Chapter 53: Population Ecology

AP Biology 2013

1

Population Ecology

- the study of populations in relation to the environmental influences on population density and distribution, age structure, and variations in population size

Fur Seals (*Callorhinus ursinus*), St. Paul Island, Alaska

2

Population

- group of individuals of a single species living in the same general area
- populations evolve through natural selection
- Density - the number of individuals per unit area or volume
- Dispersion - the pattern of spacing among individuals within the boundaries of the population

3

Density: A Dynamic Perspective

- Density is often estimated from population indexes like number of nests, burrows, tracks or feces.
- Mark and Recapture Method
- Birth rate and death rate
- Immigration - influx of new individuals from other areas
- Emigration - movement of individuals out of a population

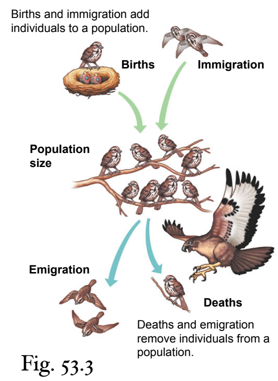


Fig. 53.3

4

Mark and Recapture

- Assumes each organism has an equal chance of being captured
- Scientists capture, tag, and release a random sample of individuals (s) in a population
- Marked individuals are given time to mix back into the population
- Scientists capture a second sample of individuals (n) and note how many of them are marked (x)
- Population size (N) is estimated by the equation $N=(sn)/x$

5

Dispersion Patterns

- Environmental and Social factors influence spacing.
- Types of spacing:
  - Clumped
  - Uniform
  - Random

6

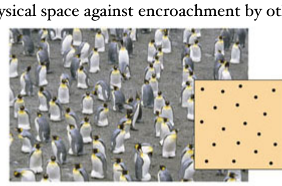
Clumped Dispersion

- Individuals aggregate in patches
  - Plants and fungi can be clumped based on soil conditions (microenvironments)
  - Clumping may be associated with mating behavior
  - Increases effectiveness of predators

Fig. 53.4

Uniform Dispersion

- Evenly spaced (not as common as clumped patterns)
- May result from direct interactions between individuals in the population
  - Some plants secrete chemicals that inhibit the germination and growth of nearby individuals
  - Can be a result of antagonistic social interactions
  - Territoriality - defense of a bounded physical space against encroachment by other individuals



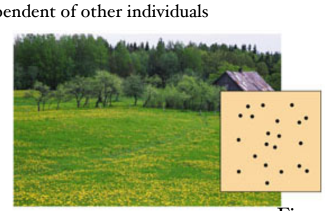
(b) Uniform. Birds nesting on small islands, such as these king penguins on South Georgia Island in the South Atlantic Ocean, often exhibit uniform spacing, maintained by aggressive interactions between neighbors.

Figure 52.3b

Fig. 53.4

Random Dispersion

- Unpredictable spacing (not very common)
- Occurs in the absence of strong attractions or repulsions among individuals of a population
- Key physical and chemical factors must be relatively homogeneous across the study area
- The position of each individual is independent of other individuals



(c) Random. Dandelions grow from windblown seeds that land at random and later germinate.

Figure 52.3c

Fig. 53.4

Demography

- the study of the vital statistics of populations and how they change over time
  - Birth rates and death rates
  - Life tables - age-specific summaries of survival patterns of a population
    - Cohort - group of individuals of the same age studied from birth to death

Survivorship Curves

- plot of the proportion or numbers in a cohort still alive at each age
- Type I - flat at start and drops steeply in older age groups (large mammals that produce few offspring but provide significant care)
- Type III - drop sharply at start and then level off (organisms that produce many offspring and provide little care)
- Type II - constant death rate (rodents, invertebrates, some lizards, annual plants)

Reproductive Rates

- age-specific summary of the reproductive rates in a population (fertility schedule)

Table 53.2 Reproductive Table for Belding's Ground Squirrels at Tioga Pass

Age (years)	Proportion of Females Weaning a Litter	Mean Size of Litters (Males + Females)	Mean Number of Females in a Litter	Average Number of Female Offspring*
0–1	0.00	0.00	0.00	0.00
1–2	0.65	3.30	1.65	1.07
2–3	0.92	4.05	2.03	1.87
3–4	0.90	4.90	2.45	2.21
4–5	0.95	5.45	2.73	2.59
5–6	1.00	4.15	2.08	2.08
6–7	1.00	3.40	1.70	1.70
7–8	1.00	3.85	1.93	1.93
8–9	1.00	3.85	1.93	1.93
9–10	1.00	3.15	1.58	1.58

Source: P. W. Sherman and M. L. Morton, Demography of Belding's ground squirrel, *Ecology* 65:1617–1628 (1984).

*The average number of female offspring is the proportion weaning a litter multiplied by the mean number of females in a litter.

