Lake organisms & 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 env.

Why?

Very common in aquatic systems

Why?

Cyclomorphosis: seasonally varying plasticity in morphology

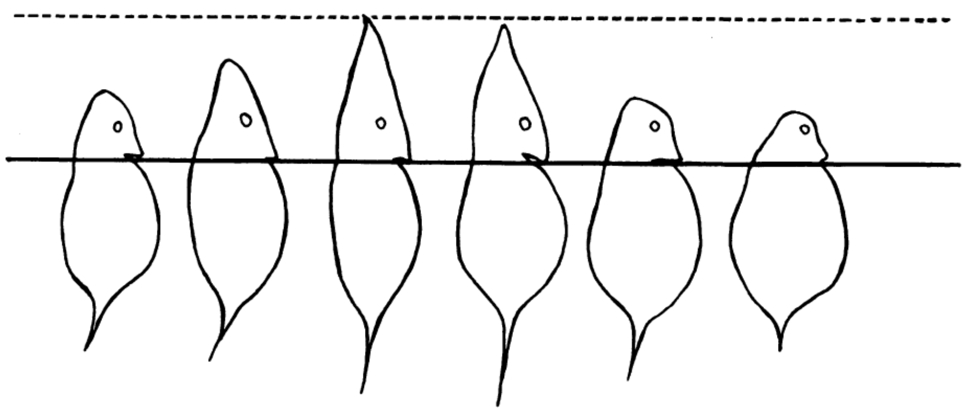
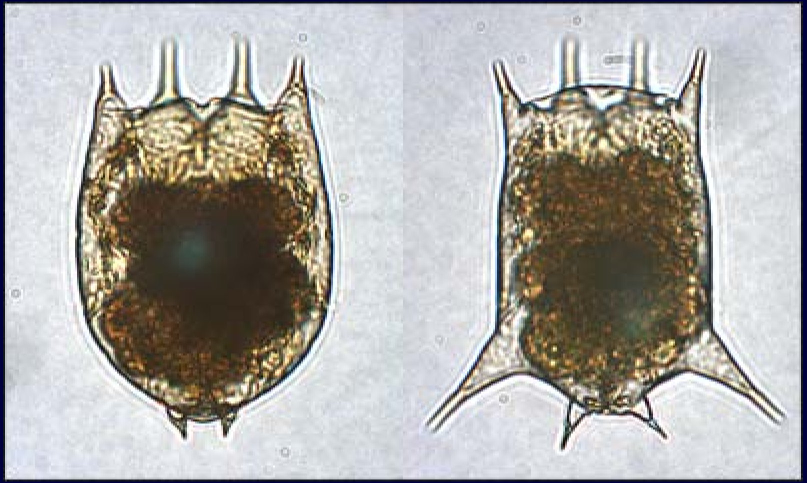
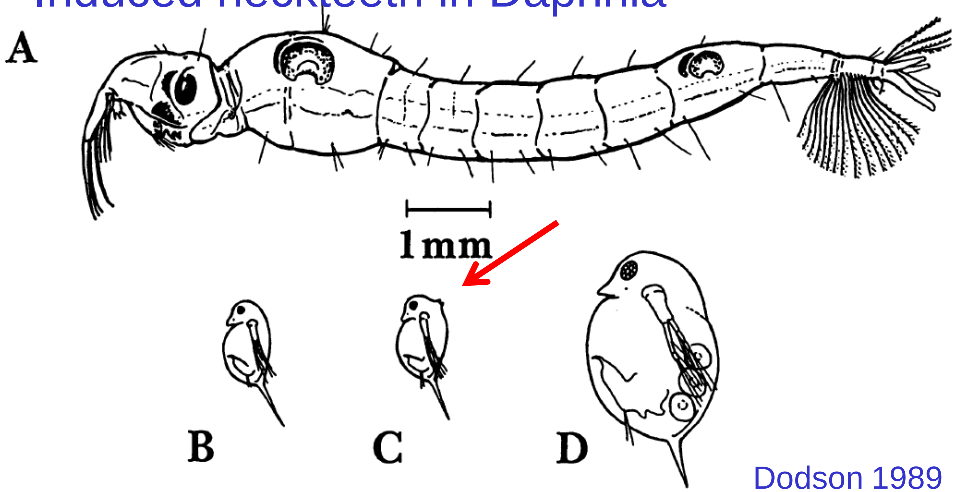


Figure 2. Helmet height in *Daphnia* as a function of the time of year. This figure is redrawn from Woltereck (1909). The adults were collected at different times of the year and belong to different generations: from left to right, 3 July, 28 July, 30 August, 15 September, 18 October, and 3 January.



