Populations in lakes

Limnology

Lecture 9

Outline

- Adaptations in lake organisms to
  - Low oxygen
  - Predation
  - Seasonal disturbance
- Populations in lakes
  - Exponential
  - Logistic
  - Metapopulation

Low Oxygen Tolerance

Hemoglobin type pigments

“Anoxibiosis” inactive, low metabolic rates

Chironomid (midge larvae)

Chaoborus

Low Oxygen Tolerance: snorkels and air tanks

Breathing tubes

Rat-tailed fly (*Eristalomyia*)

"physical lung"

Diving beetles (*Dytiscidae*)

Induced defenses

Requires reliable cue

Kairomones – chemical signals produced by predators that affect prey defenses

- Why do predators create cues?

Assumes fitness cost to trait (trade-off)

Either cost of maintaining plasticity or expressing wrong trait in wrong environment

Why?

Very common in aquatic systems

Why?

Induced defenses

Cyclomorphosis: seasonal variation in helmet and spine length in Daphnia

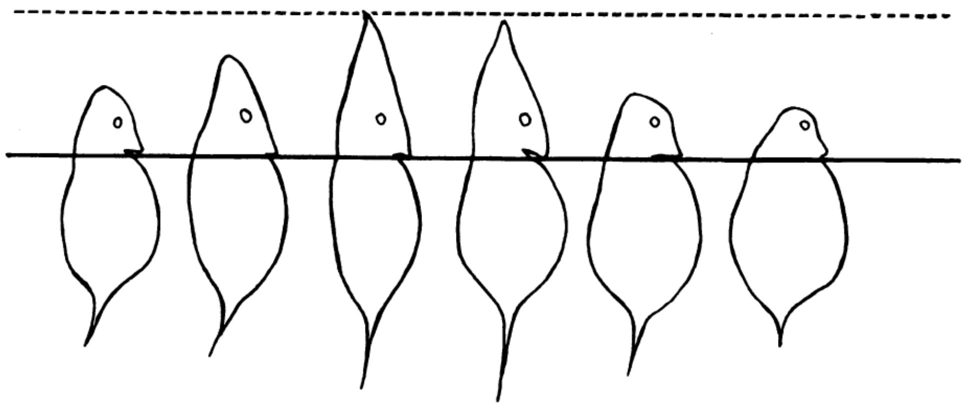
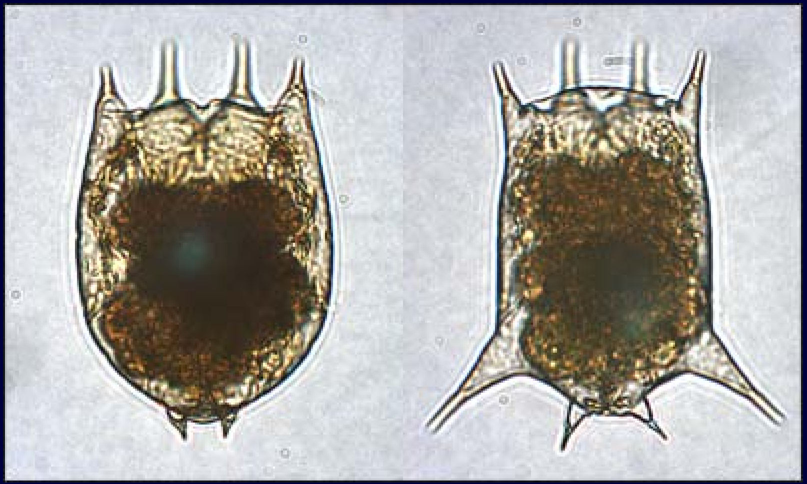
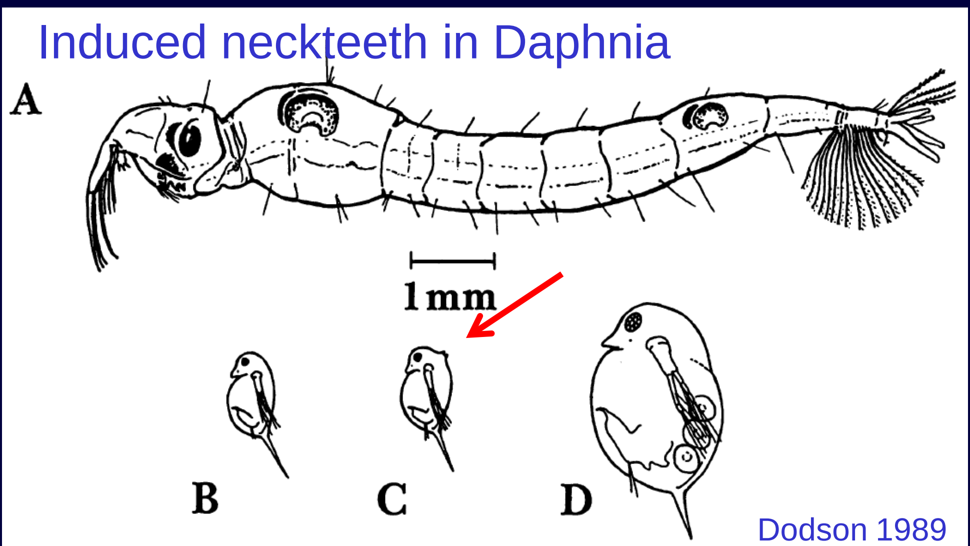


Figure 2. Helmet height in *Daphnia* as a function of the time of year. This figure is redrawn from Woltereck (1909). The adults were collected at different times of the year and belong to different generations: from left to right, 3 July, 28 July, 30 August, 15 September, 18 October, and 3 January.



