Lecture 8

Life tables

WILD3810 (Spring 2019)

Assumptions of the B-D models

Remember from the lecture 3 that our simple models of population growth were based on the following assumptions:

1) Population closed to immigration and emigration

2) Model pertains to only the limiting sex, usually females

3) Birth and death rates are independent of an individual's age or biological stage

4) Birth and death rates are constant

Assumptions of the B-D models

In lectures 4 and 6, we learned about ways to model dynamics that do not meet assumption 4:

1) Population closed to immigration and emigration

2) Model pertains to only the limiting sex, usually females

3) Birth and death rates are independent of an individual's age or biological stage

4) Birth and death rates are constant

Assumptions of the B-D models

Over the coming weeks, we will learn about why and how to relax assumption 3:

1) Population closed to immigration and emigration

2) Model pertains to only the limiting sex, usually females

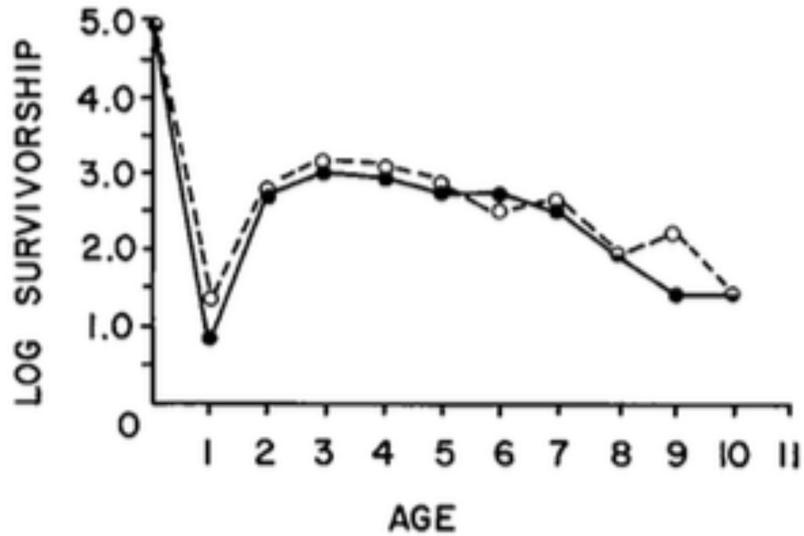
3) Birth and death rates are independent of an individual's age or biological stage

