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LECTURE NOTES AND ABSTRACTS

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FIRST ASIAN SCHOOL ON CONSERVATION BIOLOGY

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List of lectures

ABSTRACTS OF POSTER SESSIONS

2. Historical Review of Conservation Efforts in Japan

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In Japan, the Tokugawa Shogunate was initiated as a feudal system separated from the emperor system as kingdom in 1603. Under the Shogunate there were many feudal lords(daimyos). The nature conservation and wildlife management were implemented by the feudal lords until 1867. In 1867, the feudal system was cancelled and the original emperor system was revived under the Emperor Meiji in 1868. The western style modernization was commenced with invited foreign professors in various fields and young able students were sent to European (particularly German) universities and institutes to study modern science and technology, law, economics, philosophy and literature, etc.

The beginning of the Meiji Era was unlawful in nature conservation which had be regulated by feudal lords in the Tokugawa Shogunate Era. However, the idea of natural monument came from Germany and a proposal on the preservation of the historic site and natural monument was submitted to the House of Peers in 1911. The Historic Site, Scenic Beauty and Natural Monument Preservation Law was promulgated after eight years(1919). It was included into the Law for the Protection of Cultural Properties issued in 1950.

The National Parks Law was issued in 1931, and it is included in the Natural Parks Law(1957)which covers National, Quasi-National, Prefectural and Municipal Natural Parks contrary to City Parks. In addition to this, the Nature Coservation Law was issued in 1972. The nature conservation areas in a broad sense include the wilderness areas and general nature conservation areas.

Besides these, Protected Forests for Science were designated based on a circular notice from Forestry Agency in 1915, but it is not legalistic.

Then, ecological problems relating to nature conservation will be discussed as follows:

1. Construction of roads in mountainous areas
2. Expansive afforestation policy, and large scale grassland establishment
3. Sustained yield forestry
4. Condition and trend diagnosis of pastures and meadows
5. Wildlife conservation
6. Application of bio-indicators
8. Urbanization and industrialization
9. Establishment of nature reserves
10. Environmental education
11. Protection od endangered species and ecosystems
12. Vegetation mapping and naturalness rating

3. ON THE ORGANIZATION OF DIVERSITY

MADHAV GADGIL

3.1 Introduction

The focus of this workshop is on the tremendous diversity of life on earth, the threats of serious loss in the coming years, and the measures that may be adopted to save as much of this diversity as we can. This is a difficult task, given the current order of affairs in this world in which an exploding human population is engaged in consuming more and more of the resources of the earth. Any reversal of these trends surely calls for a revolution in this order of things, and we shall therefore talk not only of biological diversity, its magnitude, how it is distributed, what the various forces behind its dynamics are, but also of the human impacts on levels of diversity through historical times as well as today, and how human affairs need to be ordered if we are to preserve our planetary heritage of biological diversity for the generations to come.

These of course are complex questions. We may begin our enquiry into them by asking what we mean by diversity. Now diversity lies in heterogeneity, in the absence of sameness, of monotony. But this heterogeneity is not one created purely by chance, by random processes. Rather it is heterogeneity coupled to order, to non-random distribution of whatever entities, whatever elements one may be interested in space and time. It lies in the lawful breaking of order. The world around us may be viewed as being organized at a whole hierarchy of levels. Elements at each level of this hierarchy interact to produce new structures to give rise to new entities that constitute the elements of the next level of hierarchy. Thus atoms interact to give rise to molecules, while they themselves can be decomposed into elementary particles. The diversity at any level is then a consequence of the diversity of the elements at the next lower level of organization, and the variety of configurations that these elements are capable of assuming through various interactions. Each level has of course its own emergent properties, and its own characteristic pattern of diversity. Hence, it makes equal sense to talk of diversity of biological species, as of astronomical bodies or of quarks.

3.2 Physical Universe

Let us then look at how this diversity is organized at the the whole hierarchy of levels, physical and biological. Our universe is composed of matter and energy. At the beginning of this century we learnt that these were interconvertible, that in fact thare was continual conversion of one into the other as in the interior of the sun. We now believe that our universe originated in a big bang some 15 billion years ago either out of nothing, or from a single point where all that existed was concentrated in the form of pure energy. This then is one extreme possibility of total homogeneity. Everything was either nothing, or just one concentrated blob of energy. As this blob expanded, however, matter began to condense out as water droplets condense out of vapour cooling down. Interacting with each other, this matter began to take on a variety of forms; elementary particles, which came together to constitute nuclei of variable compositions, atoms and then molecules. All this matter was put together in a diversity of forms; crystalline and amorphous solids, liquids, gases, plasmas; distributed over the universe in a great variety of forms, as galaxies, stars, interstellar matter. We live today in times of tremendous diversity. Not that this diversity is destined to last forever. According to a popular scenario, as time progresses the universe will continue to cool down, eventually reaching a temperature of absolute zero,when all energy would have been converted into matter, matter that would finally come to assume the form of stablest of atoms, those of iron. The world, physicists believe is destined to thus end as nothing but iron in form of quantum crystals. As at the beginning, the end too would be a completely homogeneous state.

3.3 Anthropic principle

Why then all this diversity in between ? A very interesting principle may be invoked to explain it. This is the so-called anthropic principle, which says that the world is as it is because man had to evolve to observe it. And man is very much a product of the diversity of life. In effect then we are saying that the physical world is as it is because it had to make possible the origin and evolution of life, first very simple; but then increasingly complex, and finally capable of symbolic communication and of appreciating the existence of the vast universe.

3.4 Elementary particles

To appreciate what this implies, let us begin with the simplest level of organization, the elementry particles. Some years ago one heard of quarks as the most elementary particles. But as matter is being studied at higher energy levels, we have come to believe in quarks too being composite, being made up of preons. Interestingly enough physicists now believe that there is an indefinite variety of preons, and perhaps an indefinite hierarchy of levels to which they could be decomposed as one reaches higher and higher energy levels. At the next level, there are at least seven, perhaps a larger number of quarks, but they are never free, just as two ends of srtings are never by themselves. The free elementary particles are the leptons, the hadrons, the baryons; more than one hundred and fifty different kinds at the lattest count. But only four are enough for the stuff we are made up of. There are the protons (made up of three quarks of charge +1/3), neutrons (made up of three quarks, two of charge +1/3 and one of -2/3) that make up atomic nuclei and pions (made up of two quarks, one of charge +1/3 and one of -1/3) that hold the particles in nuclei together, and the electrons that revolve around them. A variety of elements are created by a variable number of protons and neutrons interacting to form atomic nuclei. Some 92 of these are known to occur naturally, the upper limit being 136 beyond which the Bohr radius reaches the size of a proton. However, atomic nuclei become unstable in their configuration well before they reach this atomic number of 136, because as the nuclei grow large, the binding energy amongst the protons and neutrons within the nucleus can no longer match their kinetic energy so that nuclei begin to fall apart through the process we call radioactive disintegration.

3.5 Chemical elements

The abundance of different elements in the universe depends on the stability of the configuration of the protons and neutrons coming together to form the nuclei. It tends to decrease with increasing atomic number, but not in a monotonic fashion. The lightest element, hydrogen is of course by far the commonest in the world, quite common too are other lighter elements such as helium (atomic number 2), carbon (atomic number 6) and oxygen (atomic number 8). Of the heavier elements those belonging to the iron group are quite stable, beyond that the heavier elements rapidly become increasingly unstable. One can thus discern a process of equilibration, with different kinds of atomic nuclei changing one into another, with the more stable ones, that is, those that change into others at a lower rate achieving higher abundances. This selective process is a precursor of the process of natural selection, of such great significance in the generation of the diversity of life.

3.6 Molecules

The different atoms interact with each other. This interaction is reflected in the structure of the matter. In plasmas the atomic nuclei and electrons move around freely .In a monoatomic gas such as helium too, there is no interaction, no order either in terms of spatial position or orientation amongst the atoms constituting that gas. Only when we cool it down to temperature close to absolute zero does some short range spatial order get created amongst the atoms and the helium liquifies. We have order over medium range as any matter comes to form an amorphous solid, and order over long range as it begins to crystallise.

Atoms, not only of the same elements, but of different elements too may interact primarily by exchange of electrons; that gives rise to the next hierarchical level of organization. Here the process of equilibration, of movements of atoms from one kind of association into another is far more evident than at the level of elementary particles mentioned above. Again some molecules are more stable than others, with high binding energies, and the world tends to be rich in such stable molecules. Such for example are water, H_2O and sand and clay, silicon dioxide, SiO_2.

3.7 Crystals

Crysrtals are ordered objects of great interest, for they are capable of drawing other atoms or molecules into their fold, persuading them to accept order. That is why crystals can grow from a small seed. But to do this they need to have in their environment other molecules precisely like themselves. Living organisms have taken a giant step forward. They can grow too, but they can do so in a wide range of environments by converting other forms of molecules into forms appropriate for themselves. This flexibility is the great strength of living organisms. To accomplish this they must deal in molecules that are stable, but not excessively so, so that they can be changed from one form into another. That is why nucleic acids have binding energies of 5 to 10 kcal per mole, in contrast to water for which binding energy is of the order of hundreds of kcal per mole. Of course this water is vital to life as the medium in which all sorts of molecules can be dissolved, and moved around freely to change from one form into another.

Living organisms are highly complex aggregates, in solid and liquid phases of large molecules. Interestingly enough, for the inorganic molecules complexity implies instability; as the molecules become larger, their affinity power to add on more saturates. The largest inorganic molecules are therefore of the size of a micron, with number of atoms of the order of 10^{12}. On the other hand DNA molecules can reach lengths of one centimeter, as much as 10000 times greater. With living molecules complexity implies stability combined with flexibility.

