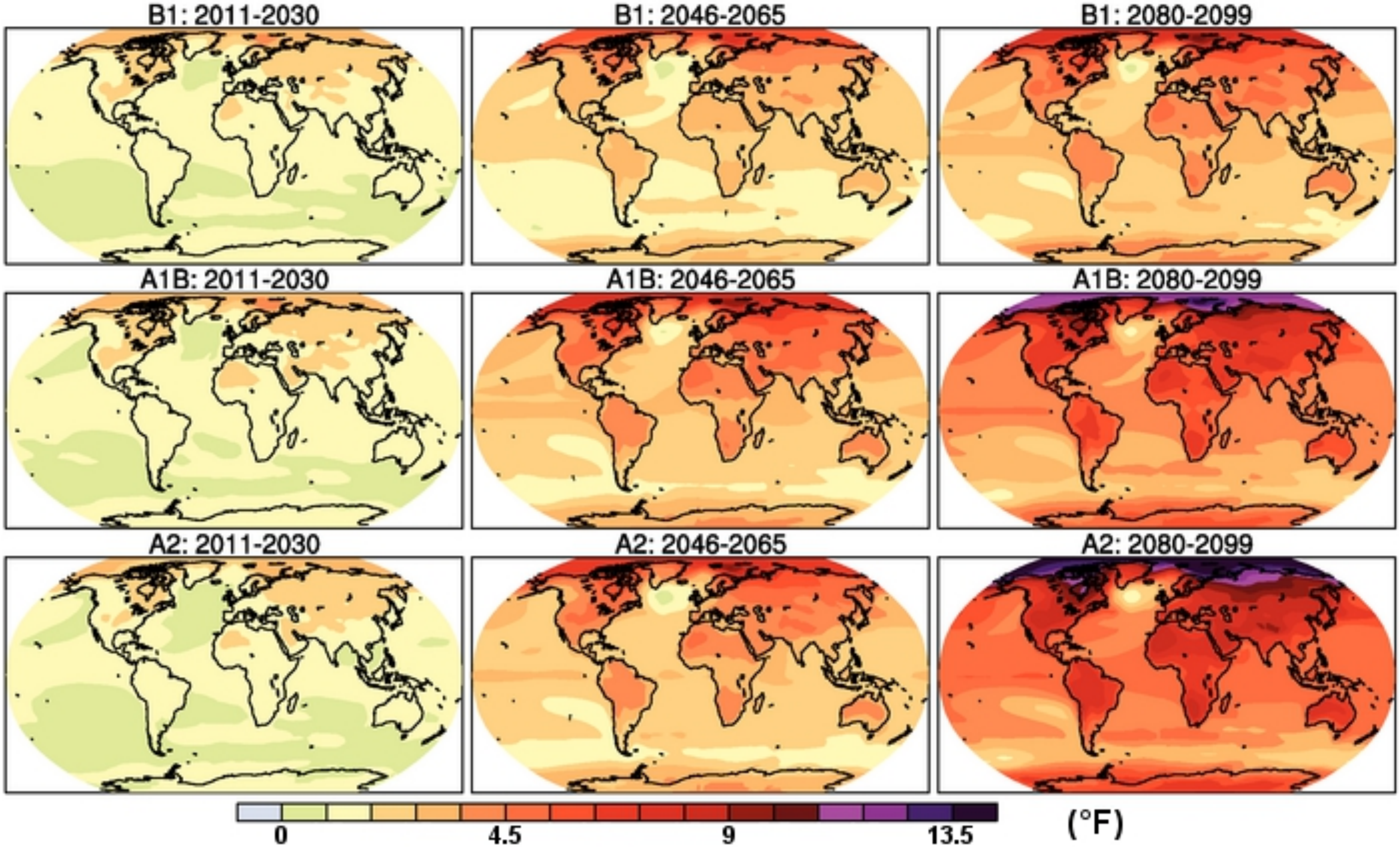
INTRODUCTION TO POPULATION MODELS



Cory Merow

Yale University

The environment is changing…



projected temperature changes

Meehl et al. 2007

