Overview of Population Dynamics

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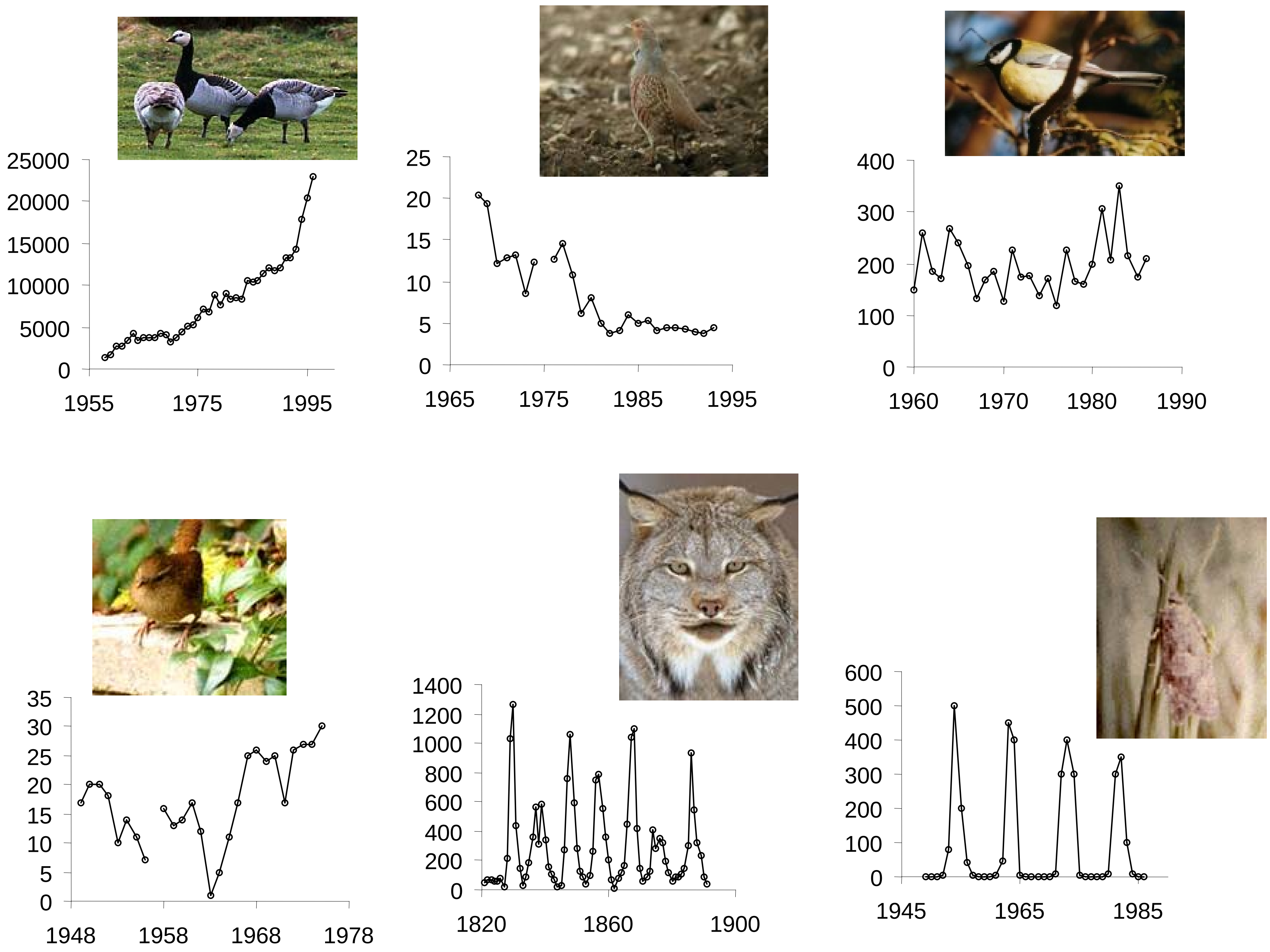
What is “population dynamics”?

All populations fluctuate over time; population dynamics is the study of causes underlying these fluctuations.

Why study it?

- **Conservation management**
- **Management of biological resources**
- **Because it’s incredibly interesting!**



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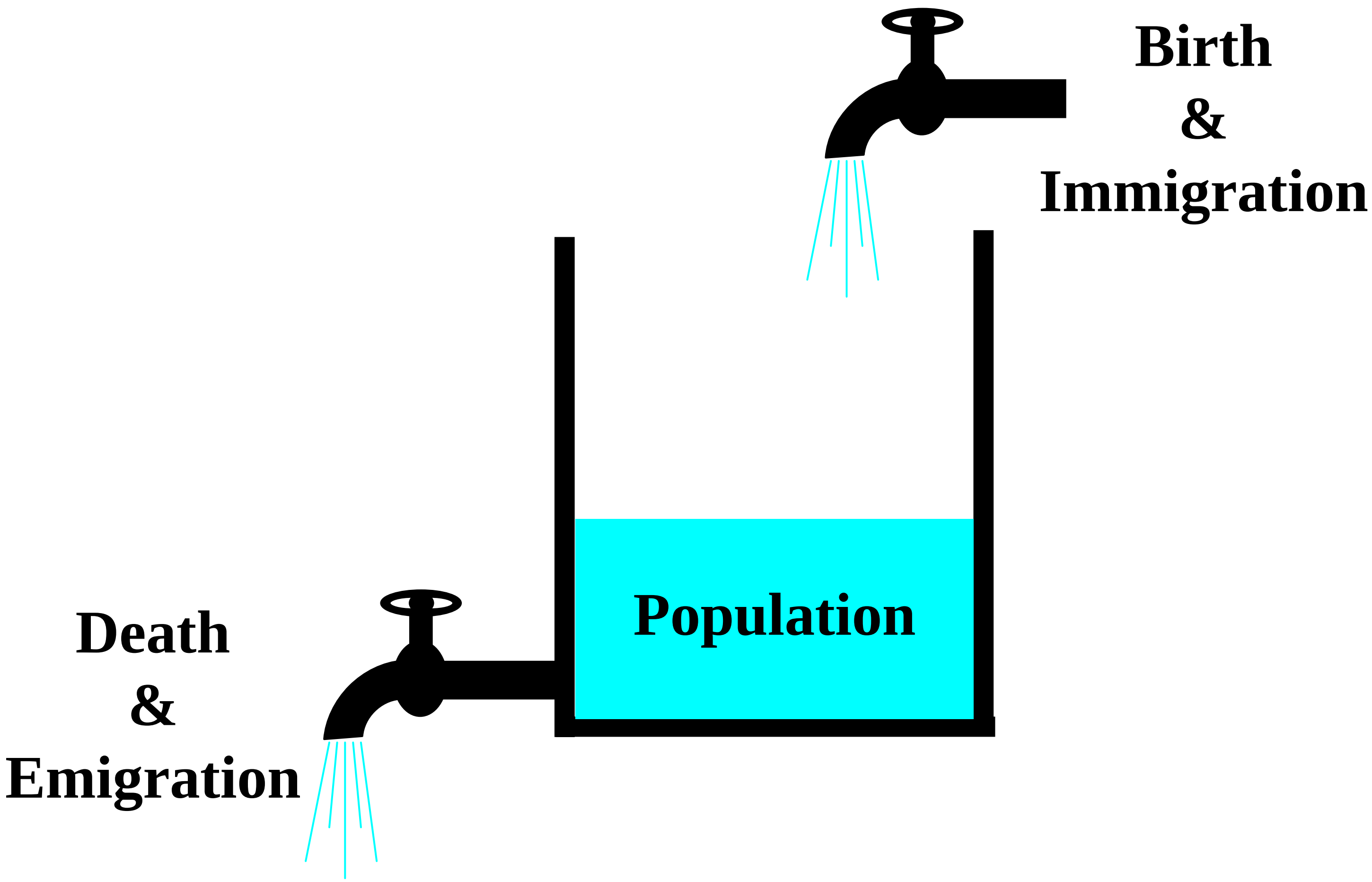
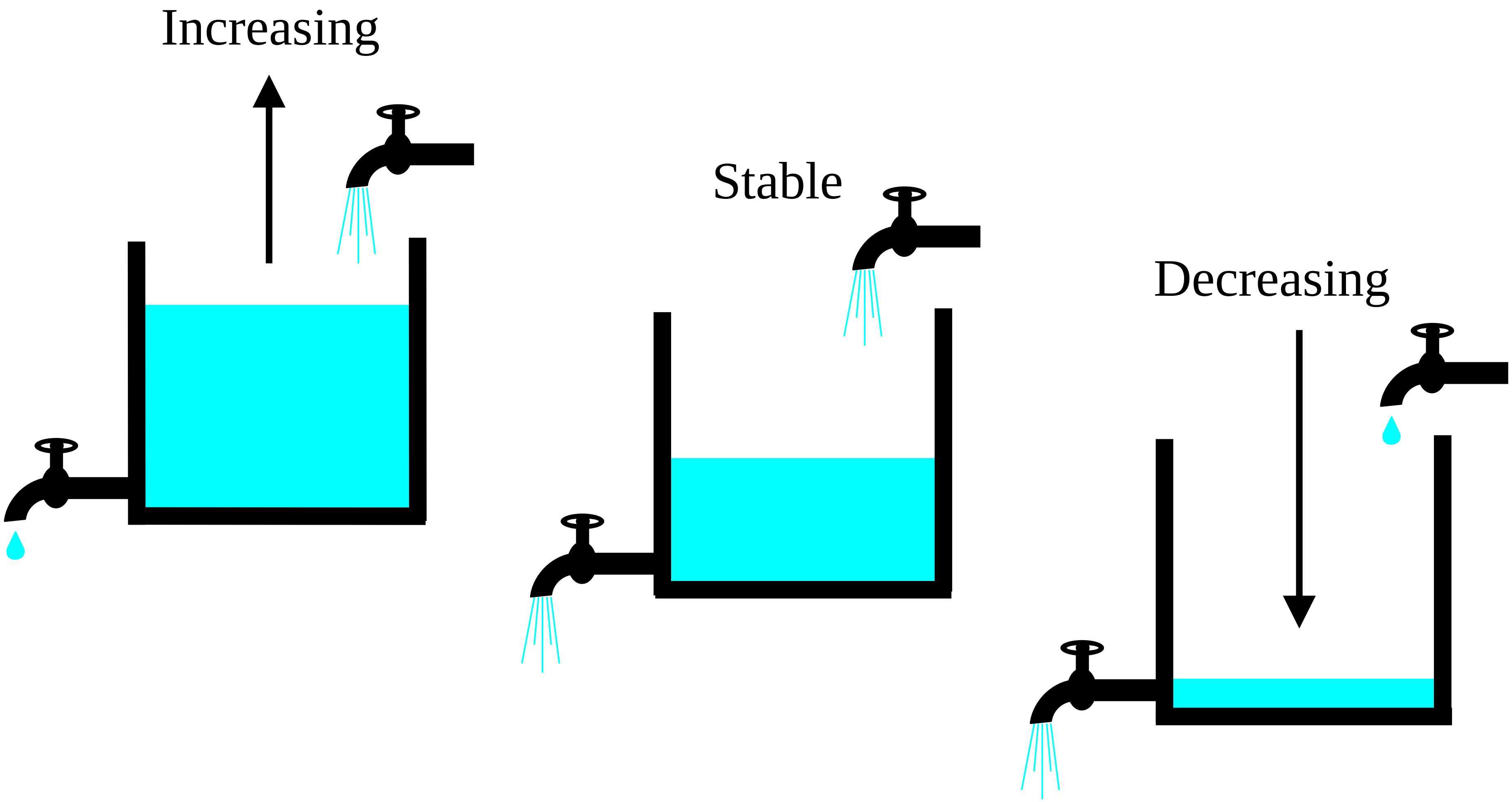
1945
1965
1985

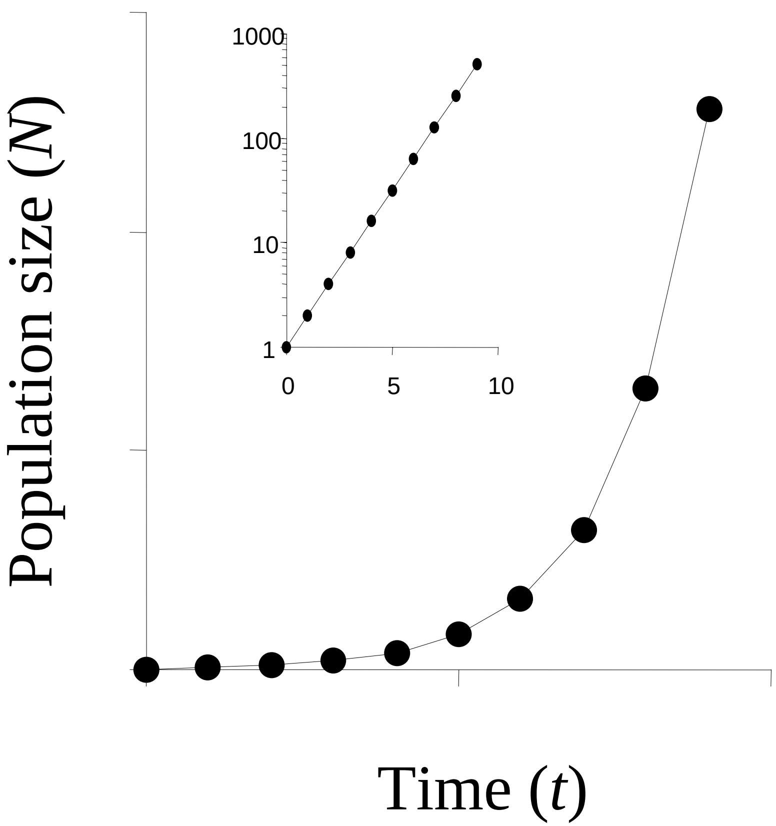
Population dynamics is about flows

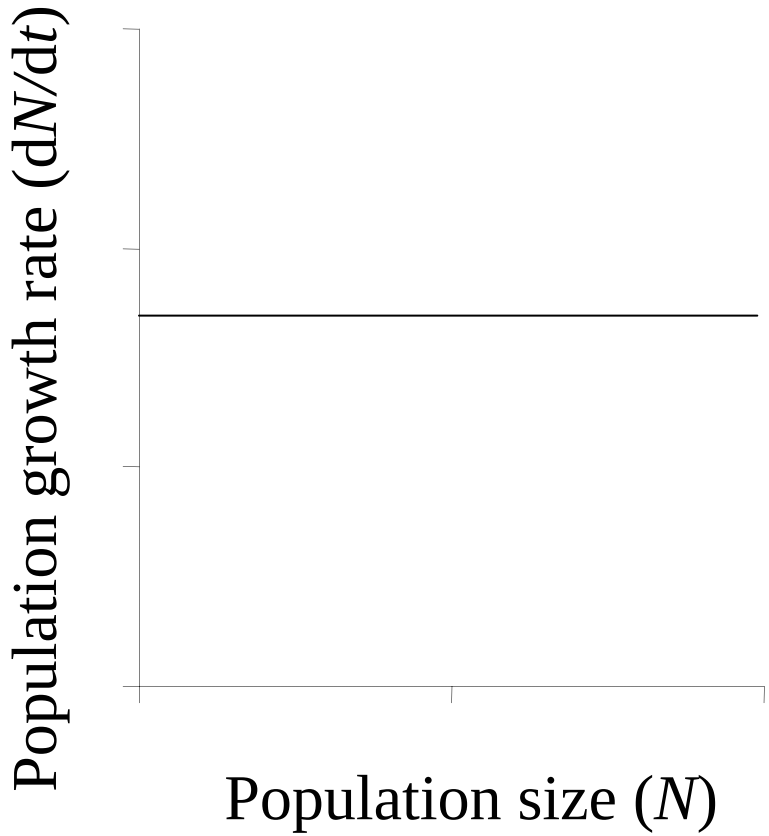


Net flows determine:
"population growth rate"

