Chapter 52: Population Ecology

Population Ecology is concerned with measuring changes in population size and composition, and with identifying the ecological and evolutionary causes of these fluctuations.

A Population consists of individuals of a single species that:

A. Simultaneously occupy the same general area
B. Rely on the same resources
C. Are influenced by similar environmental factors
D. Have a high likelihood of interaction among themselves

At any given moment, every population has geographical boundaries and a population size.

A. A population size is the number of individuals included in that population.
B. A population's boundaries may be **natural** (specific island in Lake Superior where terns nest), or **arbitrarily defined** by and investigator (oak trees within a specific county in Minnesota).

I. The Characteristics of a population are shaped by interactions between individuals and their environments on both ecological and evolutionary scales, and natural selection can modify these characteristics. *Two important characteristics of any population are* ***density*** *and its* ***dispersion***.

A. **Population Density** is the number of individuals per unit area or volume. Ex) the number of oak trees per kilometer squared in Minnesota county.

1. It is possible to determine the density and the population size by actually counting the individuals within the boundaries of the populations. But this occurs in very rare cases. Ex) it is possible to count the number of sea stars in a tide pool, or herds of elephants. *In most cases it is impossible to count all the individuals in a population. Hence, numerous sampling techniques are used to estimate densities and total population sizes.*
2. Ecologists can estimate the number of alligators in the Florida Everglades by counting individuals in a few representative plots of an appropriate size. These estimates are more accurate when there are larger sample plots, and when the habitat is homogeneous.
3. Sometimes population sizes are estimated by **indirect indicators** (number of nests or burrows), or **signs** (droppings or tracks).
4. Another commonly used way of estimating the wildlife populations is the **mark-recapture method**. *Animals are trapped, marked released, and trapped again. The number of marked individuals found in the second capture indicated the total percent of individuals marked in the population. Dividing the first number marked by this % givens the estimated population size.*

B. Dispersion is the pattern of spacing among individuals within the geographical boundaries of the population. Individuals may be spread though out the population's geographical range in several patterns. *(this is mainly due to patchy environment and patterns of spacing exhibited by individuals in relation to other members of the population)*

1. **Clumping:** the most common pattern. Individuals are aggregated in patches.

a) <u>Plants</u> may be clumped in certain areas because the soil and other factors many favor germination and growth. Ex) eastern red cedar is often found clumped on lime stone outcrops, where soil is acidic than the surrounding areas.

b) <u>Animals</u> may often spend their time in certain microenvironments that favor their requirements. Ex) many forest insects and salamanders are clumped under logs where the humidity remains high.
c) Clumping of <u>animals</u> may be also due to their mating or other social behavior. Ex) Mayflies often swarm in great numbers. This increases their chance of mating.
d) Some <u>animals</u> may clump for safety. Ex) fish swim in large schools. This reduces their chance of being eaten by predators than a fish swimming alone or in a small group.

2. Spatial variations or environmental patchiness, as they relate to size and activity levels of organisms, are referred to as the grain of an environment.

a) **A coarse-grained environment** has patches so large in scale relative to the organism that the organism can choose among patches.
b) **A fine-grained environment** has patches so small relative to the organism's size and activity that no patch choices are made.

Temporal variations in the environment can be either coarse or fine grained.

Daily variations in environmental factors are usually fine-grained for most organisms.

Seasonal variations or **long-term shifts** in climate are coarse-grained even for the largest organisms.

3. **Uniform** distribution, or evenly spaced, pattern of dispersion are usually related to competition for resources, resulting in interactions that produce territories or spaces between individuals.

4. **Random** spacing is not very common. It usually indicates:

a) the absence of strong attractions or repulsions among individuals of a population
b) the position of each individual is independent of other individuals.

Often, populations within a species show distributional patterns-concentrating in clusters in a species' range. Ex) populations of coattails are unevenly distributed through out their range. They cluster in areas along rivers and lakes and in wetlands.

Demography is the study of factors that affect the growth and decline of populations.
Changes in population sizes reflect the relative rates of processes that add or eliminate individuals from the population. *Additions* occur through **births** and **immigration** (movement of individuals into a population). *Eliminations* occur through **deaths** and **emigration** (movement of individuals out of a populations).
Birth and death rates vary among subgroups within a population depending on age and sex.

II. Two most important demographic features are population's **age structure** and **sex ratio**.

A. Many organisms *(except for adults of annual plants and insects that die at about the same time they reproduce)* exhibit over lapping generations. The coexistence of generations gives most populations an **age structure**-relative number of individuals of each age. Often **age pyramids** are used to show the age structure of a population. *Every age group has a characteristics* ***birth and death rate.***

1. Birthrate or **Fecundity** is the number of offspring produced during a certain amount of time. It is often greatest for individuals of intermediate age. Ex) in humans the birthrate is highest in 20year old women.

