



Chapter 14: Population Ecology
*Study of the Abundance and
Dynamics of Species Populations*

July 29, 2004

Population



Group of interbreeding
individuals

Population Ecology

Central ? is what regulates the abundance and distribution of a species

- Across the Landscape (Spatial)
- Over Time (Temporal)

Spatial Arrangement

(pattern of dispersion)

- Clumping - with the clumps distributed randomly or non-randomly
- Regular spacing - approaching a uniform distribution – e.g. even-aged forest stand
- Random - not usually characteristic of plant, animal, or microbial species
- Scale of dispersion differs by species

More about clumping

(contagious distributions)

- Reproduction and dispersal – depends on distance propagules move
- Variations / limitations of physical environment – e.g. light dependent only in gaps
- Active locomotion in response to a common stimulus – e.g. deer congregating under thermal cover in winter
- Modification of the physical environment by the organism (facilitation) – e.g. snowmelt “islands” of trees
- Aggregation as the result of biotic factors – e.g. animals moving in packs to decrease predation

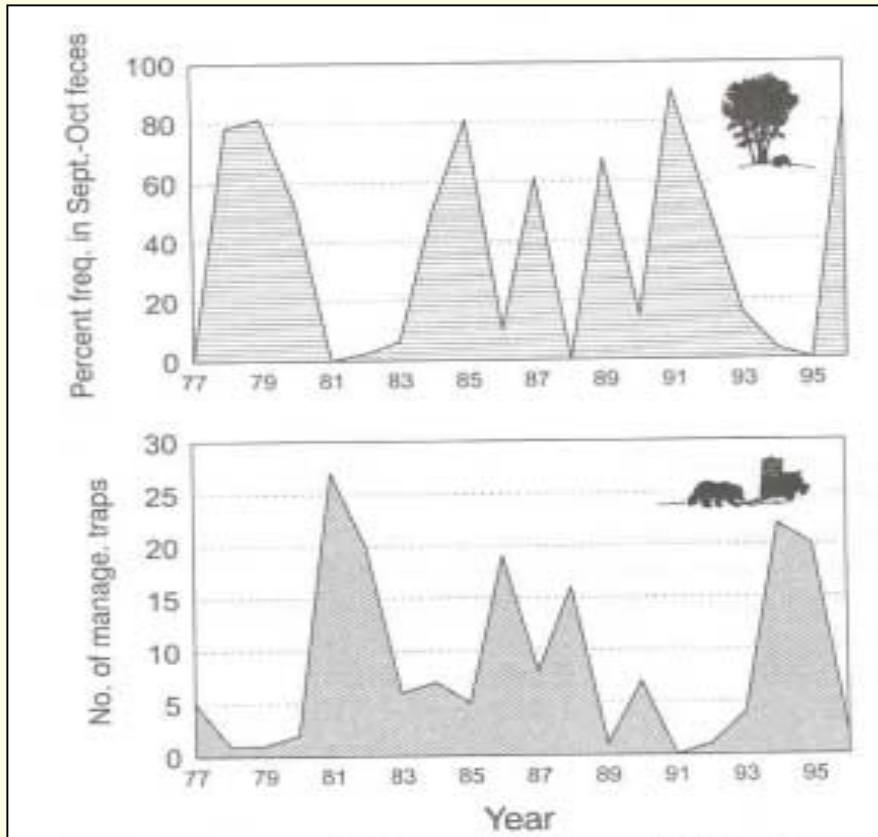
Clumping (e.g.)



Whitebark pine (*Pinus albicaulis*) in a mixed upper subalpine forest community

Clumping in Whitebark pine

May be the result of ...



Grizzly bear dispersal of seeds



Blister rust
(*Cronotarium
ribicola*)



Clark's nutcracker

Seed caching

Benefits of belonging...

- Protection
 - environment, predators
- Reproduction
 - critical lower population size and density
- Genetic Diversity
 - genetic variation and polymorphism
- Intra-specific Competition
 - promotes high fitness and adaptability
- Division of Labor and Cooperation
 - colonial and social behavior

Disadvantages of belonging...

- Intra-specific competition
 - overpopulation / overstocking, stagnation
- Increased stress levels
 - stress changes morphology & physiology
- Alteration of environment
 - changing / degrading of the environment
- Disease transmission
 - increased host density, monoculture vs. mixed
- Physical interference
 - interrupt normal behavior patterns

Intra-specific Competition



Lodgepole –
serotinous cones



Douglas-fir

Figures 14-2 and 14-3

Population Growth - Geometric

(Exponential)

- Species with short generation time
- All required resources in excess
- Population increase unlimited
- Curvilinear increase with time