Brachionus rotifer – induced spines

Induced neckteeth in Daphnia



Reliable indicator of predation leads to altered prey traits

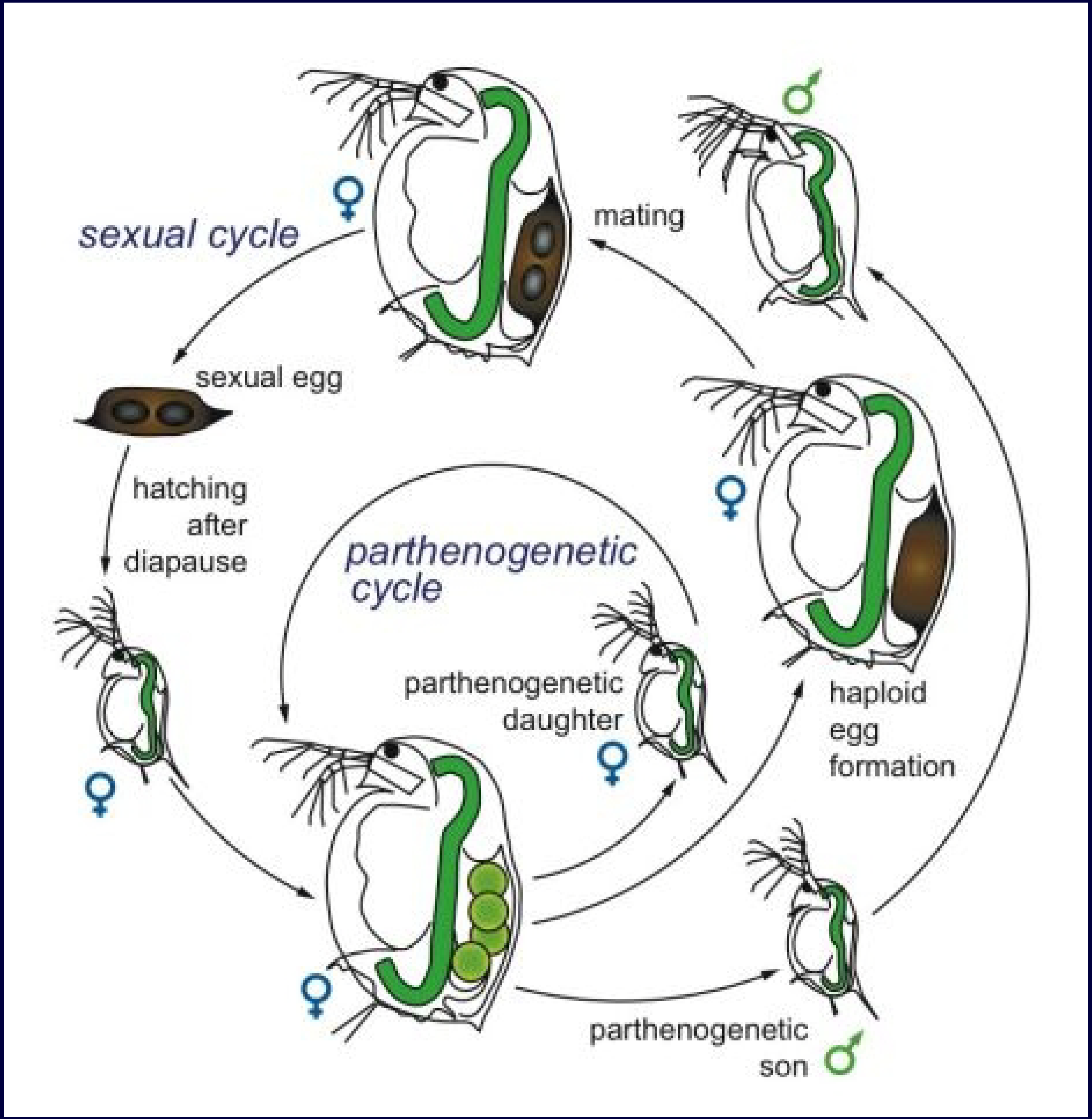
Phenotypic plasticity – trait change in response to enviroment

Seasonal disturbance

Diapause: Physiological state with suspended metabolism

Ephippium [Gr. “saddle”] – molted carapace containing 2 sexual eggs

- resists drying, freezing, digestion


sexual cycle
♀
mating
♂
sexual egg
hatching
after
diapause
parthenogenetic
cycle
♀
parthenogenetic
daughter
♀
haploid
egg
formation
♀
♀
parthenogenetic
son ♂

Disturbance: diapause

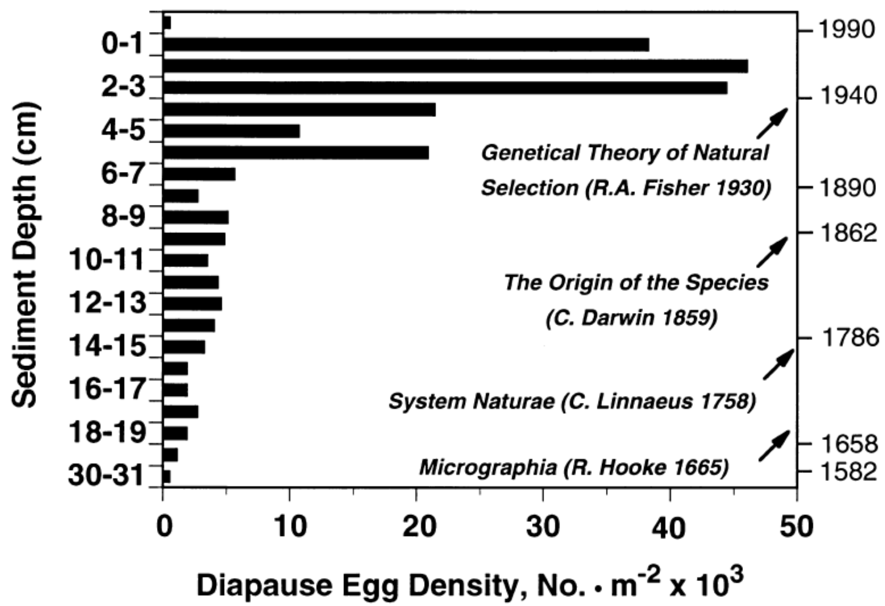


FIG. 2. The depth distribution of viable diapausing eggs of *Diaptomus sanguineus* in the egg bank of the central deep sediments of Bullhead Pond, R.I. Sediment dates determined by ^{210}Pb-dating (see Fig. 4). Key publication landmarks in evolutionary biology are provided as reference points for when the still-viable diapausing eggs were originally laid. Data from Hairston *et al.* (1995).

