Synthesizing individual, population, community, and landscape level data to aid management of savanna ecosystems

Tim Coulson

University of Oxford

At previous savanna networking meetings members of my group spoke

Wildlife demography

Foraging and movement of elephants

Ecoexist project

- William Bond asked me "How can you take the modelling approaches you have developed for detailed individual-based studies and apply them to other systems to help with management?"
- Am reporting back

How can we maintain our savannas?

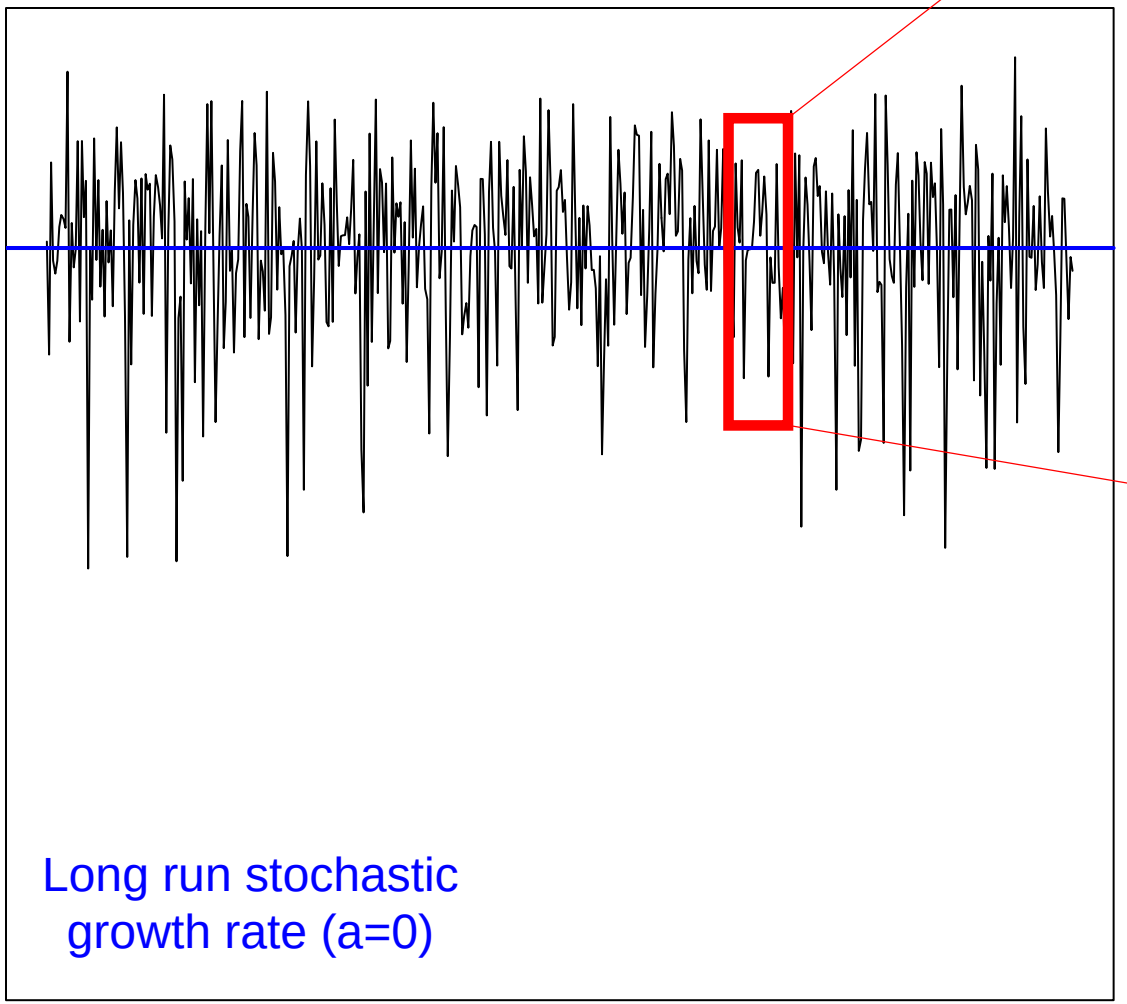
- Multiple threats
  - Climate change
  - Increasing CO_2 levels
  - Invasive species
  - Novel diseases
  - Over-exploitation
  - Change fire frequency

