CHAPTER 24: POPULATION ECOLOGY

CHAPTER SYNOPSIS

Ecology is the study of complex relationships of organisms with one another. Organisms are grouped in progressively larger levels of organization: communities, ecosystems, and biomes. A population of organisms comprises individuals of a given species that occurs in one place at one time. It has characteristic features including range, dispersion, and size. No populations can exist in all locations, nor do population ranges remain the same. Population ranges expand and contract as the environment changes. Individuals in populations are arranged in one of three kinds of spacings. Clumped spacing is most common in nature, although randomly and evenly spaced populations also exist. Clumped distributions tend to form as a result of individuals clustering in microhabitats which themselves are not generally uniformly distributed. Metapopulations are networks of distinct, interacting populations. The interactions result from the exchange of individuals between populations. Populations in better areas are called sources, while those in poorer areas are called sinks. Sink populations would often become extinct if not for the regular addition of individuals from source populations.

Demography is the statistical study of populations. Numerous factors affect population growth rates including sex ratio and generation time. Each population has a unique age structure. Life tables are used to assess how natural populations change over time. Populations also exhibit typical survivorship curves that indicate the percentage of the original population that survives to a given age. Type I have low mortality while young and high mortality in postreproductive years. Individuals in type II populations are equally likely to die at any age. Type III produce many offspring that are likely to die early. Established adult individuals have low mortality. An organism's complete life cycle is called its life history. Life histories are very diverse and wholly dependent on each organism. They often reflect trade-offs between reproduction, growth, and survival. Natural selection favors maximizing lifetime reproductive success. When there is a low cost of reproduction, as when resources are abundant, many offspring should be produced. When there is a high cost of reproduction, as when reproduction affects survival or future reproduction, fewer offspring should be produced. The number of offspring produced is overall less important than that offspring's ability to reproduce.

All healthy populations have the capacity to grow, although over time most populations remain relatively constant regardless of the number of offspring produced. The intrinsic rate of increase is the population's biotic potential expressed by the equation $dN/dt = r_iN$. Overall the rate of change over time is equal to the intrinsic rate of growth of that population multiplied by the number of individuals in that population. The normal innate capacity for population growth is exponential. The carrying capacity of a population is its characteristic limit imposed by environmental shortages. This capacity is a dynamic value that varies over time, fluctuating around a mean population value. Graphing population growth over time generally produces a sigmoid curve where the rate of increase declines as the population numbers increase. Population growth is also affected by density-dependent and density-independent processes. The former include size of the population, predators, behavioral changes, and emigration. The latter include factors like weather and the physical disruption of the habitat. Populations may exhibit regular, repeated cyclic patterns. The most common example is that of the snowshoe hare. Increased numbers of prey result in increased predator numbers. This decreases the prey population and leads to a decrease in number of predators. The prey population is additionally affected by amount of its own food source. Populations are characterized as either *r*- or *K*- selected adaptations. The former populations exhibit exponential growth with sudden crashes and have a high intrinsic rate of growth (*r*). They reproduce early, have many offspring in a large brood. The offspring are generally small, mature rapidly, and receive little parental care. *K*-selected adaptation populations exhibit sigmoid growth curves limited by carrying capacity (*K*).

They reproduce later in life and have small broods. Their offspring are generally large, mature more slowly, and receive more intensive parental care. Human populations continue to grow exponentially as humans have expanded the carrying capacity of their habitats — often at the expense of other living organisms.

CHAPTER OBJECTIVES

ä   Understand what constitutes a population and the changes that can occur in its characteristic features.

ä   Differentiate among random, even, and clumped spacings.

ä   Understand what a metapopulation is and how it is associated with source and sink populations.

ä   Define demography and understand how such information indicates the stability and composition of a population.

ä   Understand the value of life tables.

ä   Describe the three types of survivorship curves and give examples of each.

ä   Understand why and how reproductive success is maximized.

ä   Explain how a population's biotic potential differs from its actual rate of increase.

ä   Define carrying capacity and understand how it is associated with population size.

ä   Compare density-dependent and density-independent growth regulating effects and give examples of each.

ä   Explain and give examples of predator-prey cycles.