Brachionus rotifer – induced spines

Induced neckteeth in Daphnia



Dodson 1989

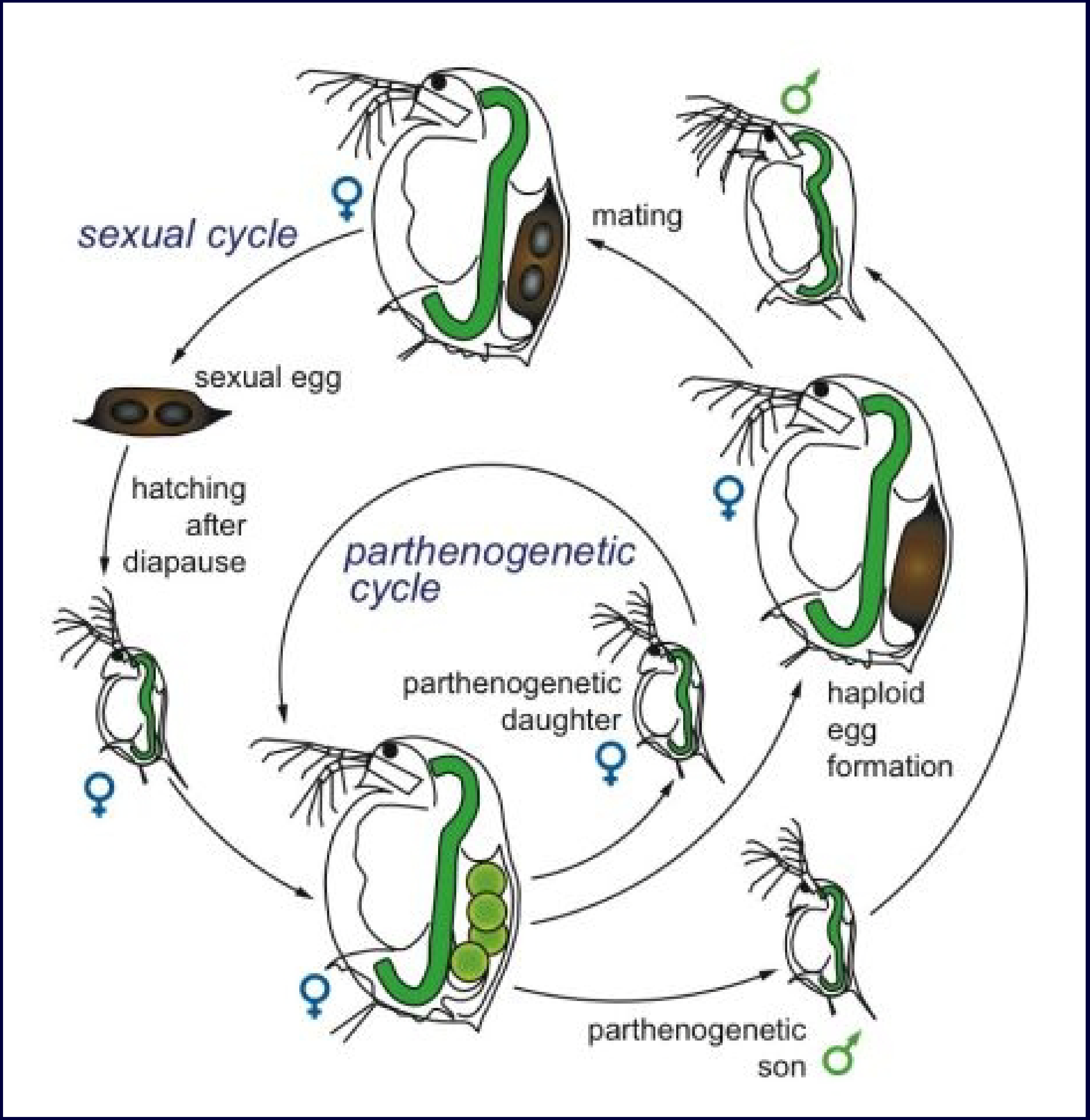
Reliable indicator of predation leads to altered prey traits

Seasonal disturbance

Diapause: Physiological state with suspended metabolism

Seed or egg bank in lake bottom – can help populations get through tough seasons or many years