4) Birth and death rates are constant

Structured populations

Age-structured populations

Survival and birth rates often vary with age

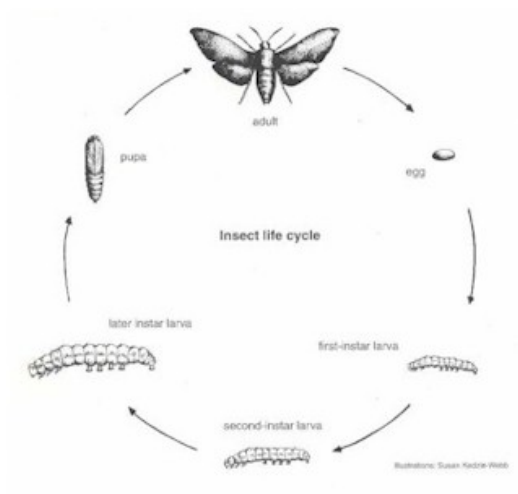


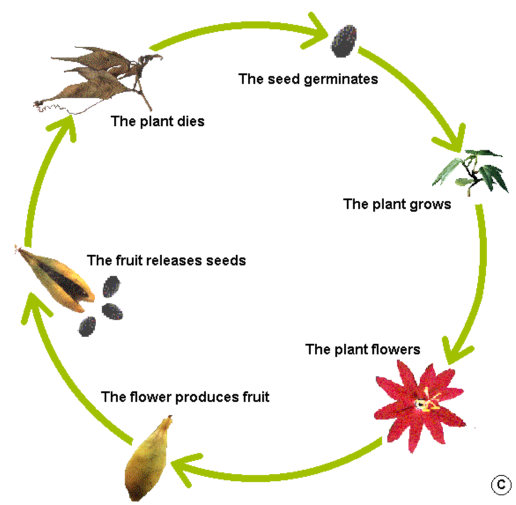
Stage-structured populations

In some cases, age is not a relevant predictor of survival and birth rates

Instead, survival and birth rates vary with **stage**

- life cycle stage



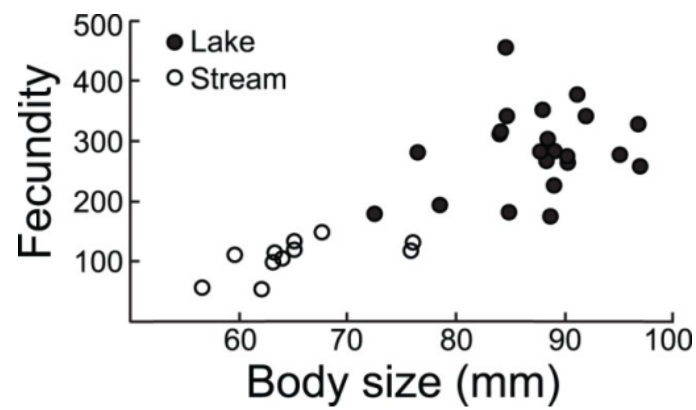


Stage-structured populations

In some cases, age is not a relevant predictor of survival and birth rates

Instead, survival and birth rates vary with **stage**

- life cycle stage
- size



Age-structured populations

Age-structured populations

Life tables

- earliest accounting tool for calculating age-specific survival and mortality

Applications to:

- Human demography
- Insurance industry (actuarial sciences)
- Health professions

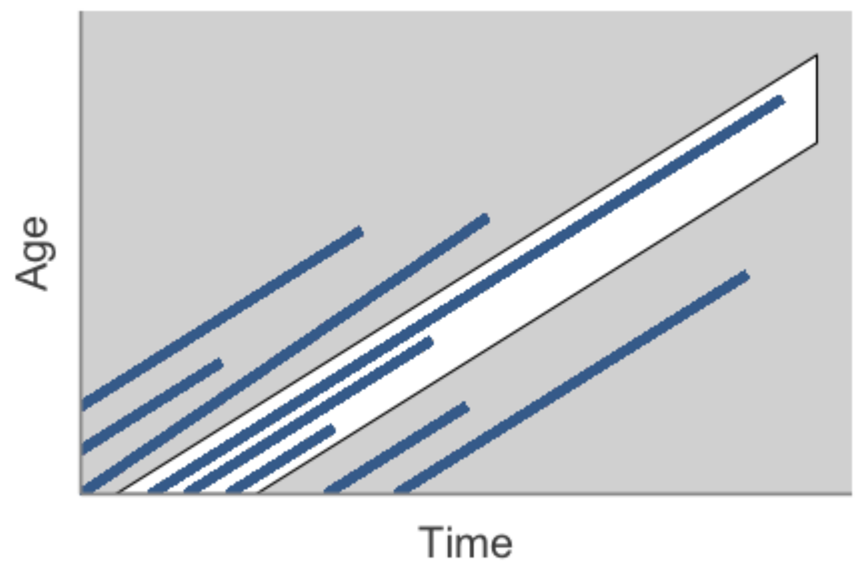
Pearl and Parker (1921) were the first to calculate a non-human life table

- *Drosophila melanogaster* (a fruit fly)
- Since used in ecology, evolution, and natural resource management

Life tables

Cohort life table

- follow group of individuals born within short period (a **cohort**) until each individual's death
- develop life table for groups of individuals with similar traits (e.g., one for males, one for females)
- **longitudinal** study design



Life tables

- x: age of individuals
- N_x: number of individuals observed alive at age x (sometimes called S_x)

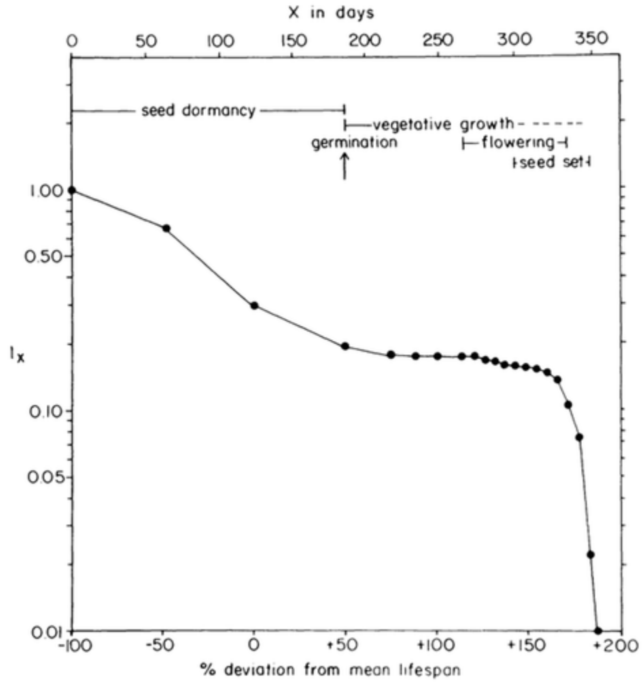
x	N_x				
0	100				
1	75				
2	50				
3	40				
4	0				

