r and k selection: Bubble Survivorship

SC Academic Standards: 4.L.5A; 5.L4A; 6.L.4B; 7.EC.5A,B; H.B.6A,C.

NGSS DCI: 5-ESS3.C; MS-LS2A,C,D; MS-ESS3.C; HS-LS2.A,C.

Science and Engineering Practices: S.1A.1; S.1A.2; S.1A.3; S.1A.4; S.1A.5; S.1A.6; S.1A.7

Crosscutting Concepts: Patterns; Scale, Proportion, and Quantity; Stability and Change; Scale, Proportion, and Quantity; and Systems Models.

Focus Question(s): How does parental care affect survivorship of young "bubbles"? How are r and k selected species different? Which strategy is better?

Conceptual Understanding: Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. Limiting factors include the availability of biotic and abiotic resources and challenges such as predation, competition, and disease.

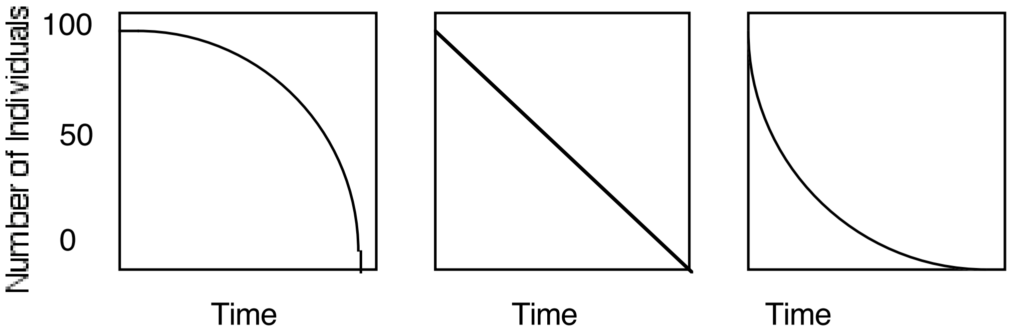
A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively stable over long periods of time. Fluctuations in conditions can challenge the functioning of ecosystems in terms of resource and habitat availability

Each plant or animal has a unique pattern of growth and development called a life cycle. Some characteristics (traits) that organisms have are inherited and some result from interactions with the environment.

In all ecosystems, organisms and populations of organisms depend on their environmental interactions with other living things (biotic factors) and with physical (abiotic) factors (such as light, temperature, water, or soil quality). Disruptions to any component of an ecosystem can lead to shifts in its diversity and abundance of populations.

Background: A **survivorship curve** traces the decline in number, over time, of a group of individuals born at the same time (a **cohort**). It can be thought of as the probability of an individual surviving to various ages, or the average **Life Expectancy. Life expectancy** is different from the **Maximum Life Span** (i.e. the American robin, *Turdus migratorius*, can live to be 7 years old but the probability of a newly hatched robin doing so is less than 1 %. Many live only a year or two. Life **expectancy** is 1-2 years, **maximum** life span is 7 years). There are **three typical population survivorship curves**: Type I, Type II and Type III. Humans have a

Type I survivorship curve, with low infant mortality and a high probability of living until you are old (at which time the probability of death increases).



Type I (Humans, large mammals) Type II (songbirds) Type III (marine invertebrates)

To determine age specific mortality and survivorship curves for a population, ecologists will follow a **cohort** - a group of individuals born within the same time interval (for example, a year, 5 years, or a month, depending on the species we are looking at). The cohort is followed until all members of the cohort are dead; gender and age at death is recorded for each individual. We find that each species has a characteristic life span and survivorship pattern, although few may reach the maximum age.

In this lab we will construct survivorship curves for bubbles. We have two types of bubbles, those that are receiving parental care, and those that are not. This reflects two different types of strategies that we see in nature for the allocation of energy and resources. Some animals and plants spend most of their energy on reproduction, others on growth. Generally, you aren't both large and very fecund.

Ecologists call this **r vs. k selection** – some organisms (ex., whales, bears, gorillas, annual grasses) have longer lifespans, grow larger, spend a lot of energy growing big, and delay reproduction till later, have only a few young at a time, may reproduce more than once, and often give **parental care** to their fewer offspring. **These organisms are k-selected, and typically have type I** (like humans) or type II (like songbirds) survivorship curves. Other organisms, like dandelion weeds, most frogs, most insects, spend little energy on growth but put the bulk of their energy into reproduction. They have shorter life spans, are often smaller, and generally grow quickly to adulthood, reproduce once – but have lots of well developed offspring, and give little parental care (often dying after reproduction). **These organisms are r-selected and often have a type III survivorship curve.**

Life history theory, which is more in favor these days than r / k selection, states that natural selection tends to increase **fitness** of any organism (that is, to have reproductive success, so that your genes make it into the next generation, and the next, and so on. This depends on both reproduction and survival of offspring to adulthood. Fitness, essentially, is who can produce the largest number of surviving offspring. We are hardwired (genetics) to do this. Life history characteristics, such as age of first reproduction, reproductive lifespan, number and size of offspring, etc, are important and vary from species to species. The variations lead to different allocations of energy / resources (to reproduction? To growth? Time and effort to grow means less available time and effort to reproduce. It is a trade-off). Life history characteristics can change population density and size.

