Chapter 27
Conservation Genetics

Conservation Genetics -- Application of genetics to preserve species as dynamic entities capable of coping with environmental change and encompasses:

- **genetic management of small populations**
- **resolution of taxonomic uncertainties**
- **defining management units within species**
- **use of molecular genetic techniques in forensics & understanding species biology**

Diversity of life on Earth is under increasing pressure from the direct and indirect effects of explosive human population growth.

Time	*Human Pop. Number*
10,000 years ago	**10 Million**
2,000 years ago	**100 Million**
1950	**2.5 Billion**
1993	**5.5 Billion**
2100	**19 Billion**

WHY SHOULD WE BE CONCERNED WITH LOSING BIODIVERSITY?

When a population or species disappears, all the genetic information carried by that population or species is lost forever!!!

When a contiguous population is fragmented into many small populations, genetic diversity within each fragment may decay over time

"*Gene pools are becoming diminished and fragmented into gene puddles*" (Thomas Foose, 1983).

Why Genetics?

Evolution is the single most unifying organizational concept in all of biology and should play a prominent role in conservation as well.

Evolution is dynamic and change is expected.

Ecological systems are dynamic and generally not in equilibrium.

The best way to manage such dynamic systems is a "CONSERVATIONIST" rather than a "PRESERVATIONIST" approach.

Three biological reasons to believe genetics can make important contributions to conservation biology.

First, the *Fundamental Theorem of Natural Selection* tells us that the rate of evolutionary change in a population is proportional to the amount of genetic diversity available.

***Darwin-Wallace Theory of Natural Selection* states that if supplied with sufficient nutrients and protection, the total population size will increase geometrically. However, due to high death rates, geometric increase is not maintained indefinitely.**

All species are variable.

Those individuals with variations of characters that better enable them to survive and reproduce will leave proportionally more offspring.

This results in the increase of the advantageous characters in the next generation.

Second, there is a consensus among population geneticists that heterozygosity, or high genetic variation within individuals or populations, is positively related to fitness.

Third, the global pool of genetic diversity represents all the information for all biological processes on the planet.

Loss of such diversity will probably decrease the ability of organisms to respond to environmental changes and discard information potentially useful to humans.

World Conservation Union (IUCN)

25% mammals, 11% birds, 20% reptiles, 25% amphibians, and 34% fish species are "VULNERABLE" or "ENDANGERED".

12% vascular plant species are "THREATENED"

Food and Agriculture Organization (FAO)

since 1900, 75% of genetic diversity in agricultural crops have been lost; also, out of about 5,000 different breeds of domesticated farm animals world-wide, 1/3 are at risk of being lost.

Thus, the biological diversity of the planet is being rapidly depleted due to direct and indirect consequences of humans.

Scale of this problem is enormous and has been termed the "*Sixth Extinction*" as its magnitude is comparable with that of the other 5 mass extinctions revealed in the geologic record.

Therefore, conservation genetics is motivated by the need to reduce current rates of extinction and to preserve biodiversity.

Why Conserve Biodiversity?

Because humans derive many direct and indirect benefits from the living world, we have a stake in conserving biodiversity for the following reasons.

1. RESOURCES WE USE -- bioresources include all food, many pharmaceuticals, clothing fibers, rubber & timber with a value in billions of dollars annually.

About 25% of all pharmaceutical prescriptions in the U.S. contain active ingredients derived from plants.

Moreover, the natural world contains many potentially useful novel resources: Ants contain novel antibiotics that are being investigated for use in human medicine.

2. ECOSYSTEM SERVICES IT PROVIDES

These ecosystem services are essential biological functions that are provided free of charge by living organisms and which benefit mankind such as:

Oxygen production by plants
climate control by forests
nutrient cycling
natural pest control
pollination of crop plants

These services have been valued at $33 trillion/year or almost double the $18 trillion yearly global national product!!!

3. AESTHETICS -- humans derive pleasure from living organisms. This translates into direct economic values.

Koalas are estimated to contribute $70 million annually to the Australian tourism industry.

