Population Structure

“Populační ekologie živočichů“

Stano Pekár

Demography

- study of organisms with special attention to stage or age structure
- processes are associated to age, stage or size

- fecundity is dependent on age (e.g., mammals), stage (e.g., insects) or size (e.g., fish)

<u>Four concepts</u>:

1. Every population has a structure – individuals in each class have similar rate of reproduction and mortality

2. Every population has a specific intrinsic rate of increase

3. Every population has specific mortality

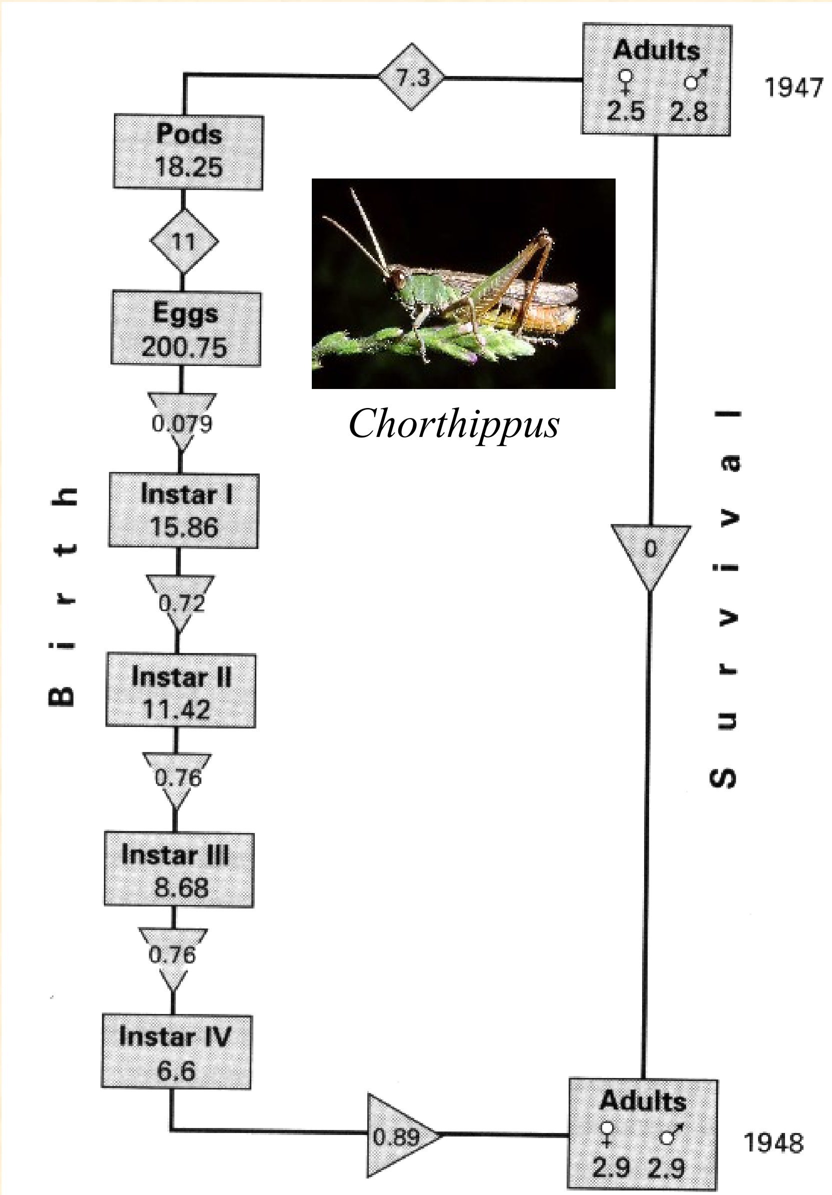
x .. age/stage/size category

p_x .. age/stage/size specific survival

$$p_x = \frac{S_{x+1}}{S_x}$$

4. Every population has a specific reproductive rate

m_x .. reproductive rate (expected average number of offspring per female)

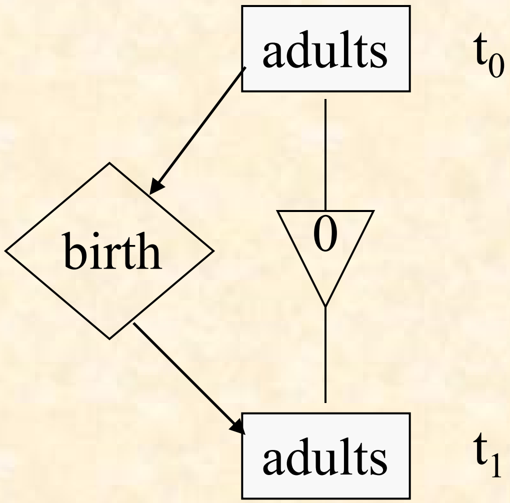


Richards & Waloff (1954)

- main focus on births and deaths
- immigration & emigration is ignored
- no adult survive
- one (not overlapping) generation per year