In this lab we will investigate survivorship of bubbles. Some bubbles are given parental care; some are not. Will we see a difference in survivorship?

Materials: Bubbles and bubble wands, stopwatch or clock with a second hand. This exercise is easily done outside. You can make your own bubbles: The recipe is: 8 cups of water with 1/2 cup liquid dish soap, and 1 teaspoon glycerin (optional, and can be replaced with 4 TBS corn syrupcorn syrup). This amount will be enough for 8 groups of 4 students (32 students total). Each group will use 1 cup or less of the bubble solution. For the **extension**, you will want an empty 8x11 picture frame.

Previous Knowledge: (ecology): not every plant or animal fits nicely into r (rate) vs. k (carrying capacity) selection. For example, sequoia trees are very large and very long lived and reproduce more than once in their lifetime - but produce millions of tiny seeds to which they give no parental care, and they have low survivorship to adulthood: it's a mixture of r and k traits, and we see this with a lot of organisms, including sea turtles! And, the theory originally predicted that r-selected species would be found in unstable areas where the environment was very changeable from year to year, so that quick reproduction is an advantage; further that k-selected species would tend to be found in stable environments – however, in all environments you can find a mix of r and k species, and some species that seem to have characteristics of both strategies, like the aforementioned sequoia. Last, it isn't always all genetic either: studies with guppies have shown that the presence of predators can influence the life history traits of prey populations. Predators shifted the prey population toward earlier maturation, more rapid reproduction, and smaller offspring.

Previous Knowledge: (sociology): It's is good to have a little sociological background on your area: There are great variations in life expectancy between different parts of the world, mostly caused by differences in public health, medical care, and diet. The impact of AIDS on life expectancy is particularly notable in many African countries. In the United States, particularly the southeast, in the 1700's there were a couple scarlet fever epidemics (1735-40, 1786); during the civil war (1860-1865) typhoid epidemics and malaria claimed lives; there was a flu epidemic in 1857-59 and in 1918-19 (the Spanish Flu of 1917/18 infected 1/5 of world population, with 3% dying from flu).

And, from Sundstrom, William, et al. "Industrialization and Fertility in the 19th Century: Evidence from South Carolina."
http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCIQFjAA&url=http%3A%2F%2Fweb.utk.edu%2F~mwanamak%2FJEHarticle.pdf&ei=0S8sVPDkE4eyyQTQzIG4AQ&usg=AFQjCNFM7BmNn6zy4b1tTO2SFk-YAQin-Q&bvm=bv.76477589,d.aWw

> “By the dawn of the 20th century, fertility rates in the United States had undergone a century of steady decline. In 1800, white American females could expect to bear 7.0 children on average; by 1900, this number was 3.6. The factors behind the 19th century decline have been the subject of a lengthy literature highlighting the importance of intergenerational bequests, the economic value of children, and the cultural context for American family formation.
>
> There are a number of mechanisms by which industrialization may have altered a household's fertility outcome. First, several models of economic growth and fertility decline highlight the role of human capital in increasing the incentives of households to invest in child quality over quantity, thereby reducing the number of children born. Second, industrialization may have induced a rise in the implicit costs of raising children. In particular, industries with high rates of female employment increased the opportunity cost of female time. Under the assumption that the child production process is female time- intensive, this would have reduced the incentive to bear children. Third, the movement away from agricultural and at-home production to centralized production, in addition to more restrictive child labor laws, may have reduced the economic return to children, again lowering parental demand and fertility rates. Fourth, industrialization was associated with increased urbanization and the crowding that occurred may have increased the explicit costs of raising children through higher housing and food costs without an associated increase in the benefit. Finally, the developing economy in the United States witnessed decreases in child mortality rates, especially after 1880.”

<u>Procedure:</u>

Question: Which bubbles will survive longer, those with parental care, or those without?

Hypothesis:

Prediction:

1. In your group of 4 students, designate one student as the bubble blower, one as the time keeper, one as the “parent”, and one to watch a bubble. (The parent just watches in the first round of 50 bubbles).

2. In round one, the group members must do nothing to interfere with the bubbles.
3. Blow a few bubbles. The watcher immediately picks one bubble and yells "start". The watcher must keep her/his eye on the bubble as long as possible (sometimes a little harder outside). When the bubble pops, the watcher yells "stop".
4. The time keeper starts keeping time, in seconds, and will stop when the bubble watcher yells "stop".
5. Record the number of seconds the bubble stayed "alive". Put a mark on the tally sheet in the corresponding time interval.
6. Repeat for 50 bubbles.
7. Round two. Repeat steps 1-6 but this time have the fourth member of the group, the "parent", use his/her hands, mouth (blowing air), or paper fans to "care" for the "babies" (bubbles) and try to prevent them from coming into contact with anything that might pop them. The goal is to keep the bubble "alive" for as long as possible without popping.
8. Summarize your data: for each round, how many died at each "age"? How many survived at each "age"? Calculate percent survival for each age.

