Population ecology of animals

"Populační ekologie živočichů"

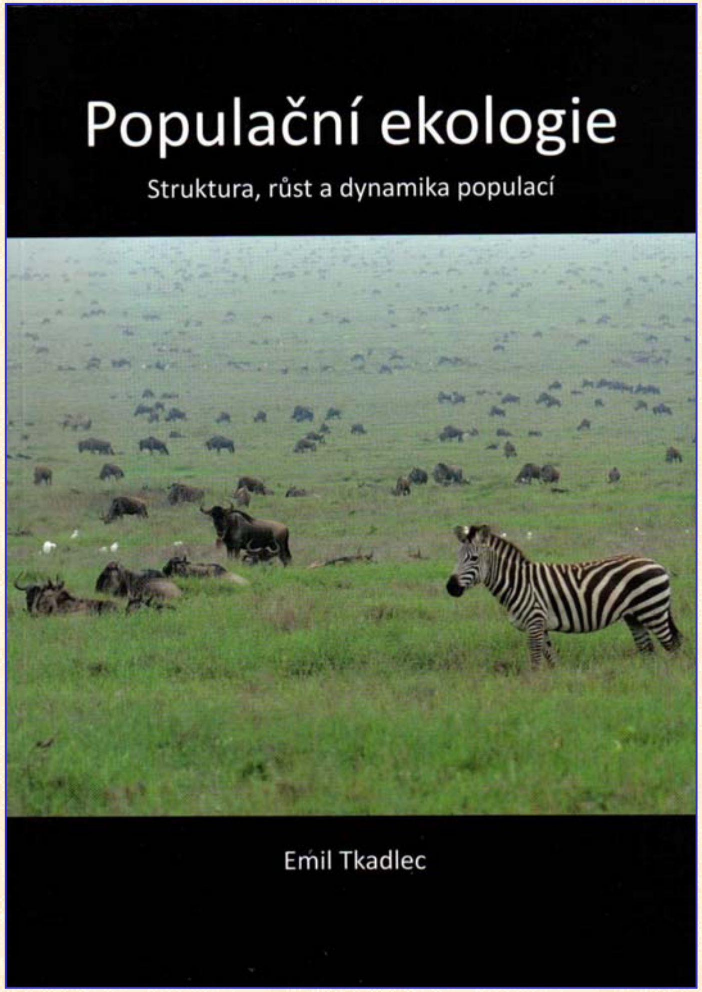
Stano Pekár

Lectures

	Téma	Datum
1	Adaptácia, fitness a fenotypova platicita	5.10.
2	Evolúcia pohlavia, determinácia pohlavia	5.10.
3	Početnosť a cykly	26.10.
4	Koncepcia r- a K- selekcie	26.10.
5	Geografická variabilita, teplota a klimatické zmeny	2.11.
6	Management ohrozených a invazívnych druhov	2.11.
7	Vnútrodruhová konkurencia	9.11.
8	Kooperácia a Alleeho efekt	9.11.
9	Medzidruhová konkurencia a princíp konkurenčného vylúčenia	16.11.
10	Nika a koexistencia	16.11.
11	Amensalizmus, komensalizmus a mutualizmus	23.11.
12	Posun znaku a konkurenčné uvolnenie	23.11.
13	Obrana pred predátormi	30.11.
14	Herbivóri/paraziti a ochrana rastlin/hostiteľov pred nimi	30.11.
15	Regulácia škodcov, lov a zber	7.12.
16	Teória optimálneho získavania potravy a teorém medznej hodnoty	7.12.
17	Sukcesia	14.12.
18	Pohyb v priestore, migrácia	14.12.

	Téma
1	Adaptation, fitness and phenotype platicity
2	Evolution of sex, sex determination
3	Abundance and cykles
4	Koncept of r- and K- selection
5	Geografic variability, temperature and climatic changes
6	Management of endangered and invasive species
7	Intraspecific competition
8	Cooperation and Allee efect
9	Interspecific competition and the competitive exclusion principle
10	Niche and coexistence
11	Amensalism, comensalism and mutualism
12	Character displacement and competitive release
13	Defence agains predators
14	Herbivores/parasites and defence of plants/hosts
15	Regulation of pests and harvesting
16	Optimal foraging and the marginal value theorem
17	Succesion
18	Movement in space and migration

Literature



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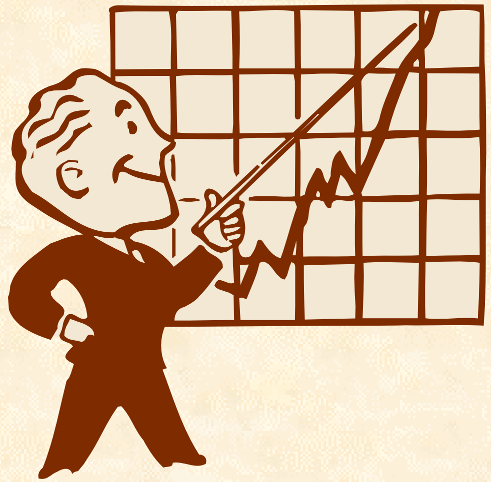
Population Ecology

- a major sub-field of ecology which deals with description and the dynamics of populations within species, and the interactions of populations with environmental factors

