Human Population Demography

Introduction

Life tables and survivorship curves are useful in helping us understand the interaction between an organism and its environment. Species vary in schedules of mortality and reproduction. For example, oysters experience high mortality early in life but produce huge numbers of offspring annually, whereas elephants have a high probability of survival after birth but females produce only one calf at a time.

Life tables provide many different columns of information about a population, including information related to mortality (e.g., number of individuals dying at a given age, l_x; expected remaining years of life, e_x) and reproduction (e.g., number of female offspring produced at each age, m_x).

Survivorship curves are graphical representations of the numbers or fractions of individuals all born at the same time (a cohort) that die at a given age. There are species that have (a) low mortality at a young age, (b) constant mortality throughout life, or (c) high mortality at a young age (Types I, II, and III, respectively; e.g., see Fig. 10.18 in Molles 2010). These curves can help us determine possible causes of population limitation—periods of heaviest mortality may have the greatest impact on population growth.

Knowing patterns of death and reproduction can be important in managing plant and animal populations. For example, fisheries managers might adjust the allowed catch after good and poor years of reproduction; managers trying to eliminate invasive plants might be able to target specific ages of plants for removal; and managers seeking to protect rare species might know what ages of individuals most need protection.

There are a variety of ways to construct life tables and survivorship curves. The best way, as represented by the studies of Darwin's finches by Peter and Rosemary Grant and their colleagues, is to follow a number of cohorts over time. In this way, Gibbs and Grant (1987) showed that survival of *Geospiza fortis* varies among years. For example, the 1978 cohort had a higher overall survival rate than did the 1981 cohort. Although cohort-derived life tables (also called dynamic life tables) and survivorship curves provide the best quality data, they are difficult and time consuming to construct.

Sometimes scientists develop static life tables and use those to estimate survival rates. Two major ways to develop a static life table and survivorship curve are to (1) discover the age at death of members of a population or (2) count the number of individuals in each age class alive at one time. Deevey (1947) constructed a life table from Adolph Murie's data on Dall sheep. Murie had collected and aged horns that he found lying on the ground, thus providing an estimate of the age at death of each sheep (static method 1). Alternatively, ecologists often collect and age samples of animal or plant populations and use these data to construct a static life table and survivorship curve (static method 2). A classic data set that was used in this way is the number of red deer in different age classes (Lowe, 1969).

There are assumptions involved in both of the static methods. Both methods assume a **stable age distribution**—a situation in which the percentage of individuals in each age class does not change from one time period to the next—even though the total population size may be changing exponentially. They also assume the population size is constant (no change in birth rates and no net emigration/immigration). Using ages of death averages

any changes in survivorship rate over many cohorts. Using the age structure of a population gives less reliable information because it simply provides a snapshot of the population at one instant in time. However, the snapshot may be better than nothing.

In this exercise, you will use the static age at death method to construct a life table and survivorship curve for humans. Visiting a cemetery and calculating the age at death of people will allow you to construct a life table and survivorship curve (Fig. 1) in the same way that Murie did with Dall sheep.

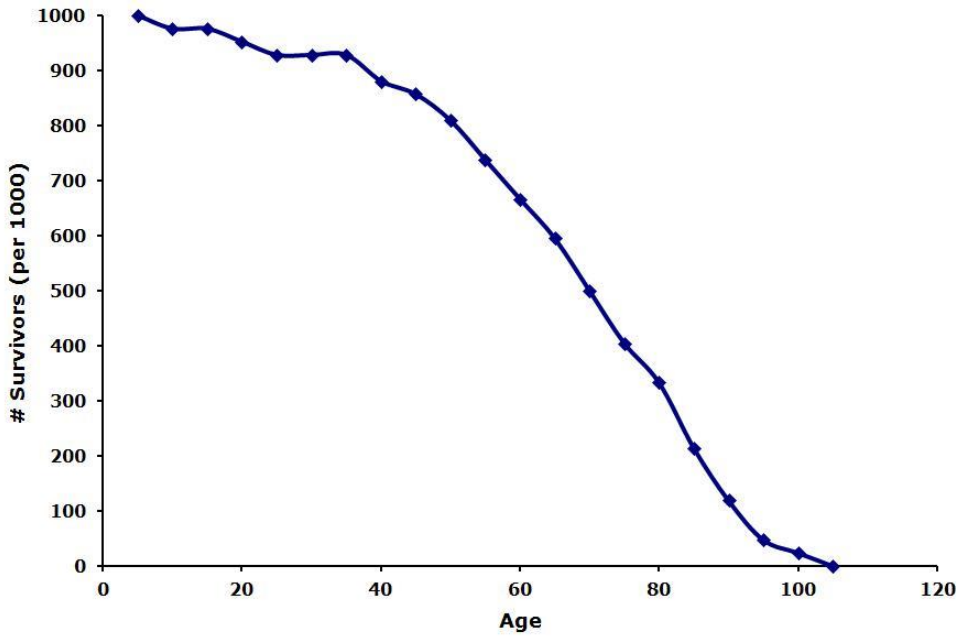

Fig. 1. Survival of African-American women born before 1926 and buried in Pleasant Grove Cemetery in Calhoun County, Arkansas. Data were collected from on-line cemetery records.

