Preservation of Biodiversity

Chapter 8
8.1 Conservation Biology

**Conservation biology** is a biological discipline that studies every aspect of biodiversity with the goal of conserving natural resources for current and future generations. This relatively new branch of biology is concerned with both the development of scientific concepts and with the application of these concepts to the everyday world. The management of biodiversity for sustainable use by humans is a primary goal of conservation biologists and to achieve this goal, conservation biologists must come from many areas of expertise to form a cohesive whole. To bring about necessary change within the international community conservation biologists often work with local and federal government officials.

Conservation biology unabashedly supports the following ethical principles: 1) biodiversity is desirable for the biosphere and therefore for humans; 2) extinctions, due to human actions, are therefore undesirable; 3) the complex interactions in ecosystems support biodiversity and are desirable; and 4) biodiversity brought about by evolutionary change has value in and of itself, regardless of any practical benefit.

As we have learned, never before in the history of the Earth have so many extinctions occurred in such a short amount of time. At least 10 to 20% of all species living now will become extinct in the next 20 to 50 years unless something is done right away. The scientific discipline of conservation biology arose to deal with this crisis.

8.2 The Value of Biodiversity

Biodiversity is a resource of immense value and various individual species perform great services for human beings. Some of the most obvious direct values include medicines, crops, timber, and foods. Indirect values include biogeochemical cycles, waste disposal, fresh water, prevention of soil erosion, regulation of the climate, and ecotourism.

**Direct Value of Biodiversity**

- Most of the prescription drugs used throughout the world were originally derived from living organisms.
- Crops such as wheat, corn, and rice are derived from wild plants.
- Wood is one of the most significant products obtained from natural environments.
- Wild fruits and vegetables, skins, fibers, beeswax, and seaweed are sold in marketplaces around the world.
- Many people obtain their meat from the environment by hunting and fishing.

**Indirect Value of Biodiversity**

- We are dependent on biogeochemical cycles for fresh water, removal of carbon dioxide from the atmosphere, uptake of excess soil nitrogen, and provisions of phosphate.
- We dump millions of tons of waste into natural ecosystems and depend on decomposers to break down dead organic matter and other types of wastes into inorganic nutrients.
- Forests and other ecosystems filter water and maintain water quality.
- Intact ecosystems naturally retain soil and prevent soil erosion.
- Trees provide shade and reduce the need for fans and air conditioners during the summer as well as take up carbon dioxide to prevent global warming.
- In the United States, people spend over $4 billion each year on fees, travel, lodging, and food while vacationing in a natural setting.

8.3 Establishment of New Populations

Conservation biology aims to decrease the probability of species extinction. We have learned that small populations are a serious threat to a species going extinct. By simply increasing the number of individuals in a population the chances for extinction dramatically decrease. However, in order for an establishment program to be effective the factors that led to the population decline must be understood and addressed. There are three basic approaches to the establishment of new populations of animals or plants, reintroduction, augmentation, and introduction.

A **reintroduction program** involves the release of captive-bred or wild-collected individuals into the species’ historical range where the species no longer occurs. These sites are known to be suitable habitats because the species had once lived there. The principle objective of a reintroduction program is to create a new population in its original environment and to help restore a damaged ecosystem. Because individuals are released near the site where they or their ancestors were collected their genes are known to have evolved in that site and are known to be adapted to that particular environment.

An **augmentation program** involves the release of individuals into an existing population to increase the population size and introduce new alleles into the gene pool. The released individuals are normally raised in captivity but may also be wild individuals that were collected elsewhere. Animals that are especially susceptible to death at a young age are sometimes “headstarted”, an approach in which animals are raised in captivity during their vulnerable young stage and then are released into the wild.

An **introduction program** involves moving captive-bred or wild-collected animals and plants to areas suitable for the species outside their historical range. This is usually only done when the species’ normal environment has deteriorated to the point where the species can longer survive there, or when reintroduction is impossible because the factor that caused the original decline is still present. Care must be taken to ensure that the species will not damage its new ecosystem or harm populations of any local endangered species.
Questions

1. Name two specific direct values found in the biodiversity at Drey Land.

2. Name two specific indirect values found in the biodiversity at Drey Land.

3. Black rhinos released into new South African game reserve

31 Oct 2006 -- KwaZulu-Natal, South Africa -- Twelve black rhinos have recently been released into a game reserve in northern KwaZulu-Natal, forming the third founder population of a rhino conservation project.