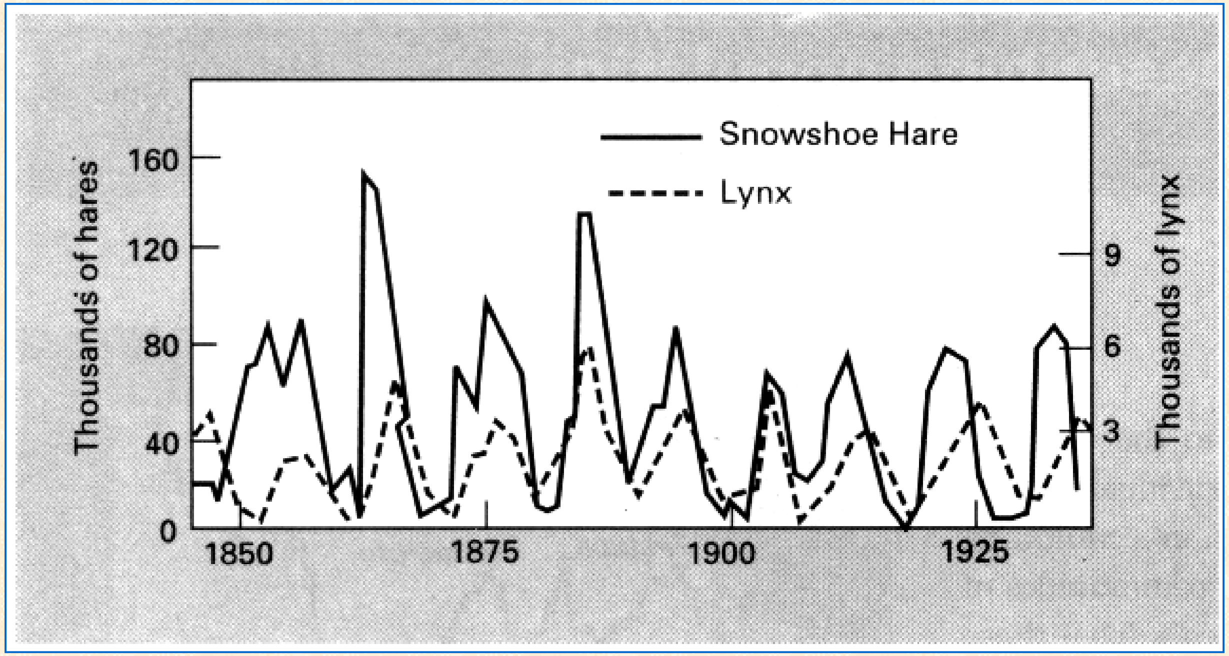
- expanding field (Price & Hunter 1995):
  - populations 52 %, communities 9 %, ecosystems 10 %

- main focus on
  - **Demography** = description of populations that gave rise to **Life-history theory**
  - **Population dynamics** = describe the change in the numbers of individuals in a population



‣ populations of member species may show a range of dynamic patterns in time and space

‣ central question: “WHAT DOES REGULATE POPULATIONS?“



Change in abundance of *Lynx* and *Lepus* in Canada

‣ density independent factors, food supply, intraspecific competition, interspecific competition, predators, parasites, diseases

Utilization

1. Conservation biology

- World Conservation Union (IUCN) uses several criterions (population size, generation length, population decline, fragmentation, fluctuation) to assess species status

- by means of Population viability analysis (PVA) estimates the extinction probability of a taxon based on known life history, habitat requirements, threats and any specified management options

Saiga tatarica

critical: 50% probability of extinction within 5 years

endangered: 20% probability of extinction within 20 years

vulnerable: 10% probability of extinction within 100 years

2. Biological control

- to assess ability of a natural enemy to control a pest

- in 1880 *Icerya purchasi* was causing infestations so severe in California citrus groves that growers were burning their trees

Rodolia cardinalis (Coccinellidae) eating *Icerya purchasi* (Hemiptera)

- in winter 1888-1889 *Rodolia cardinalis* and *Cryptochaetum* were introduced into California from Australia, growers took the initiative and applied the natural enemies themselves

- by fall 1889 the pest was completely controlled

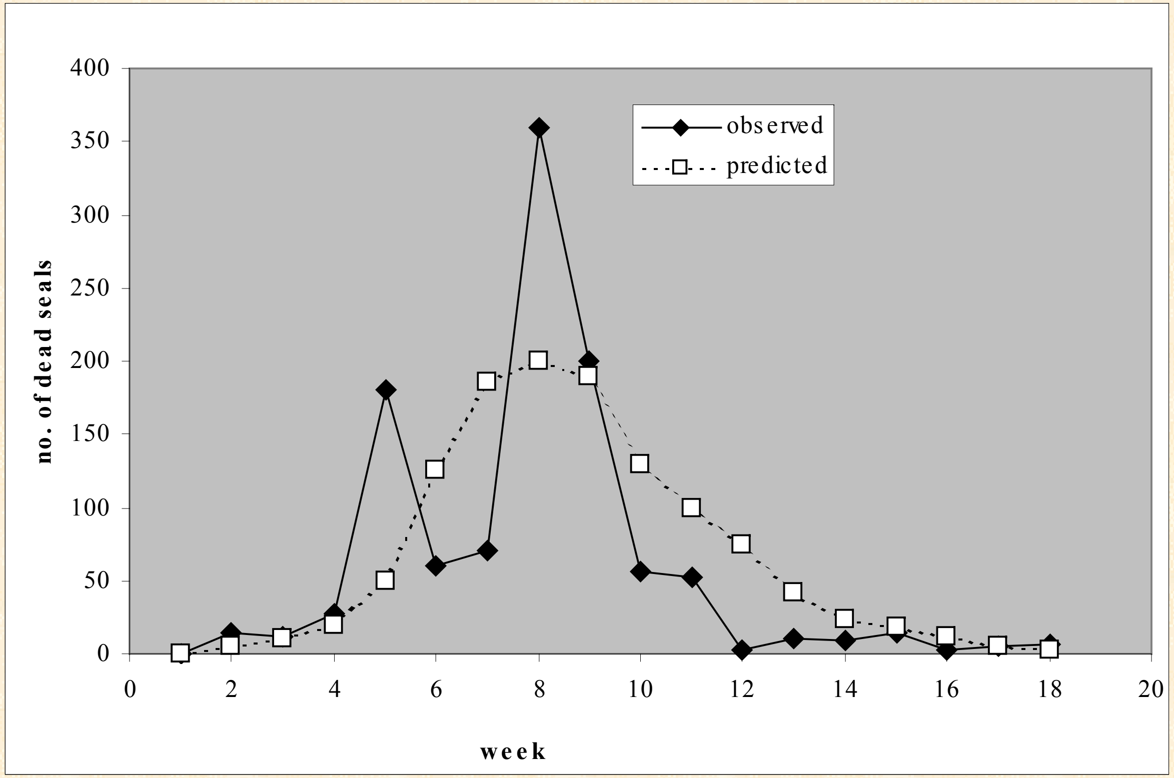
- *Rodolia cardinalis* has been exported to many other parts of the world

