Chapter 52

Population Ecology

PowerPoint Lectures for
Biology, Seventh Edition
Neil Campbell and Jane Reece

Lectures by Chris Romero

Population ecology

- Populations in relation to environment
  - Population
    - density and distribution
    - age structure
    - variations in population size

Sea lions in Alaska

- Question: What is causing declines in the sea lion population in Alaska?
  - Hypotheses?
  - How do we know what is "normal"?
  - Gather information

Population density, dispersion, and demography

- A population
  - Is a group of individuals of a single species living in the same general area
- Density
  - Is the number of individuals per unit area or volume
- Dispersion
  - Is the pattern of spacing among individuals within the boundaries of the population

How do you measure density?

- Impractical to count all members of population.
- Therefore;
  - Random sampling
  - Stratified random sampling
  - Mark-recapture

Population size

- Between processes that add individuals to a population and those that remove individuals from it

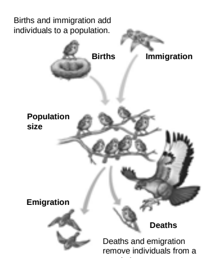


Figure 52.2

How you sample depends on dispersion

- A clumped dispersion
  - Is one in which individuals aggregate in patches
  - May be influenced by resource availability and behavior

(a) Clumped. For many animals, such as these wolves, living in groups increases the effectiveness of hunting, spreads the work of protecting and caring for young, and helps exclude other individuals from their territory.

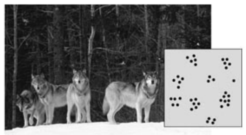


Figure 52.3a

- A uniform dispersion
  - Is one in which individuals are evenly distributed
  - May be influenced by social interactions such as territoriality

(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.

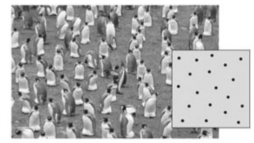


Figure 52.3b

- A random dispersion
  - Is one in which the position of each individual is independent of other individuals

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

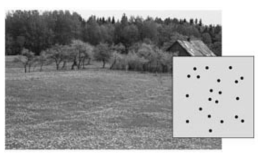


Figure 52.3c

Demography

- Demography is the study of the vital statistics of a population
  - Death rates and birth rates
  - Immigration and emmigration
  - Intrinsic rate of population growth

- addition = birth (survivability) + immigration
- subtraction = mortality (death) + emigration
- Age structure - relative number of each age
  - important for determining future birth & death rates
  - fecundity (birth rate) - usually highest in middle age
  - death rate - usually highest at low and high age
  - generation time - average time between birth and having offspring

Life tables

- An age-specific summary of the survival pattern of a population – follow a cohort

Table 52.1 Life Table for Belding's Ground Squirrels *(Spermophilus beldingi)* at Tioga Pass, in the Sierra Nevada Mountains of California*

	FEMALES					MALES				
Age (years)	Number Alive at Start of Year	Proportion Alive at Start of Year	Number of Deaths During Year	Death Rate†	Average Additional Life Expectancy (years)	Number Alive at Start of Year	Proportion Alive at Start of Year	Number of Deaths During Year	Death Rate†	Average Additional Life Expectancy (years)
0–1	337	1.000	207	0.61	1.33	349	1.000	227	0.65	1.07
1–2	252**	0.386	125	0.50	1.56	248**	0.350	140	0.56	1.12
2–3	127	0.197	60	0.47	1.60	108	0.152	74	0.69	0.93
3–4	67	0.106	32	0.48	1.59	34	0.048	23	0.68	0.89
4–5	35	0.054	16	0.46	1.59	11	0.015	9	0.82	0.68
5–6	19	0.029	10	0.53	1.50	2	0.003	0	1.00	0.50
6–7	9	0.014	4	0.44	1.61	0				
7–8	5	0.008	1	0.20	1.50					
8–9	4	0.006	3	0.75	0.75					
9–10	1	0.002	1	1.00	0.50					

*Males and females have different mortality schedules, so they are tallied separately.
†The death rate is the proportion of individuals dying in the specific time interval.
**Includes 122 females and 126 males first captured as one-year-olds and therefore not included in the count of squirrels age 0–1.

Source: Data from P. W. Sherman and M. L. Morton, "Demography of Belding's Ground Squirrel," *Ecology* 65(1984): 1617–1628.

