Lecture 17:
Age-structured populations and life histories

- Breaking a population into age classes
- Life-table parameters, survivorship and fecundity
- Life-histories: tradeoffs, cost of reproduction
- Alternative life history strategies: iteroparity and semelparity
- Summary statistics derivable from life tables

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Typical life history for higher plants & animals

- Start life at small size
- Grow for a period without reproducing
  - This period is for resource accumulation
- When have enough resources, become mature, start spending resources on reproduction
  - Organisms show various lifestyles after sexual maturity
  - Some expend all resources at once, some spread them out
- Need to consider age structure of populations to:
  - Better predict population trajectories
  - Understand paradoxes of evolutionary ecology

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Age-structured population growth

- Still considering a single population
- But now, fecundity and survivorship vary with age
- Variation summarized by life tables of age-specific rates
- Important implications for:
  - Evolution of life histories
  - Conservation of populations

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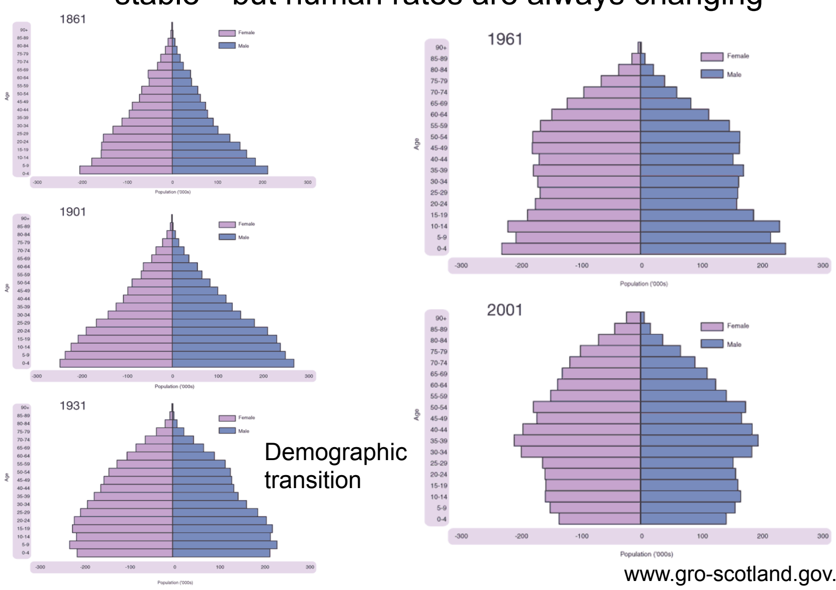
Age-sex pyramids, Scotland 1861-2001

If birth & deaths rates stay constant, pyramid shape is stable—but human rates are always changing



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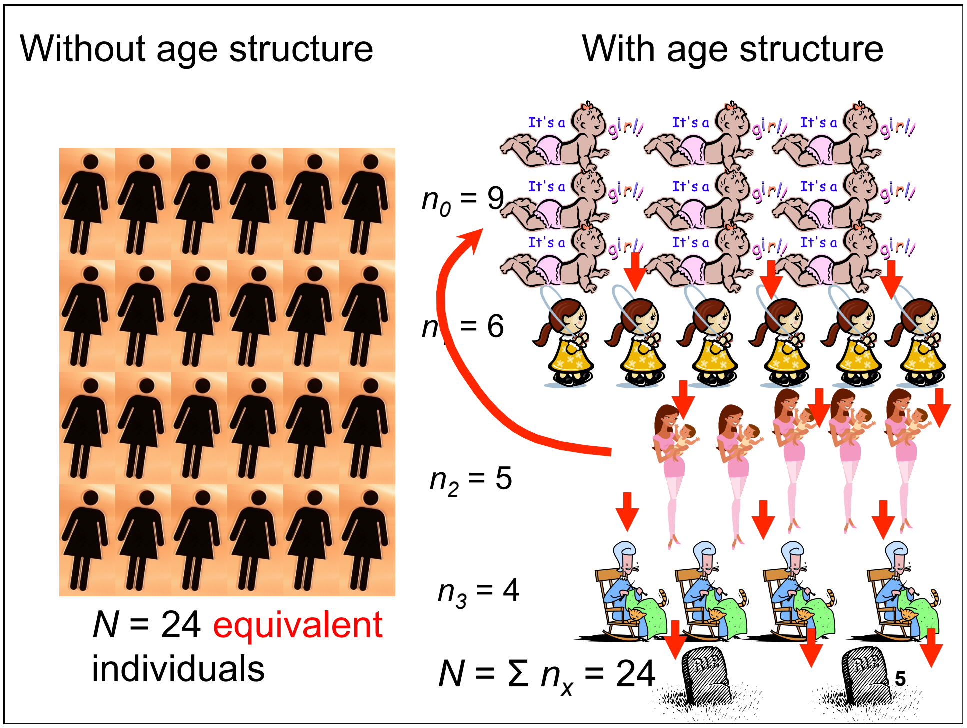
www.gro-scotland.gov.uk