- the interest of growers and the public in this project was due to its spectacular success: the pest itself was showy and its damage was obvious and critical; the destruction of the pest and the recovery of the trees was evident within months

3. Epidemiology

- to predict the diffusion of a disease and to plan a vaccination
- phocine distemper virus was identified in 1988 and caused death of 18 000 common seals in Europe
- during 4 months the disease travelled from Denmark to the UK
- the population of common seals in the UK declined by about half

Grenfell et al. (1992)



Observed and predicted epidemic curves for virus in common seals in the UK

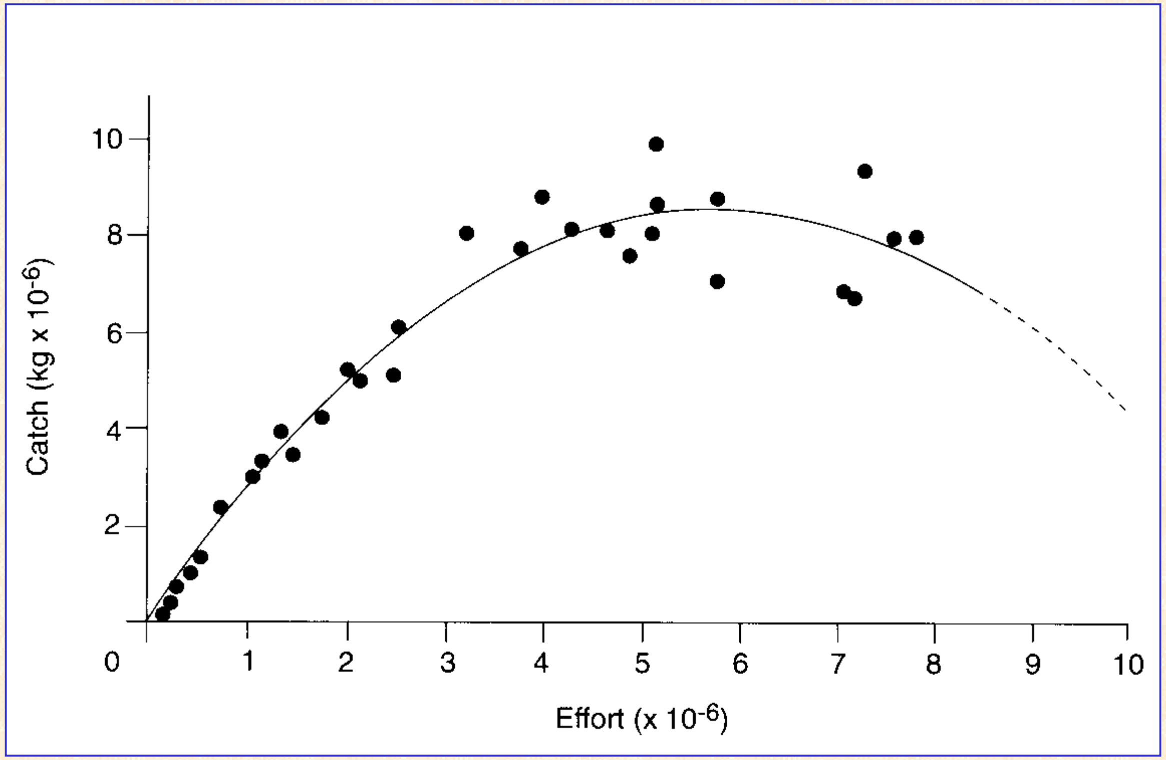
4. Harvesting

- to predict maximum sustainable harvest in fisheries and forestry but also used to regulate whale or elephant hunting
- when population is growing most rapidly ($K/2$) then part of population can be harvested without causing extinction
- density is determined by means of fitting logistic curves to data

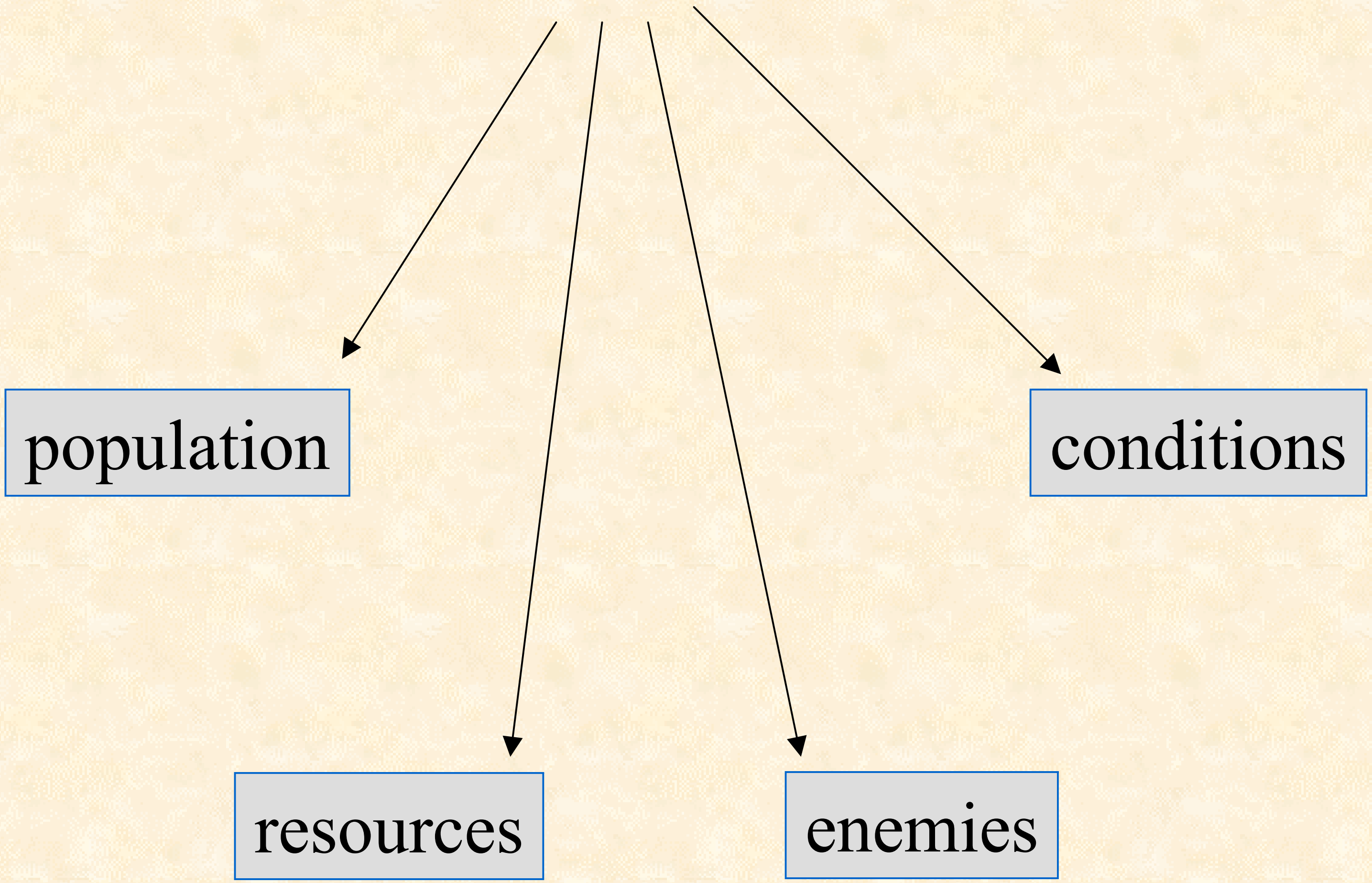
Beddington (1979)