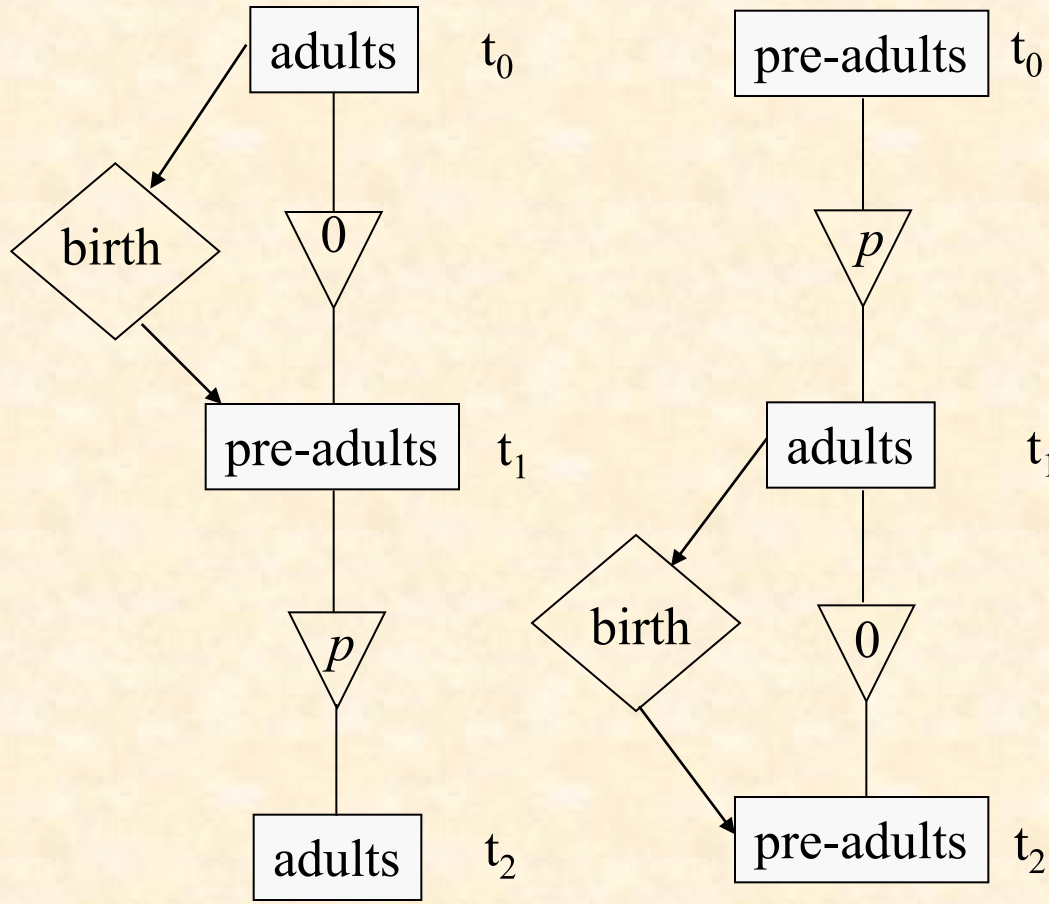
- egg pods over-winter
- despite high fecundity they just replace themselves

Annual species



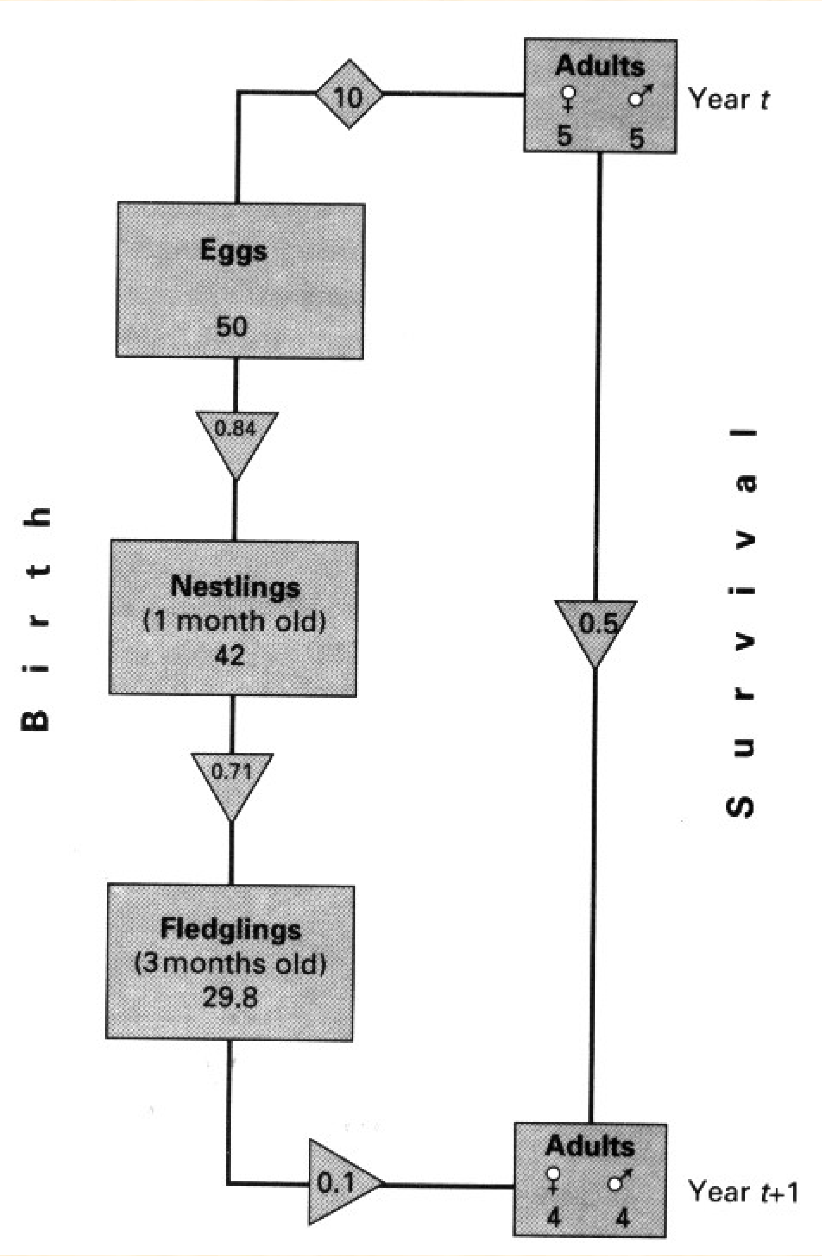
- breed at discrete periods
- no overlapping generations