2. Death rate or **Mortality** is greatest in the first year and in old age. This is because, in most species, individuals of intermediate age are more capable of hunting for food and avoiding predators.

a) **Generation Time:** the average span between the birth of individuals and the birth of their offspring. Generation time is strongly related to body size over a broad range of organisms. *Small organisms (E.coil, Euglena) have short generation times than organisms with longer body lengths (human, whale).*

B. Sex Ratio is the proportion of individuals of each sex.

1. the number of **females** is usually directly related to the number of births expected.

2. the number of **males** is less significant, because in many species one male can mate with many females.

Life Tables have the average life expectancy of an individual.

A Survivorship Curve is a graphic way of representing the data in a life table. *There are three types:*

Type 1 curve: flat at start—low death rate during early and middle ages, drops steeply as death rate increases with age. Ex) humans.

Type 3 curve: drops sharply at the left of the graph—high death rate among the young, then flattens out as death rate declines for those who survived. Ex) marine invertebrates.

Type 2 curve: intermediate—mortality more constant over a lifespan. Ex) annual plants, gray squirrel.

Many species either show more complex patterns or fall between these basic types. Ex) In birds the death rate is higher in the youngest (type 3) but remains constant later (type 2).

The traits that affect an organism's schedule of reproduction and death make up its **life history**. It affects the population's growth.

III. Life History Traits

A. Life histories are diverse.

1. vary due to environmental factors. Ex) increasing clutch size in songbirds with increasing latitude.
2. vary with respect to each other. Ex) in birds death and birth rtes tend to vary in close association. Delayed maturity and high parental investment in each offspring tend to correlate with low birth and death rates.

B. Limited resources cause trade-offs between investments in reproduction and in survival.

1. the production of many offspring with little chance of survival may result in fewer descendants than the production of a few well-cared-for offspring that can compete vigorously for limited resources.
2. since organisms have a limited energy budget, they cannot maximize all life history factors simultaneously.
3. evolution has fashioned how individuals in a population a) choose how often to breed, b) at what age to begin reproduction, c) how many offspring to produce.

a) **Number of reproductive episodes per lifetime**.

(1) Some plants and animals invest most of their energy in growth and development, expend their expend their energy in a single large reproductive effort, and then die. This type of life history is called **semelparity.** Ex) annual plants, bamboos.

(2)Some organisms produce fewer offspring at a time over a span of many seasons. This type of life history is called **iteroparity.** Ex) perennial plants.

b) **Age at first reproduction.**

(1)Birds with higher chance of surviving gain experience during long period as juveniles. This makes them more successful at rearing offspring. Ex) Albatrosses.

(2)Birds with lesser chance of surviving from one year to another usually start reproducing as soon as possible. Ex) Ducks, Chickens.

c) Number of offspring per reproductive episode.

(1) The number of offspring produced is related to the adult's chance of survival to the next breeding season. Those with Type 3 curve usually produce larger number of small eggs or offspring.

(2)Fewer, larger offspring may have better chance of surviving—those with type 1 and type 2 curves.

IV. Population Growth Models: observations, experiments, and mathematical modeling are used to determine rates of population growth, to study variables affecting growth, and to predict population sizes.

A. **Exponential Model:** describes and idealized population in an unlimited environment.

1. if the environment resources are unlimited, a population has no restrictions aside from the inherent physiological limitations.

2. if immigration and emigration were excluded, then the change in the population size would be the number of births minus the number of deaths in a specific period of time.

$\Delta N/\Delta t=B-D$

ΔN= change in population size; Δt=time interval; B=absolute # of births; D=absolute # of deaths.

3. annual per capita birth rate—the number of offspring produced per year by an average member of the population.
4. annual per capita death rate—the number of deaths of average members in a population per year.
5. knowing per capita death and per capita birth rates, it is possible to calculate the expected number of births and deaths in a population of any size.

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

b= annual per capita birth rate; d= annual per capita death rate; N= # of individuals in the population

6. population ecologists use **r** to identify the different in per capita birth rate and per capita death rate. (r=b-d)
   a) a positive r value tells that a population is growing
   b) a negative r-value tells that a population is declining.
7. **ZPG** or **Zero Population Growth** occurs when per capita birth and death rates equal, and r=0
8. **The Intrinsic Rate (r_{max})** is the fastest growth rate possible for a population reproducing under ideal conditions.
   a) A population with higher intrinsic rate of increase will grow faster than one with a lower rate of increase.
   b) The value of r_{max} for a population is influenced by
      (1) Age at the beginning of reproduction
      (2) The number of young reproduced
      (3) How well the young survive
   c) Usually generation time and r_{max} are inversely related.
9. **Exponential Growth Rate**—$dN/dt=r_{max}N$
   a) The size of a population increases rapidly
   b) J shaped growth curve when population size is plotted over time.
   c) Characteristic of some populations that are either
      (1) introduced into a new or unfilled environment
      (2) Or in populations whose numbers have been drastically reduced due to catastrophic event and are rebounding.

