Life Tables and Life Histories

- Life tables
  - Types: cohort/dynamic vs. static
  - Survivorship and fertilities schedules
  - Net reproductive rate, generation time, rate of increase
- Estimating a Leslie matrix from a life table
- Life-history patterns
  - Tradeoffs
  - Constraints
- Chris Benda: Headstarting Feasibility for Blanding's Turtle

The key ingredients of a Life Table

x	N_x	B_x
0	1000	0
1	186	0
2	58	690
3	34	465
4	22	314
5	12	201
6	5	87
7	2	35
8	0	0

- *X* is age (years), N_x (or S(x))is number of individuals alive at beginning of age x, and B_x (b(x))is number of offspring produced at given age.
- All other life table calculations are derived from these three columns.
- Common to use only females.
- These data can be gathered in two main ways.

1. **Cohort life table** (aka dynamic)

- A cohort is group of individuals born at same time

- A cohort life table is derived by following a single cohort over time

- Mark a bunch of newborns individually and track their survival and reproduction as they age.

- Difficult approach for long-lived or mobile species

x	N_x	B_x
0	1000	0
1	186	0
2	58	690
3	34	465
4	22	314
5	12	201
6	5	87
7	2	35
8	0	0

Implicit **ASSUMPTIONS:**

- No yearly variation in vital rates

- Stable age distribution

x	N_x	B_x	l_x	S_x
0	1000	0	1.000	0.186
1	186	0	0.186	0.312
2	58	690	0.058	0.586
3	34	465	0.034	0.647
4	22	314	0.022	0.545
5	12	201	0.012	0.417
6	5	87	0.005	0.400
7	2	35	0.002	0.000
8	0	0	0.000	0

Survivorship (l_x): probability of surviving *from birth to a given age*

$$l_2 = \frac{N_2}{N_0} = \frac{58}{1000} = 0.058 \qquad l_x = \frac{N_x}{N_0}$$

Survival rate (S_x): probability of surviving *from a given age to the next*

$$S_2 = \frac{N_3}{N_2} = \frac{34}{58} = 0.586$$

To calculate survivorship (to age x) from survival rates:

$$l_x = S_0 \; S_1 \; \cdots \; S_{x-1}$$

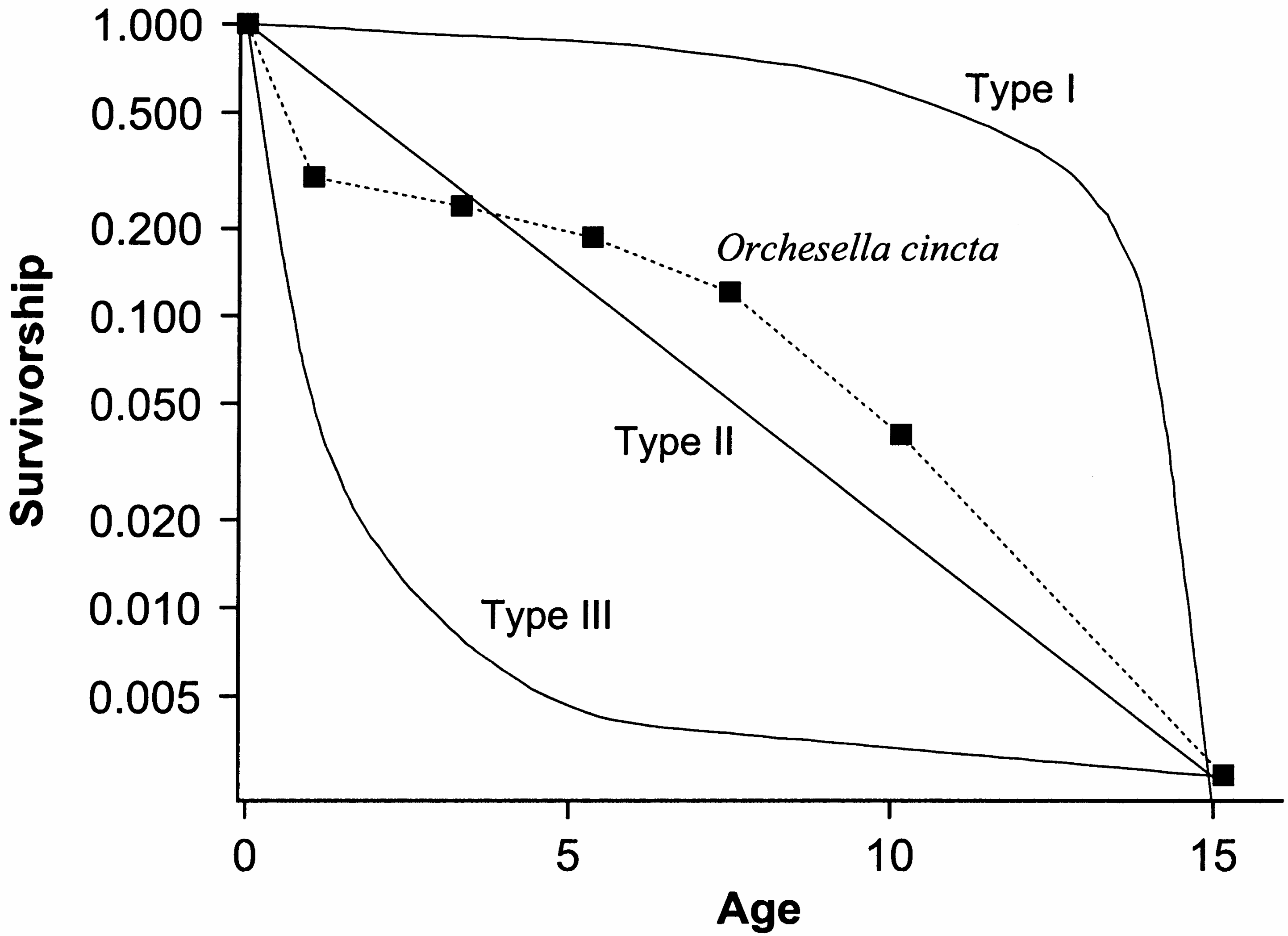
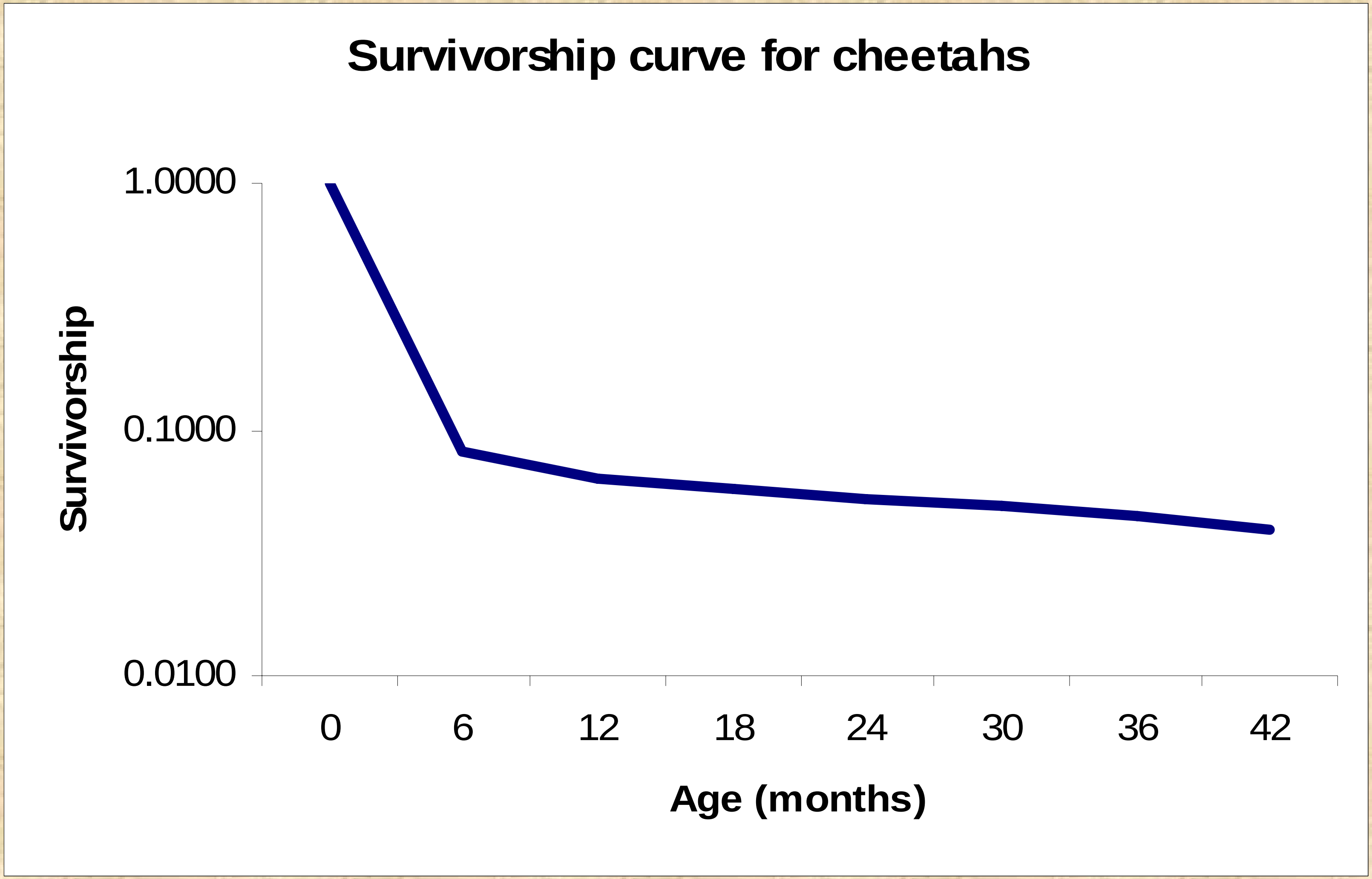