Table 52.1

Survivorship curve

- A graphic way of representing the data in a life table
- The survivorship curve for Belding's ground squirrels
  - Shows that the death rate is relatively constant

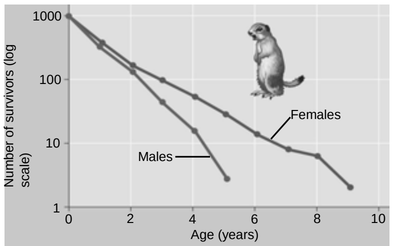


Figure 52.4

- Survivorship curves can be classified into three general types
  - Type I, Type II, and Type III

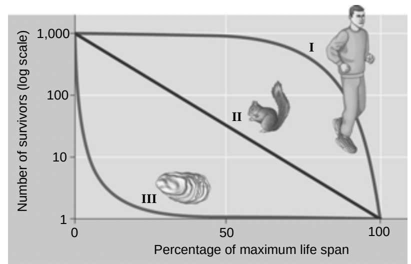


Figure 52.5

A reproductive table

- Describes the reproductive patterns of a population

Table 52.2 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

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

Data from P. W. Sherman and M. L. Morton, "Demography of Belding's Ground Squirrel," *Ecology* 65 (1984): 1617–1628.

Table 52.2

Life histories

- Life history traits are products of natural selection
- Life history traits are evolutionary outcomes
  - Reflected in the development, physiology, and behavior of an organism
- Life history traits are diverse

Semelparity

•Species that exhibit semelparity, or "big-bang" reproduction reproduce a single time and die

Figure 52.6

Iteroparity

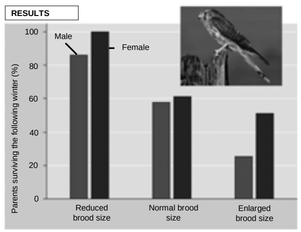
•Species that exhibit iteroparity, or repeated reproduction

- Produce offspring repeatedly over time

“Trade-offs” and Life Histories

- Organisms have finite resources
  - Which may lead to trade-offs between survival and reproduction

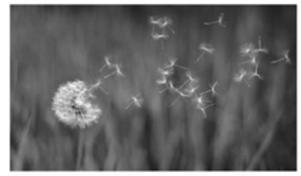
EXPERIMENT Researchers in the Netherlands studied the effects of parental caregiving in European kestrels over 5 years. The researchers transferred chicks among nests to produce reduced broods (three or four chicks), normal broods (five or six), and enlarged broods (seven or eight). They then measured the percentage of male and female parent birds that survived the following winter. (Both males and females provide care for chicks.)



CONCLUSION The lower survival rates of kestrels with larger broods indicate that caring for more offspring negatively affects survival of the parents.

Figure 52.7

- Some plants produce a large number of small seeds
  - Ensuring that at least some of them will grow and eventually reproduce



(a) Most weedy plants, such as this dandelion, grow quickly and produce a large number of seeds, ensuring that at least some will grow into plants and eventually produce seeds themselves.

Figure 52.8a

- Other types of plants produce a moderate number of large seeds
  - That provide a large store of energy that will help seedlings become established

(b) Some plants, such as this coconut palm, produce a moderate number of very large seeds. The large endosperm provides nutrients for the embryo, an adaptation that helps ensure the success of a relatively large fraction of offspring.

Figure 52.8b

- Parental care of smaller broods
  - May also facilitate survival of offspring

Population growth models

- Exponental growth
- Logistical growth

Per Capita Rate of Increase

Assume for *__ideal population growth__* model:

- a small group of individuals
- unlimited resources

ΔN = change in population #

Δt = change in time

B = # of births during Δt

D = # of deaths during Δt

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

Generalized equation for population change

N = # in population at start of year

b = # of births/year (0.034) (birth RATE)

d = # of deaths/year (0.016) (death RATE)

$\Delta N / \Delta t = bN - dN = N(b-d)$

- r = (b - d) = difference in birth and death rate
- then $\Delta N / \Delta t = rN$
- or at any instant in time $dN / dt = rN$

Per Capita Rate of Increase

- If immigration and emigration are ignored
  - A population's growth rate (per capita increase) equals birth rate minus death rate
- Zero population growth
  - Occurs when the birth rate equals the death rate
- The population growth equation can be expressed as

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

Exponential Growth

- Exponential population growth
  - Is population increase under idealized conditions
- Under these conditions
  - The rate of reproduction is at its maximum, called the intrinsic rate of increase

