Conservation Biology
Age Structure and Life Tables

Brook Milligan

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This exercise is intended to help you understand life tables used to characterize age-structured populations. In the process you will also further improve your skills with spreadsheets.

The following instructions come in two parts. The lefthand column describes the steps in a conceptual way. That is, each step is described in terms of its higher level purpose. In contrast, the righthand column describes the actual cell manipulations required to accomplish the task. It will behoove you to understand the connection between the conceptual and concrete levels. In the future, it will be taken for granted that you understand how to implement the higher level concepts in terms of concrete cell manipulations.

Once you have constructed your spreadsheet, you should review and answer the questions on page 10. Do not just answer these by rote; give them some thought. Also, I am not at all interested in seeing a disorganized dump of your spreadsheet. Organize what you are turning in so that it conveys that you understand the spreadsheet, the questions, and your work. **Please turn in your work on Wednesday, October 28.**

Prerequisite In order to complete this assignment you will need access to a computer containing a spreadsheet program. Although the most common one may be Microsoft Excel, you will be able to do this on almost any modern spreadsheet program. For example, you can download a copy of OpenOffice to use on almost any computer system from the following site: `http://www.openoffice.org/`.

1 Generate Survivorship Curves

Instructions

1. Open a new spreadsheet and set up titles and column headings as shown in Figure 1

Annotation

These are all literals, so just select the appropriate cells and type them in.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Life Tables and Survivorship Curves												
2	Age (x)	S_x: Type I	S_x: Type II	S_x: Type II	l_x: Type I	l_x: Type II	l_x: Type III	g_x: Type I	g_x: Type II	g_x: Type III	e_x: Type I	e_x: Type II	e_x: Type III
3	0	1000	2048	10000									
4	1	990	1024	100									
5	2	970	512	30									
6	3	940	256	20									
7	4	900	128	18									
8	5	850	64	17									
9	6	750	32	16									
10	7	500	16	15									
11	8	200	8	14									
12	9	40	4	13									
13	10	1	2	12									
14	11	0	0	0									

Figure 1: Excel file shell for survivorship curves

2. Set up a linear series from 0 to 11 in column A.

In cell A3, enter the number 0.
In cell A4, enter the formula **=A3+1**.
Copy the formula in cell A4 into cells A5–A14.

3. Enter the values shown in Figure 1 for cells B3–D14.

These are the raw data of three survivorship schedules — one for each survivorship curve. Each number is the number of surviving individuals from a cohort at each age.

4. Enter formulae to calculate standardized survivorship, l_x, for each survivorship schedule.

In cell E3, enter the formula **=B3/\$B\$3**. Copy this formula into cells E4–E14. This corresponds to the equation

$$l_x = \frac{S_x}{S_0}.$$

Note the use of a relative cell address in the numerator and an absolute cell address in the denominator.
The formula in cell F3 should be **=C3/\$C\$3**, and the formula in cell G3 should be **=D3/\$D\$3**. Copy cells F3–G3 down to F14–G14.

5. Enter formulae to calculate age-specific survivorship, g_x, for each survivorship schedule.

In cell H3 enter the formula **=B4/B3**. Copy this formula into cells H4–H13. *Do not* copy it into cell H14, because the formula would attempt to divide by zero and thus generate an error. Copy cells H3–H13 into cells I3–J13. This corresponds to the equation

$$g_x = \frac{S_{x+1}}{S_x}.$$

Note that all cell addresses are relative.

6. Enter formulae to calculate life expectancy, e_x, for each age.

In cell K3 enter the formula **=SUM(E4:$E$13)/E3**.
In cell L3 enter the formula **=SUM(F4:$F$13)/F3**.
In cell M3 enter the formula **=SUM(G4:$G$13)/G3**.
Copy cells K3–M3 into cells K4–M13.

