Demography

Demography

- *Future population is a result of the interplay between internal characteristics and processes and extrinsic forces and processes.*
- *We will begin by focusing on the internal factors - the demographics.*

Future Population Size

- *Predicting future population size requires understanding the internal workings of the population.*
- *We learn about these "workings" by observing changes in populations and looking for principles which would allow us to predict them.*

Population Change

- *Speed of population change is referred to as rate of increase.*
- *Change results from interplay between fecundity rate, mortality rate, and composition (age distribution and sex ratio).*

Population Change

- *Future population size can be predicted from current population size and its rate of change:*
- $N_{t+1} = N_t$ *x (rate of change)*
- $N_{t+1} = N_t \ \lambda$
- λ *= finite rate of increase*
- $\lambda = N_{t+1} / N_t$
- *If population is constant* $\lambda = 1.0$

Instantaneous Rate of Change

- *Sometimes its better to express the finite rate of increase as an instanteous (or exponential) rate of increase (r):*
- $\lambda = N_{t+1} / N_t = e^r$
- $\ln \lambda = \log_e \lambda = r$
- *If population is constant then r = 0*

Future Population Size

- *If rate of change is constant then*
- $N_t = N_0 e^{rt}$
- $\ln N_t = \ln N_0 + rt$
- *Equation for a straight line:*
- $y = a + bx$

Examples:

Estimating rate of increase

- Finite rate of increase:
- $\lambda = N_{t+1} / N_t$
- Instantaneous rate of increase:
- Regress ln N_t on t
- $r = (\ln N_t - \ln N_0) / t$

Rate of change

- What really determines the rate of change (increase or decrease) in a population?
- Births?
- Deaths?
- Immigrants?
- Emigrants?

Rate of change

- Change results from balance between rates of increase and decrease
- Increase: Births + Immigrants
- Decrease: Deaths + Emigrants
- $\Delta N = (B + I) - (D + E)$
- Immigrants and Emigrants are samll in number and depend on other populations so we'll simplify it by ignoring them (for a while).

Deaths = Mortality

- What do mortality rates depend on?
- Age? Population size? Resources?
- Summarize mortality in a life table

Life table

- x = age (years)
- $f_x = n_x$ = Survival frequency
- l_x = Survivorship
- d_x = Mortality
- q_x = Mortality rate

Cohort Life Table

- Survival of male Song Sparrows hatched in 1976 on Mandarte Island, BC

Age	f_x
0	115
1	25
2	19
3	12
4	2
5	1
6	0

Static Life Table (Catch Curve)

- Ages of male reindeer, South Georgia Island

Age	f_x
0	78
1	40
2	19
3	14
4	10
5	5

Constructing a Life Table

Standardize to l_0 = 1.0

- Male reindeer, South Georgia Island

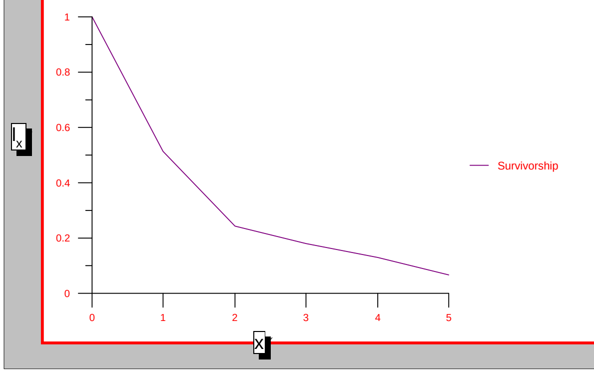
Age	f_x	f_x / f_0	l_x	d_x
0	78	78/78	1.000	0.487
1	40	40/78	0.513	0.269
2	19	19/78	0.244	0.064
3	14	14/78	0.179	0.051
4	10	10/78	0.128	0.641
5	5	5/78	0.064	0.064

Constructing a Life Table

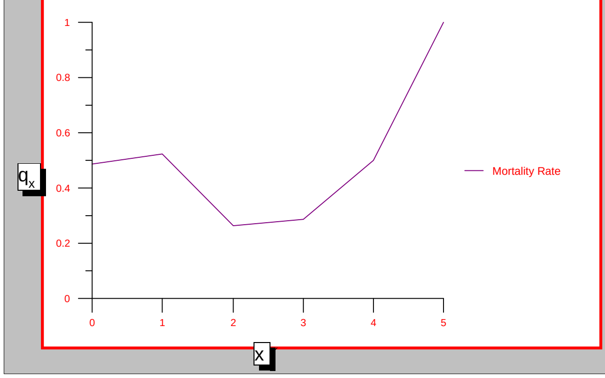
- Male reindeer, South Georgia Island

Age	f_x	l_x	d_x	q_x
0	78	1.000	0.487	0.487
1	40	0.513	0.269	0.525
2	19	0.244	0.064	0.263
3	14	0.179	0.051	0.286
4	10	0.128	0.641	0.500
5	5	0.064	0.064	1.000