Figure 4.6. Three idealized types of survivorship (l_x) curves as a function of age, x (solid curves), and survivorship curve for *Orchesella cincta*, a forest insect, with age in weeks (dotted curve; data from van Straalen 1985).


Survivorship curve for cheetahs
1.0000
0.1000
0.0100
Survivorship
0
6
12
18
24
30
36
42
Age (months)

x	N_x	B_x	l_x	S_x	m_x
0	1000	0	1.000	0.186	0.00
1	186	0	0.186	0.312	0.00
2	58	690	0.058	0.586	11.90
3	34	465	0.034	0.647	13.68
4	22	314	0.022	0.545	14.27
5	12	201	0.012	0.417	16.75
6	5	87	0.005	0.400	17.40
7	2	35	0.002	0.000	17.50
8	0	0	0.000	0	0

- Fertility (maternity, m_x) is the average number of offspring produced by individuals in each age class

    (or average number of daughters per female in each age class)

- Note that this is not equivalent to the Fecundity values that we use in the Leslie matrix, which depend on fertility plus survival rates.

Several useful life-history values can be calculated from the survivorship schedule (l_x) and fertility schedule (m_x)

1. **Net reproductive rate** is the expected number of offspring produced by an individual over its lifetime.

$$R_0 = \sum l_x m_x$$

x	N_x	B_x	l_x	S_x	m_x	$l_x \cdot m_x$
0	1000	0	1.000	0.186	0.00	0.000
1	186	0	0.186	0.312	0.00	0.000
2	58	690	0.058	0.586	11.90	0.690
3	34	465	0.034	0.647	13.68	0.465
4	22	314	0.022	0.545	14.27	0.314
5	12	201	0.012	0.417	16.75	0.201
6	5	87	0.005	0.400	17.40	0.087
7	2	35	0.002	0.000	17.50	0.035
8	0	0	0.000	0	0	0
					Total = R_0 =	1.792

2. **Generation time** ($T = T_G$) is a measure of the average age of reproduction.

$$T_G = \frac{\sum x l_x m_x}{\sum l_x m_x} = \frac{\sum x l_x m_x}{R_0}$$

x	N_x	B_x	l_x	S_x	m_x	$l_x \cdot m_x$	$x \cdot l_x \cdot m_x$
0	1000	0	1.000	0.186	0.00	0.000	0.000
1	186	0	0.186	0.312	0.00	0.000	0.000
2	58	690	0.058	0.586	11.90	0.690	1.380
3	34	465	0.034	0.647	13.68	0.465	1.395
4	22	314	0.022	0.545	14.27	0.314	1.256
5	12	201	0.012	0.417	16.75	0.201	1.005
6	5	87	0.005	0.400	17.40	0.087	0.522
7	2	35	0.002	0.000	17.50	0.035	0.245
8	0	0	0.000	0	0	0	0
					Total = R_0 =	1.792	5.803
					T =	3.238	