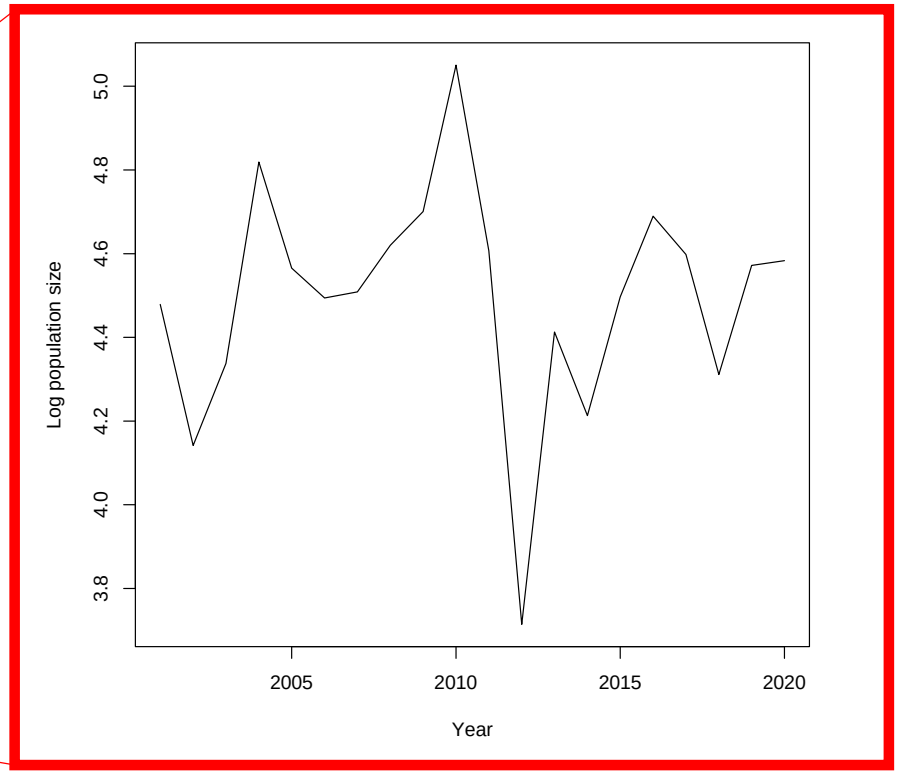
- Answer involves understanding **the states in which ecosystems can exist**

Stationary states (= stochastic equilibria)