Life tables

- l_x: Probability of surviving to age x
- $l_x = N_x / N_0$

x	N_x	l_x			
0	100	1.0			
1	75	0.75			
2	50	0.5			
3	40	0.4			
4	0				

Life tables



X in days
0
50
100
150
200
250
300
350
seed dormancy
vegetative growth
germination
flowering
seed set
l_x
1.00
0.50
0.10
0.05
0.01
-100
-50
0
+50
+100
+150
+200
% deviation from mean lifespan

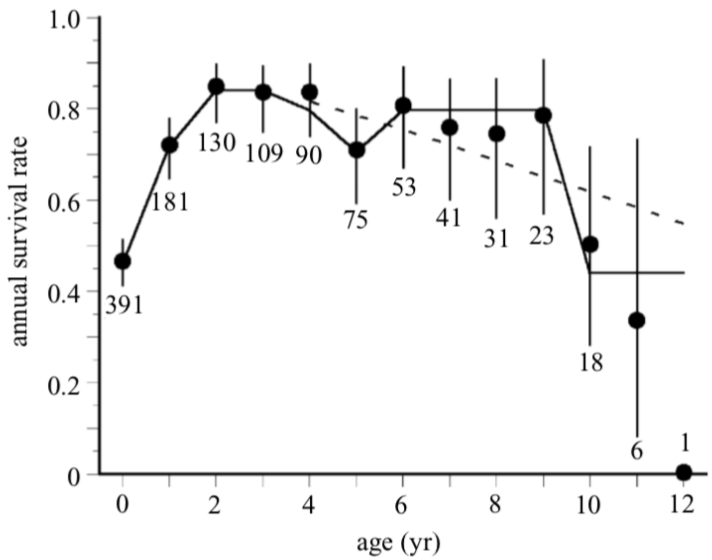
Life tables

- P_x: Probability of surviving **from** age x **to** the next age (of those alive at age x)
- $P_x = l_{x+1}/l_x$

x	N_x	l_x	P_x		
0	100	1.0	0.75		
1	75	0.75	0.667		
2	50	0.5	0.8		
3	40	0.4	0		
4	0		-		

Life tables

Age-specific survival of fallow deer (*Dama dama*)



Life tables

- q_x: Probability of dying **between** age x the next age (of those alive at age x)
- $q_x = 1 - P_x$

x	N_x	l_x	P_x	q_x	
0	100	1.0	0.75	0.25	
1	75	0.75	0.667	0.333	
2	50	0.5	0.8	0.2	
3	40	0.4	0	1	
4	0		-	-	

Life tables

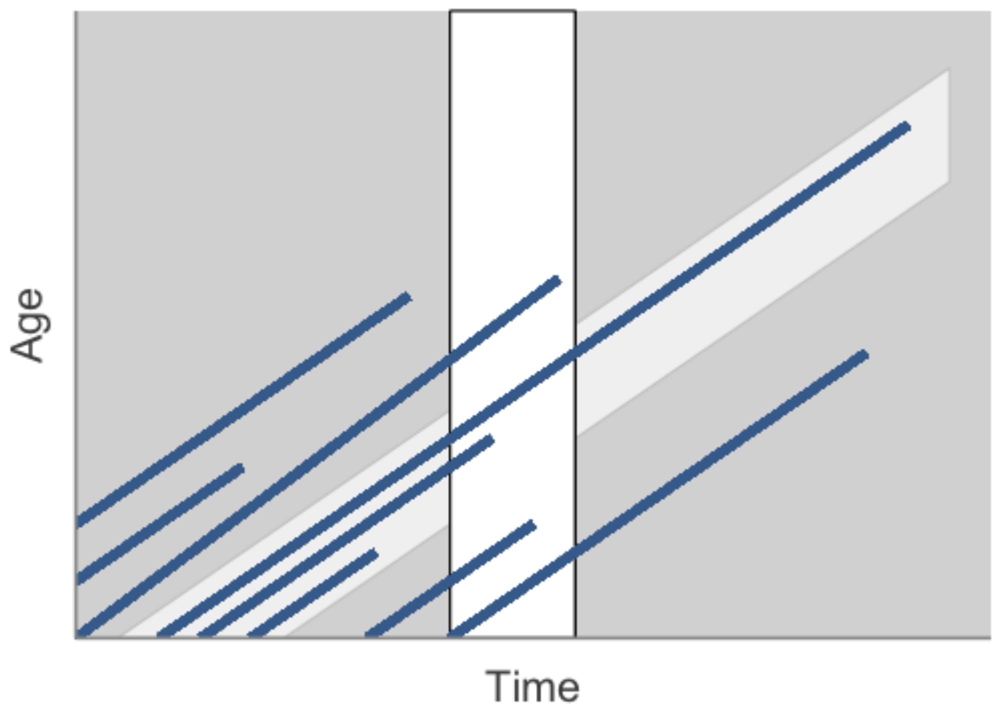
Cohort tables

- Assume that all live individuals are available for observation at every age until death
- Most readily applied to:
    - Human populations (e.g., CDC NCHS)
    - Plants
    - Sessile animals
    - Mobile animals on small islands with high observer detection
    - Animals in captivity (zoos)

