INDIAN INSTITUTE OF SCIENCE
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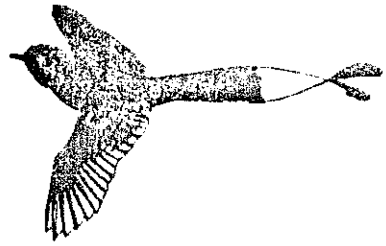

FIRST NATIONAL SCHOOL ON CONSERVATION BIOLOGY

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11-14 and 17-21 November	9:30 am - 10:15 am 10:20 am - 11:15 am 11:05 am - 11:20 am 11:20 am - 12:05 am	Lecture I Lecture II Tea break Lecture III
	1:30 pm - 2:30 pm	Computer simulations
	3:30 pm - 5:00 pm	Presentations by participants
21 November	7:30 pm	Dinner
22 November	10:00 am - 12:30 pm	Function in connection with release of festschrift in honour of Dr. Salim Ali

Introduction

The First National School on Conservation Biology was held November 10-22, 1986 at the Centre for Ecological Sciences (C.E.S.), Indian Institute of Science, Bangalore. The theme of the School was biological diversity - the processes creating and eliminating diversity, the distribution of diversity, and the conservation of diversity.

Participants from all over India, and from various departments and levels of study attended the School. About 20 of them gave presentations in the afternoons on their research as it related to conservation. In the mornings, C.E.S. faculty gave lectures that focussed on the processes that create and eliminate diversity. The lectures exposed participants to the basic background theories relating to conservation, and the newest ideas in evolution and diversity studies.

Thanks to funding by the Department of Environment, Government of India, many participants were able to attend. The following pages are a synopsis of the lectures given at the School, the topics of the talks given by the participants, and the names and addresses of those who attended the School.

Acknowledgement

The First National School on Conservation Biology, held November 10-22, 1986, was made possible by a grant from the Department of Environment, Government of India. The Centre for Ecological Sciences, Indian Institute of Science, Bangalore, gratefully acknowledges this funding and would like to thank the Department of Environment for the help and support it extended, which enabled so many scientists to attend.

Lectures by Faculty of the Centre for Ecological Sciences

10 Nov.'86 Monday	1. Overview of lectures on Conservation Biology	M. Gadgil
	2. Order and diversity	M. Gadgil
11 Nov.'86 Tuesday	3. Effective population size	N. V. Joshi
	4. Heterozygosity and fitness	R. Sukumar
	5. Neutral theory of genetic diversity I	N. V. Joshi
12 Nov.'86 Wednesday	6. Neutral theory of genetic diversity II	N. V. Joshi
	7. Inbreeding depression	R. Sukumar
	8. Extinction	N. V. Joshi
13 Nov.'86 Thursday	9. Evolution of sex	N. V. Joshi
	10. Genetics and conservation - the short- and long-term implications	R. Sukumar
	11. Species diversity and diversity gradients	R. Gadagkar
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	13. Productivity-stability hypothesis	R. Gadagkar
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	16. Island biogeography I	R. Gadagkar
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18 Nov.'86 Tuesday	18. Minimum viable populations	R. Sukumar
	19. Diversity information system	R. Daniels
	20. Conserving rare, endemic and keystone species	R. Sukumar

19 Nov.'86 Wednesday	21. Conserving ecosystems - the problems of tropical rain forest conservation	R. Sukumar
	22. Edge effects and diversity	R. Gadagkar
	23. Should we have a few large or several small reserves?	R. Sukumar
20 Nov.'86 Thursday	24. Culture and conservation I	M. Gadgil
	25. Culture and conservation II	M. Gadgil
	26. Captive breeding and re-introduction	R. Sukumar
21 Nov.'86 Friday	27. Ongoing conservation efforts in India	M. Gadgil
	28. Conservation of the Asian elephant	R. Sukumar
	29. Genetic engineering and conservation	R. Gadagkar

Order and Diversity

The focus of this Workshop is on the tremendous diversity of life on earth, the cause of this diversity, the threat of serious loss in the coming years, and the measures that may be adopted to save as much of it as we can. Exploitation of this variety by the exploding human population must needs be studied and planned if diversity on earth is to survive.

Let us begin by discussing the levels of diversity to be found on earth. At the lowest, simplest level, we have matter composed of an indefinite number of elementary particles called preons, leptons, hadrons and baryons. These combine variously to form quarks, which are the precursors of protons, neutrons and electrons. These last three make up the various elements, like carbon, hydrogen, oxygen and nitrogen. The abundance of elements on earth depends on the stability of their nuclei. The nuclei of unstable elements tend to break down into those of stable ones, resulting eventually in a larger proportion of stable elements. Elements combine to form compounds, and again, the most stable compounds are also the most abundant ones found - water and silicon dioxide, for example. Living matter is composed of large, complex, quasi-stable molecules made from a small number of building blocks - amino acids, nucleotide bases, sugars, phosphates - perhaps a hundred in all. The fantastic diversity of life arises from the myriads of combinatorial possibilities that these building blocks contain.

The possibilities that we see realized around us are such t...

the potential for variation. Once we have self-replicators (nucleic acids) whose replication is not perfect, variants will be continually created. These will have different efficiencies of self-replication in different environments. The outcome is the replacement of the less efficient by the more efficient, and the gradual colonization of environments by living creatures.

Man has evolved by the same process of natural selection that gave rise to the astounding level of diversity on earth. By ruthless exploitation, he is now on his way to destroying the very diversity that bore him. As an intelligent being, he has not only the privilege of using this diversity to his advantage, but also the responsibility of preserving it.

Effective Population Size

The outcome as well as the rate of various evolutionary processes (selection, extinction, fixation, inbreeding, etc.) in organisms is influenced to a considerable extent by the population structure. The dynamics of gene frequencies thus depend on how population size fluctuates from time to time, on the proportion of males and females, on how the reproductive success varies between individuals, on dispersal rates, on how the population is subdivided into local populations, etc. Though the exact mathematical description needed to include these is complex, the net effect can be conveniently described in terms of an ideal population, with a population size different from the actual population.

This size of an ideal population, whose rates and outcomes of evolutionary processes are identical to that of the real population with a complex population structure, is called the effective population size, Ne.

1. Unequal sex ratios:

$$Ne = \frac{4\,Nm.Nf}{Nm + Nf}$$

where Nm and Nf are the number of males and females, respectively, in the population.

2. Fluctuations in the population size:

$$1/Ne = 1/y\ (1/N1 + 1/N2 + \ldots + 1/Ny)$$

where the population size in the first generation is N1, ... and in the yth generation is Ny.

Ne is called the harmonic mean of N1 ... Ny.

3. Variation in reproductive success:

$$Ne = \frac{4N - 2}{Vb + 2}$$

where Vb is the variance of the number of offspring per individual.

4. Dispersal within the population:

$$Ne = 4.n.Vd$$

where n is the population density and Vd is the variance of the distance between place of birth and place of breeding.

5. Subdivided population:

$$N_e = NH + N/4(E + m) + N.NH/(E + m)$$

where N = the number of subpopulations

NH = the harmonic mean of the population sizes

E = the extinction rate

m = the migration rate.