Time now measured in age-class intervals

- Arbitrary units of time chosen to give a reasonable number of age classes for the organism in question
- For microbes, minutes to hours;
- Most insects, weeks;
- Most mammals and birds, years;
- Humans, typically 5-year intervals, therefore about 20 age classes

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Life tables

- Data that summarize the life events that are statistically expected for the average individual of a specified age in a population
- Age of death
- Age and timing of reproduction
- For modeling, these are treated as constants
- Usually consider females only

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Survivorship schedules

- Age classes denoted by subscript x
- L_x = probability of being alive at age x
- L_0 = 1.0 by definition
- "Survivorship curve" = a graph of L_x vs. x
- L_x necessarily declines with x
- Shape of L_x curve is characteristic of species

(The *L's* are usually rendered in lower-case, but I use caps because L's otherwise look like ones in this font)

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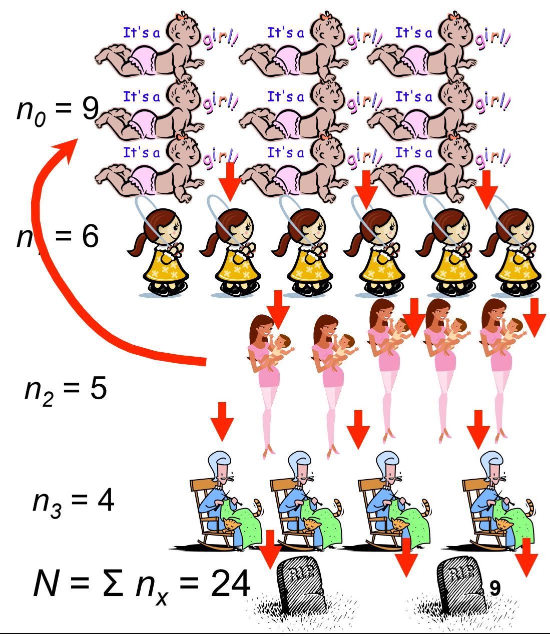
X	n_x	L_x
0	9	1
1	6	6/9 = 0.67
2	5	5/6 = 0.83
3	4	4/5 = 0.8
4	0	0.0



