Goal I: Conserving species
What is needed for long-term persistence of populations?

Populations/ species — How do populations work?
- *Population genetics*
- *Population dynamics*

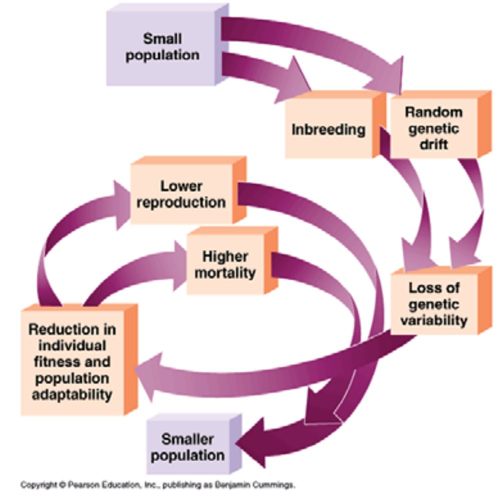
Population genetics
- Why is genetic diversity important for population persistence?
- What processes influence population genetic diversity?

Population dynamics
- Why are small populations especially vulnerable to extinction?
- Why and how do populations change in size?

Some practical goals
- **Conservation biology** – managing against population decline
- **Human population growth** – where are we headed?
- **Disease ecology** – under what conditions do pathogens outbreak?
- **Species interactions** – what keeps population sizes stable?

1) Why are small populations so vulnerable to extinction?

low genetic variation?
- *inbreeding, genetic drift, and the extinction vortex*



1) Why are small populations so vulnerable to extinction?

low genetic variation?
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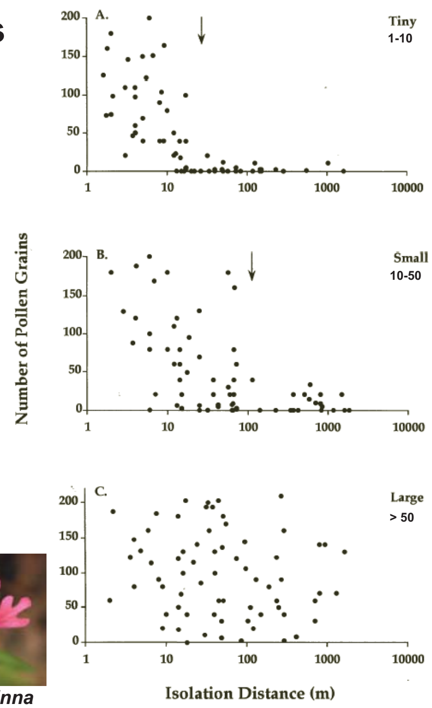
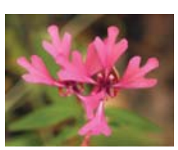
~ or ~

low numbers?
- *Allee effects*





Clarkia concinna

1) Why are small populations so vulnerable to extinction?

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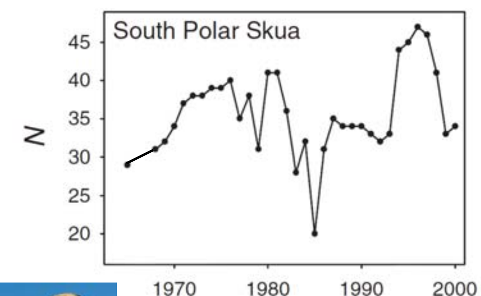
~ or ~

low numbers?
- *Allee effects*
- *demographic stochasticity*



Stercorarius maccormicki

1) Why are small populations so vulnerable to extinction?

low genetic variation?