ä   Differentiate between *r*-selected adaptations and *K*-selected adaptations.

KEY TERMS

age structure	ecology	mortality rate
Allee effect	fecundity	population
biotic potential	generation time	population pyramid
carrying capacity	iteroparity	r-selected
cohort	K-selected	semelparity
cost of reproduction	life history	sex ratio
demography	life table	sigmoid growth curve
density-dependent effect	metapopulation	source-sink metapopulation
density-independent effect	mortality	survivorship curve

CHAPTER OUTLINE

24.0   Introduction

I.   ECOLOGY

   A. The Study of Relationships of Organisms with One Another and the Environment

   B. Includes Properties of Populations, Emphasizing Population Dynamics   fig 24.1

24.1   Populations are individuals of the same species that live together

I. POPULATION ECOLOGY

   A. Definition of Population
      1. Organisms live together as members of populations
      2. Chapter topics
         a. Properties of populations
            1) Elements that influence growth or decrease
            2) Rate of increase or decrease
         b. Focus on human population growth over last few centuries
      3. Comprised of individuals of a species in one place at one time
         a. Similar terms for all populations
         b. Boundaries may be sharp or fuzzy
      4. Three important aspects
         a. Range through which population occurs
         b. Dispersion of individuals within range
         c. Size the population attains

   B. Population Distributions
      1. No population occurs in all habitats throughout world
         a. Most species have limited geographical ranges   fig 24.2
            1) Devil's Hole pupfish lives in one hot spring in Nevada
            2) Socorro isopod lives in one spring in New Mexico
         b. Some species are widely distributed, like whales
      2. No population has individuals that can live in all environments
         a. Polar bears adapted to live in arctic, not tropical rain forests
         b. Bacteria can live in boiling geysers, but not nearby cooler springs
      3. Each population has its own requirements that determine where it can/not live
         a. Includes temperature, humidity
         b. Also includes certain types of food
      4. Presence of other organisms may exclude population from occupying an area
         a. Include predators, competitors
         b. Also includes parasites

   C. Range Expansions and Contractions
      1. Two reasons why population ranges change over time
         a. Environment may change
            1) Retreat of glaciers allowed species to expand northward
            2) Elevation shifts due to climate warming   fig 24.3
         b. Expansion into previously inhospitable areas
            1) Cattle egret native to Africa
            2) Appeared in northern South America in late 1800s
            3) Now found throughout most of U.S.   fig 24.4

II. POPULATION DISPERSION

   A. Individuals Are Arranged in Certain Ways   fig 24.5

   B. Randomly Spaced
      1. Do not interact strongly with each other or nonuniform microenvironment
      2. Not common in nature
      3. Include some trees in Amazon rain forests

   C. Uniformly Spaced
      1. Often results from competition for resources, means varies
      2. Behavioral interactions may cause animals to be uniformly spaced
         a. Individuals defend territory, other animals excluded
         b. Provide owner with exclusive access to resources
         c. Individuals tend to be spaced evenly across habitat
         d. Non-territorial species may defend certain space from intruders
      3. Direct competition for resources cause plants to be evenly spaced
         a. Closely-spaced individuals compete for sunlight, nutrients, water
         b. May be direct competition as in shading
         c. May be indirect via efficiency in extracting resource from shared area
         d. Adequate spacing needed for survival, promoting uniform spacing

   D. Clumped Spacing
      1. Respond to uneven distribution of resources
      2. Common in nature
         a. Individuals prefer certain microhabitats
         b. Defined by soil type, moisture
      3. Can occur due to social interactions
         a. Some species move around in large groups
         b. Include herds of antelope, bird flocks, wolf packs
         c. Provide advantages to group
            1) Awareness and defence against predators
            2) Decreased energy cost of moving through air or water
            3) Access to knowledge of all group members
      4. Populations are usually more dense on interior, less dense at edges
         a. Results from the way the environment changes
         b. Populations best adapted to conditions at interior of distribution
         c. As conditions change, populations are less well-adapted
         d. Edge marked where population cannot exist at all

   E. The Human Effect
      1. Humans alter environment allowing some species to change ranges
         a. Coyotes have expanded ranges
         b. Effect damaging to most species
      2. Humans serve as agents of dispersal
         a. Transplantation of starlings to New York City in 1896
         b. Success of one group usually at expense of native species

