

## EXPERIMENTS

### **Demography from physical cemeteries, “virtual cemeteries,” and census data**

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#### **ABSTRACT**

This lab provides a rich and flexible version of widely-used demography exercises that have been previously based on data collected from cemeteries.

This lab teaches life tables and survivorship curves. Over two lab periods, small student groups develop and answer questions comparing the survival patterns of different groups of humans (e.g., groups that differ in geographic area, time period, gender, socio-economic background, or ethnicity). Data on human demography are available from three sources: (1) tombstones in local cemeteries that provide ages at death, (2) on-line cemetery records, and (3) census records that provide the numbers of people alive in different age classes. Students may also compare survivorship curves on the same groups generated by different data sets.

#### **KEYWORD DESCRIPTORS**

- **Ecological Topic Keywords:** cemetery, demography, life history, life table, mortality, population, population ecology, survivorship curve
- **Science Methodological Skills Keywords:** collecting and presenting data, formulating hypotheses, graphing data, oral presentation, quantitative data analysis, question generation, use of spreadsheets, use of graphing programs



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- **Pedagogical Methods Keywords:** [alternative assessment](#), [bounded inquiry](#), [cooperative learning groups](#), [group work assessment](#), [scoring rubrics](#)

## **CLASS TIME**

Two, two-hour labs. In the first lab period, students learn how to collect data and calculate survivorship curves and choose a comparison for their group to study; in the second lab period, students present the results of their projects.

## **OUTSIDE OF CLASS TIME**

Approximately three to four hours per student team to collect data, analyze data, and prepare a presentation for the class.

## **STUDENT PRODUCTS**

A computer-generated presentation from each group is used to assess the students' work. Students present (1) background that provides a rationale for their question, (2) their question and methods of answering the question, (3) their results, and (4) their interpretation of the significance of their results. A [rubric](#) for this assessment is provided to the students ahead of time. Logrank (Mantel-Cox) tests can be used to compare curves generated from two groups statistically.

## **SETTING**

This lab can be completed in almost any classroom. To collect data, students need access to computers with internet access (their own or the school's), local cemeteries, or census books in a library. The second lab period requires a room with a projector.

## **COURSE CONTEXT**

This lab can be taught at any time of the year. I use it in a junior-level ecology course with 12-20 students. Students work cooperatively in groups of two to four.

## **INSTITUTION**

This lab is used at a public, metropolitan university.

## **TRANSFERABILITY**

This lab can be used in any general ecology course or an upper division ecology course. More extensive comparisons can be required in an advanced course.

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Statistical analyses can be required if the students have good statistical backgrounds. No specialized equipment is necessary. Using strictly electronic data reduces limitations imposed by geography, travel time and expense, and any mobility impairments students may have. One limitation of oral presentations can be laboratory time. In this case, posters can be used for presentations.

## **ACKNOWLEDGEMENTS**

This lab builds on many “cemetery” labs written by other authors (e.g., Flood, Nancy. 1993. Cemetery demography. In: Experiments to Teach Ecology. Edited by Jane M. Beiswenger. Volume 1. Ecological Society of America [[http://tiee.esa.org/vol/expv1/expv1\\_toc.html](http://tiee.esa.org/vol/expv1/expv1_toc.html)]). Because the traditional labs have so few comparison options (e.g., only sex or time period), I tried to find additional sources of data. A newspaper article about historic cemeteries alerted me to the fact that many cemetery records are on-line. News about the 2010 census gave me the idea of using census data for this lab. I would also like to thank Karen Russ for help in accessing census data. Finally, I thank three anonymous reviewers for their thoughtful suggestions and Kathy Winnett-Murray for additional suggestions and much-appreciated encouragement.

## **SYNOPSIS OF THE EXPERIMENT**

### **Principal Ecological Question Addressed**

Life tables and survivorship curves are the topics of the lab exercise. Students explore differences in human demography over time and/or among populations that differ in factors like geography, ethnicity, or socio-economic background. Students develop their own questions and then investigate them by calculating and comparing life tables, survivorship, age structure, and other demographic characteristics.