As part of the Black Rhino Range Expansion Project — a partnership between WWF and Ezemvelo KZN Wildlife — the rhinos were released in the Pongola Game Reserve on 13,000ha of land made up of six neighbouring properties. This adds to 80,000ha of land in KwaZulu-Natal that have been set aside especially for black rhino conservation.

The black rhino, which used to be the most numerous rhino species in the world, became critically endangered following a catastrophic poaching wave in the 1970s and 1980s that wiped out 96 per cent of Africa’s wild black rhino population in only 20 years. At the lowest point, there were just 2,500 black rhinos left. Today, thanks to conservation efforts, numbers have increased to about 3,600.

The WWF-supported rhino project aims to increase black rhino numbers by increasing the land available for their conservation, thus reducing pressure on existing reserves and providing new areas in which they can breed.

“This is best for rapid population growth, essential for the long-term health of a critically endangered species,” said WWF project leader Dr Jacques Flamand.

Is this story an example of a reintroduction, augmentation, or an introduction program? How are these programs different?
8.4 Ex Situ Conservation Strategies

The best strategy to preserve biodiversity is to preserve natural communities and populations in the wild, a process known as **in situ**, or on-site, preservation. However, if the last remaining population of a rare and endangered species is too small to maintain the species and is still declining despite conservation efforts then in situ preservation may not be effective. It is likely that the only way species in such circumstances can be prevented from going extinct is to maintain individuals in artificial conditions under human supervision. This strategy is known as **ex situ**, or off-site, preservation.

The long-term goal of many ex situ conservation programs is the eventual establishment of new populations in the wild, once sufficient numbers of individuals and a suitable habitat are available. Ex situ facilities for animal preservation include zoos, game farms, aquariums, and private breeders, while plants are maintained in botanical gardens, arboretums, and seed banks. Individuals from ex situ populations can be periodically released into the wild to augment in situ conservation efforts. Ex situ conservation efforts also allows for basic biological research on captive populations and to educate the public about the need to preserve species.

Captive populations are subject to the patterns of genetic drift and inbreeding that operate in small populations, and to a number of additional genetic influences. When a captive population is established, for example, another source of reduced genetic variation operates: the **founder effect**. A small group of individuals used to found a captive breeding population possesses only part of the total variability of the wild population. If the individuals are closely related or come from a small part of the total species’ range, they may lack much of the allelic variation in the population.

Thus, if possible, a captive population should be founded with unrelated individuals drawn from various parts of the wild population.

The okapi, an African forest antelope, illustrates how difficult it is to obtain a good representation of the variability in a wild population. Okapis in captivity around the world are derived from only 75 individuals captured in the wild. Of these, only 30 have bred, and only 23 have living offspring. Those that have bred vary considerably in the number of offspring they have left. The result is that the present genetic structure of the captive population is equivalent to that which would be produced by only 12 wild individuals.

In small captive populations, these problems are enhanced with a peculiar selective environment. Since individuals are artificially protected from predators and are provided food and shelter, selection to maintain natural survival behaviors is nonexistent. To make matters worse, selection is usually strong for characteristics relating to tolerance of confined quarters and absence of normal social contacts.

Still another problem that may arise in artificially managed populations is **outbreeding depression**, or reduced fitness of offspring of distantly related individuals. The clearest cases of outbreeding depression result from hybrid offspring of individuals from populations adapted to different environments. In such situations, local populations may have become adjusted genetically to local conditions. Hybrid offspring of individuals from parents of two different habitats may be adapted to neither.

In zoo populations of many animals, the interbreeding of individuals belonging to different subspecies, or occasionally species, has been frequent. An inaccurate understanding of the taxonomy of the
species, poor record keeping, and a shortage of possible breeding individuals have all contributed to this sort of hybridization. The result is that some zoo populations are unsuitable for use in captive breeding programs aimed at in situ conservation strategies. A major priority to avoid outbreeding depression in captive breeding programs must be accurate analyses of the genetics of animals in captive programs.

8.5 Conserving Genetic Variability

The first strategy in the conservation of genetic variability is to prevent populations from reaching “bottleneck” levels. Efforts have been made to determine what the minimum population size is to prevent loss of evolutionary adaptability. This minimum population size must only apply to the breeding individuals in a population. Consequently, the genetically effective population size is much smaller than the actual population. As a formal genetic concept, the genetically effective population size is the ideal breeding population (a 1:1 sex ratio, random mating pattern, and random variation in number of offspring per mating) that will retain the genetic diversity present in the original population. Consider a hypothetical population of nine male and nine female elephant seals in which only one male mates with each of the females. Eight males are excluded from breeding and, therefore, the genetically effective breeding population is reduced. It may be reduced still more because of the close relation of each of the individuals. In the next generation the various females, in this example, would all be full or half siblings. The chances of losing alleles by genetic drift would be about equal to that in a population of only two males and two females.