The environment is changing…

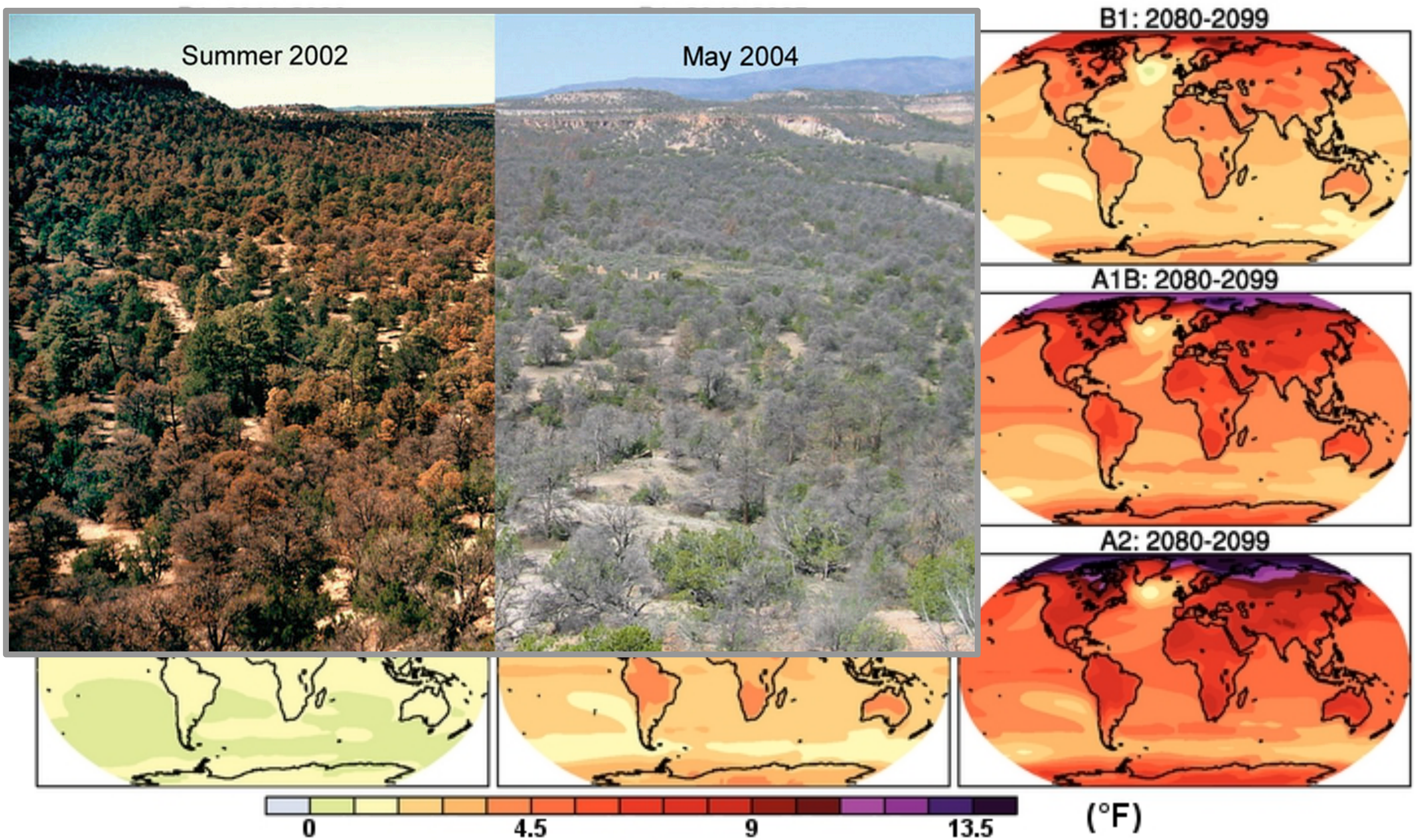


Photo: Craig Allen

projected temperature changes

Meehl et al. 2007

The environment is changing…