3.8 Molecules of life

The large molecules of life are ultimately made up of a small number of building blocks; 20 amino acids, 4 or 5 nucleotide bases, a few sugars, phosphates; may be 100 in all. But the order in which these building blocks are put together is important; diversity of life is essentially an outcome of the myriads of combinatorial possibilities based on a small number of basic elements. If an average protein is 300 amino acids long, then with 20 amino acids to choose from, one can form 20^{300} or 10^{400} different kinds of proteins. Similarly if an average gene is 1000 base pairs in length, then there can be 4^{1000} or around 10^{600} different kinds of genes. These are astronomical numbers, far exceeding even the total number of elementary particles in the universe!

3.9 Genes

A living organism is a cooperative endeavour of molecules of proteins and nucleic acids, each catalysing the synthesis of the other. Given the variety of proteins and nucleic acids possible, the variety of living prganisms that may in theory be generated through different proteins and nucleic acids coming together is, for all practical purposes, infinite. Not all these configurations would of course be equally adept at producing more configurations like themselves. Some would be more successful than others, and the principle of natural selection merely states that the world should be predominantly populated by the more successful of the configurations. Since a new configuration only arises through a change, generally slight, in some old configuration, historical accidents are bound to play an important role in determining the composition of the configurations; or in other words, the kinds of living organisms in the biosphere.

How many of the 10^{600} different kinds of genes possible, do we expect to be present in the biosphere today ? The simplest of living organisms, some of the viruses have just 3 genes. But an average living creature probably has of the order of 10^4 to 10^5 genetic loci. Only about 0.1 of these loci will carry more than one kind of allele, and assuming that there are an average of 10 different alleles at each polymorphic locus, each species should carry 10^4 to 10^5 distinct genes. Now the total number of distinct species of living organisms on the surface of the earth today is of the order of 10^7. If all of them carried distinct genes, the total number of distinct genes in the biosphere today would be of the order of 10^{12}. Of course a fraction of genes will indeed be shared amongst different species so that the total number of standing stock of different genes in the biosphere today is more likely to be of the order of 10^9. This of course is a very small fraction of the potential.

3.10 Organisms and populations

This estimated one billion different genes go on to constitute the next level of organization, that of organisms. There are perhaps some 10^{13} of them living at any one time in the world, and these cluster into groups of genetically related organisms potentially capable of mating with members of the opposite sex of the same group. Such groups are made up of individuals belonging to the same species, the diversity across species tending to be much greater than within a species. The total number of such species in the world today lies somewhere between 5 to 30 million. Members of a species, perhaps averaging on the order of 1 million per species are further structured into a number of sub-groups that share the same habitat, tend to compete for the same resources and may be actual mates. Such groups are demes or local populations; these go to make up the total population of the species, the metapopulation. The total stock of diversity of the metapopulation of a species can then be partitioned into within population and between population components. The magnitude of within population component is governed by the population size, the breeding system and interactions at the genetic level. The between population component would relate to the range of environments inhabited, and the extent of intermigration between the populations. In some highly inbred, small populations like those of Ozark lizards the variation is largely concentrated between the populations, in others, including the human species the within population component may be much larger.

3.11 Biological communities

Living organisms depend on each other for food, for shelter, for services such as pollination, seed dispersal or being rid of ectoparasites. Individuals of many different species therefore cooccur and give rise to the next level of organization, the community. The limits of a community would depend on the kinds of organisms of interest, varying for instance with whether one is interested in soil microorganisms or trees. In each case an area largely homogeneous in physical parameters on the spatial scale of interest would delineate the community. Within community diversity is then best measured as species diversity, α- diversity in this case. Levels of α- diversity or ecological species packing seem largely to be governed by levels of productivity and extent of seasonal and interannual fluctuations.

Biological communities may grade one into another, gradually as when forest becomes stunted as one approaches a hill top, or abruptly as at the boundary between a freshwater marsh and forest. The mosaic of communities thus formed on the scale of some appropriate topographical pattern constitutes a landscape. The diversity of species compositions between communities making up a landscape is then the μ- diversity or ecological mosaicity. Its magnitude depends on fine scale topographic and hydrological variation.

The set of landscapes of a broad climatic zone with similar physiognomies of component communities constitute a biome, for instance tropical rain forest or alpine meadows. The species composition, however, does change along environmental gradients within a biome. This is β-diversity or ecological species turnover. Its magnitude depends on the medium scale topographic and hydrological changes.

The set of biomes of a connected region of land or waters tends to constitute a biogeographic province. Barriers to dispersal of majority of taxa of living organisms then separate one biogeographical province from another. Isolation of populations across such barriers promotes speciation, so that one set of species may be replaced by another, often ecologically equivalent set of species from one biogeographic province to another. Such biogeographic species turnover has been termed γ-diversity. Its magnitude will be governed by large scale patterns of topography and climate. Perhaps one may distinguish two scales of γ-diversity, γ_1 , between provinces of a

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single biogeographic realm such as Oriental or Ethiopean, and Υ_2 between several biogeographic realms.

The organization of diversity of the biological world may therefore be summarised as below :

Organizational level	Measure of diversity	Governing factors
Gene	Intragenomic diversity	Epistatic interactions, heterosis
Organism	Within populations genetic diversity	Breeding systems, Population size
Population	Between poppulation genetic diversity	Population structure, dispersal, environmental gradients
Community	α -species diversity	Productivity, seasonality, area distance from other communities
Landscape	λ -species diversity	Fine scale topography and hydrology
Biome	β -species diversity	Medium scale topography and hydrology
Biogeographic province	Υ_1-species diversity	Large scale topography, climatic variation
Biosphere	Υ_2-species diversity	Configuration of continents, climatic regime

In the presentations that follow, we would attempt to explore what we know of diversity on these various scales. At each organizational level we would be interested in answers to the following two scientific questions :

What natural processes enhance, sustain or decimate biological diversity ?

What human affected processes enhance, sustain or decimate biological diversity ?

Based on this understanding, we would like to set priorities for our conservation efforts and to suggest how best to channelize them.

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4. BIOLOGICAL DIVERSITY : AN EVOLUTIONARY PERSPECTIVE

MADHAV GADGIL

4.1 Origination and extinction

Earth has witnessed a tremendous diversification of life since its origin more than 3 billion years ago. Incomplete as it is, the fossil record documents the continual origin of novel groups of organisms, increasingly complex in their structure and often adapted to newer environmental regimes. This process of diversification has gone hand in hand with that of extinction, and far more biological species have disappeared from than continue to survive on the face of the earth.

The total number of present day biological species is variously estimated from 5 to 30 million; the number of extinct species is even more uncertain, perhaps in the range of 100 to 1000 million. The simplest model of the history of this diversity would treat the rates of origination of new species or of extinction of existing species, per existing species, to have remained around some constant level throughout the evolutionary history. Then

$$dS/dt = S(O - E)$$

$$S_t = S_o e^{(O - E)t}$$

and $$S_t(E) = \left(E/O-E\right)(S_t - S_o)$$

where, S = number of species, S_t = number of surviving species at any time t, $S_t(E)$ = number of species that have gone extinct till time t, O = rate of origination of new species, E = rate of extinction of existing species.

We may then estimate O and E assuming a single origin of life, and based on our estimates of $S_9 = 3 \times 10^6$ to 30×10^6, and $S_{3x10^9}(E) = 10^7$ to 10^8. O will then lie in the range of $4.67 \times 10^{-8} \times 10$ to 4.67×10^{-7} per species per year and E in the range of 4.66×10^{-6} to 4.66×10^{-7} per species per year. In other words O and E are of the order of 10^{-7} and E/O-E is of the order of 10^2. Similar models could be constructed for other taxonomic levels such as families, for which the fossil record is more reliable.

4.2 Adaptive radiations

Such a deterministic model projects a continual, exponential increase in the diversity of life. The fossil record, however, suggests that this is not quite the case and that life has waxed and waned in bursts. There are bursts of diversification following an evolutionary lineage invading a new ecological zone, and occasional spasms of mass extinction, perhaps due to astronomical causes. The invasion of land by plants, followed by the evolution of insects and birds are examples of the colonization of new adaptive zones by evolutionary lineages. Such crossing of an ecological threshold is presumably rendered possible by some adaptation to the existing mode of life which, by accident, also enables the lineage to survive in the new mode of life. What is thus envisioned is a preadaptation, making possible the crossing of an ecological threshold. Such a crossing would be difficult, but once accomplished would tend to free the lineage of much of competition and predation pressures attendant on the earlier mode of life. The new adaptive zone would also make available a number of subzones that could be readily colonized with some further adaptation. There would therefore be bursts of diversification following a lineage invading a new adaptive zone, with rates of diversification slowing down as the various subzones of that zone get filled up. One may thus visualize some equilibrial number of species that any adaptive zone, for instance, that occupied by autotrophs on land may approach. As this equilibrial number is approached, not only will the rate of diversification slow down, but the rate of extinction may also pick up due to increasing levels of competition (Ayala and Valentine, 1979).

One may then visualize an equilibrial model of change in global diversity levels. Sepkoski has thus looked at the number of global marine families diversifying towards three successive equilibrial levels - the first in the Cambrian (600 - 505 million years ago), a second higher level in the late Palaeozoic (505 - 245 million years ago) and a third post - Permian. The equilibrial levels were assumed to be 100, 350 amd 1800 successively. He further assumed that these three great "faunas" are cohesive units that compete with each other (Benton, 1987).