References:

1. D. L. Hartl, (1981).
   A Primer of Population Genetics
   Sinauer Associates Inc.

2. J. F. Crow and M. Kimura, (1970)
   An Introduction to Population Genetics Theory
   Harper and Row.

Heterozygosity and Fitness

The classical model of genetic variation is one of homozygosity at most gene loci of wild type individuals. However, recent electrophoretic studies on gene loci of several individuals of a species have shown that this model does not hold true. Most of the gene loci were heterozygous for the alleles studied, giving rise to what is known as the balanced model of genetic diversity. This model postulates a high percentage of heterozygosity at many gene loci. The same electrophoretic studies have discovered heterozygosity ranging from 3.6% in mammals to 34% in plants. The low degree of heterozygosity in mammals, compared to plants, may be attributed to the lower effective population sizes in the former.

Heterozygosity has been found to confer greater disease resistance in people having sickle cell anaemia, greater hatching success in the pigeon species Columbia livia, and greater survivorship and growth in the ribbed mussel Modiolus demissus, the coot clam, and the American oyster. The cheetah in South Africa, an endangered species, has an extremely low sperm count, a high percentage of abnormal sperm, a very low birth rate, and a high juvenile mortality rate. Almost all of the 250 gene loci electrophoretically studied were found to be homozygous, compared to extremely low homozygosity in other cat species!

Although this seems to prove that heterozygosity is positively related to the fitness of a species, there is evidence that apparently thriving homozygous populations also exist. The elephant seal, which almost went extinct and is now extant in large numbers, has a very large number of homozygous gene loci. Similarly, a species of gopher, lizards on small islands, and a facultatively self-fertilized snail have been found to be largely homozygous at their gene loci. Whether these species are as resilient in recovering from setbacks as more heterozygous species has yet to be observed.

The conflicting evidence has led to dispute about whether genetic heterozygosity does indeed confer increased fitness. Although the balanced model is generally accepted, the amount of heterozygosity that is favourable has not been found or conclusively proved.

Neutral Theory of Genetic Diversity – I

The theory of evolution by natural selection emphasizes the importance of adaptation. Individuals with qualities which make them better suited to their environment tend to increase in numbers – as demonstrated by the example of industrial melanism. The selectionist view, expressed in terms of events at the molecular level, thus suggests that most of the alleles which are present in high frequencies are present because of the selective advantage they confer on the organism.

The neutral theory of molecular evolution, on the other hand, asserts that a majority of the alleles are fixed in the populations merely as a result of chance events, and have very little or no selective advantage compared to the alleles which they replace.

The difference is shown quantitatively in the expression for the probability of fixation (u) of a single allele with selective advantage S, in a population of N individuals, with an effective population size Ne.

$$u = 1 - Exp(-4Ne.S.1/N) / 1 - Exp(-4Ne.S)$$

When Ne . S << 1, it is seen that u = 1/N, independent of the selective advantage. The neutral theory thus asserts that for the majority of the alleles which are eventually selected, the selective advantage is so small that Ne . S << 1.

The neutral theory predicts that the rate of replacement of alleles in the population is proportional to the mutation rate alone, together with the probability that the mutation is selectively neutral. The following patterns of mutant substitution, observed from the protein sequences and gene sequences, can be satisfactorily explained by the neutral theory, while some of them are inconsistent with the selectionist point of view:

1. The rate of evolution (rate of amino acid substitution) for a particular class of proteins is nearly constant across species, independent of the population size and structure.

2. Functionally less important molecules evolve at a faster rate.

3. Synonymous substitutions have a higher rate of evolution than amino acid changes.

4. Pseudogenes have a higher rate of evolution than normal genes.

5. At the levels of individual nucleotides, the rate of substitution at the third position is higher than that at the other two positions.

It is evident that the neutral theory automatically accounts for genetic diversity, since existence of polymorphism is natural consequence of the process of random fixation of selectively equivalent alleles.

References:

1. M. Kimura, (1969). Nature 217, 624.
2. M. Kimura, (1979). Scientific American 24/15 94.
3. M. Kimura, (1983). The neutral theory of molecular evolution. Cambridge University Press, Cambridge.

Neutral Theory of Genetic Diversity - II

In a population with effective size N, the mean number of generations for fixation of a neutral allele is 4N, with a standard deviation about 2N. The mean for extinction, on the other hand, is 2log 2N, with a standard deviation of 4N*0.5 ("*" symbolizes "to the power of" For a population of 10*5 individuals, the number of generations for fixation is 4 x 10*5, while for extinction, only 24, but with a standard deviation of nearly 1200. Selectively neutral mutants persist for a long time, and thus contribute to genetic diversity.

The genetic diversity of a population can be characterised by the parameter H (heterozygosity, i.e. the proportion of individuals that are heterozygous). If the frequencies of different alleles are P1, P2, ..., Pn, then H = 1 - [illegible]. If m is the mutation rate, and if every mutation produces a different allele, it can be shown that

$$H = 4Nm / (4Nm + 1)$$

Typically, N is about 10*5, m = 10*-7, and the value of H is nearly equal to 0.04 or 4%. The neutral theory also predicts that the proportion of alleles with frequency x is 4Nm.x*-1.(1 - x)*(4Nm - 1). Thus, if heterozygosity, H, is known, 4Nm can be computed from H, and used in the above formula. The agreement with observations is satisfactory, except for very rare alleles, which are much more than predicted. The predicted relation between variance of heterozygosity and the mean heterozygosity is also consistent with the data.

Of the alternative explanations for genetic diversity, the heterozygote advantage is contradicted by the data on haploid organisms, which show high diversity. The variable environment hypothesis is contradicted by the high diversity found in the species inhabiting the deep sea bottom. There are a lot of conflicting data about frequency-dependent selection.

In summary, the neutral theory of molecular evolution seems to satisfactorily explain the existing genetic diversity.

References:

1. F. J. Ayala, (1974). American Scientist 62, 692.
2. F. J. Ayala and J. W. Valentine, (1979) Ecology 60, 24.
3. R. Milkman, (1973). Science, 182, 1024.
4. G. S. Mani, ed. (1984). Evolutionary Dynamics of Genetic Diversity. Lecture Notes in Biomathematics, Springer Verlag.

Inbreeding Depression

Inbreeding is the mating of related individuals, resulting in a large number of genes that are common to most of the individuals of the inbreeding population. Inbreeding always results in a shift towards homozygosity and away from heterozygosity. Due to this shift, deleterious recessive genes are expressed more often in inbreeding populations than in outbreeding ones, which are more heterozygous. This decrease in overall fitness of an inbreeding population is known as inbreeding depression. This depression is not random in its effects. It selectively affects those alleles which 1) show strong dominant-recessive characteristics, or 2) have a low percentage of heritability; e.g. age at sexual maturity sperm count, etc.

Inbreeding depression is a well-established phenomenon When Chinese swine in the 1930's were inbred, litter size dropped from 7.15 to 4.26 in the second generation alone. Survivorship also plummeted, and the experiment had to be discontinued. Sewall Wright, in 1977, inbred 35 lines of guinea pigs. After 9 years of inbreeding, only 50% survived - the rest went extinct. Of those that survived, only 5 lines were vigorous enough to continue breeding, and their fecundity was 3% that of the control!

However, a few species seem to be unaffected by inbreeding depression. Domesticated fowl, which have long been inbred, show fewer effects of inbreeding than other wild, gallinaceous birds It has been hypothesized that this is due to deleterious genes having been weeded out by mortality early on in the inbreeding process, leaving only beneficial genes. The same argument has been applied to explain the apparent vigour of Hindu families in Andhra Pradesh which have a regular custom of maternal uncle-niece marriages.