- *inbreeding, genetic drift, and the extinction vortex*

~ or ~

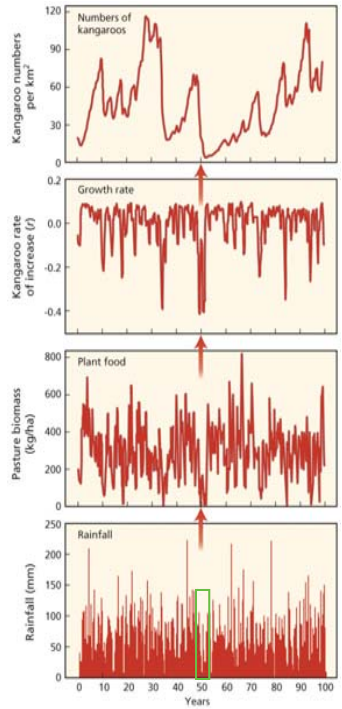
low numbers?

- *Allee effects*
- *demographic stochasticity*

+ small range size

- *environmental stochasticity*

Macropus rufus



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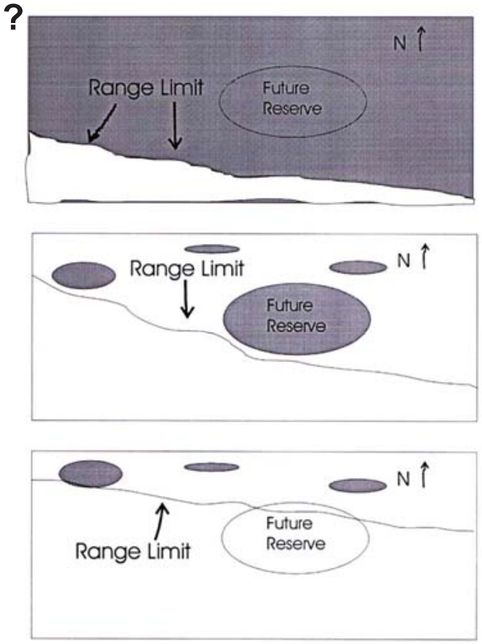
~ or ~

low numbers?

- *Allee effects*
- *demographic stochasticity*

+ small range size

- *environmental stochasticity*
- *climate change*



2) How do populations change in size?

➢ they gain and lose individuals

pop. size one time step past "t"

pop. size at time "t"

$$N_{t+1} = N_t + \text{gains} - \text{losses}$$

gains: *Birth*, *Immigration*

losses: *Death*, *Emigration*

$$N_{t+1} = N_t + B - D + I - E$$

$B - D$: "intrinsic"

$I - E$: exchange with other populations

2) How do populations change in size?

$$N_{t+1} = N_t + B - D$$

⬇ *rearrange*

change in N in one time step:

$$N_{t+1} - N_t = B - D$$

⬇

change in N per change in time:

$$\Delta N / \Delta t = bN - dN = rN$$

b: **"per capita" birth rate** — average number of offspring per individual per unit time

d: **"per capita" death rate** — average probability of death per individual per unit time

Q: when will a population grow? when will it shrink?

2) How do populations change in size?

$$N_{t+1} = N_t + B - D$$

⬇ *rearrange*

change in N in one time step → $$N_{t+1} - N_t = B - D$$

⬇

change in N per change in time → $$\Delta N / \Delta t = bN - dN \;\; = rN$$

"per capita" rate of increase

average rate of population change per individual per unit time

"intrinsic rate of increase"

Example

$b = 0.3$/year

$d = 0.1$/year

$r = ?$

Q: when will a population grow? when will it shrink?

2) How do populations change in size?

"Exponential growth model"