Resurrection ecology

Hairston & Kearns 2002

Populations in Lakes

Critical goal in ecology and fisheries management

Populations in Lakes

Population – group of conspecifics living in same place*

* birth/death dynamics determined by local mechanisms rather than immigration

- source and sink populations

- a sink becomes extirpated if you remove emigration

- sub-population - part of meta-population

Lake populations very dynamic

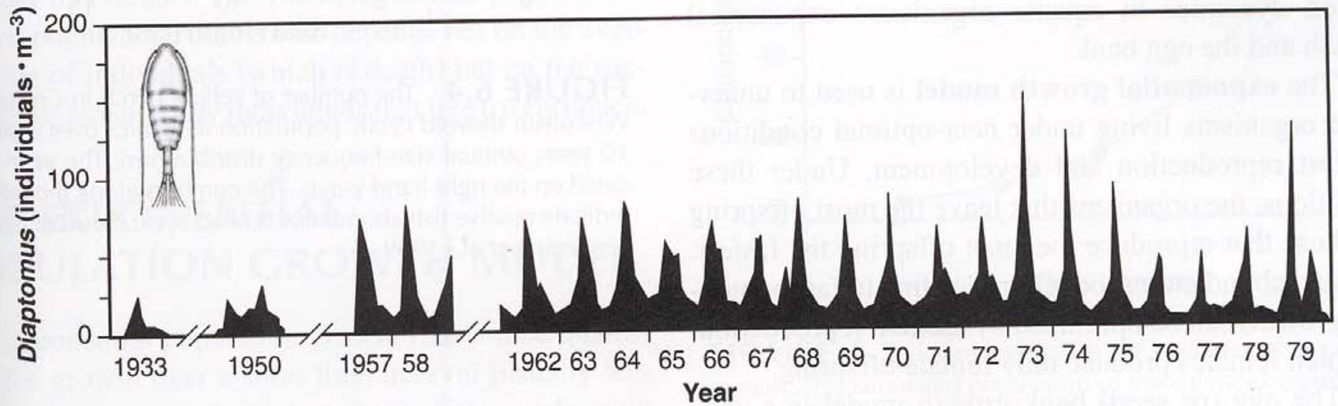


FIGURE 6.3 A graph of number of the calanoid copepod (*Diaptomus ashlandi*, an aquatic population with high variance in bers over time, with a strong annual component to the variation, Lake Washington. **Source:** Data from Edmondson & Litt, 1982.

Fig. 6.3

Populations sometimes cycle over longer periods

Cohort effects – strong recruitment

Cannibalism leads to small future size classes

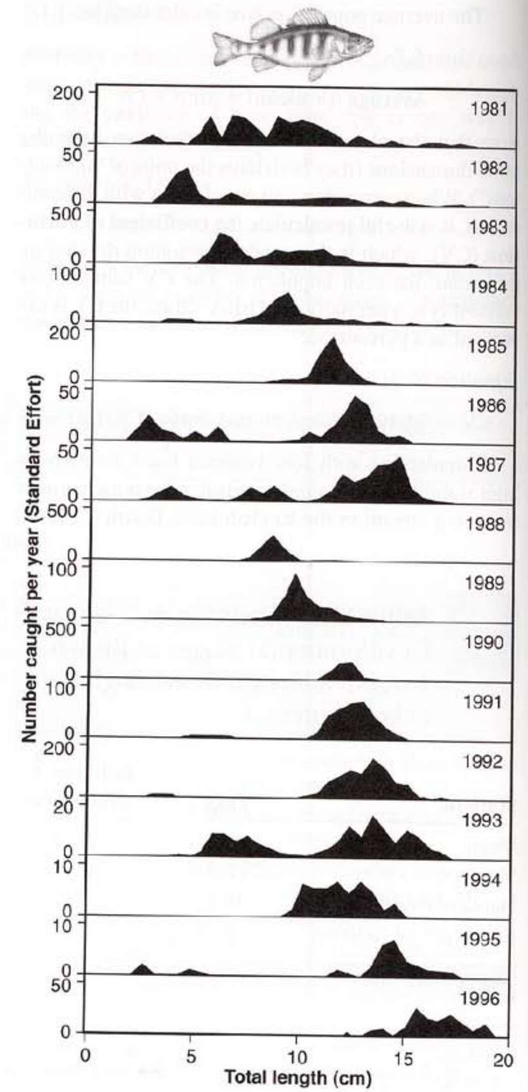
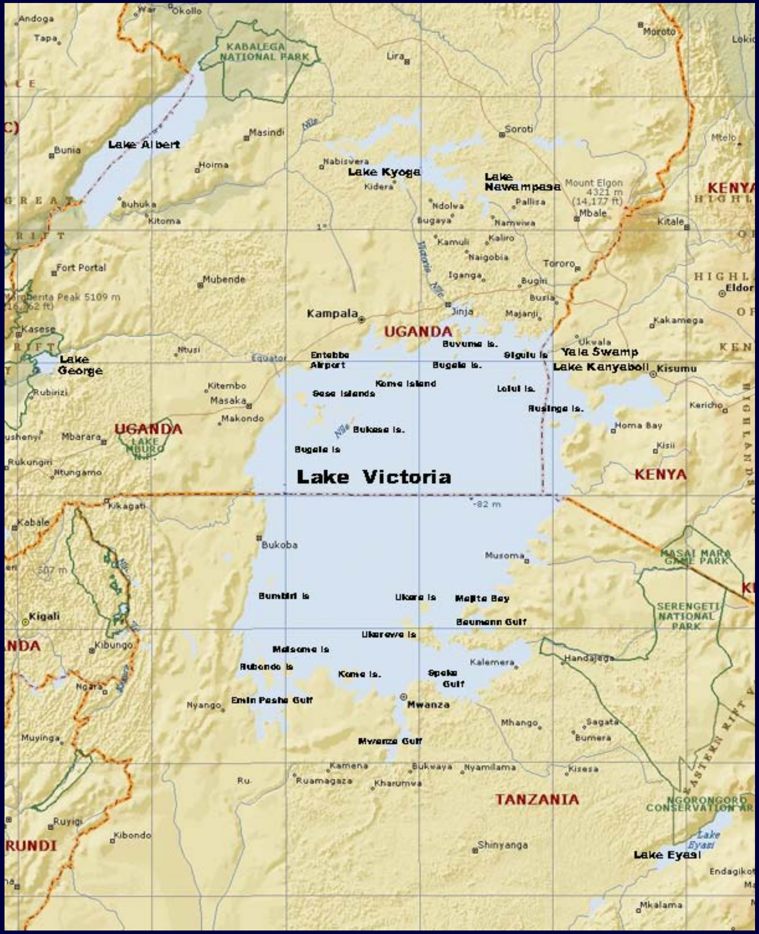


FIGURE 6.4 The number of yellow perch in Crystal Lake, Wisconsin showed cyclic population dynamics over a period of 10 years (annual size-frequency distributions). The year is indicated on the right-hand y-axis. The numbers along the left y-axis indicate relative fish abundance for each year. **Source:** data from Sanderson et al., 1999.

