

**BIOL 208 - POPULATION AND COMMUNITY BIOLOGY**  
**HUMAN DEMOGRAPHY LAB**

**Objectives**

- To construct a life table for several human populations
- To generate survivorship curves and mortality curves using these data
- Understand the relationship of life tables and their variables to ecological questions and research

**Introduction**

“Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio.” – Thomas Malthus, *An Essay on the Principle of Population* 1798

Population size is determined by a number of factors, with a maximum population size determined by the **carrying capacity** of the environment. This does not prevent organisms from “over-reproducing” but a balance between birth rates and death rates controls population growth. Therefore, the control of population growth must necessarily be related to death rates in most natural populations. The study of **mortality**, how organisms die and when they die, is an important aspect of the study of life, and is of considerable interest to population biologists. Of course, this is not easy in natural populations, primarily because dead or dying organisms are not often found and if they are, their age at death and the reason they died are not easily determined.

These difficulties can be addressed by long-term monitoring and censusing of populations. Several populations have been tracked in this manner and have provided useful data to understand the control of population growth by death.

The objective of the collection of mortality data may be to construct a **life table** or to plot **survivorship curves**, both of which may give us a clue as to how population numbers are controlled. Life tables may be of two types: a **horizontal life table**, where a cohort of individuals (all born at a particular time and place) is followed through time with deaths recorded as they occur in each age class, or a **vertical life table**, where all the age classes present at a particular time are followed. Vertical tables calculate age-specific death rates for an entire population on the assumption that there is no change in the environment from year to year (and hence age-specific death rates remain constant) and that no immigration or emigration occurs. The horizontal type is by far the more accurate but has the drawback of being very time consuming when long-lived organisms are being studied. In this exercise, we will demonstrate the construction of a vertical life table in humans.

**Purpose**

Using data from gravestones in a local cemetery, we will generate life tables and create survivorship and mortality curves for several populations. These life tables and survivorship/mortality curves will enable us to analyze historical factors affecting survivorship of the human population in and around Lewisburg and how these factors change through time. We will attempt to make connections between life table data and historical events/patterns and to look for differences in survivorship between males and females from several time periods.

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**Methods**

For the two combined lab sections for each afternoon we will collect the following data:

1. Age at death and sex of at least 400 individuals born in 1840 or before
2. Age at death and sex of at least 1000 individuals born between 1860 and 1890 inclusive

Work in pairs to collect data. Divide a piece of paper into two columns on each side. One side is for pre-1840 data and the other is for 1860-1890 data. The columns are for males and females. Select an area of the cemetery that is not likely to be used by another pair, and note the birth and death dates and sex for 60-70 individuals who were born in the periods of interest.

Do not record data from stones for which you are not sure of the individual's sex or age at death. Note that some stones have only age and date of death – you will have to calculate dates of birth for these. Record stones systematically to avoid bias; do not jump around from place to place.

**In particular, do not overlook small stones, as these are often from young children and their omission would bias the sample.**

Upon returning to the lab, you need to determine the number of individuals dying in each age class (age classes are 5-year intervals: 0-5, 6-10, 11-15, ...) for each of the human populations. Calculate these for your own data set and enter these values into the Google Spreadsheet linked from the course website. Your data will be combined with those of your classmates (on each lab day) to provide a complete data set for each population. These data will be entered into an Excel spreadsheet and made available on the course website (under “Labs”) for you to access.

**Data Analysis**

*Life Tables:*

Prepare life tables separately for males 1860-1890 and females 1860-1890 containing the following columns (you do not need to prepare complete life tables for the pre-1840 populations):

1. Age interval ( $x$ ) (5 year periods: 0-5, 6-10, 11-15, ...)
2. Number alive at beginning of age interval ( $n_x$ )  
NOTE:  $n_{0-5}$  is the total # of individuals in the data set (for each population)
3. Number dying during the age interval ( $d_x$ ) –  
NOTE:  $d_x$  for each population is provided in the original Excel spreadsheet (just copy this column)
4. Proportion of original population surviving to the beginning of the age interval ( $l_x$ )
5. Proportion of individuals entering an age interval to die during that age interval ( $q_x$ )
6. Number of individuals alive at the midpoint of each age interval ( $L_x$ )
7. Total number of person-years still to be lived by population of age  $x$  ( $T_x$ )
8. Life expectancy of individuals entering each age interval ( $e_x$ )

Calculations for all columns except  $L_x$ ,  $T_x$ , and  $e_x$  should be self-explanatory.