Biennal species



- breed at discrete periods
- adult generation may overlap

Perins (1965)



Perennial species

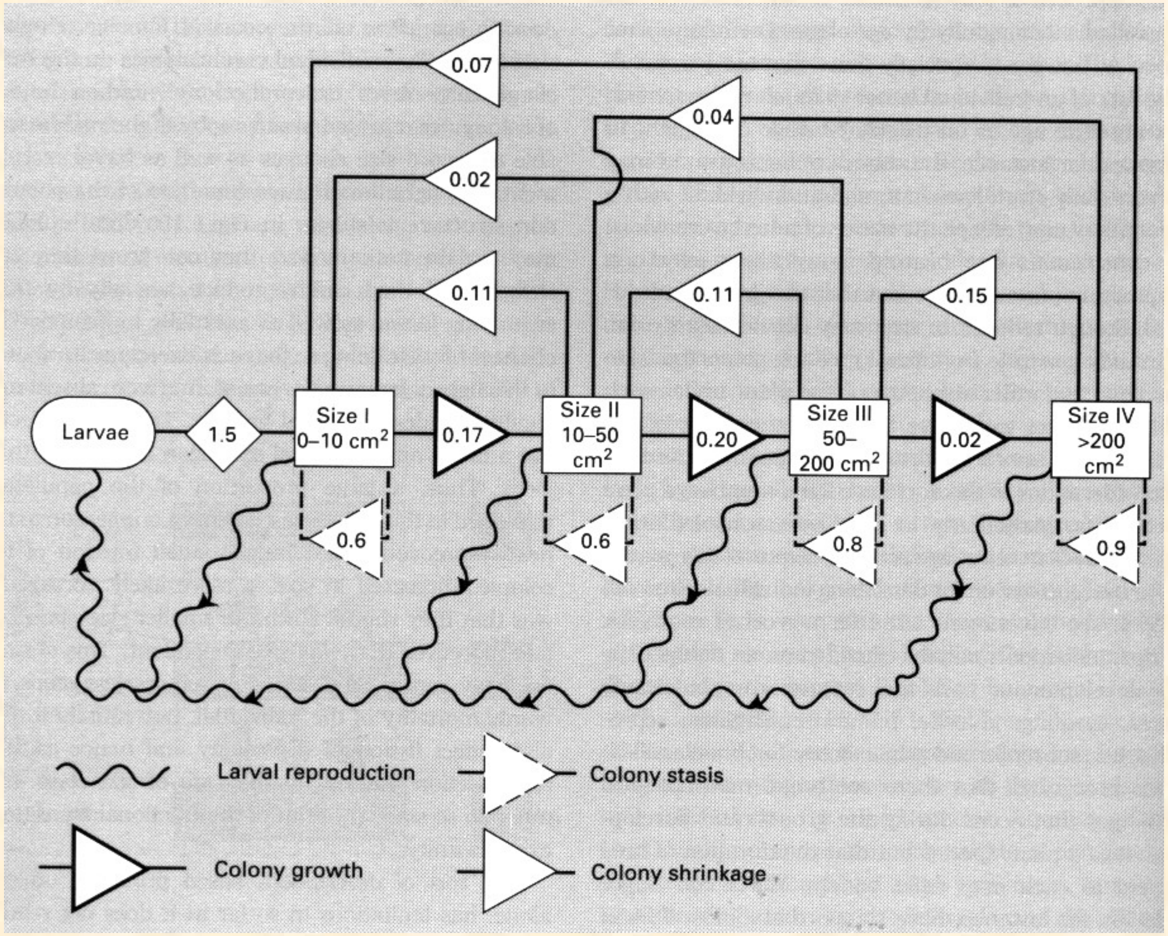
- breed at discrete periods
- breeding adults consist of individuals of various ages (1-5 years)
- adults of different generations are equivalent
- overlapping generations