There are serious objections to such equilibrial models. In particular, they assume that the extinction rates will increase with increasing global diversity. In fact, the exact opposite seems to have been happening, and the rates of extinctions of marine families have been falling from around 5 per million years 600 million years ago to only around 2 per million years in recent epochs (Benton, 1986). It is also difficult to objectively estimate the equilibrial number of taxa in any given adaptive zone. Furthermore new adaptive zones have continually arisen during the course of evolution through interactions with existing species in a way that cannot be specified in advance. Thus the diversification of many insect orders as pollinators for flowering plants could not have been foretold.

4.3 Mass extinctions

Another notable feature of the history of diversity on earth has been the spasms of extinction during which a proportion of taxa far greater than during normal times is wiped out. Five such episodes of "mass extinction" have been identified, at Late Ordovician, Late Devonian, end of Permian, Late Triassic and the Cretaceous - Tertiary boundary. In each of these a wide variety of plant and animal groups distributed over extensive geographical areas suffered extinction. Of these, the event at the end of Permian was most striking with rates of extinction jumping to 20 from a normal 4-5 families of marine animals per million years. During this episode, rostroconchs, trilobites and blastoids went totally extinct, and as many as 95% of marine animal species may have disappeared. Another notable mass extinction took place at the Cretaceous - Tertiary boundary when ammonites, belemnites, plesiosaurs, mosasaurs, pterosaurs and dinosaurs went totally extinct (Benton, 1986).

These extinction spasms have been debated on many grounds. It is contended that they are merely episodes of occasional high rates of extinction, with such deviations well within bounds of expected levels of fluctuations. Others would however contend that these are truly exceptional events caused by extraordinary perturbations such as a shower of comets triggered by a disturbance of the Oort cloud. There have been suggestions that the mass extinctions have a periodicity of

26-30 million years related to some astronomical phenomenon such as the oscillation of the solar system through the galactic plane. It has also been suggested that the selective pressures during such extinction spasms are rather special and the groups to survive such episodes tend to be those which have a wide distribution ; groups with narrow geographical distributions suffering far greater chances of extinction.

4.3 Coevolution

The ongoing diversification of life has been marked by a tendency towards the production of structurally and functionally more and more complex organisms. This is firstly because the invasion of newer adaptive zones involves adaptation to environments that depart further and further fron those in which life first originated, and therefore require more complex structures to cope with them. Thus the colonization of land by autotrophs required structural tissues far more elaborate than those of aquatic plants supported by water. These land plants in turn opened up a new adaptive zone for arthropods to colonize, resulting in the evolution of the most diverse group of organisms, the insects. Birds took to air after insects, and this called for a higher rate of metabolism than ever before in the history of life ,leading to complex adaptations for warm bloodedness.

Living organisms have diversified and become more and more complex also because other living organisms are a major selective force in their environment. Thus the plants of tropical rain forests and insects appear to have been in a continual evolutionary struggle, the former to produce newer and newer chemicals such as alkaloids and tanins to restrict insect herbivory, and the latter to device ways of neutralizing these metabolites. In fact such a process of hostile coevolution may have played a major role in evolutionary history.

Sex, a major source of diversity of living organisms seems to be a response to such hostile coevolutionary pressures. Sexual reproduction involves a halving of the rate at which an organism may multiply and hence would require strong selective pressures in favour of it to overcome this disadvantage. The most likely candidate for such selective pressure is the struggle between hosts and diseases. Since disease organisms complete many life cycles for each one of the host, they could always evolve to break down any defences of a host. Hence what is adaptive for a parent may be maladaptive for the offspring. When there is such a negative correlation between generations for fitness of a trait, selection would favour the generation of vast amounts of diversity that sexual reproduction makes possible.

Coevolution may also explain another very interesting feature of fossil record, namely the constancy of probability of extinction of an evolutionary lineage regardless of its age. Van Valen first discovered this when he plotted the number of mammalian genera surviving each interval of time, say 1 million years, 2 million years etc. against the duration of that interval. He found that the curve had a constant slope, so that the probability of extinction of any group remained constant. This suggests that an evolutionary lineage cannot enhance its adaptibility with time and thereby decrease its probability of extinction with age, nor does it tend to lose adaptation as environment gradually changes and thereby suffer an increase in its probability of extinction. Rather it appears that an evolutionary lineage is constantly adapting to an ever changing environment, but remaining adapted roughly to the same degree at all times. This reminded Leigh van Valen of the remark made by the Red Queen to Alice in Through the Looking Glass, "Now here, you see, it takes all the running you can do, to keep in the same place." It appears as if an organism's competitors, prey, predators, parasites are all constantly evolving so that an organism must also evolve just to maintain its adaptation (Hallam, 1977).

4.4 Positive feedback

Living organisms thus constantly changing and influencing each other have over the evolutionary history invaded newer and newer environments, and created novel apportunities for existence through their own actions. Thus the primitive earth had no free oxygen in its air and waters. This was created by the photosynthetic activities of the early autotrophs. Initially this was a poisonous gas for prokaryotic organisms evolved in and adapted to anoxygenic conditions. But then organisms evolved the ability not only of tolerating, but using oxygen to step up their rates of metabolism. This made possible the evolution of more complex eukaryotic cells that opened up new modes of life. Similarly construction of reefs by corals has prompted the evolution of a whole variety of marine animals totally adapted to coral reef environments, and the evolution of trees on land the evolution of a whole variety of terrestrial animals totally adapted to forest environments.

In fact the greatest diversification of life has occured amongst the insects inhabiting tropical forests. As the following table shows, insects and other arthropods account for nearly 2/3 of the 1.39 million species of living organisms so far described. An amazing diversity of insects, as yet largely unknown, is however known to inhabit the canopy of tropical forests. Terry Erwin has been systematically looking at this fauna using new techniques of collection. What he found was as many as 41,000 species of insects, over 10,000 of them beetles, in a single hectare of Peruvian forest. Moreover 4 out of 5 species collected live exclusively in a particular forest type, and 13 percent are confined to one species of tree. A single tropical forest tree species thus harbours perhaps several hundred insects peculiar to itself. Erwin thus argues that each tropical tree species supports an average of 400 unique arthropod species. Next he argues that there are another 200 unique arthropod species per tree species on the forest floor. There are an estimated 50,000 species of tropical trees, which would give an ultimate total of 30 million species of living arthropods. While there are many possible objections to this estimate, it is likely that there are many more than 10 million species of living organisms on the earth.

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TABLE 4.1 : KNOWN AND ESTIMATED DIVERSITY OF LIFE ON EARTH

Form of life	Known species	Estimated total species
Insects and other arthropods	874,161	10 million to 30 million
Higher plants	248,400	275,000 to 400,000
Invertebrates other than arthropods	116,873	Over 1 million, perhaps 3 to 4 million
Lower plants	73,900	Not available
Microorganisms	36,600	Not available
Fish	19,056	21,000
Birds	9,040	9200
Amphibians and reptiles	8,962	9000
Mammals	4,000	4200
TOTAL	1,390,992	10 to 30 million

4.5 Human impact

Diversity of life has thus grown feeding on itself. A few million years ago however it has produced a species, Homo sapiens that has acquired an ability to radically transform the environments on the surface of earth. Mankind has then striven to convert the whole of the biosphere as a niche for this single species, in the process drastically reducing its heterogeneity. He has also stepped up tremendously the mortality rates for a whole lot of organisms, either through direct hunting, or poisoning. The result has been a stepping up of the rates of extinction well beyond what held over geological times. For instance, 153 bird species have disappeared in the last three centuries, thus this implies rates of extinction of the order of 5×10^{-5} per species per year. These are 10 to 100 times higher than the background geological rates and hence paralleling what happened during episodes of mass extinction. It is feared that the impending destruction of tropical forests might wipe out as many as one million species in the next decade. These would be rates of the order of 10^{-2} per species per year, 10 to 100 thousand times the rates normally prevalent, and well exceeding those during spasms of mass extinction as well.

5. DIVERSITY AT THE LEVEL OF THE GENOME

RAGHAVENDRA GADAGKAR

The triumph of molecular biology has been to elucidate the molecular basis of heredity and describe the structure of the genome in almost all the different kinds of organisms known. Barring some exceptions double stranded DNA molecules are the carriers of heredity information. Single stranded DNA and RNA molecules are known to perform this function in some viruses. The triumph of molecular biology has also been to decipher the genetic code. In other words, we now understand the language of the genes. Conservation biologists wish to understand in detail the mechanism of evolutionary change. This depends very significantly on an understanding of the organization of the genome and it is precisely here that our knowledge is far from complete.

Much progress may be said to have been made in understanding genome organization but judging by the fact, that new surprises are still being thrown up, we have a long way to go. At one extreme, we see viruses trying to outsmart each other and minimising the amount of genetic material they need. We now know of many viruses which code different genetic messages on the same stretch of DNA in an overlapping fashion. At the other extreme, most higher organisms seem to have almost an order of magnitude more DNA than they need. This suggests that there are important gaps in our knowledge of the molecular basis of heredity and evolution.

A perusal of the history of molecular biology reveals that most of what used to be standard assumptions are now being challenged.

Today we know that double stranded DNA is not the only possible hereditary material. Some organisms manage with single stranded DNA or RNA. There is growing evidence that some show viruses have no nucleic acid at all. Reverse transfer of information fron RNA to DNA is now common knowledge and discovery of information transfer back from proteins is probably on the horizon. Recent researches have shown that a gene is not necessarily a continuous stretch of DNA and the genome is not a static entity that it was once believed to be. Jumping genes are proving to be so ubiquitous that some people have described the genome as a flowing river. Somatic mutations and other genomic changes during development are being discovered. Most of the assumptions in our current population genetics models are likely to be challenged as a result of these surprising developments in molecular biology. Because, conservation efforts depend heavily on our understanding of the process of creation, maintenance and elimination of genetic diversity these developments are bound to have serious consequences. The moral of the story is that conservation biologists should keep their eyes and ears open to developments in molecular biology.