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Calculate  $L_x$  for each age class as follows:

$$L_x = \frac{n_x + n_{x+1}}{2} \text{ and for the oldest age class, } L_x = \frac{n_x}{2}$$

Calculate  $T_x$  for each age class as follows:

$$T_x = \left( \sum_{n=0}^x L_x \right) * 5$$

Or put verbally,  $T_x$  is  $L_x$  for each age class plus  $L_x$  for all “older” age classes. You multiply by 5 because each age interval is 5 years. If you didn’t multiply by 5,  $T_x$  would give the number of age classes still to be lived by individuals in  $x$  age class, not years.

Calculate  $e_x$ , the mean life expectancy for someone of a particular age class, using:

$$e_x = \frac{T_x}{L_x}$$

Or put verbally,  $e_x$  is the total number of person-years remaining to be lived ( $T_x$ ) divided by the number of individuals left to live them ( $L_x$ ).

*Survivorship and Mortality Curves:*

Your data can be used to generate survivorship and mortality curves. These curves are a visual summary of important population parameters, and they can help you understand a great deal about the lives and environment of the population members. To plot survivorship and mortality curves, use Microsoft Excel or another acceptable graphing software. To do this, you will need to calculate  $l_x$  and  $q_x$  for all populations (you already have them from the 1860-1890 life tables). Age class should be on the x-axis with survivorship ( $l_x$ ) or mortality ( $q_x$ ) on the y-axis, and you should plot all relevant populations ON THE SAME GRAPH.

**Lab Report**

- A. (36 points) 2 life tables (males born 1860-1890, females born 1860-1890) with descriptive heading (above table) for each
- B. (17 points) 4 survivorship curves (on one graph) with descriptive figure caption (below graph)
- C. (17 points) 4 mortality curves (on one graph) with descriptive figure caption (below graph)
- D. (30 points) Answers to the following questions (single-spaced, typed):
  1. (5 points) How have survivorship and mortality changed between the two time periods? Describe the patterns for each time period and note any differences.
  2. (6 points) Do the survivorship or mortality curves show any irregularities that might be related to historical factors? Which historical factors might have caused the patterns in  $l_x$  and

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$q_x$  in your data? You might need to look closely to see patterns, particularly in middle age classes of mortality curves (hint).

3. (4 points) Do your survivorship curves bear out the established fact that women tend to live longer than men? At what age do women seem to have greatest survival advantage?
4. (4 points) Using the data from your life tables, calculate the proportion of 36-40 year-old men and women (keep sexes separate) born from 1860-1890 that will die before their 61<sup>st</sup> birthday. Show your work.
5. (5 points) How does the difference in life expectancies between men and women born 1860-1890 change with age?
6. (6 points) What are possible sources of error in our data, and how would these affect our results?

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Microsoft Excel Instructions

1. Enter data (example from previous year's lab) and add up all individuals in each population.

	A	B	C
	Age Class	Pre-1840 Female	Pre-1840 Male
1			
2	0-5	0	1
3	6-10	0	0
4	11-15	3	1
5	16-20	1	1
6	21-25	4	1
7	26-30	2	3
8	31-35	1	5
9	36-40	8	5
10	41-45	3	8
11	46-50	6	5
12	51-55	8	11
13	56-60	13	12
14	61-65	18	14
15	66-70	15	29
16	71-75	34	36
17	76-80	25	26
18	81-85	31	22
19	86-90	14	8
20	91-95	5	5
21	96+	1	0
		=sum(B2:B21)	=sum(C2:C21)

	A	B	C
	Age Class	Pre-1840 Female	Pre-1840 Male
1			
2	0-5	0	1
3	6-10	0	0
4	11-15	3	1
5	16-20	1	1
6	21-25	4	1
7	26-30	2	3
8	31-35	1	5
9	36-40	8	5
10	41-45	3	8
11	46-50	6	5
12	51-55	8	11
13	56-60	13	12
14	61-65	18	14
15	66-70	15	29
16	71-75	34	36
17	76-80	25	26
18	81-85	31	22
19	86-90	14	8
20	91-95	5	5
21	96+	1	0
22	sum	192	193