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

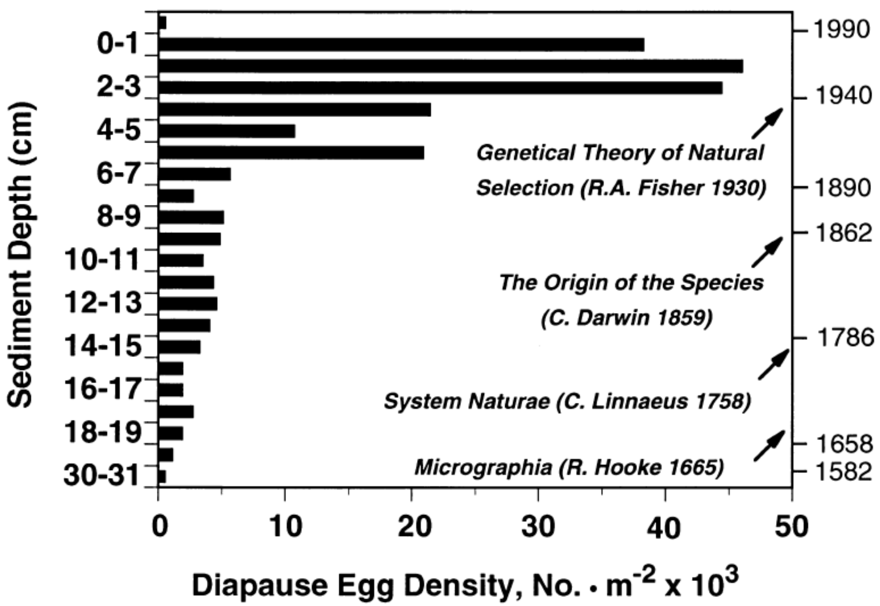


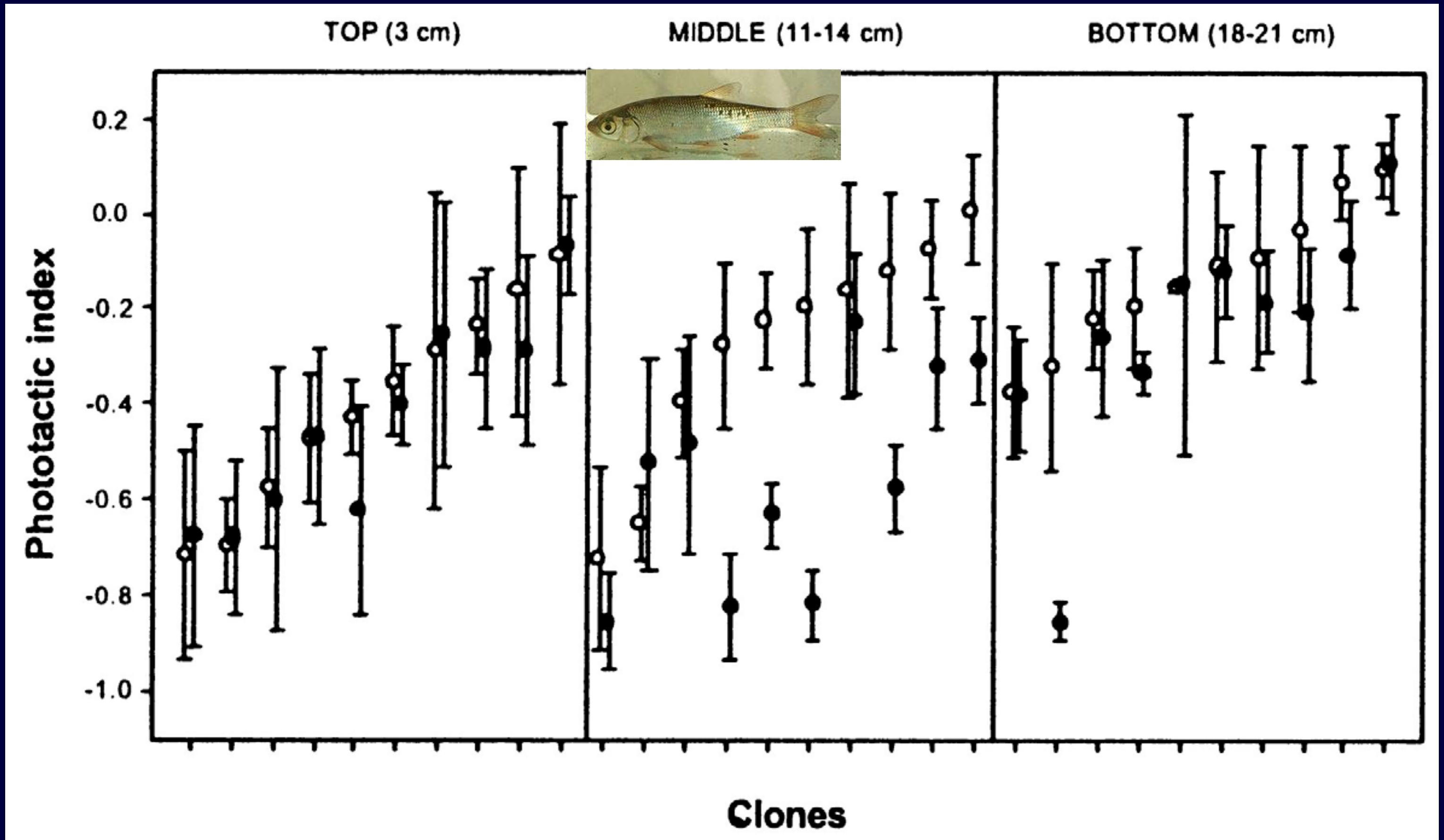
FIG. 2. The depth distribution of viable diapausing eggs of *Diaptomus sanguineus* in the egg bank of the central deep sediments of Bullhead Pond, R.I. Sediment dates determined by ^{210}Pb-dating (see Fig. 4). Key publication landmarks in evolutionary biology are provided as reference points for when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

Hairston & Kearns 2002

"Resurrection" ecology

Recreate past communities

Search for evolution



Populations in Lakes

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

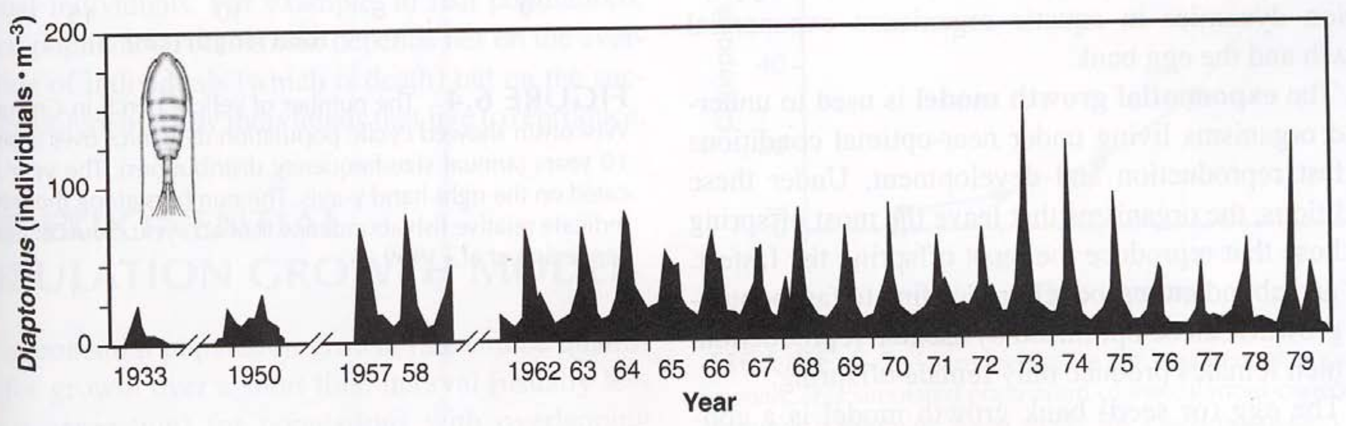


FIGURE 6.3 A graph of number of the calanoid copepod (*Diaptomus ashlandi*, an aquatic population with high variance in bers over time, with a strong annual component to the variation, Lake Washington. **Source:** Data from Edmondson & Litt, 1982.