$$N_{t+1} = N_t + rN_t$$

N_t: number present

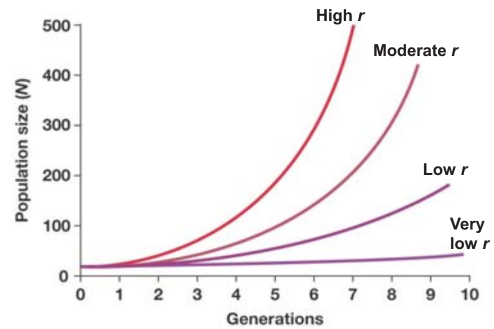
rN_t: number added by growth

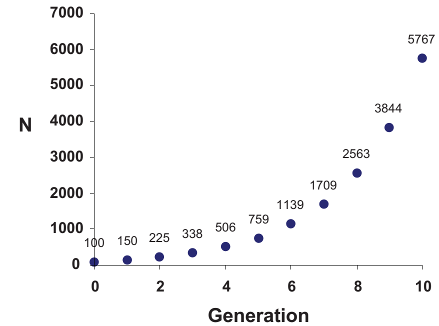
Ex. $r = 0.5$, $N_0 = 100$

$N_1 =$ ☐ + ☐ = ☐

$N_2 =$ ☐ + ☐ = ☐

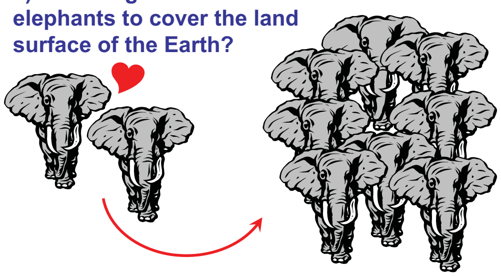
$N_3 =$ …





Exponential growth is powerful! Two examples

1) How long would it take for elephants to cover the land surface of the Earth?

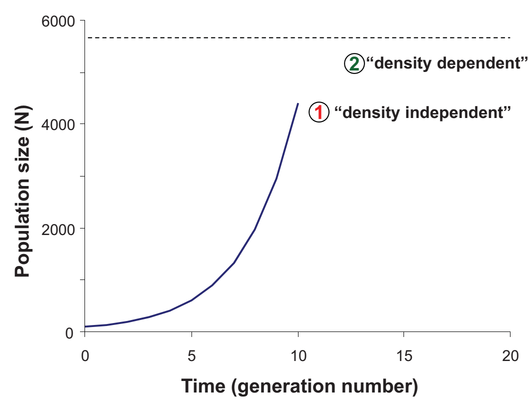


year 50: 8 elephants

2) How long would it take descendants of 1 bacterium (weighing 10^{-9} g and dividing every 20 min) to equal the weight of the Earth?

2) How do populations change in size?

Comparison of simple population growth models



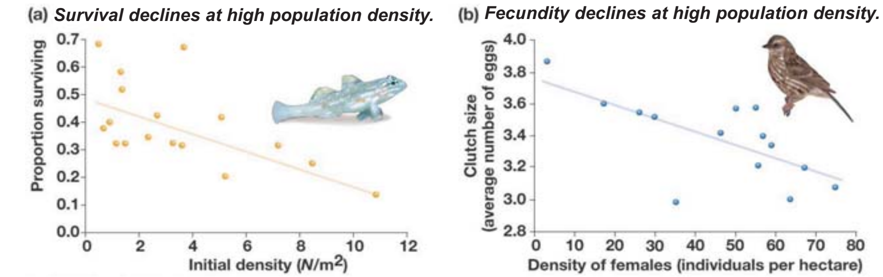
	①	②
growth curve		
density effects?		
factors that limit growth		

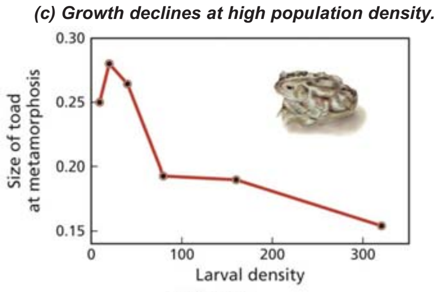
What limits exponential growth?
- ① "Density-independent" factors (for example…)
- ② "Density-dependent" factors (for example…)

Q: When is exponential (density-independent) growth realistic?

2) How do populations change in size?

Density dependent effects regulate most populations





Q: In what two basic ways do these processes influence population growth?

2) How do populations change in size?