*Theoretical

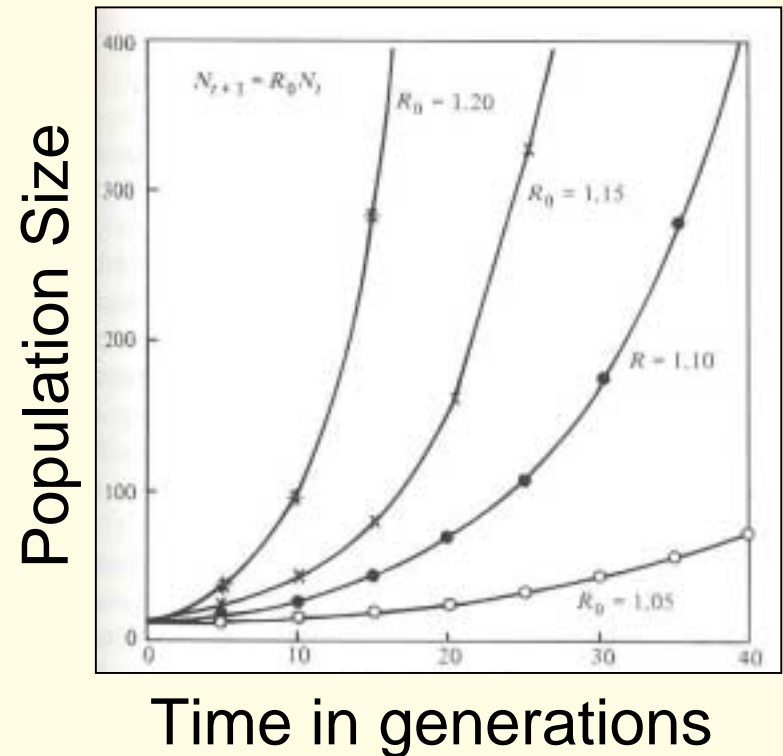


Fig 14.4

Geometric Growth

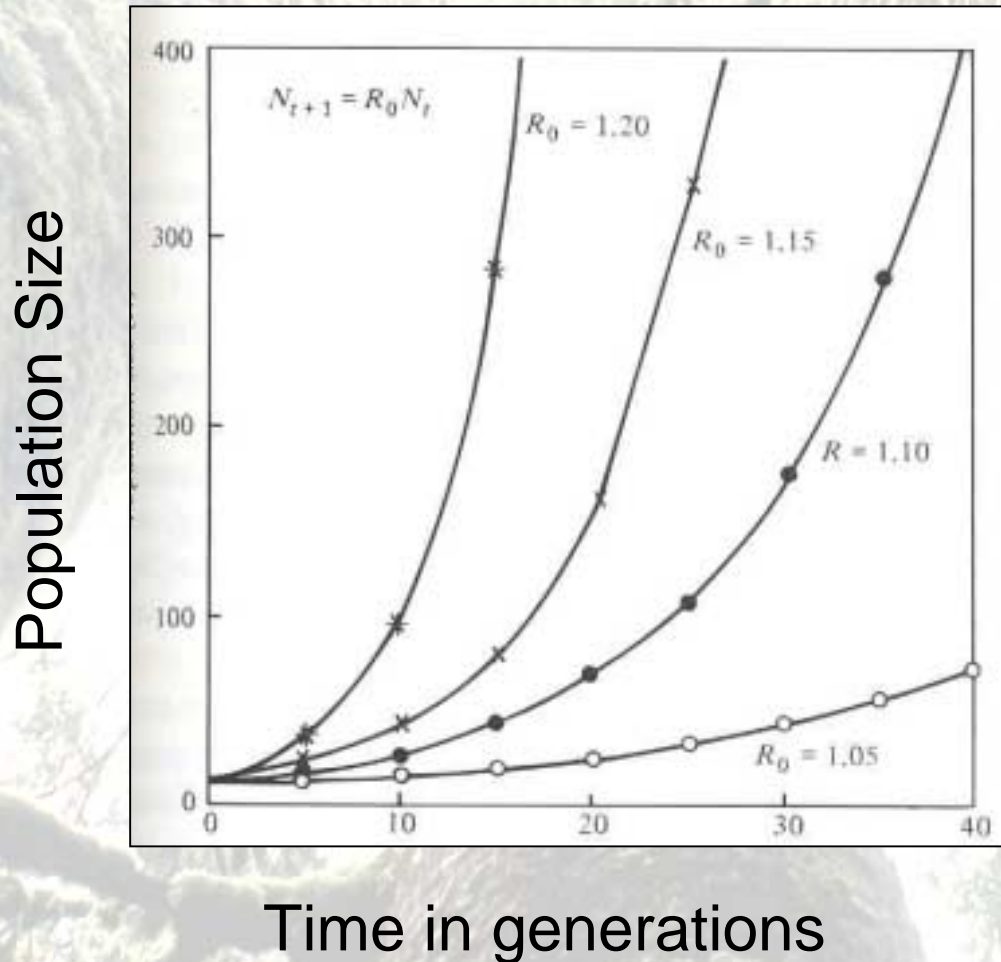
$$\frac{dN}{dt} = r \cdot N$$

Rate of population growth per unit time $\frac{dN}{dt}$ = Rate of increase r • Population size N

$$N_t = N_0 \cdot e^{rt}$$

Population size at time (t) = Population size at time (0) • $e^{\text{rate of increase} \cdot \text{time}}$

Geometric Growth (revisited)



$$N_t = N_0 \cdot e^{rt}$$

Population Growth - Logistic

(Sigmoidal)

- Exponential growth to a limit
- Limit = carrying capacity (k)
- Results from negative feedback
- When K is reached, environment is saturated

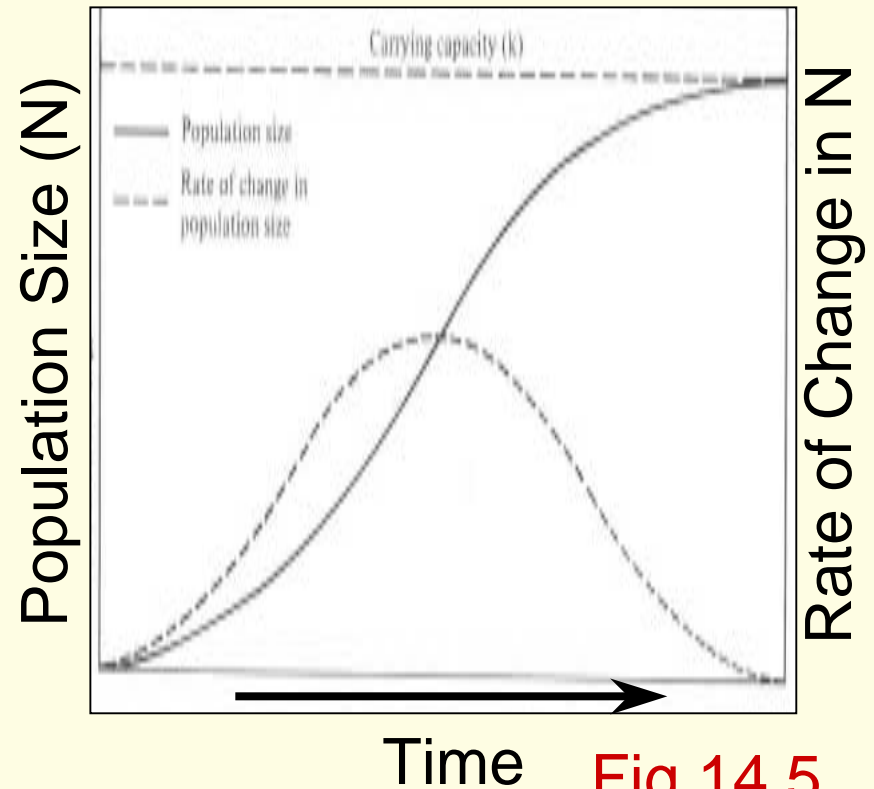


Fig 14.5

*Theoretical

Logistic Growth

Geometric Growth

$$\frac{dN}{dt} = r \cdot N$$

Rate of population growth per unit time becomes = Rate of increase • Population size

$$\frac{dN}{dt} = r \cdot N \left(1 - \frac{N}{K}\right)$$

Where $(1 - N/K)$ is the proportion of carrying capacity that remains unused.