Fig. 6.3

Often spring bloom

Decrease in summer and winter

Sometimes fall bloom

Populations sometimes cycle over longer periods

Cohort effects – strong recruitment

Cannibalism then leads to small future size classes

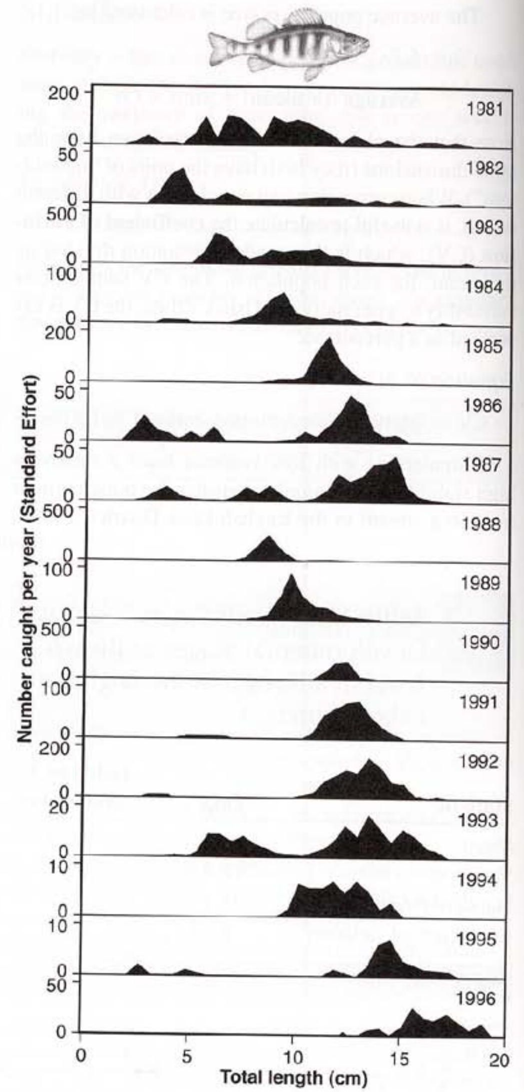


FIGURE 6.4 The number of yellow perch in Crystal Lake, Wisconsin showed cyclic population dynamics over a period of 10 years (annual size-frequency distributions). The year is indicated on the right-hand y-axis. The numbers along the left y-axis indicate relative fish abundance for each year. **Source:**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

Population dynamics

Critical goal in ecology and fisheries management

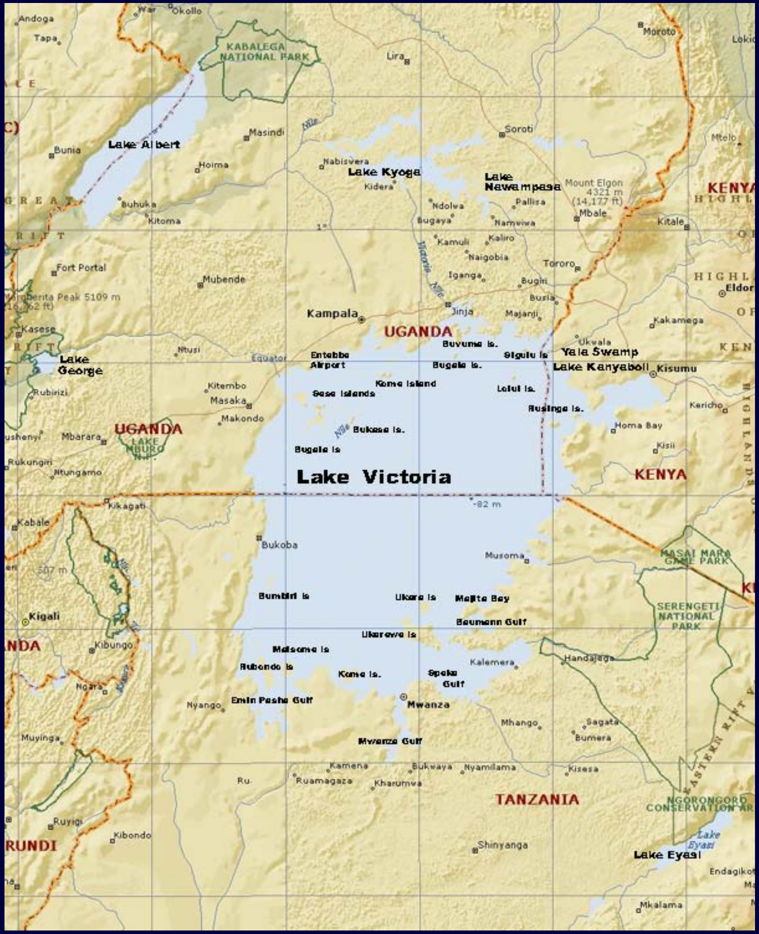
Create simple to complex models to predict numbers, and sustainable exploitation

Exponential increase is most basic

If a hydra population starts with 1 individual and doubles in size every two days, after 90 days the number of hydra will be:

A. 90
B. 180
C. approximately 9,000
D. approximately 2.5 million
E. approximately 35 trillion

Nile perch introduced to Lake Victoria in 1950s

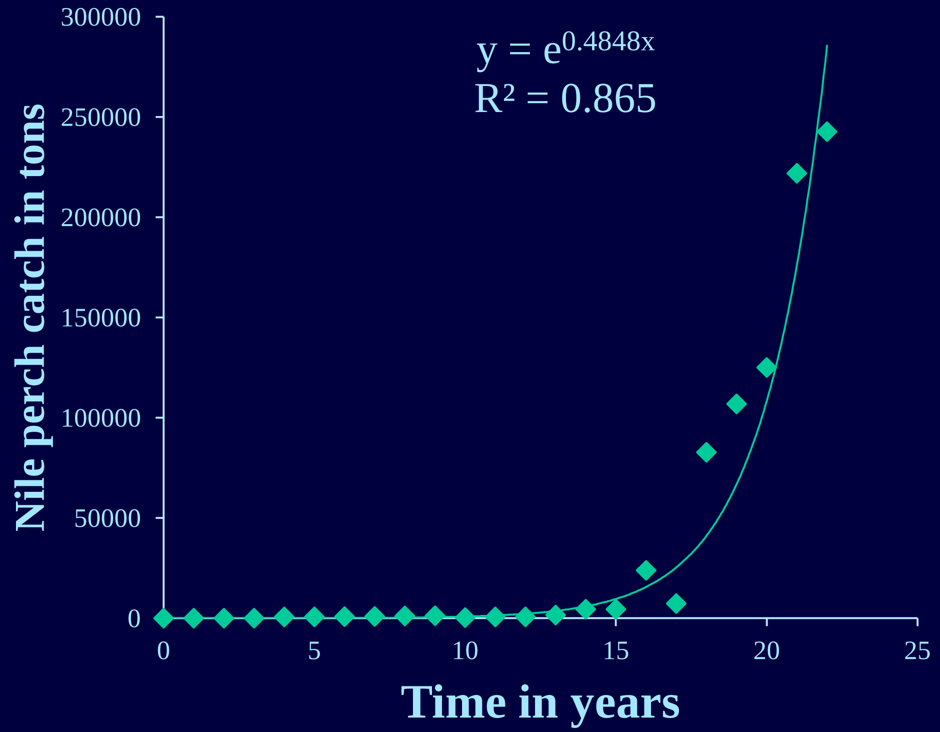


> 400 lbs

> 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

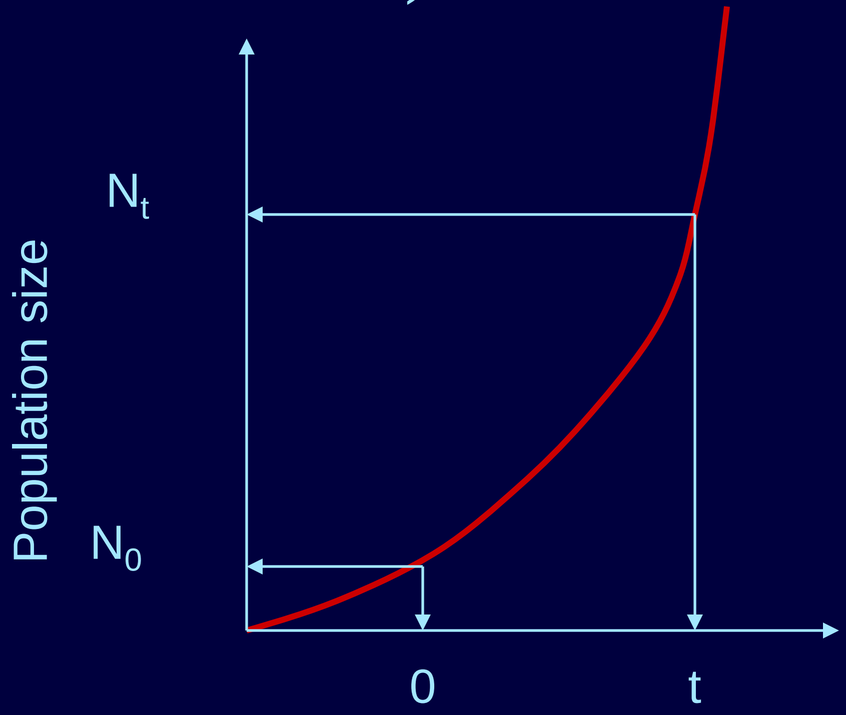
Geometric growth (seasonal births)