Relationship between capture and fishing effort

Panulirus cygnus



Population + environment = population system



Population

- molecules → organels → cells → tissues → organs → organ systems → organisms → **populations** → communities → ecosystem → landscape → biosphere
- a group of organisms of the same species that occupies a particular area at the same time and is characterised by an average characteristic (e.g., mortality)
- characteristics:

Individual	→	**Population**
Developmental stage		Stage structure
Age/stage		Age/stage structure
Sex		Sex ratio
Territorial behaviour		Spatial distribution
Size		Size structure

Events & Processes

Event – an identifiable change in a population

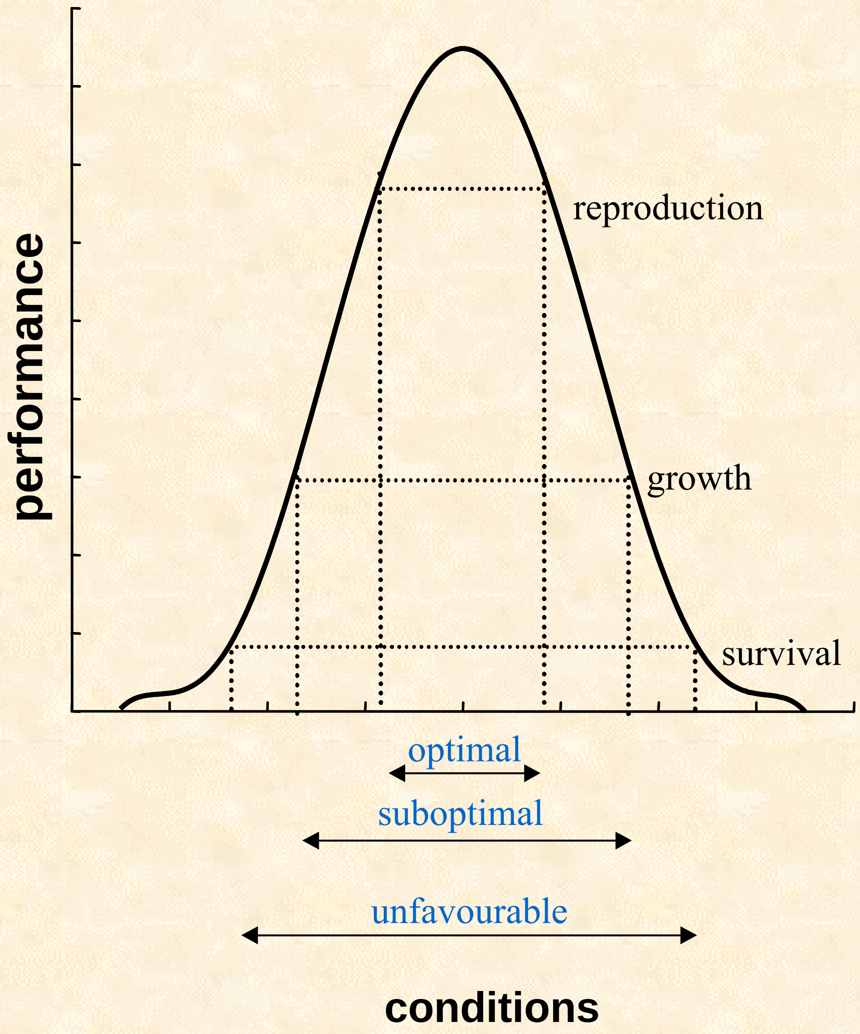
Process – a series of identical events

- ***rate*** of a process – number of events per unit time

Event	**Process**
Birth	Natality („birth rate“)
Death	Mortality („mortality rate“)
Increment [gram]	Growth
Increment [number]	Population increase (“rate of increase”)
Acquisition of food [gram]	Consumption (“consumption rate”)

Conditions

- inherent characteristics of the evironment (pH, salinity, temperature, moisture, wind speed, etc.)
- not modified by populations
- not consumed by population
  ⇒ no feedback mechanisms
  ⇒ do not regulate population size
- limit population size



Resources

- any entity whose quantity is reduced (food, space, water, minerals, oxygen, sun radiation, etc.)
- modified (reduced) by populations
- defended by individuals (interference competition)
- regulate population size
- non-renewable resources - space

Renewable resources

- regeneration centre outside the population system $\Rightarrow$ no effect of the consumer (e.g., oxygen, water)

