Population Dynamics, Carrying Capacity, & Conservation Biology

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Outline

1. Characteristics of Populations
   size, density, dispersion, age structure, dynamics
2. Population Dynamics & Carrying Capacity
   growth limits, exponential vs. logistic growth, carrying capacity
3. Reproductive Strategies & Survival
   r– vs. K–strategists; survivorship curves
4. Conservation Biology
   extinction, ecosystem integrity, habitat fragmentation,
   corridors, bioinformatics
5. Human Impacts on Ecosystems
   humans modification of ecosystems, sustainability
6. Ecosystem Restoration

1. Characteristics of Populations

*Changes in population size, density, dispersion, & age distribution are known as **population dynamics**.*

- **population size** is the number of individuals in a population at a given time;
- **population density** is the number of individuals per unit area in terrestrial ecosystems or per unit volume in aquatic ecosystems;
- **dispersion** is the spatial patterning individuals;
- **age structure** is the proportion of individuals in each age group (e.g., prereproductive, reproductive, & postreproductive) of a population.

Characteristics of Populations

In terms of dispersion, individuals of a population can be clumped, uniform, or randomly distributed.

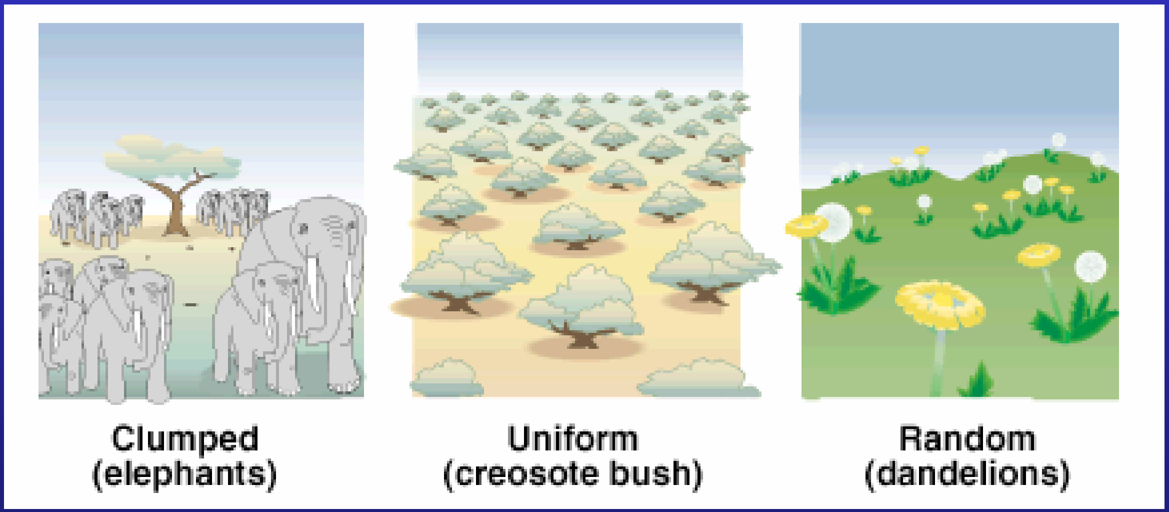


Fig. 10–2

2. Population Dynamics & Carrying Capacity

Population size is governed by births, deaths, immigration, and emigration:

[Population Change] = [Births + Immigration] – [Deaths + Emigration]