Another phenomenon must be noted at this point - that of outbreeding depression. Sometimes, outbred animals have been found to have lower fitnesses than relatively inbred ones. For example, in a study in which bobwhite quail in the southern

United States, adapted to warm weather, were hybridized with northern cold-adapted bobwhite quail, it was found that the hybrids fared worse than either pure species in the colder northern climate. This has been held to be due to the coevolution of gene groups to adapt to certain environmental situations (e.g. climate). These gene groups lose their effectiveness in conferring enhanced survivorship when they are separated by outbreeding.

Extinction

What are the rates of extinction of species? How likely is a species to go extinct? Is extinction a cyclic process, and, if so, on what does it depend? These are questions that must be answered if the race to conserve diversity is to be won.

By studying the fossil record, it is possible to estimate the length of time during which a single species was extant. For example, one genus of pelecypods was observed to have lasted for 78 million years, so its rate of extinction was 1/78. The rate of extinction differs for different genera, because the number of species in each genus differs, and this affects the speed at which a genus goes extinct.

The exponential equation for the number of species at the end of time t may be expressed as follows:

$$N = No \cdot e^{*rt}$$

where N = the number of species after time t

N_0 = the initial number of species

r = the rate of speciation - the rate of extinction

t = time, in years or millions of years.

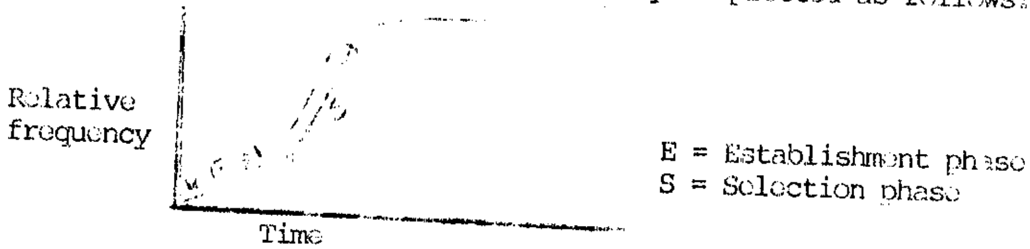
Another important concept in the study of extinction is expressed by van Valen's law, which states that every species is as likely to go extinct as every other species, regardless of how long it has been around.

Finally, is extinction cyclic in nature? There is some evidence that this might be so. When the percentage of extinctions is plotted on a graph against time, a series of peaks is seen at intervals of roughly 26-30 million years. These intervals are on the time scale of astronomical events. Hence, some scientists have hypothesized that meteoric, cometary or solar events have left a series of extinctions in their wake. Large amounts of iridium have been found on the earth's surface that correspond to those periods of extinction. This appears to lend some weight to the theory.

Studies of past extinctions - their causes, rates, and patterns - may give us a clue to understanding the present ones. And with that understanding, perhaps we can stem the flood of disappearing species from our earth.

<u>Evolution of Sex</u>

In this lecture, theories that explain why sexuality or diploidy arose are discussed. The increase in relative frequency over time of an advantageous mutation may be plotted as follows:



If the establishment phase in a certain population takes longer than the selection phase, then a sexual population has an advantage over an asexual one because individuals can interbreed often and with many individuals, to propagate the advantageous mutation. This raises the frequency of the advantageous mutant much faster than by asexual means, where the haploid individual can propagate an advantageous mutation in its genetic make-up only by self-propagation. However, if the selection phase is longer than the establishment phase, then it does not matter if individuals are haploid or diploid, since selection pressures will apply equally to both. Hence the establishment-selection hypothesis cannot fully explain the evolution of sex or diploidy.

A second argument for diploidy is illustrated by "Muller's ratchet": a haploid population is a one-way evolutionary process and, like turning a ratchet, its direction cannot be reversed. Beneficial genes arising by mutation are carried on until they are lost by another mutation, and so are deleterious ones. In a diploid population, however, recombination and spread of genes by mating will ensure that beneficial genes stay in the gene pool, and deleterious ones are at least masked, if not removed. Clearly, then, diploidy has great advantages over haploidy.

Another case where diploidy has the advantage is in a changing environment. Genes can be recombined much more rapidly by sexual means than by asexual means. When the environment becomes deleterious for a particular gene combination, a haploid population could become extinct, whereas if a diploid population has time to breed, a few of the reshuffled gene combinations might survive the change and continue to propagate.

In general, it may be said that haploid, asexual organisms are to be found mostly in simple habitats, where the environment is constant, and selection pressures are not strong; in such limited conditions, they can viably compete with diploid organisms. Diploid, sexual organisms, on the other hand, are t be found everywhere, and fare significantly better than haploid ones in complex, changing environments, where their ability to reshuffle their genes rapidly is an advantage.

Genetics and Conservation - the Short- and Long-Term Implications

When a population goes through a bottleneck, both heterozygosity and alleles may be lost. The heterozygosity lost is expressed as 1/2N, where N is the number of individuals in th population. The fraction of heterozygosity remaining is therefore 1 - 1/2N. This heterozygosity or genetic variance will be greater if a larger number of individuals survives to breed after the bottleneck. Also, a rapidly-reproducing population can introduce a larger amount of variance than a slower one. A bottleneck is therefore not as deleterious for an r-selected population as for a K-selected one.

Can inbreeding depression as a result of a bottleneck be overcome? A general rule of thumb holds that if loss of variance in a population is less than 1% per generation, then that population is viable, at least in the short term. This is expressed by:

$$\Delta F = 1/2Ne >= 1\%$$

where ΔF is the per generation rate of loss of heterozygosity and Ne is the effective population size. This means that Ne must be greater than, or equal to, 50 individuals for short-term conservation. This number is a useful figure on which to base conservation measures for an endangered species, so as to ensure at least a short-term viable population.

There are two theories on the evolutionary potential of a species: phyletic optimism and phyletic empiricism. The theory of phyletic optimism holds that there is always sufficient variation in nature to produce evolutionary novelty, which is brought about by phyletic evolution. Phyletic empiricism holds taht genetic variation in natural populations may not always be sufficient to produce evolutionary novelty. The variation may be insufficient if the population has passed through a bottleneck in its past, for example; hence, genetic variation of a natural population depends on its history and population structure. A large population is therefore always necessary to ensure that there is sufficient evolutionary potential for novelty to arise by speciation.

Franklin, in 1980, studied bristle characteristics in Drosophila, and found that there was equilibrium between loss and gain of alleles when 1/2Ne was greater than or equal to 0.1%, i.e. when Ne was greater than or equal to 500. His studies appear to support the theory of phyletic empiricism by indicating that an Ne much larger than 50, namely 500, is required for evolution to reach equilibrium. The standard deviation for drift is expressed by pq/2Ne , where p and q are the frequencies of the dominant and recessive alleles, respectively, and Ne is the effective population size. The change in frequency of the recessive allele, Δq, is calculated by:

$$\Delta q = (-s)(q*2)(1-q)$$

where s is the selection coefficient against the recessive allele, q.

In conclusion, we can say that the few and somewhat inadequate experiments that have been performed seem to indicate that a minimum of 50 individuals are required for short-term conservation, and a minimum of 500 for long-term conservation, in order to have an evolutionarily stable population. Although the numbers are somewhat arbitrary, having arisen from the study of a few species only, they are better than nothing. We can use them, with judgement, to serve as the bases on which to build conservation strategy.