6. DIVERSITY AT THE LEVEL OF THE POPULATION

N.V.JOSHI

6.1 Introduction

As described in chapter 3 , there is a considerable diversity at the level of the population ; members of a population differ from each other (Wright , 1978). This chapter focuses on the genetic variability in the population. Two parameters are generally used to characterize the extent of genetic diversity. The degree of polymorphism P is the proportion of polymorphic loci amongst those examined. The degree of heterozygosity H is the average proportion of heterozygotes at a locus. The extent of P and H for various groups of organisms is seen in fig. 6.1 , reproduced from Hartl (1981). Increasingly more sensitive methods have revealed a much higher degree of genetic variability in populations than anticipated earlier.

6.2 Factors promoting diversity

Mutations are the primary agents for the generation of diversity. However , the extent of diversity seen (or retained) in a population depends on several factors. Interspecific comparisons are helpful in bringing out the factors likely to have a bearing on diversity.

It has been seen that generally species having a large geographical range (and occupying many different kinds of habitats) have higher diversity. Sexually reproducing organisms tend to have a higher diversity. Fluctuating environments promote higher levels of diversity. Coevolution resulting from hostile biotic interactions (e.g. predator-prey , host-parasite) favour higher levels of

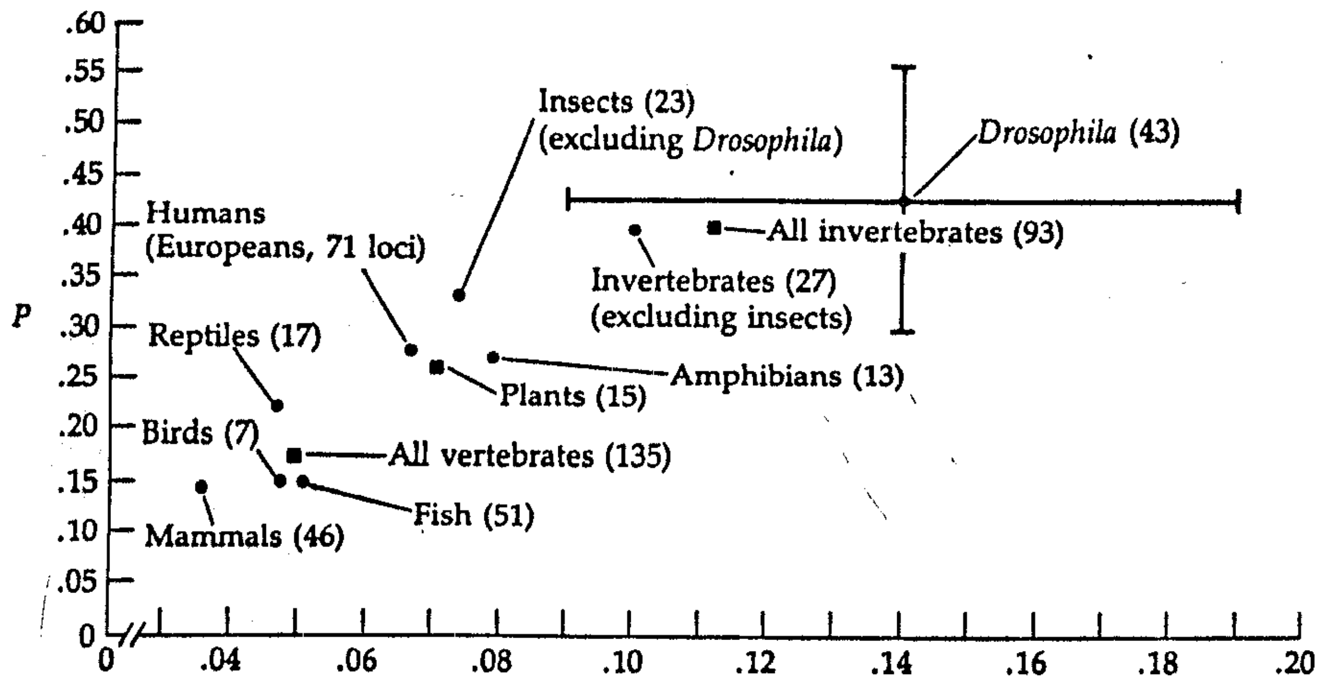

FIGURE 6.1

Levels of heterozygosity (H) and proportion of polymorphic loci (P) found in allozyme studies of various groups of plants and animals. The number of species studied is shown in parenthesis beside each point. Squares denote averages for plants, invertebrates, and vertebrates. The bars across the *Drosophila* point show the range of H and P within which about 70 percent of the *Drosophila* species fall. Other groups would have similarly large bars. (Data from Nevo, 1978.)

FROM HARTL (1981)

diversity. Rarity advantage resulting from behaviour of conspecifics (disassortative mating) or predators (dietary preference for more common phenotypes) also promote higher levels of diversity.

6.3 Maintainance of diversity : the neutrality hypothesis

In a given population , why is diversity maintained ? Conventional explanation is in terms of selective advantages. Spatial or temporal heterogenity causes changes in the relative fitnesses of different alleles and thus leads to the persistence of more than one alleles. Secondly , superiority of a heterozygote over both the homozygotes also leads to both the alleles being maintained.

The neutral theory of Kimura (1984) , on the other hand , accounts for diversity mainly in terms of a balance between mutations and genetic drift. According to this theory , most of the mutations are selectively equivalent , and whether an allele is retained in a population depends largely on chance factors. The neutral theory makes quantitative and testable predictions about quantities such as levels of heterozygosity expected in a population , sampling variance of heterozygosity etc. There seems to be a satisfactory agreement between theory and data (Kimura , 1984) , though this is perhaps one of the most controvertial topics in population genetics (Nevo et. al. 1983).

6.4 Implications for conservation : effective population size

In any finite population , the genetic diversity is gradually lost due to genetic drift - chance variations in gene frequencies leading to fixation of some alleles and loss of others. The rate of loss depends on the population size , and smaller the population , higher is the rate of loss. To minimize the rate of loss , it is desirable to maintain as high a population size as possible.

However , the effective population size (i.e. the size relevant for determining the extent of genetic drift) is not merely the total number of adults , but depends on several parameters of the population (Frenkel and Soule , 1981). Unequal number of males and females tend to reduce the effective population size. For a fluctuating population , the effective population size is given by the harmonic mean of the population numbers , and is therefore much closer to the smallest value taken by the population size. A larger variance in the reproductive success of individuals also decreases the effective population size.

Knowledge of the dependence of effective population size on the various parameters would help in devising suitable conservation strategies for maintain high effective population sizes. Culling of a small proportion of juveniles so as to reduce the variance in the reproductive success (Frenkel and Soule , 1981) may be cited as a particularly illustrative example.

7. ON SETTING PRIORITIES FOR THE CONSERVATION EFFORT

MADHAV GADGIL

7.1 Introduction

Given that a serious effort at conservation of biological diversity is urgently called for, a number of issues arise. This is because the magnitude of biological diversity is enormous, as is the scale of human impact on the biosphere. However we may wish, therefore, we cannot conserve all the wealth of genes, of species, of communities, of landscapes, of ecological process that still survives on our planet. We must then set priorities and decide that a particular individual organism, for instance, the Banyan tree in Bodhigaya, or a particular species such as the Siberian crane, or a particular community such as the Manipur lake that supports the Thamin, or a particular biome, say the mangrove forests merit a high priority for conservation. But such choice must be based on sound rationale, and we should enquire into why these, and not some other elements merit a high priority in conservation effort. Given the rationale as to why, and the priorities that flow from it of what, we should also consider the modalities of how. How are the elements to be conserved implies decisions as to how much of financial, land, water and other resources are to be devoted to their conservation, and what the technologies of conservation are. We shall address these questions of why, what and how in this lecture.

7.2 The Rationale

A variety of reasons, economic, scientific, aesthetic, cultural, religious and moral may be adduced for conservation of biological diversity. Man's economic well being depends significantly on other organisms, living or in fossil form, as food, fuel, drugs, structural materials and as manure and fodder or biological control agents. Of these, their role as producers of chemicals is preeminent, as other roles are usurped by man made materials and sources of energy such as hydroelectric and nuclear power. The role of living organisms as chemical factories is gaining further prominence as developments in biotechnology make it possible to move genes around and implant, for instance, a bacterial gene for the production of compounds poisonous to insects into a crop plant. Since each distinct structural gene manufactures a distinctive protein, this suggests that we should aim to preserve the entire diversity of genes of the biosphere. However, mere preservation of genes is insufficient, for we would need further information on organismic as well as ecological level processes to assess the value of any particular gene. Thus antibiotics were discovered from seemingly worthless organisms by observation of the ecological process of suppression of other microorganisms. Biological control agents of economic value, for instance of weeds like Eupatorium, can be identified only by noting ecological processes in intact communities. At an even more complex scale, one might need to preserve complex landscapes to appreciate the rationale of, say, hill agriculture, which may turn out to be an economically optimal use of such a landscape.

The scientific understanding, which is so vital to realizing economic potential, as well as is important in its own right as an exercise of human spirit of enquiry, would require the preservation, not only of genetic diversity, but of a whole range of ecological processes. As our knowledge deepens, we are realizing that many processes neglected earlier, for instance host-parasite coevolution are of crucial significance. Scientists would therefore like to see conservation of ecological processes on all scales, and including those involving rare, specialist species. In particular, they would like to see the operation of these processes in the setting in which evolutionary forces have been operating. This would require the preservation of large natural communities.