Nile perch introduced to Lake Victoria in 1950s

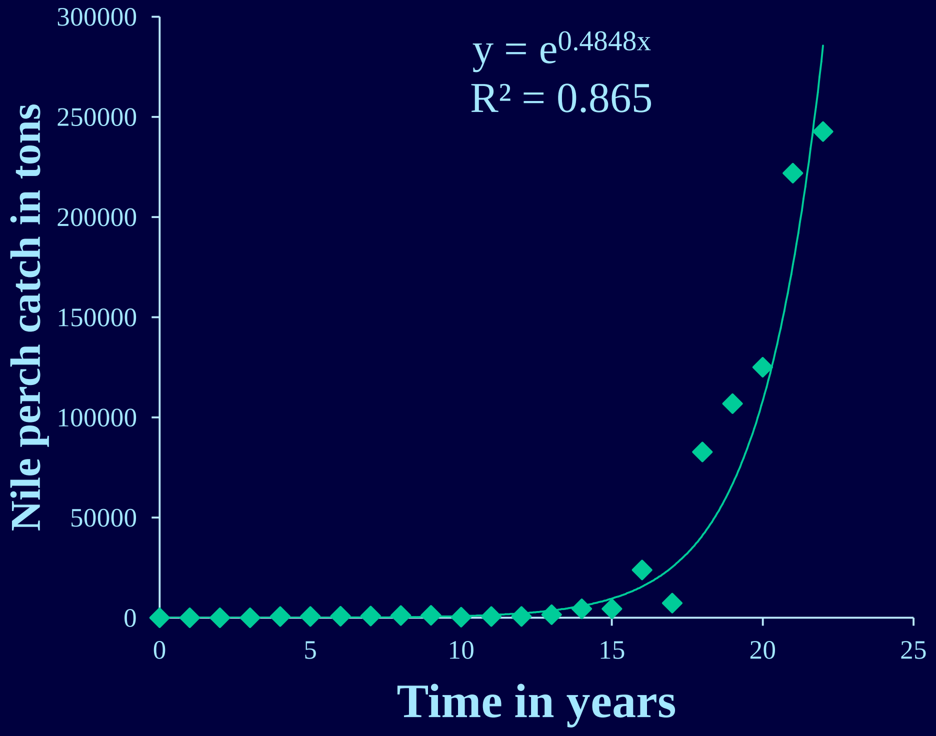


> 400 lbs

> 6 ft long

One of world's 100 worst invasive species

Nile perch expansion and its ecological effects



Nile perch drove many cichlid species to extinction

Exponential growth

Differential Equation

$dN/dt = rN$

N = population size

r = intrinsic rate of natural increase

= $(b-d)$ per capita birth rate – per capita death rate

What does per capita mean?

Exponential growth

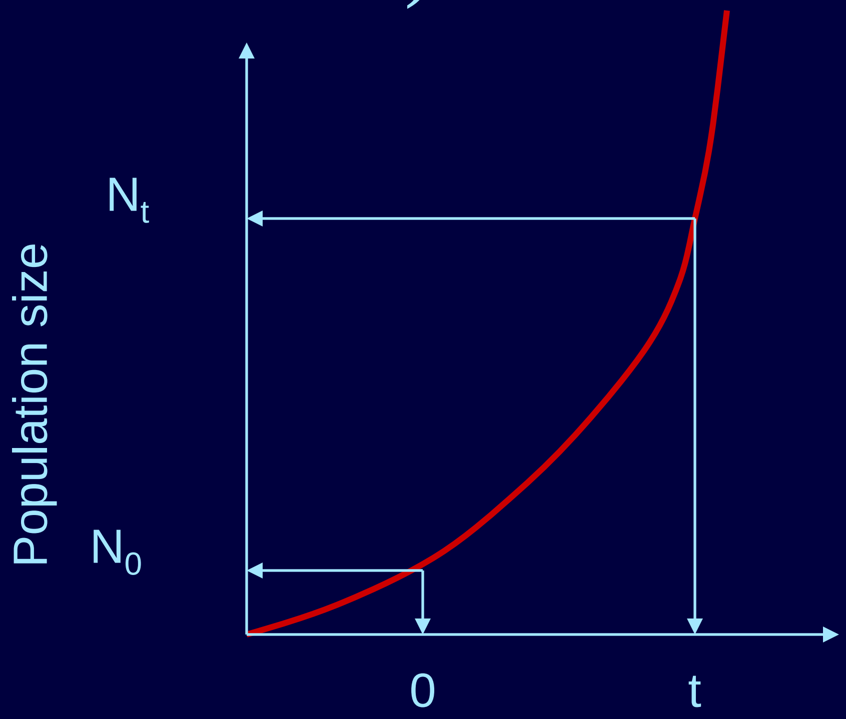
Geometric growth (seasonal births)

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

$$N_t = N_0 \lambda^t$$

$\lambda = e^r$

$r=0, \lambda = 1$



What values for r mean a decreasing pop.?

What values for λ mean a decreasing pop.?

Exponential growth

Geometric growth (seasonal births)

