Age-structured populations

NRES 470/670

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When d and b depend on more than just density...

Figure 1:

Take this Indian elephant for example. How does reproductive rate depend on age in this case?

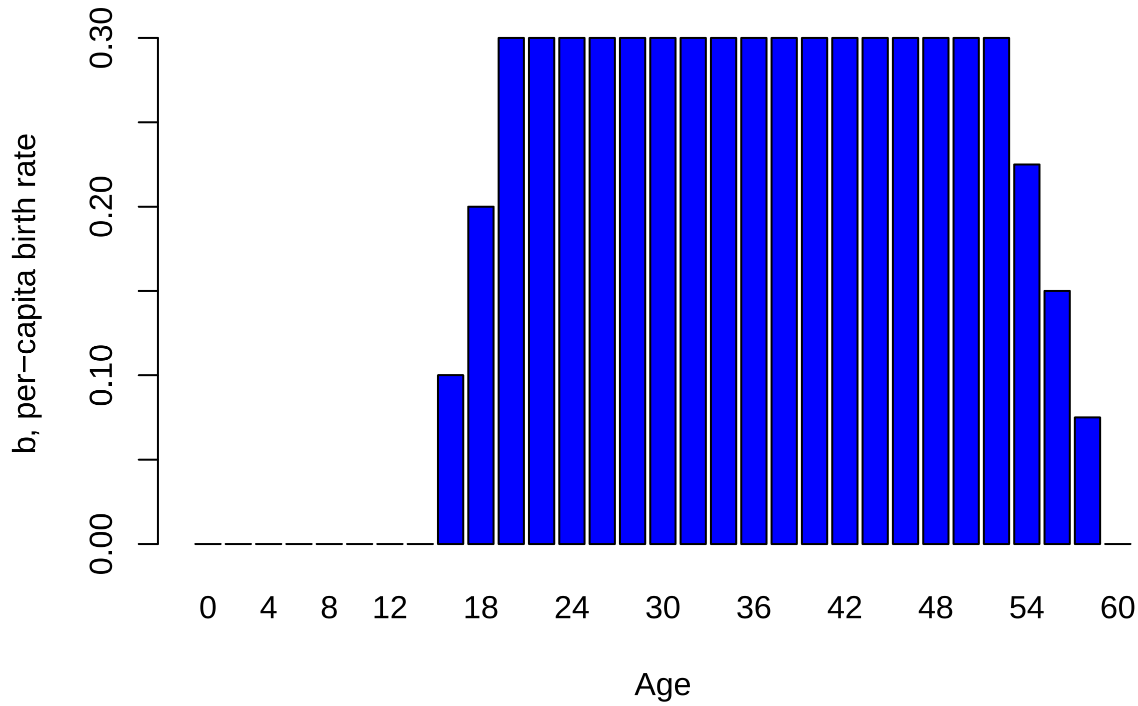
We might imagine it looks something like this!

```
Elephant_age <- seq(0,60,by=2)

Birth_rate <- c(rep(0,times=7),seq(0,0.3,length=4),rep(0.3,times=15),seq(0.3,0,length=5))

names(Birth_rate) <- Elephant_age

barplot(Birth_rate,xlab="Age",ylab="b, per-capita birth rate",col="blue")
```



What about per-capita death rates for a tortoise? We might imagine something that looks like this...