2. Set up life table.

	A	B	C	D	E	F	G	H
	Age Class	dx	nx	lx	qx	Lx	Tx	ex
1								
2	0-5	0						
3	6-10	0						
4	11-15	3						
5	16-20	1						
6	21-25	4						
7	26-30	2						
8	31-35	1						
9	36-40	8						
10	41-45	3						
11	46-50	6						
12	51-55	8						
13	56-60	13						
14	61-65	18						
15	66-70	15						
16	71-75	34						
17	76-80	25						
18	81-85	31						
19	86-90	14						
20	91-95	5						
21	96+	1						

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3. Fill in equations.

	A	B	C	D	E	F	G	H
1	Age class	dx	$n_x$	$l_x$	$q_x$	$L_x$	$T_x$	$e_x$
2	0-5	0	=sum(B2:B21)	=C2/\$C\$2	=B2/C2	=(C2+C3)/2	=sum(F2:F21)*5	=G2/F2
3	6-10	0	=C2-B2	=C3/\$C\$2	=B3/C3	=(C3+C4)/2	=sum(F3:F21)*5	=G3/F3
...			...					
21	96+	1	=C20-B20	=C21/\$C\$2	=B21/C21	=(C21+C22)/2	=sum(F21:F21)*5	=G21/F21

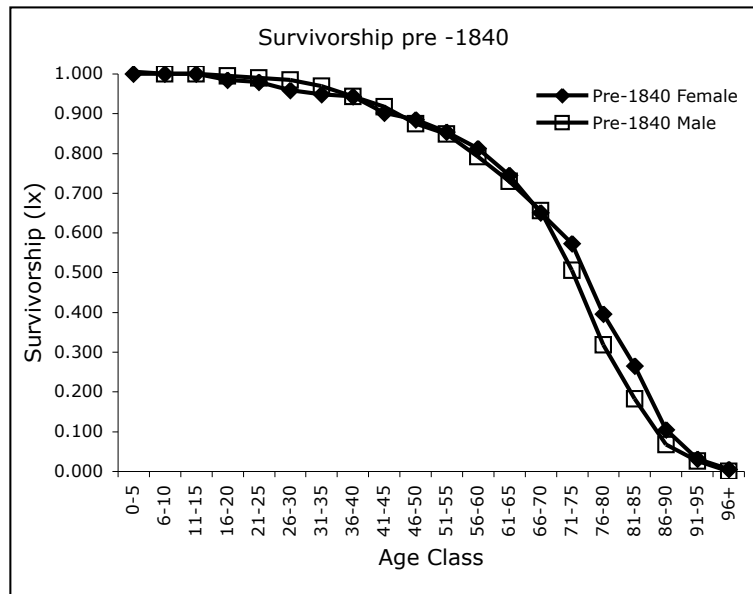
4. Making graphs using Excel

Ex. Survivorship curves:

Chart Wizard: Line graph

Data: It's easier to set the data up away from the life table as follows:

Age Class	Pre-1840 Female	Pre-1840 Male
0-5	1.000	1.000
6-10	1.000	1.000
11-15	1.000	1.000
16-20	0.984	0.995
21-25	0.979	0.990
26-30	0.958	0.984
31-35	0.948	0.969
36-40	0.943	0.943
41-45	0.901	0.917
46-50	0.885	0.875
51-55	0.854	0.849
56-60	0.813	0.792
61-65	0.745	0.729
66-70	0.651	0.656
71-75	0.573	0.505
76-80	0.396	0.318
81-85	0.266	0.182
86-90	0.104	0.068
91-95	0.031	0.026
96+	0.005	0.000



NOTE: EXCEL DEFAULTS LOOK BAD – CHANGE SETTINGS FOR YOUR GRAPHS

Changes:

Plot area – no fill, no border, enlarge to fill the area (legend defaults to right using valuable space; enlarging the plot area will require you move legend as appropriate)

Axes – make scales appropriate and align so labels can be seen

Gridlines – remove

Line and symbol colors – black and white, not different colors

Symbols – use different symbols (shapes, not different colors, remove any “shadow” effects)

Font size as appropriate