### **What Happens**

First, students are introduced to the ideas of life tables and survivorship curves and are shown how to calculate them using published data. Students are then shown (1) how to locate ages of death of people using on-line cemetery inventories and (2) how to access and use U.S. government census data. If the instructor chooses, the class may visit a local cemetery or locations of local cemeteries may be given so that groups may visit them individually. Groups of 2-4 students then develop an hypothesis about variation in human demography between genders or among populations that differ in time that they lived, geographical area, socio-economic group, or ethnicity. They collect and analyze

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appropriate data and present and interpret their results orally to the rest of the class.

## Experiment Objectives

At the conclusion of the project, students should be able to

- (1) calculate survivorship curves from ages at death or from censuses;
- (2) explain how two different groups of humans differ or do not differ in their survival rates;
- (3) explain assumptions involved in developing survivorship curves from the type of data they used; and
- (4) explain how survivorship curves provide insight into the ecology of other species.

## Equipment/ Logistics Required

Access to the internet and U.S. census tables are necessary. For computer-generated presentations, a computer, appropriate software, a projector, and a screen are required.

## Summary of What is Due

Students will use a computer-generated presentation to explain to the rest of the class their question, results, and conclusions. Included will be survivorship curves of two comparison groups.

## DETAILED DESCRIPTION OF THE EXPERIMENT

### 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

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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.

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In this exercise, you can use either static method to construct a life table and survivorship curve for humans. Visiting a cemetery (in person or virtually) 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. Examining U.S. census data will allow you to take a snapshot of age structure at a specific point in time and develop a survivorship curve (Fig. 2) in the same way that Lowe developed a survivorship curve for red deer.