B. Logistic Model: incorporates the concept of carrying capacity.

1. **Carrying Capacity**:
   a) Maximum population size that a particular environment can support with no net increases or decrease over a relatively long time.
   b) Varies over space and time with the abundance of limiting resources.
   c) Symbolized by K
   d) Other factors like shelters or refuges from predators and suitable nesting and roosting sites, are also limited.
2. when a population's size is below K, population growth is rapid according to logistic model, but as N approaches K, population growth is slow.
3. when N reaches K, the growth rate (r) is 0
   a) birth rate=death rate
   b) population size doesn't increase
4. population growth is density dependent (according to logistic model)
5. the logistic model produces and S-shaped curve (sigmoid)
6. maximum increase in population numbers occurs when N is intermediate.
7. the logistic model makes some assumptions:
   a) any increase in population numbers will have a negative effect on population growth
   b) populations approach carrying capacity smoothly.
8. logistic model is a model of **Intraspecific Competition**—the reliance of individuals of the same species on the same limited resources.

POPULATION GROWTH MODELS AND LIFE HISTORIES.

A. Logistic model predicts different growth rates for populations under conditions of high and low-density relative o the carrying capacity of the environment.

1. at high densities, each individual has few resources available. Therefore, population growth is slow.
2. at low densities, each individual has abundant resources available. Therefore, population growth is rapid.

B. M. Cody introduced the concept that different life history adaptations would be favored under different conditions.

1. at higher density, selection favors adaptations that allow organisms to survive and reproduce with few resources available.
2. at lower density, adaptations that favor rapid reproduction are selected.

C. **K-selected populations** or **Equilibrial populations**—populations that are most likely to be living at a density near the limit imposed by their resources.

D. **R-selected populations** or **Opportunistic populations**—populations that are likely to be found in variable environments in which population densities fluctuate, or in open habitats when individuals are likely to face little competition.

V. Factors Limiting a Population.

A. Density-Dependent Factors:

- intensity as population size increase.
- reduce the population growth by

- ◊ decreasing reproduction
- ◊ increasing mortality in a crowded population

- ▪ determines the carrying capacity of the environment.

1. **Predation** may be a density-dependent factor when a predator shows switching behavior and feeds preferentially on a prey that has reached a high density.
2. **Limited Food Supply** often limits reproductive output. Increased population densities affect health and survivorship.
3. **Accumulation of toxic metabolic wastes.**
4. **Intrinsic Factors.** In mice, even when food or shelter was not limited, population size stabilizes when high densities induce a stress syndrome of hormonal chances that inhibit reproduction.

B. Density-Independent Factors:

1. unrelated to population size
2. affect the same percent of individuals regardless of population density.
3. most common and important factors are related to weather and climate.
4. population size of many species, particularly insects and other small organisms (Thrips of Australia), is probably limited at some point primarily by density-independent factors.

C. A mix of density-dependent and density-independent factors

1. limits the growth of most populations
2. the relative importance of density-dependent and density-independent controls many vary seasonally. Ex) bobwhite quail, Dungeness crab.

***D.* Some populations have a regular boom and bust cycles:** *some populations of insects, birds, and mammals show regular density fluctuations. There are several hypotheses for this cause.*

1. crowding many produce stress that affects hormonal balance. Therefore, reduces fertility and increases aggressiveness.
2. time lag in a population's response to density-dependent factors causes large fluctuations of population size above and below K.

VI. Human Population Growth.

A. Exponential

1. lower death rate, higher birth rate.
   a) Improved nutrition
   b) Better medial care
   c) Sanitation

B. In the future the human population growth will vary widely

1. global decrease of fertility (# of children per woman)
2. Earth's ultimate carrying capacity
   a) Food (malnutrition, famines)
   b) Space
   c) Resources—metals and fossil fuels

C. Most important factor that causes variation in growth rates among countries

1. age structure
   a) reveals a population's growth trend
   b) indicates a population's social condition

D. K in human population chances with human cultural evolution

1. advent of agricultural and industrial technology has increased K at least twice.
2. technology has increases Earth's K for humans.
3. if the human population fluctuates about K, we would expect periods of increase followed by mass death (plague).

4. human population must eventually stop growth.