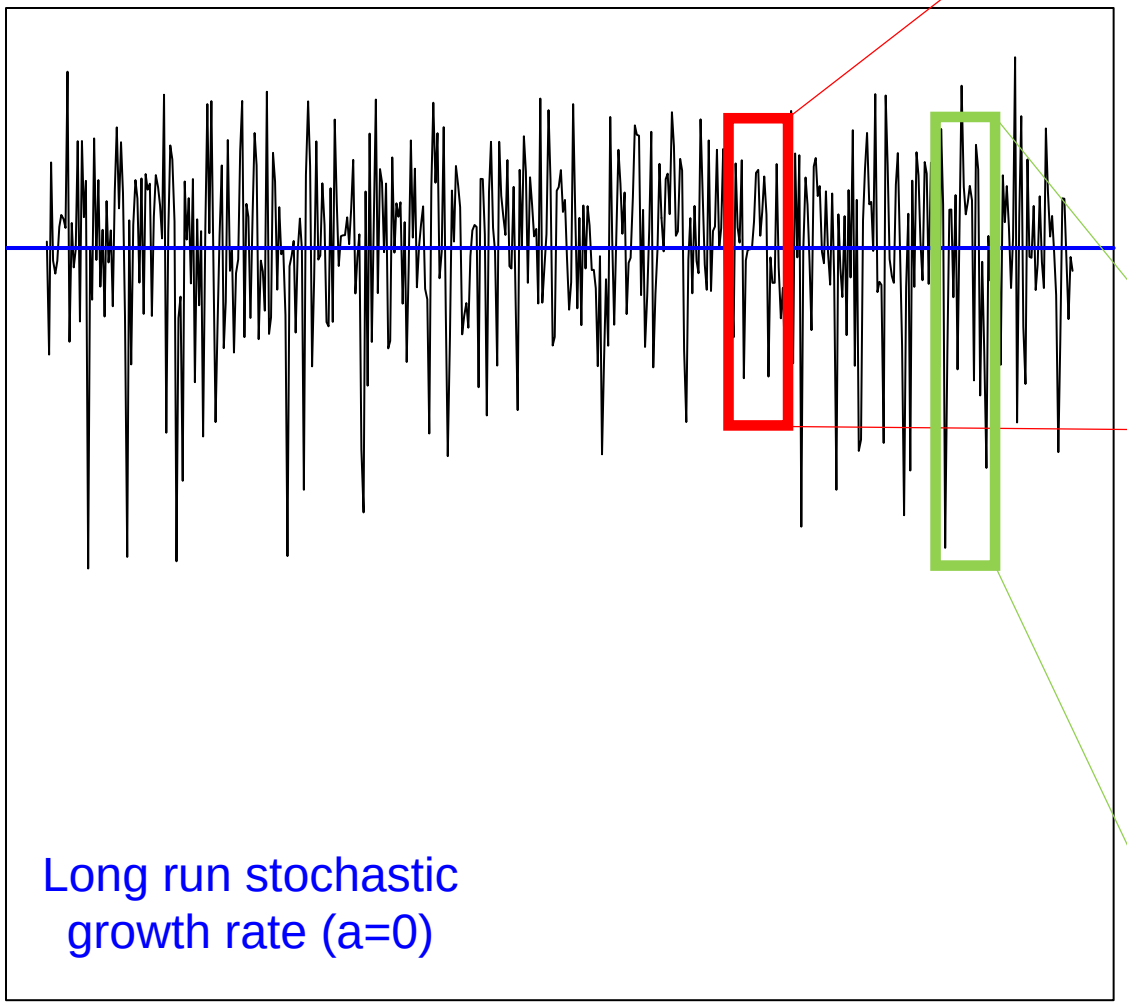
- We rarely focus on '**normal**' conditions because we live in a changing world
- Under '**normal**' conditions, species composition remains relatively constant – invasions and extinctions are rare
- A consequence of this is population sizes of **all** species within an ecosystem fluctuate within bounds
- Slow evolution (change in phenotypic trait means and allele frequencies)