Parus major

Age-size-stage life-table

Agaricia agaricites

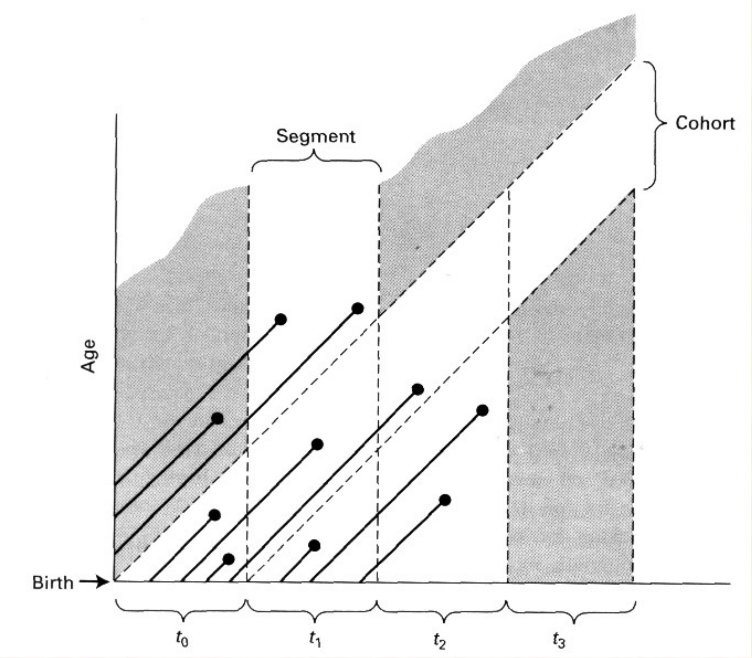
- age/stage classification is based on developmental time
- size may be more appropriate than age (fish, sedentary animals)
- Hughes (1984) used combination of age/stage and size for the description of coral growth



Age-dependent life-tables

- show organisms‘ mortality and reproduction as a function of age

Cohort (horizontal) life-table



- examination of a population in a cohort = a group of individuals born at the same period
- followed from birth to death
- provide reliable information
- designed for short-lived organisms
- only females are included

S_x .. number of survivors

D_x .. number of dead individuals

$$D_x = S_x - S_{x+1}$$

x	Sx	Dx	lx	px	qx	mx
0	250	50	1.000	0.800	0.200	0.000
1	200	120	0.800	0.400	0.600	0.000
2	80	50	0.320	0.375	0.625	2.000
3	30	15	0.120	0.500	0.500	2.100
4	15	9	0.060	0.400	0.600	2.300
5	6	6	0.024	0.000	1.000	2.400
6	0	0	0.000			

l_x .. standardised number of survivors

$$l_x = \frac{S_x}{S_0}$$

q_x .. age-specific mortality

$$q_x = \frac{D_x}{S_x}$$

p_x .. age-specific survival

$$p_x = \frac{l_{x+1}}{l_x}$$

Vulpes vulpes

Static (vertical) life-tables

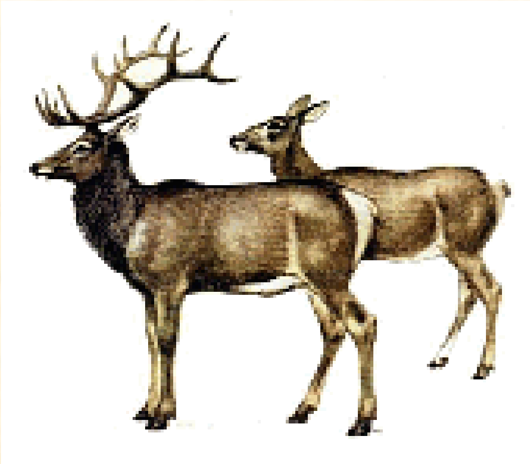
- examination of a population during one segment (time interval)
- segment = group of individuals of different cohorts
- designed for long-lived organisms

- ASSUMPTIONS:
- Birth rate and survival are constant over time
- population does not grow
- proportions of age classes in a sample corresponds to the real state

- DRAWBACKS: confuses age-specific changes in e.g. mortality with temporal variation

x	Sx	Dx	lx	px	qx	mx
1	129	15	1.000	0.884	0.116	0.000
2	114	1	0.884	0.991	0.009	0.000
3	113	32	0.876	0.717	0.283	0.310
4	81	3	0.628	0.963	0.037	0.280
5	78	19	0.605	0.756	0.244	0.300
6	59	-6	0.457	1.102	-0.102	0.400
7	65	10	0.504	0.846	0.154	0.480
8	55	30	0.426	0.455	0.545	0.360
9	25	16	0.194	0.360	0.640	0.450
10	9	1	0.070	0.889	0.111	0.290
11	8	1	0.062	0.875	0.125	0.280
12	7	5	0.054	0.286	0.714	0.290
13	2	1	0.016	0.500	0.500	0.280
14	1	-3	0.008	4.000	-3.000	0.280
15	4	2	0.031	0.500	0.500	0.290
16	2	2	0.016	0.000	1.000	0.280

Lowe (1969)



Cervus elaphus

Stage or size-dependent life-tables

- survival and reproduction depend on stage / size rather than age
- age-distribution is of no interest
- used for invertebrates (insects, invertebrates)
- time spent in a stage / size can differ