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

Doubling time

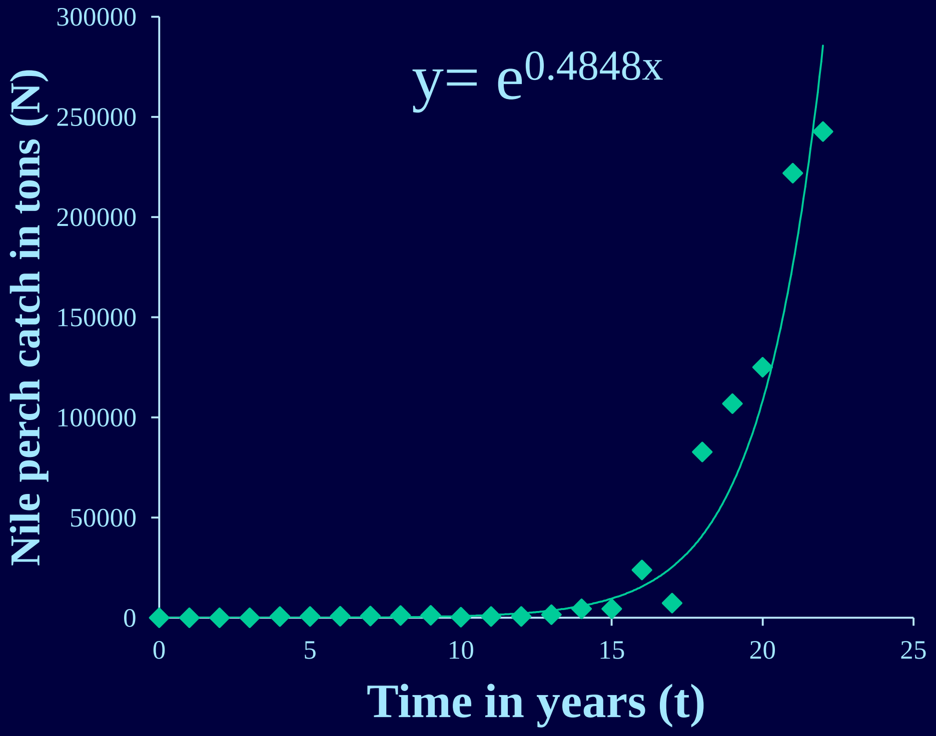
$$N_t / N_0 = 2 = e^{rt}$$

$$\ln(2) = 0.69 = rt$$

$$t_{doubling} \sim 0.7/r$$

$$\sim 70/r*100$$

Nile perch



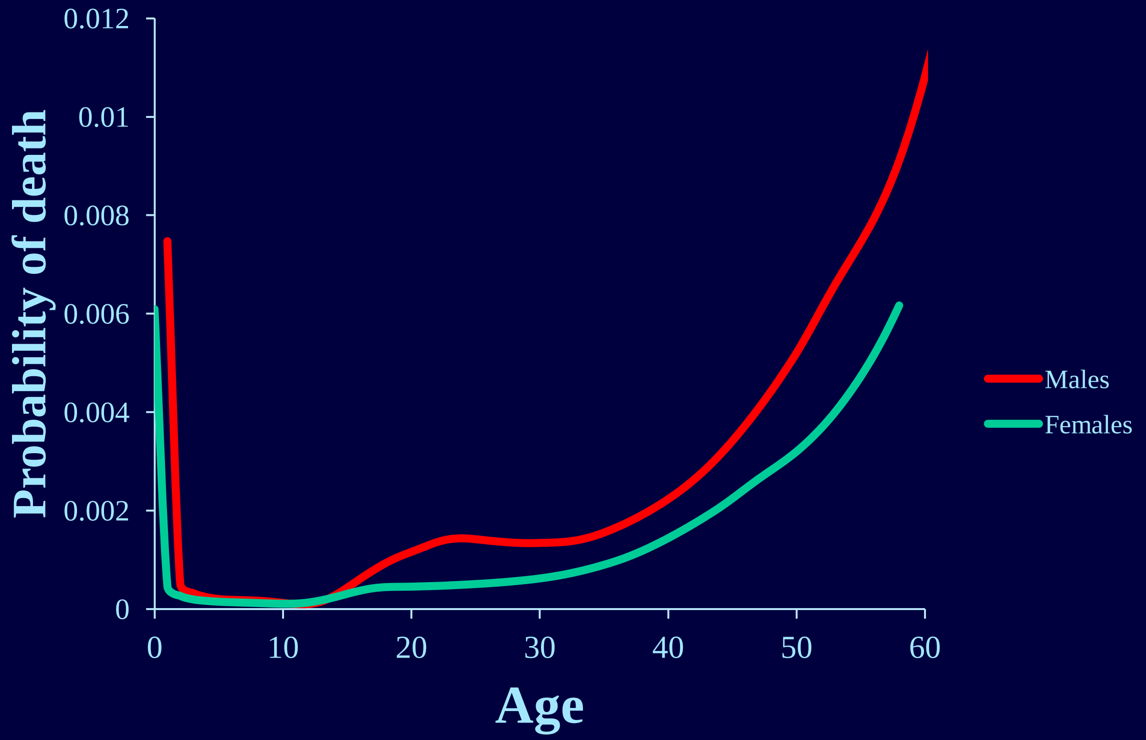
$N_t = e^{0.5t}$

$N_t = N_0 e^{rt}$

What is the doubling time?