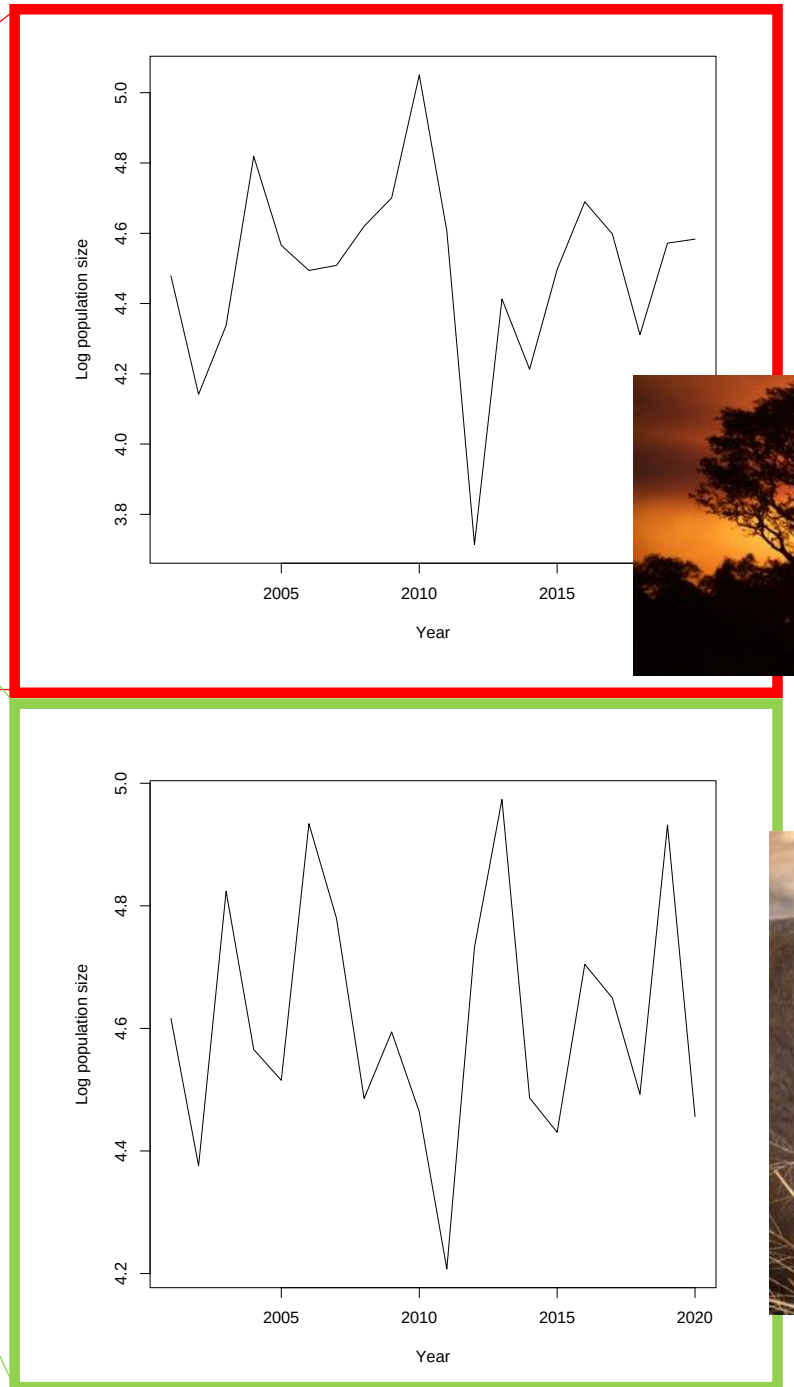
Stationary state





Stationary states





Climate

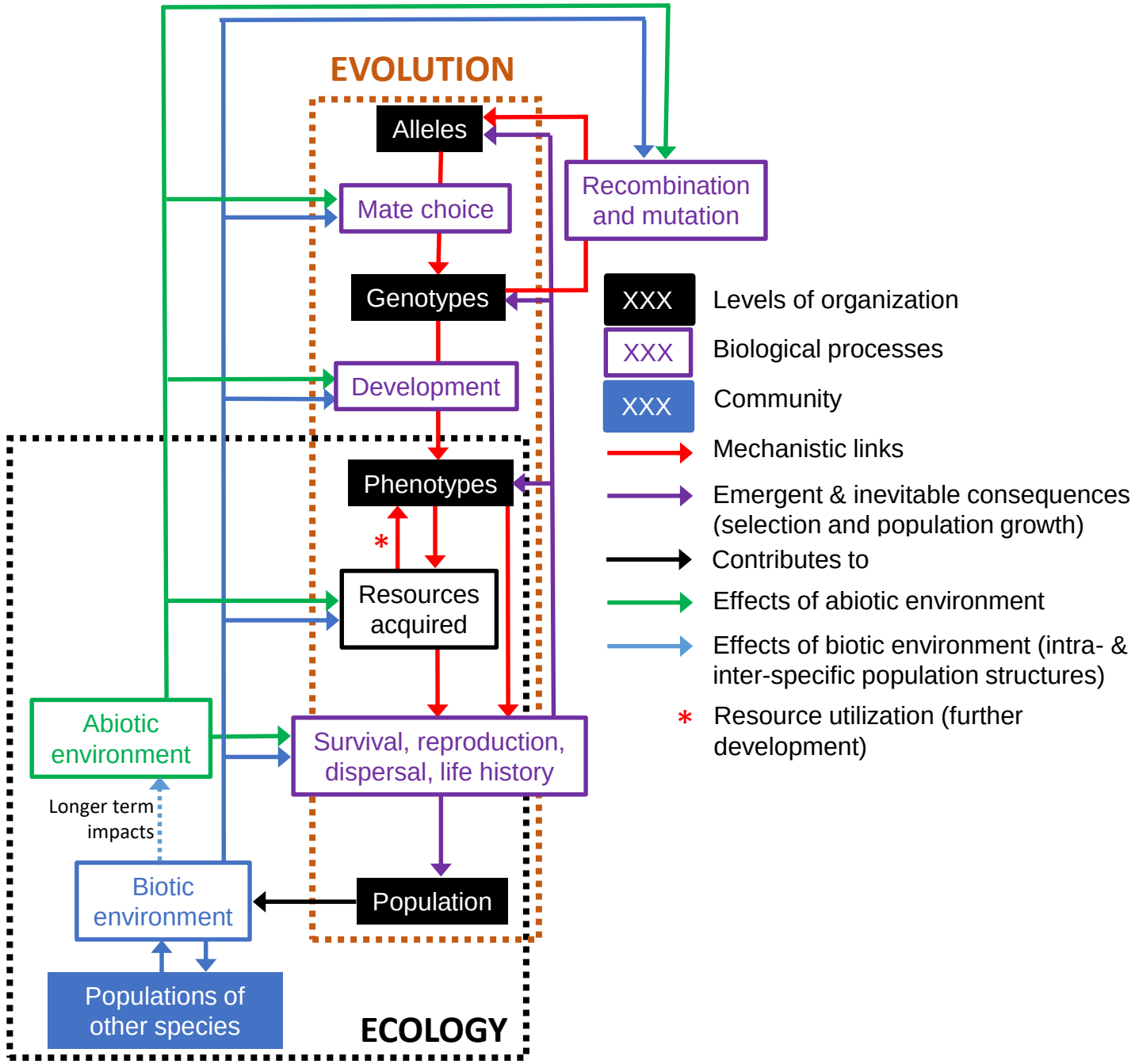
Predation

Stationary states

- Each population limited by a process that is the primary cause of death or failure to reproduce
  - Predation, food, disease
- Species have functional traits that allow them to detect, acquire and utilize resources given the limiting environment