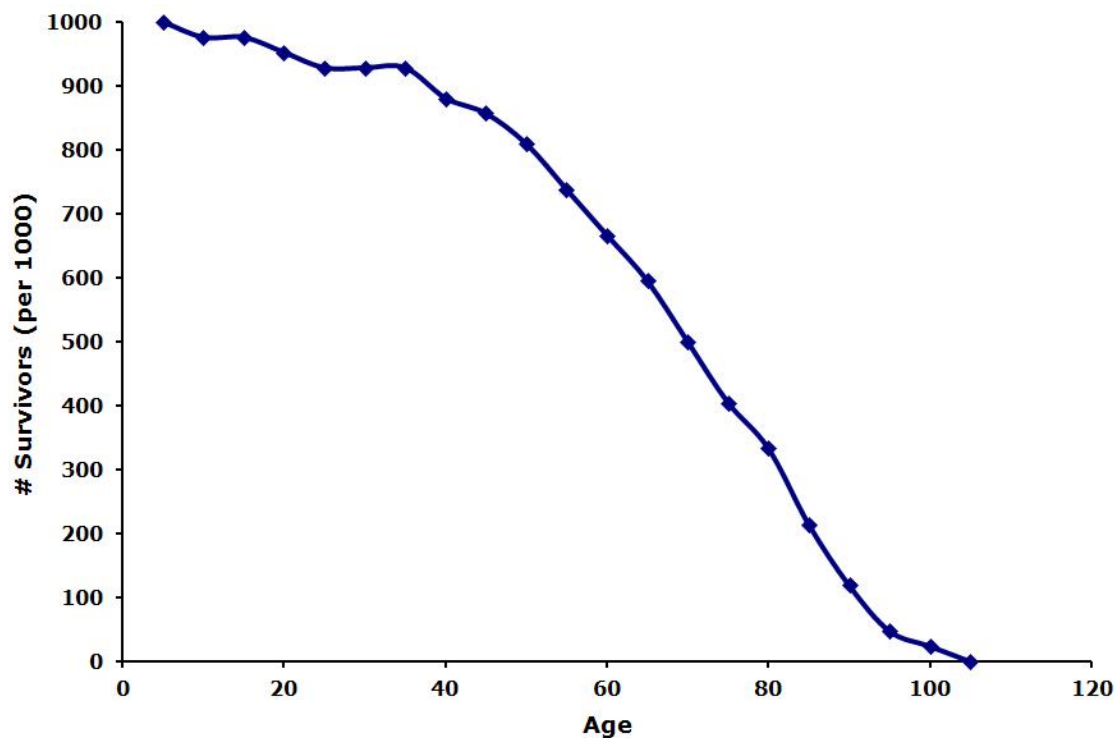


Fig. 1. Survival of African-American women born before 1926 and buried in Pleasant Grove Cemetery in Calhoun County, Arkansas. Data were collected from on-line cemetery records.

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

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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. Your instructor may ask you to present your question and rationale before proceeding with data collection.

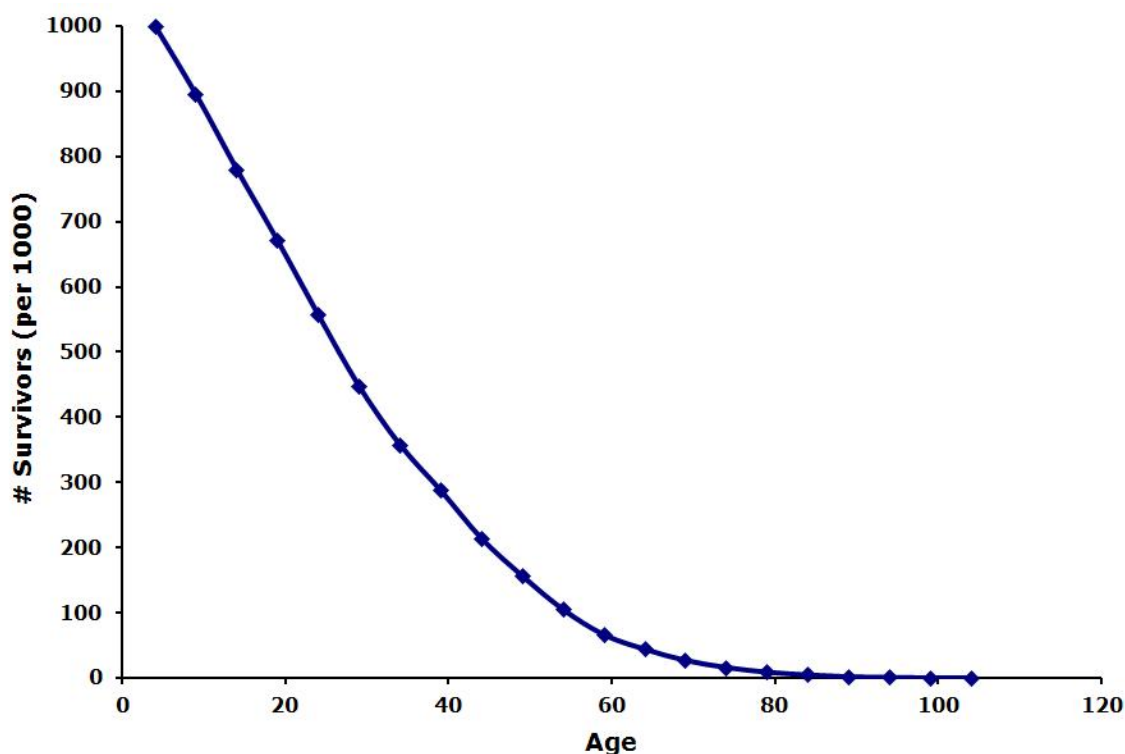


Fig. 2. Survival of African American women in Arkansas as calculated from the 1930 census.

## Materials and Methods

### *Method 1—Ages at death*

1. Brainstorm within your group about the kinds of questions that interest you. Supplement this brainstorming with an examination of the cemeteries that provide their data on a website and a list of cemeteries in your area. For the on-line information two good starting points are <http://interment.net/> for many cemeteries and <http://africanamericancemeteries.com/> for African American cemeteries. Remember that urls change relatively frequently—be prepared to search for cemetery records if a url changes. Don't forget that visiting local cemeteries is an option; many areas have very old, small

cemeteries that when combined might make a good comparison to larger, more recent cemeteries. Many large cemeteries in urban areas have not entered their data electronically.