- regeneration centre inside of the population system $\Rightarrow$ influenced by the consumer (e.g., prey)

Enemies

- competitors, predators, parasites, pathogens
- negative effect on the population
- top-down regulation of the population

Population Growth

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Population processes

- focus on rates of population processes

- number of cockroaches in a living room increases:

- influx of cockroaches from adjoining rooms → immigration [***I***]
- cockroaches were born → birth [***B***]

Blatta orientalis

- number of cockroaches declines:

- dispersal of cockroaches → emigration [***E***]
- cockroaches died → death [***D***]

$$N_{t+1} = N_t + I + B - D - E$$

- population increases if $I + B > E + D$

- rate of increase is a summary of all events ($I + B - E - D$)

- growth models are based on ***B*** and ***D***
- spatial models are based on ***I*** and ***E***

Ecological Models

- aim: to simulate (predict) what can happen
- models are tested by comparison with observed dynamic

- realistic models - complex (many parameters), realistic, used to simulate real situations
- strategic models - simple (few parameters), unrealistic, used for understanding of model behaviour

- a model should be:

1. a satisfactory description of diverse systems
2. an aid to enlighten aspects of population dynamics
3. a system that can be incorporated into more complex models

- deterministic models - everything is predictable
- stochastic models - including random events, chaos

- <u>discrete models:</u>

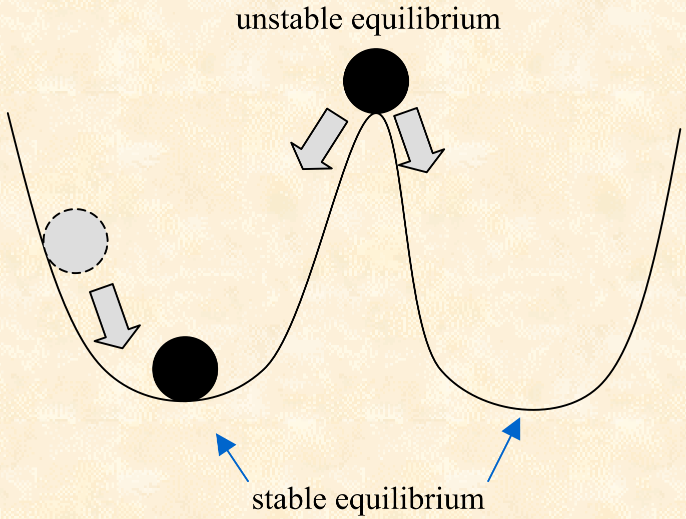
- time is composed of discrete intervals or measured in generations
- used for populations with synchronised reproduction (annual species)
- modelled by difference equations

- <u>continuous models:</u>

- time is continual (very short intervals) thus change is instantaneous
- used for populations with asynchronous and continuous overlapping reproduction
- modelled by differential equations

STABILITY

- stable equilibrium is a state (population density) to which a population will move after a perturbation



Density-independent Population Growth

Assumptions:

- immigration and emigration are ignored
- all individuals are identical
- reproduction is asexual
- resources are infinite

Discrete (difference) model

- for population with discrete generations (annual reproduction)
- if births and deaths do not depend on population size
- exponential (geometric) growth
- Malthus (1834) realised that any species can potentially increase in numbers according to a geometric series

N_0 = initial density
b .. birth rate (per capita)
d .. death rate

$$\Delta N = bN_{t-1} - dN_{t-1}$$

$$N_t - N_{t-1} = (b-d)N_{t-1}$$

$$N_t = (1+b-d)N_{t-1}$$

$$1+b-d = \lambda$$

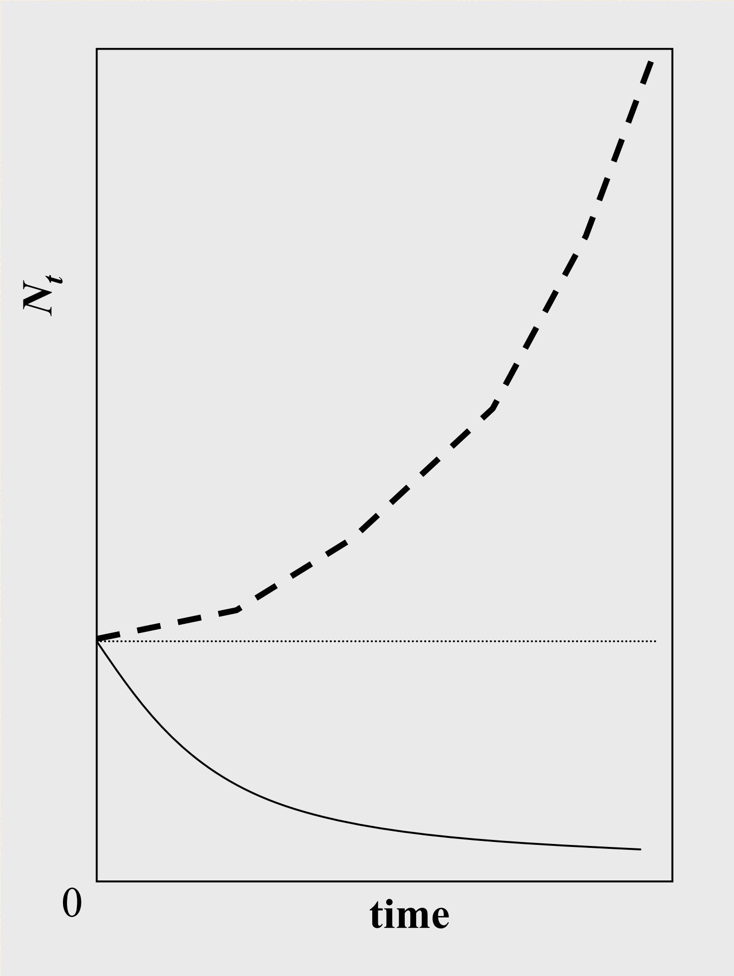
$$N_t = N_{t-1}\lambda$$

- population number in generations ***t*** is equal to

$$N_2 = N_1\lambda = N_0\lambda\lambda$$

$$N_t = N_0\lambda^t$$

$\lambda < 1$ .. population declines
$\lambda > 1$ .. population increases
$\lambda = 1$ .. population does not change