Species Diversity and Diversity Gradients

It is obvious that, before we attempt to conserve biological diversity, we must try to understand how much biological diversity exists on earth, how it is distributed, and what factors determine the levels of biological diversity. Ten million is a common estimate for the total number of species of living organisms that may be present on earth. A very large proportion of these are insects and indeed, there are more species of beetles than any other kinds of organisms! Why ten million, and why so many beetle species? In order to simplify matters, let us ask a simpler question: what determines the number and composition of species in a particular community? Is it possible to predict these, or the consequences of removing or adding some species? Do the members of a biological community come together merely by chance, or are there underlying biological processes that lead to well-defined, structured communities?

It may sound surprising, but we are only just beginning to approach these questions, and have no more than vague answers. Even the precise definition of a biological community is not easy. A community is usually defined as an assemblage of mutually interacting species. But biological species usually interact with their neighbours, so that it is not clear where one community ends and another begins. The presence of obvious natural boundaries is usually helpful, because we can speak of the biological community in a freshwater pond. In the absence of any such natural boundaries, the species area curve is usually ne of the methods of delimiting a community.

The definition of diversity is also a matter of some difficulty. The most commonly used index of diversity is usually the number of species, and is called alpha diversity. This, however, does not take into account the relative numbers of individuals of the different species constituting a community (beta diversity). For instance, two communities are rated equally if each has two species, although in the first community 50% of the individuals may belong to each species, while in the second community, 99% of the individuals may belong to a single species and only 1% to the other species. It is clear, therefore, that a good index of diversity should consider both alpha and beta diversity. Two commonly used indices of diversity which satisfy these criteria are:

the Simpson's Index: $= 1 - \sum_{i=1}^{S} pi*2$

where pi is the proportion of individuals belonging to the ith species, and S is the total number of species; and

the Shannon-Weiner Index: $H' = - \sum_{i=1}^{S} (pi. \ln pi)$

Here, if each species is equally abundant, the maximum value of the diversity index is obtained by $Hmax = \ln S$. Thus, $H'/Hmax = E$, a measure of the equitability of species in the community.

Many broad generalisations can be made regarding the distribution of animal and plant species diversity on earth:

1. A gradient of increasing diversity is usually seen as one

moves from the poles to the equator.

2. Diversity usually increases as one moves up the slope of a mountain.

3. Terrestrial communities normally have greater diversity per unit area compared to marine comminities.

4. Islands usually have lower diversity per unit area compared to continents.

5. Habitats with extreme environmental rigour, such as hot springs or polar deserts, usually have very low diversity.

6. In benthic communities in the oceans, shallow regions have low diversity, while deeper regions ahve higher diversity.

7. One notable exception is that freshwater planktonic communities are more diverse in temperate regions compared to their tropical counterparts.

8. Other exceptions may arise when we look at specific groups. For instance, Ichneumonid wasps are more diverse in temperate regions than in the tropics.

Niche Theory of Diversity and Productivity-Stability Hypothesis

A number of factors have been invoked to explain the observed patterns in the distribution of biological species diversity. Most of these hypotheses usually explain only the patterns observed in a particular situation. There does not yet appear to be any satisfactory general theory applicable to a wide variety of situations. Some of these hypotheses are discussed the community. What the predator does is to harvest these dominating species and keep their numbers low. This permits even those species which are inferior at competing for space to coexist in the community. However, this does not always work: the introduction of a predatory fish, Cichla ocellaris in Gatun lake in Panama resulted in a drastic reduction in diversity (Zaret and Paine, 1973).

4. The latitude-area hypothesis: it is interesting that due to the spherical shape of the earth, there is much more area (both water and land) in the tropical than in the temperate regions. This might itself permit greater population sizes and higher diversity in the tropics (Osman and Whitlatch, 1978). In addition, the cloud cover over the equator gives it a uniform temperature (Terborgh, 1973).

5. Succession hypothesis: Studies of deciduous forests in eastern North America show a clear increase in tree species diversity with succession (Monk, 1967). It is, of course possible that succession is associated with changes in other environmental factors such as soil moisture and calcium levels which might, in turn, affect species diversity.

6. Habitat heterogeneity hypothesis: an intermediate level of disturbance might actually promote diversity in the tropics, by increasing the heterogeneity in the habitat and thus creating more niches. MacArthur (1965) has argued that there may be more species in the tropics both because of an increase in the number of species per habitat as well as an increase in the number of

habitats per unit area.

7. The competition or niche diversification hypothesis: it is usually believed that two species having identical niches cannot coexist; one will eliminate the other. However, there are a variety of examples of organisms changing their morphology, physiology and behaviour during coexistence with other species having similar niches, and this could explain some of the patterns observed in diversity.

Biogeography I and II

Why do novel species, genera, families, orders, classes, phyla evolve? By coming up with novel ways of life that enable organisms to take advantage of newly arising opportunities. Such opportunities would be particularly abundant when the environment, physical or biological, is changing rapidly. Mammals originated some 200 million years ago by taking advantage of the newly abundant insects, especially by feeding on them at nights when reptiles could not be active. For the first 130 million years they remained at low levels of diversity with rates of origin of genera around 1 per million years. With the breakup of continents and rapid climatic changes that began 65 million years ago, these rates climbed to 50 to 100 million years, and later to an incredible 800 per million years in the early Pleistocene, followed by a crash in the late Pleistocene.

What determines the range of distribution of various taxa?

genera: Anathana, Melursus, Platacanthomys, Tetraceros, Bosephalus, and Antelope. Notably, these are Peninsular species, since this tract provides habitats largely absent in other parts of the Oriental region. The overall diversity is, however, highest in the northeast, and in the Western Ghats tract. We shall examine this with respect to primate distributions:

Region	# of species	# of restricted species
Punjab	0	0
Gangetic	2	0
Western Peninsula	3	0
Eastern Peninsula	3	0
Western Ghats	6	2
Ladakh	0	0
Himalayan	4	1
North-Eastern Hills	6	2

From the table, it is observed that the Western Ghats and the North-Eastern Hill region are richest in the number of primate species, and both contain the largest number of restricted species, i.e., species restricted to that region alone.

Studies of the biogeographical distribution of species raise many questions for conservationists - how can we conserve the total biological diversity? Will it be conserved by conserving samples of all biomes? Will it be conserved by conserving representative samples of each biome in each biogeographic province? The studies cannot provide answers - but they do provide data which we can use in decision making for conservation.

Island Biogeography I and II

Islands provide a relatively simple and consequently attractive situations for studying the distribution of biological diversity. The first and, to date, the only serious attempt to develop a general theory of island biogeography was that of MacArthur and Wilson (1967). Their theory states that the number of species on an island is determined by an equilibrium between the rates of immigration of new species and extinction. It follows that islands which are closer to the mainland should have more species than distant ones because immigration to closer islands would be easier. It also follows that larger islands should have more species than smaller ones, because extinction would be less likely on larger islands where larger populations can be maintained. These three predictions of the theory of island biogeography have been repeatedly verified. The most interesting empirical studies are certainly those of Simberloff and Wilson (Simberloff and Wilson, 1969, 1970; Wilson and Simberloff, 1969; see also Simberloff, 1974; Williamson, 1981) who used methyl bromide to defaunate small mangrove islands and later followed their recolonization.

Minimum Viable Populations

A quantitative understanding of the relationship between the size of a population and its chances of extinction is necessary for planning conservation strategy. A minimum viable population is one that can not only maintain itself under average conditions but can also withstand the numerous stochastic or random perturbations to which it is subject, without going extinct. The concept of a minimum viable population is required to obtain actual figures to use in conserving populations.