  - Detection: senses
  - Acquisition: morphology, behavior
  - Utilization: metabolism, life history

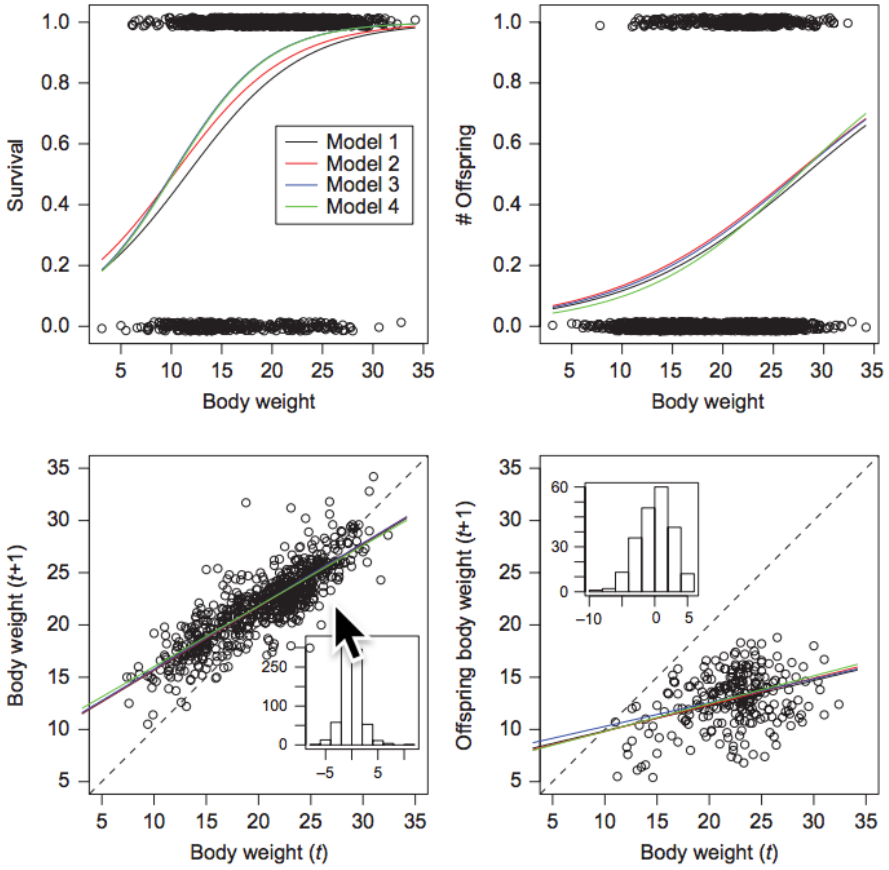
Levels of biological complexity within a population

- Biotic environment – size and structure of interacting species
- Abiotic environment – climate, geology, nutrients
- **Do not need all this complexity to make predictions, but useful to think which levels you want for each question**