"Logistic growth model"

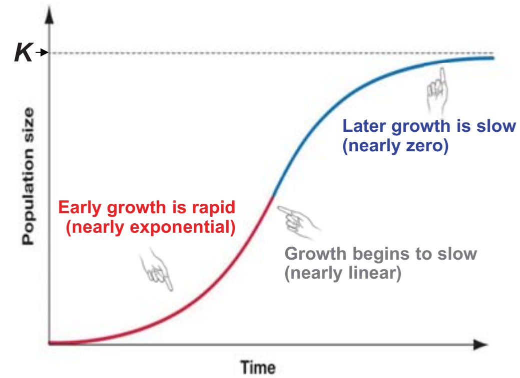
"Density-dependent" growth

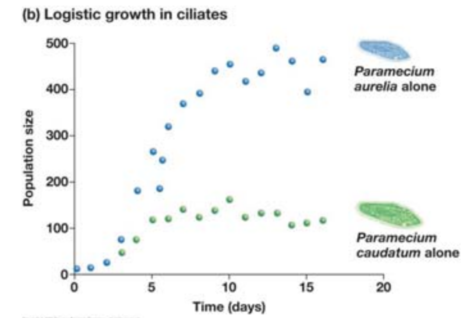
number present — number added by growth

Exponential $N_{t+1} = N_t + r\,N_t$

Logistic $N_{t+1} = N_t + \left[r_{max}\left(1-\frac{N}{K}\right)\right] N_t$

N = 0?
N = K?

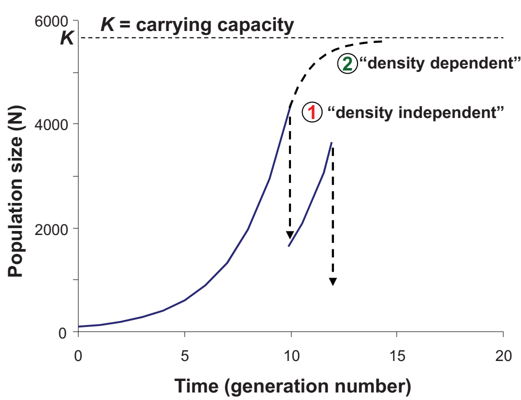




Q: when will a population grow? when will it shrink?

2) How do populations change in size?

Comparison of simple population growth models



	①	②
growth	exponential	logistic
curve	J-shaped	S-shaped
density effects?	independent	dependent
factors that limit growth	abiotic	biotic

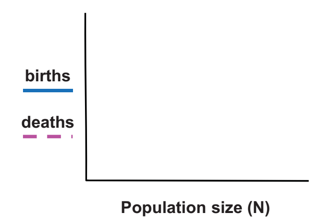
What limits exponential growth?
→ ① "Density-independent" factors (for example…)
→ ② "Density-dependent" factors (for example…)

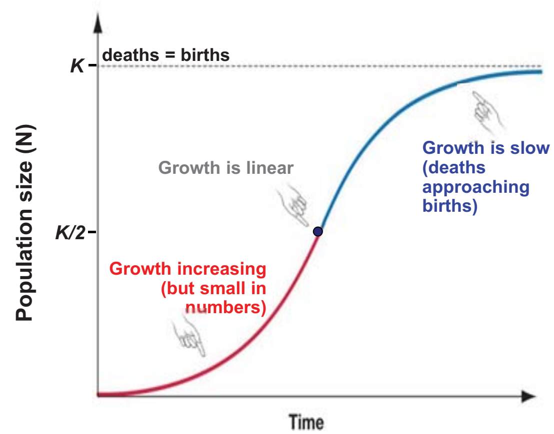
Q: When is exponential (density-independent) growth realistic?

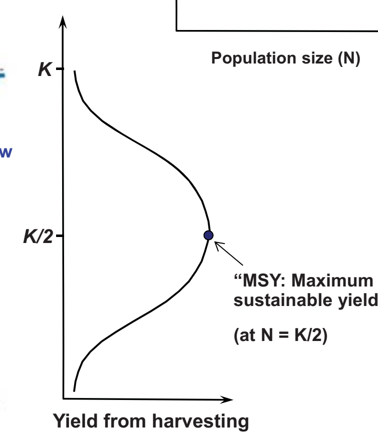
2) How do populations change in size?

Practical application of growth models

→ what is the best point to harvest resources?







Why is population less productive at low and high N?