2. Select two groups that you wish to compare. Make sure to keep your two groups 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, either local cemeteries or cemeteries that have published their records on-line (or both).
4. Record the births and deaths of at least 200 people (more is better) from each of the two groups. You do not need the same number of people in each group.
5. Calculate the age of death for each person for the first group.
6. Group the ages into 5-year intervals (1-5 years, 6-10 years, 11-15 years, etc.) and make two columns in a table. Column 1 will have the age groups and column 2 will have the number of people dying in each age group.
7. Calculate the number of individuals surviving to the start of each age class and place these numbers in column 3 of your table. To do this, first sum the number of all individuals (this is the number of individuals alive at time 0); next, subtract the number of individuals who died between age 1 and 5 from your total and place the number in column 3; for each age group, continue to subtract the number dying in the age class from the number remaining alive and place this number in the next row of column 3.
8. Calculate the probability of surviving to the start of a given age class ( $l_x$ ) by dividing each number in column 3 by the total number of people and placing these numbers in column 4.
9. Standardize the data per 1000. This step will allow you to compare the two samples. To standardize your numbers to 1000, take each number in column 4 and multiply by 1000.
10. Draw a survivorship curve for each group (e.g., [Fig. 1](#)). Draw your curve either with an arithmetic y-axis or a log y-axis. Think about how these two kinds of graphs differ.
11. Repeat steps 5-10 for the second group.
12. 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.

13. Develop an 8-10 minute oral presentation that explains the groups you are comparing and why, the assumptions involved, your conclusions, and future projects you would recommend (see [rubric](#)).

#### *Method 2—Snapshot of age structure*

1. The U.S. census has published a huge amount of data on the U.S. population. The first census was taken in 1790, the most recent one in 2010. Many libraries have books and books of these data (see sample page, [Fig. 3](#)). The original forms filled out by households are available from the censuses taken 70 years ago and earlier. But all census years have published aggregate data. The early data are not useful for this lab project because they only counted the number of people. However, starting in 1850 the census data includes ages of people, and these data may be used to develop survivorship curves like Lowe did for the red deer.

2. The data available for different censuses may differ. In the attached sample ([Fig. 3](#)), the data are aggregated according to age, sex, and race, for Mississippi and Arkansas. But Congress wanted different information at different times and so the same questions cannot be answered from each census. For example, some censuses report population in urban/rural-farm/rural-non-farm categories. To discover what questions were asked, look at samples of the forms. Examples of blank census forms can be viewed in a booklet entitled “200 Years of U.S. Census Taking: Population and Housing Questions, 1790-1990” (1989. U.S., Department of Commerce). This document is available on-line at <http://www.census.gov/history/pdf/200years.pdf>.

3. Brainstorm within your group about the kinds of questions that interest you. Supplement this brainstorming with an examination of the available census data. Your library may have census books; ask a reference librarian. Alternatively, you may access aggregated census data on-line. Remember that urls change relatively frequently—be prepared to search for census data if a url changes.

Go to <http://census.gov/prod/www/abs/decennial/> and click on the desired census. What you do next varies a bit from census to census. Sometimes you can click directly on a ZIP file and sometimes you need to click on a link to summary population statistics before you can click on a ZIP file. A ZIP link downloads a ZIP file to the computer. Opening the ZIP file gives links to more files. You may need to explore the ZIP files until you find the one you want.

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Volumes 2 and 3 are often the most relevant to this activity. Clicking on a file with “TOC” (Table of Contents) is useful because these files contain “clickable links” that open up the actual data files. To get to the particular table, page down manually. Searching is not an option because these appear to be scanned files.