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

- Exponential population growth
  - Results in a J-shaped curve

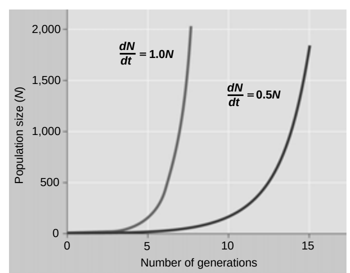


Figure 52.9

- The J-shaped curve of exponential growth
  - Is characteristic of some populations that are rebounding

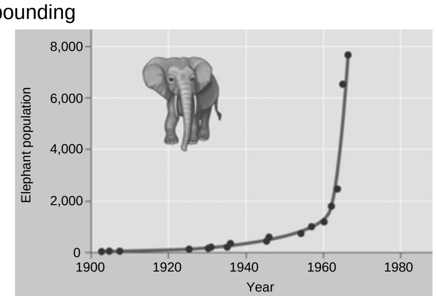


Figure 52.10

Logistic growth model

- Includes the concept of carrying capacity
- Exponential growth
  - Cannot be sustained for long in any population
- A more realistic population model
  - Limits growth by incorporating carrying capacity

The Logistic Growth Model

- In the logistic population growth model
  - The per capita rate of increase declines as carrying capacity is reached
- Carrying capacity (*K*)
  - Is the maximum population size the environment can support

- The logistic growth equation
  - Includes *K*, the carrying capacity

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

- A hypothetical example of logistic growth

Table 52.3 A Hypothetical Example of Logistic Population Growth, Where K = 1,000 and r_{max} = 0.05 per Individual per Year

Population Size: N	Intrinsic Rate of Increase: r_{max}	$\left(\frac{K-N}{K}\right)$	Per Capita Growth Rate: $r_{max}\left(\frac{K-N}{K}\right)$	Population Growth Rate:* $r_{max}N\left(\frac{K-N}{K}\right)$
20	0.05	0.98	0.049	+1
100	0.05	0.90	0.045	+5
250	0.05	0.75	0.038	+9
500	0.05	0.50	0.025	+13
750	0.05	0.25	0.013	+9
1,000	0.05	0.00	0.000	0

*Rounded to the nearest whole number.

Table 52.3

- The logistic model of population growth
  - Produces a sigmoid (S-shaped) curve

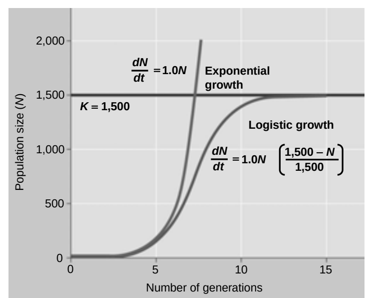
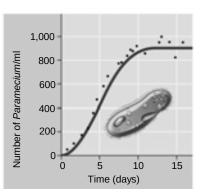


Figure 52.12

The Logistic Model and Real Populations

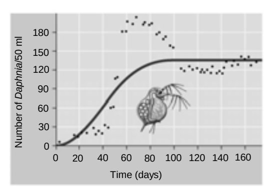
- The growth of laboratory populations of paramecia
  - Fits an S-shaped curve



(a) A *Paramecium* population in the lab. The growth of *Paramecium aurelia* in small cultures (black dots) closely approximates logistic growth (red curve) if the experimenter maintains a constant environment.

Figure 52.13a

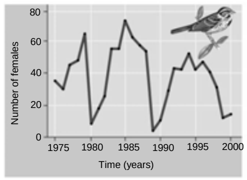
- Some populations overshoot *K*
  - Before settling down to a relatively stable density



(b) A *Daphnia* population in the lab. The growth of a population of *Daphnia* in a small laboratory culture (black dots) does not correspond well to the logistic model (red curve). This population overshoots the carrying capacity of its artificial environment and then settles down to an approximately stable population size.

Figure 52.13b

- Some populations
  - Fluctuate greatly around *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

- The logistic model fits few real populations
  - But is useful for estimating possible growth

The Logistic Model and Life Histories

- Life history traits favored by natural selection
  - May vary with population density and environmental conditions

- *K*-selection, or density-dependent selection
  - Selects for life history traits that are sensitive to population density
- *r*-selection, or density-independent selection
  - Selects for life history traits that maximize reproduction

- The concepts of *K*-selection and *r*-selection
  - Are somewhat controversial and have been criticized by ecologists as oversimplifications

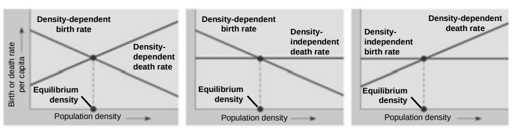
- Concept 52.5: Populations are regulated by a complex interaction of biotic and abiotic influences
- There are two general questions we can ask
  - About regulation of population growth

- What environmental factors stop a population from growing?
- Why do some populations show radical fluctuations in size over time, while others remain stable?