This corresponds to the equation

$$e_x = \frac{\sum_{i=x+1}^{k} l_i}{l_x}.$$

7. Your spreadsheet is complete. Save your work.

Compare your results to Figure 2.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Life Tables and Survivorship Curves												
2	Age (x)	S_x: Type I	S_x: Type II	S_x: Type III	l_x: Type I	l_x: Type II	l_x: Type III	g_x: Type I	g_x: Type II	g_x: Type III	e_x: Type I	e_x: Type II	e_x: Type III
3	0	1000	2048	10000	1	1	1	0.99	0.5	0.01	6.141	0.99902344	0.0255
4	1	990	1024	100	0.99	0.5	0.01	0.97979798	0.5	0.3	5.2030303	0.99804688	1.55
5	2	970	512	30	0.97	0.25	0.003	0.96907216	0.5	0.66666667	4.31030928	0.99609375	4.16666667
6	3	940	256	20	0.94	0.125	0.002	0.95744681	0.5	0.9	3.44787234	0.9921875	5.25
7	4	900	128	18	0.9	0.0625	0.0018	0.94444444	0.5	0.94444444	2.60111111	0.984375	4.83333333
8	5	850	64	17	0.85	0.03125	0.0017	0.88235294	0.5	0.94117647	1.75411765	0.96875	4.11764706
9	6	750	32	16	0.75	0.015625	0.0016	0.66666667	0.5	0.9375	0.988	0.9375	3.375
10	7	500	16	15	0.5	0.0078125	0.0015	0.4	0.5	0.93333333	0.482	0.875	2.6
11	8	200	8	14	0.2	0.00390625	0.0014	0.2	0.5	0.92857143	0.205	0.75	1.78571429
12	9	40	4	13	0.04	0.00195313	0.0013	0.025	0.5	0.92307692	0.025	0.5	0.92307692
13	10	1	2	12	0.001	0.00097656	0.0012	0	0	0	1	1	1
14	11	0	0	0	0	0	0						

Figure 2: Completed spreadsheet.

8. Graph standardized survivorship, l_x, against age.

Select cells A2–A14. Hold control key and select cells E2–G14. Create an XY-scatter graph. Edit your graph for readability. It should resemble Figure 3.

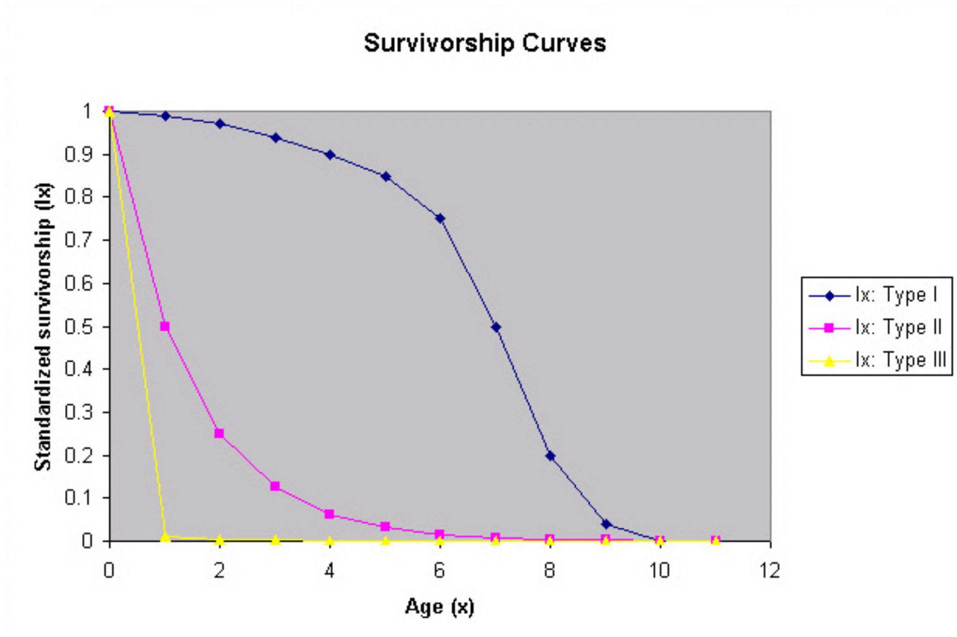

Figure 3: Survivorship curves.

9. Change the y-axis to a logarithmic scale.

Double-click on the y-axis and choose the “number” tab in the resulting dialogue box. Set the number of decimal places to 3. Choose the “scale” tab. Check the box for Logarithmic Scale. Set the Minimum to 0.001, the Major unit to 10, and the Value (x) axis Crosses at to 0.0001. Your graph should resemble Figure 4.