You may need to be persistent in order to find the tables you want. Some data are repeated in different volumes of the same census. For example, in the 1930 census, age distribution by sex and “color” for Arkansas can be found in Volume II, Chapter 10, Table 24 and in Volume III, Part I, Table 3. The information in Volume II is better because age groups are presented in 5-year intervals from 0-100, whereas the Volume III table presents 10-year intervals after age 50. Ask your instructor for help in accessing the data that you need.

4. Select two groups that you wish to compare. Make sure to keep your two groups 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 in similar places. Other possible comparisons are people of one sex in different states in the same census or one sex and race in two different censuses. Depending on the questions asked in the census, you may be able to make urban-rural comparisons.

5. Because the data are already aggregated, data collection is much easier than with method 1. However, calculation of  $l_x$  values is slightly more complicated. In order to compute the number of people who died in a given age interval with the census numbers, you must assume that all individuals were born in the same year (i.e., were members of the same cohort) but died at the age they were when the census was taken. Use this clue to calculate the number of people who survived to the start of each age class (“calculated number alive”).

6. Next, calculate the probability of surviving to the start of each age class ( $l_x$ ) by dividing the calculated number alive by the total in the entire sample. Enter these numbers in the next column in the table. Try to do these calculations (steps 5 and 6) and check with your instructor that your methods are correct.

7. Standardize the data per 1000. This step will allow you to compare the two samples. To standardize your numbers, multiply each  $l_x$  by 1000.

8. Draw a survivorship curve for each group (see [Fig. 2](#)). Draw your curve either with an arithmetic y-axis or a log y-axis. Think about how these two kinds of graphs differ.

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9. Repeat steps 5-10 for the second group.
10. 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.
11. Develop an 8-10 minute oral presentation that explains the groups you are comparing and why, the assumptions involved, your conclusions, and future projects you would recommend (see [rubric](#)).

### *Method 3—Compare the two methods*

1. An interesting project might be to compare the survivorship curves that you get from the two different methods.
2. To conduct a project like this, make sure to choose comparable data. For example, get a sample of males who died in the 1930s and then look at the census from 1930 from the same area.
3. Follow the appropriate methods to develop two life tables and two survivorship curves.
4. Compare the survivorship curves and assess how similar the results are.
5. Develop an 8-10 minute oral presentation that explains the groups you are comparing and why, the assumptions involved, your conclusions, and future projects you would recommend (see [rubric](#)).

### **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?  $m_x$  schedules?
4. How likely is it that population size was constant?

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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?
  
9. Explain how much variability exists in the survivorship of different cohorts of *Geospiza* and the possible causes of the variability (see Gibbs and Grant, 1987). Do the two species differ in survival rates? Predict what would happen to survival rates if researchers experimentally added seeds to the environment.

## References and Additional Resources

On-line African American cemetery data: <http://africanamericancemeteries.com/>

On-line cemetery data: <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.

Lowe, V. P. W. 1969. Population dynamics of the red deer (*Cervus elaphus* L.) on Rhum. Journal of Animal Ecology 38:425-457.

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

U.S. Census Bureau. 1933. Fifteenth Census of the United States: 1930. Population Volume II, General Report, Statistics by Subjects. United States Government Printing Office, Washington, D.C.

U.S. Department of Commerce. 1989. 200 years of U.S. census taking: population and housing questions, 1790-1990. This document is available on-line at <http://www.census.gov/history/pdf/200years.pdf>.

## **Tools for Assessment of Student Learning Outcomes**

Use the attached [rubric](#) to help you design your project and presentation.

## **NOTES TO FACULTY**

### **Challenges to anticipate and solve**

This exercise is fairly straightforward and provides certain advantages over the “traditional” approach to teaching life tables and survivorship curves, which relies on collecting data at cemeteries. The most important advantage is that many more comparisons are possible and this diversity of projects allows students to make their own creative decisions about what to explore. Similar data can be collected from field surveys but the classroom management involved usually requires that the question (comparison) is assigned by the instructor. Another advantage this approach provides is that data collection can be less time consuming and more of the invested time can be devoted to data analysis.

Examples of comparisons that students can choose include: different time periods, rural vs. urban, African-American (or other group with specialized cemeteries) vs. Caucasian, and geographic areas.