Logistic Growth (revisited)

$$dN / dt = r \cdot N (1 - N/K)$$

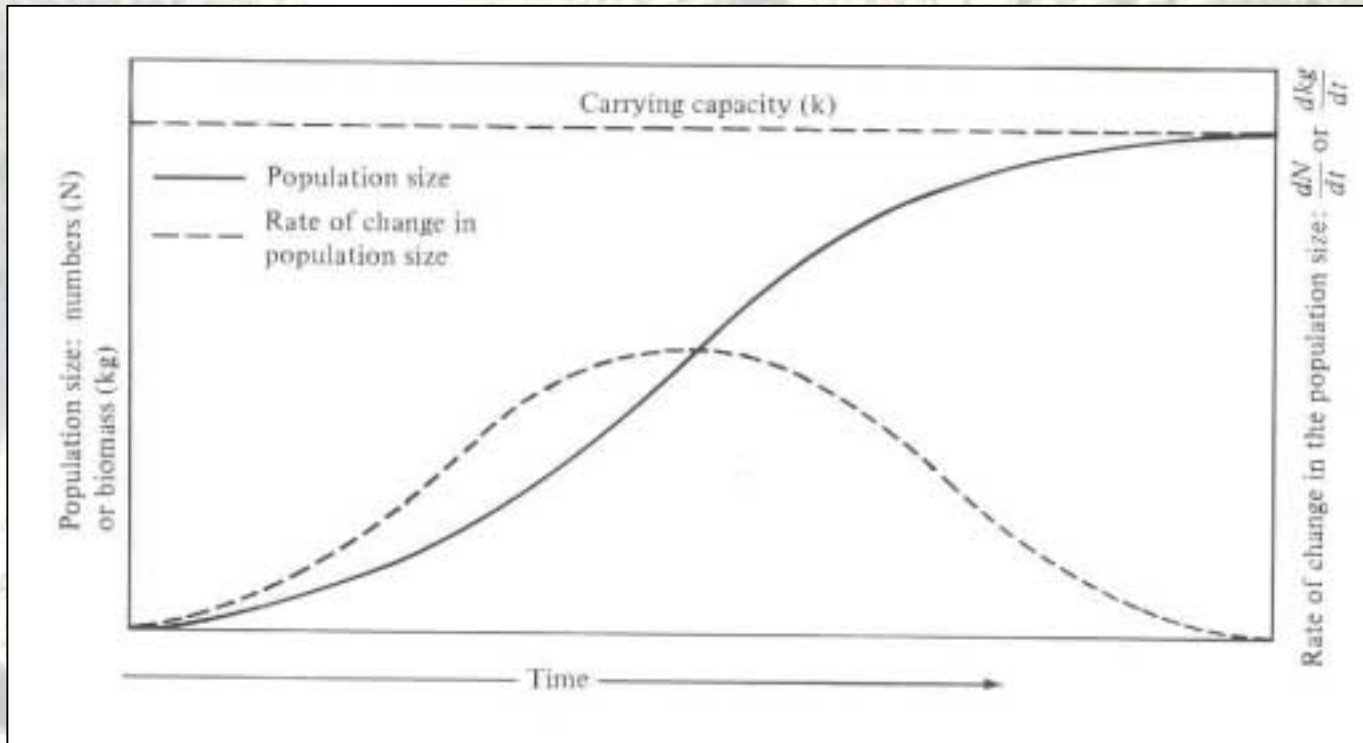
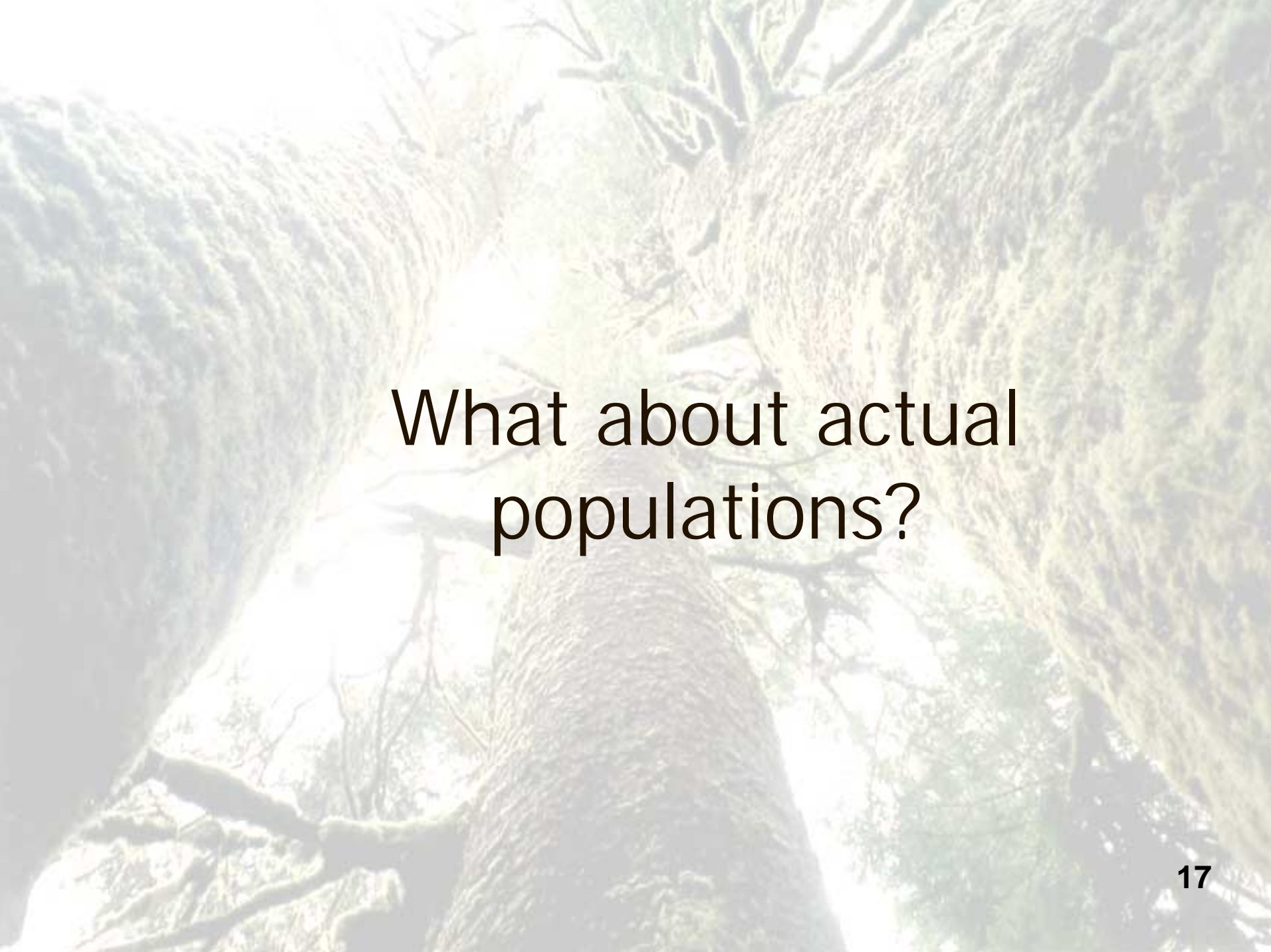


Fig 14.5 16

A low-angle photograph of a forest with sunlight filtering through the trees. The image is slightly faded and serves as a background for the text.

What about actual
populations?