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

$$N_t = N_0 \lambda^t$$

$\lambda = e^r$

$r=0, \lambda = 1$



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

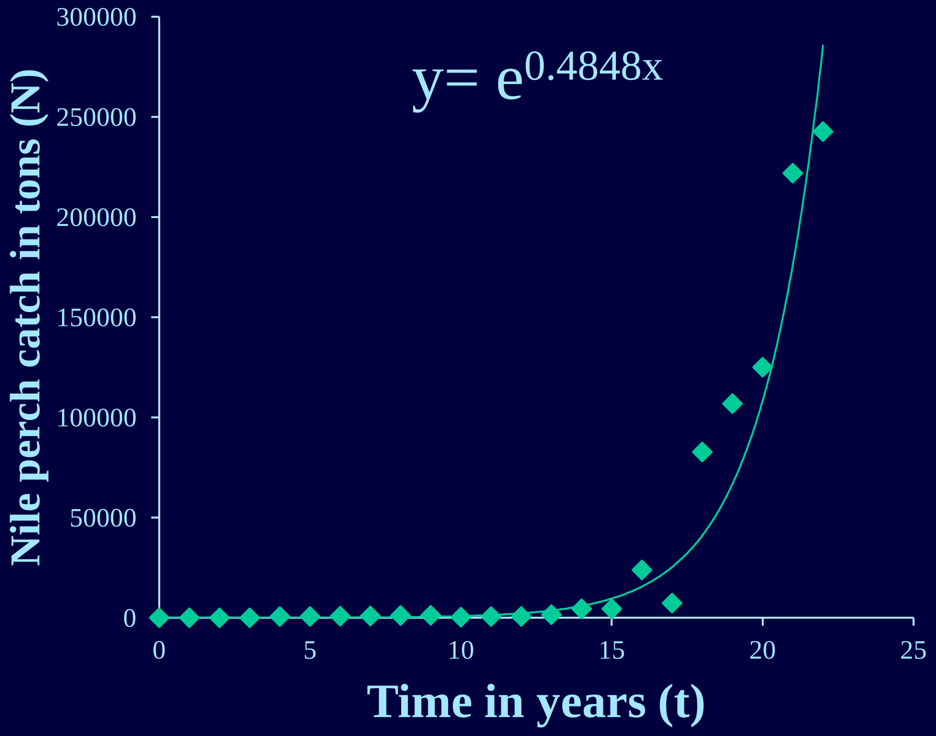
$N_t / N_0 = 2 = e^{rt}$

$\ln(2) = 0.69 = rt$

$t_{doubling} \sim 0.7/r$

$\sim 70/r*100$

Nile perch



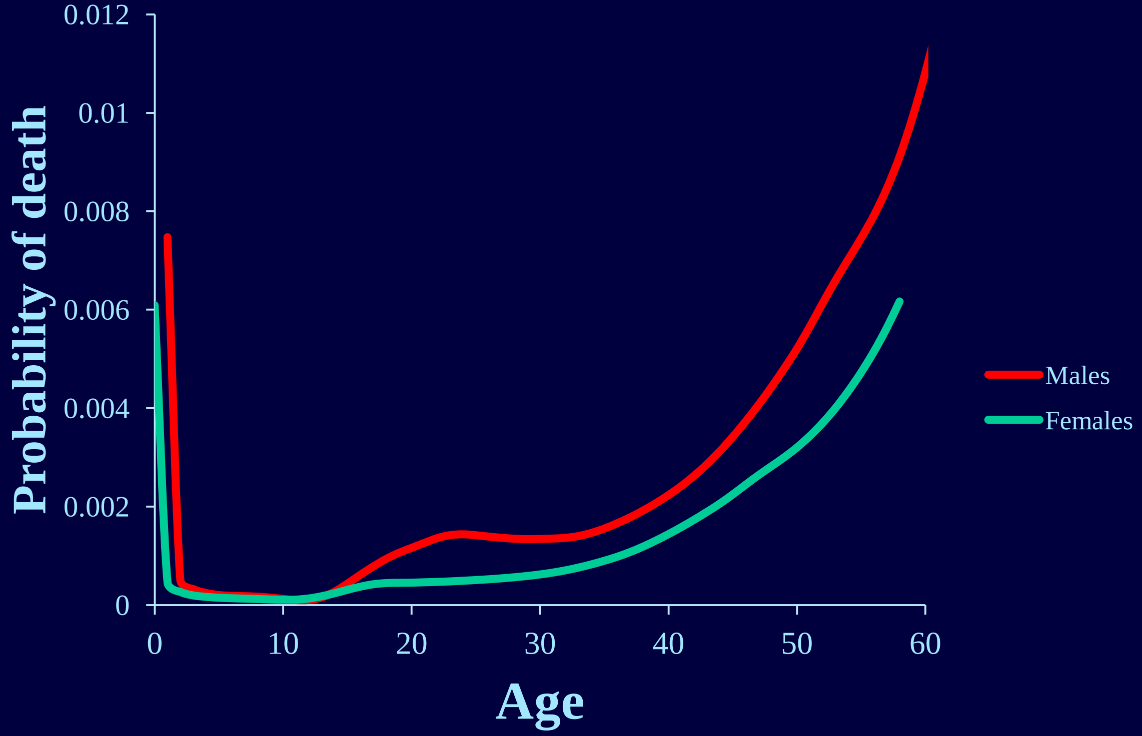
$N_t = e^{0.5t}$

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

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

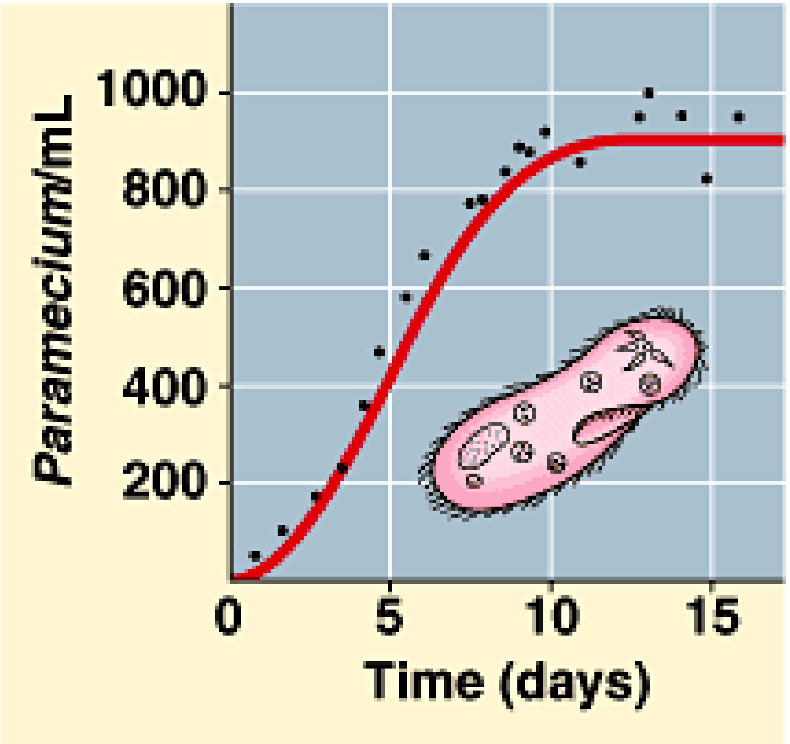
Beginning with 1 Hydra

99 days to span across equator

Any organism growing exponentially would soon take over the Earth

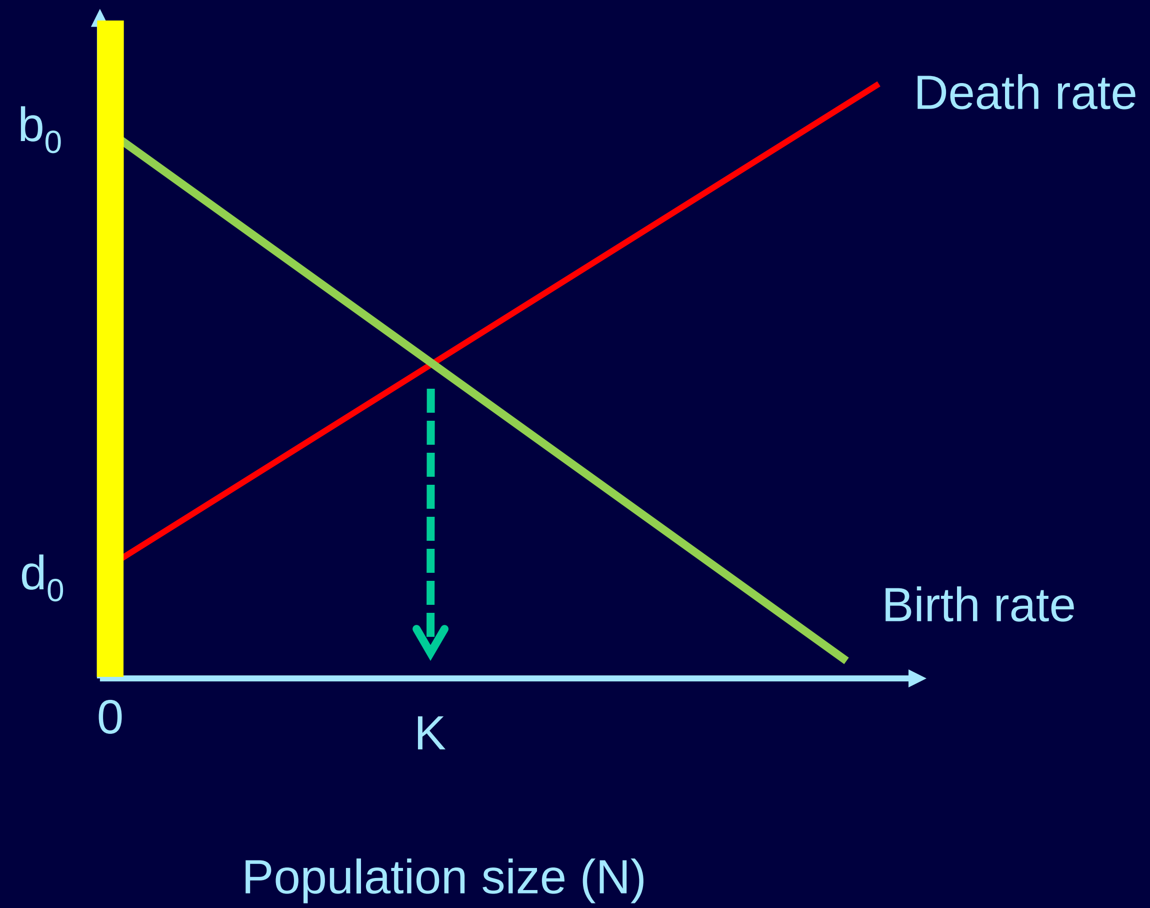
What is population regulation?