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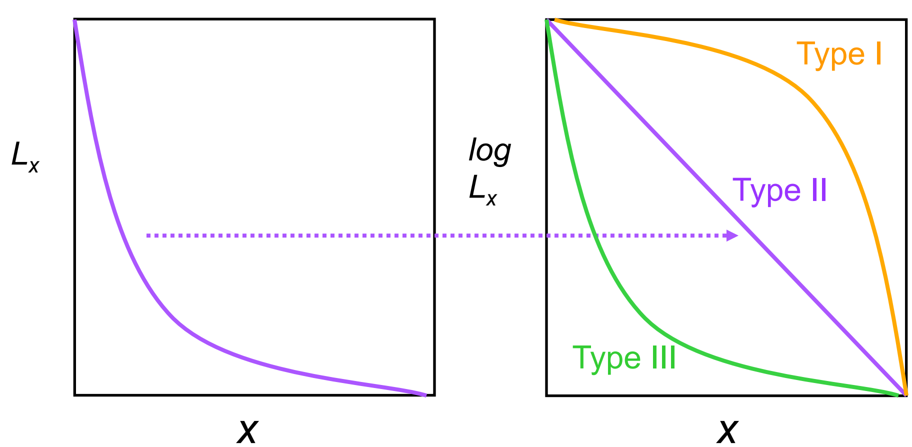
"Types" of survivorship: If mortality is constant with age, get exponential decline with "half-life" (Type II); usually graph L_x curves as log plots, where Type II is a straight line



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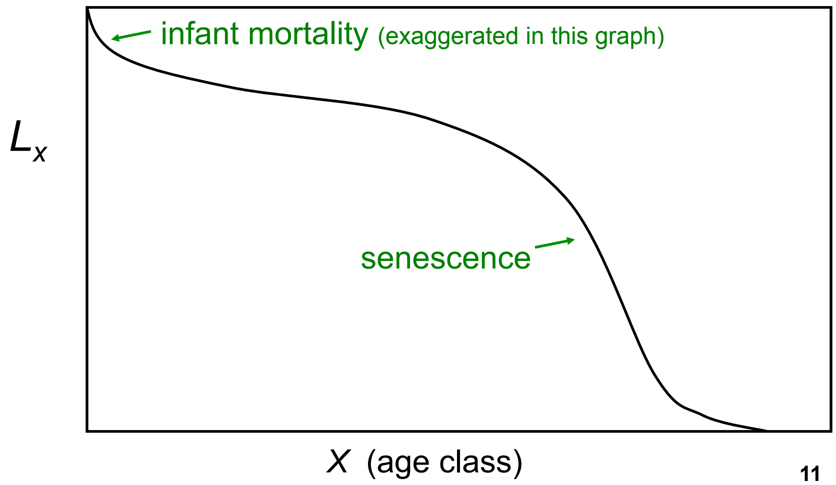
Real shapes more complex: human L_x have these elements



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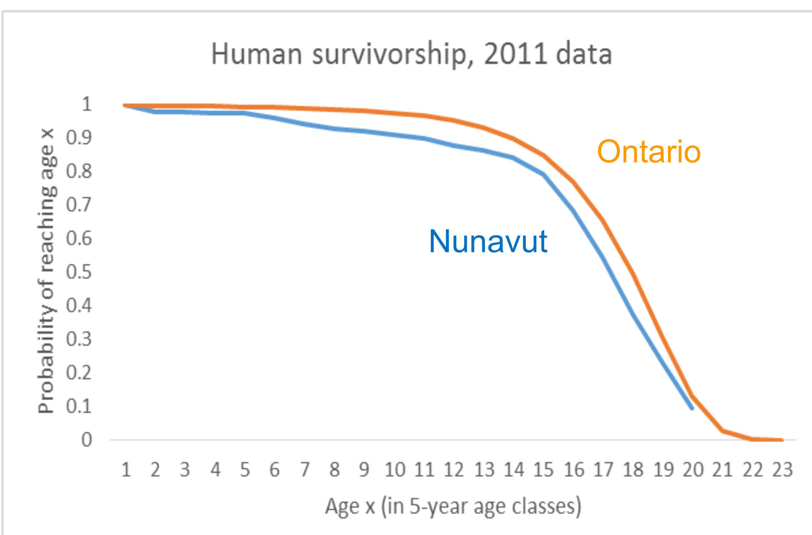
Real human data, developed country with good medical care (data from Statistics Canada)