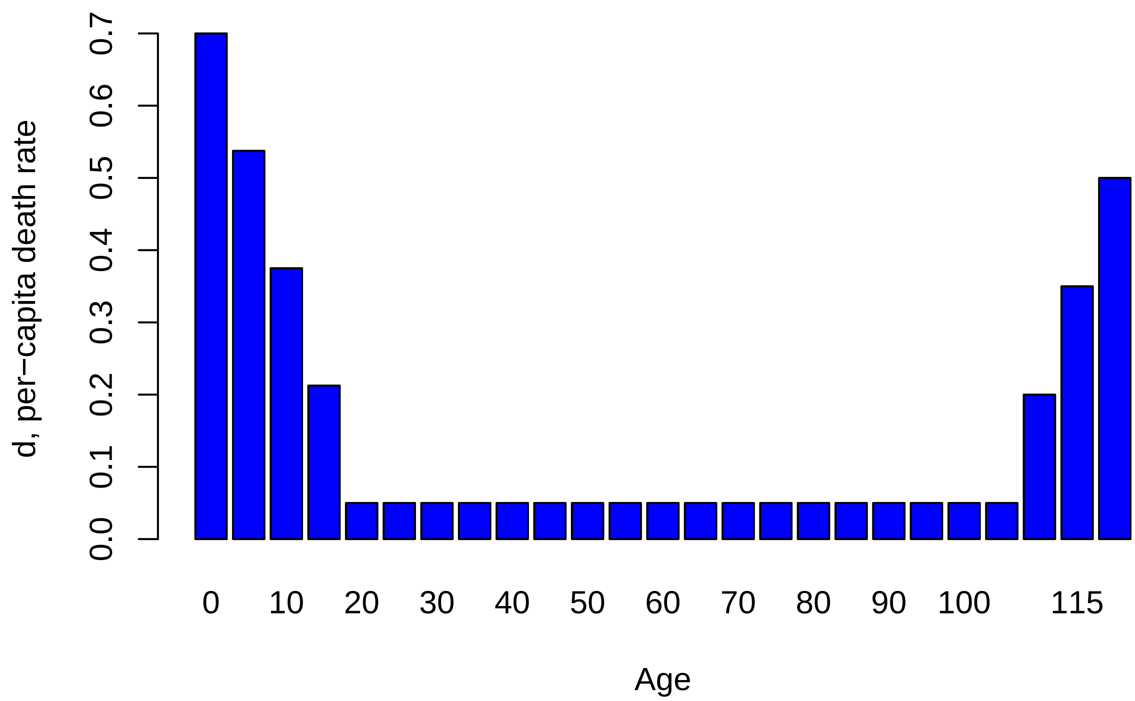
```
Tortoise_age <- seq(0,120,by=5)

Death_rate <- c(seq(0.7,0.05,length=5),seq(0.05,0.05,length=16),seq(0.05,0.5,length=4))

names(Death_rate) <- Tortoise_age

barplot(Death_rate,xlab="Age",ylab="d, per-capita death rate",col="blue")
```

Figure 2:



So, for many species per-capita birth rate and death rate are fundamentally dependent on age!

Thought Q: Imagine you were trying to re-establish a population of spadefoot toads. You take 1000 tadpoles from a captive population and place them in a temporary wetland right after a rainstorm. What would population growth look like over the next few years, assuming the reintroduction strategy was successful?

Thought Q: Imagine a population of 100 golden-headed lion tamarins (*Leontopithecus chrysomelas*) that consists of all adult males and post-reproductive females. What is the conservation status of this population?

Life table!

Age structured populations are often represented by a table called a **life table**, which looks something like this:

x	S(x)	b(x)	l(x)	g(x)
0	500	0	1.0	0.80
1	400	2	0.8	0.50
2	200	3	0.4	0.25
3	50	1	0.1	0.00
4	0	0	0.0	NA

Fecundity schedule

The fecundity component of the life table is called the "fedundity schedule"! The term $b(x)$ represents per-capita fecundity rate for females of age x.

Figure 3:

Figure 4:

Survivorship schedule

Fecundity is only half the story! The survival component of the life table is called the "survivorship schedule"!

The term **cohort** represents a bunch of individuals that were all born at the same time. In the life table, the term S(x) refers to the number of individuals from a particular cohort that are *still alive at age x.* From this raw data, we compute two terms, called **survivorship** and **survival rate**

The term $l(x)$ represents the *probability of survival to age x from age 0.* This is called **survivorship**

The term $g(x)$ represents the *probability of surviving from age x to age x+1.* This is called **survival rate**

Types of survivorship schedules...

There are three main types of survivorship schedules, classified as **Type I**, **Type II**, and **Type III**.

Survivorship curves describe how survivorship ($l(x)$) drops off with age. These three types of **life history** pattern can be illustrated with three real-world examples: humans, songbirds, and frogs.

Type I

Type II

Type III

Thought Q: Which survivorship curve is the most common in nature??

In-class exercise: age-structured population growth

In this exercise we will explore some facets of **age-stuctured populations**.