3) Beyond assumptions of simple models

1. No immigration or emigration

$$N_{t+1} = N_t + B - D + I - E$$

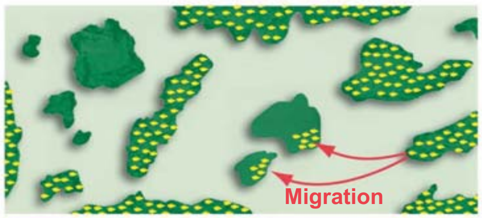
How much will these contribute?

Metapopulation: a set of small populations linked by migration

Time 1

Time 2

Time 3



the "rescue effect"

3) Beyond assumptions of simple models

Glanville fritillary

Metapopulations are dynamic – repeated local extinction and recolonization

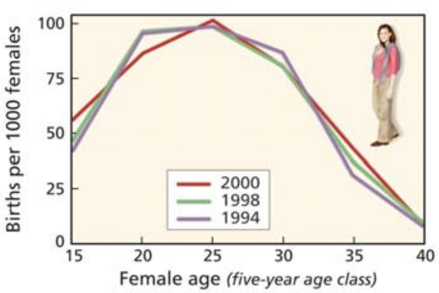
Why are metapopulations significant for conservation?

3) Beyond assumptions of simple models

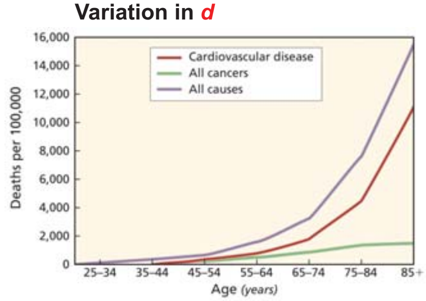
~~X~~ 1. No immigration or emigration

~~X~~ 2. All individuals contribute equally to population growth

Variation in *b*



Variation in *d*



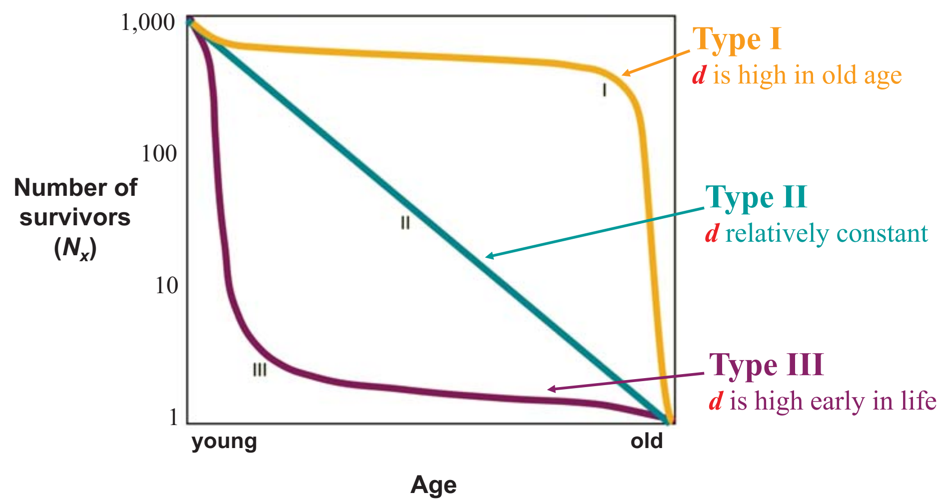
Birth (*b*) and death (*d*) rates can vary with:

- age
- stage (of development)
- body size
- social status, etc.