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Fecundity schedules

- Age classes denoted by subscript x
- b_x = # daughters born to female of age x during the interval x to $x + 1$
- Shape of b_x curve characteristic of species
- Reproductive period usually preceded by resource-accumulation phase
- Reproductive period starts at age of first reproduction
- Fecundity-survivorship tradeoffs = cost of reproduction

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Net reproductive rate R_o

X	L_x	b_x	$L_x b_x$
0	1.0	0	
1	0.5	1	0.5
2	0.4	3	1.2
3	0.2	2	0.4
4	0.0		0

$R_0 = \Sigma L_x b_x = 2.1$
= average number of daughters a female has in her lifetime
= net reproductive rate

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Population growth rates

- Average ("expected") # of daughters a female has in her lifetime = net reproductive rate = R_0
- $R_0 = \Sigma L_x b_x$
- Why does it work? Σb_x would be the total # daughters produced by a mother who doesn't die early; multiplying by L_x discounts expected production by the probability that some mothers *do* die early

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R_0 vs λ

R_0 = average number of daughters a female has in her lifetime

λ = average contribution of an individual to population growth

if λ OR R_0=1 ➔ N remains constant

if λ OR R_0>1 ➔ N grows exponentially without limit

if λ OR R_0<1 ➔ N declines to zero

The main difference between R_0 and λ is that λ is the amount of growth over one time step and R_0 is the amount of growth over one generation

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Generation Time

X	L_x	b_x	
0	1.0	0	
1	0.5	1	
2	0.4	3	
3	0.2	2	
4	0.0		

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Generation time T (= average age at which a female gives birth)

- $T = \Sigma x L_x b_x / \Sigma L_x b_x = \Sigma x L_x b_x / R_0$

female's age

multiplying x by $L_x b_x$ weights x by how many offspring are produced at that age

dividing the sum of the weighted x's by the total lifetime production of daughters (R_0) gives a weighted average that specifies when a female gives birth, on average

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Approximate relationship between R_o and λ

- Both these parameters indicate the factor by which a population changes during a discrete interval of time, but those intervals are different
- As you would expect, the two parameters can be related mathematically:
- $R_o = \lambda^T$
- $\lambda = R_o^{1/T}$

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Generally, organisms with higher λ's have higher fitness…

…So why aren't all plants annuals? Why aren't all mammals mice? Why don't all organisms produce as early as they can?

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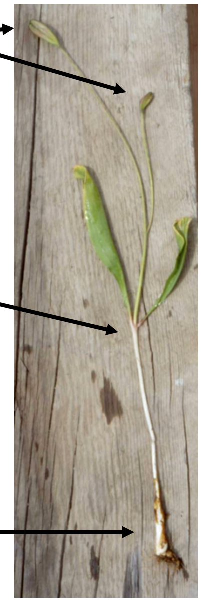
Organismal digression: costs of reproduction in the glacier lily, *Erythronium grandiflorum*