There are four types of stochastic processes that can cause a population to go extinct:

1. Demographic stochasticity arises from chance events in the survival and reproductive success of a finite number of individuals.

2. Environmental stochasticity is the temporal variation of habitat parameters and the populations of competitors, predators, parasites and diseases.

3. Natural catastrophes; these are floods, fires, droughts, etc. which may occur at random intervals through time.

4. Genetic stochasticity results from changes in gene frequencies due to the founder effect, random fixation, or inbreeding.

How is a minimum viable population estimated? There are three possible ways: 1) by experimentation, which is usually impractical in reality; 2) by examining biogeographical patterns of species on islands or in insular areas. By this method, one can estimate the minimum area required for a species, its density, and therefore the minimum viable population size of that species, and 3) by computer simulation models; these can be very useful in plotting the extinction of a population based on quantitative data.

Extinction rates of land birds have been estimated by observing their biogeographical patterns on oceanic versus land-bridge islands (i.e. islands which were connected to the mainland by land bridges until the last glaciation). The following observations were made:

1. Below an island area of 250 sq km, the two types of islands were indistinguishable in the number of species they contained.
2. However, on the larger islands, there were more species on the land bridge islands than on the oceanic islands.
3. On islands with areas greater than 2500 sq km, the land-bridge islands had three times the number of species on the oceanic islands.

Schaller (1978) used the computer simulation approach on a grizzly bear population in America. Genetic information being inadequate, and natural catastrophes unimportant, he restricted his analysis to a study of the demographic and environmental stochasticity, and found that populations of less than 30-70 bears have a less than 95% chance of surviving for even a 100 years. Survival was most affected by changes in mean mortality rate, cub sex ratio, and age at first reproduction of female bears.

Terborgh (1974) has formulated the following expression to obtain the decrease in the number of species over time:

$$-\frac{dS}{dt} = k \cdot S*2$$

where k is the extinction coefficient, and S is the number of species (squared to account for the effects of interspecific competition). The coefficient of extinction, k, can be obtained from:

$$k = \left(-\frac{1}{Sp} - \frac{1}{So}\right) / t$$

where Sp is the final number of species present, So is the initial number of species, and t is the time elapsed.

A recorded case study of extinction is found in the Barro Colorado Island which became an island in 1914 following construction of the Panama Canal. In 1920, bird surveys conducted by Chapman revealed the number of species of breeding birds to be 208. By 1970, 45 of these had become extinct, and several more had become rare or endangered. The number of species calculated to have gone extinct in these 50 years was 16.6. The observed value was 13 to 18 species, a fairly close fit. Of those that went extinct, 15 species were either large for their trophic class or were species that forage or nest on the ground. Since the area of the island could not sustain large carnivores, a large number of nest robbers such as peccary, opossum, monkeys and the coati mundi became unusually abundant.

Based on the above and on other studies, it has been observed that certain species are especially vulnerable to extinction. These are:

1. Species on top of the trophic rung, and the largest members of guilds.

2. Widespread species with poor dispersal abilities.

3. Continental endemics, e.g. Barbour's map turtle, inhabiting a few rivers in Florida, USA.

4. Endemics of oceanic islands.
5. Species with colonial nesting habits, e.g. passenger pigeon.
6. Migratory species.

Diversity Information System

If biological conservation is to be successful in the long run, a good deal of effort has to be taken, besides all scientific planning, to create local awareness of the need to conserve life forms. One of the most effective ways of creating local awareness is teaching children the various facts of nature. Since most schools in Uttara Kannada are open to such educational programmes, nature camps have been organized and conducted through many schools. Usually, they have been one or two day programmes, where high school students are taught to identify birds in the field, and to understand the different roles they have to play in the ecosystem. The need to preserve species is emphasized. Birds are easy to identify in the field, and are always encountered. Further, they can be very well used to explain the various ecological principles that mould organisms into their niches. Therefore, bird watching has played a central role in all the nature camps. An hour-long lecture clarifying doubts regarding what the children have seen or experienced in life about birds or other organisms usually precedes or follows the field trip. Whenever possible, this is done through a slide show. Generally, about 30 students (girls and boys) from the 9th and 10th standards are selected for the programmes. Such nature camps have been conducted in the following high schools, so far:

1.	Vanalli High School, Vanalli	Feb. 2, 1985
2.	Yedahalli High School, Yedahalli	Jan. 18-19, 1986
3.	Ave Maria High School, Sirsi	Feb. 28, 1986
4.	Salkani High School, Salkani	May 10-11, 1986
5.	Sarkulli High School, Thattikai	Oct. 2, 1986
6.	Masur High School, Masur	Nov. 30, 1986
7.	Hindu High School, Karwar	Dec. 7, 1986
8.	St. Michael's School, Karwar	Dec. 6-7, 1986

Besides these, there were slide shows in Valley School (Bangalore), Kendriya Vidyalaya (Yeshwantpur), and in the Metallurgy Department of Indian Institute of Science for a set of school students in June, July and September 1986 respectively. Also, a lecture on bird preservation was delivered at the Government Arts and Sciences College at Karwar on Dec. 8, 1986. More than 60 students and staff from various disciplines attended the programme.

A five-day lecture programme was organized for the students of the Indian Institute of Science, Bangalore. All lectures were in the evenings between 6:00 and 7:00 pm at the seminar hall of the Centre for Ecological Sciences. Between 30 and 40 research students attended each day, and there were a few outsiders too. The following topics were covered during the brief course:

1. Bird migration
2. Birds and their habitat
3. Birds and their environment

4. Bird songs - their significance
5. How to identify birds in the field.

As a kind of teaching aid, sets of cards titled "Know your birds", illustrating 15 common birds of Uttara Kannada in colour, and carrying details of their food, habits, etc. behind the illustrations have been prepared. These have been distributed in schools where nature camps have been conducted.

Conserving Rare, Endemic and Keystone Species

A species may be rare for a number of reasons:

1. Its required habitat is spatially a small proportion of the total habitat.
2. Conditions for successful regeneration of the species occur infrequently.
3. The species is a recent immigrant from outside population centres.

It has been found that a greater fraction of rare species are specialized by regeneration niche (moderate or extreme heliophiles, for example) than are specialized by habitat. About one third to one half of all rare species do not have self-maintaining populations, but depend on immigration for their continued existence in a given locality.

Most of the rare and endemic species of the world are found in tropical rain forests. The problem of conserving them is thus inseparable from the problem of conserving tropical rain forests.

Hence, further discussion of rare and endemic species conservation will be included in the following lecture, "Conserving Ecosystems - the Problems of Tropical Rain Forest Conservation."

Conserving Ecosystems - the Problems of Tropical Rain Forest Conservation

Tropical rain forests are biologically and ecologically the most complex and diverse biomes on earth. Although they cover only 7% of the earth's land surface, they contain about 50% of all species! It is therefore regrettable that the tropical rain forests of the world are being destroyed at a faster rate than any other biome. The original climax evergreen forests have been estimated to have covered about 16 million hectares of land. Today, only about 8.5 million hectares remain.