- number of individuals is multiplied each time - the larger the population the larger the increase

λ = finite growth-rate, per capita rate of growth
$\lambda = 1.23$ .. 23% increase

R ..average of finite growth rates

$$R = \left(\prod_{i=1}^{t} \lambda_i\right)^{\frac{1}{t}} = (\lambda_1\lambda_2 \ldots \lambda_t)^{\frac{1}{t}}$$

Continuous (differential) model

- populations that are continuously reproducing
- when change in population number is permanent

$$N_t = N_0 \lambda^t$$

$$\ln(N_t) = \ln(N_0) + t\ln(\lambda)$$

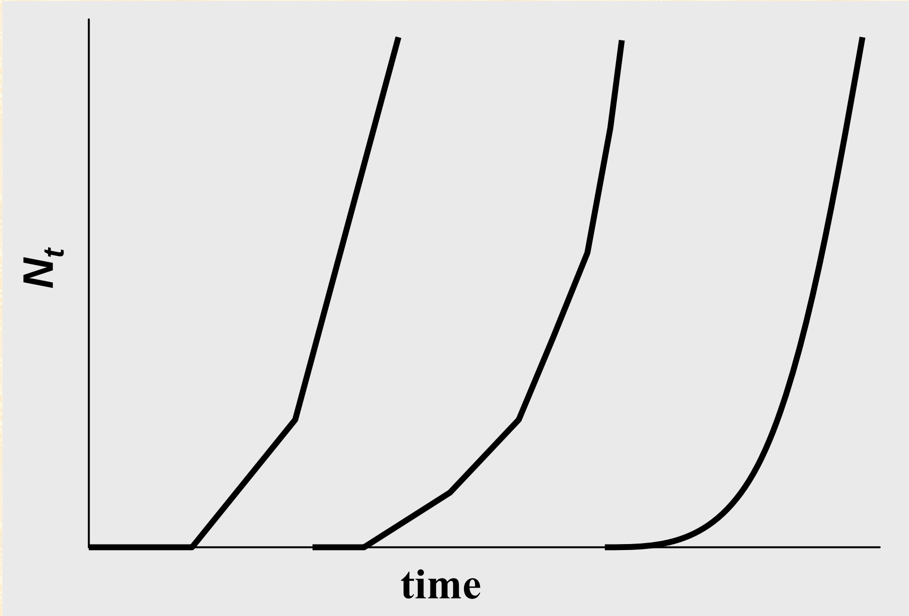
$$\ln(N_t) - \ln(N_0) = t\ln(\lambda)$$

$$\frac{dN}{dt}\frac{1}{N} = \ln(\lambda)$$

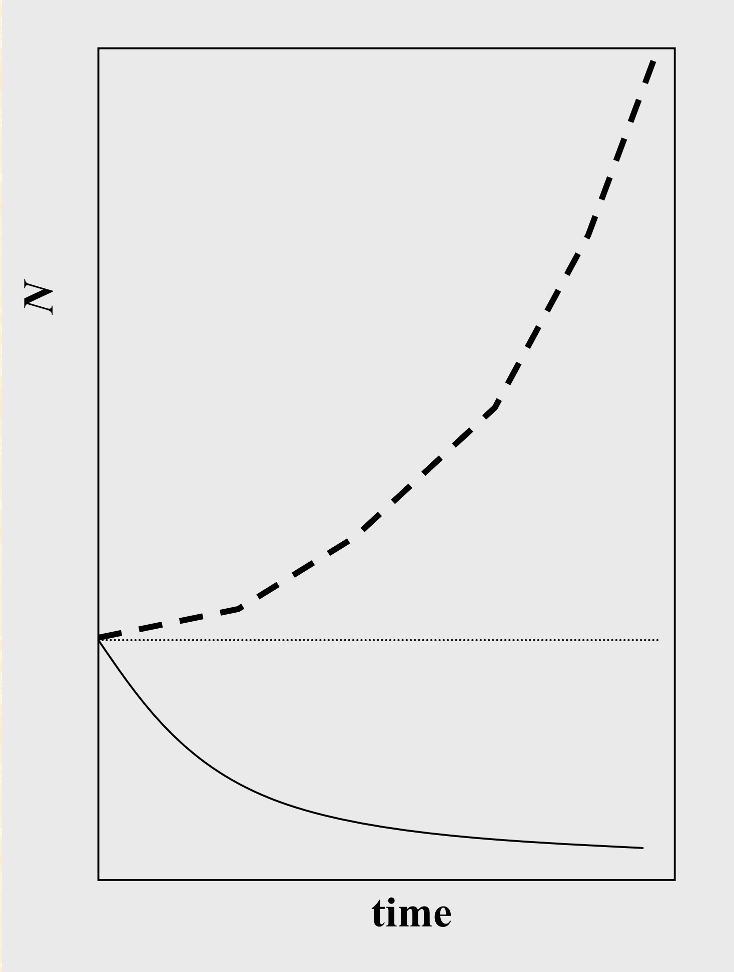
$$\frac{dN}{dt} = N\ln(\lambda)$$

$$r = \ln(\lambda) \qquad \frac{dN}{dt} = Nr$$

Comparison of discrete and continuous generations



r - intrinsic rate of natural increase, instantaneous per capita growth rate



$r < 0$ .. population declines
$r > 0$ .. population increases
$r = 0$ .. population does not change

<u>Solution of the differential equation:</u>

- analytical or numerical

▸ at each point it is possible to determine the rate of change by differentiation (slope of the tangent)