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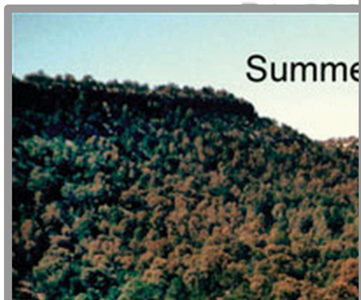
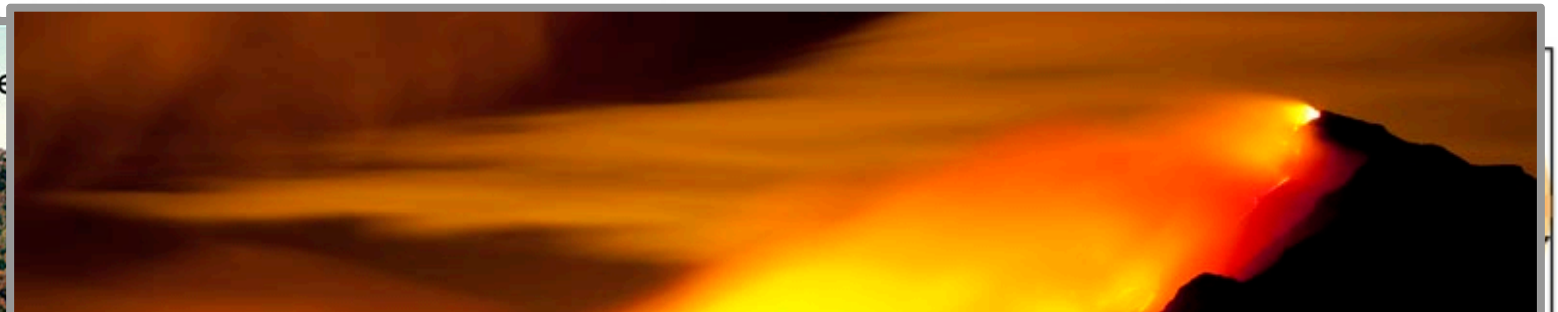
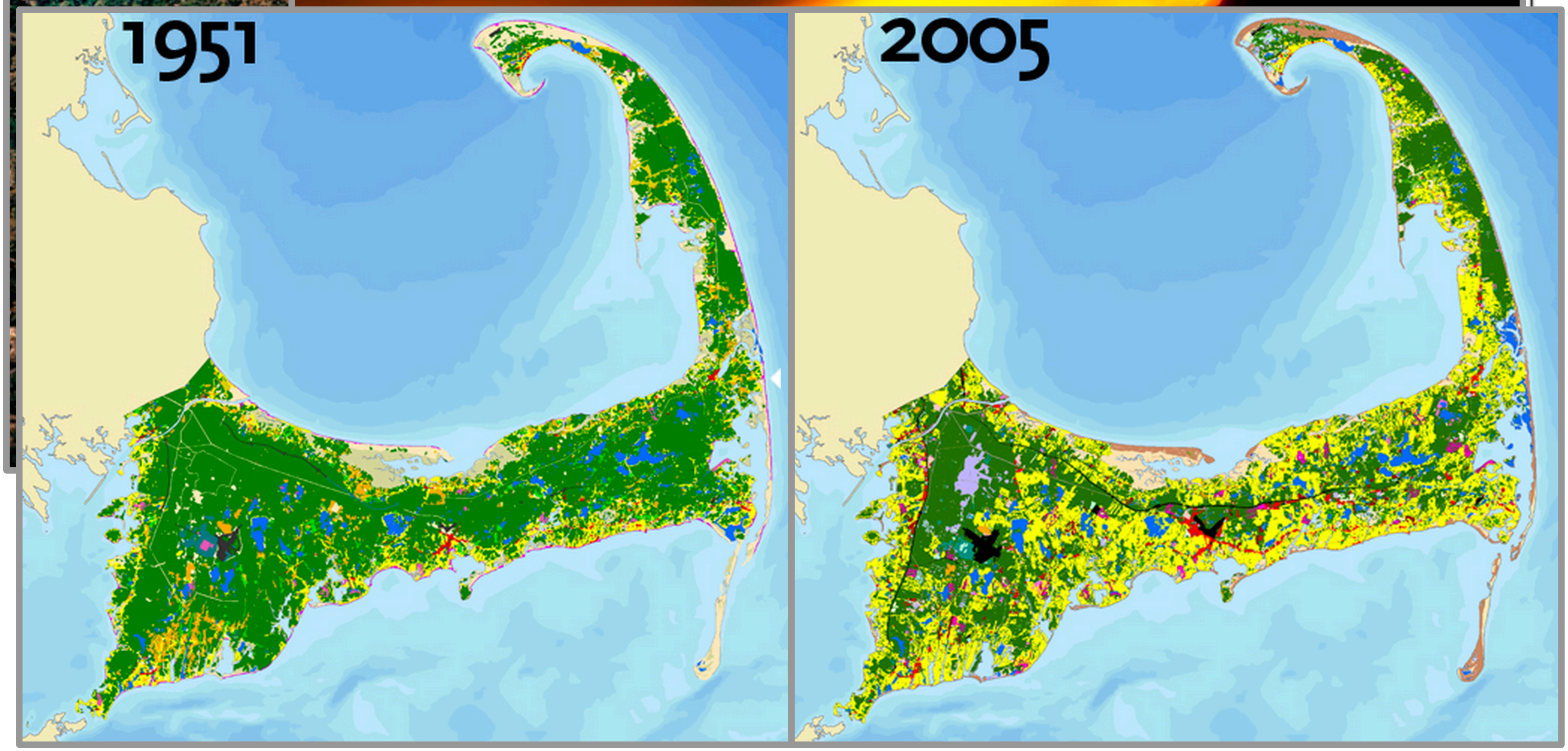
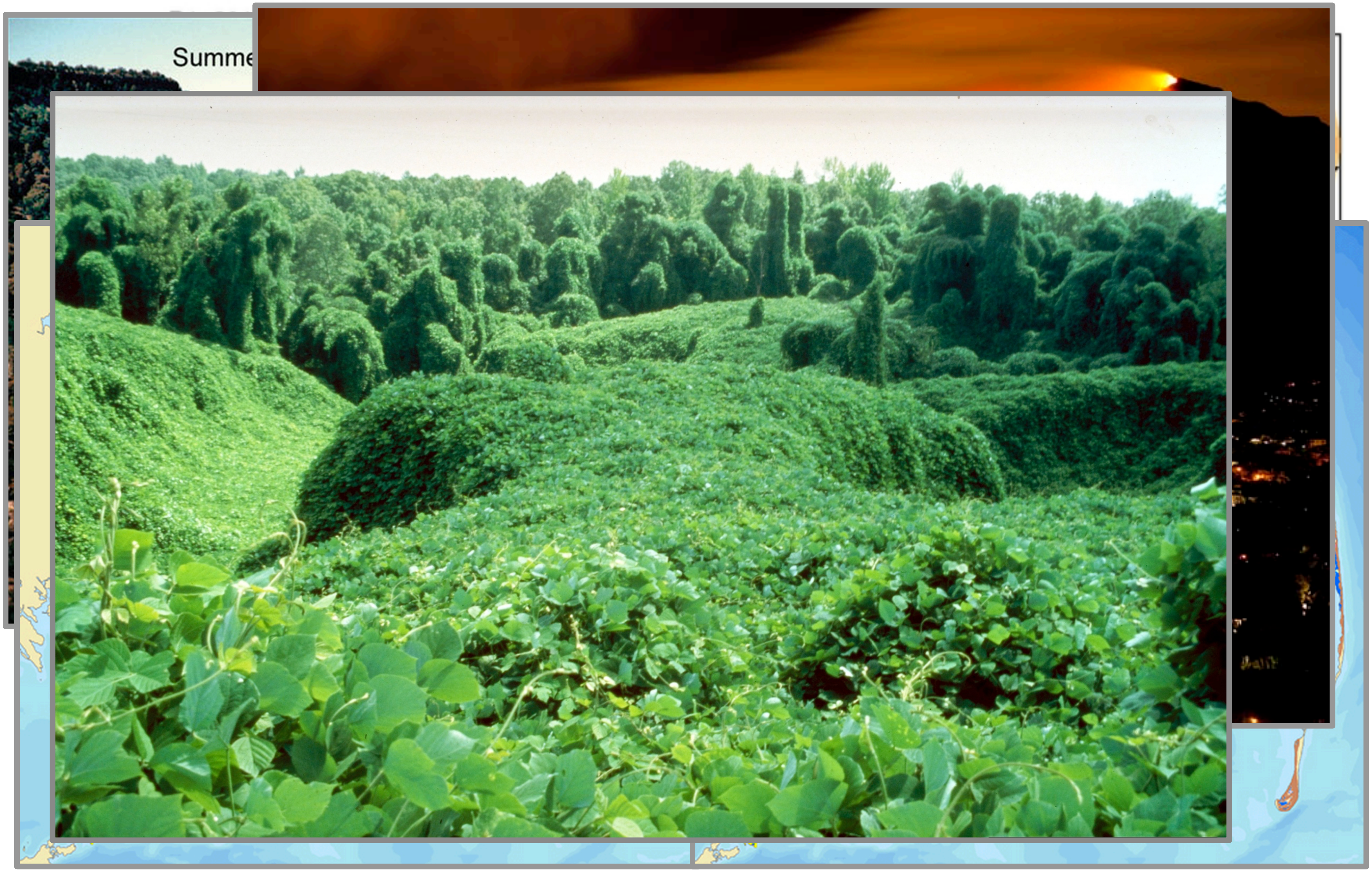