Population Change and Population Density

- In density-independent populations
  - Birth rate and death rate do not change with population density
- In density-dependent populations
  - Birth rates fall and death rates rise with population density

- Determining equilibrium for population density



(a) Both birth rate and death rate change with population density.

(b) Birth rate changes with population density while death rate is constant.

(c) Death rate changes with population density while birht rate is constant.

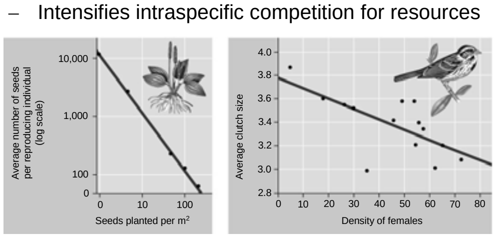
Figure 52.14a–c

Density-Dependent Population Regulation

- Density-dependent birth and death rates
  - Are an example of negative feedback that regulates population growth
  - Are affected by many different mechanisms

Competition for Resources

- In crowded populations, increasing population density
  - Intensifies intraspecific competition for resources



(a) Plantain. The number of seeds produced by plantain (*Plantago major*) decreases as density increases.

(b) Song sparrow. Clutch size in the song sparrow on Mandarte Island, British Columbia, decreases as density increases and food is in short supply.

Figure 52.15a,b

Territoriality

- In many vertebrates and some invertebrates
  - Territoriality may limit density

- Cheetahs are highly territorial
  - Using chemical communication to warn other cheetahs of their boundaries

Figure 52.16

- Oceanic birds
  - Exhibit territoriality in nesting behavior

Figure 52.17

Health

- Population density
  - Can influence the health and survival of organisms
- In dense populations
  - Pathogens can spread more rapidly

Predation

- As a prey population builds up
  - Predators may feed preferentially on that species

Toxic Wastes

- The accumulation of toxic wastes
  - Can contribute to density-dependent regulation of population size

Intrinsic Factors

- For some populations
  - Intrinsic (physiological) factors appear to regulate population size

Population Dynamics

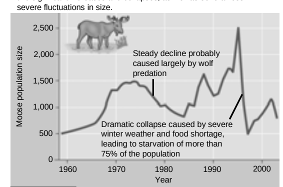
- The study of population dynamics
  - Focuses on the complex interactions between biotic and abiotic factors that cause variation in population size

Stability and Fluctuation

- Long-term population studies
  - Have challenged the hypothesis that populations of large mammals are relatively stable over time

FIELD STUDY Researchers regularly surveyed the population of moose on Isle Royale, Michigan, from 1960 to 2003. During that time, the lake never froze over, and so the moose population was isolated from the effects of immigration and emigration.

RESULTS Over 43 years, this population experienced two significant increases and collapses, as well as several less severe fluctuations in size.



CONCLUSION The pattern of population dynamics observed in this isolated population indicates that various biotic and abiotic factors can result in dramatic fluctuations over time in a moose population.

Figure 52.18

- Extreme fluctuations in population size
  - Are typically more common in invertebrates than in large mammals

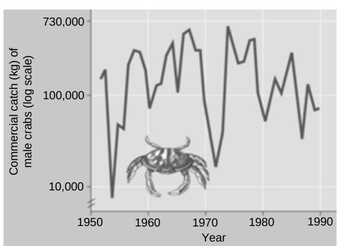


Figure 52.19

Metapopulations and Immigration

- Metapopulations
  - Are groups of populations linked by immigration and emigration

- High levels of immigration combined with higher survival
  - Can result in greater stability in populations

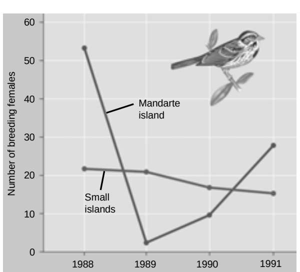


Figure 52.20

Population Cycles

- Many populations
  - Undergo regular boom-and-bust cycles

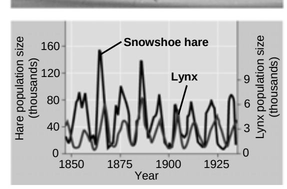


Figure 52.21

- Boom-and-bust cycles
  - Are influenced by complex interactions between biotic and abiotic factors