▸ when t is large approximated by the exponential function

$$\frac{dN}{dt} = Nr$$

$$\frac{dN}{dt}\frac{1}{N} = r$$

$$\int_0^T \frac{1}{N} dN = \int_0^T r dt$$

$$\ln(N_T) - \ln(N_0) = r(T - 0)$$

$$\ln\left(\frac{N_T}{N_0}\right) = rT$$

$$\frac{N_T}{N_0} = e^{rT}$$

$$N_t = N_0 e^{rt}$$

- doubling time: time required for a population to double

$$t = \frac{\ln(2)}{r}$$

r versus λ

$$N_t = N_0 \lambda^t \qquad N_t = N_0 e^{rt}$$

$$\lambda^t = e^{rt}$$

$$r = \ln(\lambda)$$

- r is symmetric around 0, λ is not

$r = 0.5$ ... $\lambda = 1.65$

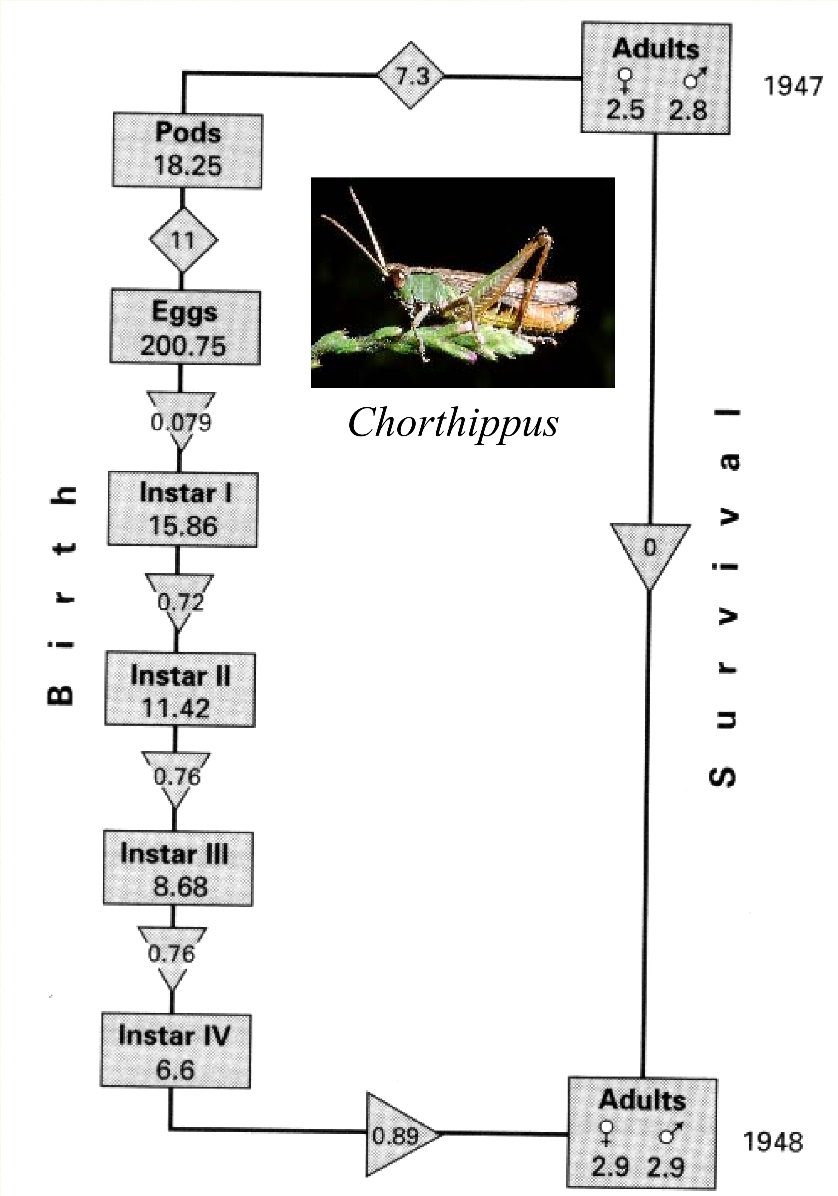
$r = -0.5$ ... $\lambda = 0.61$

Population structure

- **Demography** - study of organisms with special attention to stage or age structure
- processes associated with age, stage or size

x .. age/stage/size category
p_x .. age/stage/size specific survival
m_x .. reproductive rate (expected average number of offspring per female)

$$p_x = \frac{S_{x+1}}{S_x} \qquad m_x = \frac{x_0}{x_x}$$

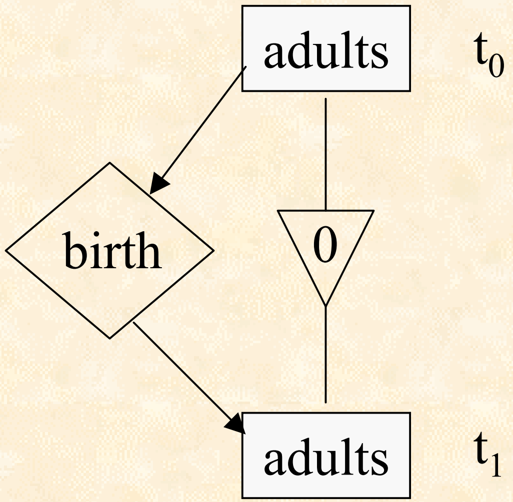


Chorthippus

Richards & Waloff (1954)