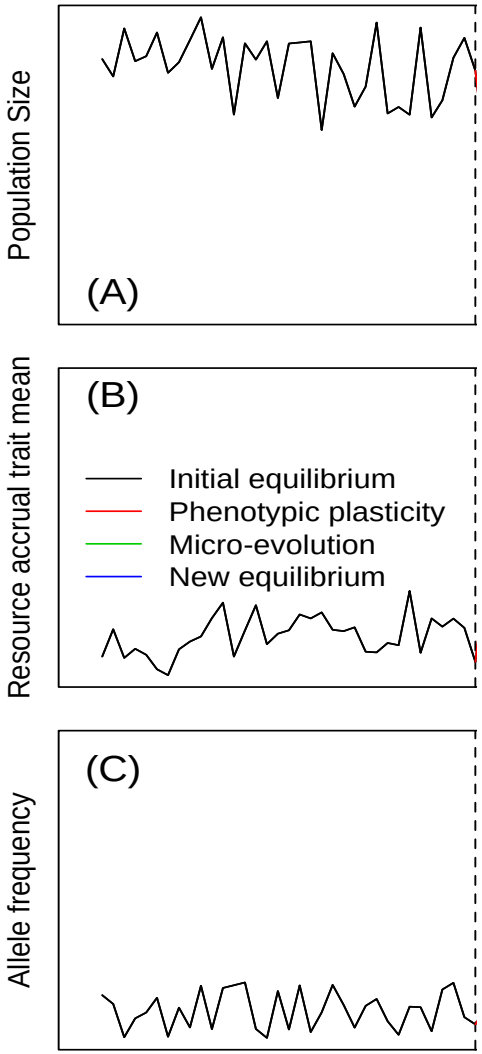


Modeling feedbacks from previous figure

- **Simple models**: population growth rate of each species influenced by
  - Size (and structure) of interacting species
  - Climatic variation
  - Landscape features
- **More complex models**: survival, fertility, development and movement of individuals of each species influenced by
  - Size (and structure) of interacting species
  - Climatic variation
  - Landscape features
- Phenomenological, process-based or mechanistic models