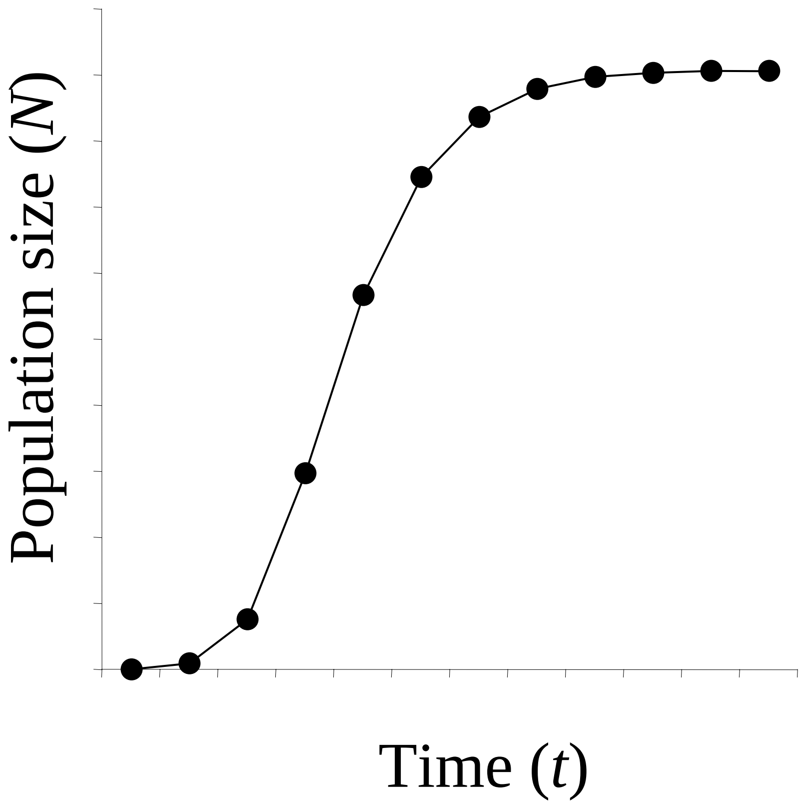


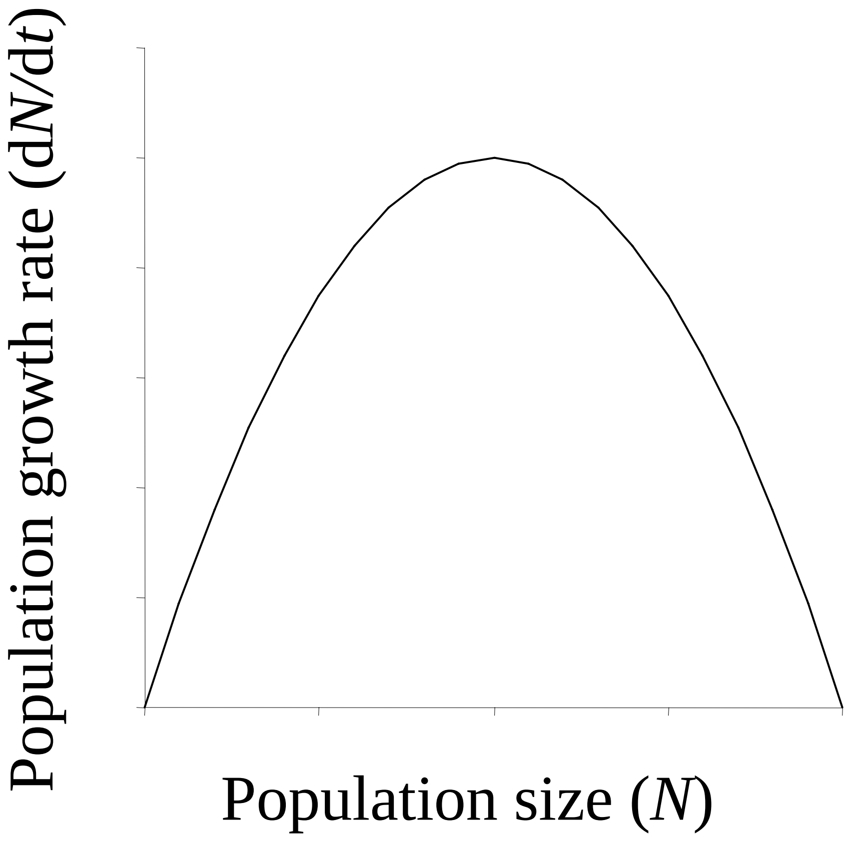
Exponential growth



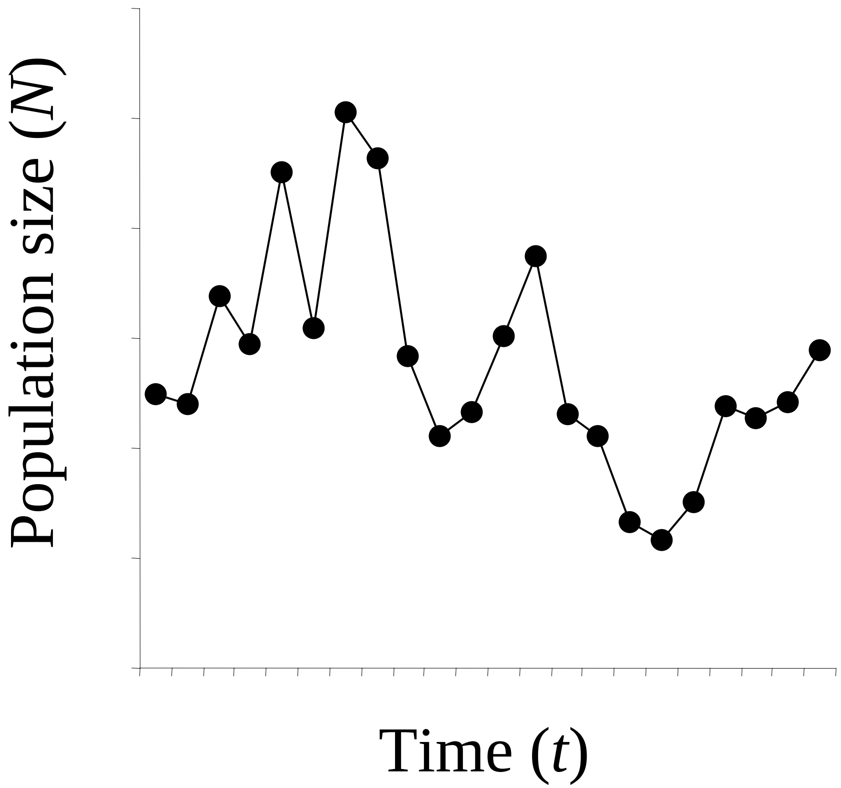


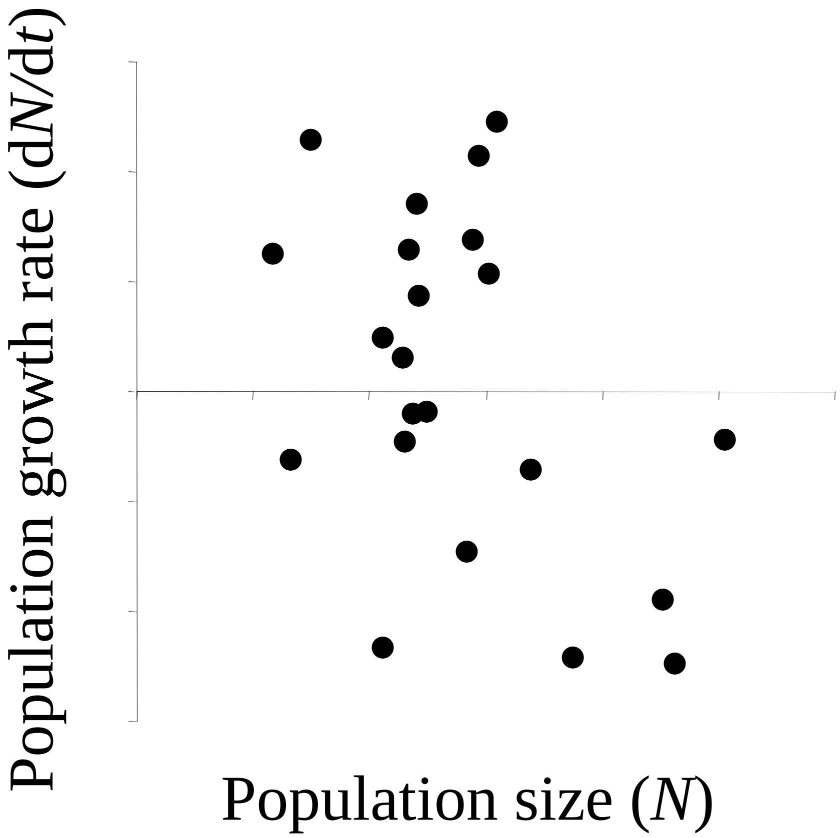
Logistic growth





Stochastic growth

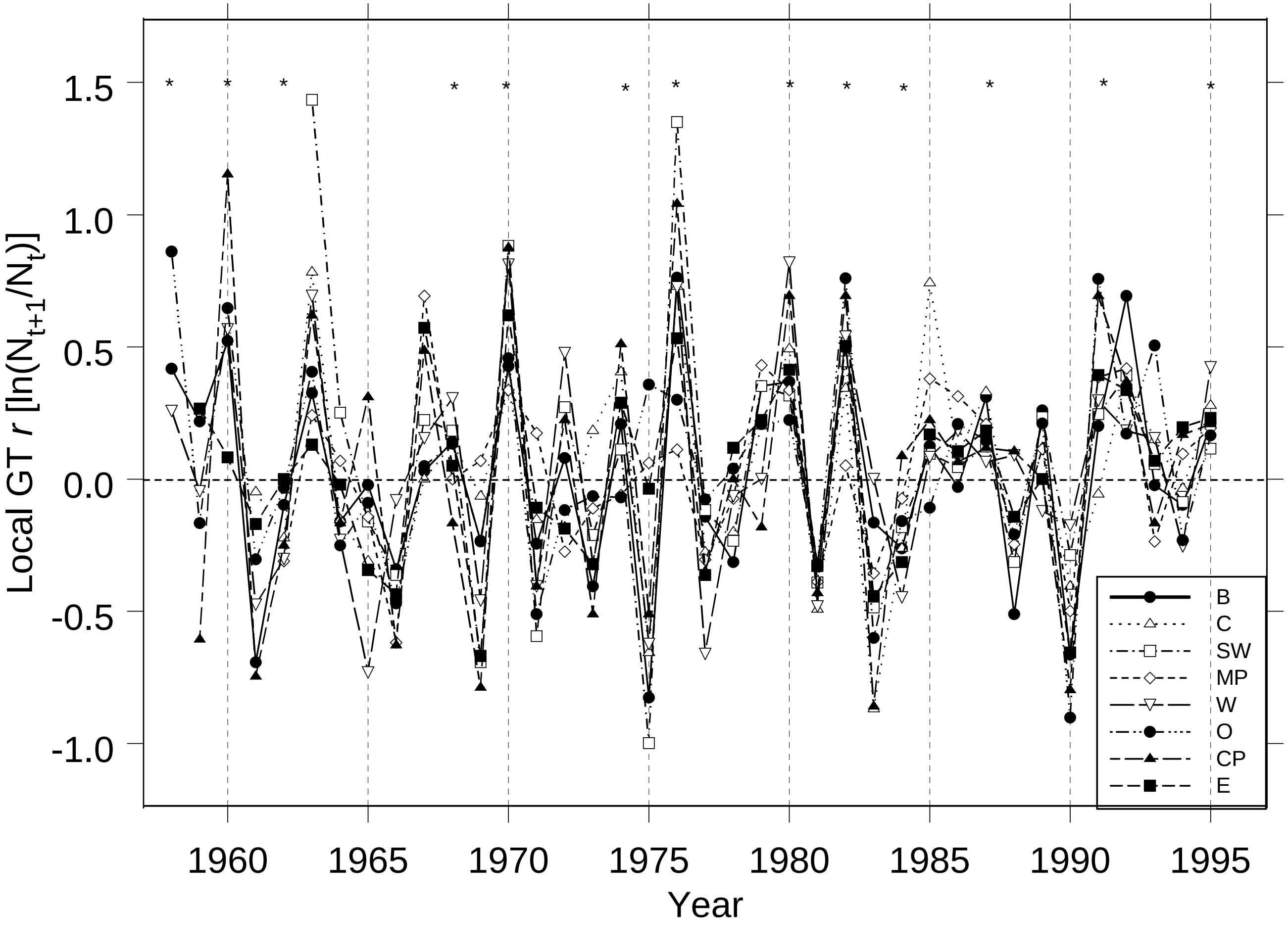




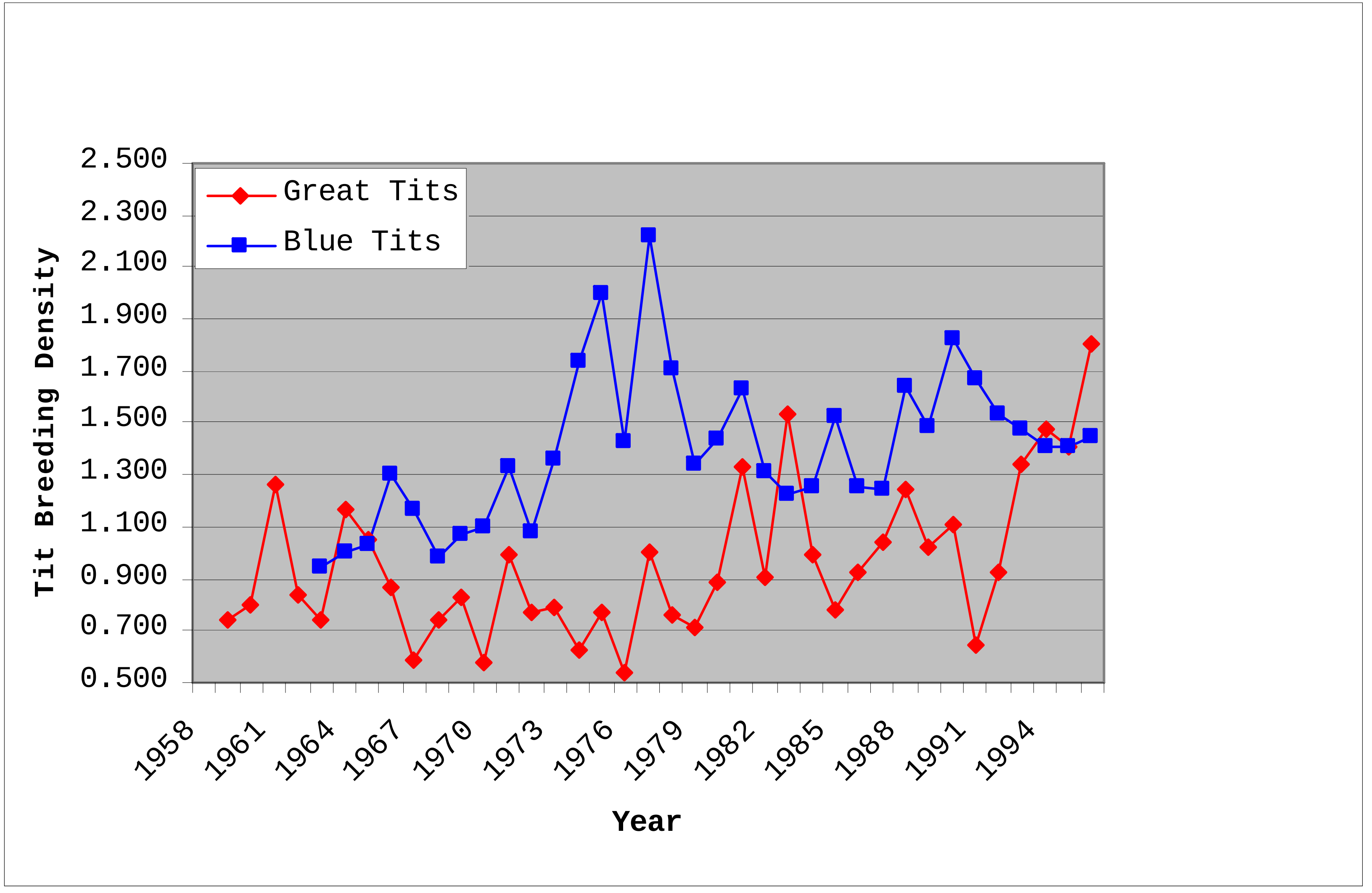
WYTHAM GREAT TIT STUDY

- Started by David Lack in 1947
- Over 1000 nestboxes by 1963
- Intensively studied every year
- Demography known extremely well
- Environmental effects well known
- Numerous exptal studies
- Genetics well known
- Most adults & all yg ringed
- Immigrants known
- Poor handle on emigrants
- Sink popn

Wytham Great tit Time Series (r)



Blue & Great Tit Breeding Densities



A little history:
are populations “regulated” or “limited”?

Is the key factor determining population size:

1940/50’s

Intrinsic, biotic
(density dependence)
(Nicholson & Lack)

OR

Extrinsic,
environmental
(Andrewartha & Birch)

↓

Now Synthesis: both are important

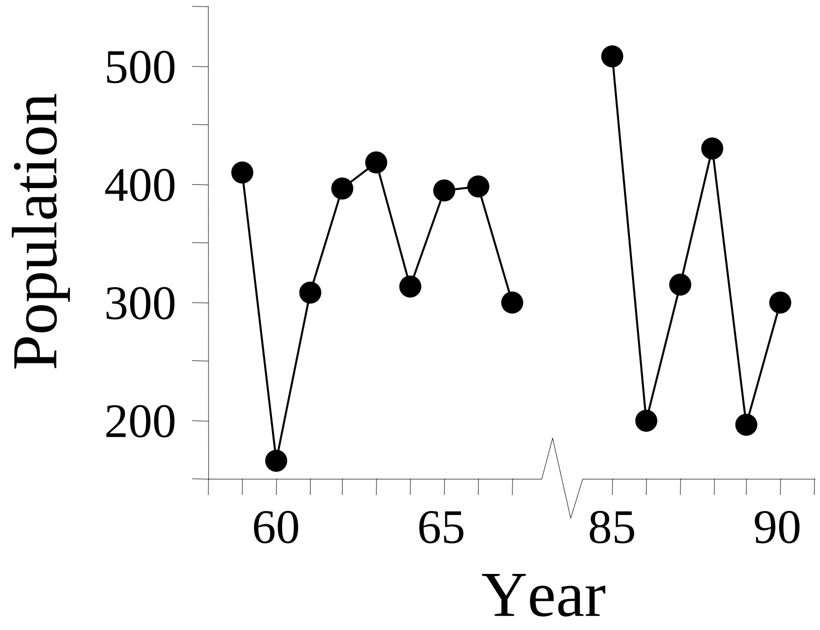
Known Demographic & Environmental Effects in Great Tits

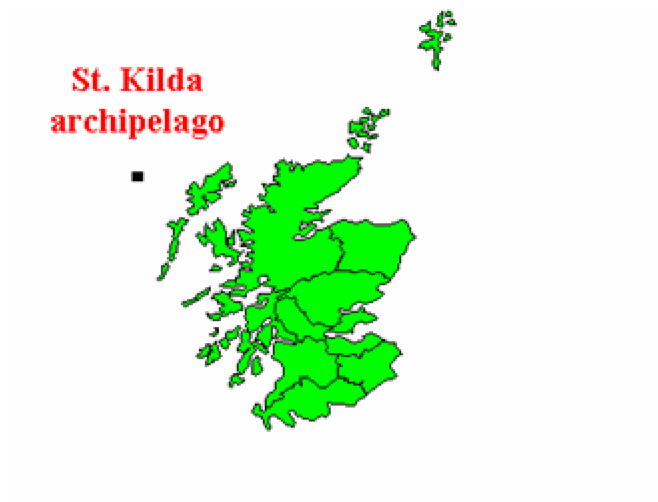
Survival of both Adults, Juveniles & Rate of Immigration from Yr_n – Yr_{n+1} affected by Winter temp & Beech mast