   F. Dispersal Mechanisms
      1. Can occur in many ways
         a. Lizards may colonize by floating eggs or on drifting vegetation
         b. Specializations occur in many plants   fig 24.6
            1) Aerodynamic seeds blown great distances by wind
            2) Have structures that stick seeds to animals that carry them long distances
            3) Enclosed in fruits, dispersed via digestive system of animals
            4) Explosive discharge of seeds by *Arceuthobium*

III. METAPOPULATIONS

   A. Networks of Distinct, But Interacting Populations
      1. Interact by exchanging individuals
      2. Occur where there is suitable habitat
         a. Habitat is patchily distributed

    b.   Separated by stretches of unsuitable habitat
3.   Degree and kind of interaction
    a.   Depends on amount of dispersal
    b.   Often not symmetrical
    c.   Large populations send out many dispersers
    d.   Smaller populations receive more immigrants
    e.   Isolated populations usually receive few arrivals
4.   Not all suitable habitats occupied at all times
    a.   Some populations may go extinct
    b.   Usually recolonized in time
    c.   May be equilibrium between rates of extinction and colonization

B.   Source-Sink Metapopulations
1.   Some habitats suitable for long-term population maintenance
    a.   Populations in better areas called sources
    b.   Populations in poorer areas called sinks
    c.   Sources send out dispersers to bolster sinks
    d.   Without additions, sink populations would become extinct
2.   Example: Butterfly metapopulation in Finland   fig 24.7
    a.   Hanski studied 1,600 fritillary butterfly populations
        1)   200 populations went extinct each year
        2)   140 empty meadows were colonized each year
    b.   Extinction possibly related to certain factors
        1)   Small population size
        2)   Isolation from immigrant sources
        3)   Low resource availability
        4)   Lack of genetic variation
    c.   Large number of extinctions linked to multiple dry summers
    d.   Continued survival dependent on metapopulation network
    e.   Continued bad weather may doom species in this locale
3.   Metapopulations and species range
    a.   With continual colonization, prevent long-term extinction
        1)   Without dispersal, each population might perish in turn
        2)   Species would disappear from entire area
    b.   Species can occupy larger area than expected
4.   Metapopulation study important due to increasing fragmentation of natural habitats

24.2   Population dynamics depend critically upon age distribution

I.   DEMOGRAPHY

A.   Statistical Study of Populations
1.   How size of population changes over time
    a.   Determine if increasing, decreasing, or constant
    b.   In growing populations, births outnumber deaths
    c.   If deaths outnumber births, population shrinks

B.   Factors Affecting Population Growth Rates
1.   Sex ratio
    a.   Proportion of males to females
    b.   Number of births generally related to number of females
    c.   May not be closely related to number of males, if males breed with many females
    d.   Few males mate frequently, others not at all
        1)   Reduce number of males, changes only identity of reproductive males, not births

2)   Reducing males in monogamous pairs decreases births
2. Generation time
  a. Average interval between birth of individual and birth of its offspring
  b. Greatly affects population growth rates, very different among species
  c. General association with body size   fig 24.8
    1)   Mice exhibit 100 generations in one elephant generation
    2)   Newts smaller than mice, but have longer generation time
  d. Close correlation between generation time and lifespan
    1)   Populations with shorter generation time can increase more quickly
    2)   Can also diminish rapidly if birth rates decrease

C. Age Structure
  1. Probability that individual reproduces or dies varies through its lifetime
  2. Cohort: Group of individuals of same age
  3. Cohort exhibits certain characteristic changes
    a. Fecundity: Characteristic birth rate = offspring produced in a standard time
    b. Mortality: Number of individuals that die over same period
  4. Population's age structure
    a. Relative number of individuals in each cohort
    b. Different ages have different fecundity and death rates
    c. Has critical impact on population's growth rate
    d. When proportion of young individuals is large, population grows rapidly
    e. If most individuals are old, population will usually decline