3) Beyond assumptions of simple models

Survivorship curves

➢ **how *d* (probability of death) changes with age**



Q: *What would an ideal organism be able to do?*

(A: live forever and reproduce at an infinite rate)

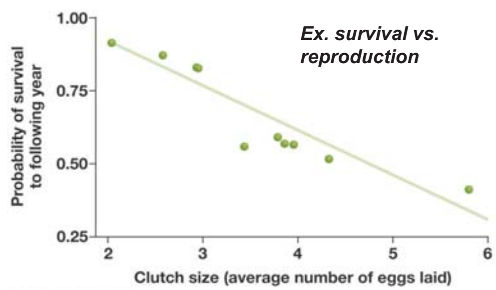
but…re$ources are *always* limited → organisms cannot be ideal

***Life history*: how re$ources are allocated**

growth ***maintenance*** ***reproduction***

Life histories involve *tradeoffs*:

- How much does an organism reproduce (and sacrifice maintenance/survival?)
- When does an organism first reproduce (and reduce investment in growth?)
- How are reproductive resources divided among offspring (affecting r_{max})?



How does consideration of life histories affect conservation?

4) How are life history tradeoffs *optimized*?

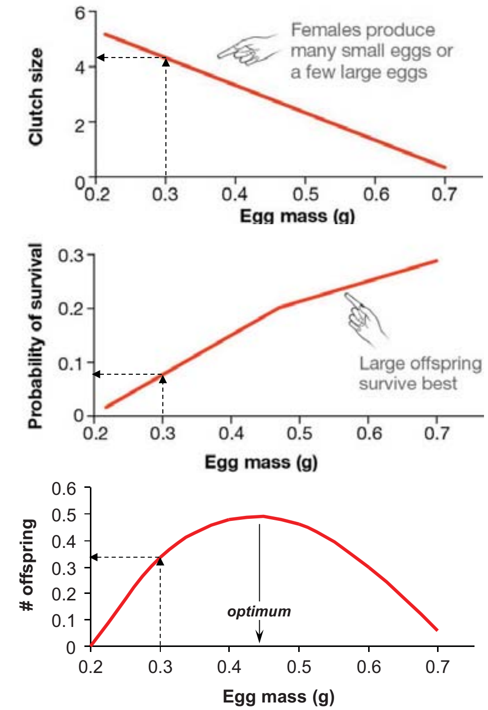
Ex.

Given an allocation of re$ources to reproduction, females could make:

few relatively large eggs

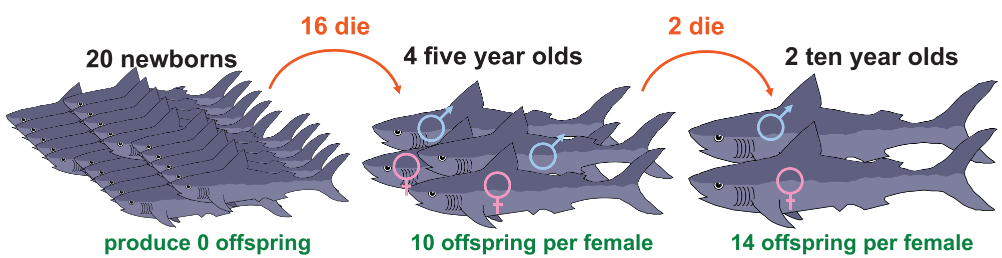
many relatively small eggs

Side-blotched lizard, *Uta stansburiana*



4) How are life history tradeoffs *optimized*?

- **incorporate how *b* and *d* vary among individuals**



survivorship (l_x) – proportion of <u>original</u> cohort surviving to start of age *x*

fecundity (m_x) – average # of <u>female</u> offspring per <u>female</u> in age group *x*

Life table:
summary of age-specific birth and death

age (x)	*survivorship (l_x)*	*fecundity (m_x)*

4) How are life history tradeoffs *optimized*?

Why life tables are useful

- can refine predictions about population growth (*b* and *d* vary)
- can see how selection will act at different ages or stages
- can identify factors that make a population vulnerable to extinction

x age	l_x *survivorship*	m_x *fecundity*	$l_x * m_x$ *female offspring per female*
0	1.00	0	0.0
5	0.20	5	1.0
10	0.10	7	0.7
15	0.05	2	0.1
20	0.01	0	0.0

$1.8 = R_0$

"net replacement"

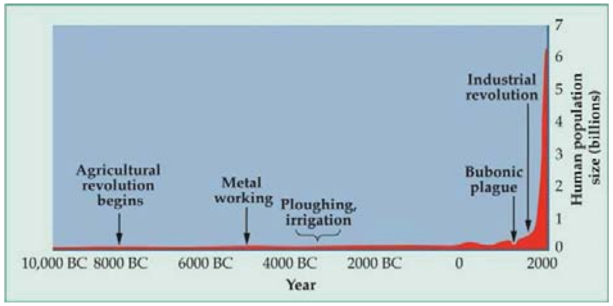
Is this population growing or shrinking? → $R_0 > 1$

Which age is contributing the most to population growth?