CS, LD, Nestling Mass, Number Fledged & Recruitment All affected by ***both*** GT & BT breeding densities

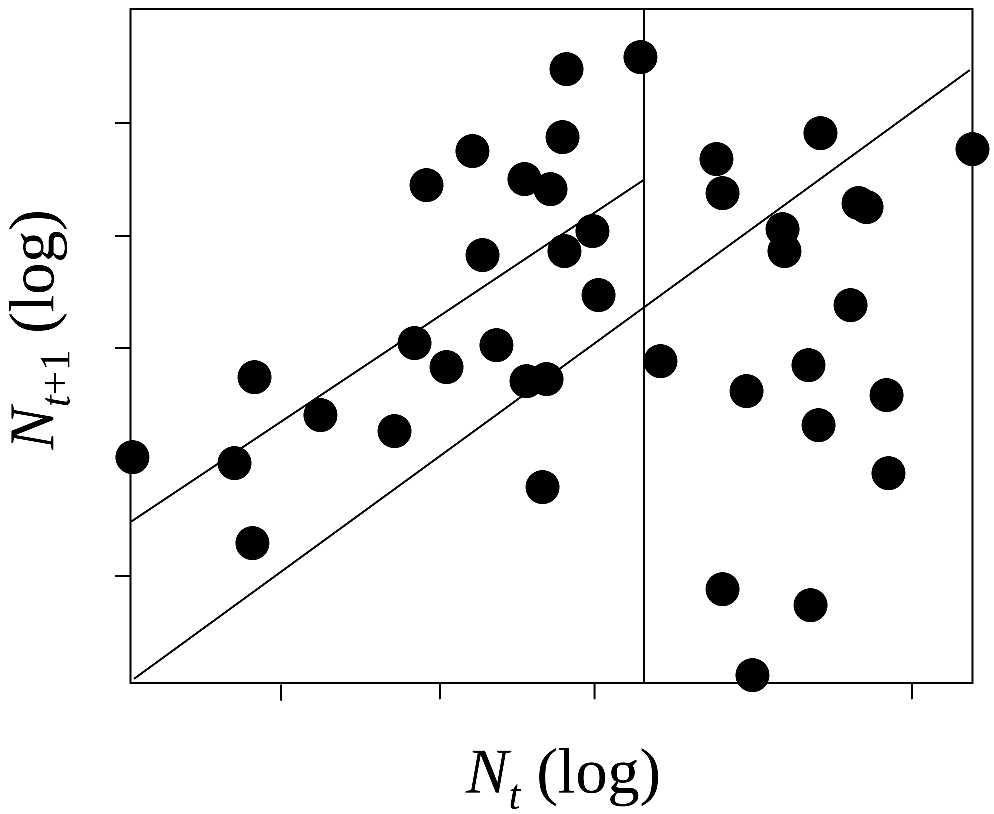
i.e. Year on year Population Dynamics of great tits results from both Environmental & Demographic stochasticity

An example of environment / density interaction: the Soay sheep





Weather and density interact



Grenfell et al 1998

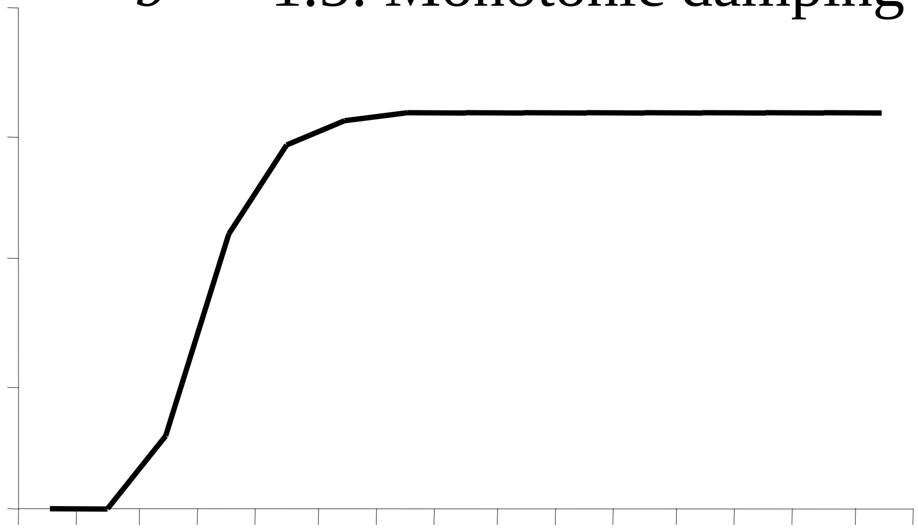
“Nothing in ecology makes sense except in the light of density dependence”

(W. Sutherland, after T. Dobzhansky)

Density dependence: simple models, complex dynamics

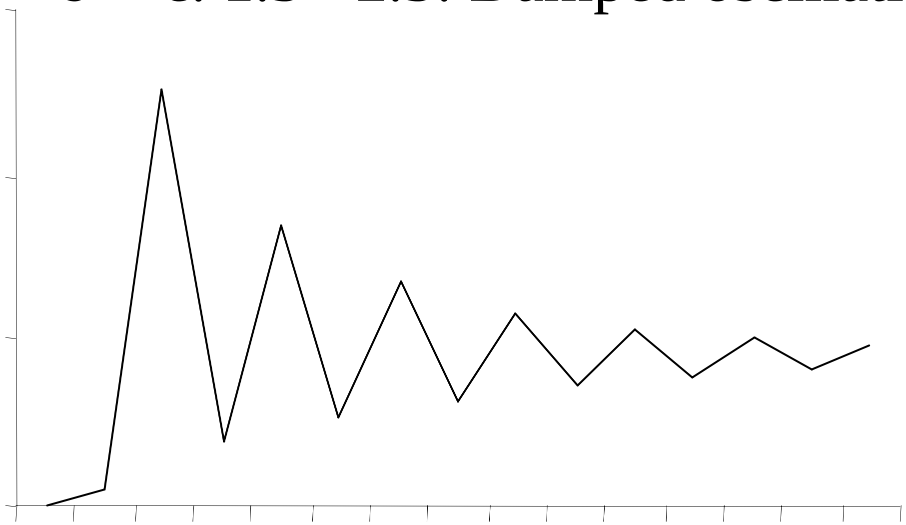
$$N_{t+1} = \frac{N_t r}{(1 + aN_t)^b}$$

b = <1.5: Monotonic damping

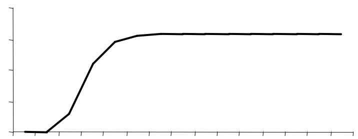


$$N_{t+1} = \frac{N_t r}{(1 + aN_t)^b}$$

b = c. 1.5 - 2.5: Damped oscillations

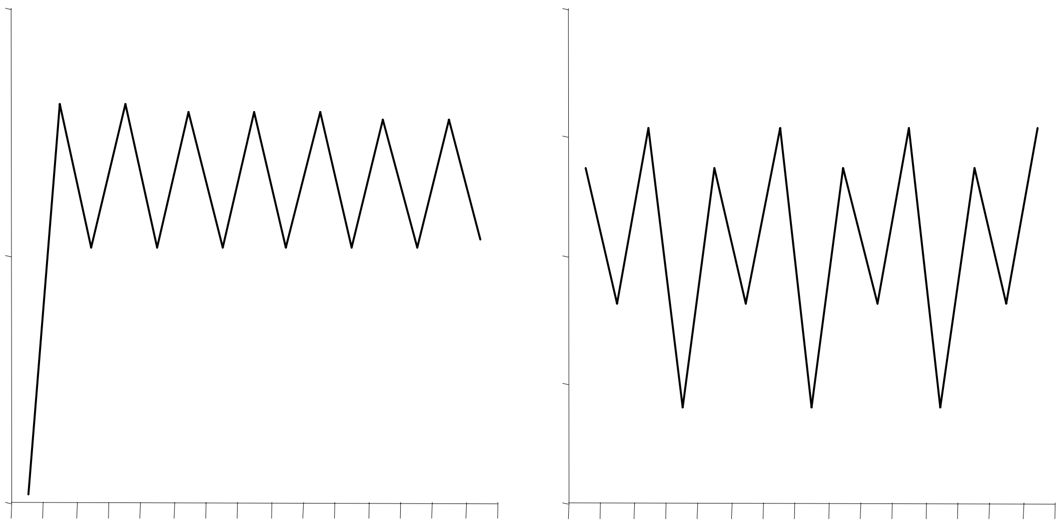


1. Monotonic damping

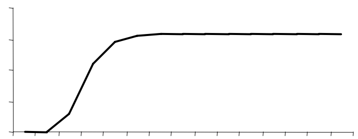


$$N_{t+1} = \frac{N_t r}{(1 + aN_t)^b}$$

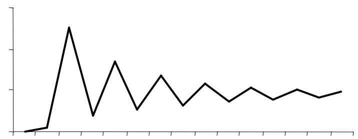
b = c.2.5 - 4: Stable limit cycles



1. Monotonic damping

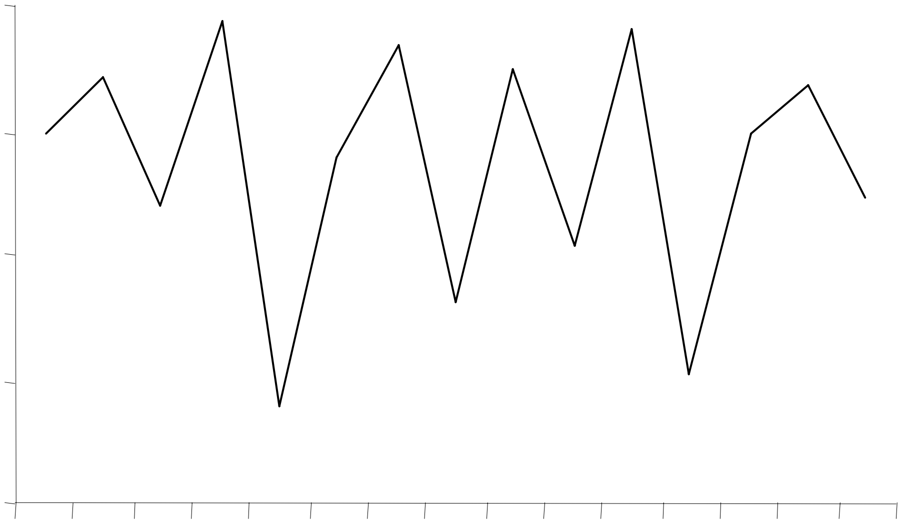


2. Damped oscillations



$$N_{t+1} = \frac{N_t r}{(1 + aN_t)^b}$$

b = >4: Chaos!



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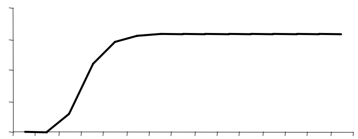

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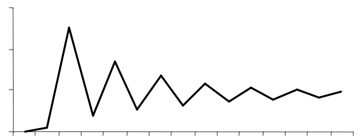
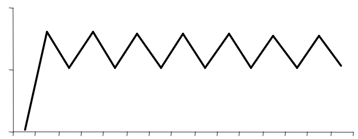
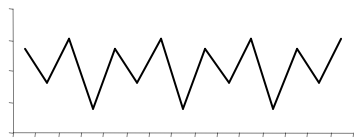
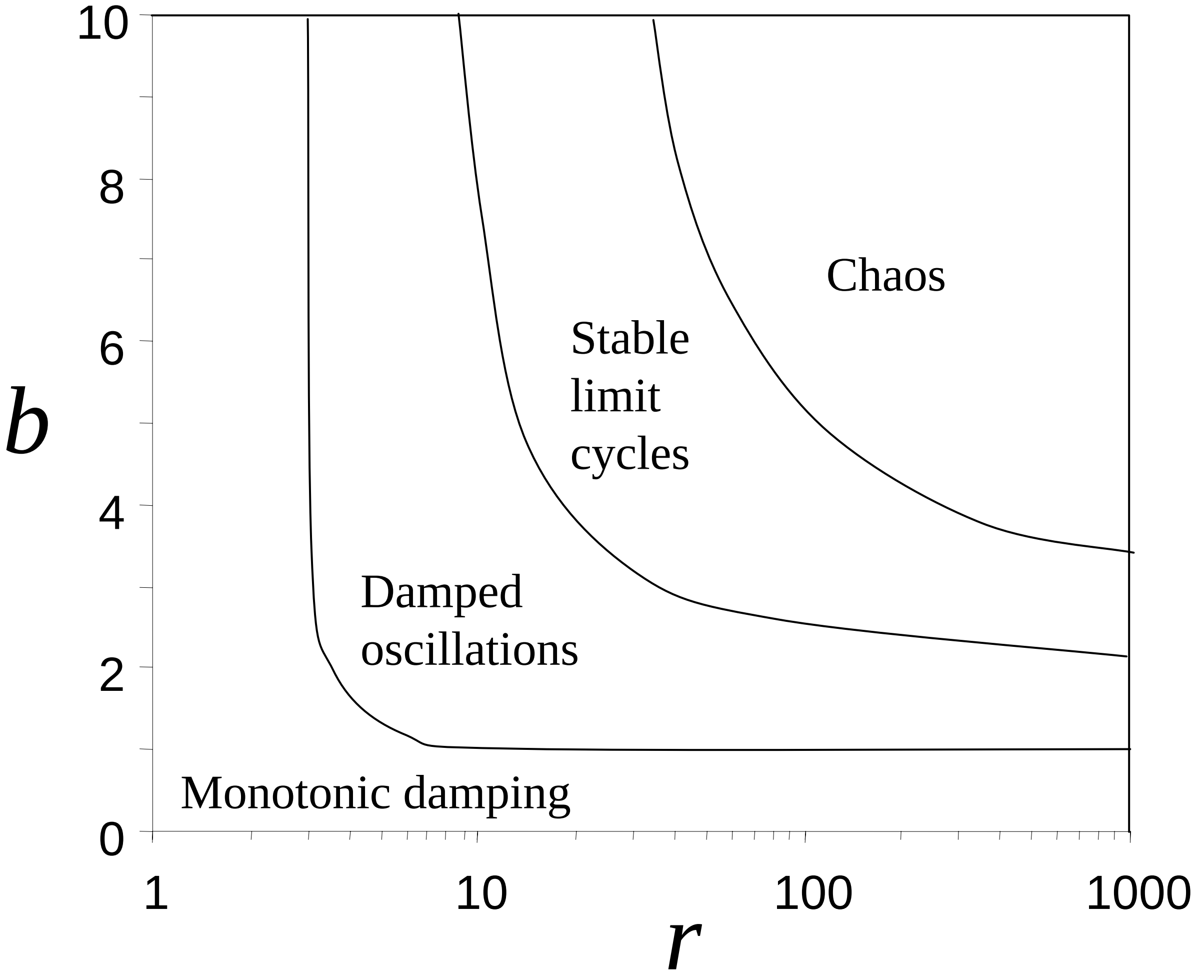


3 & 4. Stable limit cycles



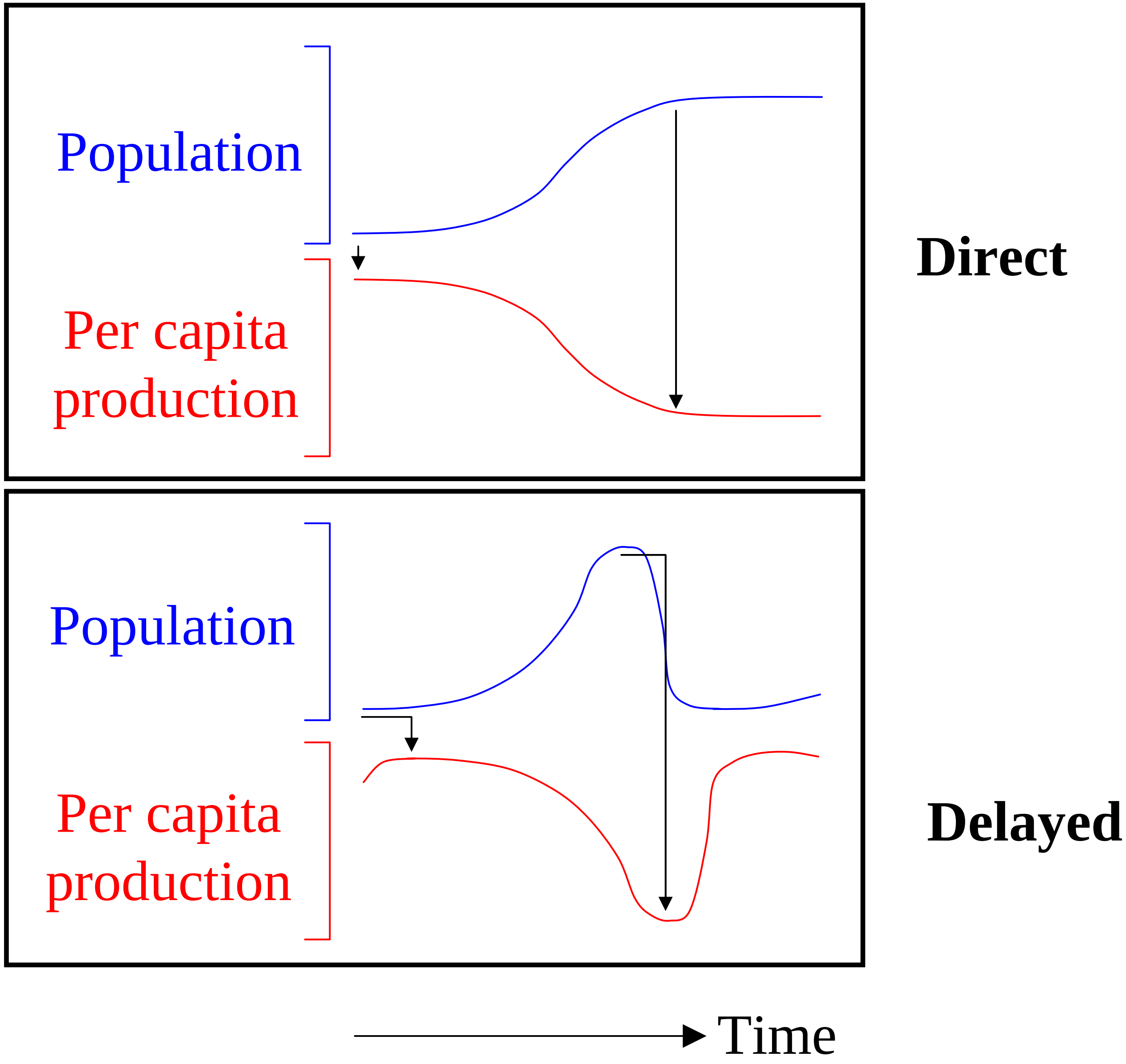


Density dependence and intrinsic growth rate interact



May 1975

Delayed density dependence destabilises



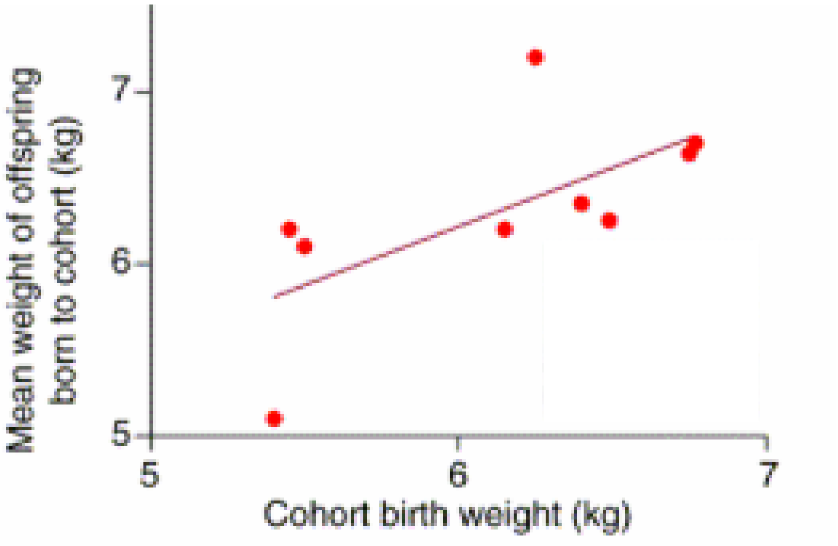
Delayed density dependence: many possible causes