The environment is changing…



Ecological responses to global change

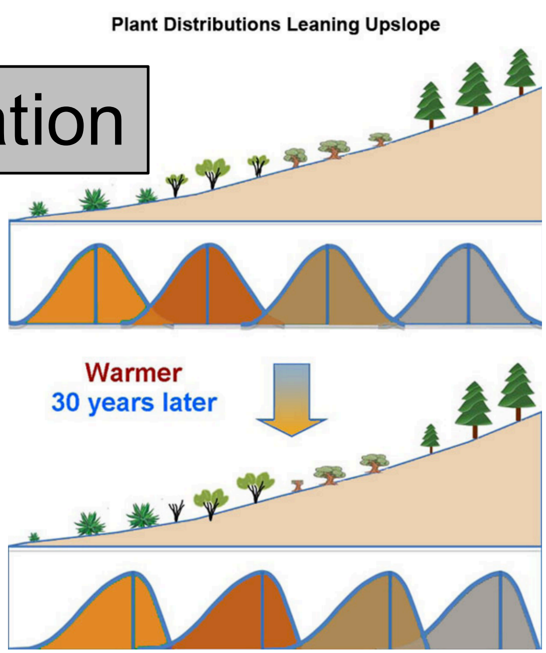
Persistence

Decline

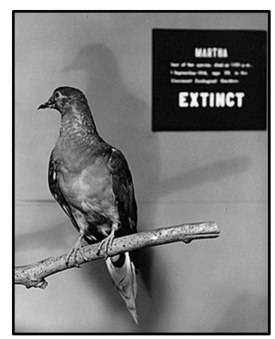
Increase

Invasive
Garlic Mustard

Migration



Extinction



Demography

Demography

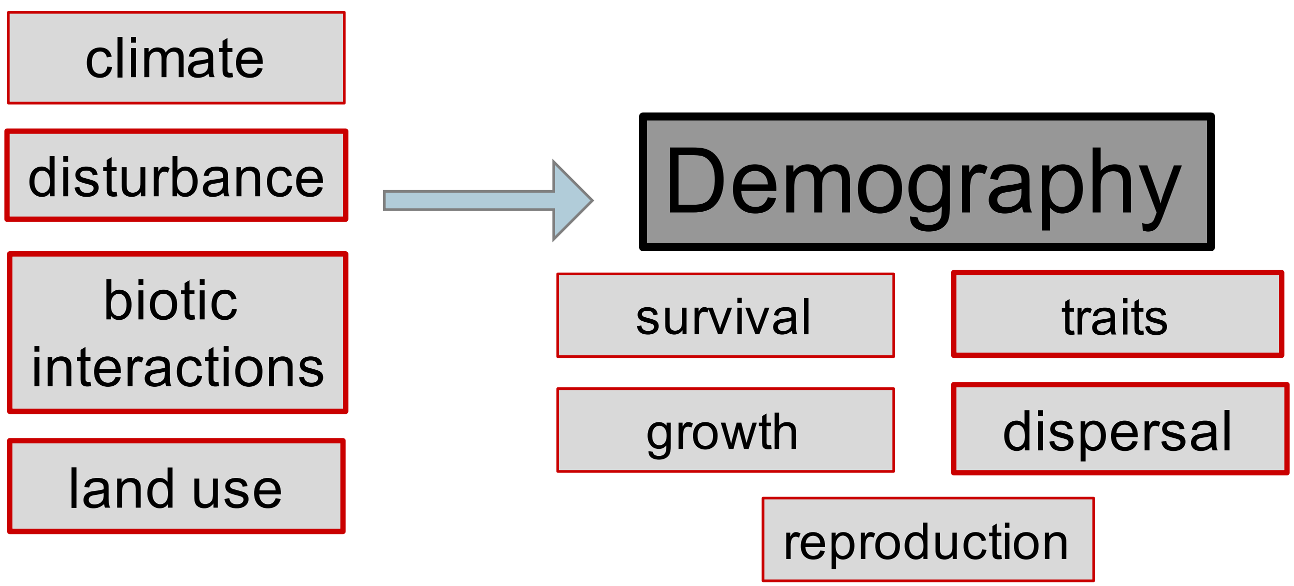
survival

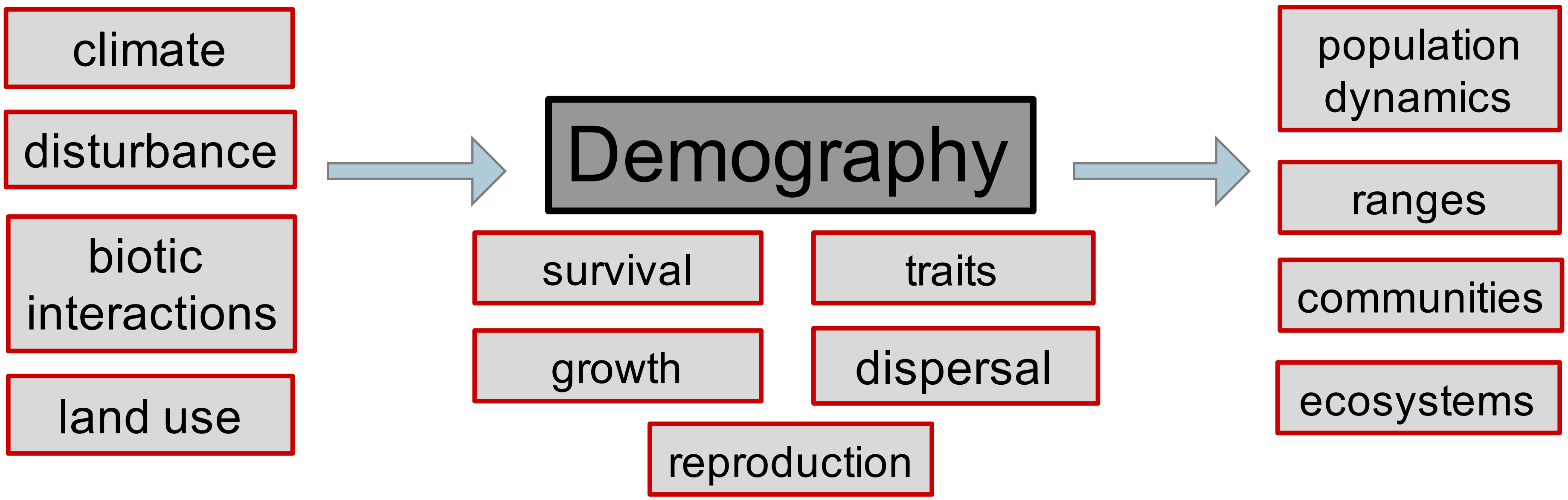
traits

growth

dispersal

reproduction


climate
disturbance
biotic interactions
land use
Demography
survival
traits
growth
dispersal
reproduction


climate
disturbance
biotic interactions
land use
Demography
survival
traits
growth
dispersal
reproduction
population dynamics
ranges
communities
ecosystems

What is Population Ecology?