Life tables

Static tables

- assess number of individuals of known age at one point in time or the age of individuals dying at any point in time



Static life tables

- a_x: Deaths between age $x - 1$ and age x

x	a_x				
0					
1	25				
2	15				
3	10				
4	7				

$\sum_{x=0}^{max(x)} a_x = 57$

Static life tables

- a_x: Deaths between age $x - 1$ and age x

x	a_x	N_x			
0		57			
1	25	57-25=32			
2	15	32-15=17			
3	10	17-10=7			
4	7	7-7=0			

$\sum_{x=0}^{max(x)} a_x = 57$

Static life tables

- a_x: Deaths between age $x-1$ and age x

x	a_x	N_x	l_x	P_x	**etc.**
0		57	1.00	0.56	
1	25	57-25=32	0.56	0.54	
2	15	32-15=17	0.30	0.4	
3	10	17-10=7	0.12	0	
4	7	7-7=0	0.00	-	

Static life tables

Static life tables most readily applied to:

- Plants and animals where age can be accurately determined for all individuals at a given moment in time

- e.g., using the rings/layering in trees, teeth, otoliths, horns, and maybe even telomere length on genes

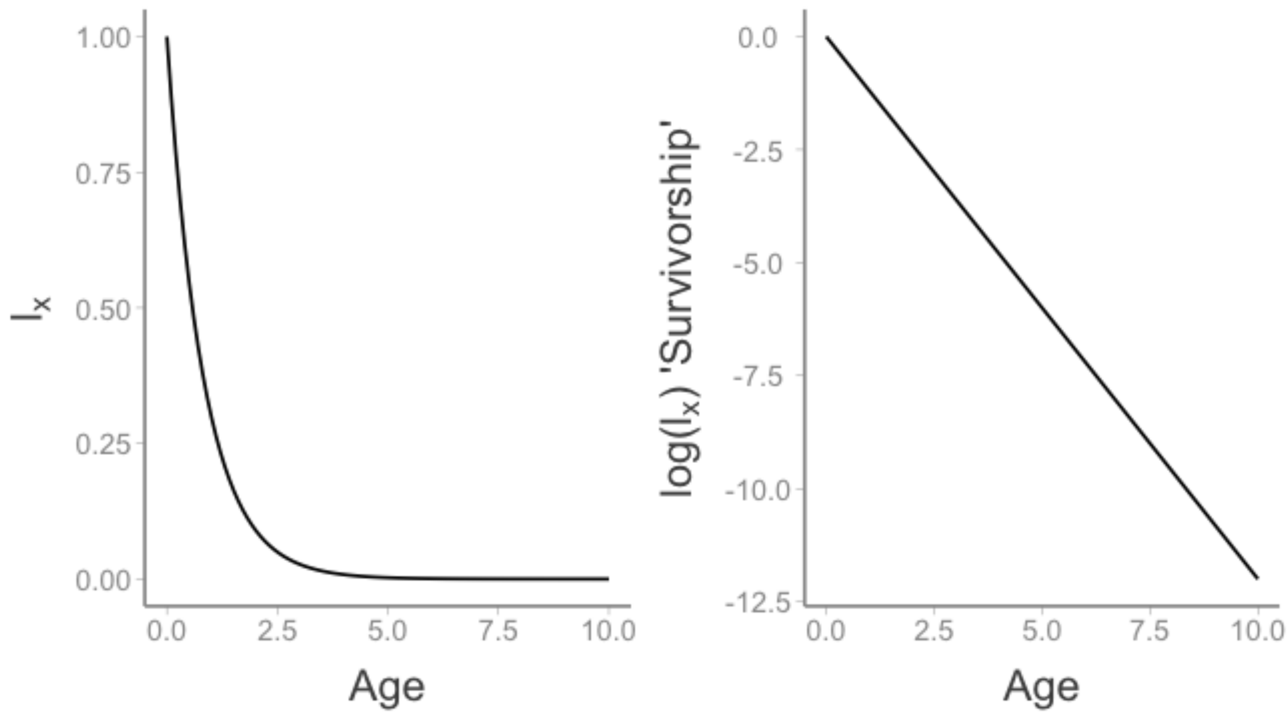
Static life tables

Static life table assumptions:

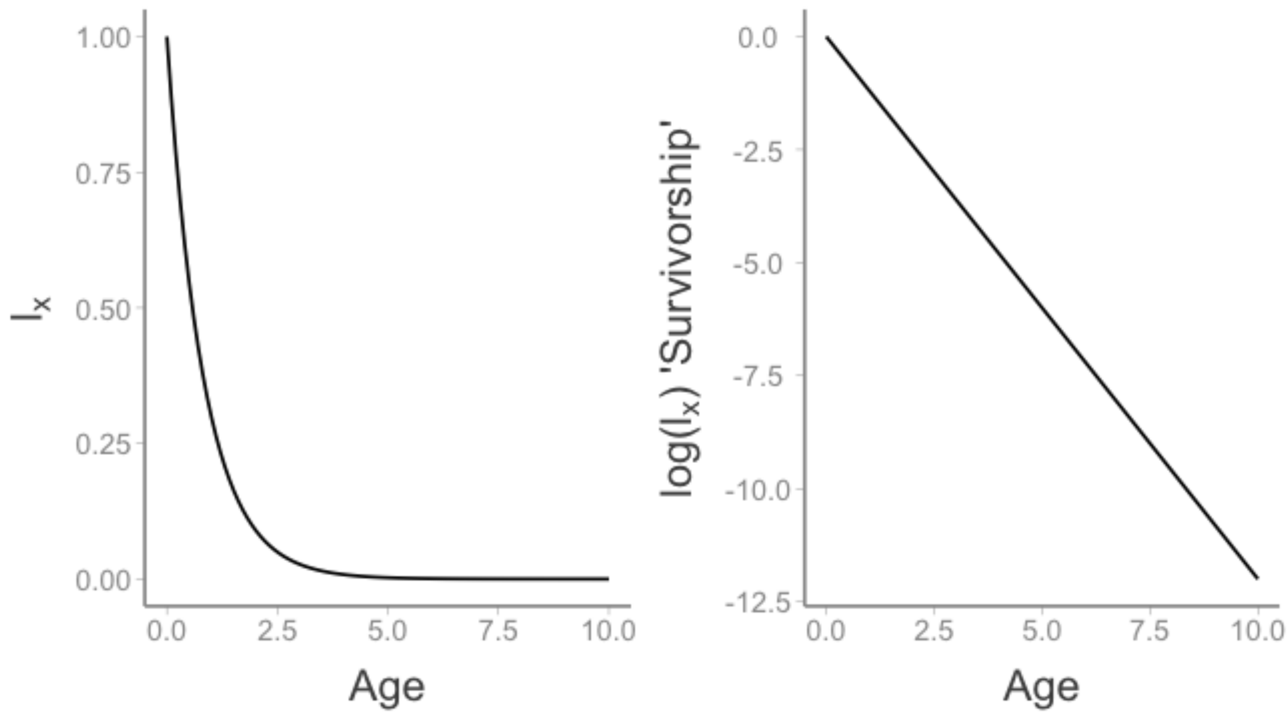
- All individuals have equivalent availability for observation, regardless of age
- Stable age distribution
- Survival does not change over time
    - If it does, time effects may appear as ‘age effects’ and lead to biased results