4. ETHICS -- The ethical justifications for conserving biodiversity are simply that one species does not have the right to drive other species to extinction!!!!

Effective Population Size (N_e)

How small must a population be before it is considered endangered?

In general, a population of less than 100 individuals is considered extremely sensitive to genetic drift, inbreeding, and reduction in gene flow.

The effective population size (Ne) is the number of individuals in a population having an equal probability of contributing gametes to the next generation.

Ne is almost always smaller than the absolute census size (N).

Ne = 4(NmNf) / Nm + Nf

Nm = Number of breeding males
Nf = Number of breeding females.

Example 1: Population of 200 individuals with an equal sex ratio (i.e., Nm = 100; Nf = 100).

Ne = (4 X 100 X 100) / (100 + 100) = 200.

Example 2: Population of 200 individuals with an equal sex ration but there is a harem system where each male controls a harem of 20 females. What is Ne?

Nm = 5; Nf = 100

Ne = (4 X 5 X 100) / (5 + 100) = 19.07.

Genetic Drift

If the number of breeding individuals in a population is small, fewer gametes will form the next generation.

Purely by chance, the alleles carried by those gametes may not be a representative sample of all those present in the population and will result in changes in allele frequencies over time.

This is known as *Genetic Drift*.

A serious result of genetic drift in populations with small Ne is the loss of genetic variation.

Genetic drift is a random process, so both deleterious and advantageous alleles can become fixed within a small population.

The probability that an allele will be fixed through drift is the same as its initial allele frequency.

Inbreeding

In small populations, the chance of inbreeding, even with random mating, is increased.

The inbreeding coefficient (F) measures the probability that two alleles of a given locus in an individual are derived from a common ancestor.

The inbreeding coefficient (F) is inversely related to the frequency of heterozygotes expected under Hardy-Weinberg Equilibrium:

$$F = (2pq - H) / 2pq$$

In a declining population that has become small enough for drift to occur, H will decrease with each generation.

The smaller the effective population size, the more rapid the decrease in H and the resulting increase in F, as can be seen from the following:

$$H_t = (1 - 1/(2Ne)^t H_o$$

Genetic Erosion is the loss of previously existing genetic diversity from a population or species.

Genetic erosion has 2 important effects on a population.

1. Genetic erosion can result in the loss of potentially useful alleles from the gene pool, reducing the ability of the population to adapt to changing environmental conditions and increasing its risk of extinction.

2. Genetic erosion can result in a reduction of heterozygosity.

At the population level, genetic erosion will result in homozygosity at a given locus.

At the individual level, genetic erosion results in a decrease in the number of heterozygous loci.

Although the level of homozygosity that can be tolerated by an individual varies from species to species, several studies have shown that populations with higher than normal levels of homozygosity have a range of deleterious effects including:

- **reduced sperm viability & reproductive abnormalities in African lions**
- **increased offspring mortality in elephant seals**
- **reduced nesting success in spotted woodpeckers**

Ways to maintain (or increase) genetic diversity.

Ex situ **("off - site") conservation involves the removal of plants or animals from their original habitat to an artificially maintained location.**

Black-footed ferrets -- last 18 individuals moved to a captive breeding program that has now produced over 3,000 ferrets that are now being reintroduced into native habitat.

California Condor -- last 12 individuals brought into captivity and have now produced over 200 individuals that are being released into natural habitats.

Gene Banks **-- these collections provide long-term storage and preservation of reproductive components such as sperm, ova, frozen embryos, seed, and pollen.**

In Situ **("on-site") conservation attempts to preserve population size and biological diversity of a species while maintaining it in its original habitat.**

Population Augmentation **-- is the approach of increasing the numbers of a declining population by transplanting and releasing individuals of the same species captured or collected from more numerous populations elsewhere.**

Examples include:

white-tailed deer east of the Mississippi River

Black Bears in central Arkansas

Florida panthers