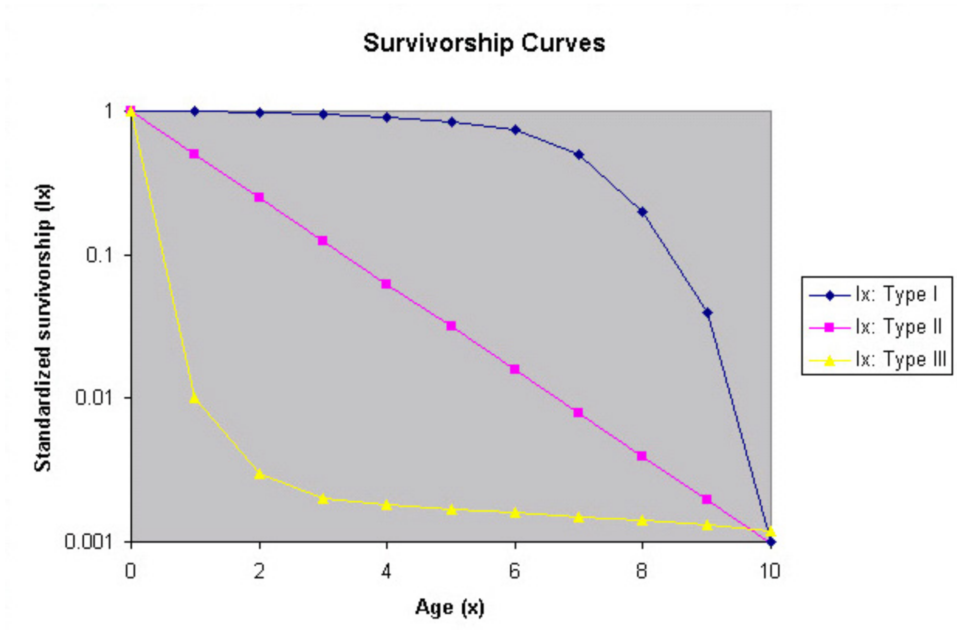

Figure 4: Survivorship curves are always plotted with a logarithmic y-axis. Can you see why?

10. Plot age-specific survival g_x against age.

Select cells A2–A13 and cells H2–J13. Make an XY-scatter graph. Your graph should resemble Figure 5.

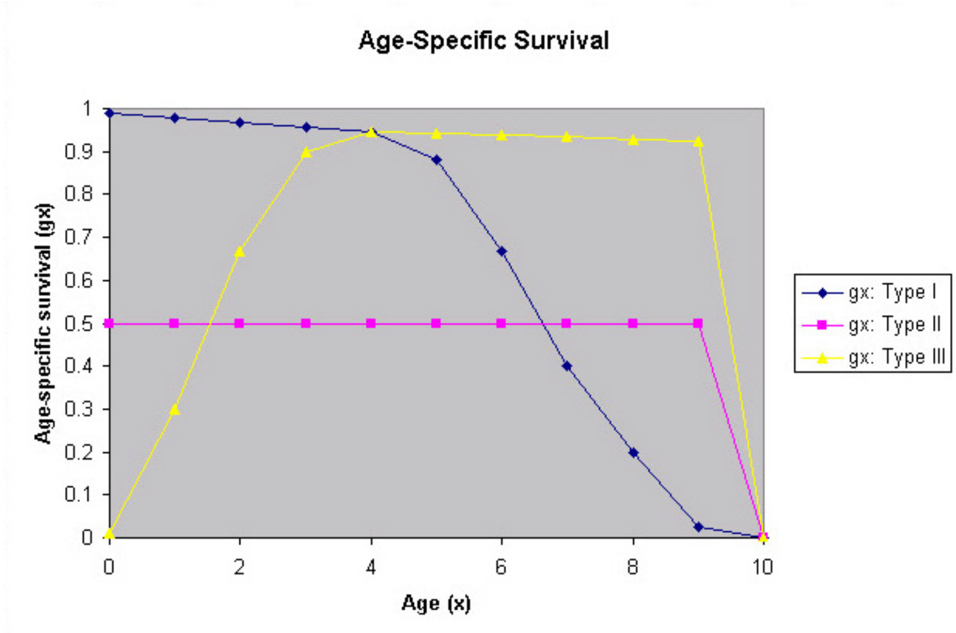

Figure 5: Age-specific survival.

11. Plot life-expectancy e_x, against age.

Select cells A2–A13 and cells K2–M13. Make an XY-scatter graph. Your graph should resemble Figure 6.