- Concept 52.6: Human population growth has slowed after centuries of exponential increase
- No population can grow indefinitely
  - And humans are no exception

The Global Human Population

- The human population
  - Increased relatively slowly until about 1650 and then began to grow exponentially

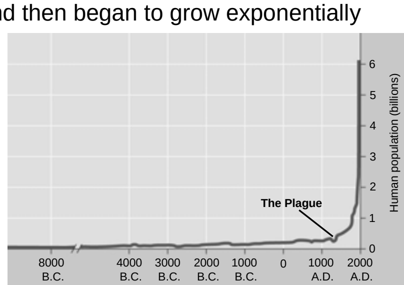


Figure 52.22

- Though the global population is still growing
  - The rate of growth began to slow approximately 40 years ago

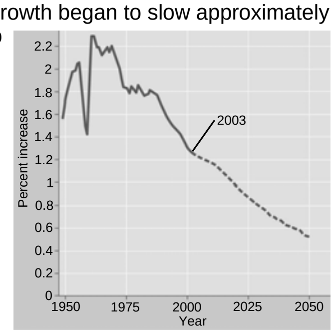


Figure 52.23

Regional Patterns of Population Change

- To maintain population stability
  - A regional human population can exist in one of two configurations

- Zero population growth = High birth rates – High death rates
- Zero population growth = Low birth rates – Low death rates

- The demographic transition
  - Is the move from the first toward the second state

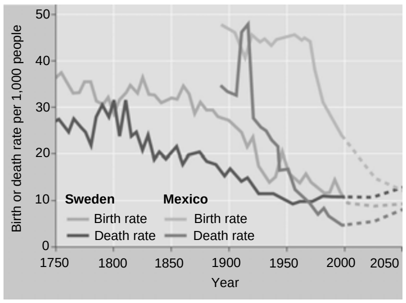


Figure 52.24

- The demographic transition
  - Is associated with various factors in developed and developing countries

Age Structure

- One important demographic factor in present and future growth trends
  - Is a country's age structure, the relative number of individuals at each age

- Age structure
  - Is commonly represented in pyramids

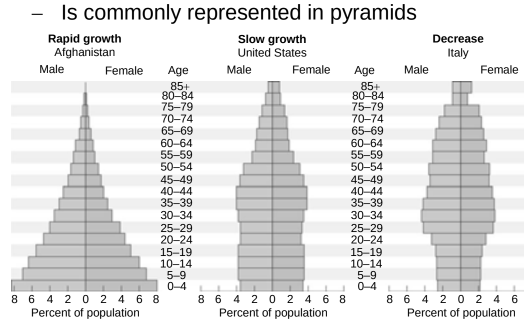


Figure 52.25

- Age structure diagrams
  - Can predict a population's growth trends
  - Can illuminate social conditions and help us plan for the future

Infant Mortality and Life Expectancy

- Infant mortality and life expectancy at birth
  - Vary widely among developed and developing countries but do not capture the wide range of the human condition

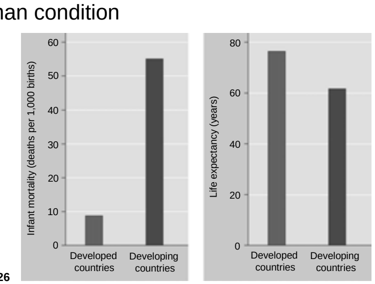


Figure 52.26

Global Carrying Capacity

- Just how many humans can the biosphere support?

Estimates of Carrying Capacity

- The carrying capacity of Earth for humans is uncertain

Ecological Footprint

- The ecological footprint concept
  - Summarizes the aggregate land and water area needed to sustain the people of a nation
  - Is one measure of how close we are to the carrying capacity of Earth

- Ecological footprints for 13 countries
  - Show that the countries vary greatly in their footprint size and their available ecological capacity

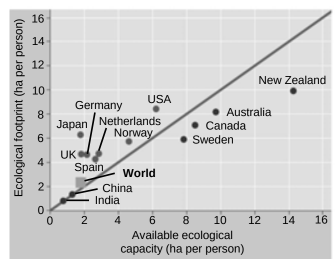


Figure 52.27

- At more than 6 billion people
  - The world is already in ecological deficit