1. Load up the life table from earlier in this lecture, by clicking here. Use this table to compute the **net reproductive rate,** R_0. This represents the mean number of female offspring produced per female over her entire lifetime. This is also known as *lifetime reproductive potential*! This can be computed as:

$R_0 = \sum_{x=0}^{k} l(x) \cdot b(x)$

Where k is the maximum age.

Q: Can you implement this formula in Excel? What's the answer?

2. If the net reproductive rate, R_0 is positive, then the population is above the **replacement rate** of 1, and therefore the population will grow. If R_0 is negative, then the population will decline. This sounds familiar, right? Just like the finite rate of growth, λ.

BUT, what is the time frame of R_0? What is the timeframe of λ? They are different right? The difference is that R_0 describes growth per **generation**!.

What is a **generation**? The most common definition (for generation time) is the *Average age of the parents of all the offspring produced by a single cohort.* This can be computed from the life table as:

$G = \frac{\sum_{x=0}^{k} l(x) \cdot b(x) \cdot x}{\sum_{x=0}^{k} l(x) \cdot b(x)}$

See if you can implement this in Excel (or whatever spreadsheet software you use!).

Q: What is the *generation time* of the population in the table?

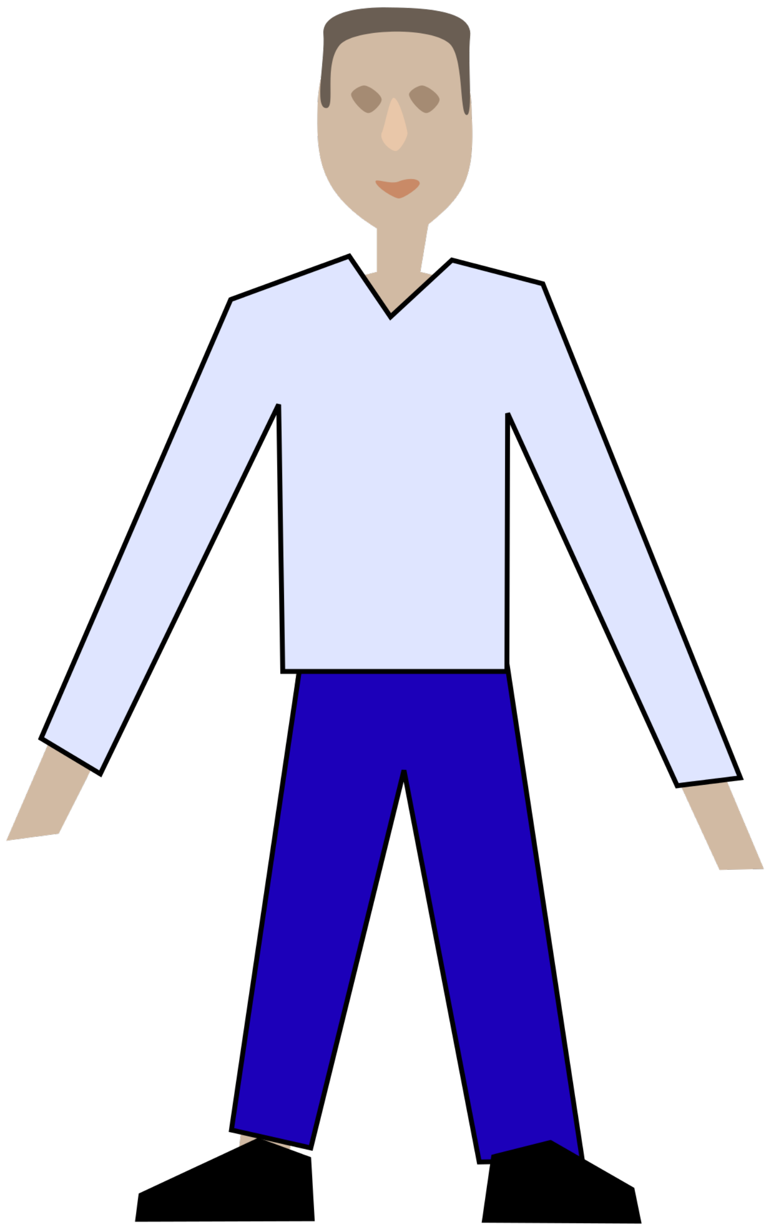


Figure 5:

Figure 6:

Figure 7:

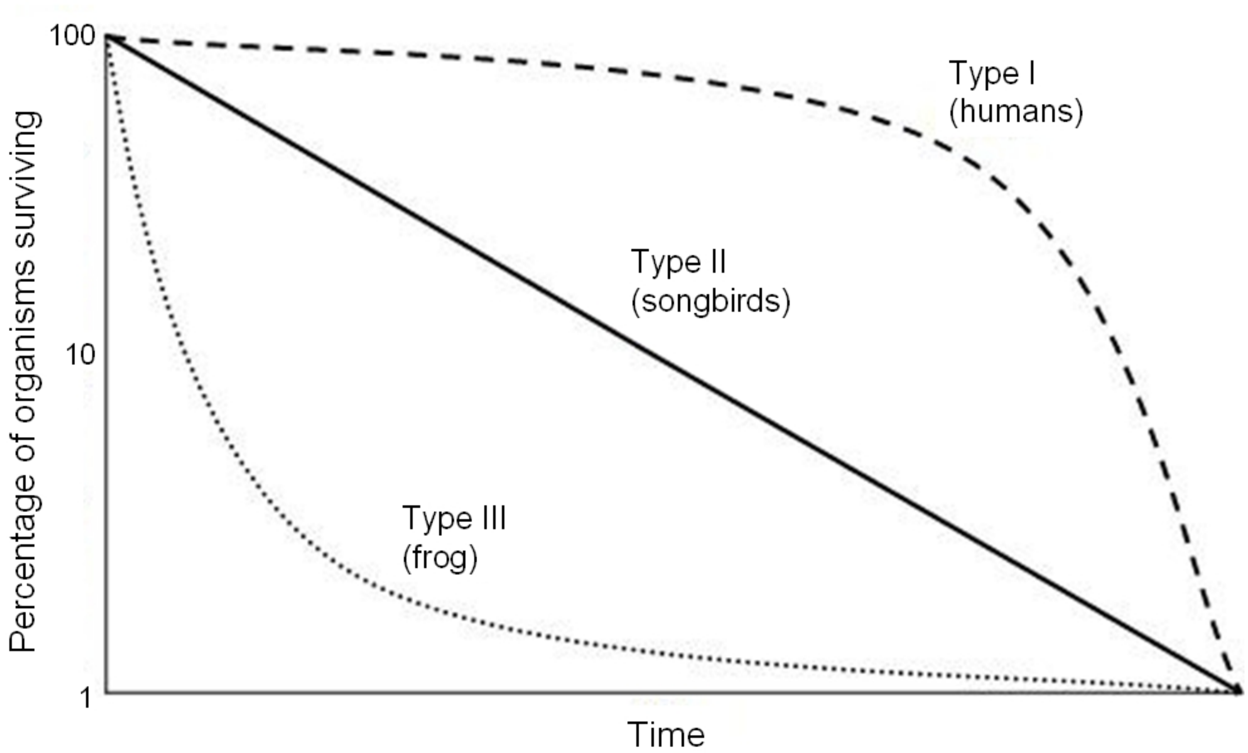


Figure 8:

3. Now, can you compute the *intrinsic rate of growth* (r) for this age-structured population?

To a first-order approximation, you can use this equation:

$r = \frac{ln(R_0)}{G}$

Just looking at this equation, you see that organisms with longer generation times (G) have slower intrinsic rates of growth, all else being equal.

Q: Implement this equation in Excel. Is this an exponentially growing population?

4. Load up an age-structured model in InsightMaker. You can clone this one, here.

   4a. Initialize the population like the spadefoot toad example from above- with only the first (juvenile) age class. What population dynamics occur at the beginning of the simulation? What about the end of the simulation?

   4b. Can you tweak the initial abundance of juveniles, subadults and adults so that the population exhibits smooth exponential growth for all three age classes? This is called **Stable Age Distribution**

   4c. Now change the vital rates (*Juv mort rate*, *Sub mort rate*, *Transition rate to Subadult*, etc.). Is the population growth still smooth? If not, can you find the *Stable Age Distribution* now??

   4d. Now change the **Simulation time step** to 5 years, and return to an initial population with only juveniles. What happens? Is this a **stochastic** model? If not, why does it look like it has a random component?

–go to next lecture–