EXTRINSIC

- Predators
- Disease

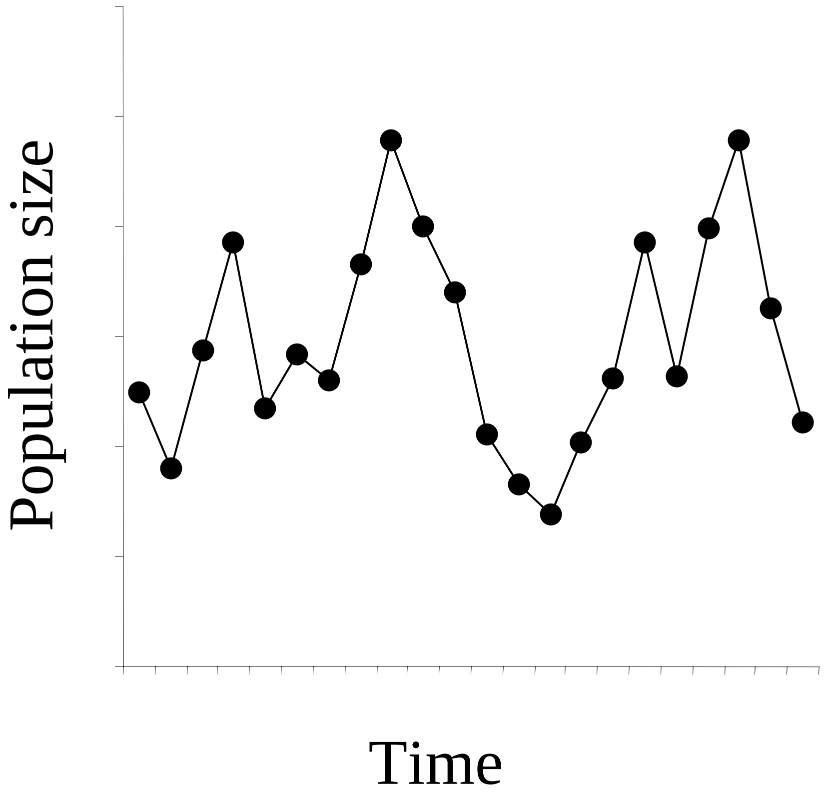
INTRINSIC

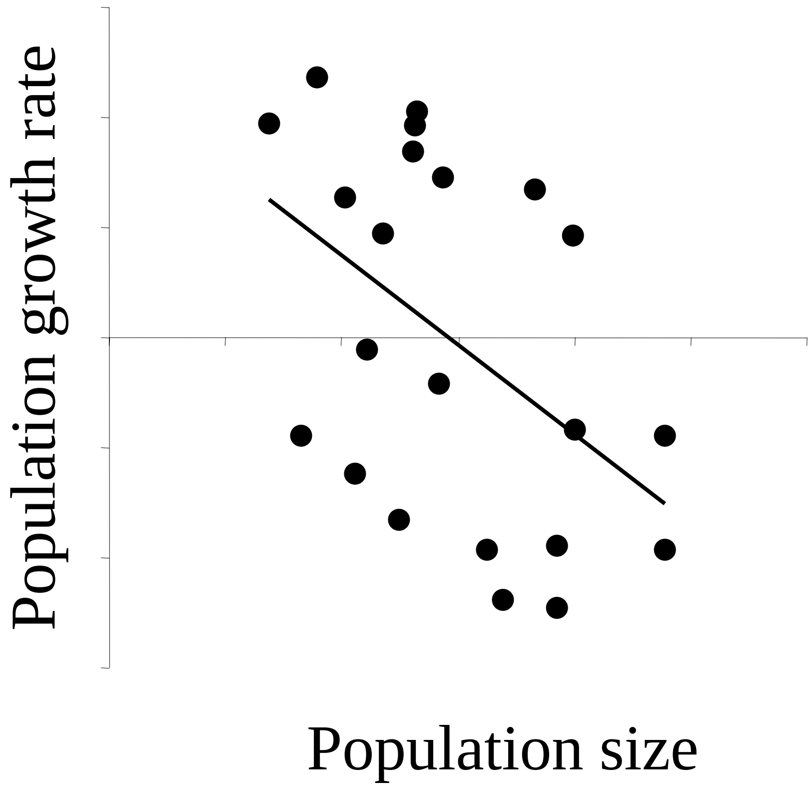
- Maternal effects
- Early life conditions
- Behaviour



Detecting density dependence

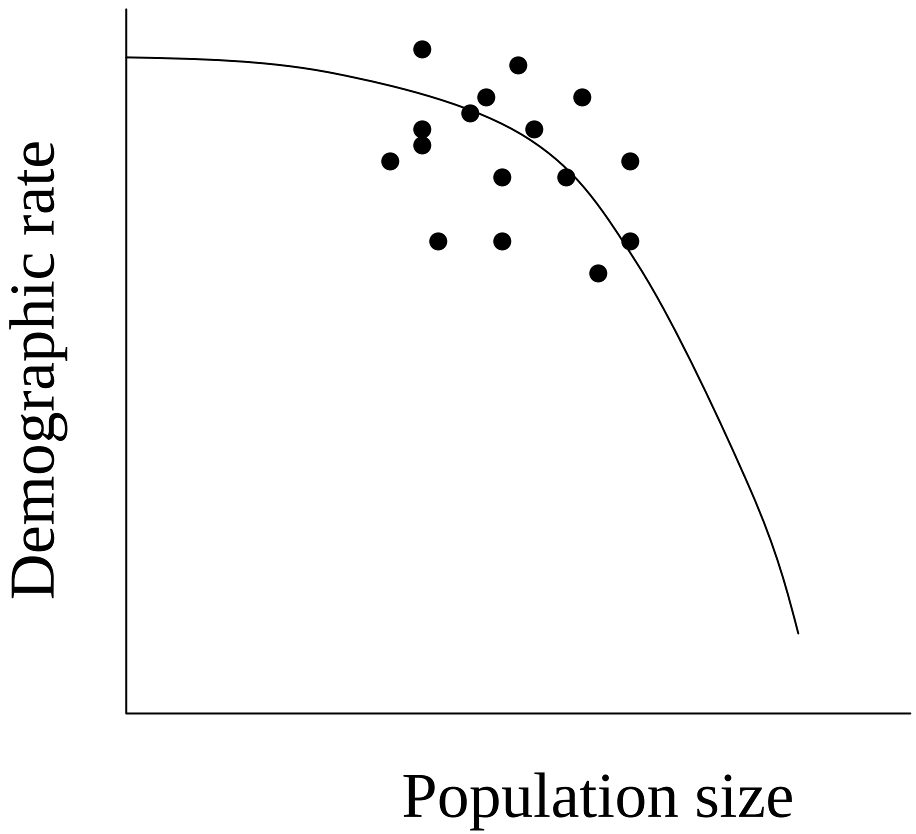
False correlations: a pitfall for the unwary



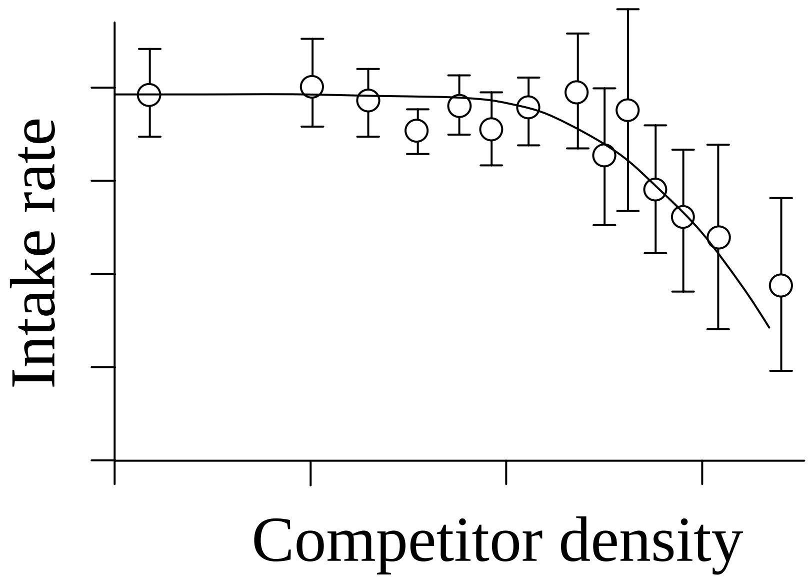


Detecting density dependence

-Try measuring the demographic rates,
-add some data – looks interesting –
-but small fluctuations and large errors effectively obscure the effect.



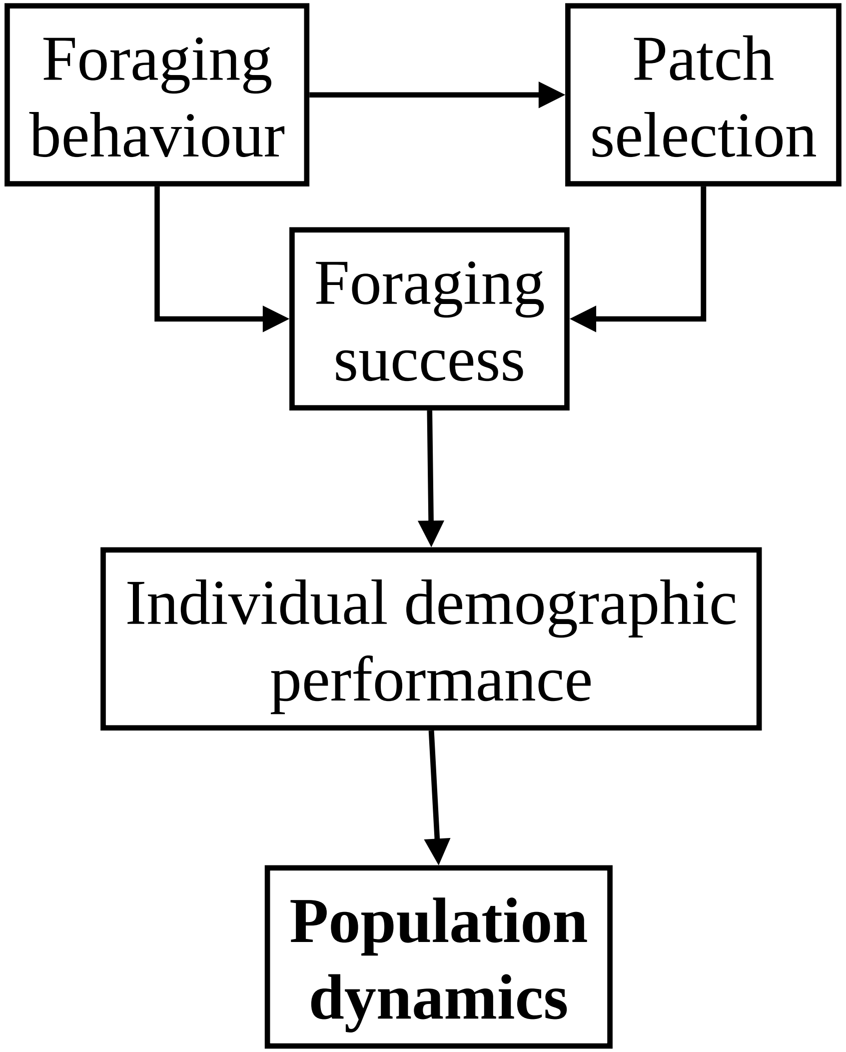
An alternative approach: population dynamics meets behavioural ecology



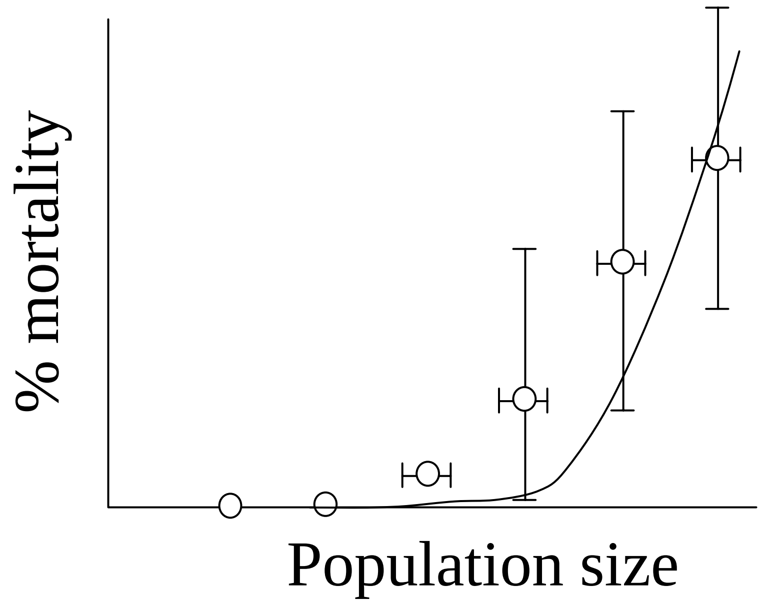
The oystercatcher

Stillman et al 2000a

A behaviour-based model



Results
observed v predicted



Stillman et al 2000b

Take home messages

- Population size is determined by an interaction between intrinsic (density dependent) and extrinsic (density independent) processes.

- Density dependence usually stabilises, but can destabilise if
  - it is very strong (and reproductive rate is high);
  - it acts with a time delay
  - it acts in reverse (Allee effect)

- Density dependence is difficult to measure in real populations – behaviour-based models can help.

Interactions between species

		Effects of A on B	
		+	-
Effects of B on A	+	Mutualism	Predation / Parasitism
	-		Competition

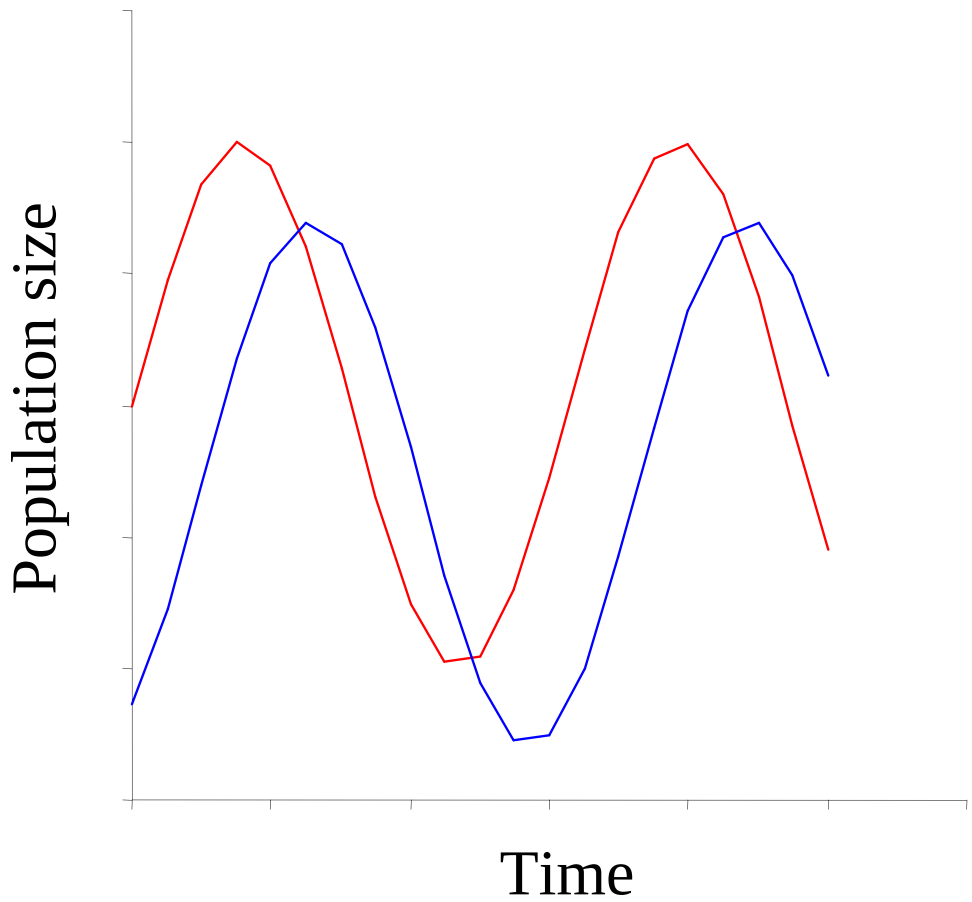
Extreme effects of predation: island birds


+

=


Of 127 avian extinctions since 1600, 92% were island endemics; Introduced predators are held responsible for >40% of these.