The rate of use and abuse of this resource is staggering. A total of 76,000-92,000 sq km of forest is being cleared every year, and a further 100,000 sq km is being grossly disrupted. That is, 1% of the biome is being destroyed, and another 1% modified, each year. The processes contributing to the decline are estimated below:

Process	Area lost (sq km)
1. Fuelwood gathering	25,000
2. Cattle ranching	20,000
3. Commercial logging	45,000
4. Small scale cultivators	remaining

At the present rate of depletion, apart from protected areas, there will be no rain forest left in most parts of the world by the end of the century. Only the two major rain forest regions, Brazil and Zaire, will still remain forested.

Tropical rain forests are among the richest on earth in the number of species they contain. Consider two examples: the forests in Ecuador contain 20,000 plant species, compared to 13,000 in Europe, which is 31 times as large as Ecuador. The forests of Costa Rica, area 52,000 sq km, contain 8000 plant species, compared to 1443 in Great Britain, which covers an area of 244,000 sq km.

A unique feature of species richness is that, even within the tropics, both plant and animal species are unevenly distributed in the biome. There are certain areas which are exceptionally rich, and others relatively poor, in species. Some of the richest areas are found in tropical Latin America's wettest portions, while the poorest are large tracts of Zaire's 1 million sq km of forest. Even within Latin America, at least 26 localities are unusually rich in species, many of them coinciding with the so-called Pleistocene refugia. Similar refugia exist in other parts of the world, including Indonesia, Madagascar, Malaysia, the Philippines, and Sri Lanka. In Sri Lanka, about 800 endemic plants occur within a 2,500 sq km area, and in Madagascar, 80% of the 10,000 forest plants are endemic,

Not only do tropical forests have greater species richness they have, on the whole, higher levels of genetic variance (heterozygosity) also, compared to temperate species.

The wealth of genetic diversity and species richness found in tropical rain forests is unparalleled, unique and irreplaceable. If we do not realize this and take steps to save them, these forests and all they contain will be lost to us forever.

Edge Effects and Diversity

An ecotone is a transition between two or more diverse communities as, for example, between forest and grassland or between a soft bottom and hard bottom marine community. It is a junction zone or tension belt which may have considerable linear extent but is narrower than the adjoining community areas themselves. The ecotonal community commonly contains many of the organisms of each of the overlapping communities and, in addition, organisms which are characteristic of and often restricted to the ecotone. Often, both the number of species and the population density of some of the species are greater in the ecotone than in the communities flanking it. The tendency for increased variety and density at community junctions is known as the edge effect.

Communities frequently change very gradually, as along a gradient, or they may change rather abruptly. In the latter case a tension zone would be expected between two competing communities. What may not be so evident from casual observation is the fact that the transition zone often supports a community with characteristics additional to those of the communities which adjoin the ecotone. Thus, unless the ecotone is very narrow, some habitats and, therefore, some organisms are likely to be found in the region of the overlap which are not present in either community alone. Since well-developed ecotonal communities may contain organisms characteristic of each of the overlapping communities plus species living only in the ecotone region, we would not be surprised to find the variety and density of life greater in the ecotone (edge effect). Furthermore, some species actually require as part of the habitat, or as part of their life history, two or more adjacent communities that differ greatly in structure. Organisms which occur primarily or most abundantly or spend the greatest amount of time in junctions between communities are often called "edge" species.

<u>Should We Have a Few Large, or Several Small Reserves?</u>

Simberloff and Abele (1976) argued that the traditional view, that reserves should be as large as possible, was not entirely correct. The available data on island biogeographic relationships is scanty, and should not be taken as an absolute in planning for conservation.

As evidence, the two scientists presented a mathematical model which showed that two small reserves may have more species than one large reserve of equal area. Secondly, an experiment was conducted in which five mangrove islands were studied. A census of the arboreal arthropod communities inhabiting them was taken in 1971, and the experimental islands were subsequently converted into archipelagoes of smaller islands by excavation. Two archipelagoes, consisting of four and two islands were then defaunated by fumigation. After a three-year period, during which equilibrium was judged to have been attained, a census of the arboreal arthropods was again taken. The results showed that a cluster of small refuges might be expected to contain more species than a single large refuge.

Simberloff and Abele supported their argument for many small reserves against one large one by the following:

1. Catastrophes such as fire or disease would affect a single reserve more than several small ones. For example, the rinderpest outbreak in Africa decimated large numbers of all kinds of animals. The epidemic was finally prevented from spreading by killing all game in a belt 50 mi wide by 167 mi long between Lake Tanganyika and Lake Malawi.

2. Each small refuge maight save a different member of a set of mutually exclusive competitors, which would not be so in a single large reserve.

3. Increased rates of extinction in smaller preserves could be more than compensated for by reinvasion from neighbouring small islands.

Simberloff and Abele's argument generated wide controversy, and several refuted it. Their arguments:

1. The kind of species in a refuge is at least as important as

the total number of species. A refuge system that conserved many species of starling and house rats, for example, while losing a few like the bobcat or timber wolf, would be disastrous.

2. Recolonization, which may be possible with neighbouring mangrove islands, is <u>not</u> possible when insular refuges are surrounded by human settlement. The only possible process is extinction. Simberloff and Abele's argument that recolonization would make up for extinction glosses over the fact that the aim of conservation is to prevent extinction in the first place.

3. Island biogeography has already clearly established that certain species are more extinction prone than others, for example: K-selected species, those with large body size, those at the top rung of a trophic ladder, etc.

4. Fugitive species (early colonising or early successional) may survive better than regular inhabitants in several small refuges. This argument is not very relevant since fugitive species thrive anywhere, even in the absence of refuges.

5. Last, but not least, small refuges would be too small to permit speciation to occur, and thus would cut off the source of future diversity.

<u>Culture and Conservation I and II</u>

Since man has such a marked effect on his environment, we will examine how diversity is conserved or destroyed through his agency, with a special focus on the Indian subcontinent.

Are there prudent predators in the animal world? Slobodkin and others have concluded that natural selection does not favour prudence, and in fact all animals have been observed to hunt in such a way as to maximize the ratio of food obtained to energy spent obtaining it. The only possible exception is the leaf-cutter ant, which does not strip the trees around its nest of all their leaves and range further in its search for leaves to culture the fungi on which it feeds. Rather, the entire population ranges over a large area and only cuts a few leaves from each tree. No-one quite knows whether this is due to prudence or territoriality.

Humans are famous for their imprudence; nevertheless, they are the only species known to deliberately use resources in a sustainable fashion. A whole range of conservation practices that arose among hunter-gatherers in early times may be broadly classified under "nature worship". Religion provides a strong, enforceable justification for preserving species which may have had a long-term rather than a short-term use. Frazer's "Golden Bough" (1922) gives details on many tribal taboos on killing animals of a certain species, sex, age, stage of maturity, etc., and on cutting of trees.

The remnants of nature worship still persist in India. There are many sacred groves, forests, ponds, stretches of river, etc. that are protected from despoilation by religion. As a result, rare species have been among those conserved: in Kerala, a climber, Kunstleria keralensis, was found in a sacred serpent grove; it was the first known representative of its genus in India. In Bangladesh, the only known world population of the turtle Trionyx nigricans survives in a sacred pond which was first Buddhist, now Islamic. Several tree species which are keystone resources, also have religious protection. Ficus trees in Asia and Africa are still sacred - and many species of birds and small animals use it for food and shelter. Five hundred years ago, the Bishnois, a Rajasthani sect, strictly protected all wildlife and especially Prosopis cineraria, an important source of fodder, food and fencing material. Today Bishnoi villages are islands ot greenery alive with peacocks and blackbuck in an otherwise desolate landscape.