Survivorship curves

Survivorship curves

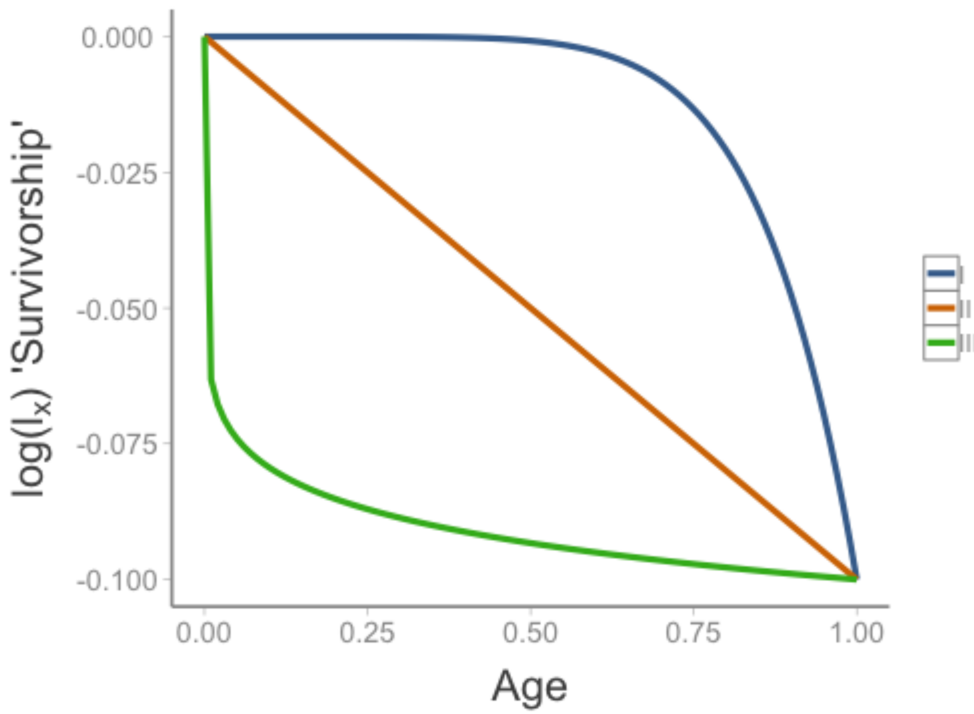


Survivorship curves



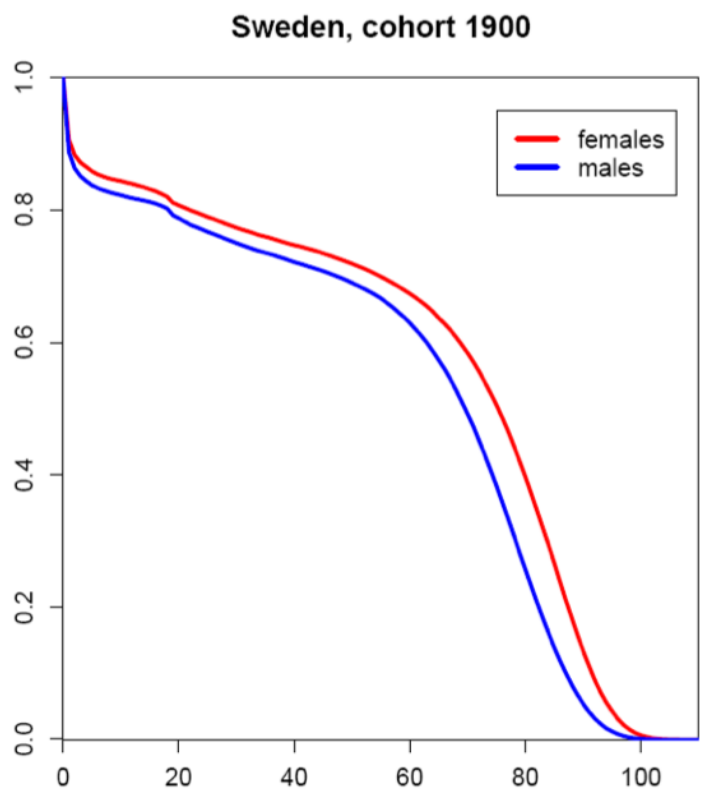
Type II Survivorship curve (Pearl 1928)

Survivorship curves



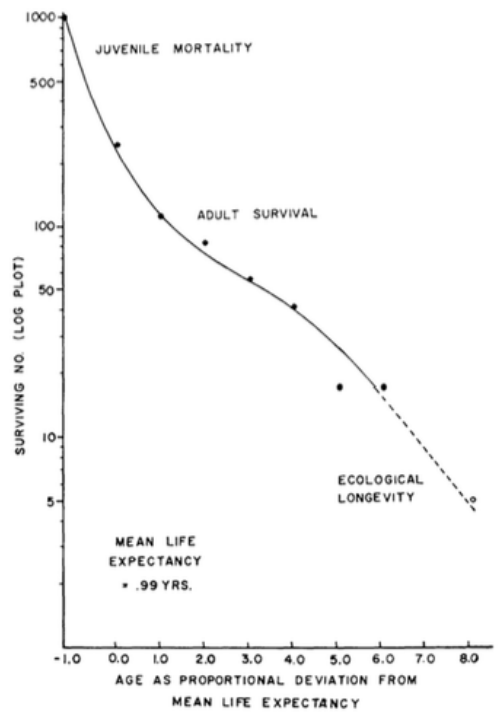
Survivorship curves

What types of species do you expect have type 1 survivorship curves?



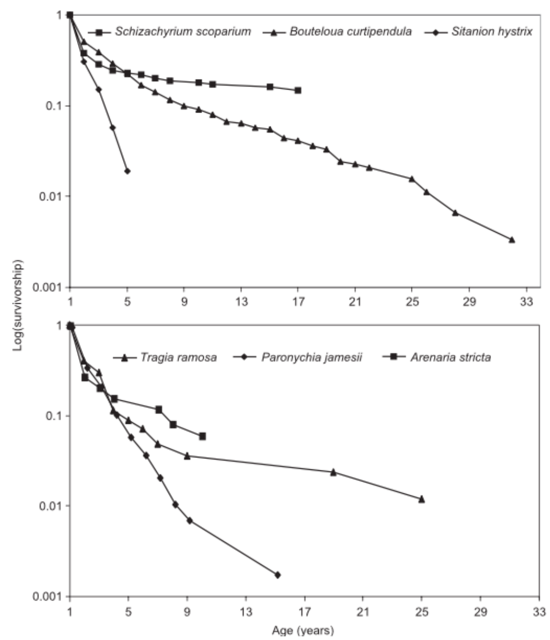
Survivorship curves

What types of species do you expect have type 2 survivorship curves?