3. Instantaneous/intrinsic growth rate (*r*)

- A good approximation is given by

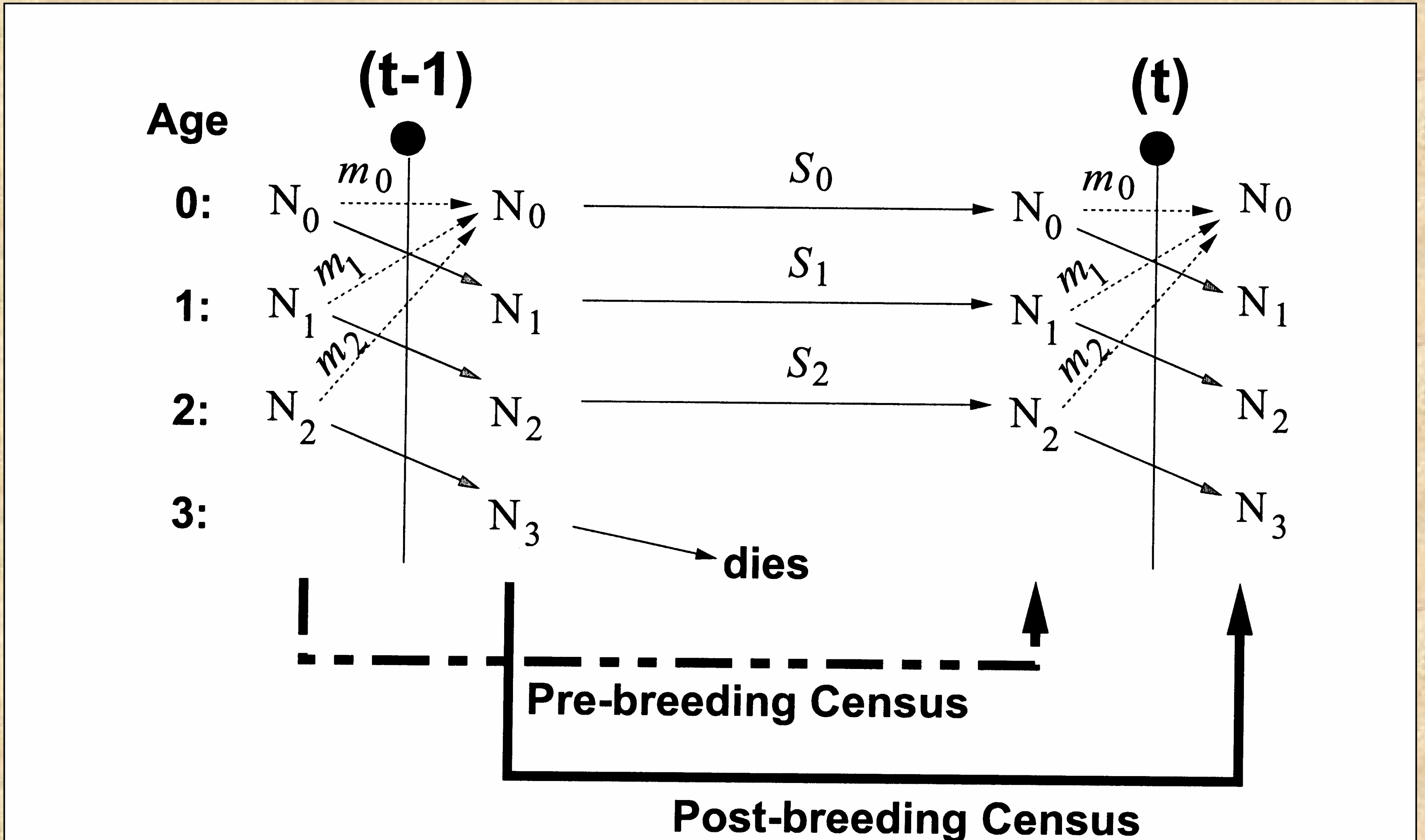
$$r_{est} = \frac{\ln(R_0)}{T_G}$$

- An exact measure can be found by finding the value or *r* that satisfies the Euler equation:

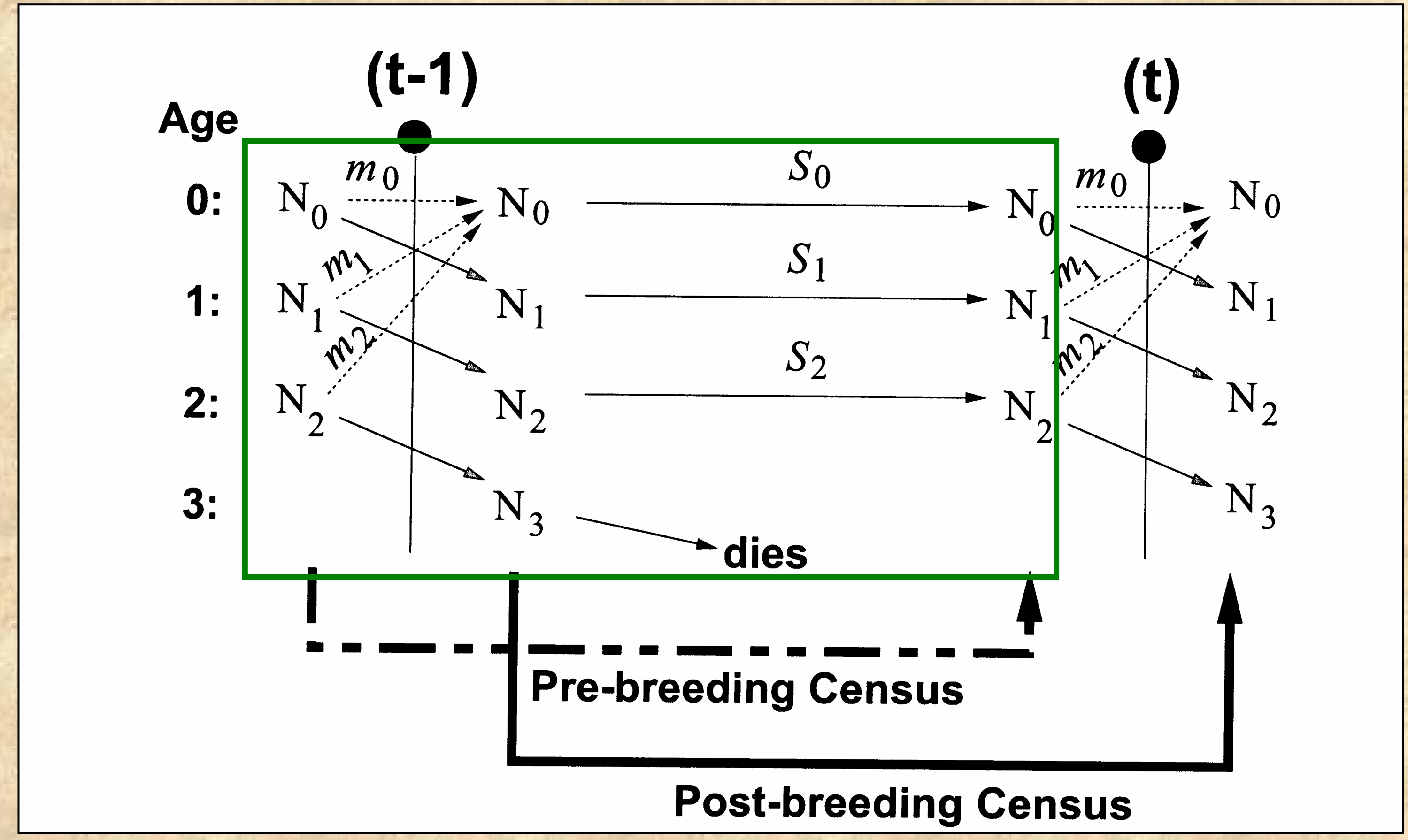
$$\sum e^{-rx} l_x m_x = 1$$

Estimating a Leslie matrix from a life table

- Calculation of survival and fecundity values for the matrix depend on timing of census in relation to breeding season.