With the spread of agriculture and a quantum leap in human population figures, a new approach to the forests arose. People burned vast tracts ot forest land for agriculture, and stripped the land for resources to feed their growing numbers. However, a few enclaves of hunter-gatherer societies still maintained and adapted old traditions. Gadgil and Malhotra (1983) conducted a study on three tribal groups, the Phasepardhis, Nandiwallas and Vaidus, in the Western Ghats. They found that each group hunted a set of prey that overlapped little with that of the other two groups. This niche diversification enabled the groups to coexist and husband their resources, and also prevented any one resource from being extensively depleted.

Belatedly, in the Seventies, a move was made toward "scientific forestry", but there was no science in it. For example, Eucalyptus and other plantations were widely propagated without pilot surveys. As a result, these introduced species often produced less timber and products than the native trees they supplanted.

It is obvious that a synthesis of the old and new is urgently called for if we are to conserve what remains of India's rich natural heritage. Conservationists and policy makers alike must once again seek to incorporate the traditional values of respect for nature into the modern, rational framework of prudent resource use.

Captive Breeding and Reintroduction

There are four major categories of captive propagation (CP): (1) stocking and replenishing zoo exhibits; (2) supplying specimens for research or experimentation; (3) for domestication or the improvement of existing stocks; (4) conservation - rescue of endangered forms and return to nature if possible. All these, except perhaps the second category, are presently carried on in zoos.

Captive propagation should attempt to minimize the following:

1. Genetic and phenotypic changes in species. These can be

minimized by mating the least related animals in each succeeding generation, providing for an equal number of offspring from each parent, and maintaining an equal sex ratio.

2. Inbreeding depression. This phenomenon is very familiar to zoo animal breeders, and manifests itself in viability depression, fecundity depression, and sex ratio depression. Inbreeding can be minimized by the same methods as in (1).

3. Behavioural changes. These must be minimized, particularly those in the direction of domestication. A close watch on the social behaviour and ecological requirements of any species is required before CP can succeed. For example, a number of waterbirds in the Bronx Zoo had not produced eggs for over five decades. In 1964, the establishment of a series of simulated waterbird habitats triggered breeding.

Unfortunately, the preservation of the majority of animals in zoos cannot be sustained on any proven economic basis. All CP programmes are highly expensive, and zoos, which depend mainly on gate receipts for funding, feel the pinch. The drive to save the California condor, for example, cost US$662,000 initially, and ran into the millions of dollars finally. Only 100-150 species of mammals can be currently raised in zoos, due to space and financial limitations.

Although reintroduction of captively bred animals into the wild would both save money and ideally conserve species, it has not been extensively tried until recent times. Reintroduction has been marked by successes as well as failures. The successes:

the European bison, released in Poland; the ibex and chamois, bred in Germany and released onto their former ranges; the Arabian oryx, bred in San Diego Zoo and released in Jordan; and crocodile and sea turtle young released into their natural habitats in India after hatching. The failures, unfortunately, are also numerous: Pere David's deer, extant only in zoos and finally reintroduced to their native China, died out there again due to habitat destruction and poaching; the Asiatic lion, reintroduced into the Chandraprabha Sanctuary in India, did not survive there. Many factors must be considered prior to reintroduction: (1) conditions in the wild habitat must be monitored and evaluated for suitability; (2) animals must be checked for any diseases they might be carrying from zoos; (3) precautions against genetic swamping by a related species must be taken; and (4) behaviour of animals must be maintained as near to natural as possible, e.g. fear of man or predators, ability to raise young, etc. Fortunately, animals have proved adaptable, so CP and reintroduction into the wild remains a viable option.

Very few species have self-maintaining populations under captive conditions. Most zoo animals still have to be replenished from the wild, and the most successful in captivity are only those, such as European bison and Przewalski's horse which have domestic relatives. Out of 291 rare or endangered species, 162 are found in zoos. Of these 162, only 61 have bred at some time or other, and only 26 are self-maintaining! Clearly, captivity is not the answer. To conserve wild species, captive propagation must be used merely as a tool to protect species in the short-term and to eventually return them to the wild, where they belong.

Ongoing Conservation Efforts in India

With the advent of World War II, and the introduction of jeeps, modern guns and DDT into India, the depletion of her forests and wildlife entered a new phase. Where before, tree-felling for fuel made innocuous demands on forest resources, jeeps could now transport hunters into forests made malaria-free by DDT, where they could shoot vast quantities of game with their newer, more efficient weapons. This led to a serious decline in wildlife, so much so that the Bombay Natural History Society persuaded the Government of India to set up the Indian Board for Wildlife. At first, this was headed mainly by members of the Indian aristocracy, who had their own interests at heart in conserving forests for hunting preserves.

Gradually, an awareness of the need to conserve diversity arose. But at first, developmental needs, and the subsistence needs of the people seemed diametrically opposed to the needs of conservation. A prime example was the Keoladeo Ghana Sanctuary. A marshy region, it was ideal for many nesting local and migratory waterbirds, and was declared a Sanctuary early on. Buffalo from neighbouring villages were allowed in to graze on the lush stands of Papsalum grass. In a flurry of conservationist fervour, the Sanctuary was closed to buffalo grazing. This precipitated a double disaster: 1) uninhibited growth of Paspalum led to a filling-in of the marshes, resulting in a serious loss of waterfowl habitat; and 2) the dense growth of dry grass in the summer posed a potentially destructive fire hazard. Only recently have conservationists realized that grazing is beneficial to the ecosystem as well.

The following table depicts the increasing awareness over time of the need to combine conservation efforts with subsistence and developmental needs:

	Conservation	Development	Subsistence
Official wildlife conservation effort	+	–	–
Government development effort	–	+	–
Kanha, Dudhwa Sanctuaries	+	–	+
Alakananda Valley, Valley of flowers	+	+	+
Ecodevelopment philosophy	+	+	+
Biosphere Reserve programmes	+	+	+

The Biosphere Reserve concept is a unique fusing of the three needs listed above. Its main objectives are:

1. Conservation of overall diversity
2. Generation of scientific research and outputs
3. Ecodevelopment

India's burgeoning population and its needs can no longer be ignored in the field of conservation. Conservation efforts must occur at the grassroots level to succeed, and this is only possible if people's basic needs are also ensured in the process of conserving biological diversity.

Conservation of the Asian Elephant

Despite the long and spectacular evolutionary history of the Proboscidea, extending back to the Eocene, there are only two living representatives - the African elephant, *Loxodonta africana* and the Asian elephant, *Elephas maximus*. While an estimated 1.3 million *Loxodonta* range over a vast area of the African continent, *Elephas* has been reduced to a number of relatively small populations comprising 36-54 thousand individuals in South and South-East Asia. At present, between 17 and 22 thousand elephants are confined to forested, hilly tracts of northwest, northeast, central and south India. They attain the highest densities in the moist and dry deciduous forests.

An "average" elephant weighing about 1.8 tons requires 27 kg dry (about 108 kg fresh) matter daily. Although the elephant is a generalist feeder, the bulk of its diet consists of plants from the following taxa - the order Malvales, and the families Leguminoseae, Palmae and Gramineae. Elephants range over great distances to optimize their diets and obtain sufficient water. The relatively large home range requirement, varying between 1? and 150 sq km annually, has important implications for conservation planning.