Predation & stability: model oscillations



Prey

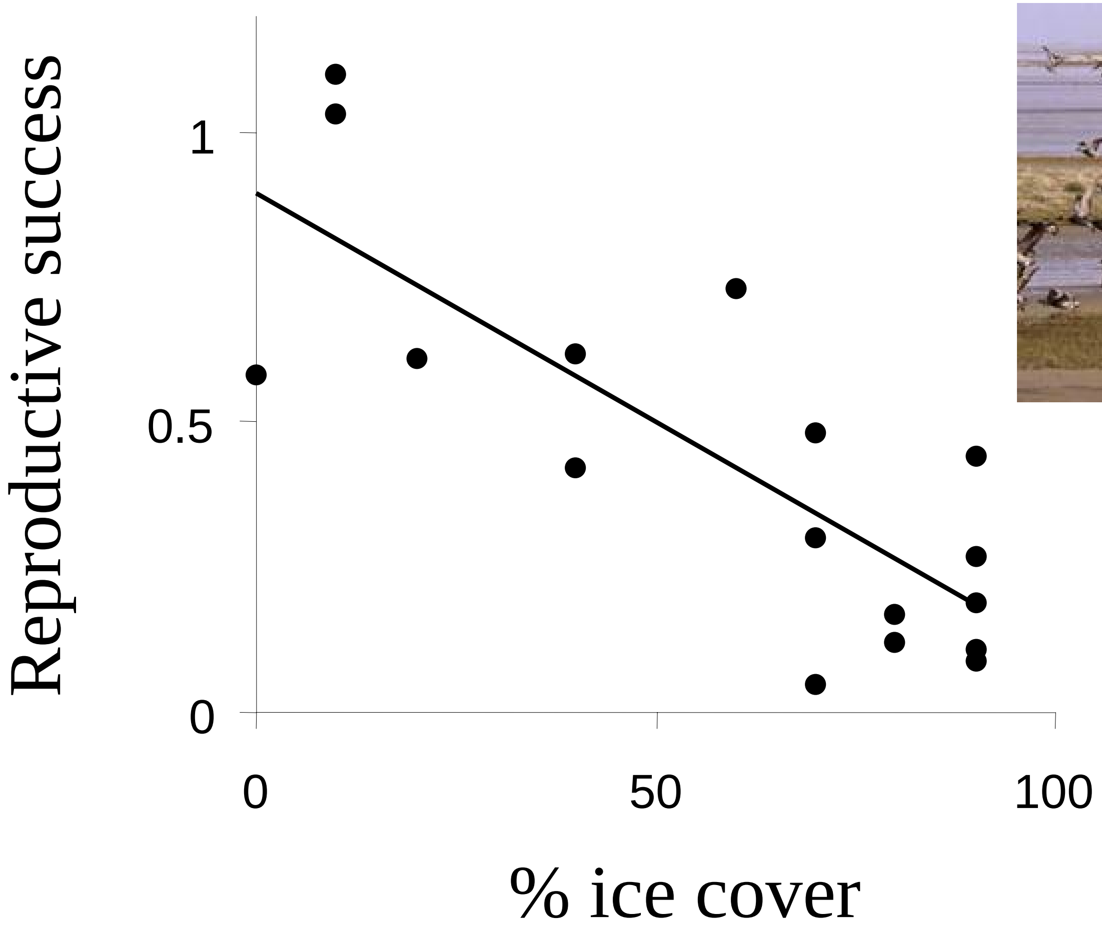
$$\frac{dN}{dt} = rN - aPN$$

Predator

$$\frac{dP}{dt} = faPN - qP$$

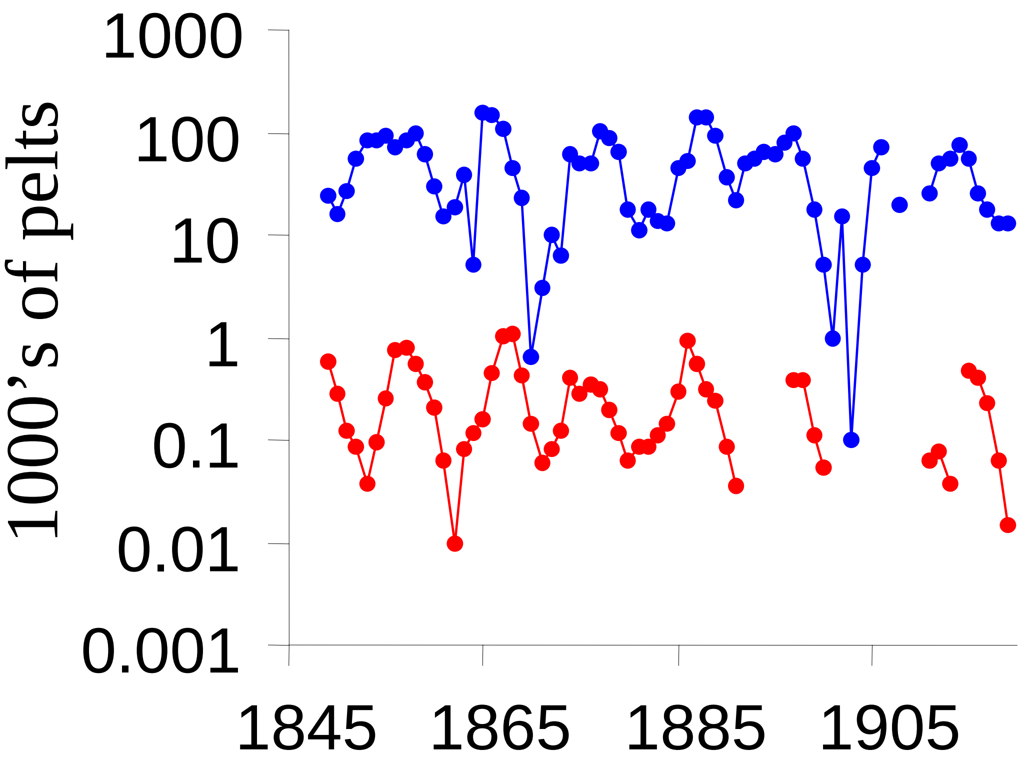
Predation interacts with other factors

Light bellied brent geese and polar bears

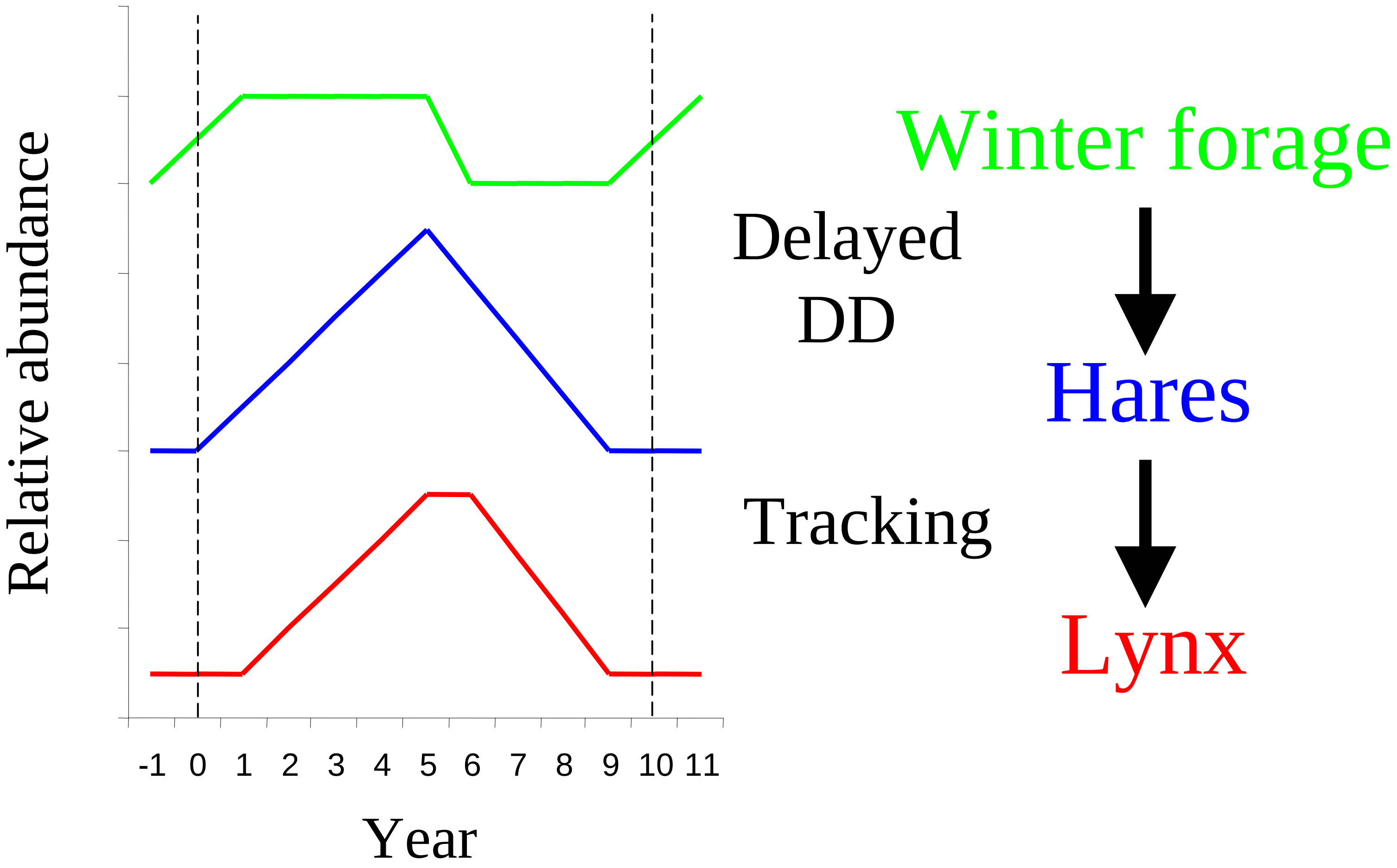


Coupled dynamics may not be linked directly

Canadian lynx & snowshoe hares: 10-year cycle

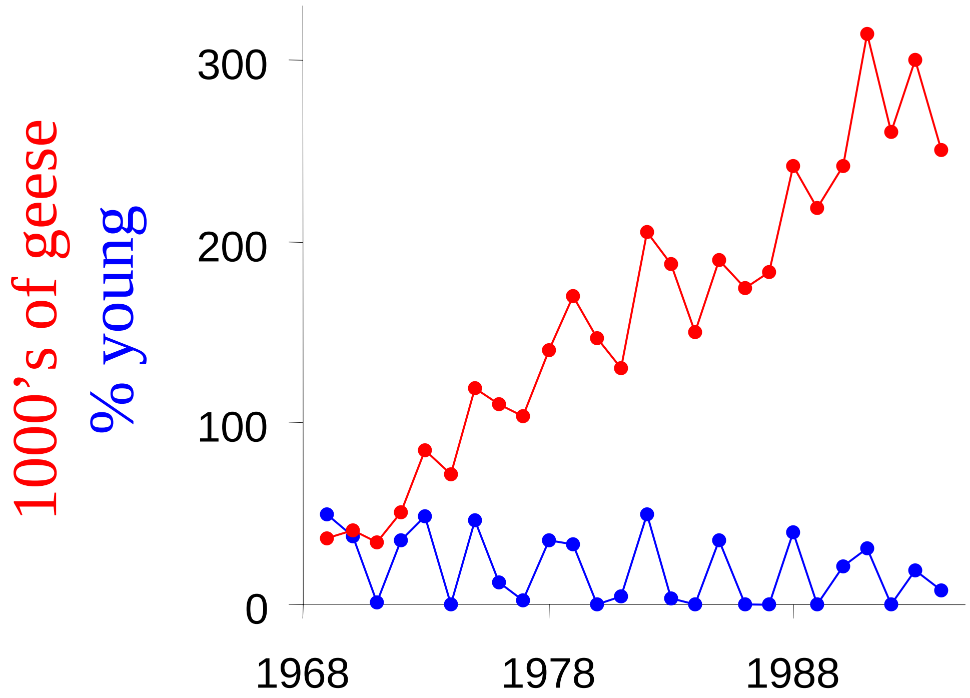


A causal chain...