Edward O. Wilson (1984) argued that human beings have an inbuilt love of diversity of life, biophilia, that prompts us to value and attempt to preserve diversity. If such is the case, however, we seem to be particularly attracted towards large, colourful, vocal animals, crocodiles, birds, ungulates, whales and plants with colourful, scented flowers and of large size. These do rank high in our conservation priorities today. Gordon Orions has argued that humans are especially attracted towards certain kinds of landscapes as well, grasslands with scattered shrub and tree growth, rolling landscapes with good vantage points, and land abbutting lakes, rivers and seas. Again man often strives to create and preserve such landscapes.

Human cultures and religions often tend to value diversity and have many practices sustaining them. Some of these appear designed to maintain diversity, such as protection to keystone taxa like <u>Ficus</u>, preservation of a network of sacred groves, and other hunting taboos. These practices are often set in a religious idiom. These cultural and religious practices continue to provide us a rationale for conservation.

Finally, there are moral grounds resting on man's realization that he is only one manifestation of the tremendous range of diversity of 10 million or more species generated through 3 billion years of evolution. It is therefore man's evolutionary responsibility to permit the process of evolution to continue unimpended; this implies the preservation of large expanses of natural communities (Wolf, 1987).

7.3 Species

There is obviously a whole spectrum of reasons for sustaining diversity, and a whole set of priorities as to what elements of diversity need to be preserved follow from these. We shall examine these at each of different levels of organization of diversity. At the genetic level, we would give high priority to elements that are likely to have a rather unique genetic constitution. These could be taxa with relatively few phylogenetic relatives, such as members of a monotypic family like the Crab Plover. On the same grounds, we would value all species that are rare, with low populations. As we shall see in greater detail later, rarity may result from (i) a species being endemic to a small geographical range, such as the extinct Mountain Quail that was restricted to Kumaon Himalayas, (ii) a species being a habitat specialist, such as the extinct Pinkheaded Duck, specialist of freshwater marshes, or (iii) a species being at a low population density everywhere, like the King Vulture. We would give priority also to taxa that play a key role in maintaining a large number of other species in the community such as <u>Ficus</u> trees yielding fruit to many frugivorous birds and primates in seasons of fruit scarcity. Other taxa of priority in conservation effort may include species threatened because of susceptibility to excessive harvests such as Rhinos because of the demand for their horns, or those susceptible to high levels of mortality because of biomagnification of pesticides such as birds of prey. We would also give priority to taxa of economic significance such as wild pepper, of religious significance such as primates over much of India or of aesthetic significance like orchids. Some taxa may have special scientific significance as well, for instance the primitively social paper wasps that are at a highly interesting stage of social evolution.

7.4 Communities

At the next level of organization, that of communities, priority would be given to communities very high in species diversity such as coral reefs, to those of very restricted occurence such as the spray zone of waterfalls and communities that are rather unique, such as those of hot springs. Communities playing a crucial ecological role, such as mangrove forests important as nurseries for fish and prawn would also have a high priority. Other communities may be particularly susceptible to disruption, for instance coral reefs and therefore be of priority. So would be highly threatened communities such as dry scrub of Indian peninsula. Finally, communities of high economic significance, such as freshwater swamps with wild relatives of paddy of special religious significance such as the sacred pond of crocodiles, or of aesthetic significance such as alpine meadows would all receive high priority for conservation.

7.5 Landscapes

At the level of landscapes too we may assign conservation priorities on several grounds. These may include (1) landscapes of high diversity, such as mountain ranges, (2) of restricted occurence, such as mountain peaks, (3) of particularly high susceptibility to disruption such as islands, and (4) those in demand for alternative use, such as mountain river valleys. We may value landscapes exemplifying traditional patterns of harmonious resource use, such as the mosaic of seral stages created by long fallow cycle shifting cultivation, and landscapes of religious significance such as some localities of high Himalayas.

7.6 Biomes

We may give priority to biomes of restricted occurence, such as the grassland-sholas of higher reaches of Western Ghats. One might also think of biomes of economic significance such as the shallow coastal zones on continental shelf as deserving conservation on high priority. Lastly whole biogeographic realms such as the Indo-Australian coastal zone with its high levels of diversity may be given special priority.

7.7 Modalities

The third facet of the problem is that of the modality of preserving diversity. At the most basic level diversity resides in the nucleotide base sequences of genes. These can now be deciphered, and diversity may simply be maintained as the information as to these sequences. Genetic diversity may also be maintained by storing seeds or spores at very low temperatures, or cell lines in tissue culture. Organisms could be maintained at agricultural research stations, in botanical gardens or in zoos. The amount of diversity that can thus be maintained *ex situ* through living organisms is however bound to be quite limited.

None of these methods would enable us to conserve ecological processes, or permit ongoing evolution. For that to happen we must conserve diversity on cultivated fields, in animal herds, or in the natural communities. There are vital issues here of the location, of the spatial scale and of relative dispersion and connectivity of these natural communities that we would like to protect.

7.8. Space and time scales

One final point relates to the space and time scale on which this conservaiton effort is conceived. Is the diversity to be thought of on a global scale and with the perspective of a geological time scale ? Or do we think of continental, biogeographic realms, provinces or much more local scales ? Thus if we have the global scale in mind, it might be appropriate to have several large nature reserves each representing one biogeographic province. On a local scale then, this may imply any given region of a few km^2 being either a pristine natural community, or under intensive agriculture or urban-industrial settlement. On the other hand, if we wish to achieve maximal levels of diversity for a given locality of a few km^2, we might opt to create a mosaic of small patches of natural communities such as sacred groves and sacred ponds, fuelwood plantations, grazing lands, small fields with a mixture of crops, some habitation and small scale industries. The latter alternative may serve far better the purpose of conserving diversity for the bulk of the population; the former for benefit of the elite. These alternatives too merit deep thought, especially in the third world context.

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8. ON INBREEDING AND OUTBREEDING DEPRESSION

N.V.JOSHI

8.1 What is inbreeding depression ?

The results of matings between two closely related individuals (sibs , parent-offspring) from a normally outbreeding species are generally unsatisfactory. The litter size is considerably reduced , juvenile mortality is much higher and the offspring are much reduced in vigour compared to those produced from matings between unrelated individuals. This phenomenon is known as Inbreeding Depression , and has been well known to plant and animal breeders for centuries.

Systematic studies providing firm evidence for inbreeding depression in cultivated plants (e.g. maize) and laboratory animals (e.g. rats , drosophila) have been described at length by Wright (1977). Not only is the fertility seen to be considerably reduced , but quite often , an inbred line is seen to go to extinction due to the absence of viable progeny. The available data for wild animals bred in zoos presented by Ralls et.al. (1979) also strongly suggests inbreeding depression. The juvenile mortality examined for sixteen species of ungulates (Indian Elephant , Zebra , Raindeer , Giraffe , Sable etc.) was found to be around 20% amongst the noninbred young and considerably above 50% amongst the inbred young in most species.

It may be pointed out that this phenomenon is not without exceptions. After an initial decline in fertility and vigor , an inbred line may gradually return to a normal status , and continue to persist in spite of the elevated levels of inbreeding (e.g. maize , drosophila described by Wright (1977) .

8.2 Genetic basis of inbreeding depression.

The immediate consequence of an increase in inbreeding is an increase in homozygosity. This leads to an increase in the probability of a recessive lethal allele being expressed in the offspring , leading to high juvenile mortality. The proportion of recessive lethal loci in wildtype populations could be quite substantial ; Hartl (1981) describing data from Mukai and Yamaguchi (1974) has concluded that about 250 of the 700 loci examined in a population of drosophila had at least one recessive lethal allele.

There is a positive correlation between the favourability of an allele and its degree of dominance ; favourable allele are generally dominant over not so favourable ones. As a result , a larger proportion of recessive alleles expressed in an inbred offspring lead to a considerable reduction in its fitness. (This , incidentally , also provides a satisfactory explanation for the complementary phenomenon of Hybrid Vigour - progeny resulting from mating between two totally unrelated individuals has a higher proportion of dominant (and thus more favourable) alleles than either of the parents , and hence higher vigour.)

Inbreeding also leads to a decrease in variance between sibs ; the offspring tend to be quite similar to each other. As a result , they are more likely to be adversely affected by large changes in environmental conditions. Wright (1977) describes an inbred line of maize whose yield was comparable to that of wildtype in normal years and which showed a more than 50% reduction in yield in a year with adverse weather conditions.

8.3 Inbreeding avoidance in natural populations

It is difficult to estimate the extent of inbreeding in natural populations , and even more difficult to establish whether the observed incidence is statistically significant. Ralls et.al. (1986) have compiled data on 13 species of birds and 15 species of mammals. The estimated proportion of inbreeding ranged from 0-3% in birds (except for values of 9.8% in mute swans and 19.4% in splendid wrens) and 0-5.5% in mammals.

On the other hand , many life-history patterns as well as behavioural patterns seem to contribute towards a reduction in the probability of inbreeding. In birds , high population turnover rates together with monogamous mating habits reduce parent-offspring matings. Sex-specific dispersal (i.e. dispersal of only one of the sexes , or substantial difference in the range of dispersal of the two sexes) observed in many small mammals and primates makes sibmating highly unlikely. In fact , inbreeding avoidance has been believed to be one of the major factors leading to the evolution of sex-specific dispersal , though this view is rather controvertial (Moor and Ali (1984) , Packer (1985)).

Ralls et.al. (1986) have also described several instances where in spite of encounters between sexually mature close relatives not being uncommon , matings between them were rarely observed , thus reducing the probability of inbreeding.

8.4 Implications for conservation

Populations of many species of interest to conservation biologists are rather small in size. Fragmentation of habitat also further reduces the size of the mating pool. Even if mating is at random , a small population size increases the probability if occurence of inbreeding , and the consequent reduction in fertility is likely to further aggreviate the status of the species.