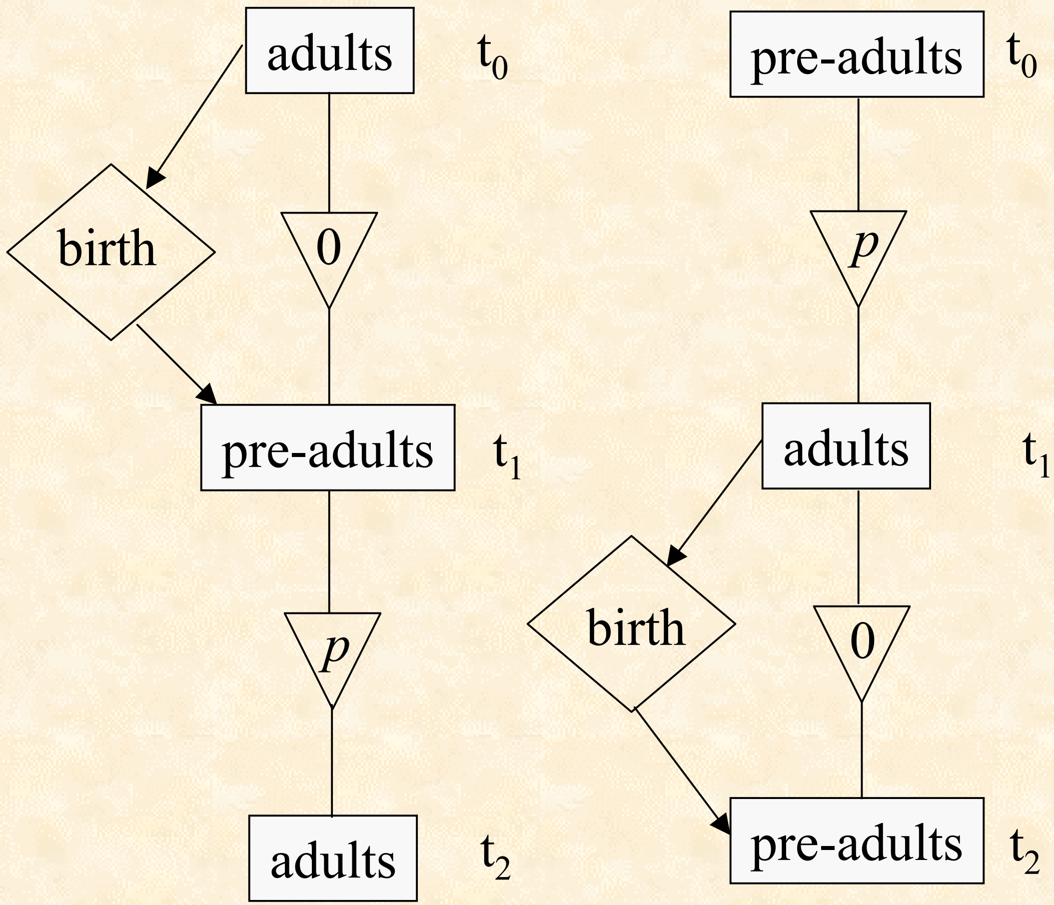
- main focus on births and deaths
- immigration & emigration is ignored
- no adult survive
- one (not overlapping) generation per year
- egg pods over-winter
- despite high fecundity they just replace themselves

Annual species



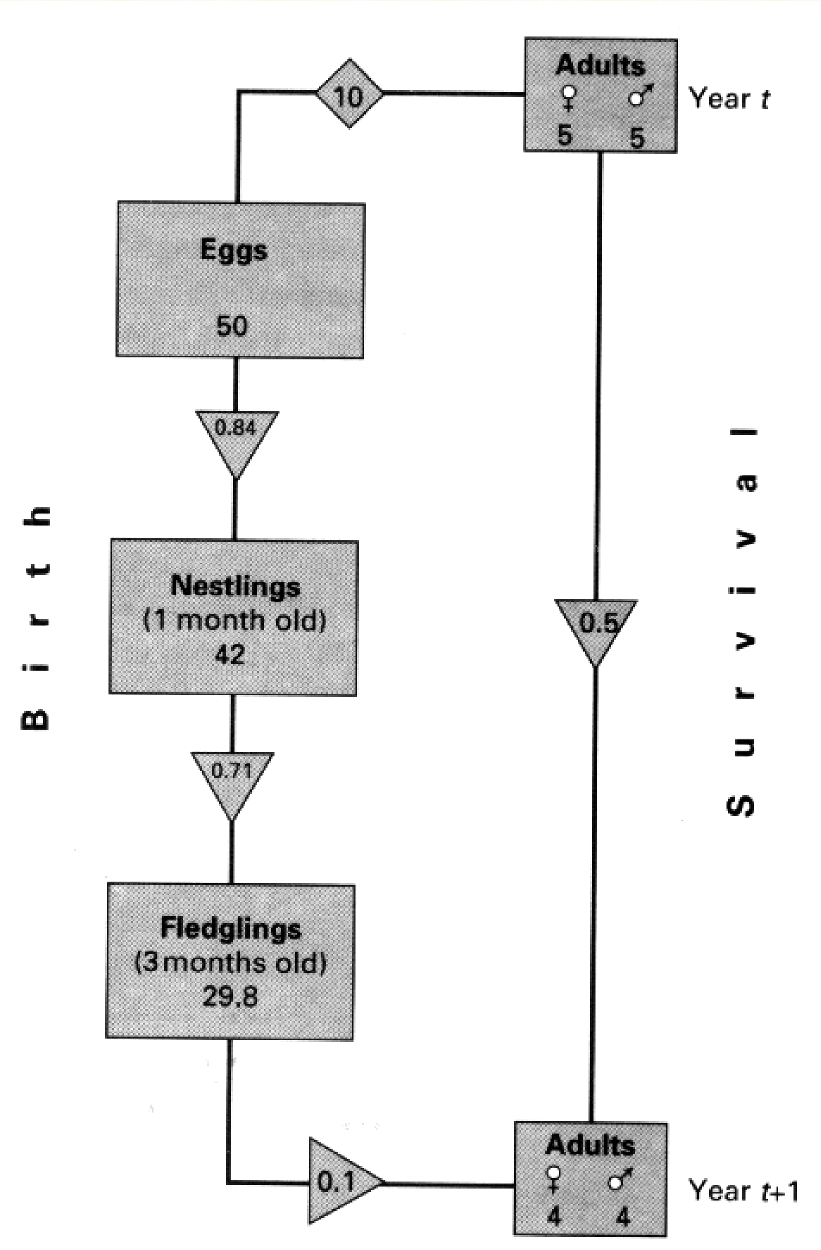
- breed at discrete periods
- no overlapping generations

Biennal species



- breed at discrete periods
- adult generation may overlap

Perins (1965)



Perennial species

- breed at discrete periods
- breeding adults consist of individuals of various ages (1-5 years)
- adults of different generations are equivalent
- overlapping generations

Parus major

Age-size-stage life-table

Agaricia agaricites

- age/stage classification is based on developmental time

- size may be more appropriate than age (fish, sedentery animals)

- Hughes (1984) used combination of age/stage and size for the description of coral growth