Fruits

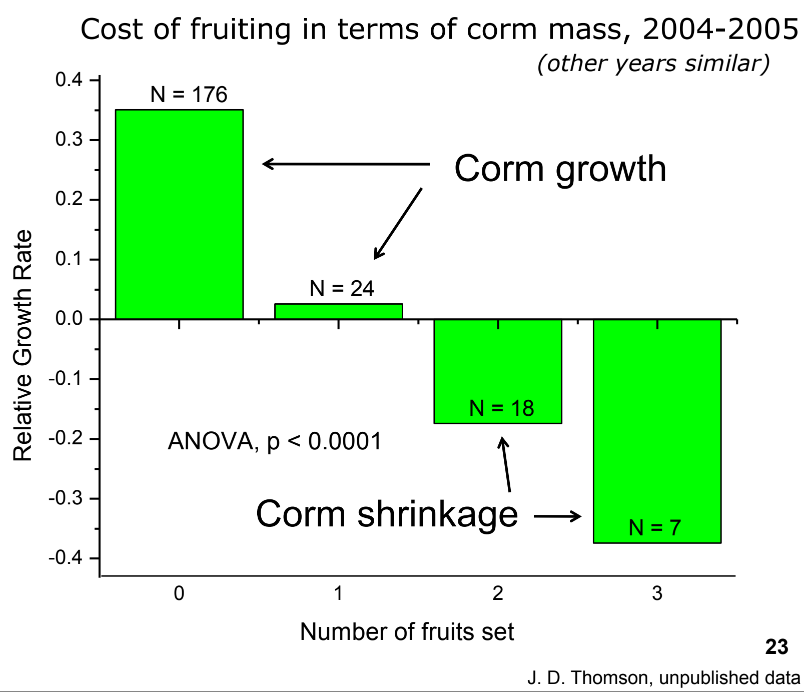
Soil level

Corm (storage)

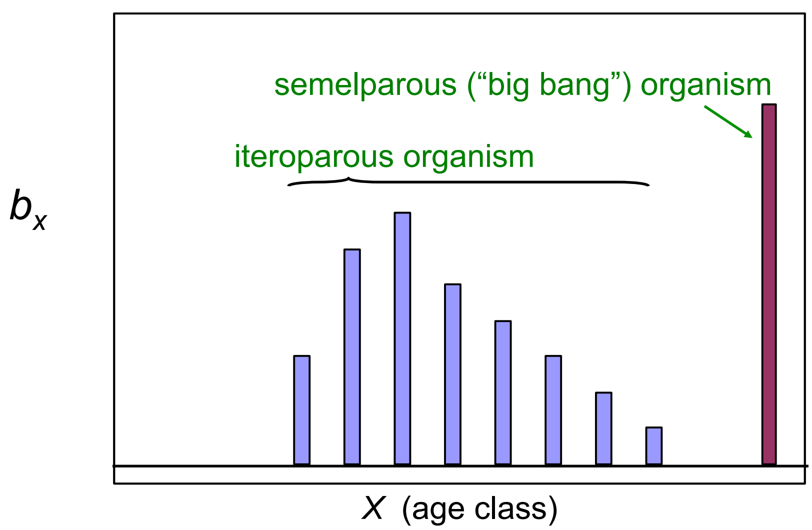


Cost of reproduction: Does making fruits exact a cost in terms of corm growth?

1. Weigh dormant corms in fall, plant in pots in "common garden"
2. In spring, control pollination to vary fruit #
3. In fall, exhume corms and weigh them again
   How much did they gain or lose?



Fecundity schedules vary widely among species, usually genetically determined



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Plant life history categories

Seasons of growth	Semelparous =monocarpic	Iteroparous
One	annual	not applicable
Two	biennial	not applicable
More than two	monocarpic perennial	perennial

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Annuals (semelparous)

desert gold poppy
(eschcholzia glyptosperma)

Old-main-in-the-spring
(Senecio vulgaris)

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What factors select for semelparity?

- When harsh seasonality prevents adult survival (e.g., desert annuals)
- When there is temporary relief from competition (e.g., weeds in disturbed site)