- Understand processes that govern abundance
  - Extrinsic (Density Independent)
  - Intrinsic (Density Dependent)

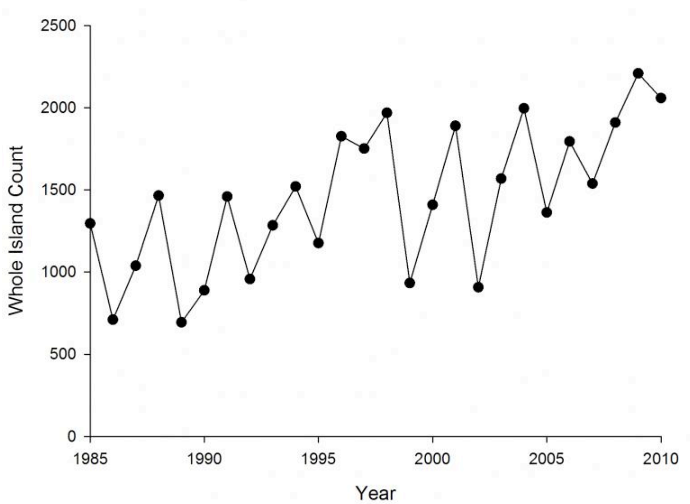
- Forecast how abundance might change
  - Population viability analysis

- Understand (st)age structure in populations

Population Growth (unstructured)

An open population

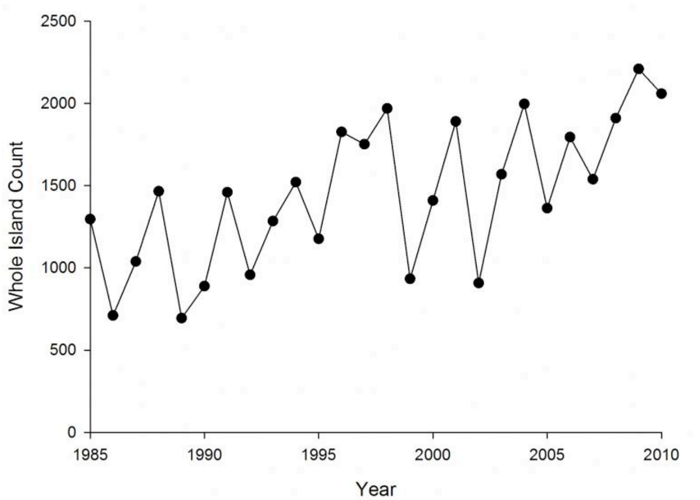
$$dN/dt = \text{Birth} - \text{Death} + \text{Immigration} - \text{Emmigration}$$



Population Growth (unstructured)

An open population $dN/dt = Birth – Death + Immigration - Emmigration$

A closed population
$$dN/dt = Birth – Death$$
$$= b^* N – d^* N$$
$$= (b-d) ^*N$$
$$= r ^*N$$