Knowledge about the phenomenon of inbreeding depression and its genetic basis suggests possible conservation strategies to counter its effects. Thus , eventhough other constraints restrict the size of a particular local population , introduction of a small number of sexually mature adults from another population is likely to help in consideraby reducing the possibility of inbreeding. However , such a course of action is not without potentially adverse side effects , as described in the next section.

8.5 Outbreeding depression.

Intraspecific hybridization between individuals from different populations often leads to a considerable decrease in fertility. This is termed as outbreeding depression and has been observed in a number of species ranging from ibex and owl monkeys to drosophila , as described by Templeton (1986).

The genetic mechanism underlying this phenomenon can be described in terms of a coadapted gene complex. A population is well adapted to its environment as a result of interaction between several genes. The process of hybridization disrupts this coadapted gene complex and leads to a reduction in fitness. Elegant experiments carried out on laboratory cultures of drosophila by Templeton (1976) have clearly indicated the negative correlation between degree of hybridization and fertility.

Outbreeding depression may also be a result of karyotypic mismatches as seen in owl monkeys (de Boer , 1982) or due to changes in the behavioural patterns of the hybrid offspring (e.g. rutting of ibex in fall , and the resulting progeny being born in highly unsuitable cold season , Grieg (1979)).

8.6 Summary.

Considerable reduction in fertility is seen when close relatives of a normally outbreeding species mate. Such inbreeding depression is bound to occur in small populations , making them further endangered. Translocation of a very small number of individuals from other populations may effectively counter this process. However , such a strategy needs to be carefully evaluated before implementation due to the risk of outbreeding depression - decline in fertility arising out of intraspecific hybridization between different populations.

9. WHAT RENDERS SPECIES PRONE TO EXTINCTION ?

MADHAV GADGIL

9.1 Size of geographical ranges

To save species from going to extinction is an evident concern of consservation biology; as a corollary the question of what renders a species prone to extinction is one of the central issues of this discipline. The susceptibility of a species to extinction must relate to the way the total population of a species is structured, and its interactions with the environment. The total population of a species, termed its metapopulation occupies its overall geographical range. Such a range would of course fluctuate over the evolutionary history of a species, beginning with an isolated population that initially diverges from the remaining lineage. If successful in establishing itself, the new species may then expand its geographical range by occupying other suitable habitats to which it has dispersed. Some of the newly established populations may then either diverge to constitute new species, or may go extinct. In these events the geographical range may contract, and may finally dwindle to zero. In general the size of the geographical range of a species will depend on the evolutionary history, the barriers to dispersal in relation to its dispersal abilities, and the nature of habitats it can occupy. It can range from populations restricted to very small localities such as the Narcodam Hornbill that occurs only on a single island of a few km^2 in Andaman and Nicobars to species distributed over much of the globe such as the Little Green Heron. Since a number of variables govern the size of the geographical range in a multiplicative fashion, their frequency distributions are of the lognormal type. This implies that there would be some ranges far larger than would be expected on the basis of mean and variance. Our major interest is of course with the very small rather than these very large ranges.

Species with geographically restricted distributions go under the rubric of "endemics". Endemicity is most likely when a habitat suitable for a species is widely separated from other suitable habitats. This is particularly apt to occur on islands; islands surrounded by water for terrestrial biota, isolated lakes or seas surrounded by land for aquatic biota or habitat islands such as isolated mountain tops. Thus as many as 91% of plant species are restricted to Hawaiian islands, 25% to Galapagos and 12% to Puerto Rico. Similarly Lake Baikal is rich in endemic fish species and isolated mountain tops of Western Ghats in species of Laughing Thrushes and Rhododendron. Spray zone of large waterfalls is another highly fragmented habitat and one of the extinct plant species of Western Ghats, the grass, Hubbardia heptaneuron was restricted to the spray zone of Sharavathy falls. Many endemics of Amazonia may also be restricted to specialized soil regimes.

9.2 Palaeo and Neoendemics

Another way to look at endemics is in terms of their evolutionary stage. Species once widespread may now be restricted to small ranges and may in fact be on the way to extinction. Pelliciera rhizophorae is one such endemic neotropical species whose relict nature is established by a long fossil record. Regions that served as refugia for forest species during the Pleistocene are believed to be especially rich in such endemic species which were once much more widespread. In contrast to such palaeoendemics may be neoendemics resulting from rapid speciation in recent times. Gentry (1986) believes the northwestern Andean region of South America to have been a centre of explosive speciation in the recent times. Epiphytes, shrubs and herbs of these regions have particularly high levels of endemism; as many as 15-20% having ranges of less than 75,000 km^2. Some isolated cloud forests have even higher levels of endemism; with 10-25% species restricted to ranges as small as 5-10 km^2.

9.3 Habitat Preference

Within its geographical range, a species would establish local populations or demes in suitable habitats. The species differ greatly in the range of habitats they can occupy. The habitat preference may also vary with the different life history stages of a species. Thus many species of forest trees have more specific requirements for regeneration than in the adult phase. We have looked at the preference of 580 bird species occuring on the Western Ghats for 24 different habitat types of this tract (Fig. 9.1). The mode lies at two, the mean being 3.2 and the standard deviation 2.1. As many as 40 species use just one habitat, and 14 use more than 9 different types of habitats. One species, the Jungle Crow is a true jack-of-all-trades occuring in 23 out of 24 habitat types. Now the Jungle Crow is also amongst the most widespread and abundant of these bird species, conforming to the rule suggested by Brown (1984) for American bird species. A correlation between habitat specialization and narrowness of geographical range has also been suggested for Moroccan butterflies by Thomas and Mallorie (1985). Rabinowitz et al (1986) however failed to find such a correlation amongst a subset of 160 of plant species of British isles.

The spatial configuration of the different local populations of any species would depend on its habitat preference. The habitat specialists would tend to have more patchy, scattered distributions in comparison with the ganeralists, although where they do occur they may be locally quite abundant. Amongst the habitat specialists, those preferring relatively rare habitat types would of course have the patchiest distributions of all. Thus Cody (1986) studying bird communities of Western Australia noted that birds preferring heaths, a highly patchy habitat tend to have small, widely scattered populations.

9.4 Population Densities

Finally, within limits of any given local population, the population of a species may be sparse or dense. This would of course vary over the range, populations being sparser at the edge of a population's geographical range or in a suboptimal habitat. In fact Hubbell and Foster (1986) found that in a 50 ha plot on the Barro Colorado island in Panama populations of several species were being maintained only through a continuous input of migrants from habitats more favourable to those species. The question however arises as to whether there are any species that are rare everywhere they occur; being locally abundant nowhere. In a survey of 160 species of flowering plants from British isles Rabinovitz et al (1986) found that at most 5% of the species could be so characterized. The top carnivores would of course tend to be by and large much sparser than species at lower trophic levels and indeed tend to be eliminated first