Interference with logistic growth

- Lack of response to K
- Time Lags
- Reduction in K by population density
- Age structure of population

Lack of Response to K

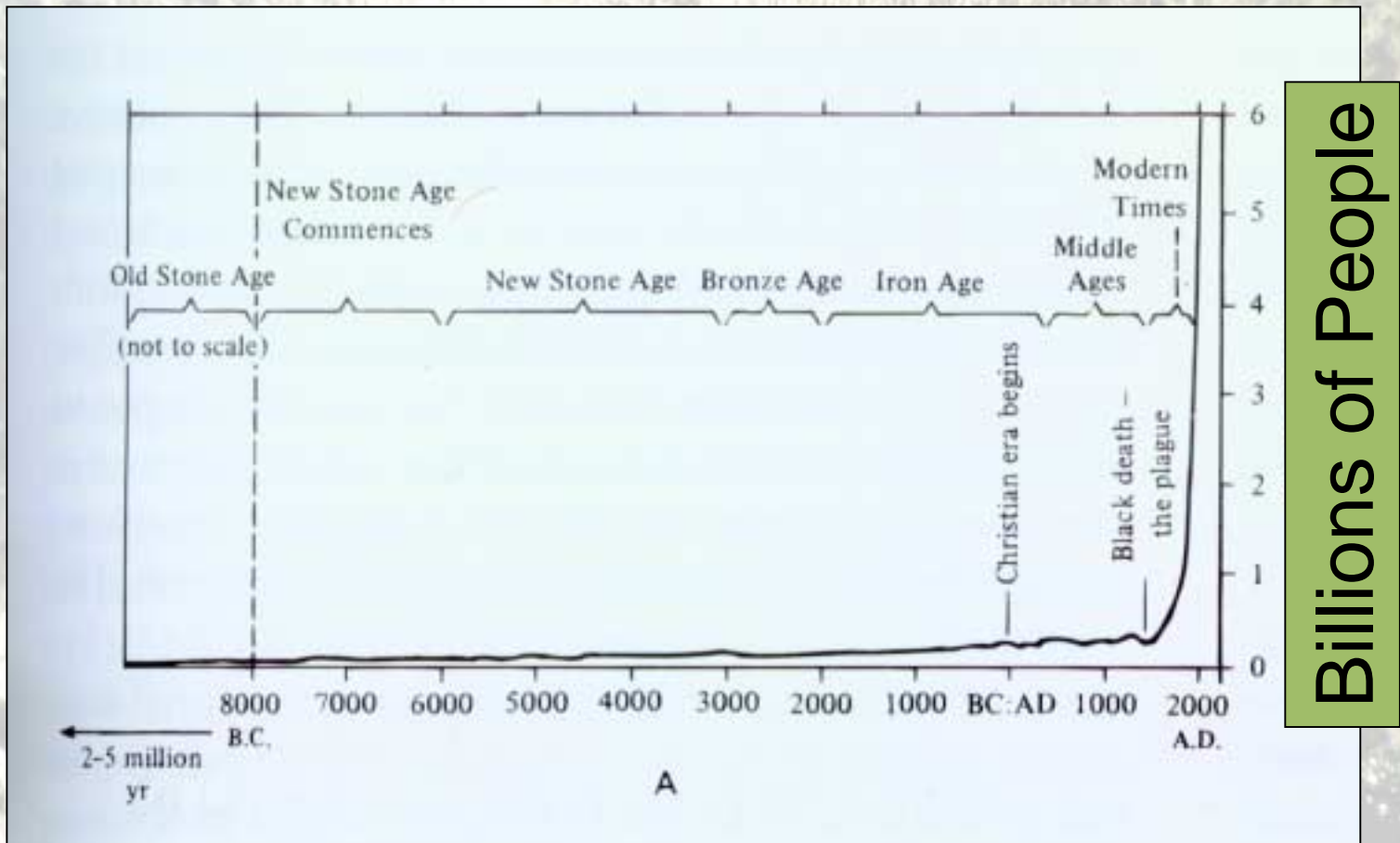
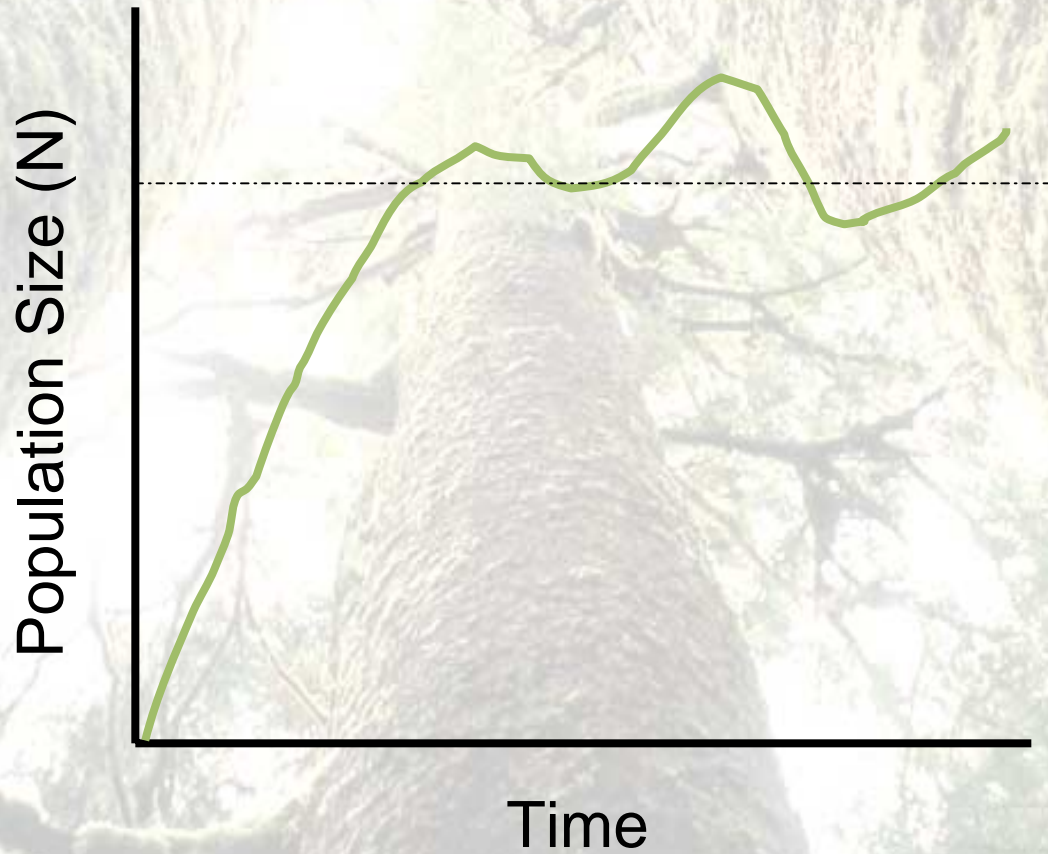