Your task is to compare the life table/survivorship curves for different groups of humans. You may use either method (or both) of developing a life table and survivorship curve.

What populations? That's up to you. You can compare males vs. females, people living at different times, people living in different places, or, perhaps, people of different ethnicities or socio-economic backgrounds. You may even think of other interesting comparisons. As you plan your project, make sure you identify a specific, interesting question, and hypothesize an answer to your question. Be prepared to explain your question and the rationale that led to your hypothesis.

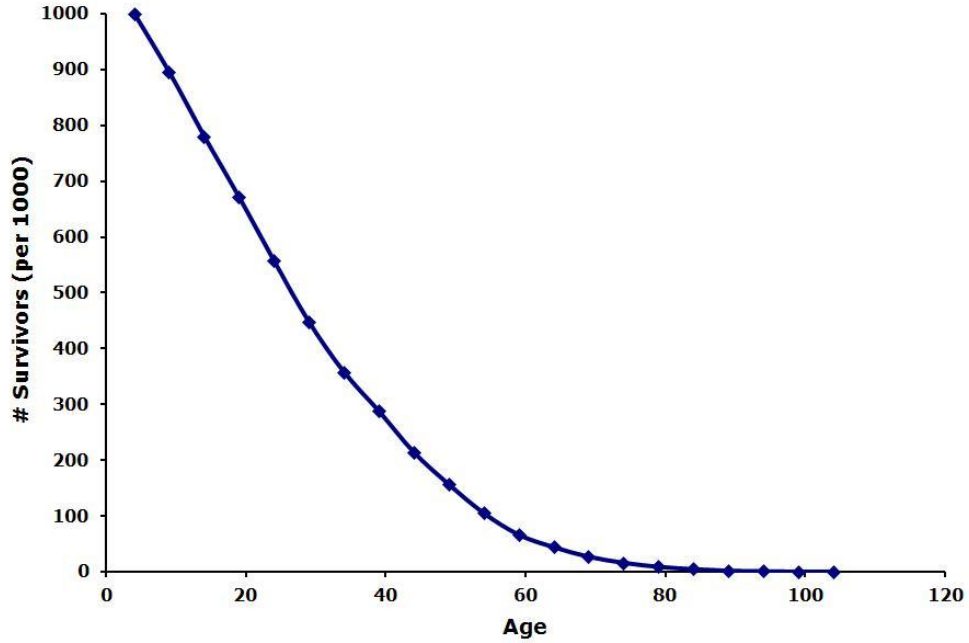

Fig. 2. Survival of African American women in Arkansas as calculated from the 1930 census.

Materials and Methods

Methods—Age at death Life Table

Data Collection: Formulate a question about two segments of human populations and gather data from cemetery records to examine your question.

1. Brainstorm about the kinds of questions that interest you. Keep in mind:
    a. You must be able to find sufficient numbers of death records (at least 100 individuals, more is better) for each comparison group to generate meaningful life tables and survivorship curves for comparison.
    b. In order to accurately portray the population trends, you should limit your sample population to individuals born in a range of years where you can reasonably assume all, or at least almost all, individuals born within that range have already died. This means you should limit yourself to births that occurred prior to 1930-1940.
2. Select two groups that you wish to compare. Make sure your two treatment groups are similar except for the factor you are investigating. For example, if you wish to compare males vs. females, make sure they lived during similar times and places.
3. Choose a data source. You may either go to local cemeteries and examine burial markers or use cemeteries that have published their records on-line (or both). See the reference sections below for online resources.
4. Record the births and deaths of at least 100 people (more is better) from each of the two groups. You do not need the same number of people in each group.

Data Analysis: Use the data gathered to complete the create life tables and survivorship curves for your populations. Each student will turn in a separate lab report.