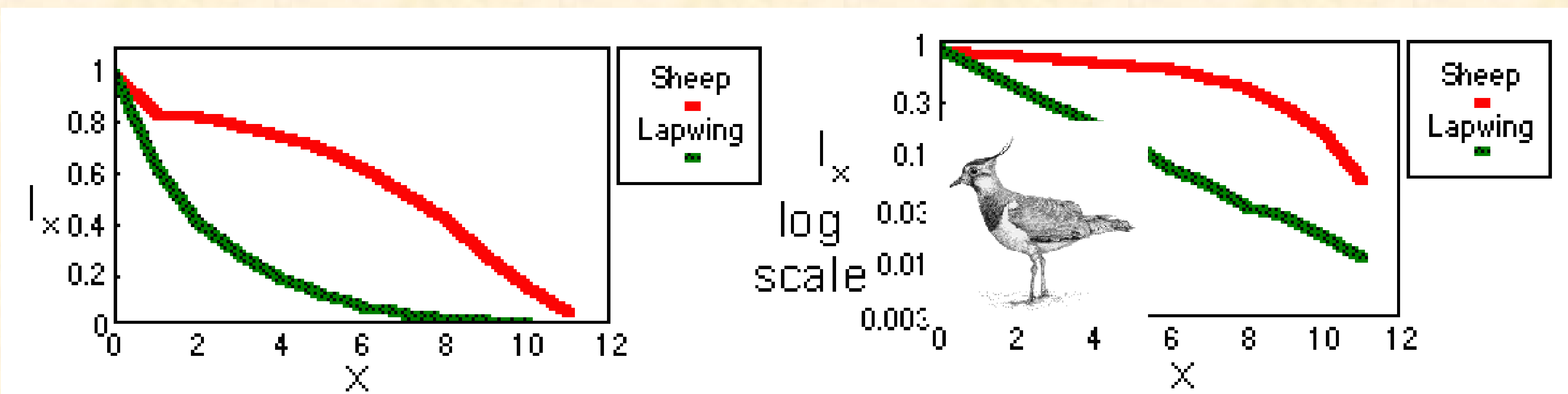
Campbell (1981)

x	Sx	Dx	lx	px	qx	mx
Egg	450	68	1.000	0.849	0.151	0
Larva I	382	67	0.849	0.825	0.175	0
Larva II	315	158	0.700	0.498	0.502	0
Larva III	157	118	0.349	0.248	0.752	0
Larva IV	39	7	0.087	0.821	0.179	0
Larva V	32	9	0.071	0.719	0.281	0
Larva VI	23	1	0.051	0.957	0.043	0
Pre-pupa	22	4	0.049	0.818	0.182	0
Pupa	18	2	0.040	0.889	0.111	0
Adult	16	16	0.036	0.000	1.000	185

Lymantria dispar

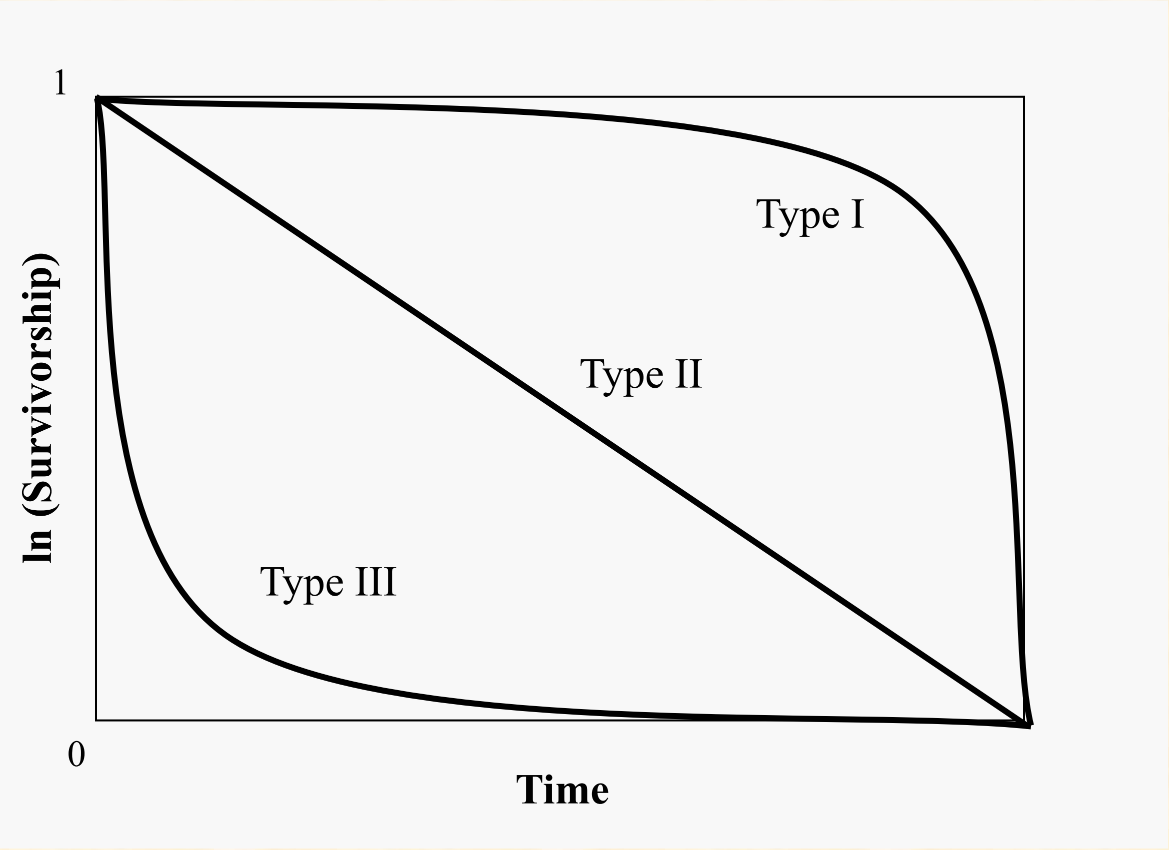
Survivorship curves

- display change in survival by plotting log(l_x) against age (x)
- sheep mortality increases with age
- survivorship of lapwing (*Vanellus*) is independent of age
  but survival of sheep is age-dependent