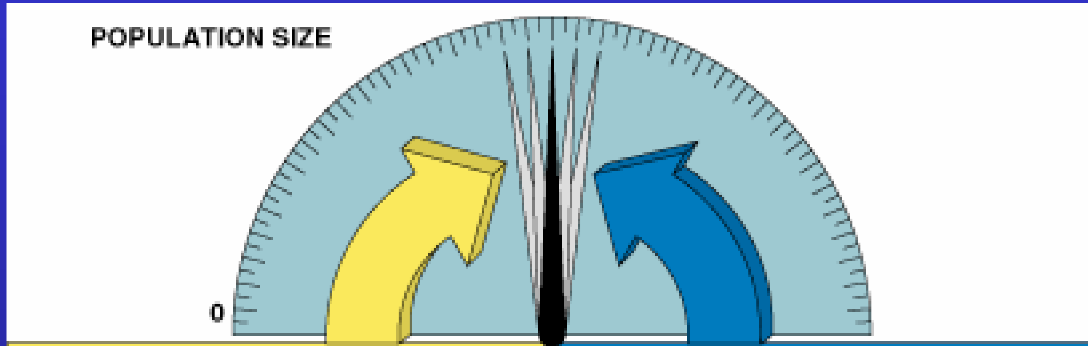
- If the number of individuals added by births & immigration are balanced by those lost by deaths & emigration then there is **zero population growth**;
- populations vary in their capacity for growth, also known as **biotic potential**;
- the **intrinsic rate of growth (r)** is the rate at which a population will grow if it had unlimited resources.

Biotic Potential of Two Houseflies

Generation	Population
1	120
2	7,200
3	432,000
4	25,920,000
5	1,555,200,000
6	93,312,000,000
7	5,598,720,000,000

Population Dynamics

Factors that tend to increase or decrease population size:



GROWTH FACTORS (BIOTIC POTENTIAL)	DECREASE FACTORS (ENVIRONMENTAL RESISTANCE)
Abiotic Favorable light Favorable temperature Favorable chemical environment (optimal level of critical nutrients)	**Abiotic** Too much or too little light Temperature too high or too low Unfavorable chemical environment (too much or too little of critical nutrients)
Biotic High reproductive rate Generalized niche Adequate food supply Suitable habitat Ability to compete for resources Ability to hide from or defend against predators Ability to resist diseases and parasites Ability to migrate and live in other habitats Ability to adapt to environmental change	**Biotic** Low reproductive rate Specialized niche Inadequate food supply Unsuitable or destroyed habitat Too many competitors Insufficient ability to hide from or defend against predators Inability to resist diseases and parasites Inability to migrate and live in other habitats Inability to adapt to environmental change

Fig. 10–3

Carrying Capacity

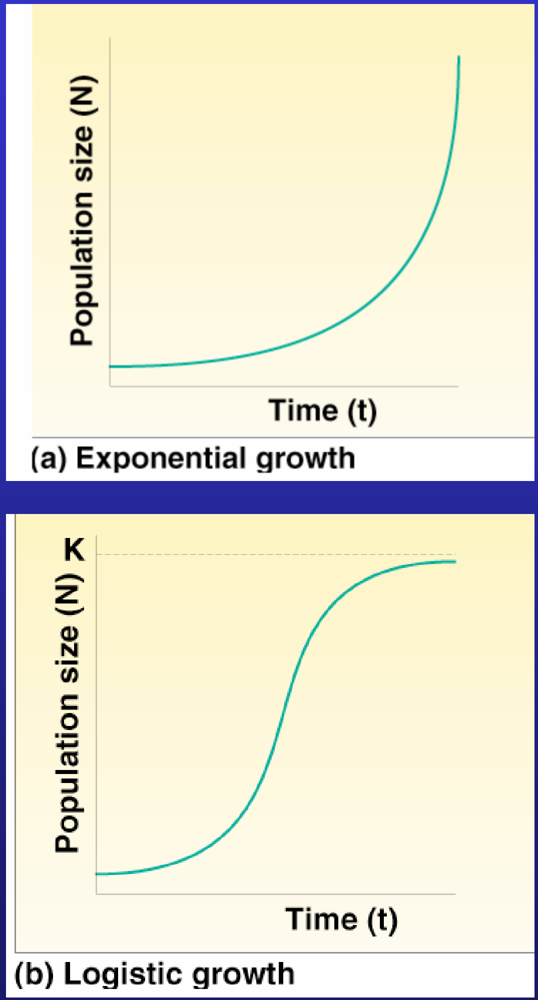
There are always limits to population growth in nature.

- **carrying capacity (K)** is the number of individuals that can be sustained in a given space;
- the concept of carrying capacity is of central importance in environmental science;
- if the carrying capacity for an organism is exceeded, resources are depleted, environmental degradation results, & the population declines.