D. Life Tables and Population Change through Time
  1. Life tables used to assess how natural populations change
  2. Constructed by following fate of a cohort from birth to death
    a. Note number of offspring produced and number of deaths per year
    b. Example: Study meadow grass *Poa annua*   tbl 24.1
      1)   First column is age of cohort, in 3 month intervals
      2)   Second column = number of survivors
      3)   Third column = proportion of original cohort still alive
      4)   Fourth column = mortality rate (individuals dying during interval)
      5)   Fifth column = average number of seeds produced during interval
      6)   Sixth column = number of seeds relative to size of original cohort
    c. Observations from this example
      1)   Probability of dying increases with age
      2)   Number of offspring produced increases with age
      3)   Break even point is 1 lost per 1 gain, this population is growing rapidly
  3. Life table analysis is generally quite complicated
    a. Difficult to track fate of cohort unless life span is short
    b. Alternative approach by constructing cross-sectional study
    c. Examine fate of all cohorts within single year

E. Survivorship Curves
  1. Survivorship curves express characteristics of populations
  2. Survivorship: Percentage of original population that survives to a given age
  3. Types of survivorship curves   fig 24.9
    a. Type II
      1)   Example: Hydra
      2)   Straight curve
      3)   Individuals are likely to die at any age

        b.   Type III
           1) Example: Oysters
           2) Produce vast numbers of offspring, few survive to reproduce
           3) Once established, mortality is low
        c.   Type I
           1) Example: Humans
           2) Relatively low mortality when young
           3) High mortality in postreproductive years
    4.   Data for *Poa annua* show it to be type II   fig 24.10

24.3   Life histories often reflect trade-offs between reproduction and survival

  I. NATURAL SELECTION AND SURVIVAL

    A. Selection Favors Traits that Maximize Offspring Surviving in Next Generation
        1.   Dependent on
           a.   How long individual lives
           b.   How many offspring produced each year
        2.   Completely maximize situation
           a.   Reproduce immediately after own birth
           b.   Produce large families of large offspring
           c.   Intensive care of young
        3.   Not enough resources for any organism to do this

    B. Organisms Allocate Resources for Reproduction Versus Survival

  II. THE COST OF REPRODUCTION

    A. Complete Life Cycle of an Organism Is Its Life History
        1.   Life history trade-offs
           a.   Change increases reproduction
           b.   Decreases survival
           c.   Thus decreases future reproduction
        2.   Example: Douglas fir
           a.   Produce many cones to increase current reproductive success
           b.   Tree grows more slowly
           c.   Number of cones related to tree size
           d.   Produces fewer cones in future year
        3.   Example: Birds   fig 24.11
           a.   More offspring in one year
              1) Greater chance of dying that year
              2) More likely to produce smaller clutch next year
           b.   Delay reproduction one year
              1) Grow faster and larger
              2) Enhance future reproduction
        4.   Collared flycatcher egg experiments   fig 24.12
           a.   Changed number of eggs per nest
           b.   If clutch size decreased, more eggs laid next year
           c.   If clutch size increased, fewer eggs laid next year
        5.   Definition of cost of reproduction
           a.   Reduction in future reproductive potential
           b.   Results from current reproductive effort

B. Natural Selection Favors Maximization of Lifetime Reproductive Success
   1. Low cost of reproduction
      a. Individual should invest in producing many offspring
      b. Little cost to do so
      c. May occur when resources are abundant
      d. Producing young does not impair survival or future reproductive success
      e. Mortality rate usually high
         1) Individuals not likely to survive to next breeding season
         2) Effect of increased reproduction does not affect future survival
   2. High cost of reproduction
      a. Lifetime reproductive success maximized by decreasing reproduction
      b. Enhance growth and survival rate
      c. Occurs when cost of reproduction affects survival or decreases future reproduction

C. Investment per Offspring
   1. Number of offspring less important than offspring's own survival to reproduce
   2. How to determine resource investment per offspring
      a. If energy limited, trade-off between number and size of offspring   fig 24.13
      b. Experimentally determined in lizard, *Uta stansburiana*
         1) Lays average of 4.5 eggs at a time
         2) Early on, surgically remove eggs from female
         3) Remaining eggs supplied with greater amount of yolk
         4) Eggs larger than normal
   3. Size of offspring affects ability to survive
      a. Larger offspring have greater chance for survival
      b. Weigh strategies to maximize survival
         1) Many, smaller offspring?
         2) Fewer, larger offspring?
      c. Best choice is usually an intermediate position
         1) Produce several, fairly large individuals
         2) Maximizes number of surviving offspring
      d. Similar to trade-offs in clutch size vs. parental investment