Survivorship curves

What types of species do you expect have type 3 survivorship curves?



Life expectancy

Life expectancy

Life Expectancy

> The average length of time an individual is expected to live, given they are currently x years old

- Directly related to the probability of surviving to a given age

Utah has the lowest per capita crude death rate in the U.S. (averaged across all ages)

Can Utahns expect to live longer than in all other states?

Life expectancy

To estimate life expectancy, start with l_x

x	N_x	l_x			
0	100	1.0			
1	75	0.75			
2	50	0.5			
3	40	0.4			
4	0				

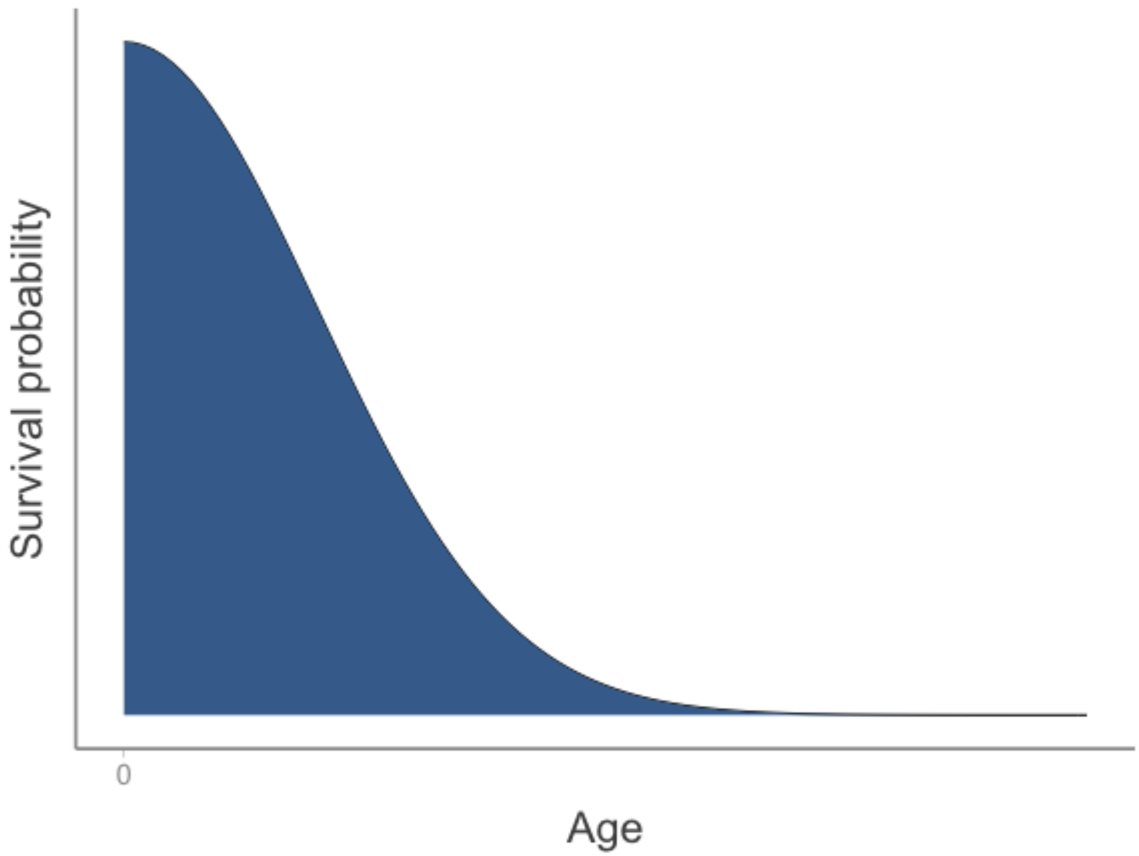
Life expectancy

- L_x: Average survival probability across successive age intervals
- $L_x = \frac{l_x + l_{x+1}}{2}$

x	N_x	l_x	L_x		
0	100	1.0	0.875		
1	75	0.75	0.65		
2	50	0.5	0.5		
3	40	0.4	0.2		
4	0		-		