Definitions/Notation

x = Age interval (e.g. 1 year, 0-5 years, etc). In general, the age class is defined by the age at the beginning of the age range. If the age range is 0-5 years, then x = 0.

n_x = Number alive at the beginning of the age interval x

a_x = Number alive at beginning of the age interval x standardized to 1000 individuals

l_x = Age-specific survivorship; Proportion alive at the beginning of age interval x

d_x = Number dying per 1000 individuals in population during age interval x

q_x = Age-specific mortality; Mortality rate during age interval x (i.e., $q_x = d_x / a_x$)

e_x = Expectation for further life of an individual of age x

b_x = The number of female offspring produced per female of age x (not used in this lab)

1. Calculate the age of death for each person in each comparison group.
2. Place individuals into 5-year age classes (make separate tables for each comparison group). The first category should be 0-5 and so on.
3. Determine the number of deaths in each age class.
4. Determine the number of individuals surviving from birth to the start of each age class (n_x). Start by placing a 0 in the lowest box of the column. To determine the next box up, add to the 0 the number of deaths that appears to the left and 1 column up. The top box in this column should be the number of tombstones counted.
5. Calculate the **age-specific survivorship** or the probability of surviving to the start of a given age class (l_x). Determine *lx*, the proportion alive at the start of age interval x, for each age class using the equation:

$$l_x = \frac{n_x}{n_0}$$

   The age-specific survivorship for the first age class (l_0) should be always be 1.0 (calculated as $l_0 = \frac{n_0}{n_0}$).
6. Standardize the life table per 1000 to allow for comparisons of life tables.

$$a_x = l_x(1000)$$

7. Calculate the Log_{10} of l_x for each time interval. This data will be used to graph survivorship curves.
8. Calculate d_x for each age category.

$$d_x = a_x - a_{x+1}$$

9. Calculate q_x for each age category

$$q_x = \frac{d_x}{a_x}$$

10. You are now ready to calculate the expectation for further life. In order to do this you must first construct a column called T_x. The sum of the a_x's from the age class in question to the oldest age class. So, T_0 would be the total of the entire a_x column.
    Ex: $T_5 = \sum_{x=5}^{x=oldest\ age\ class}(a_x) = (a_5 + a_6 + \ldots + a_{oldest})$; *and*

    $T_7 = \sum_{i=7}^{x=oldest\ age\ class}(a_x) = (a_7 + a_8 + \ldots + a_{oldest})$, and so on.

11. You can now calculate expectation for future life for each age category as follows:

$$e_x = \frac{T_x}{a_x} \times length\ of\ age\ class$$

    For this experiment, the length of age class would be 5 years. The age specific expectation of future life predicts the number of years an average individual that survives to the beginning of an age class will live beyond the beginning of the age class. This value is often not largest for the newborn age class (e_0) and may increase or decrease between age classes. The value for the newborn age class (e_0) is what is commonly referred to as the life expectancy of a population and predicts the age at which any individual born into the population will die.

12. Repeat steps 1-11 for the second group.
13. Generate professional looking life tables and survivorship curves (I suggest using excel) for each group evaluated.
14. Evaluate your data in relation to your question and hypothesis. Do the results support your hypothesis? If not, why not? Be prepared to explain your question and the rationale that led to your hypothesis. Also, evaluate the shapes of the survivorship curves compared to what you would expect for human populations.
15. Individually, prepare a lab report on this exercise. Be sure your lab report includes your life table and survivorship curves. This is not a group submission, each student should turn in a separate and different lab report, even though the data may be the similar.

Questions for Further Thought and Discussion

1. How likely is it that the assumption of a stable age distribution is met?
2. How likely is it that wild populations maintain a stable age distribution?
3. How likely is it that l_x schedules are constant over time? q_x schedules?
4. How likely is it that population size was constant?
5. What effects might immigration and emigration have on the results?
6. Given all the assumptions involved in developing static life tables and survivorship curves, are they useful? If so, how and why?
7. What shifts in survivorship and mortality curves would you expect if environmental problems get worse and pollution-related diseases increase?
8. Why is it difficult to disentangle the effects of environmental factors from the effects of socio-economic factors when examining differences between groups?

References and Additional Resources

Local cemetery data:

La Feria Cemetery – www.interment.net/data/us/tx/cameron/laferia/index.htm

Roselawn Cemetery, McAllen, TX – www.findagrave.com/cgi-bin/fg.cgi?page=cr&GScid=6474&CRid=6474&pt=Roselawn%20Cemetery&

On-line African American cemetery data:

http://africanamericancemeteries.com/

General on-line cemetary data:

http://Findagrave.com

http://interment.net/

On-line U.S. Census Records: http://census.gov/prod/www/abs/decennial/

Deevey, E. S. 1947. Life tables for natural populations of animals. The Quarterly Review of Biology 22:283-314.

Gibbs, H. L., and P. R. Grant. 1987. Adult survivorship in Darwin's ground finch (*Geospiza*) populations in a variable environment. Journal of Animal Ecology 56:979-813.

Molles, M. C., Jr. 2010. Ecology: concepts and applications. Fifth edition. McGraw-Hill, New York.