Big assumption

Birth and death rates do not vary with age



→ Matrix models

2^{nd} Big assumption

Birth and death rates remain constant regardless of population density

Beginning with 1 Hydra

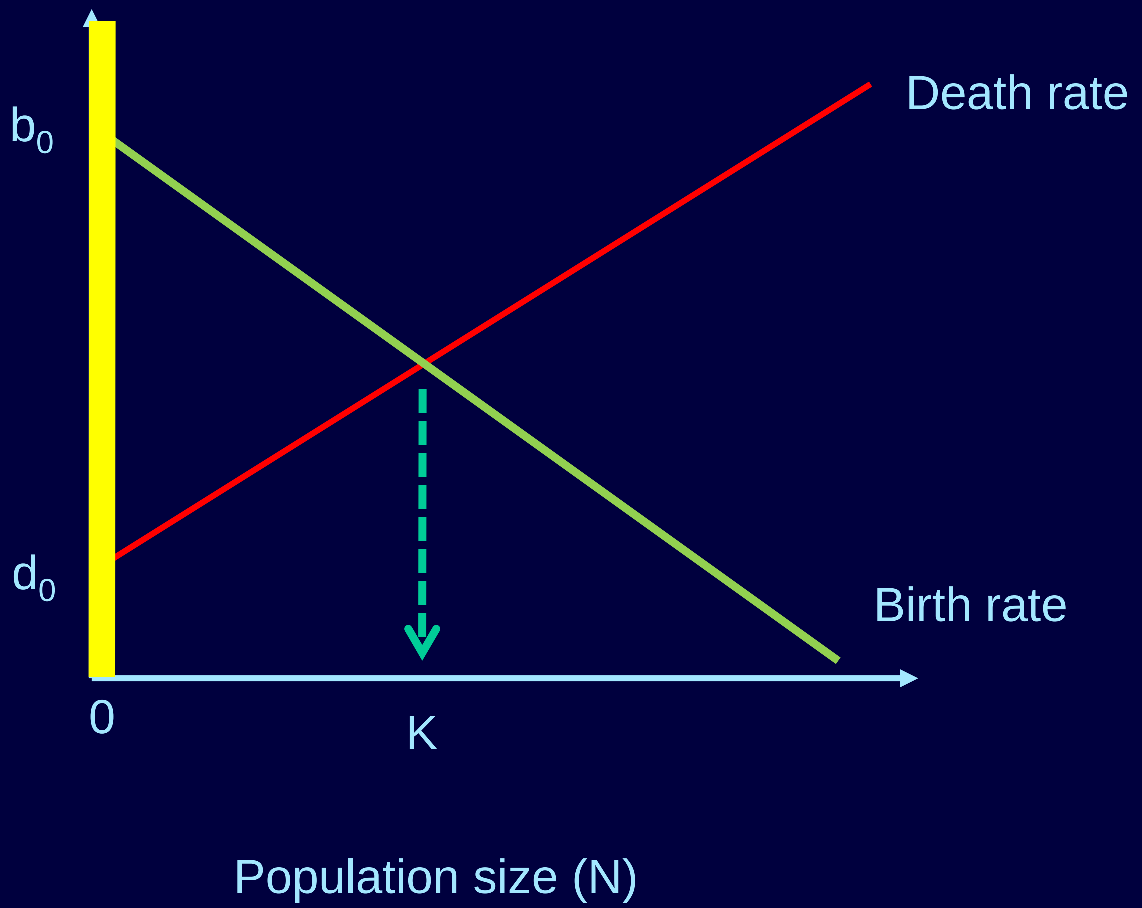
99 days to span across equator

Any organism growing exponentially would soon take over the Earth

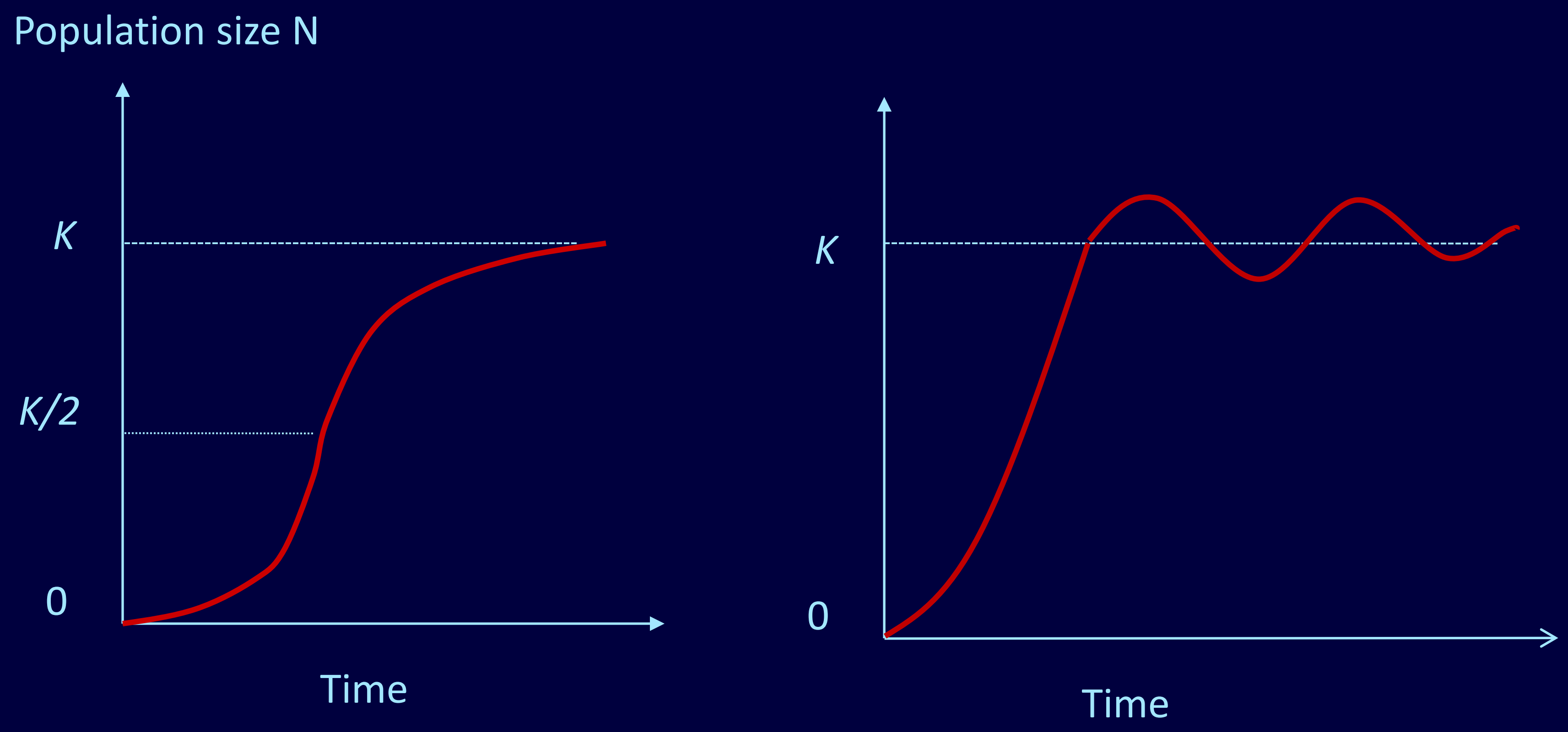
What is population regulation?

- Density-dependent control of population size
- Birth/death rates depend on population size
- Due to intraspecific competition for limited resources