Exponential vs. Logistic Growth

Exponential growth occurs when resources are not limiting.

Logistic growth occurs when resources become more and more limiting as population size increases.



(a) Exponential growth

(b) Logistic growth

Fig. 10–4

Exponential Population Growth

Exponential growth occurs when resources are not limiting.

- during exponential growth population size increases faster & faster with time;
- currently the human population is undergoing exponential growth;
- exponential growth can not occur forever because eventually some factor limits population growth.

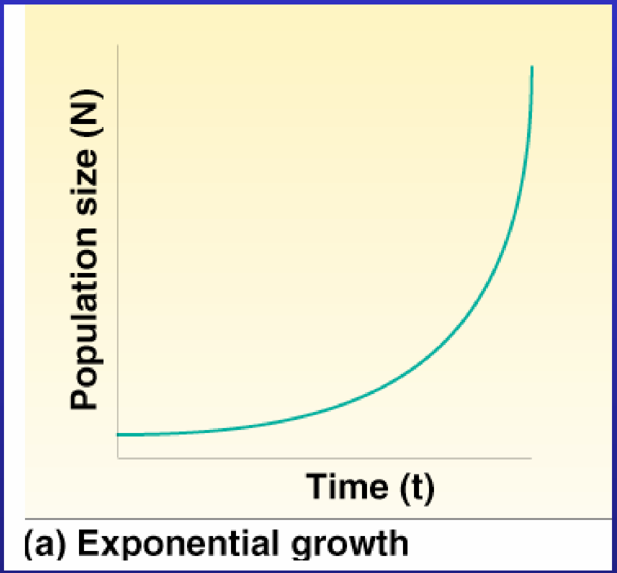
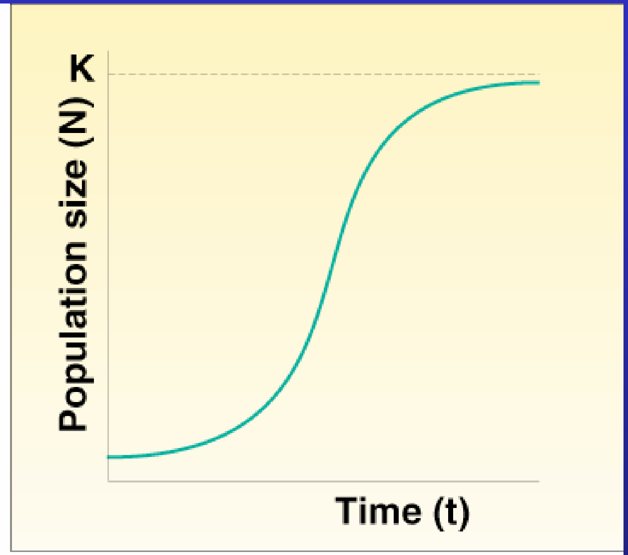


Fig. 10–4a

Logistic Population Growth

Logistic population growth occurs when the population growth rate decreases as the population size increases.

- note that when the population is small the logistic population growth curve looks like exponential growth;
- over time, the population size approaches a carrying capacity (K).



(b) Logistic growth

Fig. 10–4b

Exceeding the Carrying Capacity

During the mid–1800s sheep populations exceeded the carrying capacity of the island of Tasmania. This "overshoot" was followed by a "population crash". Numbers then stabilized, with oscillation about the carrying capacity.