Exponential Growth

- Only occurs in an idealized, unlimited environment
- Eventually as resources are depleted, population size will level off.
- Intrinsic rate of increase - rate of increase is at its maximum

Per Capita Rate of Increase

- If immigration and emigration are ignored, population rate equals birth rate minus death rate
- N = population size
- t = time
- B = number of births
- D = number of deaths
- b = per capita birth rate
- m = per capita death rate
- r = per capita rate of increase

$\Delta N/\Delta t = B - D$

$B = bN$

$D = mN$

Thus, $\Delta N/\Delta t = bN - mN$

$r = b - m$

Thus, $\Delta N/\Delta t = rN$

Per Capita Rate of Increase

- $r > 0$, population is growing
- $r < 0$, population is decreasing
- $r = 0$, population stays the same

$$\frac{dN}{dt} = r_{max}N$$

Exponential Growth

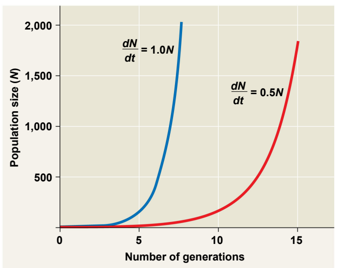


Fig. 53.7

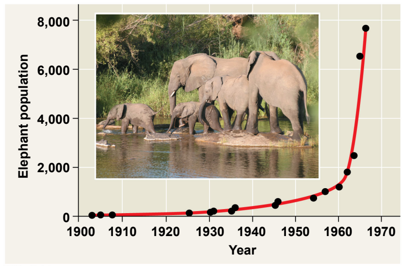


Fig. 53.8

J-shaped curve
characteristic of populations that are rebounding

Carrying Capacity

- Resources are never unlimited, thus exponential models have limited uses.
- Carrying capacity (K) - maximum population size that a particular environment can support
- Not fixed (can change over time)

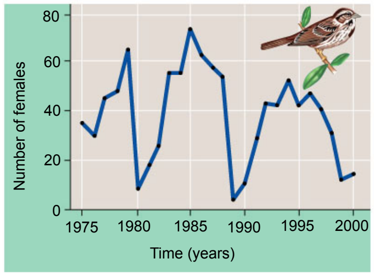
Logistic Growth Model

- Per capita rate of increase declines as carrying capacity is reached
- Start with an exponential model and add an expression that reduces the per capita rate of increase as N increases

$$\frac{dN}{dt} = r_{max}N\frac{(K - N)}{K}$$

Logistic Growth in Real Populations

Some populations fluctuate greatly and make it difficult to define K



(c) A song sparrow population in its natural habitat. The population of female song sparrows nesting on Mandarte Island, British Columbia, is periodically reduced by severe winter weather, and population growth is not well described by the logistic model.

Figure 52.13c

19

Logistic Model and Life Histories

- High density populations = few resources = slow population growth (iteroparity)
- Low density populations = abundant resources = rapid population growth (semelparity)
- K-selection - density-dependent selection (iteroparity)
- r-selection = density-independent selection (semelparity)

20

Life History

- traits that affect an organism's schedule of reproduction and survival
- Three variables:
  - when reproduction begins (age of first reproduction)
  - how often the organism reproduces
  - how many offspring are produced during each reproductive episode

21

Life History Diversity

- Semelparity (big-bang reproduction) - produce many offspring and then die (ex. salmon, agave)
- Iteroparity (repeated reproduction) - produce offspring several times over life (ex. birds, most mammals)

Fig. 53.12

22

Population Change and Population Density

- Density independent - birth rate or death rate that does not change with population density
- Density dependent - death rate rises or a birth rate that falls as population rises

23

Population and Density

- K-selection (density-dependent selection) - selects for life history traits that are sensitive to population density
- r-selection (density-independent selection) - selects for life history traits that maximize reproduction

24

Density Dependent Regulation

- Negative feedback
- Mechanisms that affect density dependent regulation:

25

Population Dynamics

- study of the complex interactions between abiotic and biotic factors that cause variation in population size

26

Stability and Fluctuation

- Long-term population studies challenge the idea that large mammals are stable over time

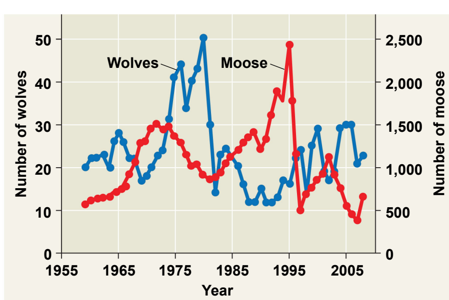


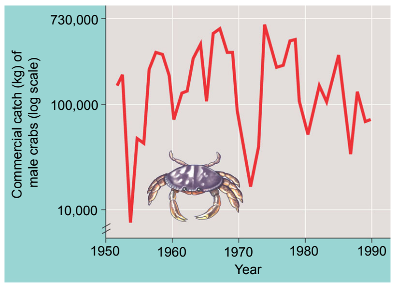
Fig. 53.18

27

Stability and Fluctuation

- Extreme fluctuation is more common in invertebrates than large mammals

Figure 52.19



Metapopulations and Immigration

- Metapopulations - groups of populations linked by immigration and emigration
- Can allow for greater stability