Density dependent vital rates



The logistic equation describes the growth of a regulated population



Logistic growth

Differential Equation

$dN/dt = rN(1 - N/K)$

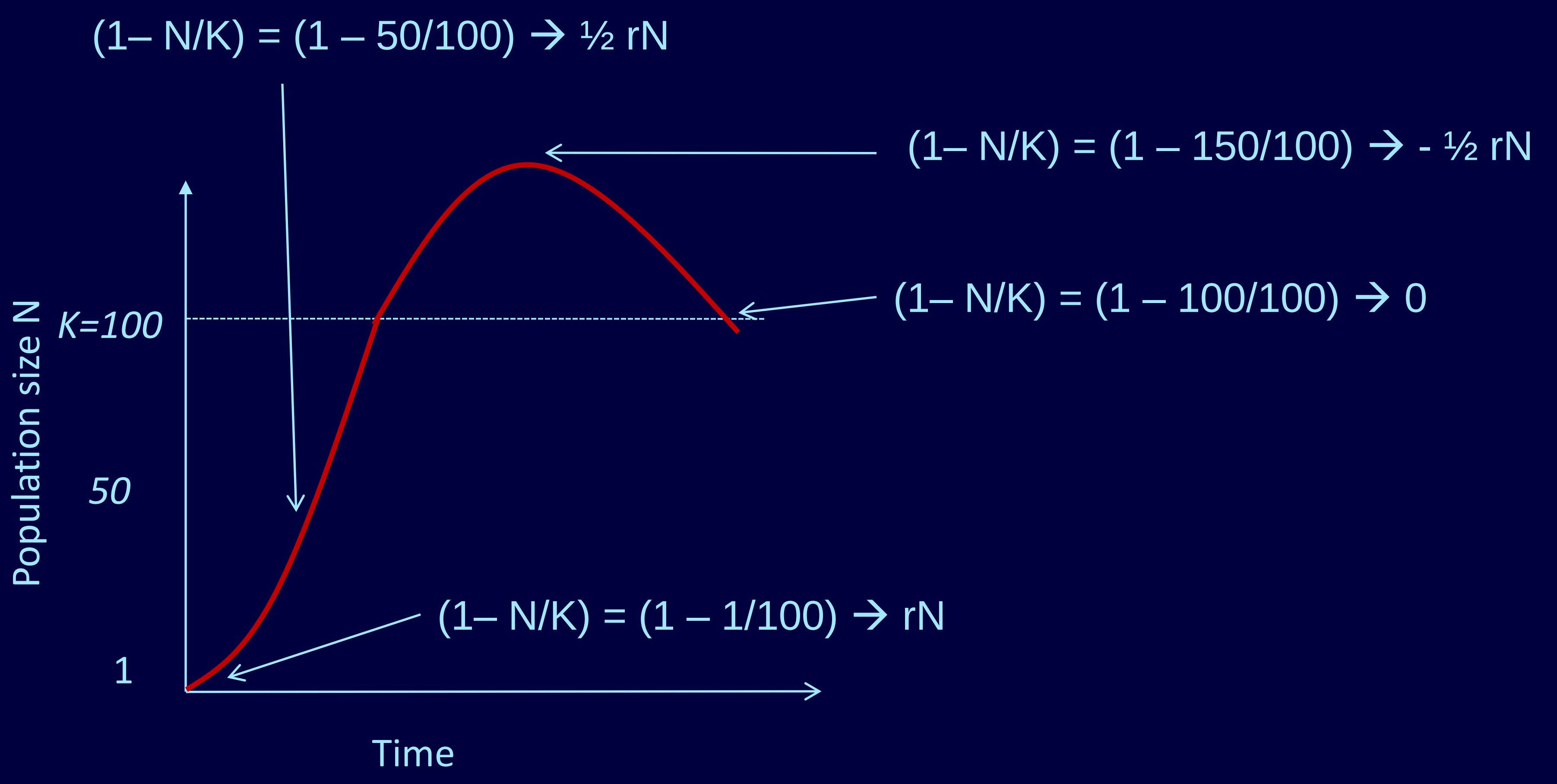
N = population size

r = intrinsic rate of natural increase

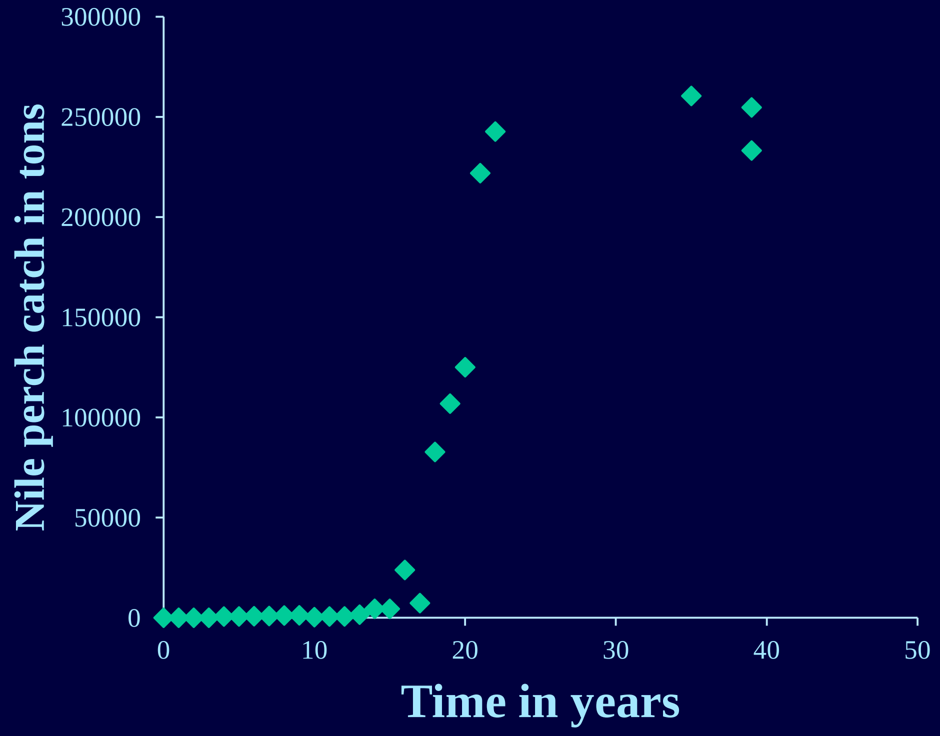
K = carrying capacity

The logistic equation

$$dN/dt = rN\,(1 - N/K)$$



Nile perch today



Population control example

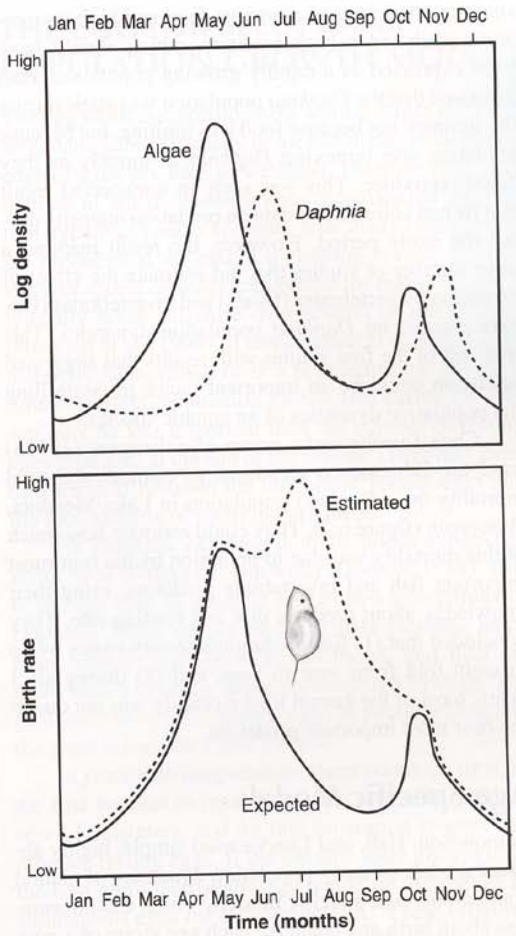


FIGURE 6.6 An idealized interpretation of a *Daphnia* population studied by Hall (1964). The top graph shows the generalized pattern of population dynamics of the algae population and *Daphnia galeata mendotae* in Base Line Lake, Michigan. The lower graph shows the *expected Daphnia* birthrate (the solid line, correlated with algae density in the upper graph) and the actual *observed* rate estimated from the algae and temperature model (dotted line). Hall's surprise was that something besides food appeared to be controlling *Daphnia* birthrate during the summer months.

Hall's work on Daphnia

Expected higher densities and birth rates during summer

Solution: ?