Graphing a Life Table: Survivorship



Graphing a Life Table: Mortality Rate



Examples of Survivorship

Expanded Life Table - Females   Add fecundity

(m_x=female offspring per female age x)

Age(x)	l_x	m_x	$l_x m_x$	$l_x m_x x$
0	1.000	0.0	0.0	0.0
1	0.8	0.6	0.48	0.48
2	0.7	1.0	0.7	1.4
3	0.6	1.0	0.6	1.8
4	0.0	0	0	0
Sum			1.78	3.68
			(fitness)	

Population Characteristics

- R_0 = Net Reproductive Rate (Fitness)

$$R_0 = \frac{\text{No. daughters generation } t+1}{\text{No. females generation } t} = \frac{\Sigma\, l_x m_x}{l_0} = \frac{1.78}{1.0} = 1.78$$

Fitness

- Fitness defined as $\Sigma\ l_x\, m_x$ for a genotype
- *This fundamental formula is at the heart of both demographic and genetic analyses for a population*
- *It is very clever because it combines both survival(l_x) and fecundity(m_x)*

Population Characteristics

- G = Mean length of a generation
- = Mean period elapsing between
- birth of parents and birth of offspring

$$= \frac{\Sigma\, l_x\, m_x\, x}{\Sigma\, l_x\, m_x} = \frac{3.68}{1.78} = 2.07$$

Population Characteristics

- $\ln (R_0)$ $\ln (1.78)$
- r = ---------- = -------- = 0.28
- G 2.07
- $\lambda = e^r = e^{0.28} = 1.32$
- $1 = \Sigma\, e^{-rx} l_x m_x$
- Note: First 2 equations are approximations, but solving this last equation iteratively is exactly correct.

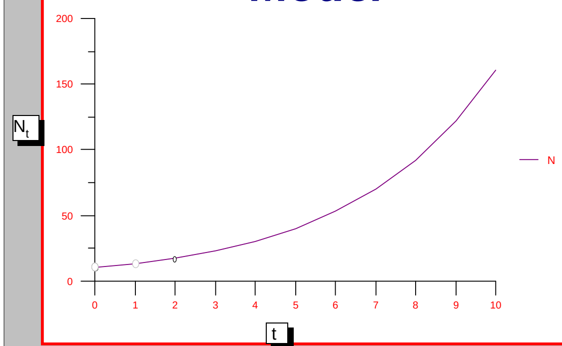
So What?

- What is value of this?
- λ and r are good descriptions for either a simple population or a more complex population.
- Our simple models to predict (or analyze) population growth might work surprisingly well.
- $N_{t+1} = N_t\ \lambda$

Finite Growth Rate

- $\lambda = 1.32$
- t N_t
- 0 10
- 1 13
- 2 17
- 3 23
- 4 30
- 5 40

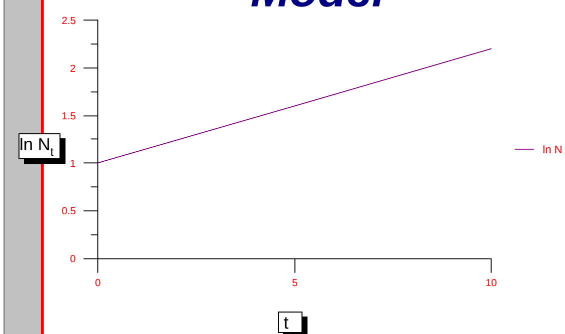
Finite Growth Rate Model



Continuous Growth Model

- $N_t = N_0\, e^{rt}$
- $\ln N_t = \ln N_0 + rt$
- Plot of $\ln N_t$ vs. t is a straight line
- slope of line is r

Continuous Growth Model



Is this correct?

- What assumptions must be true?
- Rate of increase (λ or r) is constant.
- Stable age distribution in the population.

Stable Age Distribution

- Lotka (1922) showed that a population that is subject to a constant schedule of birth and death rates will gradually approach a fixed or stable age distribution, whatever the initial age distribution may have been, and will maintain this age distribution indefinitely.

Stable Age Distribution

- C_x = proportion of population in age category x to x+1
- Mertz (1970) showed that
- $C_x = \lambda^{-x} l_x \;/\; \Sigma \lambda^{-x} l_x$
- Even if a population starts out with a different age distribution it will attain this stable age distribution after a while

Stable Age Distribution

Age(x)	l_x	λ^{-x}	$\lambda^{-x} l_x$	C_x
0	1.000	1.0	1.0	0.44
1	0.8	0.758	0.606	0.27
2	0.7	0.574	0.402	0.18
3	0.6	0.435	0.261	0.11
4	0.0	0.329	0	0
Sum			2.269	

Is the rate of increase constant?

- If resources are unlimited, such as introduction of species to new area OR if population remains at fairly similar numbers over time (i.e. r=0 or λ=1.0 approximately), but even here random environmental variation will produce random changes in r (or).
- Typically resources are limited and more animals consume more resources, reducing amount available for each animal.
- A simple case would be if the rate of increase declined with each animal in the population.
- λ (or r) = (Max λ or r) - b N_t

Rate of increase declines with N_t