Pearls (1928) classified hypothetical age-specific mortality:

- Type I .. mortality is concentrated at the end of life span (humans)
- Type II .. mortality is constant over age (seeds, birds)
- Type III .. mortality is highest in the beginning of life (invertebrates, fish, reptiles)



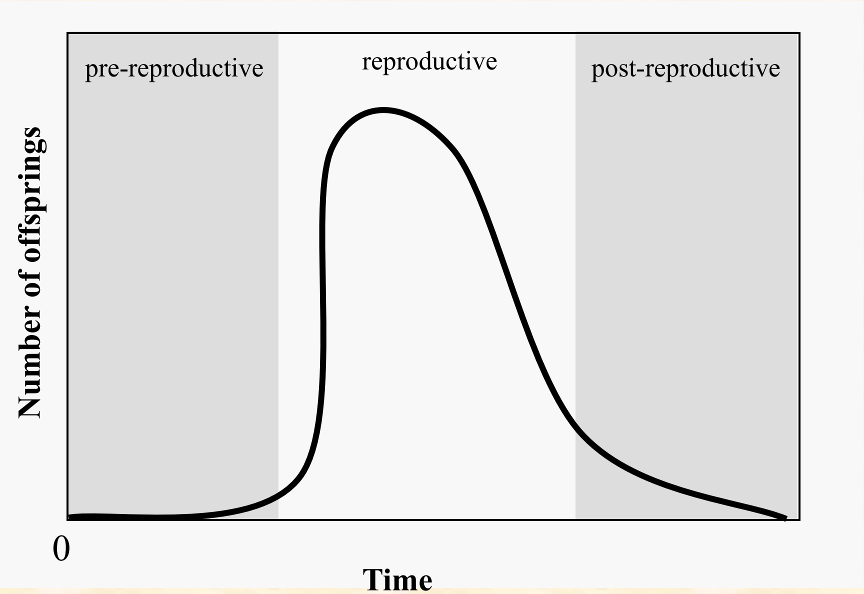
- Sum of intrinsic and extrinsic mortality

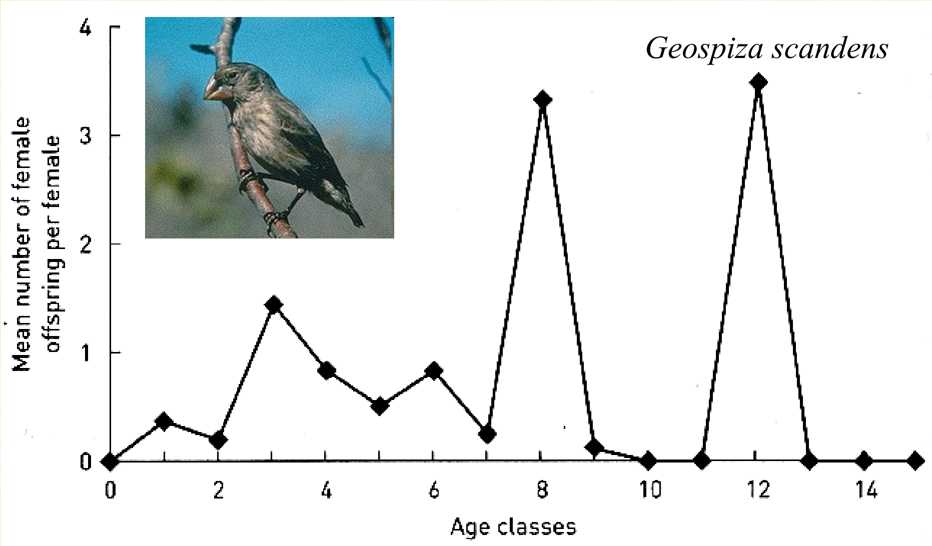
Birth rate curves

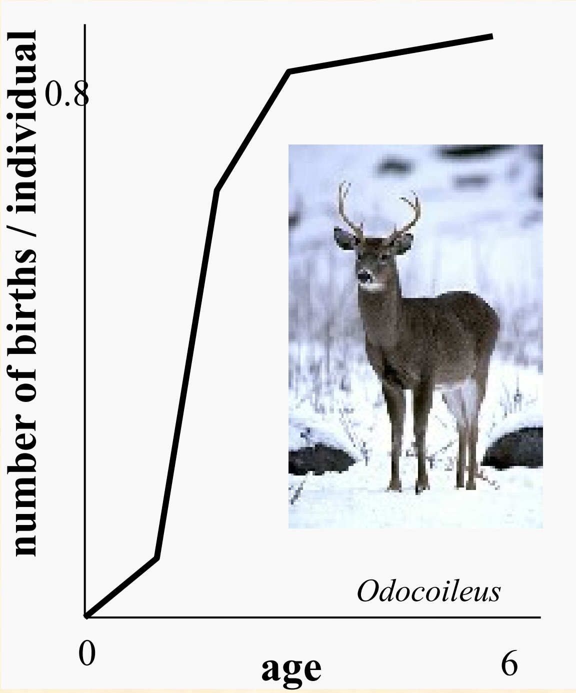
- fecundity - potential number of offspring
- fertility - real number of offspring