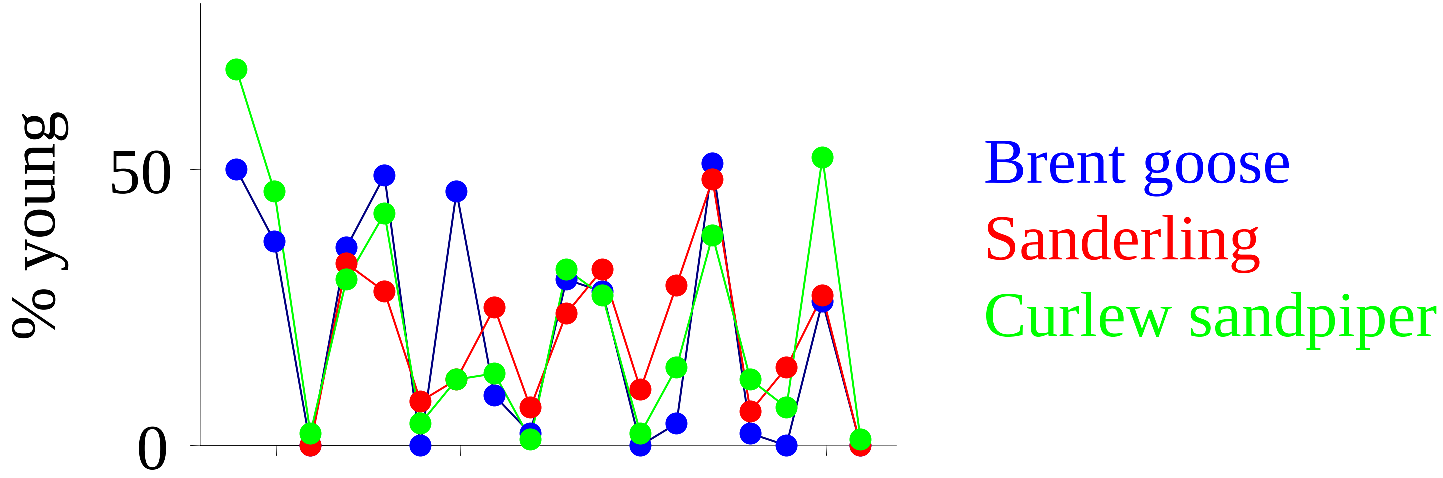


Longer chains

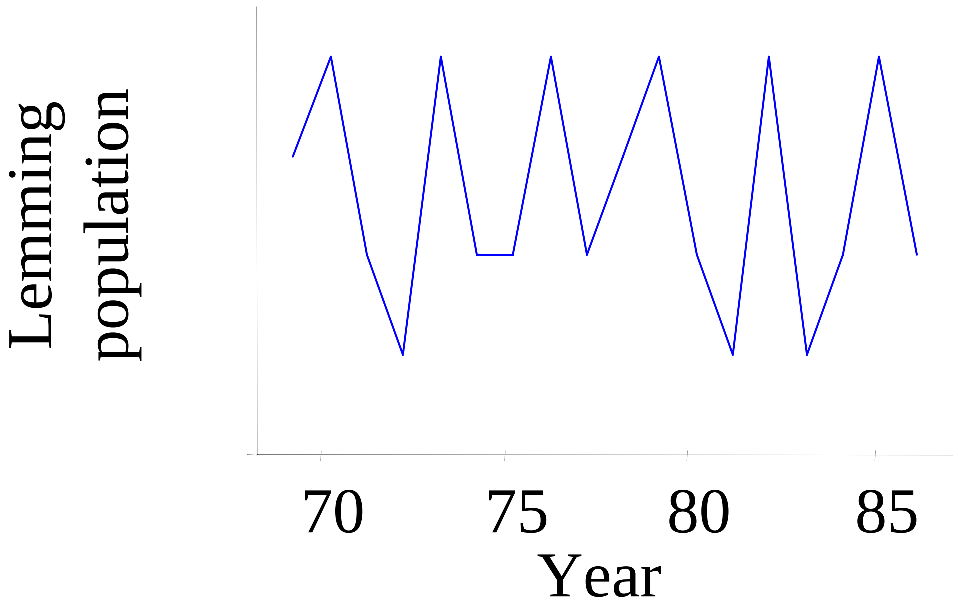
A 3-year cycle in brent geese



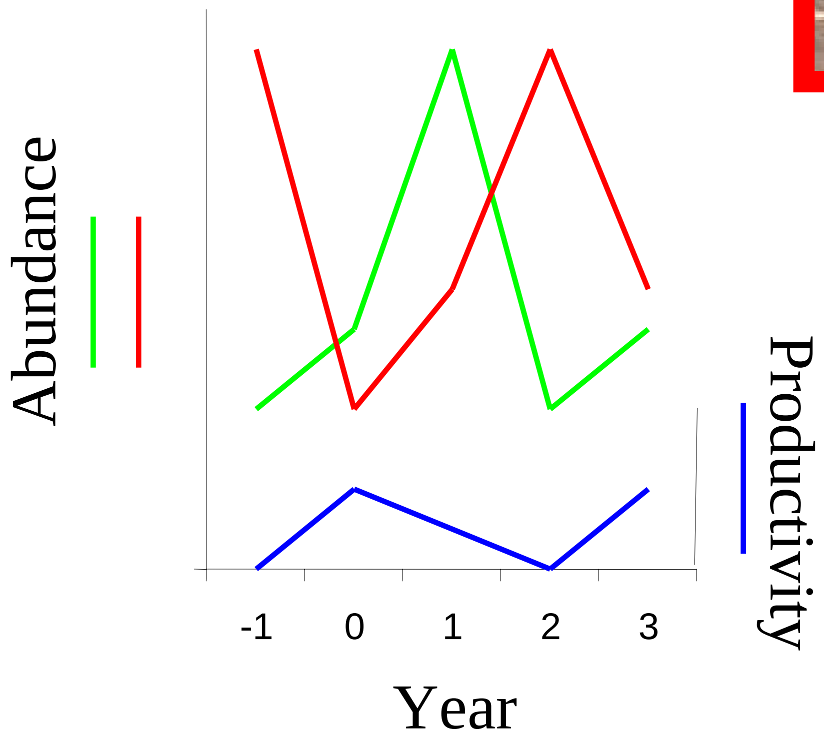
…and wading birds too…



…also in phase with lemming population



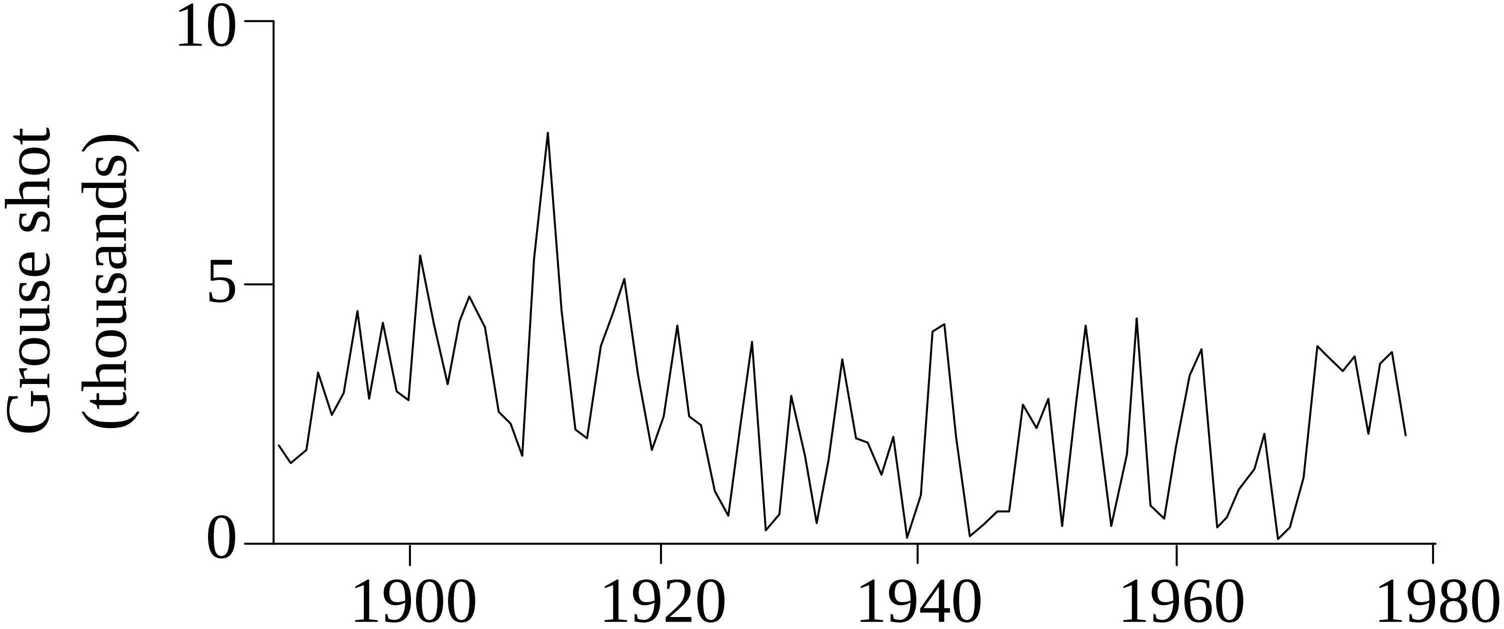
The culprits



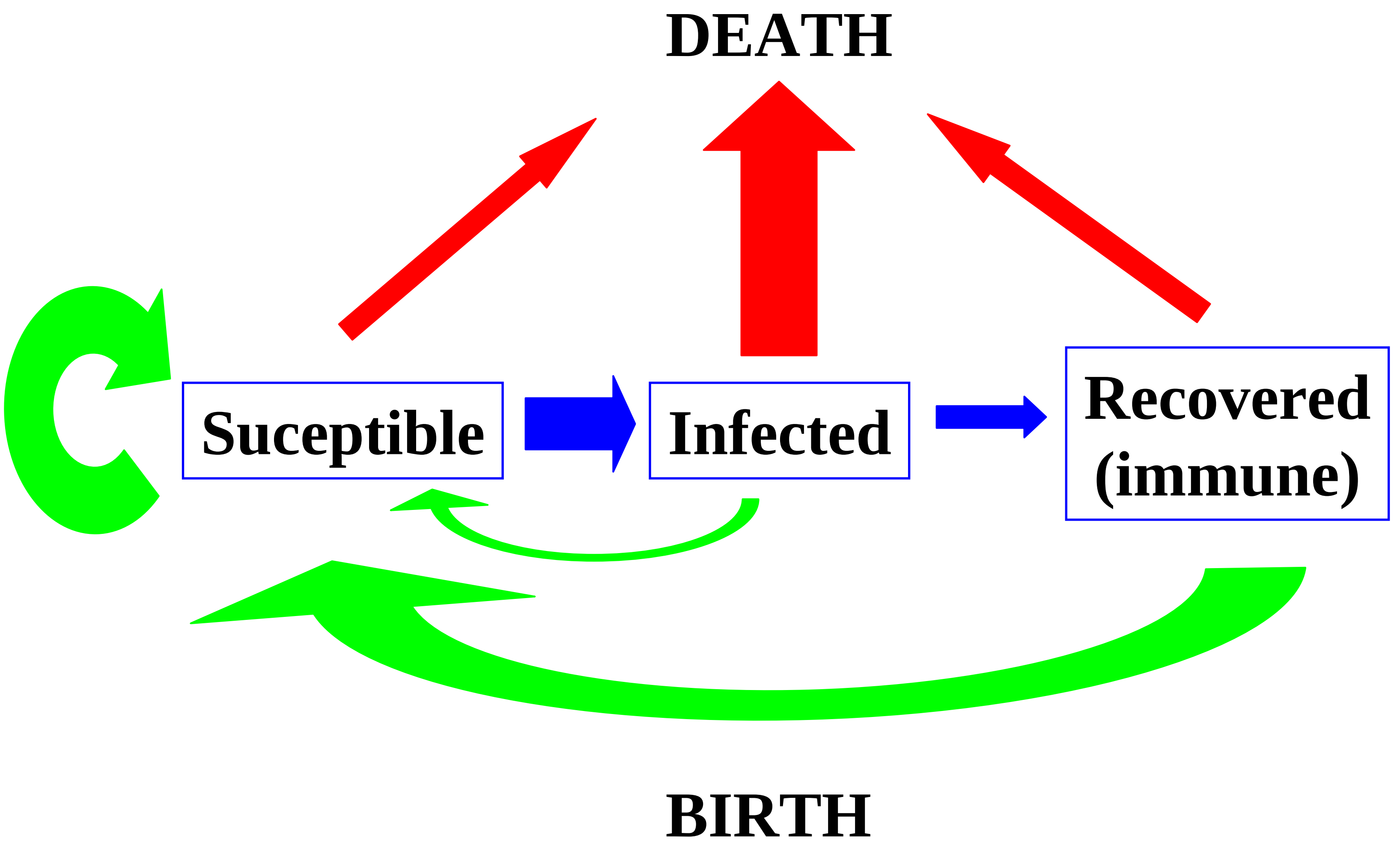
Disease & Parasitism: extreme effects possible

Frogs and chytrid fungal infection: some species already extinct.

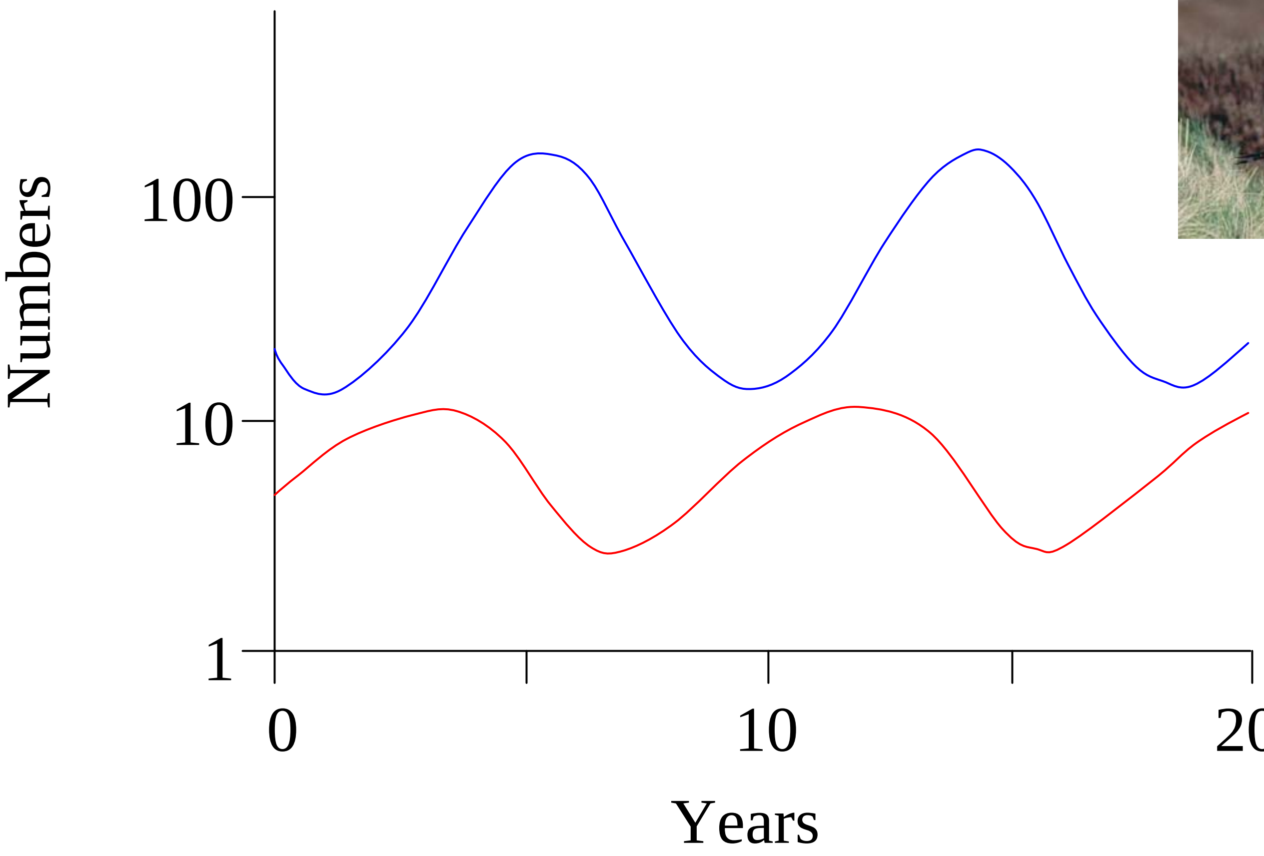
Less severe effects: red grouse



SIR models and epidemiology

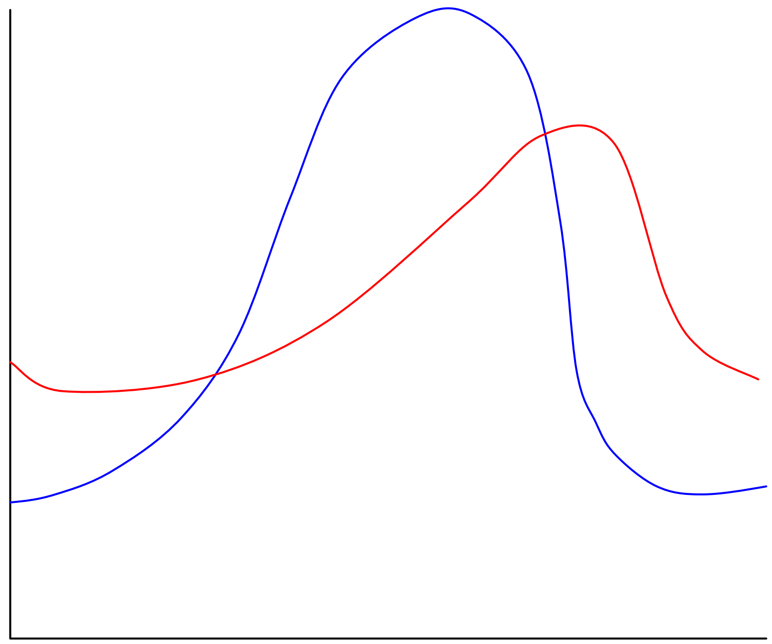


A model of trichostrongylosis in grouse



Hudson 1992

Intrinsic effects: red grouse again
A behavioural model



Aggressiveness is inversely related to:

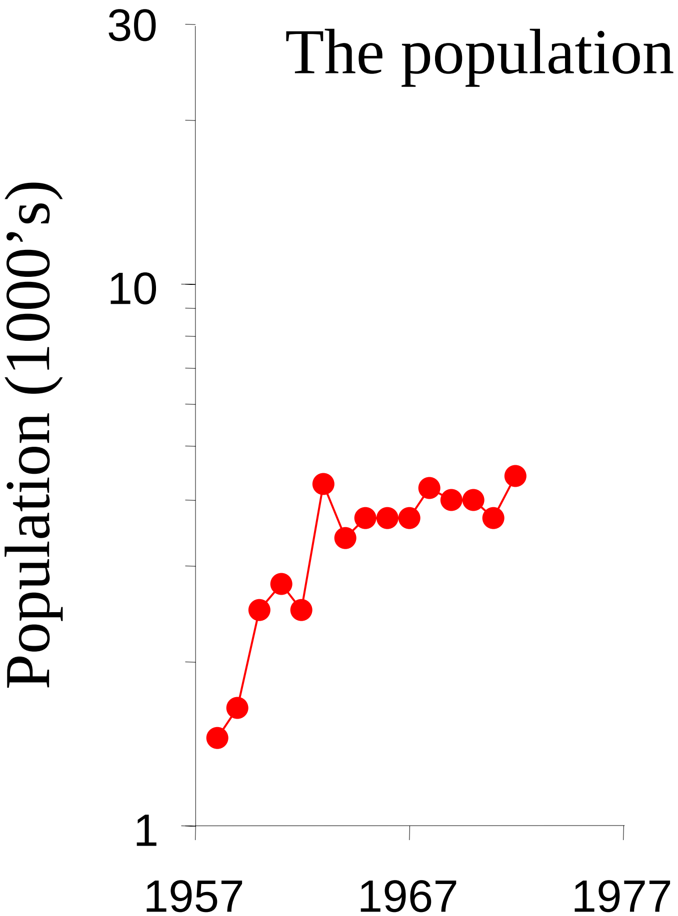
- Relatedness
- Territory size

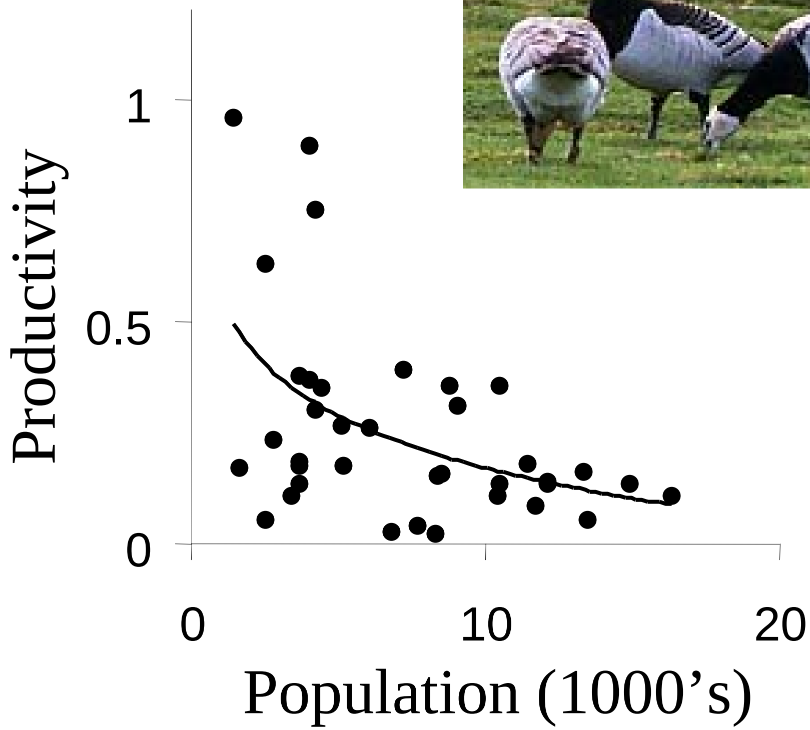
Mugeot et al. 2003

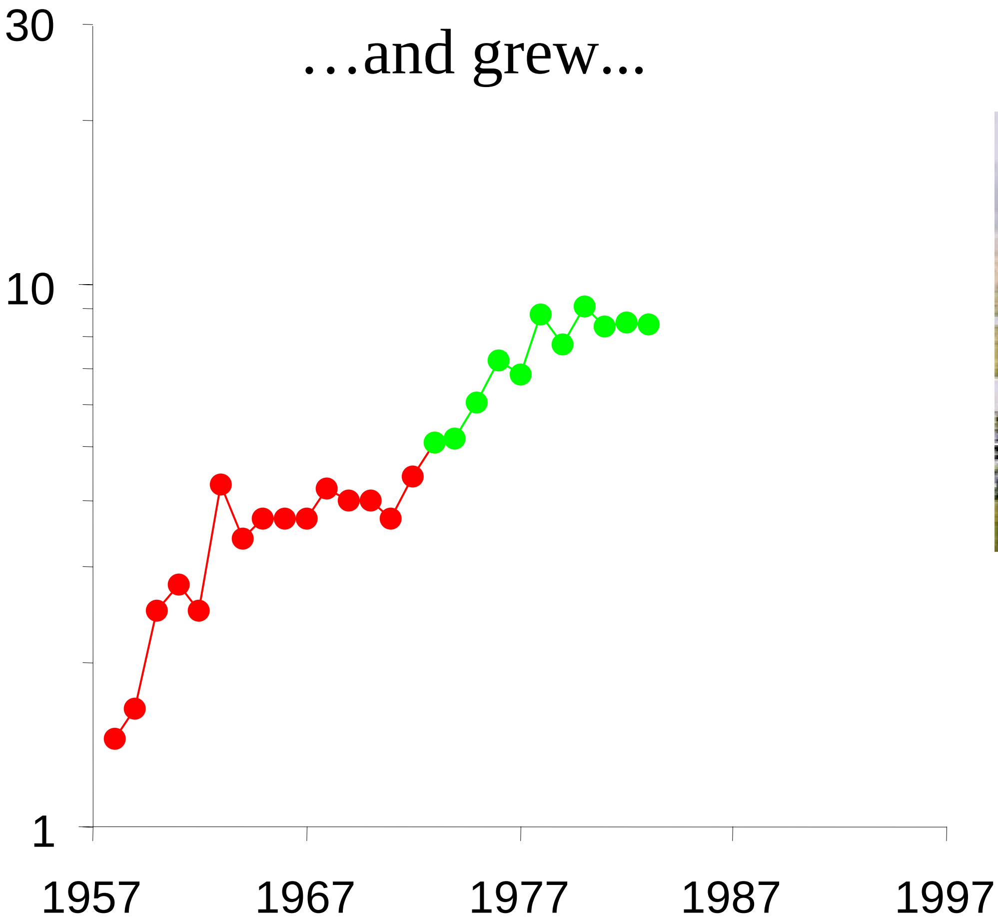
Spatial structure

Localised density dependence in barnacle geese

The population grew...