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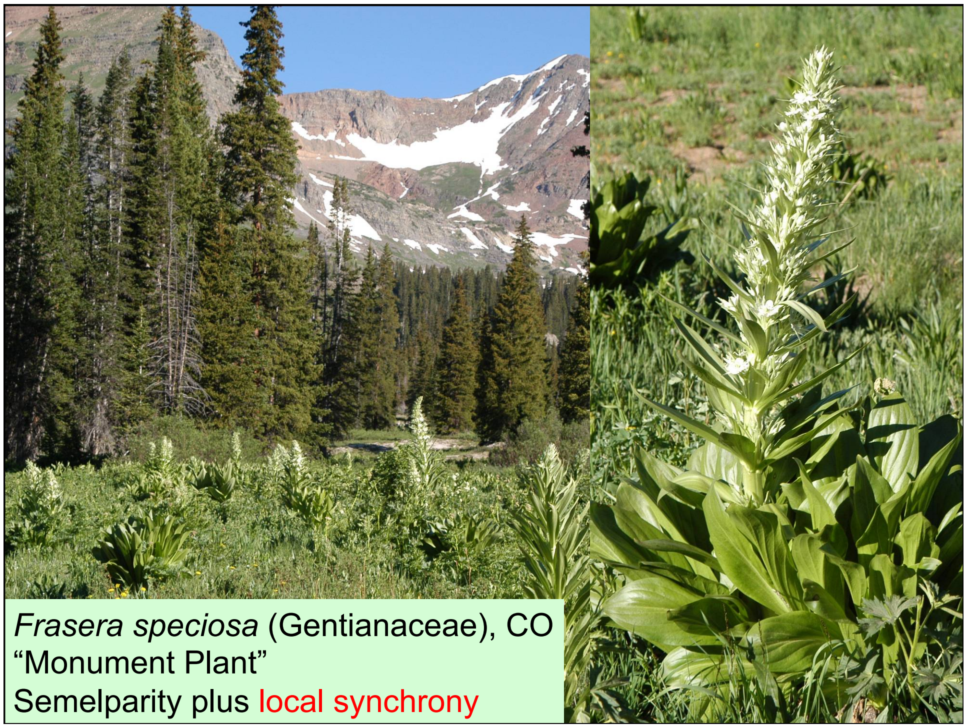

Frasera speciosa (Gentianaceae), CO
“Monument Plant”
Semelparity plus local synchrony

Some bamboo species (Poaceae)
Extremely synchronized semelparity

Advantage of synchrony? Infrequent pulses of reproduction = predator satiation tactic

Swarms of rats plague rural Myanmar

By Colin Hinshelwood

Asia Times, October 21, 2009

CHIANG MAI - A spreading plague of rats has devoured crops in western Myanmar, giving rise to a famine that threatens hundreds of thousands in the country's remote Chin State. According to a recent report issued by the Chin Human Rights Organization (CHRO), at least 54 people have died from the effects of severe malnutrition. The rights group said in September that "no less than 100,000 people [20% of the Chin population] are in need of immediate food aid". The catalyst for the rat infestation is an ecological phenomenon known locally as *mautam*, which translates loosely into English as "bamboo death". The phenomenon occurs approximately once every 50 years with the flowering of the *Melocanna baccifera* bamboo species, whose nutritious fruit attracts and increases the fertility of rats. After the fruit blossomed, an exponentially expanded population of rats was forced to forage elsewhere for food, ravaging rice, maize and sesame crops in the area. The last cycle, in 1958-9, led to the deaths of between 10,000 and 15,000 people in Chin State and the neighboring Indian states of Mizoram and Manipur, which are currently 30% covered in bamboo forest.