Where should conservation efforts be focused?

5) Practical applications of life tables

Ex1: Human population growth



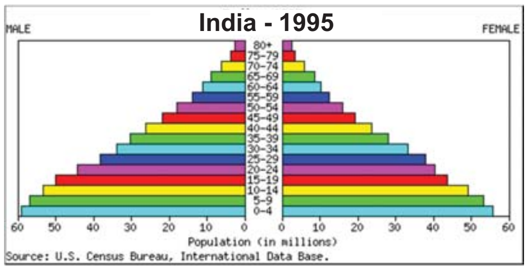
Sep 2013: 7.2 billion

? : 3.6 billion

http://www.worldometers.info/world-population/

Q: How can the human population stabilize?

- [ ] *b*
- [ ] *d*
- [ ] T_g (generation time)



Population **age structure** reflects

- *age-specific survival*
- *past patterns of **b***
- *past patterns of **d***

Q: Is this population growing, shrinking or stable?

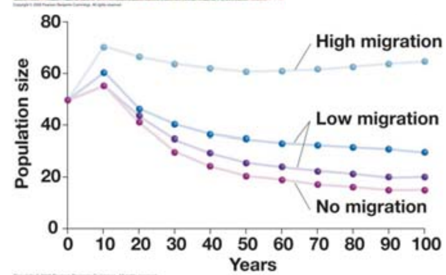
5) Practical applications

Ex2: Population Viability Analysis (PVA)

How do different parameters affect future *N*?

- *age-specific fecundity and survival*
- *migration, inbreeding and genetic drift*
- *demographic and environmental stochasticity*

(a) Leadbeater's possum



North Atlantic right whale

~300 remaining
collisions with ships
entanglement in fishing gear
} *decreasing life expectancy*
extinction within 200 years

Population viability:

↓survival (from 50 to 15 years)
↓fecundity (from 5 to 1 calf/female)

- need to save just 2 adult females/yr to reverse trend

5) Practical applications of life tables

Ex3: Why do organisms senesce (why doesn't evolution select for immortality)?

Genotype 1
- matures by age 3
- dies by age 11

	Age	Survival	Fecundity	RS
	x	*lx*	*mx*	*lx • mx*
	0	1	0	0
	1	0.75	0	0
	2	0.56	0	0
mature >	3	0.42	0.8	0.336
	4	0.32	0.8	0.256
	5	0.24	0.8	0.192
	6	0.18	0.8	0.144
	7	0.14	0.8	0.112
	8	0.11	0.8	0.088
	9	0.08	0.8	0.064
	10	0.06	0.8	0.048
dead >	11	0	0	0
			Lifetime RS ("Ro") =	1.24
			Generation time ("Tg") =	5.16
			Rate of increase ("r") =	0.042

Genotype 2
- matures by age 2
- dies by age 7

	Age	Survival	Fecundity	RS
	x	*lx*	*mx*	*lx • mx*
	0	1	0	0
	1	0.75	0	0
mature >	2	0.56	0.8	0.448
	3	0.42	0.8	0.336
	4	0.32	0.8	0.256
	5	0.24	0.8	0.192
	6	0.18	0.8	0.144
dead >	7	0	0	0
			Lifetime RS ("Ro") =	1.38
			Generation time ("Tg") =	3.45
			Rate of increase ("r") =	0.092

← ***...to start reproducing one year earlier***

} ***sacrifice 4 years of late reproduction...***

Q: It pays to reproduce early, for two reasons. What are they?

	R_o	*r*
genotype 2 / genotype 1	1.1	2.2