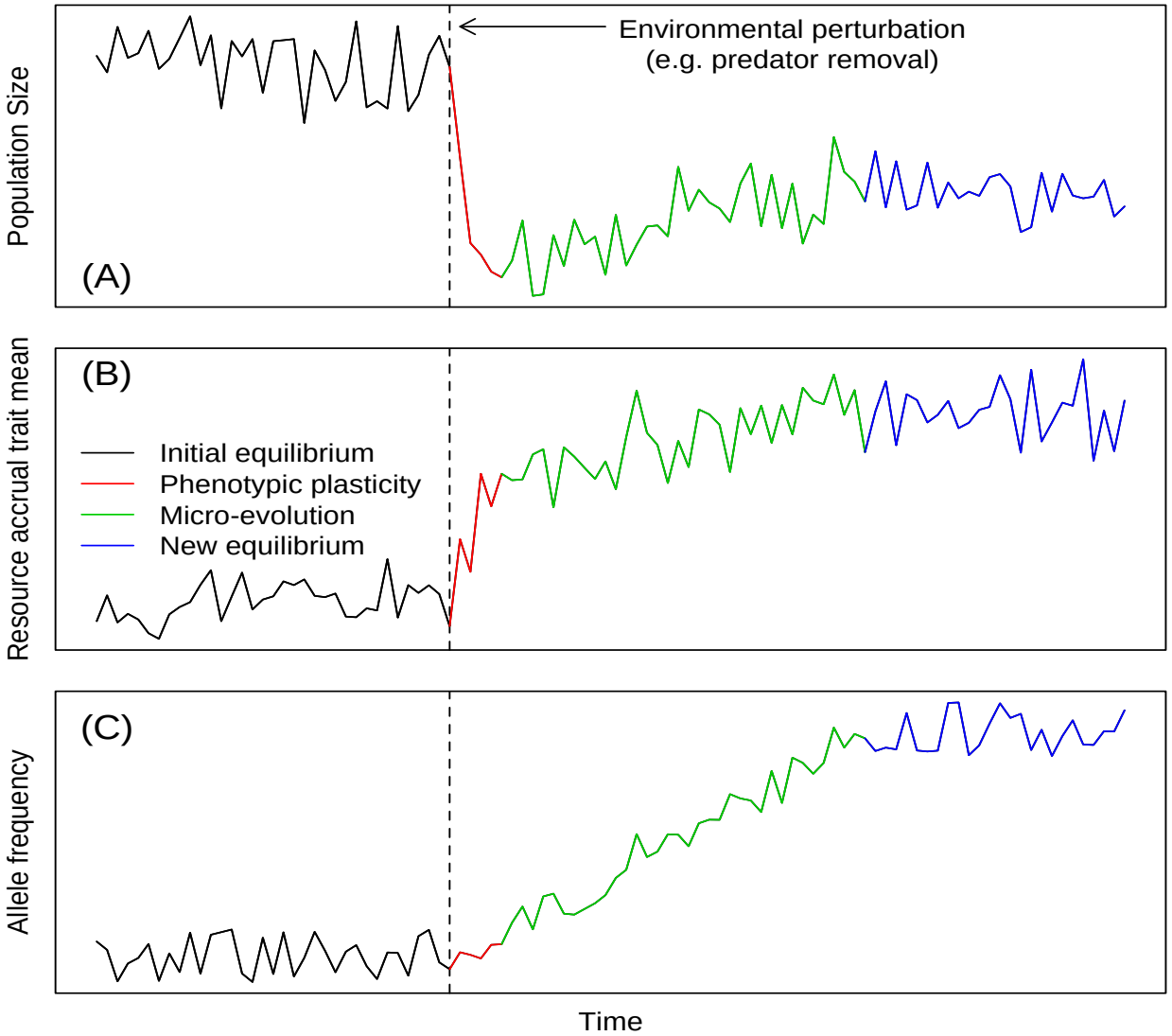


Population in stationary ecological and evolutionary state



- At evolutionary stasis
  - Stabilizing selection
- genetic variation maintained
  - Frequency-dependent selection

Perturbing the population



Initial stationary state

Period of transience

New stationary state

- Emergence of new disease
- Predator introduction / extinction
- Introduction of invasive species

Perturbing populations

- Perturbation alters limiting factor (predation to food)
- Changes population size
- Changes selection on traits associated with resource detection, acquisition, utilization

Perturbing populations

- Perturbation alters limiting factor (e.g. predation to food)
- Changes population size and optimal energy budget
- Changes selection on traits associated with resource detection, acquisition, utilization → phenotypic and life history evolution

Trait	Low Predation	High Predation
Life History		
size at maturity[1,2,3]	large	smaller
offspring #[1,2,3]	less	more
offspring size[1,2,3]	large	smaller
Demography		
density[4,5]	high	low
size structure bias[4,5]	large	small
Behavior		
schooling[6]	less	more
Morphology[7]	less streamlined	more streamlined
Swimming Performance[8]	slower	faster

Switching between states

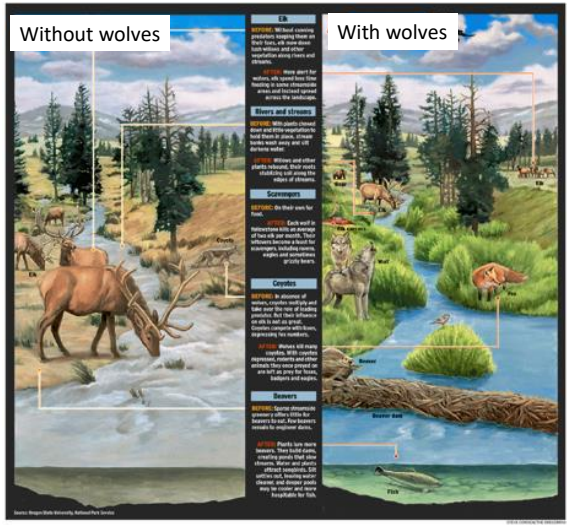
- **General question**: when does a perturbation to a population lead to change in stationary states of an ecosystems?
- Have developed theory of transitions of interacting species between ecological and evolutionary stationary states (happy to discuss)
- Losing some species **will** lead to switches between states, but losing others **will not** have such an effect

Perturbations and ecosystem rearrangement

- If a species is, or impacts, the source of primary productivity, impacting it can lead to transition between stationary states
- If change in abiotic factor impacts source of primary productivity, impacting it can lead to a transition between states