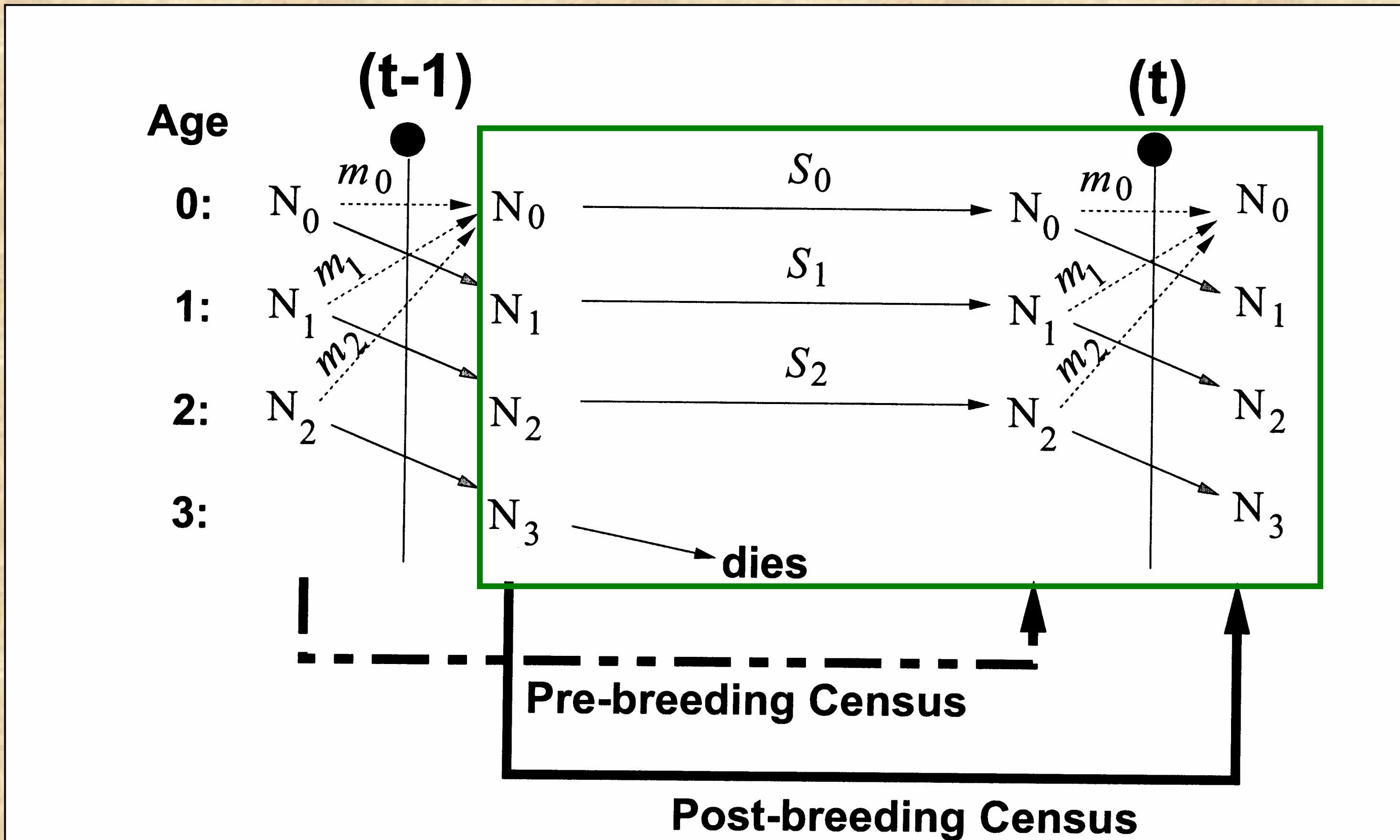


Pre-breeding census



$$\begin{bmatrix} m_0 S_0 & m_1 S_0 & m_2 S_0 \\ S_1 & 0 & 0 \\ 0 & S_2 & 0 \end{bmatrix}$$

Post-breeding census



$$\begin{bmatrix} S_0 m_0 & S_1 m_1 & S_2 m_2 & 0 \\ S_0 & 0 & 0 & 0 \\ 0 & S_1 & 0 & 0 \\ 0 & 0 & S_2 & 0 \end{bmatrix}$$

Life-History Patterns in a Nutshell

Why do we see certain life-history patterns?

Why do species tend to have certain combinations of life-history traits?

What keeps species from having optimal life histories in which survivorship and fertility are at a maximum for all age classes?