*Challenge #1. Identifying a project.* One difficulty for some students is developing a project. Brainstorming with the class during the introduction can help. I ask students what factors might affect survival rates. Answers include gender, time period, geographic area, ethnicity, socio-economic conditions, access to medical care, wars, and epidemics.

After the formal introduction to the lab, I circulate among the groups, listening to their planning and asking questions and offering suggestions as appropriate. I try to facilitate their planning and help them find a question that interests them rather than direct them to a question that I find interesting. I do try to guide students, especially advanced groups, away from the easiest questions.

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Sometimes groups will have a tendency to just choose the “quickest and dirtiest” question so that they can finish quickly. I have been known to suggest that a particular question was “boring”—e.g., when I had a sharp group that was just going to look at male vs. female survival rates. But I adjust my comments and suggestions according to the group—I would not try to dissuade a group that is particularly challenged by the ideas from choosing what I think is a rather obvious project.

Students can approach finding a question in a variety of ways. Some groups will just go to the census books or data on the government web site and see how the data are arranged and find a question by seeing what information is available. Some groups will think of a question first and then choose the most appropriate method of data collection. For example, if a group wants to ask about the benefits of antibiotic development, data on ages of death may not be the best data collection method because many people born after the general use of antibiotics have not yet died. In contrast, this question can probably be answered by looking at census data (e.g., 1940 vs. 1960). Similarly, the effect of World War II on the survival of males can probably not be answered from cemetery data because so many soldiers were buried overseas but could be addressed by comparing the 1940 and 1950 census records.

Some questions might best be answered by gathering some data from actual tombstones and some from on-line data. For example, many large cemeteries do not have their data on-line. So, a group of students that lives in or near a big city may choose to collect ages at death in a big-city cemetery and compare those data to ages at death from rural cemeteries that have posted their information on-line.

An option that some instructors might want to consider is to provide a data set and let students prepare survivorship curves before they have developed their own question. The advantage of this approach is that students will become comfortable with the procedures. Two disadvantages of this approach are that it takes more time and students will be inclined to use the method (1 or 2) chosen for demonstration by you. I have not found this necessary.

*Challenge #2. Collecting and interpreting data.* One difficulty is that not all cemetery records are online. Many websites let one search for death dates for specific people. However, these sites are not useful for this laboratory. Students may have to be persistent in searching for data if they have a narrow hypothesis they want to test.

One important point for students to consider is how to standardize their data. Because many factors can affect survival rates, the best projects standardize comparison groups. For example, in comparing survival rates of people in South

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Carolina vs. Arkansas, a student group could narrow the investigated group to African-American women born before 1920 and buried in rural cemeteries.

Explaining deviations from expected results can be challenging. For example, developing a survivorship curve on African-American women from Arkansas 1920 census data produced a Type II survivorship curve whereas the tombstone data produced a curve more like a Type I curve ([Fig. 4](#)). Further literature search revealed that there was extensive emigration of young (20s and 30s) African-Americans from the south in the 1910s and 1920s to cities in the north. Internet searches of “African American emigration from the south” and the “Great Migration” will yield a variety of sources on this phenomenon. Similar effects are likely to be observed on populations in the Great Plains in the Dust Bowl era of the 1930s.

Census data are available in books and on-line, but so much data are available that it can be difficult to find the right data. I found the census books relatively easy to access but not all libraries have the books. If you have a library that is a government documents repository, ask your reference librarian for help.

*Challenge #3. Mathematical calculations.* Many of my students seem to be challenged by the mathematical manipulations that they must conduct, even though I think they are relatively simple. This situation makes me conclude that this exercise is important to conduct—life tables and survivorship curves are important tools for ecologists and this exercise gives students experience with methods that ecologists use. If these calculations are challenging, then students probably need the practice!

It may be necessary to explain scaling raw numbers to a consistent start of 1000 when working from ages of death. It may also be necessary to explain semi-log plots.