Fig 1.1a

Time Lags



Reduced K by pop. density

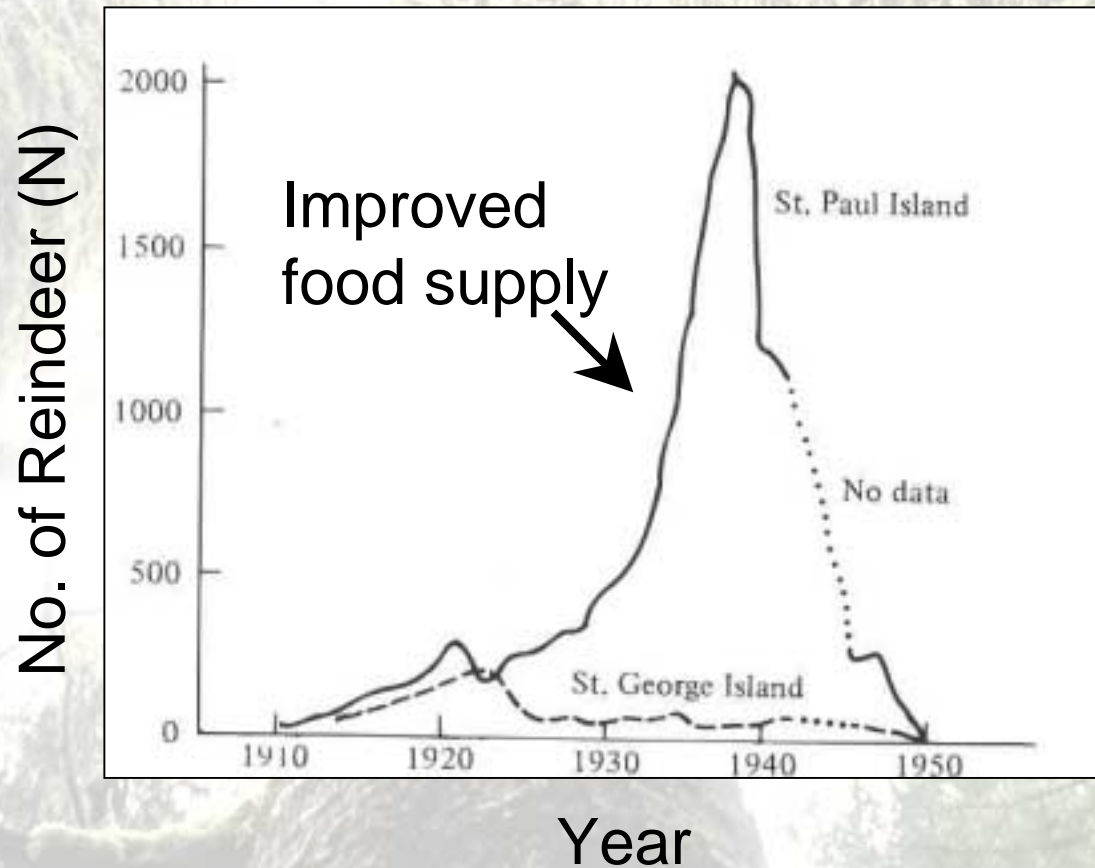
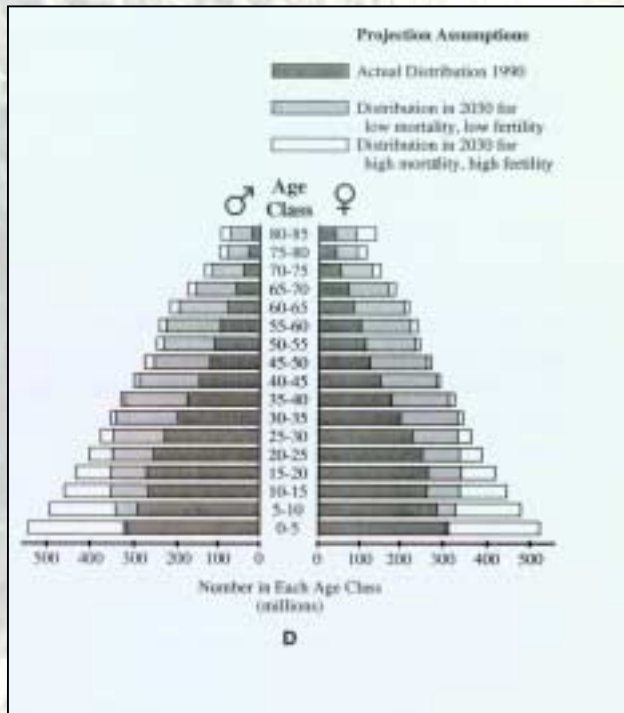


Fig 14.6: Reindeer introduced on St. Paul Island

Age Structure of a Pop.



Age-distribution diagram

Billions of People

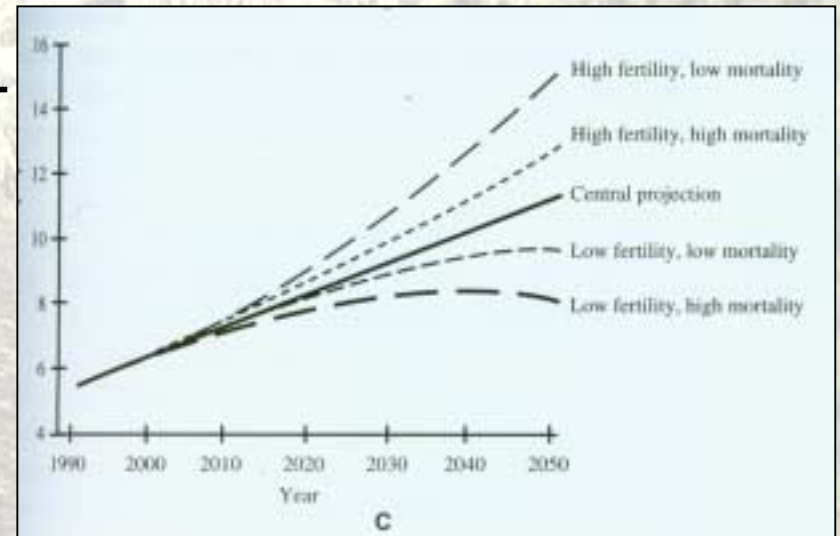


Fig 1.1 c, d

Life Tables

- Derived from census data
- Survival and Mortality numbers of individuals in each age class
- Age-distribution diagrams
- Survivorship Curves
 - Cohort or Dynamic Type – follow a group - e.g. long-term plot of trees revisited annually.
 - Static or Instantaneous – snapshot in time of the population – e.g. quantify ages of a trees in a plot at one time only.



Life Tables

- Cohort (dynamic)
 - Example: All Douglas-fir seedlings on a 1-ha plot that germinated in 1996 until they are all dead.
- Static (instantaneous)
 - Example: Age distribution of trees in a 1-ha Douglas-fir forest at the time of measurement.

Types of Survivorship Curves

- Type 1: Low mortality until the end of the life span, most dying are old.
- Type 2: Mortality evenly distributed over age classes, constant # of deaths over time.
- Type 3: Constant percentage of survivors die in each time interval
- Type 4: Heavy juvenile mortality, followed by constant mortality for the rest of life span.