Tradeoffs and Constraints

Key Life-History Traits

- Size at birth
- Growth pattern
- Age and size at maturity
- Number, size, and sex ratio of offspring
- Age- and size-specific reproductive investments
- Age- and size-specific mortality schedules
- Length of life

(from Stearns 1992)

Life-History Tradeoffs

• Tradeoffs are linkages among traits that constrain the simultaneous evolution of two or more traits.

Key tradeoffs include:

1. Current reproduction vs. survival
2. Current reproduction vs. future reproduction
3. Reproduction vs. condition/growth
4. Number vs. quality of offspring

These represent physiological tradeoffs within an individual due to allocation of limited energy.

Example: Current reproduction vs. survival in red deer

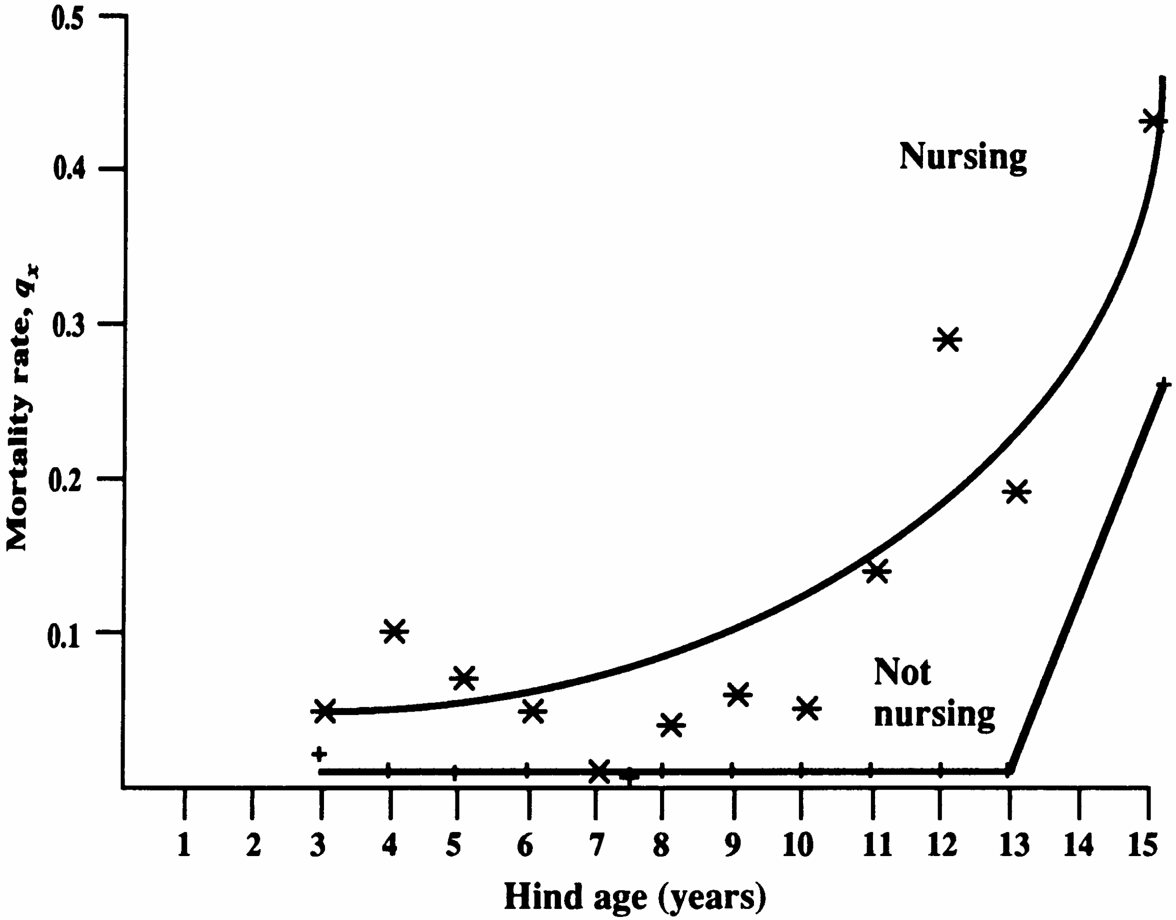


Figure 4.1 The age-specific mortality rates for nursing and non-nursing females are low and not very different for the first ten years of life. After that point, the mortality rates of reproductive hinds climb sooner and more rapidly than do those of non-reproductive hinds (after Clutton-Brock *et al.* 1982).