Estimates of the minimum genetically effective population size vary considerably. Most researchers agree that a minimum effective breeding population of 50 would be necessary to prevent deleterious short-term effects due to inbreeding -- the so-called “rule of 50”. However, one must be conscious of the biotic potential of the species being preserved. The minimum genetically effective population is related to the generation length of the organism, and would be much greater for small, short-lived organisms than that for large species with long generation times.

For an endangered population of a species of kangaroo rat, a century might be equivalent to 50 generations, whereas for the African elephant it might equate to only four generations. Based on a mathematical equation that has been derived to calculate the loss of heterozygosity (percentage of heterozygous individuals for a particular gene) through genetic drift, a population of 487 kangaroo rats would be necessary to retain 95% of the original level of genetic variability for 100 years, whereas a population of only 39 elephants would suffice. An accepted minimum of 500 breeding individuals - the total population including the nonbreeding individuals - is a rough first estimate of a genetically healthy population.

Many cases exist of populations that have fallen below the 50-individual level. In North America, populations of the whooping crane, California condor, Florida panther, and black-footed ferret have all dropped below 50 individuals. Recently, some of these populations have recovered to higher levels, but many still remain below the genetically effective population size.

In establishing captive breeding populations for in situ conservation, efforts should be made to:

- maximize genetic diversity by selecting unrelated individuals;
• carefully manage the breeding population to maximize the genetically effective population size;
• use pedigrees of captive population members to create pairings that promote genetic variability;
• reduce the effects of inbreeding by having breeding exchanges between institutions having separate populations of species;
• improve technologies of sperm and embryo banking so the effective breeding population can include individuals that cannot be transported or that are no longer alive.

Obviously, a well-integrated, international system of breeding records is essential for efforts to create minimum genetically effectively populations of species in captivity.

Because of the rapid disappearance of natural ecosystems and their species, zoos, aquaria, botanic gardens, arboreums and other facilities will bear a heavier responsibility for preserving genetic resources and diversity. Zoos, which focus their efforts on terrestrial vertebrates, will probably be faced by the need to maintain about 2000 species of larger vertebrates by some time in the next 200 years. At best, existing zoo facilities have a capacity to house about 1000 such species with minimum populations of 250 individuals. Considering the space requirements and costs of zoo maintenance, this is a major challenge.

New technologies may assist the conservation of animal germ plasm. **Cryogenic storage**, long-term preservation of semen, ova, or embryos at subfreezing temperatures, is an established technique for domestic ungulates, and has been proven applicable for many other mammals. The temperatures at which these materials are stored range from -160°C to -196°C. The length of time animal materials will remain healthy under such storage conditions is uncertain, but domestic animal semen and embryos have been stored successfully for 10-30 years.

Botanical gardens and arboreta face a similar challenge. In the United States alone about 5000 rare to endangered species of plants exist in the wild. Typically, botanical gardens focus attention on particular families or genera of plants for which their environment is best suited. The plant groups best represented are often those of horticultural interest, such as orchids or palms. Agricultural research institutions often maintain collections of plants of agronomic importance. In such collections, space is a severe constraint on the number of living individuals that can be preserved, particularly for shrubs and trees. In the United States, the Center for Plant Conservation, located in Jamaica Plain, Massachusetts and in St. Louis, Missouri, coordinates the activities of 20 botanical gardens and arboreta in the propagation of endangered plants.

Seed storage facilities have been developed for higher plants. Conventional facilities, such as the National Seed Storage Laboratory (NSSL) in Fort Collins, Colorado, store seeds at about 4.4°C with low relative humidity. The stored samples must be tested for viability at five year intervals, and propagated in the field to produce new seeds when viability begins to decline. Seeds of most crop plants must be propagated about every 15 years. Conventional facilities like the NSSL exist in many countries, primarily to protect genetic lines of plants of agronomic value.
Questions

1. What is the difference between in situ and ex situ preservation efforts?

2. If there were 500 polar bears present in the wild and of these only 20% of the males mate with the females, would this be a genetically effective population size? Why or why not?

3. How could cryogenic storage of an endangered species semen increase the genetically effective population size?