

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:

$$N(t) = N_i$$

$$N(0) = N_0$$

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:

→ $(384,000 \text{ km} \times 1000 \text{ m/km} \times 1000 \text{ mm/m}) / 1.52 \text{ mm/penny} = 2.526315789 \times 10^{11} = N$

→ $N = 1$


→ $\lambda = 2$

→ Answer: 0.7289 m (approximately 29")




Lecture 3

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



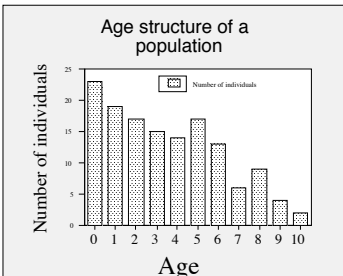
Demography

- What is demography?
- Importance of demography:
 - Human biology: _____
 - Ecologically: _____



Age structure - what is it?

Age structure of a population



Age	Number of individuals
0	23
1	20
2	18
3	15
4	14
5	17
6	13
7	6
8	9
9	4
10	2

Age structure

Why is age structure important?

- How fast would a population grow...if it consisted entirely of newborns?

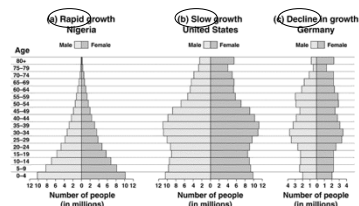


Age structure

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

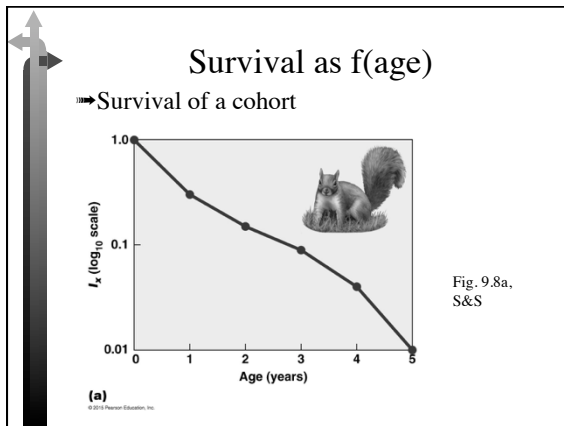


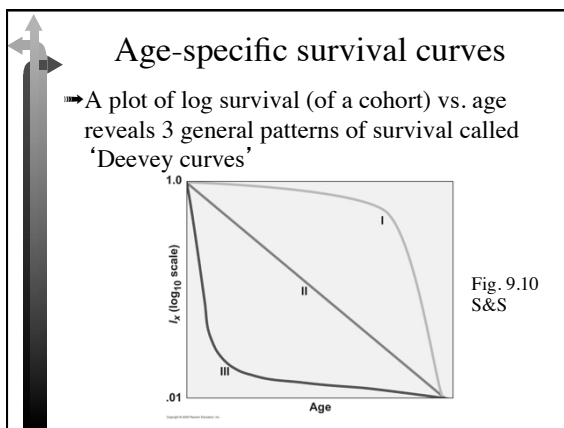
Raven/Berg, Environment, 36
Figure 8.14

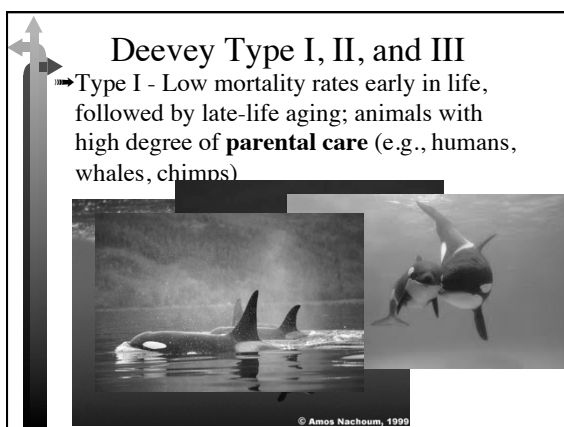


Macmillan, Inc.