D. Reproductive Events per Lifetime
   1. Semelparity
      a. Growth of individual   single reproductive event   death
      b. "Big bang" reproduction
      c. Short-lived species, great cost of surviving from brood to brood
      d. Example: Plants growing in harsh habitats
      e. Also favored when fecunditity entails large reproductive cost
      f. Example: Pacific salmon migrating to spawn
   2. Iteroparity
      a. Produce offspring many times over life history
      b. Must avoid over taxing selves in any one reproductive event

E. Age at First Reproduction
   1. Animals that live longer generally reproduce later   fig 24.14
      a. Birds gain experience as juveniles before expending high costs of reproduction
      b. Advantage of experience outweighs energy investment in survival and growth
   2. In short-lived animals, quick reproduction is more critical than juvenile training

24.4   Population growth is limited by the environment

I.   BIOTIC POTENTIAL

   A.   Population Size Remains Constant Regardless of Offspring Produced
      1.   Natural selection occurs because of checks on reproduction
      2.   Must consider circumstances and factors that limit population growth

   B.   The Exponential Growth Model
      1.   Actual rate of population increase (r)
         a.   Difference between birth rate and death rate per given number of individuals
         b.   Corrected for net emigration (movement out) or immigration (movement in)
         c. $r = (b - d) + (i - e)$
         d.   Movement of individuals can have great impact on population growth rate
      2.   Biotic potential (r): Population growing without limits at maximal rate
      3. $dN/dt = r_i N$
         a. N = number of individuals within a population
         b. dN/dt = rate of change of population number over time
         c. r_i = intrinsic rate of growth for that population
      4.   Innate capacity for growth is exponential, represented by growth curve   fig 24.15
         a.   Rate of growth remains constant
         b.   Actual increase in numbers accelerates as population increases
         c.   Causes population explosion
            1)   Pair of houseflies could produce 5 trillion descendants in 1 year
            2)   In 10 years, would cover earth with layer 2 meters thick
      5.   Such patterns of growth occur for only short periods
         a.   New organism reaches new habitat with abundant resources   fig 24.16
         b.   Examples
            1)   Dandelions colonizing North America
            2)   Algae colonizing new pond
            3)   First terrestrial immigrants arriving on new island

   C.   Carrying Capacity
      1.   Populations always reach a limit imposed by environmental shortages
      2.   Size for such stabilization is the carrying capacity (K)
      3.   Maximum number of individuals a population can support

   D.   The Logistic Growth Model
      1.   Rate of growth slows as population reaches carrying capacity
         a.   Fewer resources for individuals to use
         b.   Growth curve limited by one or more factors
      2.   Logistic growth equation
         a. $dN/dt = rN(K-N/K)$
         b. dN/dt = growth rate of the population
         c. r = rate of increase
         d. N = number of individuals present at any one time
         e. K = carrying capacity
      3.   As a population grows in size, the rate of increase declines until $N=K$ fig 24.15
         a.   Relationship is an S-shaped sigmoid growth curve   fig 24.17a
         b.   As the population stabilizes, its rate of growth slows down
      4.   Real populations show logistic growth curve   fig 24.17b
      5.   Many populations exhibit other patterns   fig 24.17c

II. THE INFLUENCE OF POPULATION DENSITY

  A. Density-Dependent Processes
    1. Depend on size of population, regulate its growth
    2. Population approaches carrying capacity
      a. Competition for resources becomes severe
      b. Produces decreased birth rate, increased mortality   fig 24.18
    3. Effect of predators
      a. Predators may focus attention to particularly common prey
      b. Results in increased mortality as populations increase
    4. Population growth affects habitat
      a. High population density leads to accumulation of toxic wastes
      b. Occurring in human populations
    5. Behavioral changes affect population growth
      a. Rodents become antisocial in larger populations
      b. Accompanied by hormonal changes
      c. May have evolved as adaptive response to scarcity of resources
    6. Growth rate may decrease due to increased emigration   fig 24.19
    7. Allee effect is positively related to population size
      a. Individuals have difficulty finding mates with sparse distribution
      b. Species rely on large groups to deter predators
      c. Large populations needed to provide stimulus for breeding activities