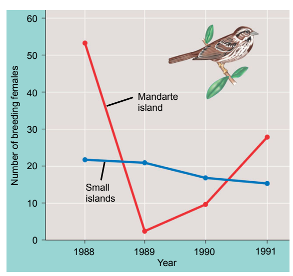
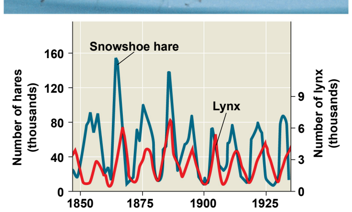


Figure 52.20

Population Cycles

- Some species have regular, predictable population cycles (boom and bust)
- Ex. Linx and Snow-shoe Hare have a ten-year cycle
  - What could cause this?
  - How could an experiment be designed to test this?

Figure 53.19



Human Population Growth

- Population explosion of humans since 1650
- Global population grows by approximately 201,000 per day (every 4 years the Earth adds about as many people as live in the United States)
- Population rate of increase has begun to fall since the 1960s
  - Impact of disease and voluntary population control

31

Regional Population Patterns

- Two options for zero population growth
  - Zero population growth = high birth rate - high death rate
  - Zero population growth = low birth rate - low death rate
- The change from the first option to the second his called **demographic transition**

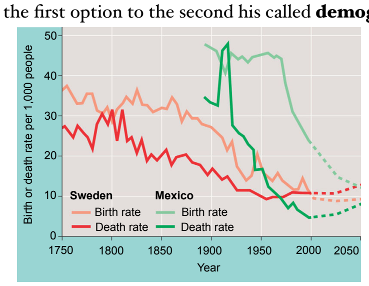


Figure 52.24

32

Age Structure

- relative number of individuals at each age

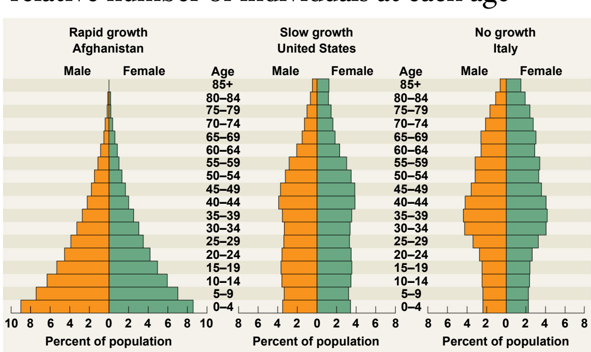


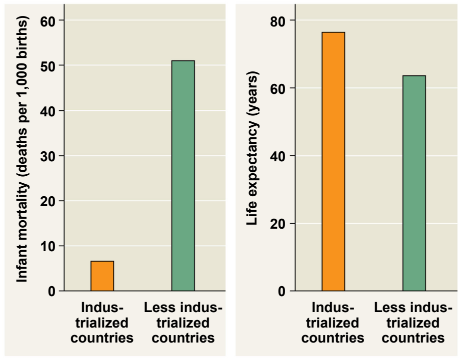
Fig. 53.24

33

Infant Mortality

Fig. 53.25

- the number of infant deaths per 1,000 live births
- Life expectancy at birth - predicted average length of life at birth



Global Human Carrying Capacity

- No idea how many people the Earth can support
  - Estimates range from 1 billion to 1,000 billion
  - Average estimate is between 10 and 15 billion (we will reach this in a few decades)

Ecological Footprint

- summarizes the aggregate land and water area appropriated by each nation to produce all the resources it consumes and absorb all the waste it generates
- calculated in hectares (1 ha = 2.47 acres)
- If you add up all the ecologically productive land each person should have about 2 ha

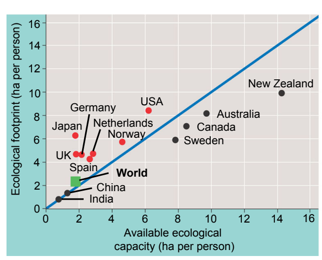


Figure 52.27

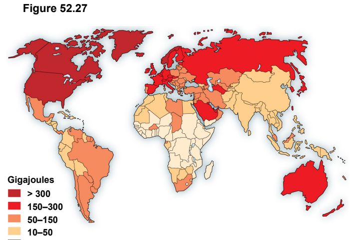


Fig. 53.26