…and grew…
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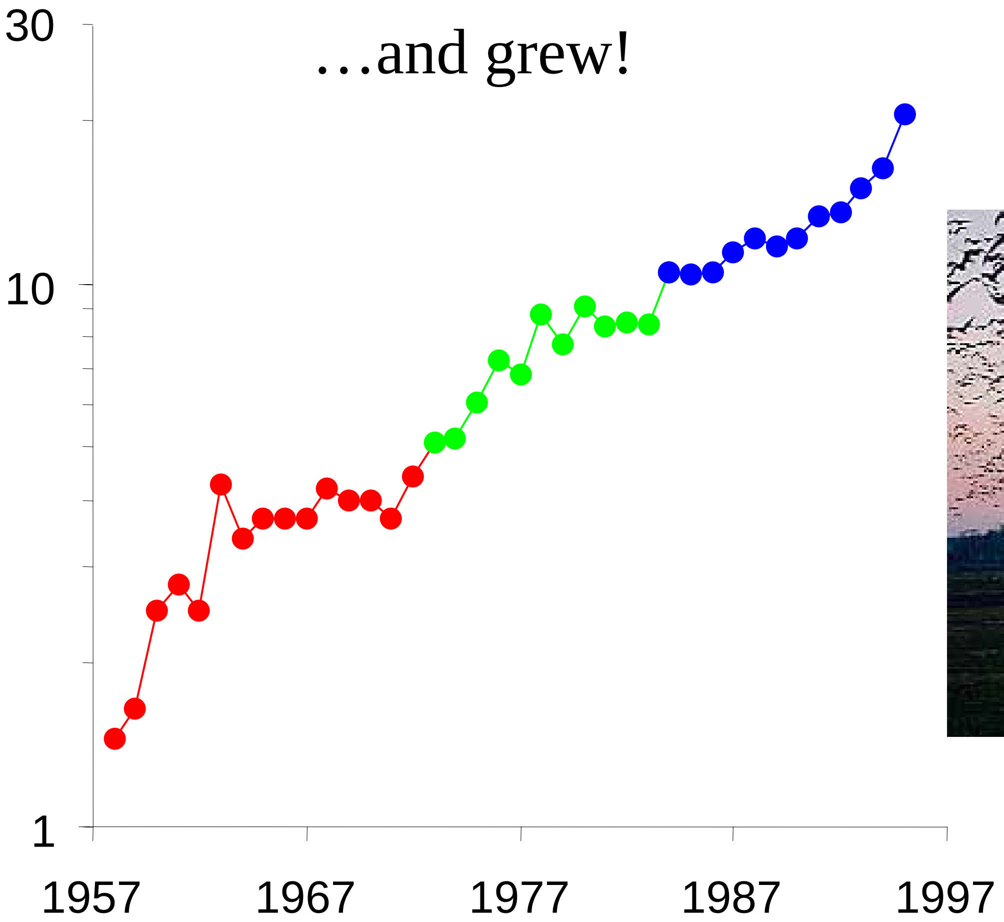
10
1
1957
1967
1977
1987
1997



…and grew!
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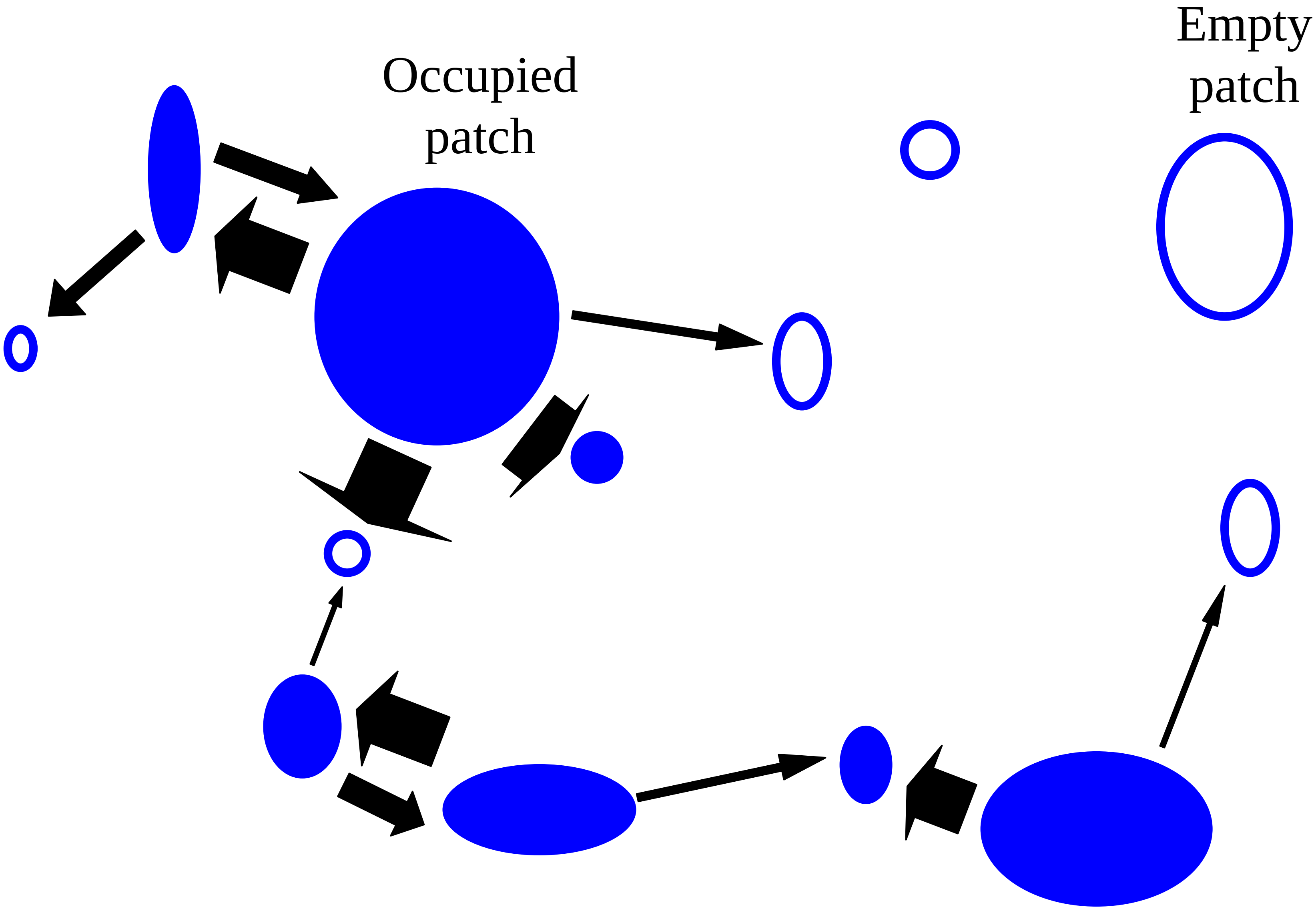
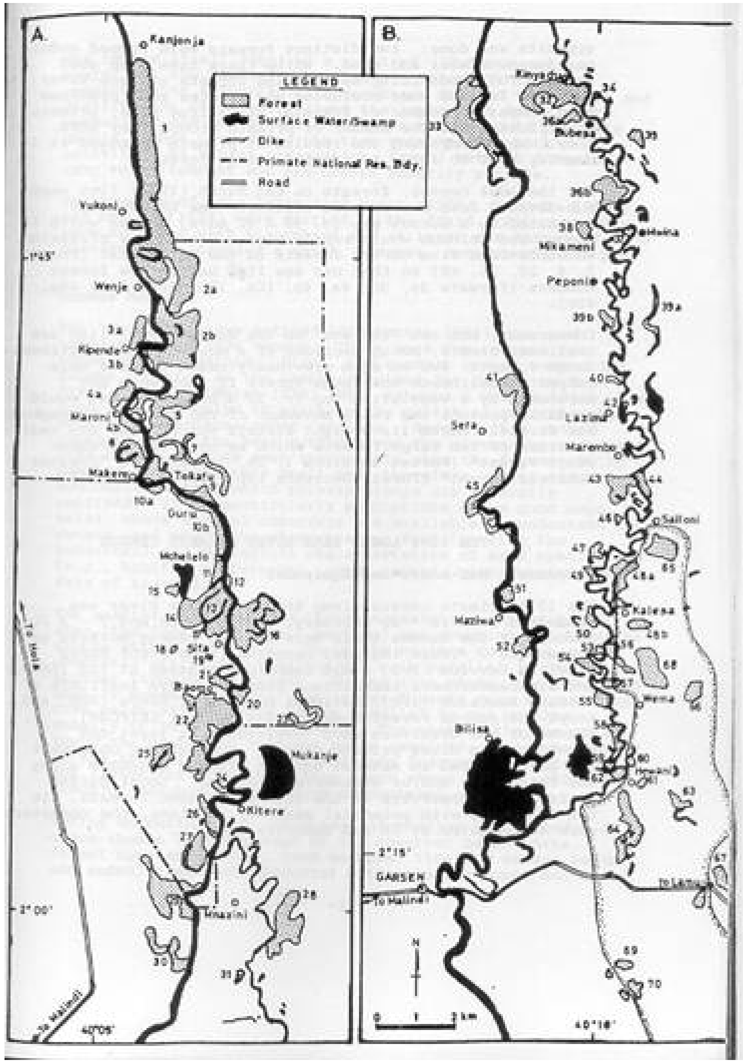
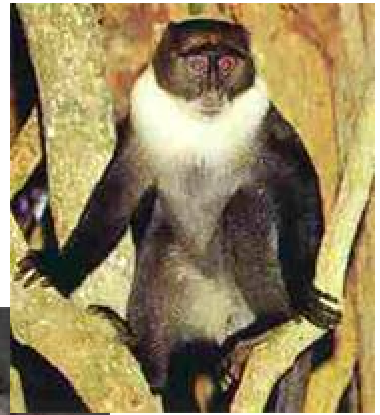
Metapopulation dynamics



Metapopulation dynamics in practice
Tana River primates



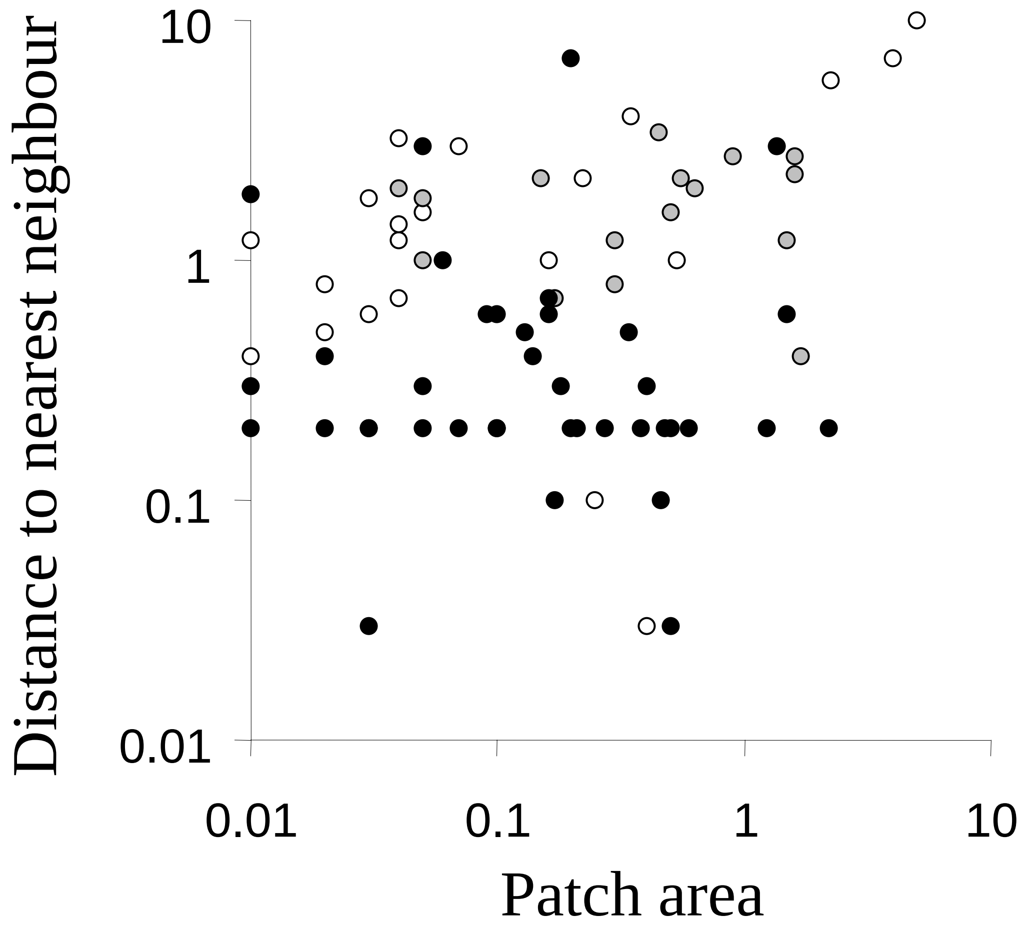
Sykes monkey



Crested mangabey

Red colobus

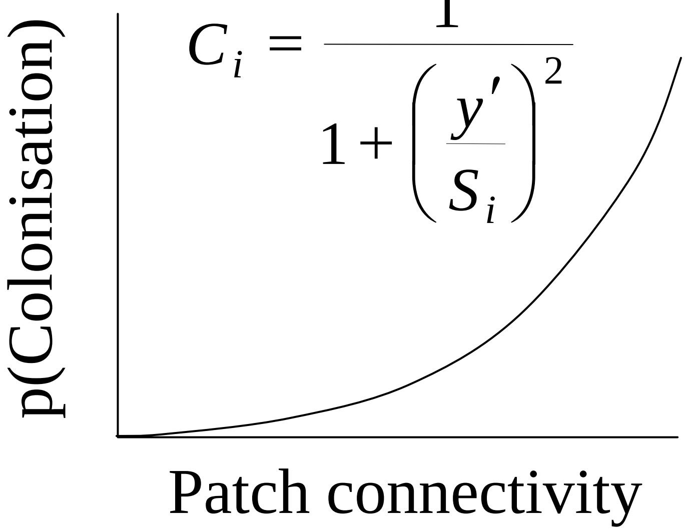
The incidence function: data requirements