  B. Density-Independent Effects
    1. Rate of growth limited by something other than population size
    2. Include factors such as weather and physical disruption of habitat
      a. Populations exhibit erratic growth patterns
      b. Grow rapidly when conditions are benign
      c. Experience extreme reduction when environment is hostile

  C. Population Cycles
    1. Some populations exhibit cyclic patterns of increase and decrease
    2. Well-studies example of snowshoe hares *Lepus americanus*
      a. 10-year cycle (really 8 to 11 years)
      b. Numbers decrease 10 to 30-fold
    3. Cycle generated by two factors   fig 24.20
      a. Food plants
        1) Prefer willow and birch twigs
        2) Hare density increases, quality of food decreases
        3) Switch to lower quality food
        4) Lower birth rates, low juvenile survivorship, low growth rates
        5) Greater predation while spending more time searching for food
        6) Fall in hare populations
        7) Takes 2 to 3 years for twigs to recover
      b. Predators
        1) Key predator is *Lynx canadensis*
        2) Shows 10-year cycle linked to hare cycle
        3) As hare numbers increase, lynx population increases
        4) More food available to lynx
        5) As hares decrease, so do lynx, due to less food
    4. Which factor produces oscillations?
      a. Hare-plant cycle versus hare-lynx cycle
      b. Field study by Krebs in 1992
        1) Food added, predators excluded = 10-fold increase, stasis, no oscillations

2) Exclude predator, no food change = cycle retained
3) Add food, no change in predators = cycle retained
c. Both factors affect cycle, interaction between the two
5. Cycles are more common than once thought

III. POPULATION GROWTH RATES AND LIFE HISTORY MODELS

A. Species Have Varied Rates of Population Growth
1. Some species have stable populations near carrying capacity
2. Other species have fluctuating populations, far below carrying capacity
3. Selective factors differ
a. Stiff competition for resources if population near carrying capacity
b. Resources abundant when population below carrying capacity

B. *r*- and *K*-Selected Adaptations
1. Resources limited, cost of reproduction is high
a. Individuals competing for limited resources, utilize them effectively
b. Cost is lower reproductive rates
c. Called *K*-selected populations   tbl 24.2
d. Thrive when population is near carrying capacity
e. Examples: Coconut palms, whooping cranes, whales, humans
2. Resources abundant, population far below carrying capacity
a. Cost of reproduction low
b. Selection favors individuals that produce maximum number of offspring
c. Called *r*-selected populations
d. Have high rate of increase (*r*)
e. Examples: Dandelions, aphids, mice, cockroaches   fig 24.21
3. Most populations show life history adaptations in a continuum
a. Range from completely *r*-selected traits to completely *K*-selected traits
b. Few populations exist at the extremes of the continuum   tbl 24.2

24.5   The human population has grown explosively in the last three centuries

I. THE ADVENT OF EXPONENTIAL GROWTH

A. Humans Exhibit Many *K*-Selected Life History Traits
1. Small brood size, late reproduction, high degree of parental care
2. Traits evolved during early life history of hominids
a. Limited resources of environment controlled population size
b. Populations regulated by food, disease, predators
c. Unusual disturbances affected population size
d. Population grew only slowly during early human history
3. Humans have expanded populations by technical innovations
a. Control over food supply
b. Weapons ward off predators
c. Cures for many diseases
d. Improvements in shelter and storage capacities
4. Humans have expanded carrying capacity of their habitats
a. Escape confines of logistic growth
b. Reenter exponential phase of sigmoid growth curve
5. Human population has grown explosively in last 300 years
a. Birth rate has remained relatively constant (30 per 1000 per year)
b. Death rate has decreased dramatically (from 20 to 13 per 1000 per year)
c. Difference produces 1.4% increase per year (was 2% until recently)

    6. Such increase has produced human population of almost 6 billion   fig 24.22
       a. 77 million individuals add to world population each year
       b. Human population will double in 39 years