Calculating  $l_x$  from census data requires some mental and mathematical gymnastics. I use the following method (shown in [Table 1](#)): First, sum all of the individuals sampled (cell B27). Then, in order to treat all individuals as members of one cohort and to calculate the number of individuals alive at a given age class, assume that all individuals alive *after* a given age class had been alive at the start of the age class. Thus, the number of people in age class 0-4 is the same as the total number of people in the census (cell D5 = cell B27) and the number of people in age class 5-9 equals the total minus the number in age class 0-4 (cell D6 = cell D5 – cell B5; 235259-25659 = 209600). Continue similar subtractions for all age classes. This method has the advantage that  $l_x$  is never greater than 1.0. One disadvantage of this method is that it includes an

assumption of no migration, an assumption that is not warranted with many human populations.

To make the instructions for calculations clearer, I am including an Excel file ([Excel survivorship template](#)) that provides the calculations for all of the figures that are referenced in the student handout; this file also contains a graph of some of the data. Faculty may choose to provide this file to their students or not.

Two other ways to calculate survival rates from census data exist but both can give  $l_x$  values above 1.0: (1) calculating  $l_x$  by dividing the number of individuals in the 0-4 age class in the first census by the number of individuals in the 10-14 age class in the census ten years later, and (2) calculating  $l_x$  by dividing the number of individuals in an age class by the number of individuals in the first age class. I don't like either of the methods because of the possibility of an  $l_x$  greater than 1.0.

*Challenge #4. Using appropriate software.* To successfully complete this project students will need to use spreadsheet (e.g., Excel), graphing (e.g., Excel), and presentation (e.g., PowerPoint) software. More and more students are becoming proficient with these software packages, but some students still need a tutorial. Several solutions to lack of skill are available. One option is to make sure each student group has at least one skilled user; the disadvantage of this method is that often the skilled student does all the computer work and the other students do not learn the skill. Another option is to provide a short in-lab tutorial that focuses on the particular skills needed. When I use this option, I give students a list of computer tasks (e.g., using formulas, choosing graph types, inserting photographs) and only talk about the tasks most students don't already know. A third option is to provide help to groups as it is needed. This option is best used when only some groups need a little bit of help.

### **Comments on Introducing the Experiment to Your Students:**

The ideas of life tables and survivorship curves should be introduced before students attempt data collection. It is important that students understand what life tables and survivorship curves reveal about organisms. I usually cover the topic in the classroom before the lab period so that during lab we can concentrate on developing questions and the methods of data collection. Brainstorming is an important part of my pre-lab routine.

This laboratory activity gives students experience with the concepts of survivorship curves and helps them see how such curves can be used to answer interesting ecological questions.



**Comments on the Data Collection and Analysis Methods Used in the Experiment:**

Data collection is relatively quick if students collect data from on-line cemetery sources and if they can access census data on-line. Visits to cemeteries make data collection more time consuming.

One drawback that I see in this lab is that comparing different data sets statistically is not easy. I use this lab early in the semester, before students have conducted any other statistical tests. Therefore, I just let students “eyeball” the curves to look for differences instead of trying to test for differences with curvilinear regression.

An appropriate statistical test to compare the curves for different data sets would be the logrank test (also call Mantel-Cox test). A good discussion of the test can be found in Pyke and Thompson (Pyke, David A., and John N. Thompson. 1986. Statistical analysis of survival and removal rate experiments. *Ecology* 67: 240-245.).

**Comments on Questions for Further Thought:**

Questions 1-5 address the assumptions of the methods. Developing static life tables and survivorship curves requires the assumptions of stable age distributions, constant  $l_x$  and  $m_x$  schedules, and no net emigration/immigration. These are not realistic assumptions in either human populations or wild populations.

Questions 6 asks whether the development of survivorship curves is useful given all of the unrealistic assumptions involved. Single snapshot views of populations can tell the researcher something about how the population interacts with the environment (e.g., is mortality concentrated early or late in life?). Furthermore, comparisons of two populations can identify causes of differential mortality or emigration/immigration.