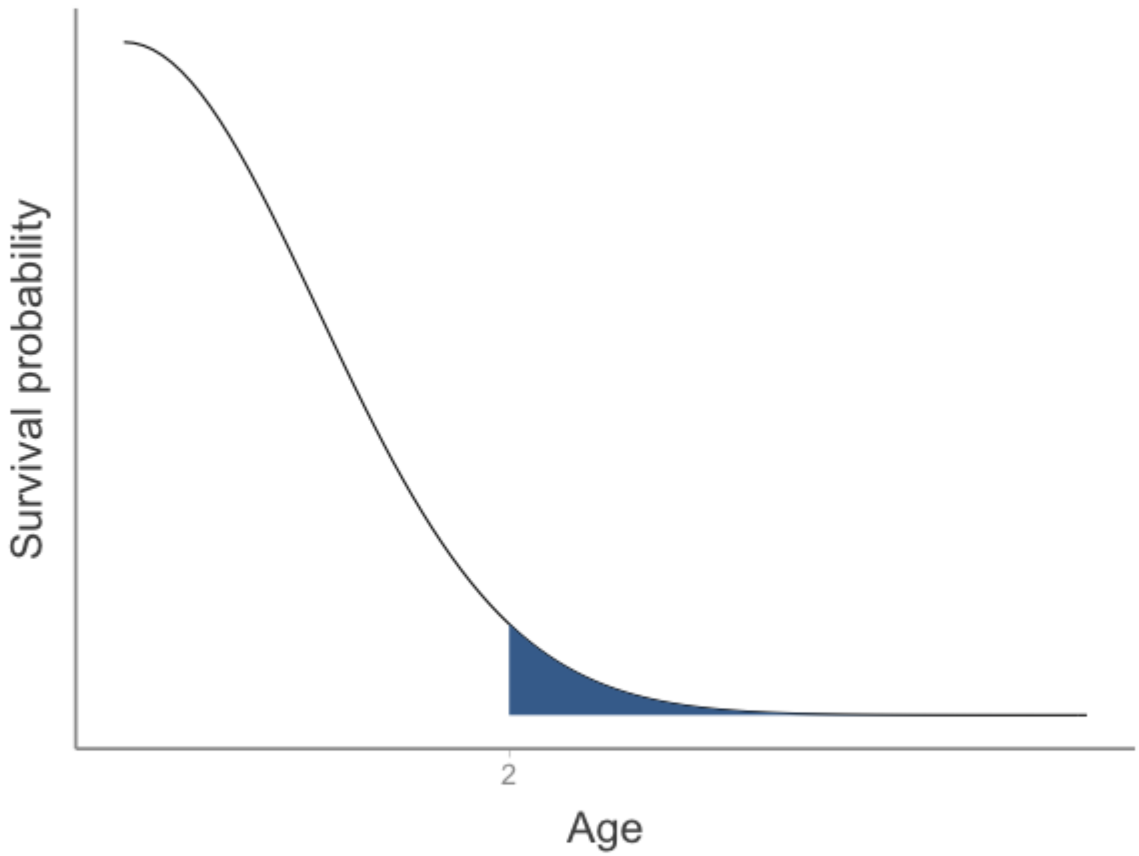
Life expectancy

- T_x: Area under the survival curve from age x onward



Life expectancy

- T_x: Area under the survival curve from age x onward



Life expectancy

- T_x: Area under the survival curve from age x onward
- $T_x = \sum_x^{max(x)} L_x$

x	N_x	l_x	L_x	T_x	
0	100	1.0	0.875	2.23	
1	75	0.75	0.65	1.35	
2	50	0.5	0.5	0.7	
3	40	0.4	0.2	0.2	
4	0		-	-	

Life expectancy

- E_x: Number of years an individual of age x is expected to survive
- $E_x = T_x / l_x$

x	N_x	l_x	L_x	T_x	E_x
0	100	1.0	0.875	2.23	2.23
1	75	0.75	0.65	1.35	1.93
2	50	0.5	0.5	0.7	1.17
3	40	0.4	0.2	0.2	0.5
4	0		-	-	-

Utah life expectancy

Utah has the lowest per capita crude death rate d in the U.S

Can Utahns expect to live longer than all other states?

Not exactly

- Life expectancy of a newborn Utahn is 80.2
- Ranked 10th in the U.S., not first

Utah life expectancy

Why is Utah's crude per capita death rate d so low?

Because Utah has the highest birth rate and consequently the youngest age structure

- % of Utahns < 18 yrs old is 32%
- % of U.S. < 18 yrs old is 25%
- % of Utahns ≥ 65 is 11%
- % of U.S. ≥ 65 = 15%

Young individuals have highest chances of survival

Having many young individuals in a population will skew the crude average d