  B. Population Pyramids
    1. Growth of human population not occurring at constant rate over whole planet
    2. Some countries, Mexico, growing rapidly, birth rate exceeds death rate   fig 24.23
    3. Assessed graphically by population pyramid
       a. Bar graph displaying numbers in each age category
       b. Males to left, females to right or vertical age axis
       c. Number of older females usually greater than older males
    4. Can predict demographic trends in births and deaths
       a. Rectangular shape indicates stable population
       b. Triangular shape shows country with rapid future growth
       c. Inverted triangle shape represents population that is shrinking
    5. Examples of population pyramids for U.S. and Kenya   fig 24.24
       a. U.S. has nearly rectangular shape, not expanding rapidly
       b. Cohort of 55 to 59 year olds are Depression babies, smaller than adjoining cohorts
       c. Cohort 25 to 44 years old is "baby boom"
       d. Triangular shape of Kenya shows explosive future growth
       e. Population expected to double in less than 20 years

  C. An Uncertain Future
    1. Rapid human population growth is challenge to future of biosphere
       a. Adding one million people every five days
       b. Staggering growth rate in certain countries   tbl 24.3
    2. Key element is uneven distribution of growth
       a. 90% in developing countries   fig 24.25
       b. Reducing fraction of those living in industrialized countries
       c. Growth centered in areas least able to deal with pressures of rapid growth
    3. Harsh consequence of increasing gap between rich and poor
       a. 23% live in industrial countries, $17,900 per capita income
       b. 77% in developing countries, $810 per capita income
       c. 85% of capital wealth in industrialized, 15% in developing countries
       d. 80% of energy used by industrialized, 20% by developing countries
       e. 94% of scientists in industrialized, 6% in developing countries
    4. Unknown whether world can sustain population of 6 billion
       a. Cannot expect to increase carrying capacity indefinitely
       b. Unavoidable need to equalize birth and death rates
       c. Must lower birth rates

INSTRUCTIONAL STRATEGY

PRESENTATION ASSISTANCE:

The cost of reproduction can be compared to spending money now versus saving for the future. If you buy that car now, yes, you will have it to drive around and be cool, but if you drive it too much you wear out the tires, and you won't have any money to buy new ones (you die). If you wait and save your money it will gather interest, then you buy the car, drive it and the interest you gained will provide the funds to buy new tires.

Source-sink metapopulations are like a socialistic society (or Robin Hood). Take from the rich and give to the poor.

Discuss the human population explosion. We too frequently think just in terms of producing enough food for the populace without considering the demands on other resources and accumulation of toxic and natural wastes.

The egg size versus clutch size problem is similar to what is found in many erythropoietic diseases/difficulties. If fewer red blood cells are produced by the stem cells, they are usually larger in size or contain more iron so that sufficient oxygen transport can still occur. This may not occur if hemoglobin precursors are limited.

Clearly differentiate between the kind of growth that occurs when there are no environmentally limiting factors (exponential growth) and that which occurs when limitations do exist (sigmoid growth). The two types of growth curves also relate to whether an organism is an *r* strategist (exponential growth) or a *K* strategist (sigmoid growth). Discuss why it is more likely for a *K* strategist to become extinct than an *r* strategist.

VISUAL RESOURCES:

Show simple interspecific competition between two microorganisms in a petri dish. Fungi "wars" can be quite impressive. Inoculate a series of plates over a period of time to show the progress

Discuss the human population explosion. We too frequently think just in terms of producing enough food for the populace without considering the demands on other resources and accumulation of toxic and natural wastes.

Common sense indicates that we should want to kill infected rats to prevent the spread of bubonic plague. New population dynamic models indicate though, that doing so may actually make an outbreak worse. If the rats are killed, the fleas will find other mammals to feed on. Fleas also live on mice, squirrels, chipmunks, prarrie dogs, and humans. Human plague outbreaks occur when rodent populations are low, forcing the hungry fleas to seek blood from other sources. Killing more rodents would only increase the fleas' need to find new hosts.

of each organism. Many microorganisms produce antibiotics to kill off other microorganisms and outcompete them in the same habitat.