Survivorship Curves

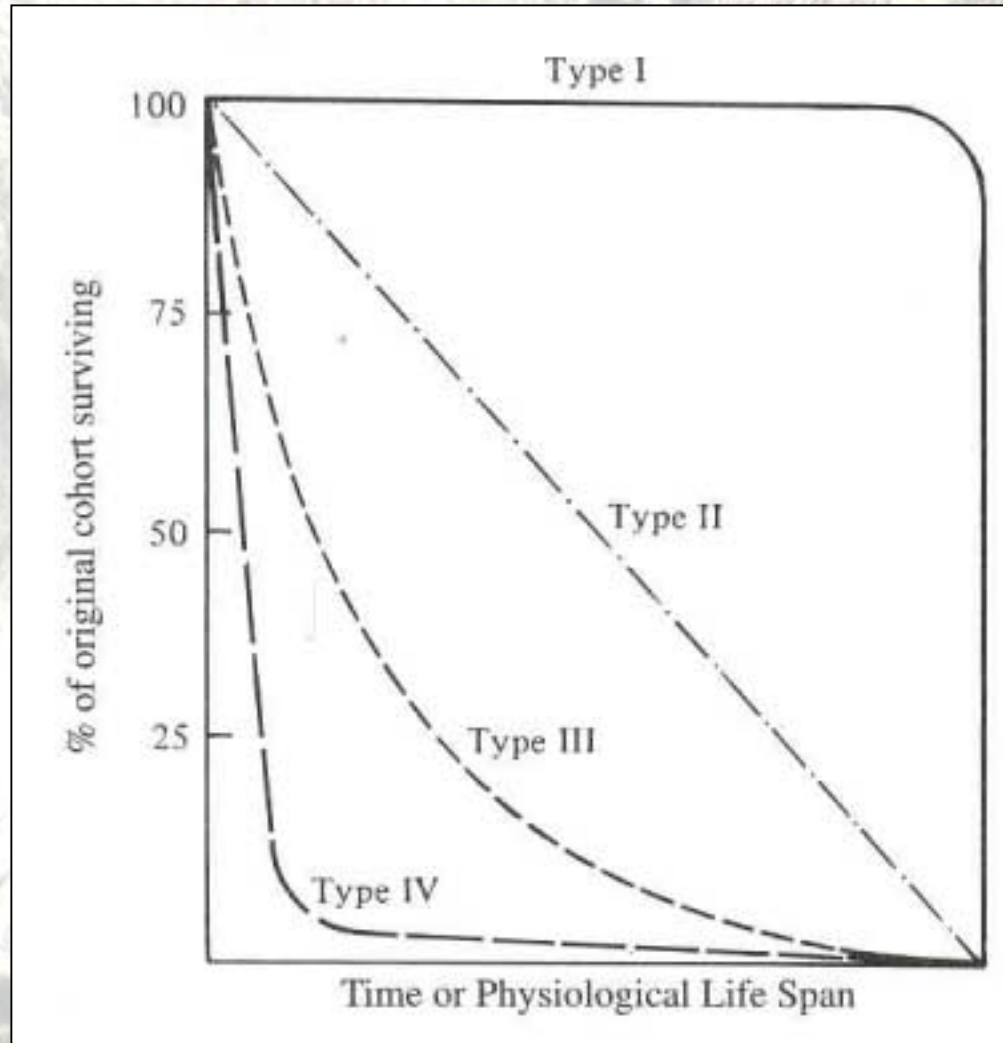


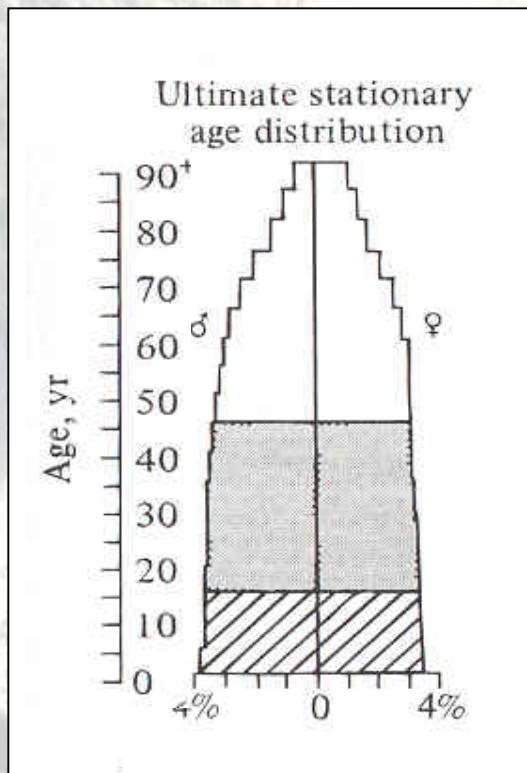
Fig 14.8

Age Distributions

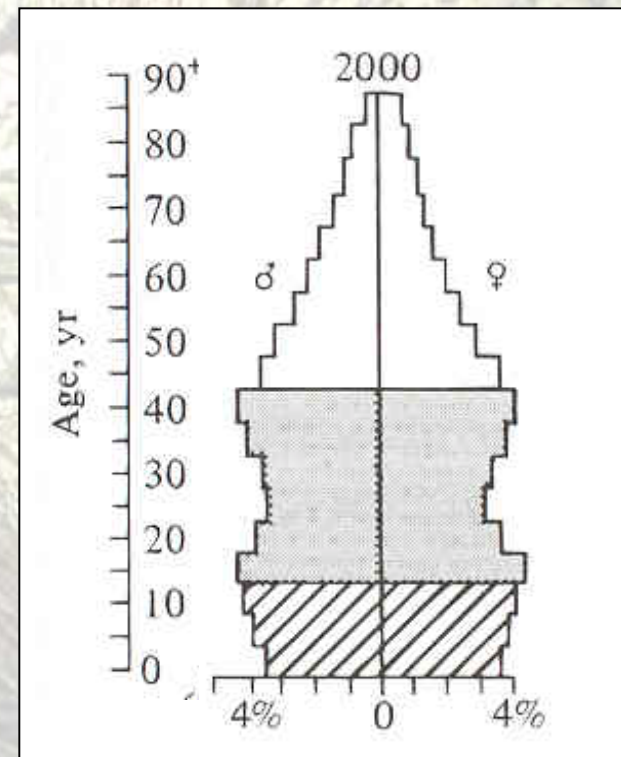
- Shape of age distribution varies with mortality and natality
- Populations with constant mortality and natality will reach stationary age distributions
- Stable age distributions – shape doesn't change but # in population may vary
- Stationary age distributions – population constant and in equilibrium

Age Distributions

Stationary



United States



Determinants of Population Size and Structure

- Birth rate (natality)
- Death rate (mortality)
- Immigration
- Emigration

* Balance of benefit of new vs. energy costs of making them

Choices in Resource Allocation

r – Strategists

- Rapid growth
- Many offspring
- Early reproduction
- Small body size
- Single reproduction
- Weed and early succession species

K – Strategists

- Slow growth
- Few offspring
- Later reproduction
- Large body size
- Repeat reproduction
- Humans, mammals vs. plants

See Table 14.6 for more details

Variation in Reproductive Age (Forest Trees)

	Early, ^a 10–20 yr	Intermediate, 20–40 yr	Late, 40–60 yr
Conifers	Jack, pitch, lodgepole, knobcone, Virginian, sand, Monterey, bishop, slash, loblolly	Red, eastern white, shortleaf	Sugar, western white, ponderosa, limber, whitebark
Other	Tamarack, black spruce, northern white cedar, Port Orford cedar, southern white cedar, cypress	Red and white spruce, balsam, fir, Douglas-fir	Spruce, true firs
Hardwoods	Willow, cottonwood, aspen, alder, gray birch, paper birch, pin cherry, red maple, bigleaf maple, box elder, scrub oak, and other fast-growing short-lived trees that produce small seeds	Hickories, maple, basswood, ash, elm, sycamore, chestnut, buckeye	Beech, oak

Source: After Daniel et al., 1979. Copyright McGraw-Hill Book Co., NY. Used with permission of publisher and authors.