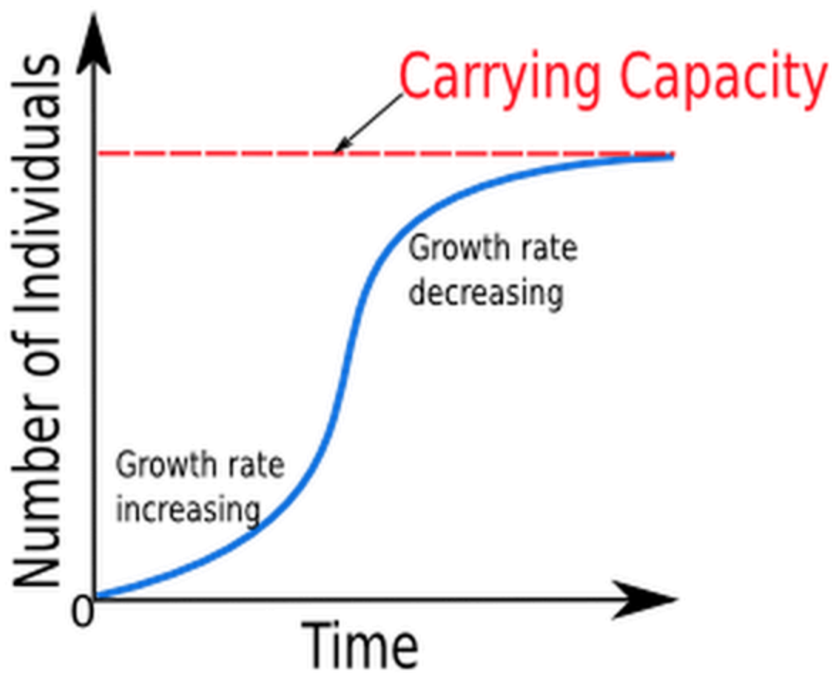


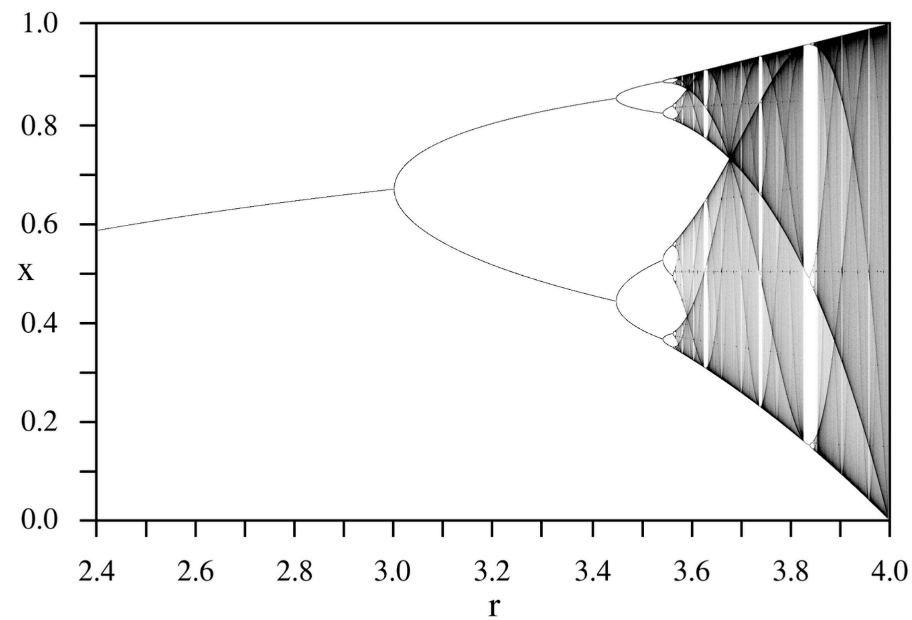
b and d are per capita rates

r is the expected number of surviving offspring – population growth rate

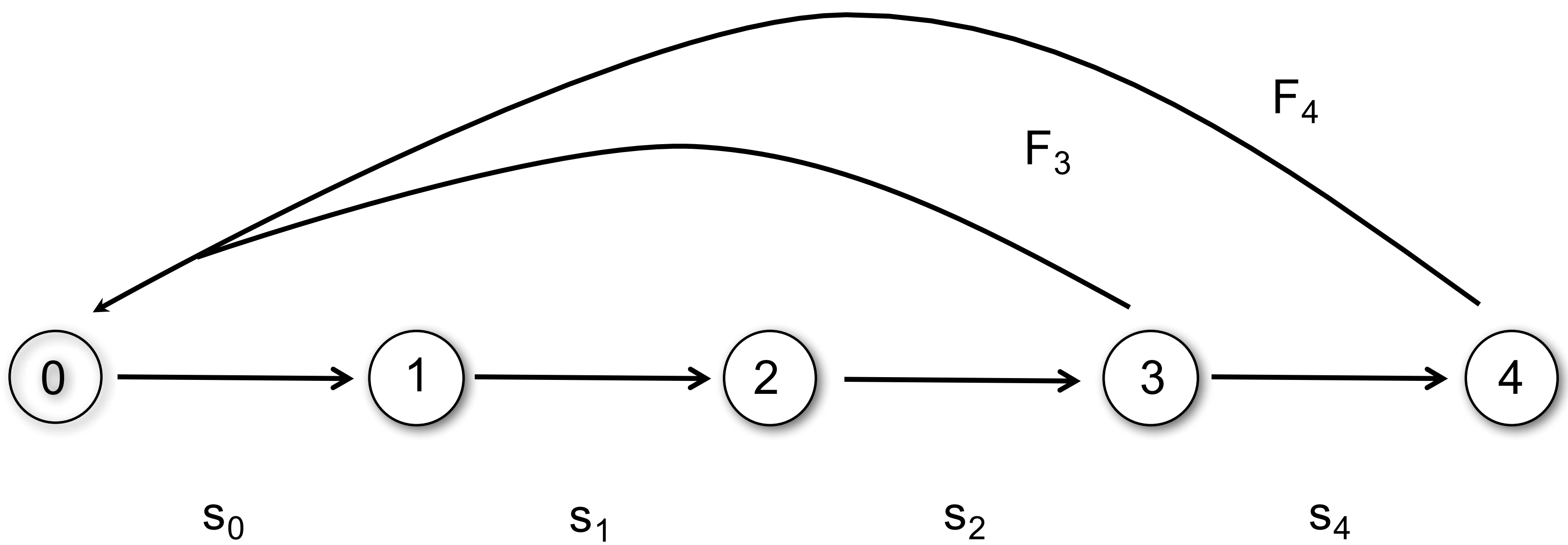
Density Dependence

$$dN/dt = r * N * (K-N)/K$$





Age Structured Populations



Leslie Matrix

	Age 1	Age 2	Age 3	Age 4
Age 1	F_0	F_1	F_2	F_3
Age 2	S_0	0	0	0
Age 3	0	S_1	0	0
Age 4	0	0	S_2	0

$$\begin{bmatrix} F_0 & F_1 & F_2 & F_3 \\ S_0 & 0 & 0 & 0 \\ 0 & S_1 & 0 & 0 \\ 0 & 0 & S_2 & 0 \end{bmatrix}$$

Elements of Leslie Matrix (**L**)

F_x – Age-specific Fecundity × age-specific survival

$$F_x = S_x m_{x+1}$$

S_x –Age-specific Survival

$$\begin{bmatrix} F_0 & F_1 & F_2 & F_3 \\ S_0 & 0 & 0 & 0 \\ 0 & S_1 & 0 & 0 \\ 0 & 0 & S_2 & 0 \end{bmatrix}$$

Population Projection

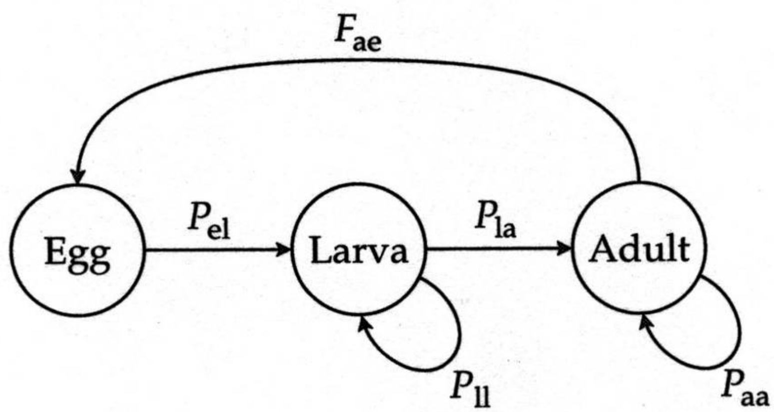
$$N_{t+1} = L \times N_t$$

$$\begin{bmatrix} N_{0,t+1} \\ N_{1.t+1} \\ N_{2,t+1} \\ N_{3,t+1} \end{bmatrix} = \begin{bmatrix} F_0 & F_1 & F_2 & F_3 \\ S_0 & 0 & 0 & 0 \\ 0 & S_1 & 0 & 0 \\ 0 & 0 & S_2 & 0 \end{bmatrix} \times \begin{bmatrix} N_{0,t} \\ N_{1,t} \\ N_{2,t} \\ N_{3,t} \end{bmatrix}$$