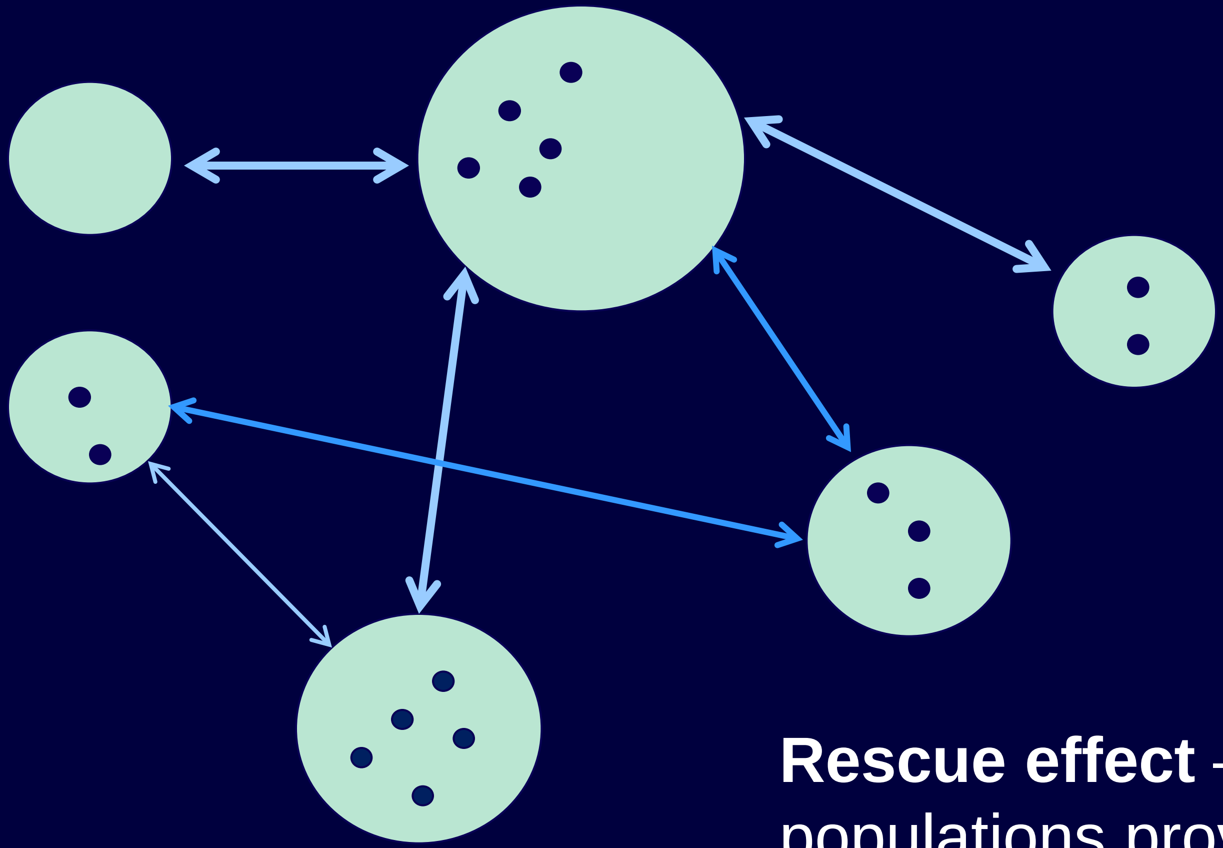
Factors affecting population size

- Density-dependent factors
  - competition for resources
  - predation (generalist)
  - Allee effects (positive)

- Density-independent factors
  - climate
  - disturbance
  - predation (specialist)

Metapopulation – multiple subpopulations linked by migration

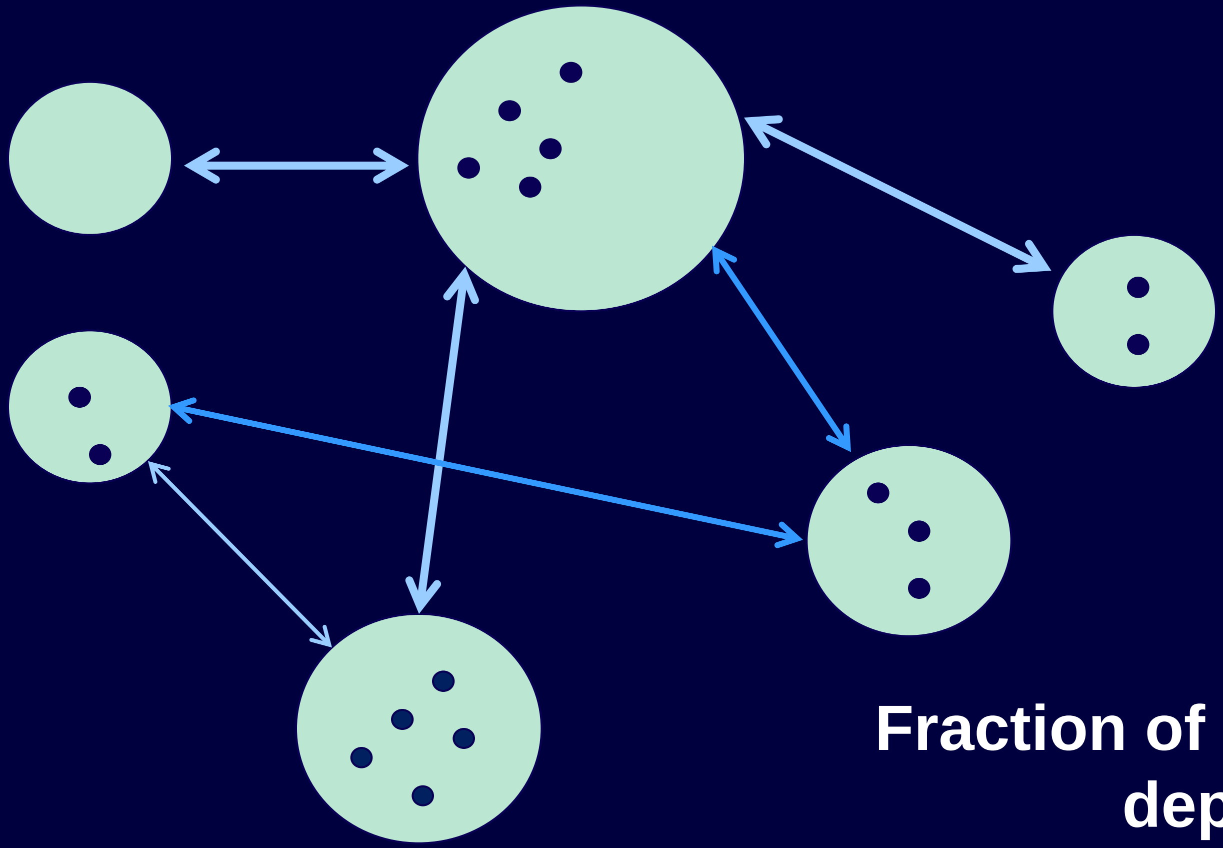
Leibold et al. 2004



Rescue effect – large productive populations provide immigrants that keep small populations from going extinct by chance

Metapopulation – multiple subpopulations linked by migration

Leibold et al. 2004



Fraction of occupied habitats depends on:

1. Migration

2. Local extinction