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

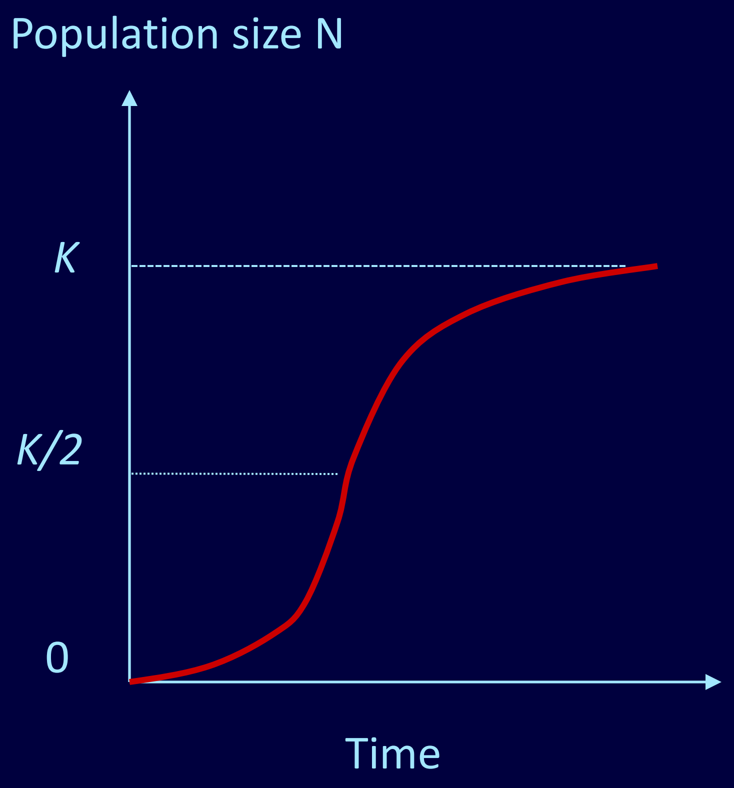


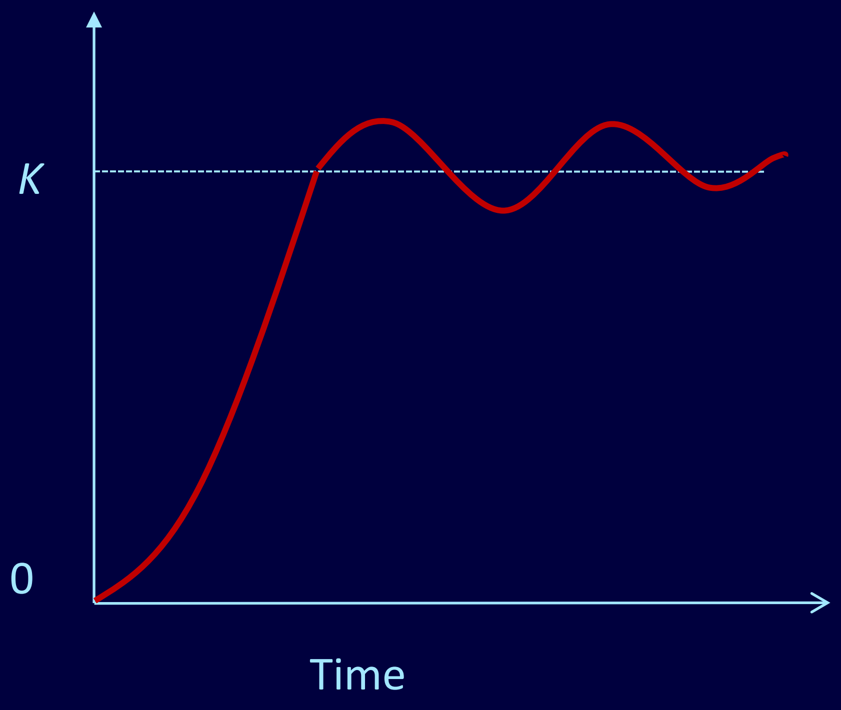
(a) A *Paramecium* population
in laboratory culture