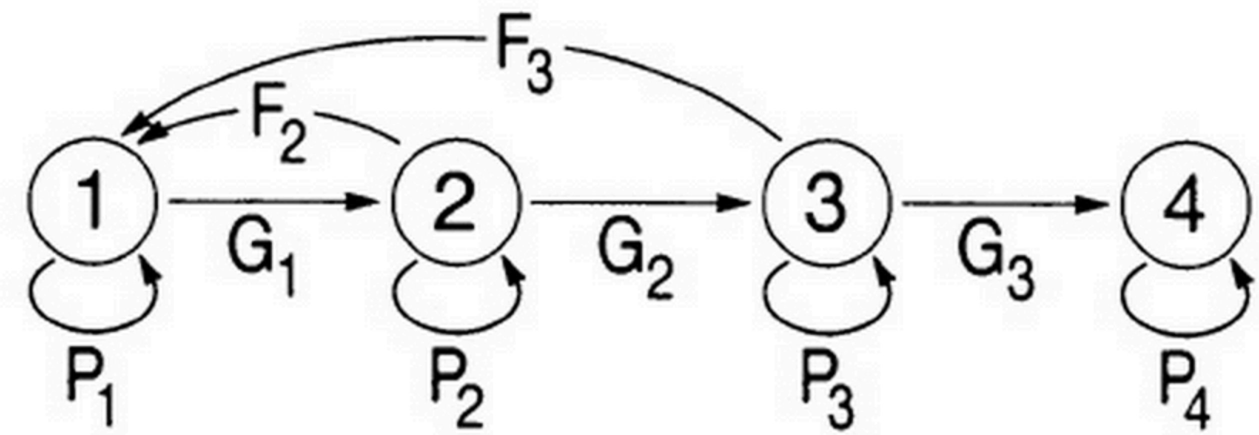
Stage Structured Models

(a) **Insect**

$$\begin{matrix} 0 & 0 & F_{ae} \\ P_{el} & P_{ll} & 0 \\ 0 & P_{la} & P_{aa} \end{matrix}$$



