Previous lecture

- *All Populations Potentially Grow Exponentially*
- *Memorize these equations and be able to use them in problems:*

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

$$N(t) = N(0)e^{rt}$$

$$N(t) = N(0)\lambda^{t}$$

Side note:
$N(t)=N_t$
$N(0)=N_0$

Population of the Earth (2012): **6,998,809,870**
Population of the Earth (2013): **7,069,216,620**
Population of the Earth (2014): **7,150,667,610**
Population of the Earth (2015): **7,229,246,583**
Population of the Earth (2016): 7,310,718,777
Growth: 81,472,194 human beings added in the last year
http://www.census.gov/ [=ca. 10 New York Cities]

Rapid Growth of the Human N

- 1 billion in 1804, 2 billion in 1927 (123 years later)
- [doubling time; 123 y]
- 3 billion in 1960 (33 years later), 4 billion in 1974 (14 years later)
- [doubling time; 47 y]
- 5 billion in 1987 (13 years later), 6 billion in 1999 (12 years later) [doubling time; 39 y]
- 7 billion in 2011 (12 years later)

Based on the above information about doubling times, what can we say about world population growth from 1804 - 1999?

A. It's slower than exponential.
B. It is exponential.
C. It's faster than exponential

Penny for your thoughts about the 'Moon Problem'

- Number of pennies to reach the moon:
- (384,000 km x 1000 m/km x 1000 mm/m)/ 1.52 mm/penny = 2.526315789 x 10^{11}=N_t
- $N_0=1$
- $\lambda = 2$
- Answer: 0.7289 m (approximately 29")

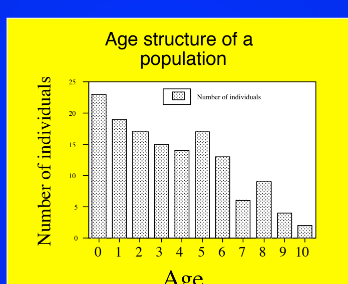
Lecture 3

- Demography
  Smith & Smith Chapter 9
  - Use the formulas given in class!!!

Demography

- What is demography?
- Importance of demography:
  - Human biology: ___________________
  - Ecologically: ______________________

Age structure - what is it?



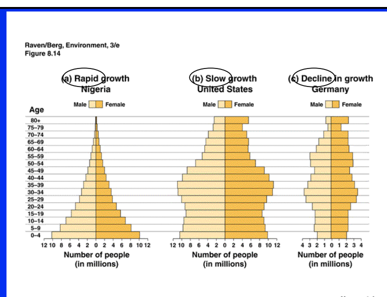
Age structure

Why is age structure important?

•How fast would a population grow…if it consisted entirely of newborns?

Age structure

•How fast would a population grow consisting entirely of postmenopausal women (or celibate males or Shakers!)



Why is there a 'bulge' in the U. S. age distribution?

A. Because contraception was invented in 1960
B. Because WW2 separated men from women
C. Because people experience midriff bulge in middle age
D. Because repeated crime waves cause mortality

Survival as f(age)

- Survival of a cohort

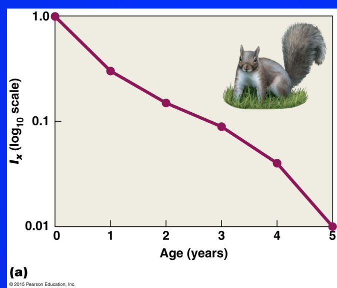


Fig. 9.8a, S&S

Age-specific survival curves

- A plot of log survival (of a cohort) vs. age reveals 3 general patterns of survival called 'Deevey curves'

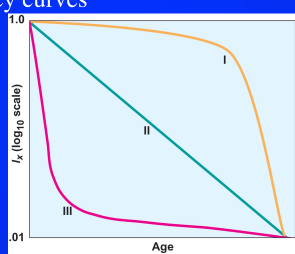


Fig. 9.10 S&S

Deevey Type I, II, and III

- Type I - Low mortality rates early in life, followed by late-life aging; animals with high degree of **parental care** (e.g., humans, whales, chimps)

Deevey Mortality Curves

- Type II - Constant mortality rates throughout life; some parental care, but equally vulnerable early and late (e.g., many bird species, squirrels)

Deevey Mortality Curves

- Type III - High mortality rates early in life, followed by low rates, if maturity is reached (insects, most plants, e.g., silverswords)

What kind of survivorship curve would this species have?

A. Type I
B. Type II
C. Type III
D. Type IV

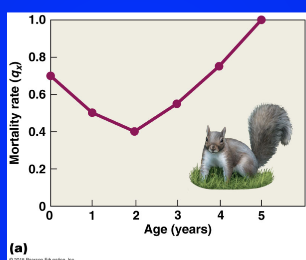
Cohort data

- By **censusing** a population annually, demographers assemble the data needed for a life table. Typical cohort data and life table statistics:

Table 9.1 Gray Squirrel Life Table

x	n_x	l_x	d_x	q_x
0	530	1.0	371	0.7
1	159	0.3	79	0.5
2	80	0.15	32	0.4
3	48	0.09	27	0.55
4	21	0.04	16	0.75
5	5	0.01	5	1.0

Life tables describe the life history



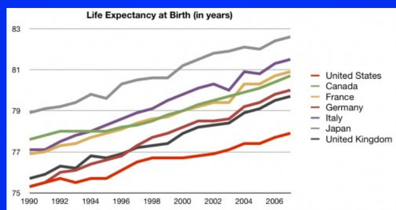
But Also Provide Useful Vital Statistics

- Life expectancy (e_x).