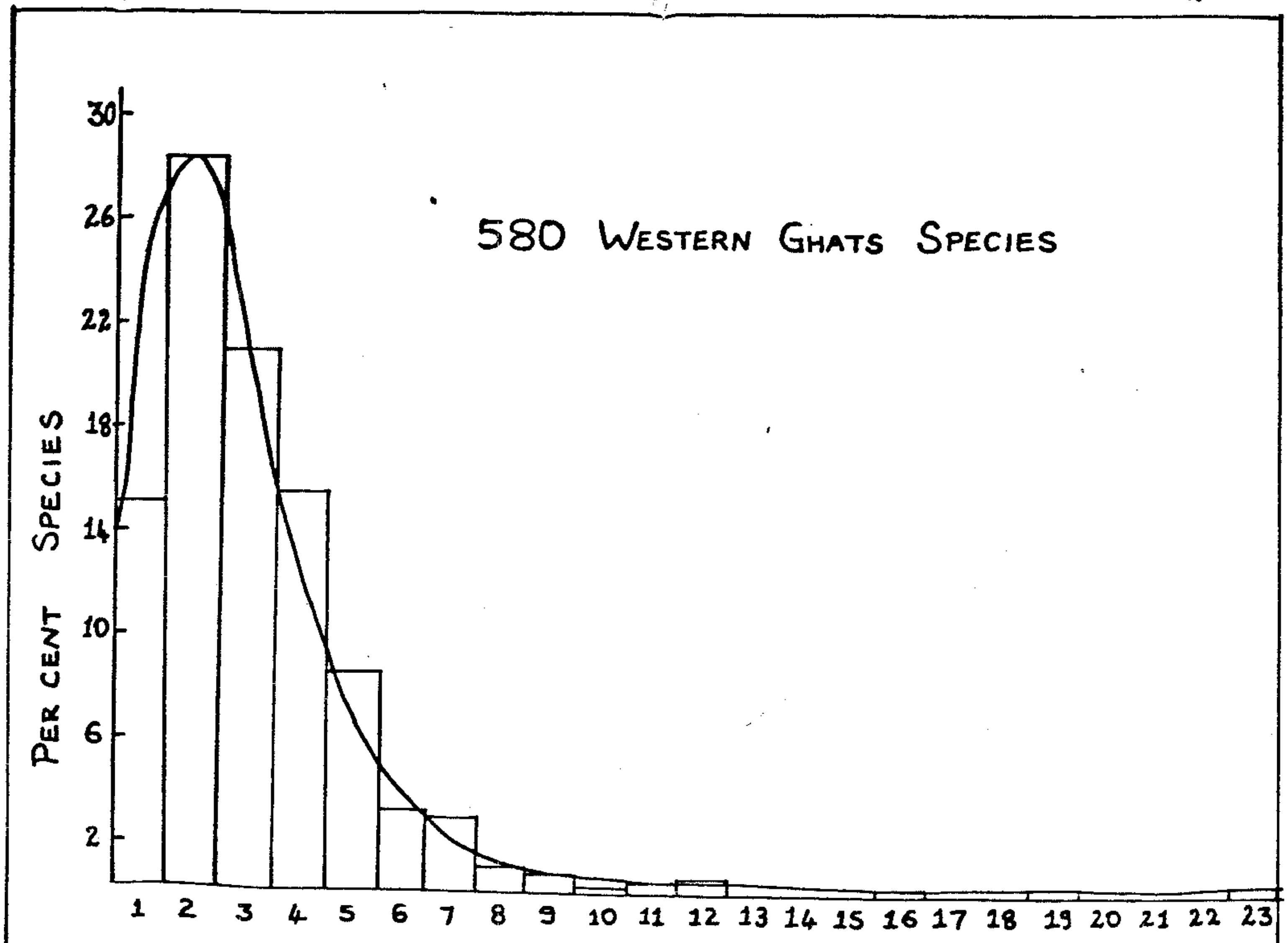

Fig. 9.1. Number Of Habitats Utilized By A Species

when the area of habitat suitable for them is reduced. Thus there are no jaguars or harpy eagles on the artificially created Barro Colorado island in Panama, although other large mammals such as sloths have in fact increased in population with strict protection. Cody (1986) also shows that population levels tend to be lower in more diverse communities. Thus in the Afromontane woodland patches in Southern Africa the average bird population in pairs/hactare/species dropped from 11 to 4 as the number of species increased from 12 to 40.

9.5 Conclusions

To summarize species whose overall populations are low, as well as species whose local populations are unlikely to be revived once exterminated because of the distance from other source populations, as also because of poor recolonizing ability are likely to be especially prone to extinction. These conditions may be fulfilled for (a) species with narrow geographical ranges such as island endemics, (b) species with narrow habitat preferences and highly patchy distributions, (c) species that are sparse everywhere they occur, such as top carnivores, and (d) species with very low recolonizing abilities, such as those whose fruits are dispersed by mammals.

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ABSTRACT

10. Considerations on Species Diversity Parameters and their Importance in Conservation Ecology.

Ajith H. Perera

The broad objective of this talk is to discuss the quantification of species diversity as a community characteristic and use this information as tool in conservation ecology. The discussion will consist of three major steps.

First, it will discuss the conceptual aspects of species divserity. The objective here is to develop the intuitive and theoretical background of species diversity and to alleviate ambiguity in terminology. The discussion will be mostly non-mathematical to accomadate biologists.

Secondly, the talk will concentrate on different species diversity indices available to ecologists and field sampling methodology employed in computing these indices. The goals here are an exposure to a wide array of differnt diversity indices, stress the importance of discriminative selection and use of the indices, and to highlight the sample-dependent nature of these index-estimates. The discussion will use examples from forest ecology.

Finally, applications of species diversity parameters in conservation ecology will be dealt with. The major issues discussed will be,

a) assesing spcies diversity in communities and cross-comparing species divesrity among communities,
b) estimating sensitivity to external impacts and post-impact resilience of communities, and
c) determining effects of conservation and other management practices on communities.

The aim here is to highlight the use of diversity parameters as a tool to obtain *a priori* information and to judge the succsess of conservation efforts. Again, the discussion will be based on examples from forest ecology.

11. PATTERNS OF BIOLOGICAL SPECIES DIVERSITY

RAGHAVENDRA GADAGKAR

11.1 Introduction

It is obvious that before making any 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. 10 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 10 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 mearly by chance or are there underlying biological processes that lead to well defined and 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 interatcing 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 fresh water pond. In the absence of any such natural boundaries, the species area curve is usually one 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. This however does not take into account the relative numbers of individuals of the different species constituting a community. For instance, two communities are rated equally if both have two species each, 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. It is clear therefore that a good index of diversity should consider both the number of species as well as their relative abundances. Two commonly used indices of diversity which satisfy this criterion are the Simpson's Index (Simpson, 1949):

$$\lambda = \sum_{i=1}^{S} p_i^2$$

and the Shanon-Weiner index (Pielou, 1966; 1975):

$$H' = -\sum_{i=1}^{S} (p_i)(\ln p_i)$$

where S is the number of species and is the proportion represented by the ith species. Here if each species is equally abundant, the maximum value of diversity index is obtained as:

$$H_{max} = \ln S$$

Thus, $H'/H_{max} = E$, a measure of the the equitability of species in the community.

A large number of indices of diversity have been developed but as their relative merits and demerits are still being evaluated.

11.2. Distribution of Biological Species Diversity:

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

A. A gradient of increasing diversity is usually seen as we move from the poles to the equator. This has been documented for a variety of organisms including mammals, birds, insects, other invertebrates and plants (Fischer, 1960; Simpson, 1964; Price, 1975;).

B. Diversity usually decreases as we move up the slope of a mountain (Whittaker, 1977; Yoda, 1967).

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

D. Islands usually have lower diversity per unit area compared to continents (Williamson, 1981).

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

F. In Benthic communities in the oceans, shallow regions have low diversity while deeper regions have higher diversity.

G. One notable exception is that fresh water planktonic communities are more diverse in the temperate regions compared to their tropical counterparts.

H. Other exceptions may arise when we look at specific groups. For instance, Ichneumonid wasps are more diverse in the temperate regions than in the tropics (Owen and Owen, 1974).

11.3. Factors affecting distribution of species diversity

A number of factors have been invoked to explain the observed patterns in the distribution of biological species diversity. Most of these factors 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.

11.3.1. The Time-Stability Factor

Life almost certainly originated in the tropics and later spread to the temperate regions. The entire biota in the temperate regions has been repeatedly destroyed because of glaciation and other catastrophic climatic events. There has thus been relatively little time for communities to evolve in the higher latitudes. This may be the reason for their poor diversity. In contrast communities have been evolving in the tropics for a very long time and apparently without serious catastrophic interruptions. This may be the reason for their species richness or diversity (Fischer, 1960; Sanders, 1968). In recent times however there has appeared some evidence that the tropics may also have undergone fairly drastic climatic changes in the past (Livingstone, 1975). A second point is that biological communities would also be evolving faster in the tropics because of the uniformly suitable conditions for life through out the year. In contrast, very little can happen during the temperate winters. In recent years again it is being increasingly realised that the transition from the wet to the dry season in many tropical areas may have fairly drastic consequences for the biota even if not as drastic as the change from summer to winter in the temperate regions. Some evidence for the effect of the time-stability factor is provided by a study of fossil Foraminifera which shows that a declining trend in species richness from the equator to the poles was present even 70-80 million years ago. Besides, the average age of the species seen in the tropical fossil records was about 15 million years while those of the temperate regions was about 25 million years. Tropical species thus seem to be evolving faster (Stehli et al 1969). Another kind of evidence comes from a study of the number of insect species associated with different tree species in Britain. All trees found in Britain must have recolonised after the last glaciation, about 10,000 years ago. There appears to be a fairly strong positive correlation between the number of insect species associated with a tree species and the time for which that tree species has been growing in Britain after recolonisation. In other words, insects have had a longer time to evolve on trees that have been growing longer in Britain and the availability of this longer time appears to have produced more species (Birks, 1980).

11.3.2. The Predation factor

Robert Paine (1966) pioneered the hypothesis that removal of a key predator increases species richness or diversity. His studies of inter-tidal communities of Molluscs and Echinoderms off the coast of the state of Washington, are well known. By removing a starfish called Pisaster, the key predator in a community consisting of at least 15 species, he found that a small number of species (8 in this case) are able to dominate and eliminate all others. In the kinds of communities that Paine studied, competition for space among the sedentary filter feeders is very crucial. In the absence of Pisaster, a few species are successful in competing for space and thus dominate 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. Janzen (1970, 1971) has extrapolated this idea to explain tropical tree species diversity. The number of seeds to fall to the ground is expected to decrease as one moves away from the tree. Conversely, the probability of seed survival is expected to increase progressively as one moves away from the parent tree. This is because seed predators are likely to be concentrated near the parent tree as they might use the parent tree itself to search for seeds. The optimum recruitment will thus be at some intermediate point where these two curves intersect. This mechanism might help space out the individuals of a species and also might permit members of other species to grow in between, thereby increasing the diversity. It should be emphasised that predation may not be expected to increase diversity under all circumstances. The introduction of a predatory fish namely Cichla ocellaris in the Gatun lake in Panama is known to have resulted in a drastic reduction in diversity (Zaret and Paine, 1973). There must clearly be situations when predators are not coevolved with their prey or predators themselves are fugitive species, so that they would exterminate their prey species leading to a reduction in diversity.

11.3.3. Productivity factor

It has been suggested that increased productivity would increase species diversity (Connell and Orias, 1964). Combined with the factor of climatic stability and increased habitat heterogeneity, increased productivity might concievably support a greater diversity. For instance, there is a significant correlation of the number of common rodent species with productivity in both the Sonoran and Mojave deserts (Brown, 1975). Productivity by itself however cannot always be expected to work in this fashion. In fact there is a good evidence of a negative correlation between diversity and productivity in some lake ecosystems (Whiteside and Harmsworth, 1967).

11.3.4. Latitude-Area factor

It is interesting that due to the spherical shape of the earth, there is much more area (both water and land) in the tropical regions than near the temperate regions. This might itself permit greater population sizes and higher diversity in the tropics (Osman and Whitlatch, 1978). This difference is further exaggerated because the distribution of clouds makes it possible for the region around the equator have a uniformly condusive temperature (Terborgh, 1973).