Question 7 asks for a prediction for the future. I would expect that mortality would increase. Possible outcomes could be a lowering of the entire survivorship curve or an increase in child mortality rates if the environmental factor acts quickly, or an increase in adult mortality if the negative effects of the environmental factor accumulate slowly. There might also be more vulnerable life stages (e.g. the very young and/or the very old) that students may want to consider.

Question 8 asks a question about scientific methodology. When there are only two groups, it is impossible to distinguish the effects of two different factors that

may be operating simultaneously. In addition, the adage “correlation need not imply causation” is relevant here.

Question 9 refers to a paper by Gibbs and Grant (Gibbs, H. Lisle, and Peter R. Grant. 1987. Adult survivorship in Darwin’s ground finch [*Geospiza*] populations in a variable environment. *Journal of Animal Ecology* 56:979-813) on survivorship of two species of Darwin’s finches (*Geospiza fortis* and *G. scandens*). Survivorship of three cohorts of the two species varies considerably, probably because of the availability of small seeds. In general, *G. scandens* has higher survivorship rates than *G. fortis*. The effect of added seeds might depend on the amount of rainfall—in high rainfall years, supplemental food might not increase survival.

### **Comments on the Assessment of Student Learning Outcomes:**

The [rubric](#) I use for assessment appears clear to students and is easy to use while the students are making their presentations. This clarity promotes good performance by my students.

If I wish, I can often grade the presentation as I listen. Alternatively, I can evaluate the student presentation after class. In either case, the grading is rather quick.

It is also possible to ask everyone in the class to evaluate the presentations with the same rubric. This process helps listeners pay attention and learn from each presentation.

You may wish to add elements to the rubric, depending on how you modify the lab from what I present. Elements that you might find useful could include statistical analysis, discussion of assumptions, and a discussion of how deviations from those assumptions might affect the results.

### **Comments of the Formative Evaluation of this Experiment:**

The high scores that most groups achieve on the rubric show me that students can perform the activities I set as goals. These activities include mathematical manipulations, production of survivorship curves, interpretation of data, assessment of the methods, and development of future questions.

I have not conducted formal formative assessment, although I provide feedback to each student team during the development of their choice of a comparative question to investigate. It is my sense that having choice in the questions that students ask increases their interest in the exercise. It is also my impression that

students in the lab do better on hour tests on this topic than students who do not take the lab portion of the course.

If you wish to conduct a formative evaluation, you may ask students for a reflective essay at the conclusion of the exercise. Such essays can encourage students to think about their learning—and this analysis can often promote their learning in the future. Questions that you might use include: (1) What do you know now that you didn't know at the start of this lesson?; (2) How much did the exercise help you learn to calculate survivorship curves?; (3) How much did the exercise help you understand how an external factor (e.g., gender, ethnicity, or time period) affects survivorship curves?; (4) How much did the exercise help you understand the assumptions involved in developing survivorship curves?; (5) How much did the exercise help you see how understanding survivorship curves provides insight into the ecology of a population?

## **Comments on Translating the Activity to Other Institutional Scales or Locations:**

This lab can be conducted with any size group, though instructor availability will become more limited as group size increases. If lab time is too limited for oral presentations, students can make posters. The wide availability of computers makes much of the data collection and presentation development easy. The lab can be conducted in any geographic location.

The use of electronic cemetery records and census data lifts geographic restrictions that are encountered when only using data from local cemeteries. Similarly, mobility-impaired students, who might find a trip to a local cemetery difficult, will be able to participate fully in the lab activities.

If you are worried about students using ideas from past years, you might post the questions students have asked previously and make these “off-limits” (not an approach I favor because it really limits student options and students may use different methods to ask similar questions). Alternatively, you can require groups to get your approval of their question before proceeding, thus allowing you to monitor the research questions and help groups refine/improve their questions.

## **STUDENT COLLECTED DATA FROM THIS EXPERIMENT**

In lieu of student data, I am providing data that I collected as described in the methods section. See [Excel survivorship template](#).

# TIEE

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