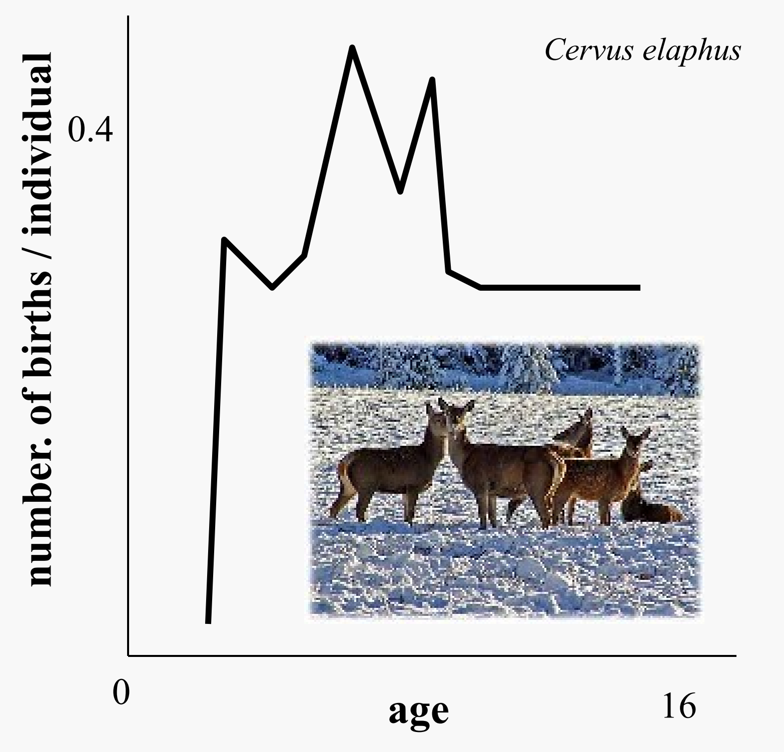
- semelparous .. reproducing once a life
- iteroparous .. reproducing several times during life

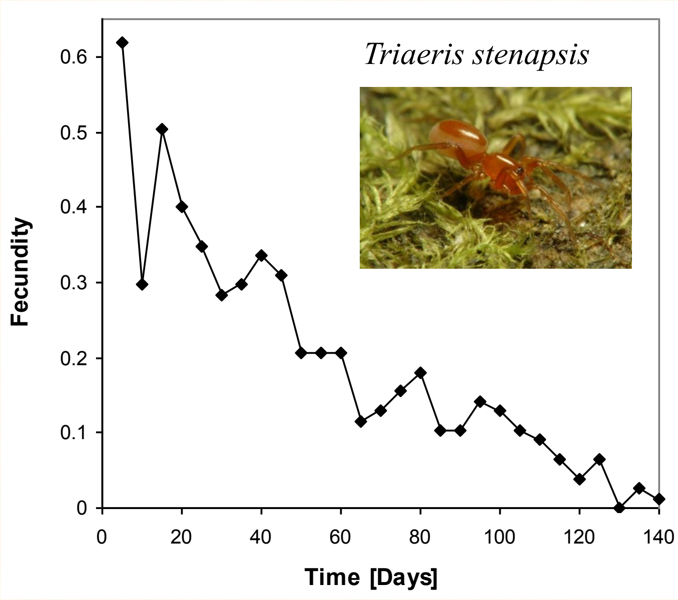
- birth pulse .. discrete reproduction (seasonal reproduction)
- birth flow .. continuous reproduction




Geospiza scandens
Mean number of female offspring per female
Age classes
0
1
2
3
4
0
2
4
6
8
10
12
14


number of births / individual
0.8
Odocoileus
0
age
6


Cervus elaphus
number. of births / individual
0.4
0
age
16


Triaeris stenapsis
Fecundity
0
0.1
0.2
0.3
0.4
0.5
0.6
0
20
40
60
80
100
120
140
Time [Days]

Key-factor analysis

- k-value - **killing power** - another measure of mortality

$$k = -\ln(p)$$

- k-values are additive unlike $\boldsymbol{q}$

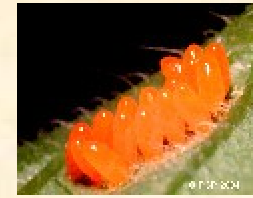
$$K = \sum k_x$$

- **Key-factor analysis** - a method to identify the most important factors that regulates population dynamics

- k-values are estimated for a number of years

- important factors are identified by regressing $\boldsymbol{k_x}$ on log(N)