Serengeti: vegetation limited by wildebeest that are not limited by lions

Yellowstone: vegetation productivity limited by elk limited by wolves

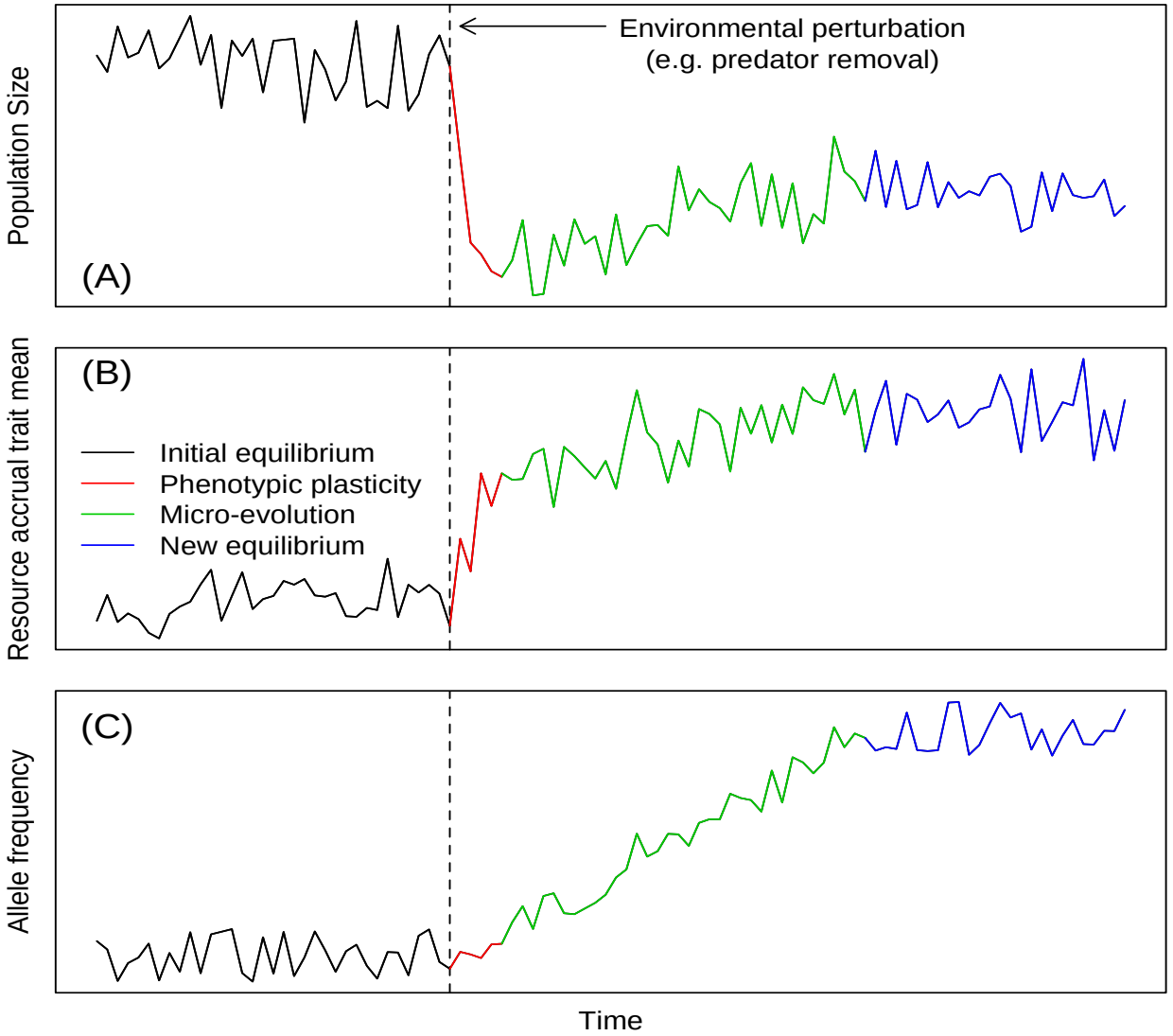


Back to savannas

- Will predicted patterns of climate change stop Serengeti wildebeest migration? (no)
- Can disease outbreaks in carnivores generate trophic cascade? (possible but likely rare)
- What impact does subsistence agriculture have on elephant movement and population dynamics North of the delta (substantial)

Next steps?

- Have general theory to explore when ecosystems switch between stationary states
- Interested in exploring for a well-studied savanna system? Kruger or Serengeti?



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