Age of Death (seconds)	Tally	Total dead at this "Age"	Total surviving to this "Age"	% Surviving to this age
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Table 1: Bubble survivorship WITH OUT parental care (n=50)

Age of Death (seconds)	Tally	Total dead at this "Age"	Total surviving to this "Age"	% Surviving to this age
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Table 2: Bubble survivorship WITH parental care (n=50)

<u>Data Analysis</u>: Record the total number of bubbles that died for each age. Determine the number that survived for each age and record. Calculate the percentage that survived for each age. Use the following formula:

$$\text{Percentage surviving to this age} = \frac{\text{Number surviving}}{50} \times 100$$

Graph the percentage surviving using a line graph. Use the same graph for both populations. Percent Survivorship, the dependent variable, is on the Y-axis, and age interval (seconds), the independent variable, is on the X. You can also do a frequency histogram (bar graph) using Table 3.

Age (seconds)	**Without Care**	**With**
0-4		
5-9		
10-14		
15-19		
20-24		
25-29		
> 30		

Table 3. Age at Death

Extensions: Add in an experiment where you have infant mortality - for example, an empty frame held one foot from bubble wand. Only the bubbles that make it through the frame survive infancy.

Try graphing your %S on semi-log graph paper.

Visit a local historical cemetery and identify ages of death. Determine trends. Graph data as was done in the Bubble activity.

Collect obituaries and identify data concerning age of death. Identify patterns based on mortality of 100 individuals.

Reflection Questions:

- **What type of survivorship curve (I, II, or III) did you find for your data? What does this reflect?** (Type I for bubbles with care, type II or III for bubbles without care).

- **Why are life expectancies throughout the world so different?** (There are great variations in life expectancy between different parts of the world, mostly caused by differences in public health, medical care, and diet. The impact of AIDS on life expectancy is particularly notable in many African countries).

- **Can you compare the bubble exercise with human survivorship?** (It is important to recognize that countries with a high child mortality rate have fewer members reaching reproductive age. A factor that has had great impact on human population growth was the advancement of medical treatment. Because improved medical treatment decreased childhood diseases, the mortality rate declined).

- **What impact does parental care have on survivorship?** (it increases survivorship and thus fitness).

- **What type survivorship curve do we see with organisms that show parental care?** (type I) **Are these r or k selected?** (k).

- **Compare: 1) Species 1 = an r-selected species that reproduces once, at a young age, and lays 100,000 eggs then dies, giving no parental care to nest or offspring, and 10 eggs survive to reach adulthood and reproduce (0.01% survival rate) and**

  2) a k-selected species that delays reproduction for ten years, then has 3 offspring the first time she reproduces (caring for them for two years at which time they young can fend for themselves) and then she reproduces two more times, having 2 young the second time and 3 again the third time (8 total offspring over her lifetime) – and 6 of the offspring survive until adulthood to reproduce on their own (75% survival rate).

  - **Is one strategy (r vs. k) better?** (r-selection makes a species prone to numerous reproduction at low cost per individual offspring, while K-selected species expend high cost in reproduction for a low number of more difficult-to-produce offspring. Neither mode of propagation is intrinsically superior, and in fact they can coexist in the same habitat, as in rodents and elephants).
  - **What is the *<u>fitness</u>* of each species?** (about the same).

<u>**Models and Explanations:**</u> In this lab we explored r and k selection and survivorship curves. **A student who demonstrates understanding** of these concepts can describe the differences in fecundity, life span, allocation of energy to growth versus reproduction, body size, and parental care patterns of r and k selected species. **A competent student can also explain** why r selected species generally show a type II or III survivorship curve, where k selected species generally show a type I survivorship curve, and explain that one strategy isn't necessarily better than the other, they are just two different strategies with the intention of maximizing fitness (survival and reproduction).

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Student Worksheet:

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Question:

Hypothesis:

Prediction:

Results / Conclusions:

- **What type of survivorship curve (I, II, or III) did you find for your data? What does this reflect?**
- **What are the dependent, independent, and controlled variables in our bubble experiment? What was the control?**
- **Can you compare the bubble exercise with human survivorship?**

- **Why are life expectancies throughout the world so different?**

- **What impact does parental care have on survivorship?**

- **What type survivorship curve do we see with organisms that show parental care? Are these r or k selected?**

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  - **Is one strategy (r vs. k) better?**
  - **What is the *fitness* of each species?**

Data Analysis: Record the total number of bubbles that died for each age. Determine the number that survived for each age and record. Calculate the percentage that survived for each age. Use the following formula:

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