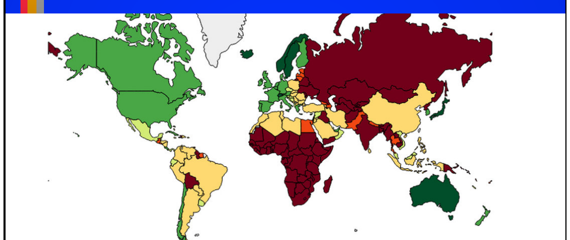
Table 9.1 Gray Squirrel Life Table

x	n_x	l_x	d_x	q_x	L_x	T_x	e_x
0	530	1.0	371	0.7			
1	159	0.3	79	0.5			
2	80	0.15	32	0.4			
3	48	0.09	27	0.55			
4	21	0.04	16	0.75			
5	5	0.01	5	1.0			

Life Expectancy in Humans



Life Expectancy Vs. Country



Life Tables May Also Contain Age-Specific Birth Rates

Table 9.4 Gray Squirrel Fecundity Table

x	l_x	b_x	$l_x b_x$
0	1.0	0.0	0.00
1	0.3	2.0	0.60
2	0.15	3.0	0.45
3	0.09	3.0	0.27
4	0.04	2.0	0.08
5	0.01	0.0	0.00
Σ		10.0	1.40

Net Reproductive Rate

Table 9.4 Gray Squirrel Fecundity Table

x	l_x	b_x	$l_x b_x$
0	1.0	0.0	0.00
1	0.3	2.0	0.60
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5	0.01	0.0	0.00
Σ		10.0	1.40

*note; in many texts, and in old sample Bio. 221 probs, b_x is called m_x

Net reproductive rate

Population Projection

- Population prediction:
- Population projection:

Population Projection

- Knowing survival rates and birth rates, we can project future population sizes
- 2 expressions of survival and fertility are needed for projections:
  - 1. s_x
  - 2. F_x

Note: In many texts, and old sample Bio 221 probs, s_x is called p_x

Population Projection

- Knowing survival rates and birth rates, we can project future population sizes
- 2 expressions of survival and fertility are needed for projections:
  - 1. s_x (= l_{x+1}/l_x)
  - 2. F_x (=$s_x b_{x+1}$)

Population Projection

- Knowing survival probabilities (s_x), the number of individuals moving into the next age class can be calculated:

$$N_{x+1}(t+1) = s_x N_x(t)$$

Population Projection (part 2)

- To complete the accounting, newborn numbers need to be estimated using fertilities (F_x):

$$N_0(t+1) = \sum_{x=0}^{lastage} F_x N_x(t)$$

Computing p_x and F_x

Table 10.4 | Gray Squirrel Fecundity Table

x	l_x	s_x	b_x	F_x	$l_x b_x$
0	1.0		0.0		0.00
1	0.3		2.0		0.60
2	0.15		3.0		0.45
3	0.09		3.0		0.27
4	0.04		2.0		0.08
5	0.01		0.0		0.00
Σ			10.0		1.40

Population Projection Equations

$$N_0(t+1) = \sum_{x=0}^{lastage} F_x N_x(t)$$

$$N_{x+1}(t+1) = s_x N_x(t)$$

Sample Projection

- The projection equations are used to determine $N_{(x+1)}(t+1)$:

Table 10.6 | Population Projection Table, Squirrel Population

	Year (t)										
Age	0	1	2	3	4	5	6	7	8	9	10
0	20	27	34.1	40.71	48.21	58.37	70.31	84.8	101.86	122.88	148.06
1	10	6	8.1	10.23	12.05	14.46	17.51	21.0	25.44	30.56	36.86
2	0	5	3.0	4.05	5.1	6.03	7.23	8.7	10.50	12.72	15.28
3	0	0	3.0	1.8	2.43	3.06	3.62	4.4	5.22	6.30	7.63
4	0	0	0	1.35	0.81	1.09	1.38	1.6	1.94	2.35	2.83
5	0	0	0	0	0.33	0.20	0.27	0.35	0.40	0.49	0.59
Total $N(t)$	30	38	48.2	58.14	68.93	83.21	100.32	120.85	145.36	175.30	211.25
Lambda	λ	1.27	1.27	1.21	1.19	1.21	1.20	1.20	1.20	1.20	1.20

One ‘iteration’ of this projection

$$N_x(t) = \begin{pmatrix} 34.1 \\ 8.1 \\ 3 \\ 3 \\ 0 \end{pmatrix} \rightarrow \begin{pmatrix} N_0(t+1) \\ N_1(t+1) \\ N_2(t+1) \\ N_3(t+1) \\ N_4(t+1) \end{pmatrix}$$

34.1*(0.3) 8.1*(0.5) Etc.

Try it!

Yields…

$$N_x(t) = \begin{pmatrix} 34.1 \\ 8.1 \\ 3 \\ 3 \\ 0 \end{pmatrix} \rightarrow \begin{pmatrix} N_0(t+1) \\ 10.23 \\ 4.05 \\ 1.8 \\ 1.35 \end{pmatrix}$$

34.1*(0.3) 8.1*(0.5) Etc.

Calculate Newborns (N_0)

$$N_0(t+1) = \sum_{x=0}^{lastage} F_x N_x(t)$$

$$N_0(t+1) = (0.6*34.1) + (1.5*8.1) + (1.8*3) + (0.88*3)$$

$$N_0(t+1) = 40.65$$

Note: Your book has a bit of rounding error for this…

Total Population Size

- Just sum across age classes!

$$N_{total} = \sum_{x=0}^{x} N_x$$

Summary

- Demography is the study of controls of birth and death in populations
- Census data are summarized in a life table
- Summary statistics derived from the life table tell us interesting properties of a species in a particular environment, such as life expectancy and net reproductive rate
- Survival (s_x) and fertility (F_x) statistics can be used to project future population sizes

Next lecture

- Population projection and fitness
- Aspects of human demography