Density dependent vital rates



The logistic equation describes the growth of a regulated population





Logistic growth

Differential Equation

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

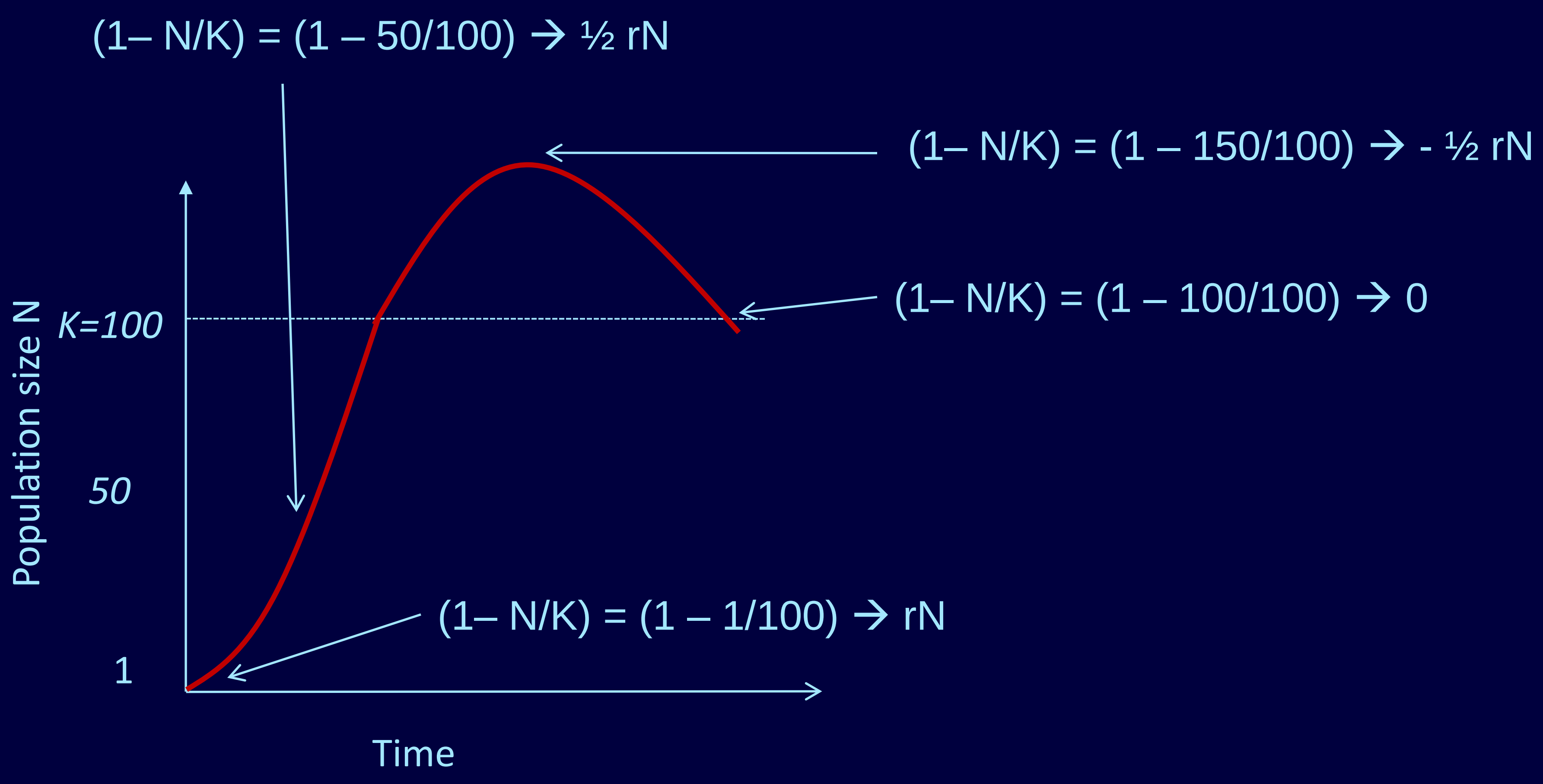
N = population size

r = intrinsic rate of natural increase

K = carrying capacity

The logistic equation

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



Factors affecting population size

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

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

Predation

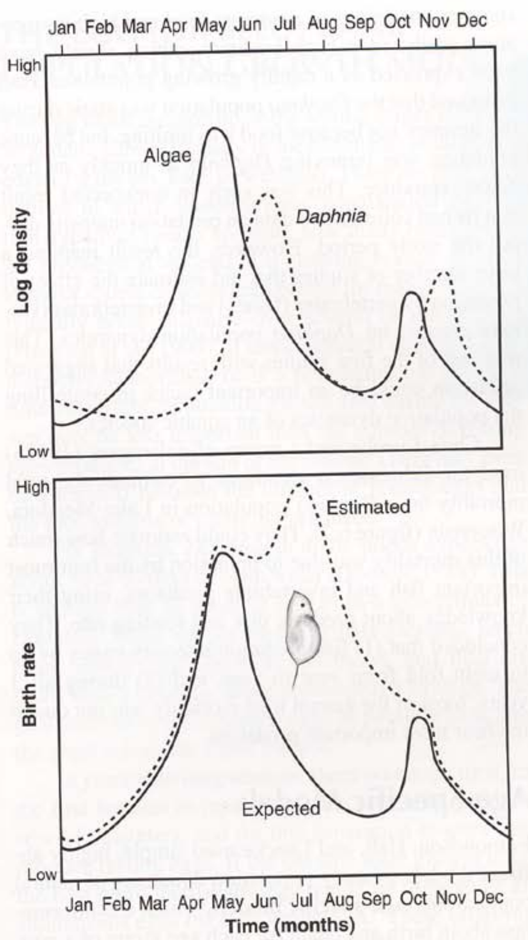


FIGURE 6.6 An idealized interpretation of a *Daphnia* population studied by Hall (1964). The top graph shows the generalized pattern of population dynamics of the algae population and *Daphnia galeata mendotae* in Base Line Lake, Michigan. The lower graph shows the *expected Daphnia* birthrate (the solid 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: Predators capture all extra births and control daphnia

Algae, zoop, predator seasonal cycles

Nile perch today