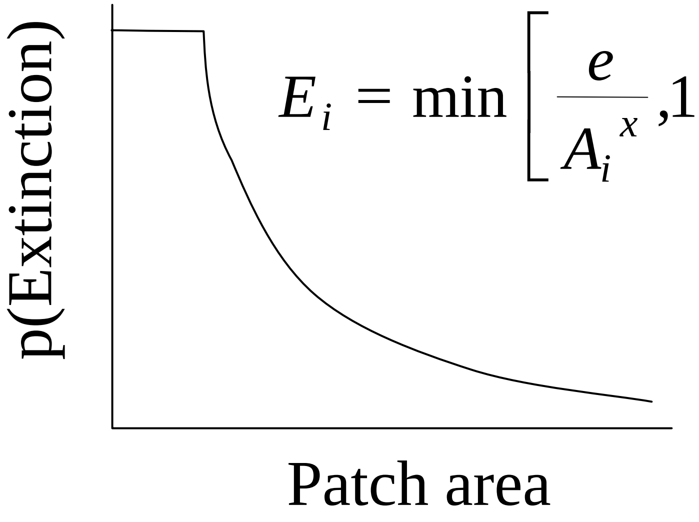
The incidence function model

Probability of occupancy depends on colonisation and extinction probabilities

$$J_i = \frac{C_i}{C_i + E_i - C_i E_i}$$



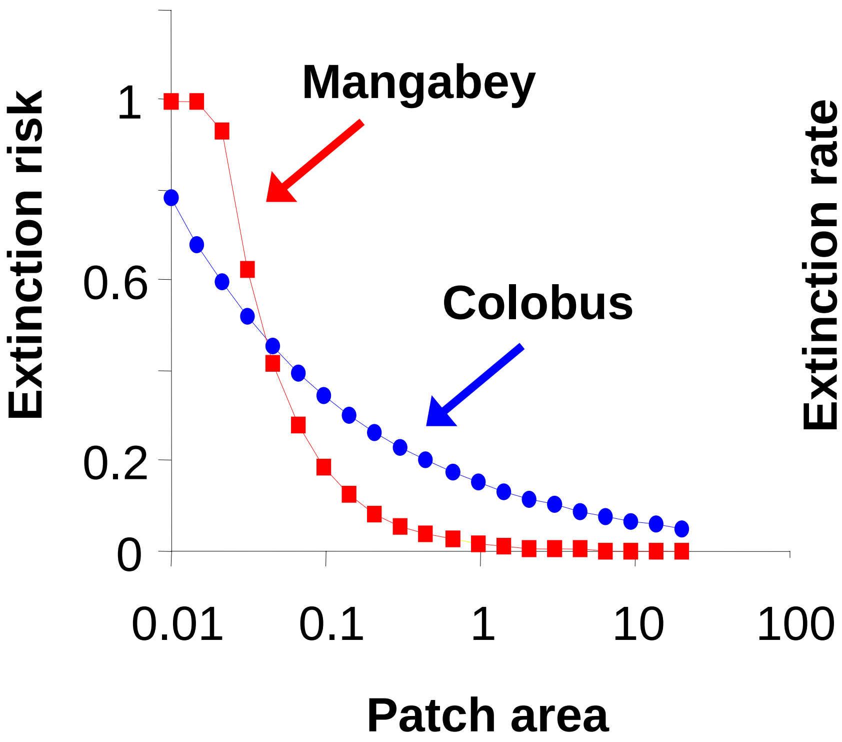
$$C_i = \frac{1}{1 + \left(\frac{y'}{S_i} \right)^2}$$



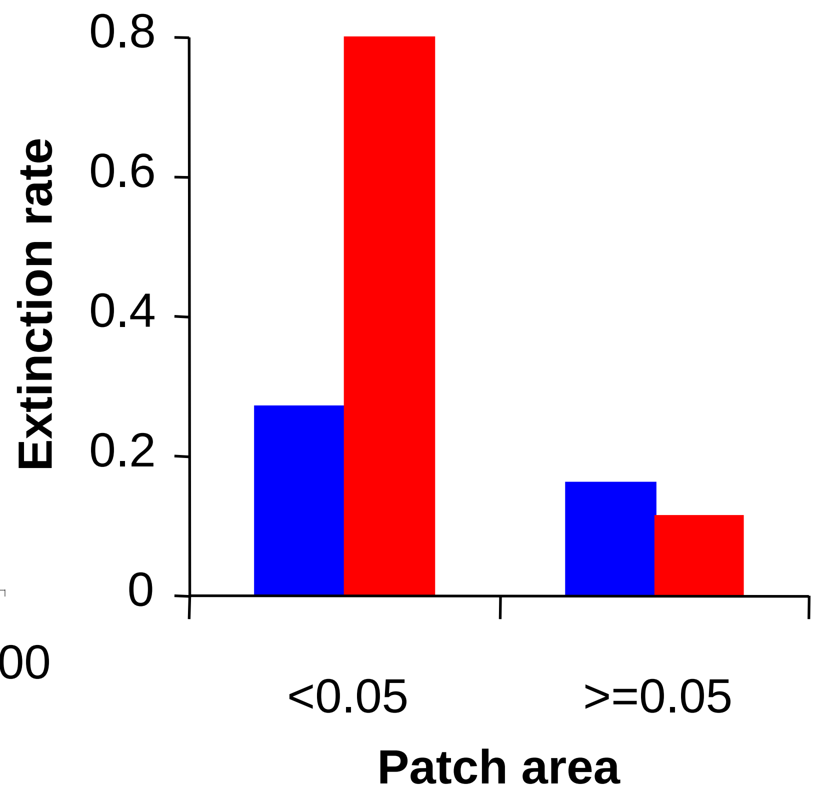
$$E_i = \min \left[\frac{e}{A_i^{\,x}}, 1 \right]$$

Does the model work?

The model



The data



General principles from metapopulation models

1. Persistence may depend on currently unoccupied habitat

2. Viability is increased by:

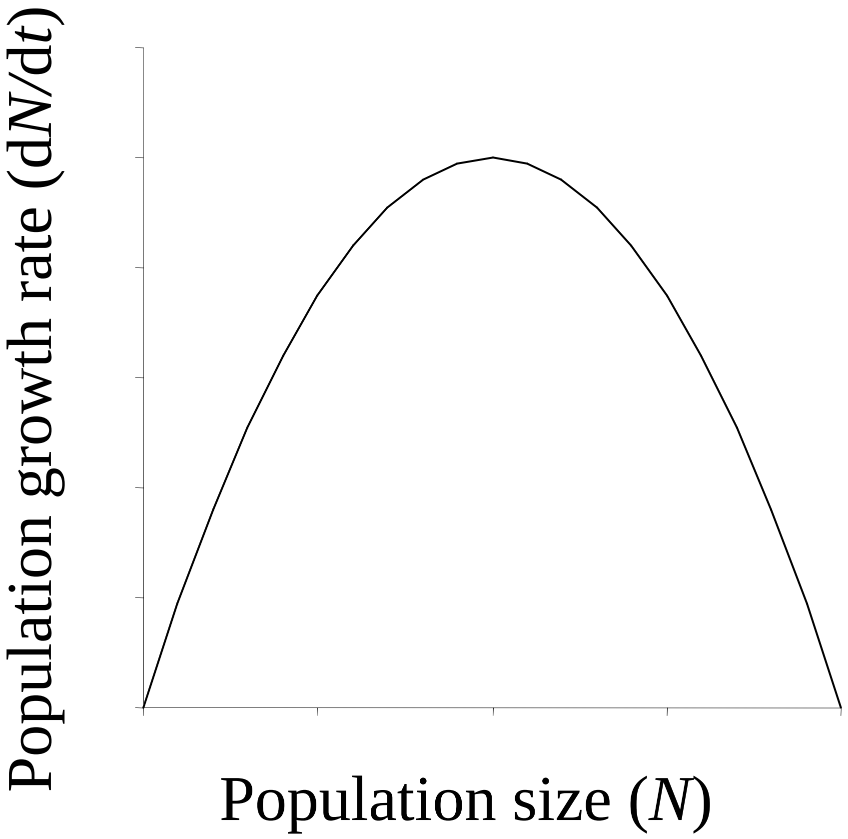
   - More habitat overall

   - Fewer larger habitat patches

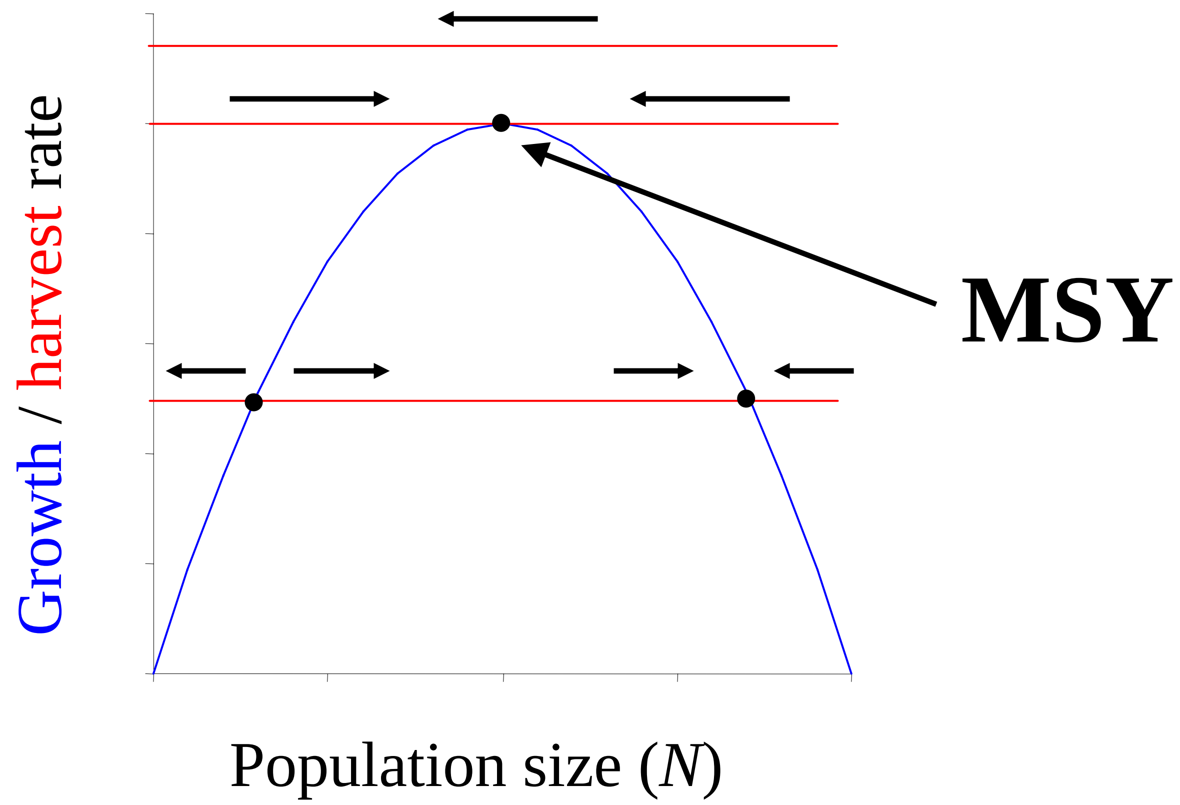
   - Greater connectivity of the matrix

   - Greater variance in patch size

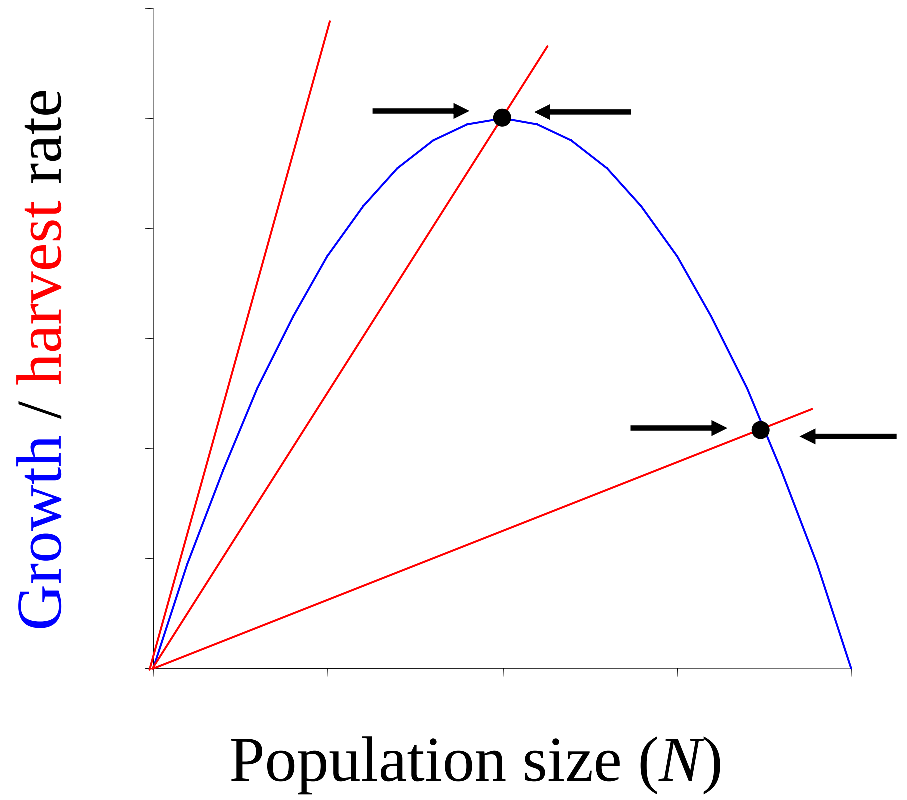
Natural resource use: how does an understanding of population dynamics help to harvest sustainably?



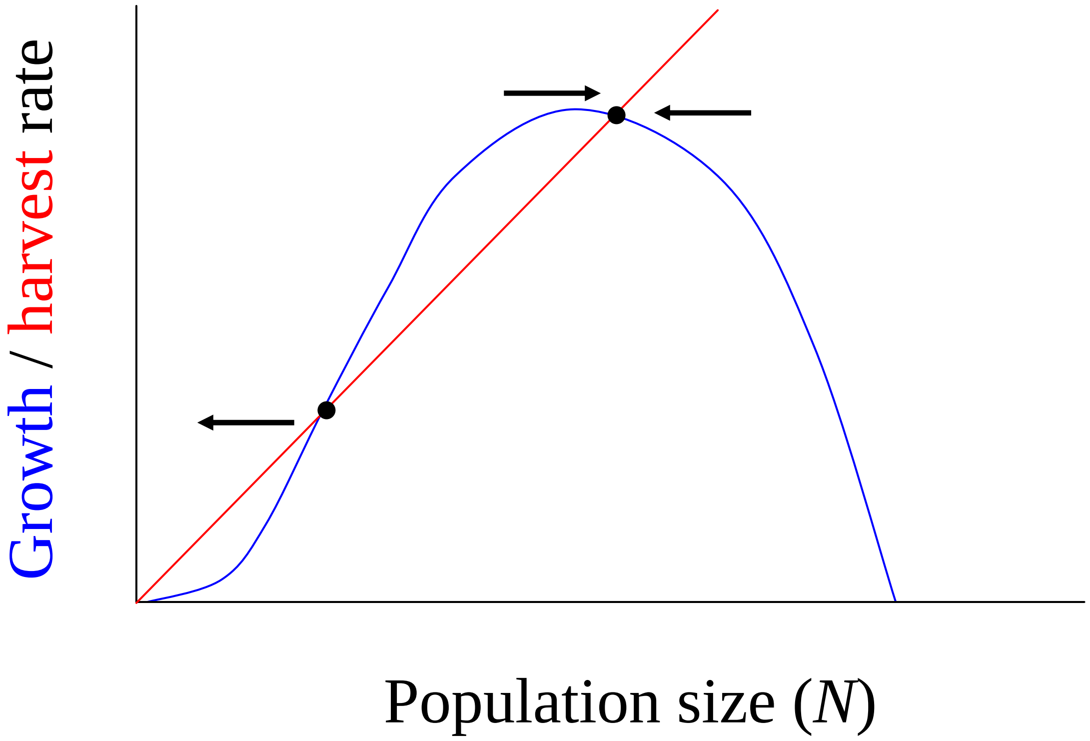
Constant offtake



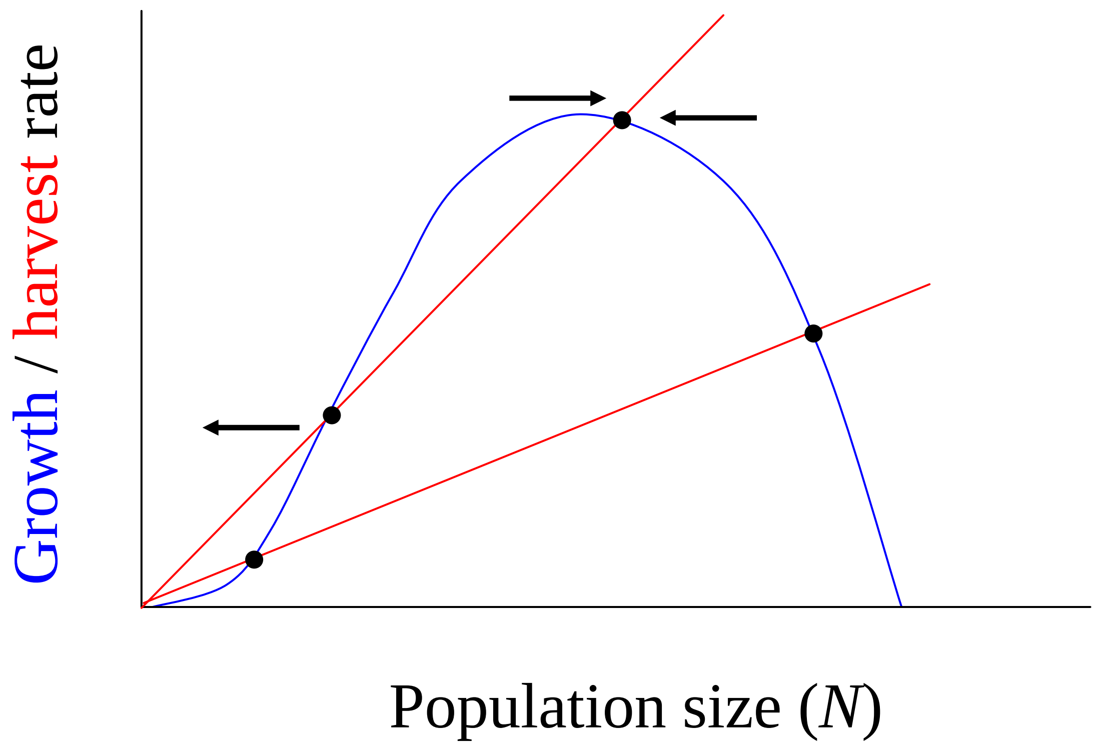
Constant proportional offtake



Harvesting and the Allee effect



Continued harvest, even if reduced, is catastrophic



Useful conclusions from a simple model

1. Harvesting a previously untouched population will always lead to a reduction

2. The reason populations can be harvested sustainably is because they are density dependent

3. If taking a constant **number**, harvesting above MSY causes rapid extinction

4. If taking a constant **proportion**, harvesting above MSY is sustainable

5. If there is an **Allee effect**, harvesting above a threshold leads to rapid extinction, even if proportional

Take home messages

- Predation – prey and host – disease interactions can be destabilising
- Spatial structure allows some escape from density dependence at a local level
- Highly fragmented populations benefit from improved dispersal possibilities and variability in patch size; empty habitat is not necessarily unimportant
- Constant effort harvesting is more likely to be sustainable than a constant yield strategy.