^aMany of these species may produce appreciable quantities of seed after as few as 5 years.

Table 14.3

Variation in Reproductive Age (Forest Trees)

	Early, ^a 10–20 yr	Intermediate, 20–40 yr	Late, 40–60 yr
Conifers	Jack, pitch, lodgepole, knobcone, Virginian, sand, Monterey, bishop, slash, loblolly	Red, eastern white, shortleaf	Sugar, western white, ponderosa, limber, whitebark
Other	Tamarack, black spruce, northern white cedar, Port Orford cedar, southern white cedar, cypress	Red and white spruce, balsam, fir, Douglas-fir	Spruce, true firs
Hardwoods	Willow, cottonwood, aspen, alder, gray birch, paper birch, pin cherry, red maple, bigleaf maple, box elder, scrub oak, and other fast-growing short-lived trees that produce small seeds	Hickories, maple, basswood, ash, elm, sycamore, chestnut, buckeye	Beech, oak

Source: After Daniel et al., 1979. Copyright McGraw-Hill Book Co., NY. Used with permission of publisher and authors.

^aMany of these species may produce appreciable quantities of seed after as few as 5 years.

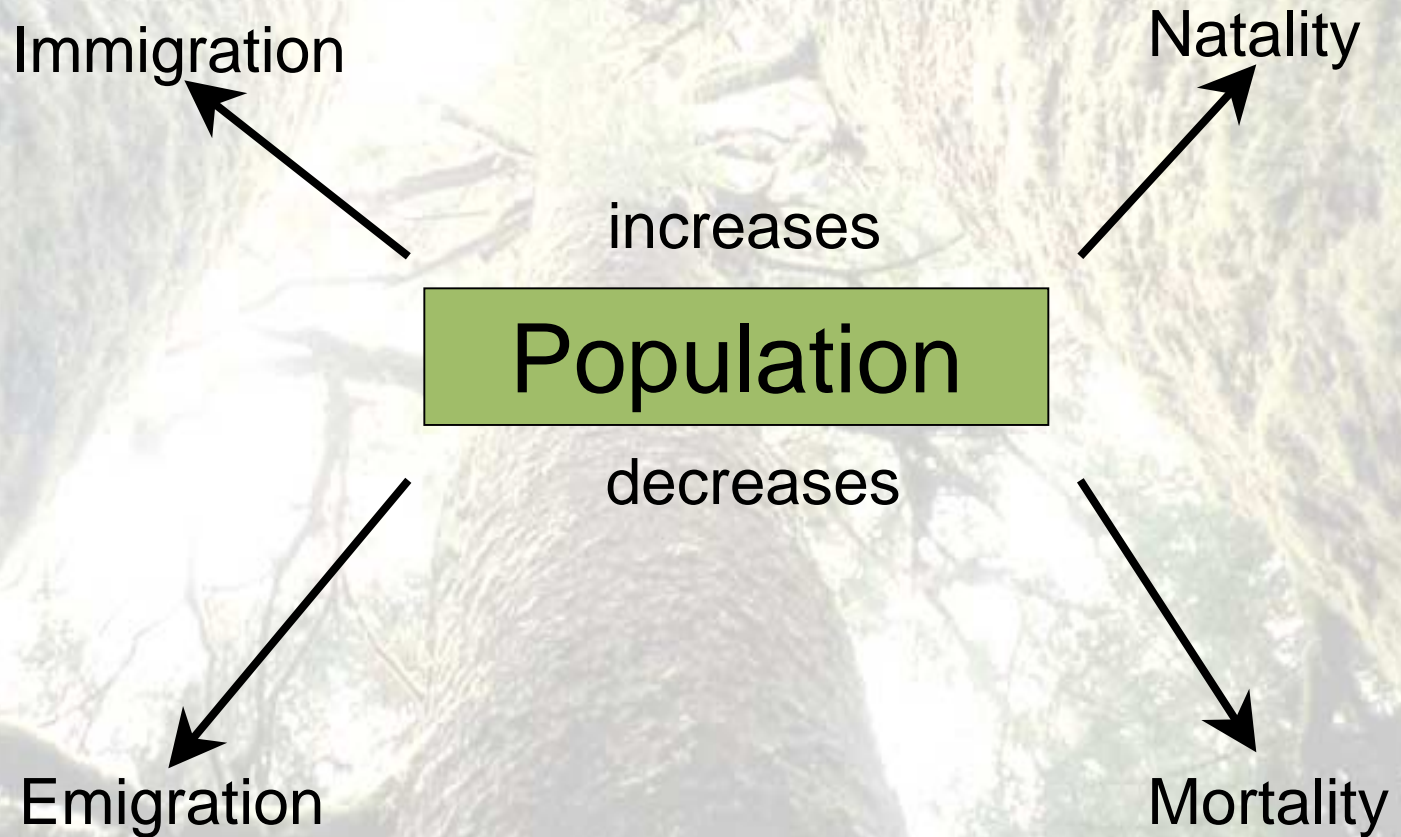
Table 14.3

Variation in Reproductive Age (Animals)

Type of Animal	Age of First Reproduction
Planktonic organisms	Few days
European voles	Few weeks
Tropical sparrow	6–8 months
Nontropical songbirds	1–3 years
Beaver, wolf, lion, and whale	2 years
Deer, bison, bear	3 or more years
Elephant	8–16 years
Rhinoceros	20 years

Table 14.4

Size Determinants of Populations



Plant Population Ecology

- Studying Plants vs. Animals: Stationary Advantage
- Complications: one plant is like a colony of animals, or a population of buds and leaves.