- Why is there a 'bulge' in the U. S. age distribution?
- Because contraception was invented in 1960
 - Because WW2 separated men from women
 - Because people experience midriff bulge in middle age
 - Because repeated crime waves cause mortality









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?

Canis lupus



- 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

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Life tables describe the life history

(a)

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But Also Provide Useful Vital Statistics

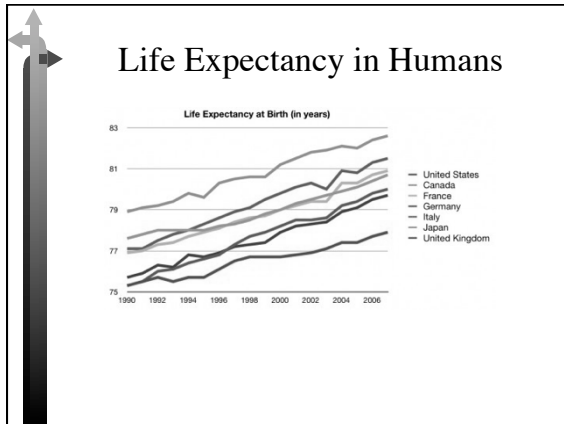
→ Life expectancy (e_x).

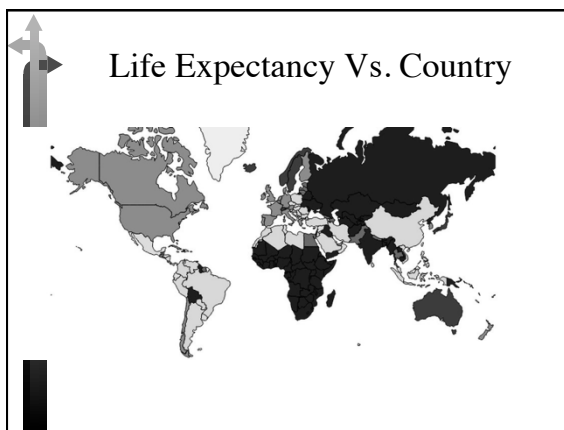
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L_x T_x e_x

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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	$l_x b_x$
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*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), 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):



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

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

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Population Projection Equations

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

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

Sample Projection

⇒ The projection equations are used to determine $N(t+1)$:

Table 10.6 | Population Projection Table, Squirrel Population

Age	Year (t)										
	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	1.20

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One 'iteration' of this projection

$$N_x(t) = \begin{pmatrix} 34.1 \\ 8.1 \\ 3 \\ 3 \\ 0 \end{pmatrix} \begin{matrix} \xrightarrow{34.1*(0.3)} \\ \xrightarrow{8.1*(0.5)} \\ \xrightarrow{\text{Etc.}} \\ \xrightarrow{} \\ \xrightarrow{} \end{matrix} \begin{pmatrix} N_0(t+1) \\ N_1(t+1) \\ N_2(t+1) \\ N_3(t+1) \\ N_4(t+1) \end{pmatrix}$$

Try it!

Yields...

$$N_x(t) = \begin{pmatrix} 34.1 \\ 8.1 \\ 3 \\ 3 \\ 0 \end{pmatrix} \begin{matrix} \xrightarrow{34.1*(0.3)} \\ \xrightarrow{8.1*(0.5)} \\ \xrightarrow{\text{Etc.}} \\ \xrightarrow{} \\ \xrightarrow{} \end{matrix} \begin{pmatrix} N_0(t+1) \\ 10.23 \\ 4.05 \\ 1.8 \\ 1.35 \end{pmatrix}$$


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) and fertility (F) statistics can be used to project future population sizes



Next lecture

- ⇒ Population projection and fitness
- ⇒ Aspects of human demography