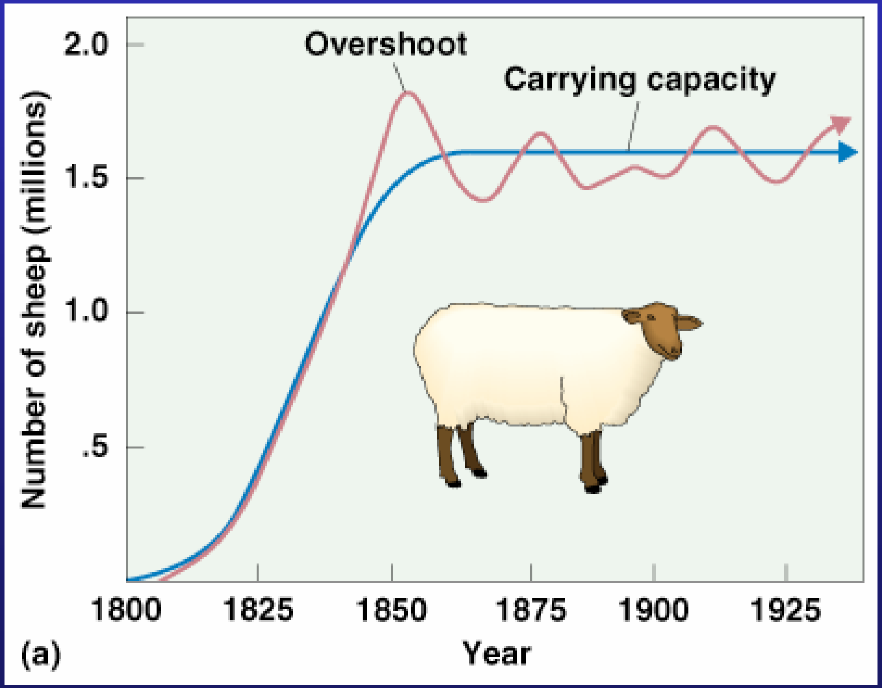


Fig. 10–5

Exceeding the Carrying Capacity

Reindeer introduced to a small island off of Alaska in the early 1900s exceeded the carrying capacity, with an "overshoot" followed by a "population crash" in which the population was totally decimated by the mid–1900s.

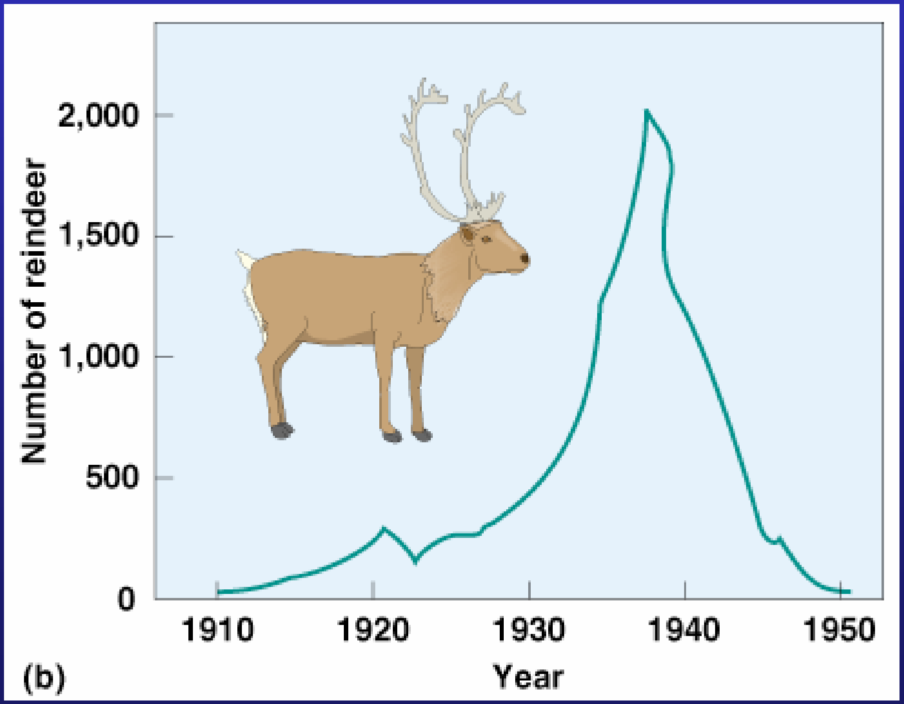


Fig. 10–5

Population Curves in Nature

*Natural populations display a broad diversity of population curves. **Stable** populations are relatively constant over time. **Cyclic** curves are often associated with seasons or fluctuating resource availability. **Irruptive** curves are characteristic of species that only have high numbers for only brief periods of times (e.g., seven–year cicada).*