Leptinotarsa decemlineata

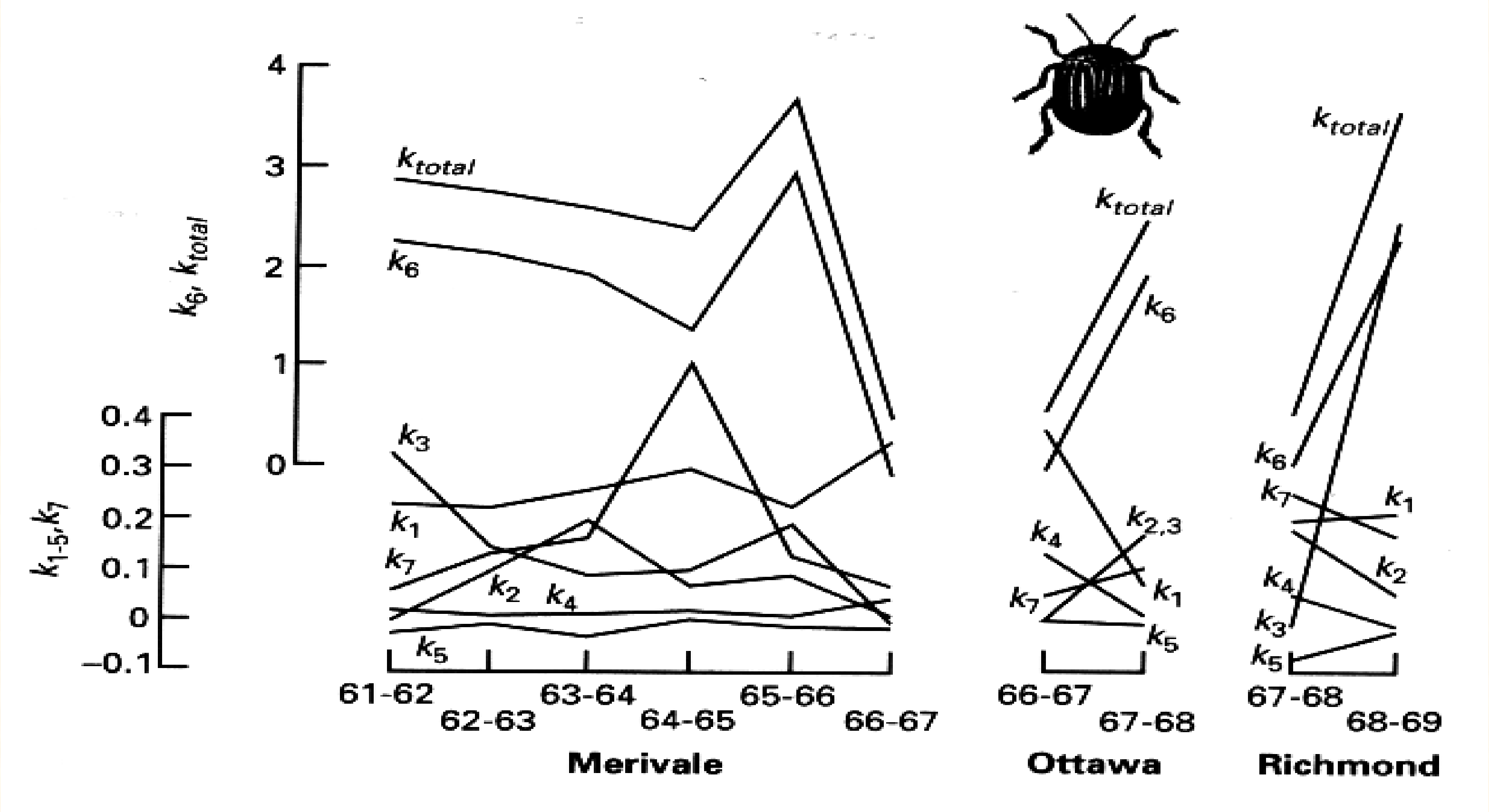


- over-wintering adults emerge in June → eggs are laid in clusters on the lower side of leafs → larvae pass through 4 instars → form pupal cells in the soil → summer adults emerge in August → begin to hibernate in September
- mortality factors overlap

Harcourt (1971)

Age interval	Numbers per 96 potato hills	Numbers 'dying'	'Mortality factor'	$\log_{10} N$	*k*-value	
Eggs	11 799	2531	Not deposited	4.072	0.105	(k_{1a})
	9268	445	Infertile	3.967	0.021	(k_{1b})
	8823	408	Rainfall	3.946	0.021	(k_{1c})
	8415	1147	Cannibalism	3.925	0.064	(k_{1d})
	7268	376	Predators	3.861	0.024	(k_{1e})
Early larvae	6892	0	Rainfall	3.838	0	(k_2)
Late larvae	6892	3722	Starvation	3.838	0.337	(k_3)
Pupal cells	3170	16	*D. doryphorae*	3.501	0.002	(k_4)
Summer adults	3154	−126	Sex (52% female)	3.499	−0.017	(k_5)
Female × 2	3280	3264	Emigration	3.516	2.312	(k_6)
Hibernating adults	16	2	Frost	1.204	0.058	(k_7)
Spring adults	14			1.146		
					2.926	(k_{total})

Summary over 10 years



- highest k-value indicates the role of a factor in each generation
- profile of a factor parallel with the ***K*** profile reveals the key factor
- emigration is the key-factor