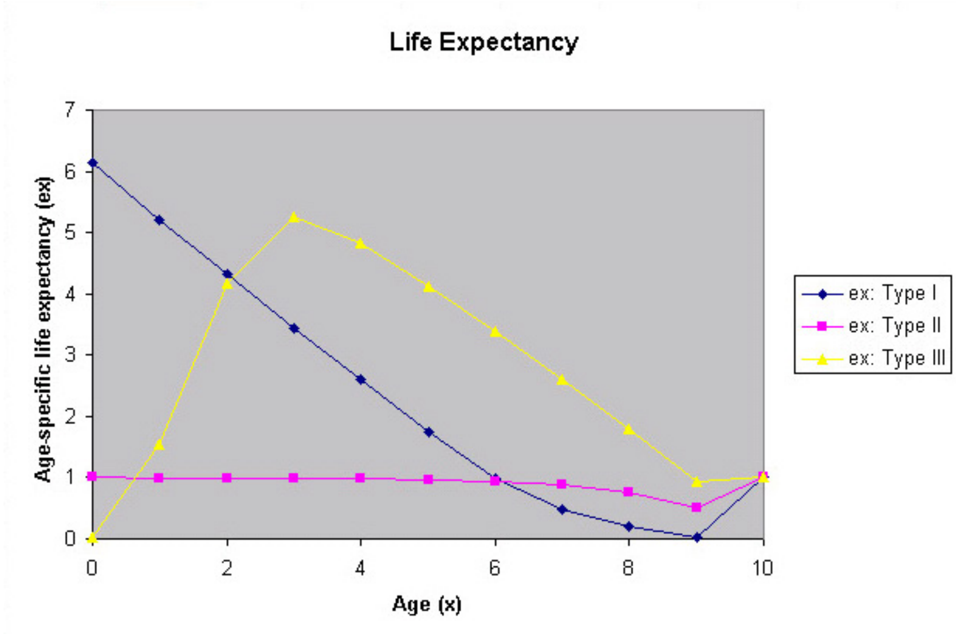

Figure 6: Age-Specific Life Expectancy.

2 Population Growth and Decline

Instructions

1. Open a new spreadhsheet and set up titles and column headings as shown in Figure 7
Set up a linear series of ages 0 to 4 in column A.
Enter the values shown for S_x.

Annotation

	A	B	C	D	E	F
1	Cohort Life Table: Fertility, Survival, and Population Growth					
2						
3	Age (x)	S_x	l_x	b_x	$(l_x)(b_x)$	$(x+1)(l_x)(b_x)$
4	0	1000		0.00		
5	1	900		0.00		
6	2	250		4.00		
7	3	10		0.00		
8	4	0		0.00		
9						
10	R_0					
11	G					

Figure 7: Cohort life table

2. Enter a formula to calculate standardized survival, l_x.

In cell C4 enter the formula =**B4/$B$4**. Copy this formula into cells C5–C8.

3. Enter the values shown for age-specific fertility, b_x.

Enter the value 0.00 in cells D4, D5, D7, and D8. Enter the value 4.00 into cell D6.

4. Enter a formula to calculate the product of standardized survival multiplied by age-specific fertility, $l_x b_x$.

In cell E4 enter the formula =**C4*D4**. Copy this formula into cells E5–E8.

5. Enter a formula to calculate net reproductive rate R_0.

In cell E10 enter the formula =**SUM(E4:E8)**.
This corresponds to the equation

$$R_0 = \sum_{x=0}^{k} l_x b_x.$$

6. Echo the value of R_0 in cell B10.

In cell B10 copy the value of E10.
You will soon change the values of S_x and b_x, and this layout will make it easier to compare the effects of different survival and fertility schedules on population growth and decline.

7. Enter a formula to calculate the product $l_x b_x (x+1)$.

In cell F4 enter the formula **=E4*A5**
This is an intermediate step in calculating generation time G.
Copy the formula from cell F4 into cells F5–F8.

8. Enter a formula to calculate the sum of the products $l_x b_x (x+1)$.

In cell F9 enter the formula **=SUM(F4:F8)**
This is another intermediate step in calculating generation time G.

9. Enter a formula to calculate generation time G.

In cell E11 enter the formula **=F9/E10**
This corresponds to the equation

$$G = \frac{\sum_{x=0}^{k} l_x b_x (x+1)}{\sum_{x=0}^{k} l_x b_x}.$$

10. Echo the value of G in cell B11.

In cell B11 copy the value of E11.
You will soon change the values of S_x and b_x, and this layout will make it easier to compare the effects of different survival and fertility schedules on generation time.

3 Questions

1. Why do we plot survivorship curves on a semi-log graph?
2. What do the shapes of the survivorship curves tell us about patterns of survival and mortality? Compare each curve to the corresponding graph of age-specific survivorship.
3. How can we interpret the graph of life expectancies?
4. Use the S_x values for real populations provided below to compare survivorship curves between animal species. You may also wish to visit `http://www.census.gov` from which you can download survivorship data for human populations in most of the countries of the world.
5. What effect does changing the fecundity schedule have on R_0 and G?
6. What effect does changing the survivorship schedule have on R_0 and G?

In all of the tables that follow, assume S_x for the next age after the oldest in the table is zero.

Table A: Survivorship schedule for Dall mountain Sheep (*Ovis dalli dalli*).

Age (years)	S_x	Age (years)	S_x
0	1000	7	640
1	801	8	571
2	789	9	439
3	776	10	252
4	764	11	96
5	734	12	6
6	688	13	3

Table B: Survivorship schedule for the Song thrush.

Age (years)	S_x	Age (years)	S_x
0	1000	5	30
1	444	6	17
2	259	7	6
3	123	8	3
4	51		

Table C: Survivorship and fecundity schedules for the barnacle *Balanus glandula*.

Age (years)	S_x	b_x	Age (years)	S_x	b_x
0	1,000,000	0	5	11	12,700
1	62	4,600	6	6.5	12, 700
2	34	8,700	7	2	12, 700
3	20	11,600	8	2	12, 700
4	15.5	12,700			