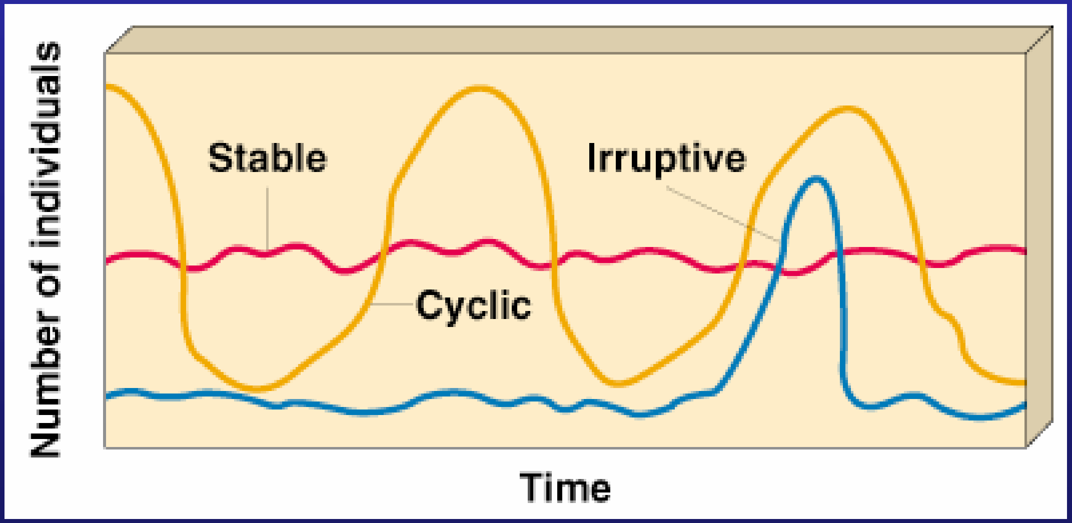


Fig. 10–6

Population Curves in Nature

Population cycles for the snowshoe hare & Canadian lynx are believed to result because the hares periodically deplete their food, leading to first a crash of the hare population & then a crash of the lynx population.

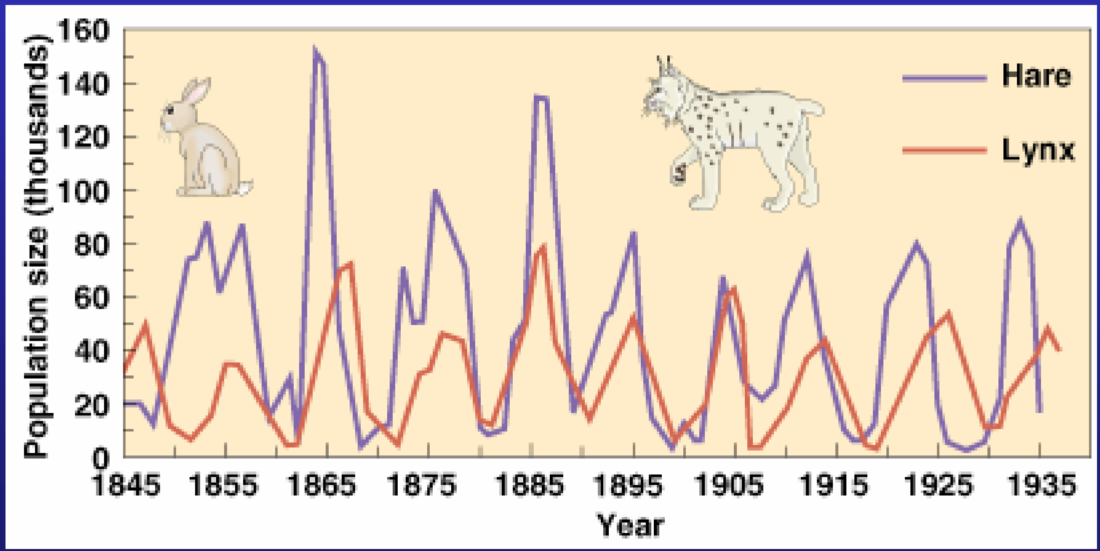


Fig. 10–8

3. Reproductive Strategies & Survival

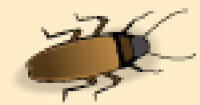
Organisms can be divided into two categories of "strategies" for reproduction & survival:

- **r–strategist species**, which tend to live in recently disturbed (early successional) environments where resources are not limiting; such species tend to have high intrinsic rates of growth (high r);
- **K–strategist species**, which tend to live in environments where resources are limiting (later succession) & tend to have lower intrinsic rates of growth and characteristics that enable them to live near their carry capacity (population size near K).

r–Strategist Species

Characteristics of r–strategists, including production of many small & unprotected young, enable these species to live in places where resources are temporarily abundant. These species are typically "weedy" or opportunistic.

r-strategists



cockroach

dandelion

Many small offspring
Little or no parental care and protection of offspring
Early reproductive age
Most offspring die before reaching reproductive age
Small adults
Adapted to unstable climate and environmental conditions
High population growth rate (r)
Population size fluctuates wildly above and below carrying cap (K)
Generalist niche
Low ability to compete
Early successional species

Fig. 10–7a

K–Strategist Species

Characteristics of K–strategists, including production of few large & well cared for young, enable these species to live in places where resources are limited. These species are typically good competitors.

Fewer, larger offspring
High parental care and protection of offspring
Later reproductive age
Most offspring survive to reproductive age
Larger adults
Adapted to stable climate and environmental conditions
Lower population growth rate (r)
Population size fairly stable and usually close to carrying capacity (K)
Specialist niche
High ability to compete
Late successional species

Fig. 10–7b

Survivorship Curves

Three kinds of curves:

- **late loss** (usually K–strategists), in which high mortality is late in life;
- **constant loss** (such as songbirds), in which mortality is about the same for any age;
- early loss (usually r–strategists), in which high mortality is early in life.

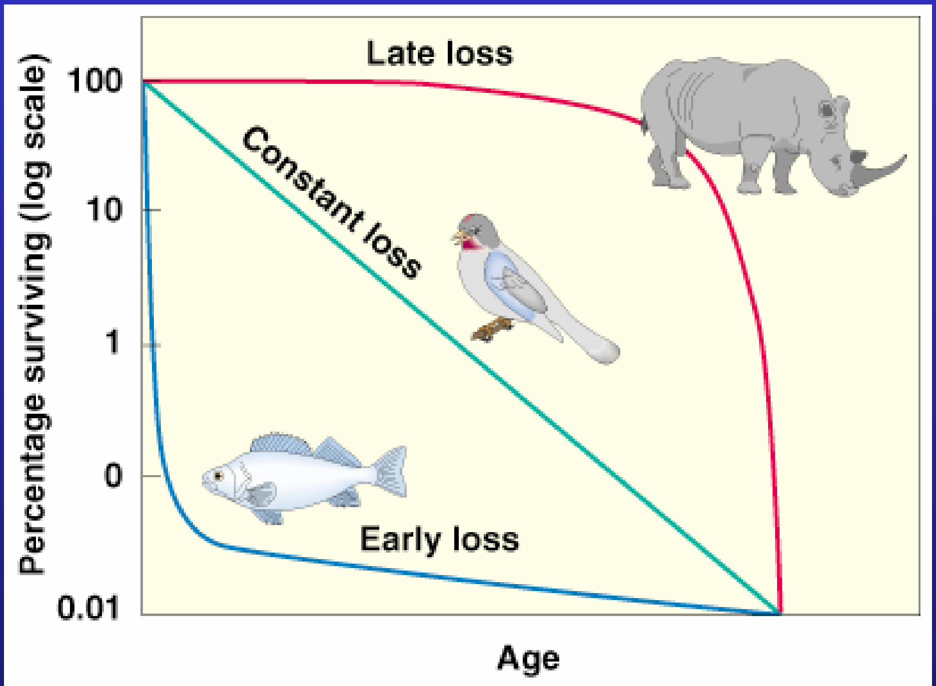


Fig. 10–9

4. Conservation Biology

Conservation biology *is the interdisciplinary science that deals with problems of maintaining Earth's biodiversity, including genetic, species, & ecosystem components of life.*

- **conservation** involves the sensible use of natural resources by humans;
- three underlying principles:
  - biodiversity & ecological integrity are useful & necessary for life & should not be reduced by human activity;
  - humans should not cause or hasten premature extinction of populations & species;
  - the best way to preserve biodiversity & ecological integrity is to protect intact intact ecosystems & sufficient habitat.