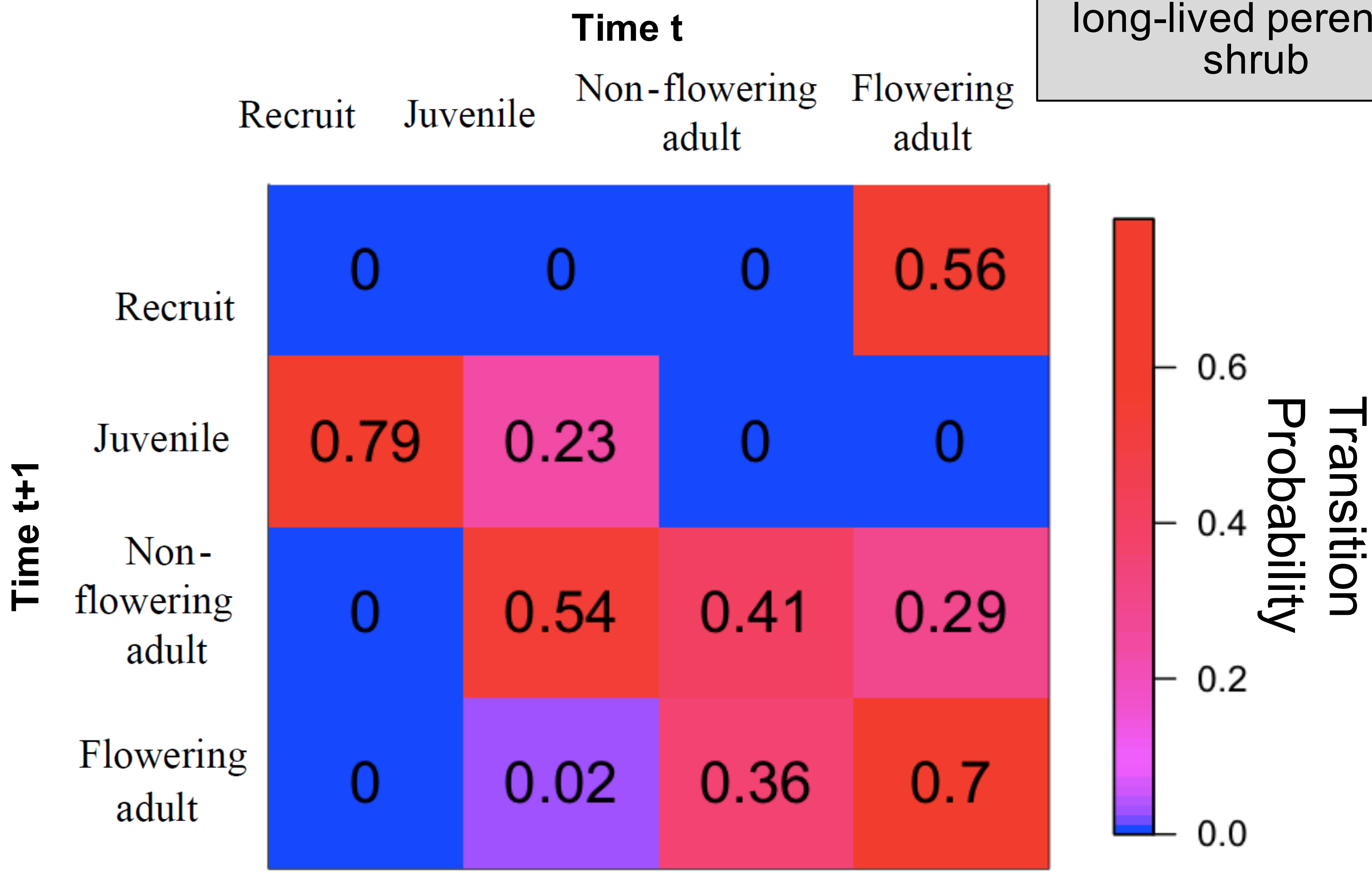
Stage Structured Models



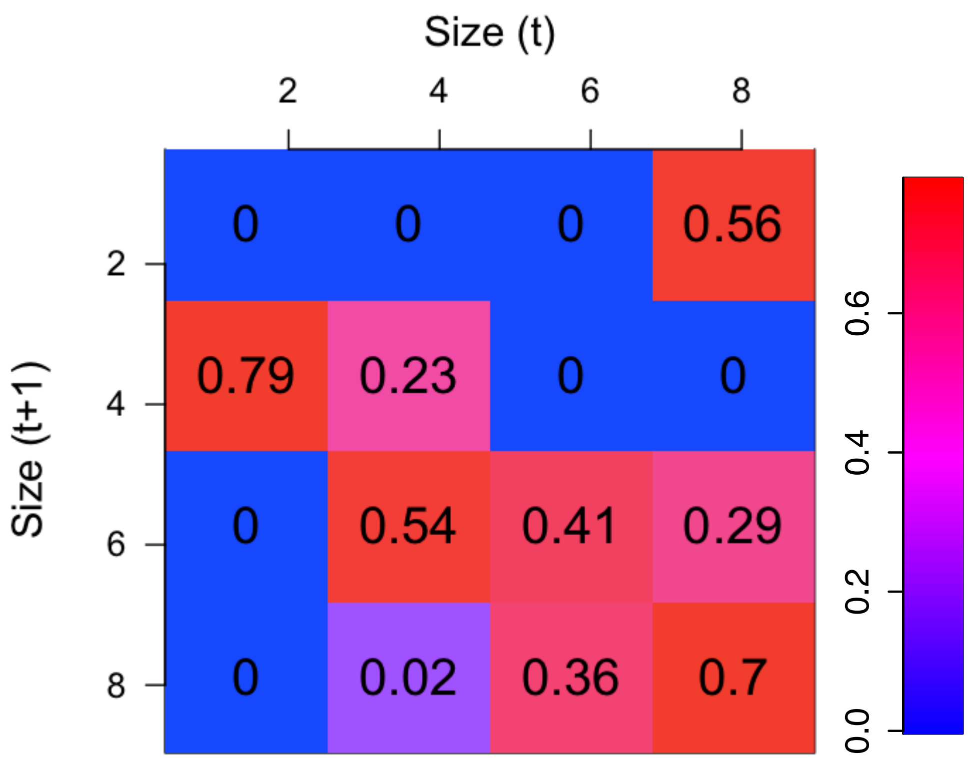
$$\begin{pmatrix} 0 & F_2 & F_3 & 0 \\ G_1 & P_2 & 0 & 0 \\ 0 & G_2 & P_3 & 0 \\ 0 & 0 & G_3 & P_4 \end{pmatrix}$$

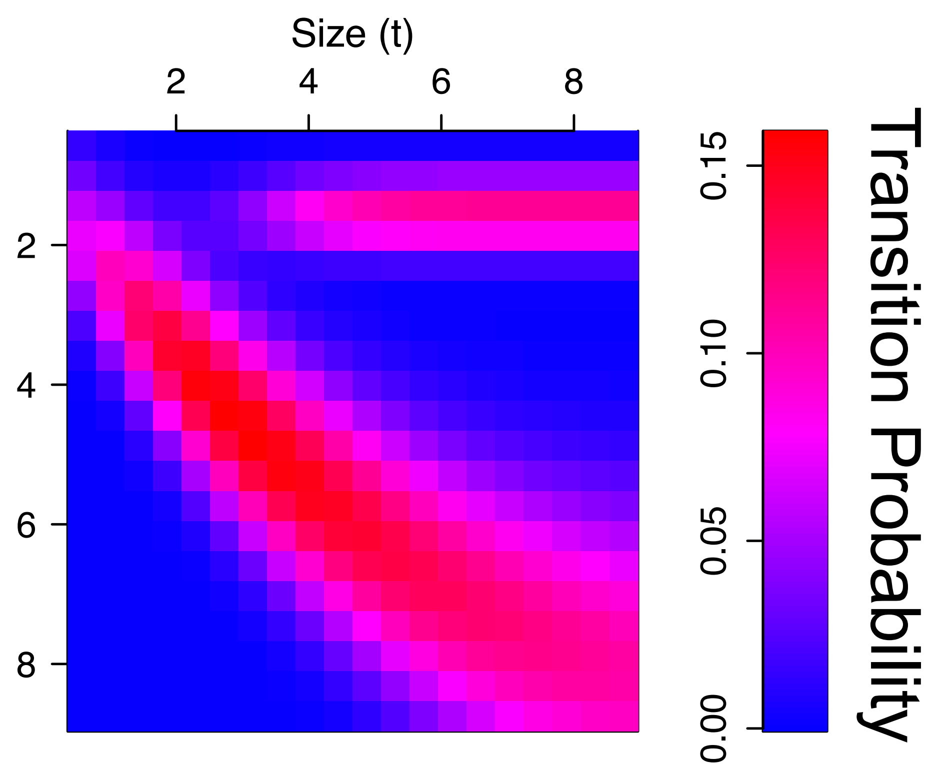
Stage Structured Models

Lefkovich matrix for a long-lived perennial shrub



Stage Structured Models





More stages = more heterogeneity among individuals

Size class borders

- ‘expert judgment’
- Algorithm to simultaneously minimize sample and distribution errors (Moloney 1986)
- Stage classes with significantly different vital rates (survival, growth, and/or reproduction)
- No size class borders

*Eigen*Analysis

- Eigenvalues
  - dominant = asymptotic growth rate at Stable Age Distribution
- Stable Age Structure
  - right eigenvector
- Reproductive Value
  - left eigenvector
- Sensitivities
  - how λ varies with absolute change in matrix elements (e.g. add .1)
- Elasticities
  - how λ varies with proportional change in matrix elements (e.g add 1%)
- Damping ratio
  - rate population approaches equilibrium $\rho = \frac{\lambda_1}{|\lambda_2|}$