Conservation strategies for the Asian elephant must focus on the following:

1. Minimum viable population size
2. Minimum viable area and habitat integrity
3. Maintenance of habitat quality
4. Reduction of poaching
5. Reduction of crop damage by elephants.

We will deal with each in turn.

The minimum viable population size for animals to counter genetic variation through drift has been estimated to be 500 (Franklin, 1980; Frankel and Soule, 1981). Sukumar (1985) has estimated that the largest population of elephants in south India has 840 breeding individuals, a comfortable level to counter the loss of genetic variation through drift. Unfortunately, rampant poaching in other areas has drastically reduced the number of male elephants, resulting in a highly disparate sex ratio.

The minimum viable area for the elephant is related to the minimum viable population size and to the carrying capacity of the habitat. Sukumar (1985) has approximated that a minimum area of 4400 sq km would be needed for its long-term conservation, assuming a carrying capacity of 0.5 elephant/sq km. Enclaves of cultivation in elephant habitat have largely destroyed its integrity, fragmenting it into smaller areas. Although this prevents the rapid spread of epidemics, it must not be used as an excuse to further fragment the habitat.

never replace sanctuaries. It is mainly an additional method of conserving diversity, to be used along with methods conserving whole species and communities. With our biological diversity rapidly vanishing, every avenue that will help to preserve it must be explored.

Where elephants range over a sufficiently large area, it is not necessary to manipulate the habitat, even if this means that they will exist at only a low density. If elephants are confined within a smaller area, then some habitat management may be justified and indeed necessary to maintain habitat quality and a viable population size of elephants.

The increasing levels of poaching in recent years has begun to seriously affect the population size of elephants, especially in south India. This calls for stronger measures against poaching, to be instituted by State and Central Governments.

Partly due to the intrusion of agriculture into the elephant's habitat, there is significant crop raiding by elephants, resulting in death to farmers and damage to crops. Deterrents are expensive and/or not feasible. Fire crackers do not work. Boundary trenches are expensive, because they have to be deep and well-maintained; besides, elephants have learned to fill in the trenches by loosening mud with their forefeet. The latest deterrent, a high voltage, non-fatal electric fence, which gives the intruder a severe jolt, is effective but expensive.

Conservation of the Asian elephant, or of any other species, has to be accepted at the grassroots level in order to be effective. Unless attempts are made to solve elephant-man conflicts, the elephant is doomed to be hated and hunted.

Genetic Engineering and Conservation

With the advent of genetic engineering, a whole new area of conservation possibilities has been opened up. With a few enzymes and techniques, scientists can insert or remove genes at will, and literally create organisms to their own specifications. Although these experiments have only been carried out on the bacterial and plant level so far, these alone have found many uses, and the entire field holds great promise for advancement.

There are several possible ways in which this new technology can be used to conserve biological diversity:

1. By developing high yielding varieties of crops that produce more per unit of land, forests that would otherwise be brought under the plough could be saved.

2. Bacteria have been developed that are able to clean up polluted environments, e.g. oil slicks, etc.

3. Insects, bacteria, and other organisms may be modified to be more effective in biological control.

4. Genomic libraries for wild varieties of crops and agricultural produce will help conserve those that are rare or endangered. These libraries will also make it possible to conserve, relatively economically and in a small space, the genomes of many species.

It must be emphasized that genetic engineering is <u>not</u> a substitute for conservation, and that genomic libraries will

Computer Simulations

Computer simulations were used to demonstrate the following:

1. Unequal sex ratios reduce the effective population size and alter the probability of fixation of a favourable mutant.

2. For a population with cyclic changes in its size, the effective population size is influenced mainly by the smallest size, and low effective population size rapidly decreases the heterozygosity in the population.

3. Evolution brought about by random extinctions and speciation shows patterns quite similar to those actually seen in the phylogenetic trees constructed from the fossil record.

4. A very wide variety of forms could be generated by gradual accumulation of mutations, even if each contributes only a small change.

5. Though the species-abundance curve is log-normal, inadequate sampling leads to a distorted (log-series) pattern.

Lectures by participants

10 Nov.'86
3:30 pm Flora of Palghat district, Kerala, with special reference to conservation.
E. Vajravelu

4:15 pm Diversity and conservation of orchids in Kerala.
C. Satish Kumar

11 Nov.'86
3:30 pm Diversity and conservation of some parasitoids.
R. Velayudhan

4:15 pm Diversity and conservation of some insects colonizing weeds.
R. S. Annadurai

12 Nov.'86
3:30 pm Diversity, stability and productivity with reference to grassland.
M. K. Mishra

4:15 pm Impact of plantation crops on the bioecology of Ashambu hills.
G. Santhakumar

13 Nov.'86
3:30 pm Wildlife conservation education in India with special reference to A.V.C. College, Mannampandal.
G. Ramaswamy

4:15 pm Environmental protection through soil and water conservation and watershed management with reference to the Nilgiris.
P. Samraj

14 Nov.'86
3:30 pm Ecological studies in the Tanaji Sagar dam catchment area, Maharashtra.
P. Totali

4:15 pm Constraints in wildlife conservation.
N. A. Madhyasta

17 Nov.'86
3:30 pm Diversity and conservation of coastal birds in the Gulf of Kachchh, Gujarat.
Taej Mundkur

4:15 pm	Conservation problems in Parambikulam Wildlife Sanctuary, Kerala. P. S. Easa
18 Nov.'86	
3:30 pm	Conservation of blackbuck in India. Vasudeva Rao
4:15 pm	Wild boar and man interaction. R. H. H. Ahmed
19 Nov.'86	
3:30 pm	Environmental impact assessment. Chinmaya Rathore
4:15 pm	Floristics of Balphakram Sanctuary. Yogendra Kumar
20 Nov.'86	
3:30 pm	Sacred groves of Sikkim. A. K. Verma
4:15 pm	Social organization of Hanuman langur, and relevance to conservation. L. S. Rajpurohit
21 Nov.'86	
3:30 pm	Conservation of orchids through tissue culture. Navdeep Shekhar
4:15 pm	The Nilgiri Biosphere Reserve. R. Sukumar

Conclusion

On the last day of the course, November 22, 1986, a function was held in honour of Dr. Salim Ali's ninetieth birthday and his efforts toward people-oriented, realistic conservation. Several conservationists and ecologists attended the talks and the following luncheon.

Dr. Mohan Ram of the Botany Department of Delhi University gave a talk on "The role of Botanical Gardens in Nature Conservation", and presented slides of several rare plant species from Botanical Gardens all over the world. Dr. Ananthakrishnan, of the Entomology Research Institute, Madras, next talked about "Habitat conservation and exploitation and related species diversity of insects", illustrating his talk with data from his researches on thrips. Both Mr. Zafar Futehally, ex-Vice President of the World Wildlife Fund and Mr. J. C. Daniel, curator of Bombay Natural History Society, having known Dr. Salim Ali for many years, spoke affectionately of his contributions to nature conservation and science.

The Workshop was felt to be a great success. In a questionnaire distributed at the end of the Workshop, several participants expressed the hope that the School would become an annual feature of the Centre for Ecological Sciences.

<u>APPENDIX</u>

List of participants at the Workshop on the "First National School on Conservation Biology" - November 10-22, 1986 at the Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560012.

1. Mr. P. S. Annadurai
   Senior Research Fellow
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   Loyola College
   Madras 600034, TAMIL NADU

2. Mr. Ranjit Daniels
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   Indian Institute of Science
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