http://www.atimes.com/atimes/Southeast_Asia/KJ21Ae01.html

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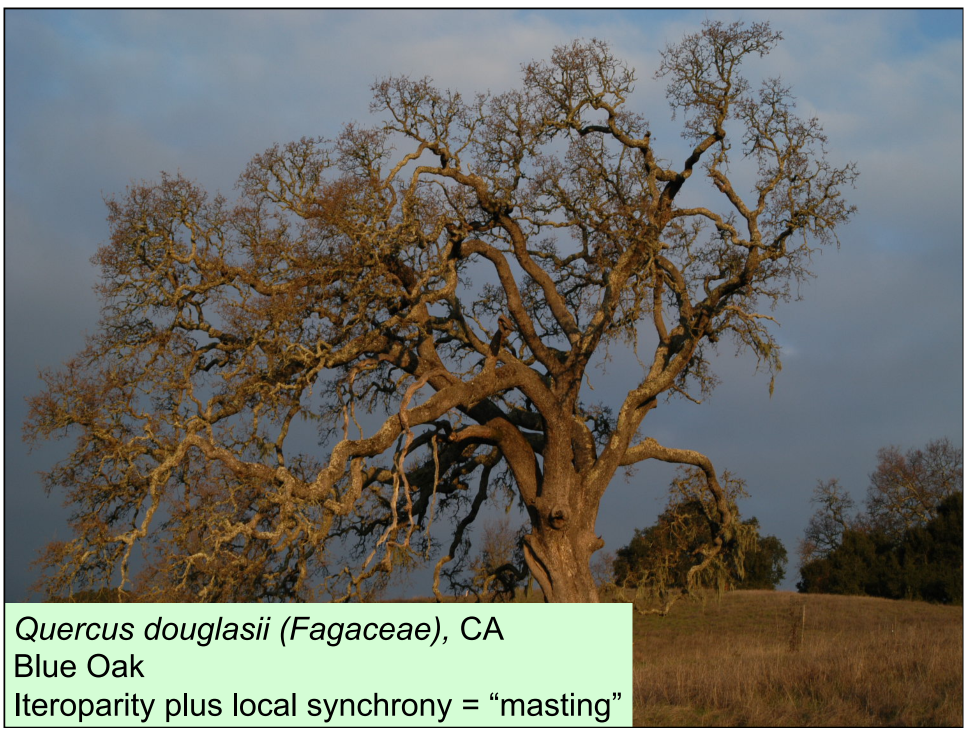

Quercus douglasii (Fagaceae), CA
Blue Oak
Iteroparity plus local synchrony = “masting”

Recap: intertwined themes in life-history

- There are fitness consequences of alternative life history strategies and tradeoffs between current reproduction and future reproduction
- Selection generally selects for early reproduction: more gene copies into population
- But the need to accumulate resources, and size-dependent mating success can override that effect, producing delayed reproduction and/or semelparity
- Semelparity selects for synchrony
- Predator satiation also selects for synchrony

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More fun with life tables

- Can calculate "life expectancy," e_x

 Expected years left to an individual of age x

Important for selling life insurance!

- Can calculate "reproductive value," v_x

 Expected # future daughters left to an individual of age x

Important for how selection acts on behaviour!

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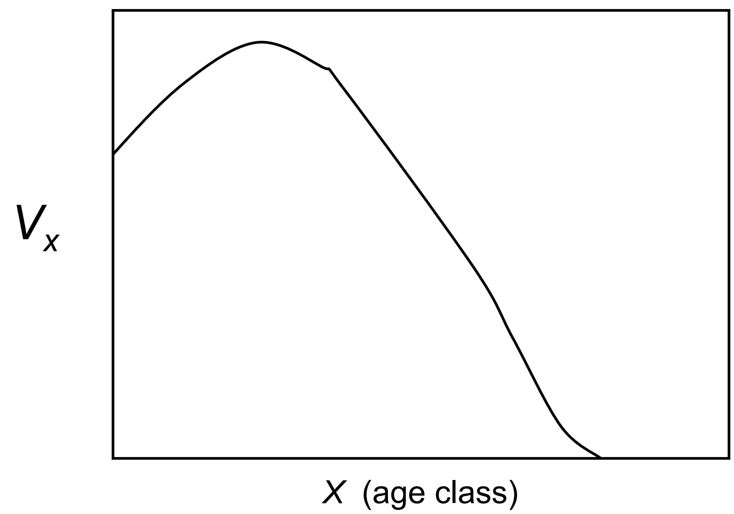
Reproductive value for a human population (Australia, early 20th C)



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How might v_x affect…

- Success of captive breeding/release programs for conservation:
- Prospective success following dispersal to new habitats:
- Mate choice in species with long pair bonds:

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