New Plants to the Population

- Recruitment can result from sexual, or vegetative reproduction.
 - Seed Rain (production and dispersal)
 - Seed Bank (species longevity in soil)
 - Bud Bank
 - Seedling bank

Seed Rain – Engelmann Spruce

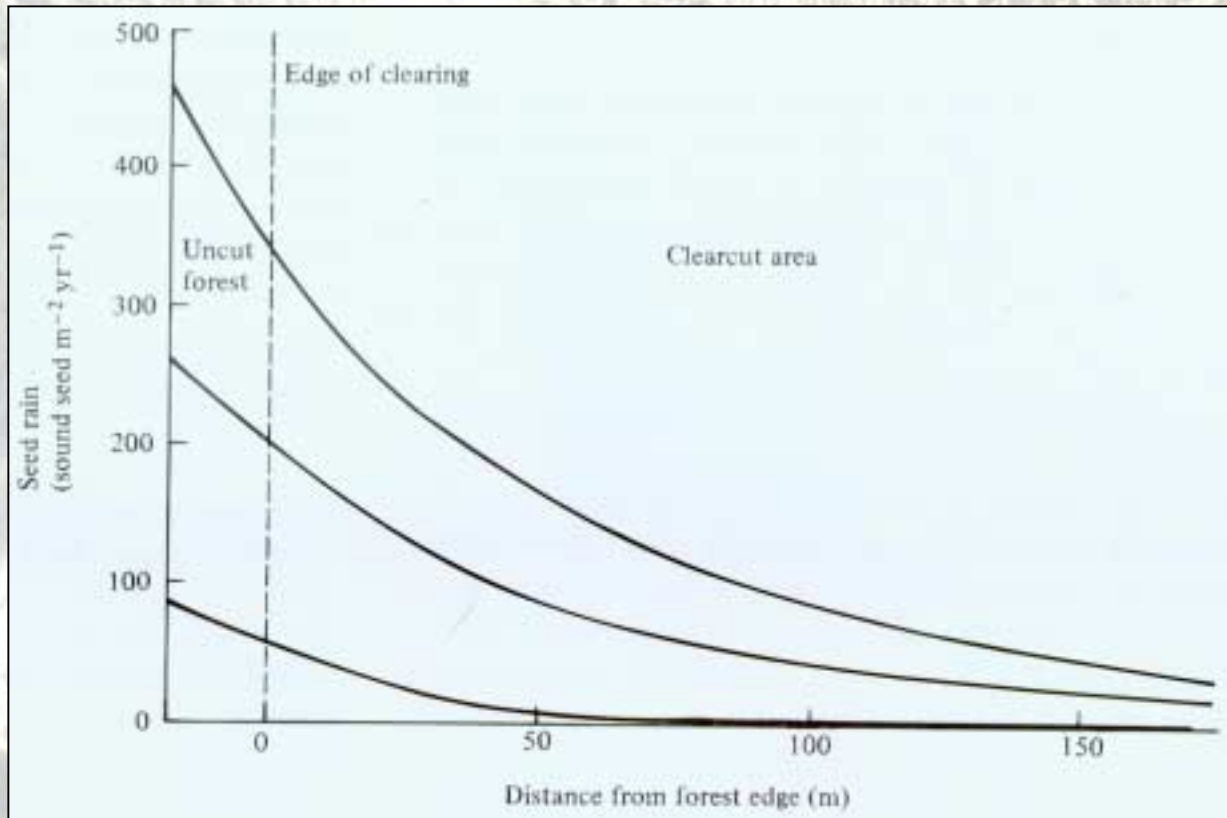


Fig. 14.14

Seed Bank

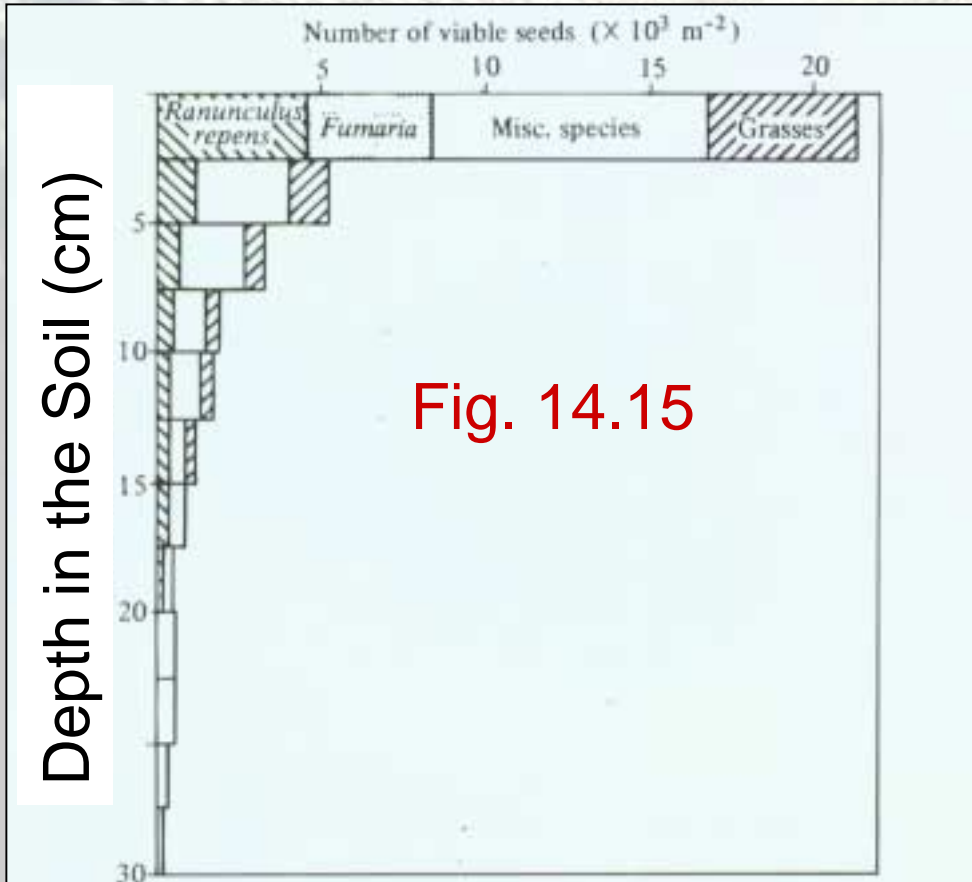


Fig. 14.15

PNW

Young closed canopy forest of Olympic Peninsula –

- 610-7009 germinants/m²,

- containing 46 native and exotic species representing a diversity of life forms (Acker et al. 1999)

Bud Bank – e.g. in Douglas-fir Stands

- Annual sprouting of aerial stems and ramets (clones) enables populations of salmonberry, salal, and probably other forest shrubs to maintain dense covers (>20 000 stems/ha).
- E.g. mean salal production ranged from:
 - 58 stems/m²/year (95% CI 25–135) – Clearcut
 - 8.6 stems/m²/year (95% CI 3.7–20.1) - Unthinned Douglas-fir stands, respectively.
- Based on length of rhizomes and bud density we estimate that only 1–5% of the buds in the rhizomes are needed to support this annual stem production.

Seed Rain and Bank...

- Depend on Safe Sites (areas with)
 - Stimulus to break seed dormancy
 - Conditions / Resources for germination
 - Mortality Agents tolerance (e.g. animals, diseases, toxic soil conditions, light and soil resources competition).

* Seedling bank may have the advantage