Conservation Biology

Major questions in conservation biology:

- What is the status of natural populations, & which species are in danger of extinction?
- What is the status of the integrity of ecosystems, & what ecosystem services, of value to humans & other species, are we in danger of losing?
- What measures can we take to ensure that we maintain habitat of the quality & size needed to ensure viable populations of wild species, and that ecosystem integrity can be sustained.

Ensuring viable populations of wild species ultimately requires protection of sufficient suitable habitat.

Conservation Biology

***Habitat fragmentation** is the process by which human activity breaks natural ecosystems into smaller & smaller pieces of land called habitat fragments.*

- one concern is whether remaining habitat is of sufficient size and quality to maintain viable populations of wild species;
- large predators, such as grizzly bears, & migratory species, such as bison, require large expanses of continuous habitat;
- habitat fragments are often compared to islands, & principles of island biogeography are often applied in habitat conservation.

Conservation Biology

***Corridors** are long areas of land that connect habitat that otherwise would be fragmented.*

- corridors permit movement of migratory animals and ensure interbreeding of plant & animal populations;
- example: corridor of protected land between protected lowland rain forest of La Selva Biological Station, Costa Rica, & mountain habitat of Braulio Carrillo National Park protects biodiversity by ensuring that species can migrate up & down the mountains;
- corridors sometimes criticized because they may be too narrow to be of value.

Habitat Corridors

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Conservation Biology

Bioinformatics *involves the management of biological information.*

- good conservation biology requires good information;
- increasingly conservation efforts require building computer databases concerning biodiversity;
- the new discipline of bioinformatics concerns itself with providing tools for acquisition, storage, & access of key biological & environmental information.

5. Human Impacts on Ecosystems

Some major human impacts on ecosystems:

- fragmenting & degrading habitat;
- simplifying natural ecosystems;
- strengthening some populations of pest species and disease–causing bacteria by speeding natural selection & causing genetic resistance through overuse of pesticides & antibiotics;
- eliminating some predators;
- deliberately or accidentally introducing new species;
- overharvesting potentially renewable resources;
- interfering with chemical cycling & energy flows.

Human Impacts on Ecosystems

Some lessons from ecology:

- living systems have six key features: interdependence, diversity, resilience, adaptability, unpredictability, & limits;
- most ecosystems use sunlight as major energy source; energy, in turn, flows through food web;
- ecosystems replenish nutrients & dispose of wastes;
- soil, water, air, plants, & animals are renewed;
- energy is always required to produce or maintain energy flow or to recycle chemicals;
- biodiversity takes forms of genes, species, and ecosystems.
- complex networks of positive & negative feedback loops operate within natural systems, whether in individual organism, populations, or whole ecosystems;
- population size & growth rate of all species are controlled by interactions with other species & the nonliving environment.

Human Impacts on Ecosystems

Some principles for more sustainable lifestyles:

- we are part of, not apart from, Earth's dynamic web of life;
- our lives, lifestyles, & economies are dependent on the sun and earth;
- we never do merely one thing;
- everything is connected to everything else; were are all in it together.

According to environmentalist David Brower we need to focus on "global CPR — that's conservation, preservation, & restoration".

6. Ecosystem Restoration

Can we restore damaged ecosystems?

- yes, in some cases; but prevention is easier;
- *natural restoration* is slow relative to human life spans;
- *active restoration* can repair & protect ecosystems, but generally with considerable effort & expense;
- <u>example</u>: in Sacramento, California, rancher Jim Callender restored a wetland by reshaping land and handplanting native plants; man of the native plants & animals are now thriving there;
- restoration requires solid understanding of ecology;
- it is not possible to undo all ecological harm, e.g., we can't foster recovery of an extinct species.