11.3.5. Succession factor

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 inturn affect species diversity.

11.3.6. Habitat Heterogeneity factor

Although climatic stability and the absence of catastrophic changes such as those caused by glaciation have been suggested as being responsible for the higher levels of diversity in the tropics, an intermediate level of disturbance might actually promote diversity in the tropics. An excellent example of this would be a large tree fall in a tropical forest. An obvious mechanism by which such disturbance might promote diversity is by increasing the heterogeneity in the habitat and thus creating more niches. MacArthur (1965) has argued that there may be more speies 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. In support of these ideas MacArthur and MacArthur (1961) and later Martin Cody (1974) have provided evidence for the increase in bird species diversity with increase in environmental heterogenity.

11.3.7. The competition factor

The niche of an organism is usually broadly defined as the sum total of its exact ecological requirements. It is usually believed that two species having identical niches cannot coexist; one will eliminate the other. An organism's niche may be defined along many different resource axes. Much theoritical and empirical work has been done in the area of competition and its effect on niche diversification. When species having similar niches coexist, they are expected either to reduce their niche breadths or increase their niche overlap. There are a variety of examples of organisms changing their morphology, physiology and behaviour during coexistance with other species having similar niches. Infact, Hutchinson (1959) showed that for species to coexist, the larger species has to be at least 1.3 times larger in linear dimension or twice as large as the smaller species in weight. This so called 1.3 size ratio has come to be rcognised as something of a rule in ecology. Since Hutchinson's work this rule has been found to hold good in many other communities including those of spiders (Uetz, 1977), tiger beetles (Pearson and Mury, 1979), lizards (Pianka, 1969), salamanders (Krzysik, 1979), squirrels (Emmons, 1980), bats (McNab, 1971), desert rodents (Brown and Lieberman, 1973), and ofcourse many kinds of birds which provide the most spectacular examples (Cody, 1973; Diamond, 1973). It is also true that many exceptions and criticisms of the Hutchinson's rule have appeared in the literature in recent years (See for instance Horn and May, 1977).

Assuming that interspecific competition plays an important role in structuring biological communities, niche theory predicts that when species coexist, their niches should either become narrower or their overlap become greater compared to the allopatric situation. There are many studies which appear to support these predictions. In summary, coexitance is made possible by niche shift (also called character displacement) (Fenchel, 1975; Giller and McNeill, 1981; Nilsson, 1965), reduction in niche width or increase in niche overlap.

The importance of interspecific competition itself is being seriously questioned by many ecologists in recent years (See Shoener, 1983; Connell, 1983 and Strong et al 1984 for contrasting views) especially by those working with insects where competition does appear to be relatively weak and unimportant. For instance, Donald Strong (1982) has shown quite clearly that a number of species of phytophagus beetles coexist on the leaves of a tropical monocot <u>Heliconia</u>. The total damage caused to leaves is very marginal and both observation and experiments show quite convincingly that interspecific competition is irrelevent. It appears therefore that like all other factors mentioned before, interspecific competition also explains certain patterns for certain species but cannot be generalised.

11.3.8. Speciation and extinction factors

All the factors mentioned so far might conceivably be the effects rather than the causes of biological diversity. It might be argued that the patterns of biological species diversity are first-order functions of the rates of speciation and extinction. Cracraft (1985) has presented the hypothesis that the rate of speciation is primarily a function of geomorphological complexity although other factors like internal morphological or genetic complexity, behavioural and ecological attributes and sexual selection might have marginal effects. This hypothesis leads to three predictions.

Prediction 1: Species will be distributed non-randomly and will be clustered in areas of endemism.

Prediction 2: Species will exhibit congruent patterns of historical biogeographical patterns.

Prediction 3: Geographic gradients in species diversity will parallel gradients in geomorphological complexity.

As far as extinction is concerned, the most reasonable hypothesis appears to be that the probability of extinction is a function of the change in the value of environmental harshness to which a species is exposed. A balance between the rates of speciation and extinction must result in the observed levels of diversity. Cracraft (1985) considers

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diversity at three levels namely diversity in different taxa or clades, diversity across the globe and diversity through geological periods and cautions against the uncritical acceptance of equilibrium models.

Efforts to integrate all these factors and provide a comprehensive model for the observed patterns of biological diversity may be found in Cracraft (1985), Connell(1978), and Huston(1979).

12. EXTINCTIONS

N.V. JOSHI

12.1 Introduction

Extinction is perhaps the most important process of interest to conservation biologists , since preventing (or at least minimizing the probability of) extinction of the species of interest is one of their chief objectives.

Following Gilpin and Soule (1986) , one may broadly classify extinctions into deterministic and stochastic. Deterministic extinctions , as the name implies , are consequences of generally unalterable processes , frequently activities of Man. Complete deforestation of a region or flooding large areas by construction of dams may be cited as examples of human activities , while periodic occurences of glaciation , of natural ones.

Stochastic extinctions , on the other hand , result from random changes in the various biotic and abiotic factors affecting the birth and survival probabilities of individuals in a population. Amongst the abiotic factors one may include natural calamities from terresterial events like severe storms , earthquakes , volcanic eruptions etc. Some of the mass extinctions , known to have occured between 10 to 250 million years before present , are believed to have extraterresterial origins viz. impact of large meteorites. Biotic calamities include emeregence of virulent and fast spreading viral or microbial strains. All of these occur unpredictably and sporadically , and there does not seem to be any satisfactory way of anticipating them or of devising suitable counterstrategies to minimize their impact.

On the other hand , following May (1973) , one can identify three other proceses which causing stochastic extinctions - genetic stochasticity , demographic stochasticity and environmental stochasticity. Genetic stochasticity results from higher levels of inbreeding encountered in a small population , as described in chapter 8 . Demographic stochasticity is due to random changes in births or survivals in the population. Fluctuations in carrying capacity due to changes in the habitat , fluctuations in the population of predators and parasites etc. constitute elements of environmental stochasticity.

Schaffer (1981) describes changes in the population of heath hen , which clearly illustrates the role played by all these factors in the extinction of the species. By 1900 , this species had survived only in Martha's vineyard , and the population size was about a hundred. In 1907 , a portion of the island was set aside as a refuge , and the population gradually increased to 800 by 1916. However , the combined effect of a fire (natural calamity) and unusually high number of predatory goshawks (environmental stochasticity) in the next two years reduced it to 100-150. Though increased to 200 in 1920 , a disease (environmental stochasticity) reduced it again to less than 100. Over the next few years , proportion of males increased (demographic stochasticity) , and the birds seemed to become increasingly sterile (genetic stochasticity). By the year 1932 , the population became extinct.

12.2 A mathematical modelling approach

It is easily seen that the probability of survival of a population increases with its size. To ensure that a particular population is conserved , one should attempt to maintain as large a population as possible. This is inherently impossible , since one wishes to maintain many species in the same reserve. Secondly , there are bound to be other constraints on the size of the reserve. For devising optimal conservation strategies , one needs to know the quantitative dependence of extinction probabilities on the various demographic and environmental parameters of the population. For example , one needs answers to questions such as - What is the average time for extinction for a population of size N , given the variance in the reproductive rate r and the carrying capacity K ? Or how large should a population be so that the probability of extinction in 100 years is less than 1% ?

In the next two sections , a brief description of some of the mathematical models aimed at answering such questions is presented.

12.3 Demographic stochasticity

Extinction due to demographic stochasticity is mainly a mathematical consequence of fluctuations in the number of births and deaths in a finite population. Even if birth and death rates were constant , independent of density , and identical for all individuals , simply due to chance , different individuals produce different number of offspring and survive for different lengths of time. The mathematical method used to analyse this phenomenon is known as the theory of branching processes. For example , if the per capita birth and death rates are b and d , the probability that a population of size N will go to extinction before time t is given by (Pielou,1977),

$$P(N,t) = \left(\frac{d \exp(b-d)t - d}{b \exp(b-d)t - d} \right)^N$$

When birth and death rates are equal , the above expression simplifies to

$$P(N,t) = \left(\frac{bt}{1 + bt} \right)^N$$

For example , if the rates are 0.10 per year , the probability that a population of 10 individuals will survive beyond 50 years is only about 84%. However , for a population with size 25 , the probability is above 99%.

Age structure , density dependence etc. lead to more complicated expressions (Pollard , 1973) and there is some controversy about the validity and relevance of these models for describing real populations (Schaffer , 1981).

12.4 Environmental stochasticity

Last decade has seen considerable ammount of work in assessing the impact of environmental stochasticity on extinction of populations. The effect of environmental changes is introduced in the population dynamics equations by treating r , the intrinsic growth rate or K , the carrying capacity (or both) as random variables (Roughgarden , 1979 ; Leigh , 1981). Though the explicit expressions are rather complex , all of them indicate rather steep rise in the probability of extinction with increasing variabilities of r and K. Moreover , the expected time to extinction increases rather slowly with N , the population size.

12.5 Implications for conservation

All the processes described above generally act simultaneously on the population of interest. As a result , a decrease in the population size due to any one of them immediately makes the population more susceptible to extinction due to the other cause as well (Extinction Vortices , as described by Gilpin and Soule , 1986). To estimate the minimum viable population size in any specific situation , it is highly desirable to set up a simulation model based on the parameters obtained from detailed field work , and including the possible impact of all the above phenomena (Soule , 1987). For example , Wilcox (1986) quotes the results of a detailed simulation of the grizzly bear population in the Yellowstone national park. The probability that a population of 70-90 bears surviving beyond 100 years was seen to be above 95%. Such studies are likely to lead to as reliable estimates of minimum viable populations as are possible presently , to enable devising appropriate conservation strategies.

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14. INTRASPECIFIC POPULATIONS AND SPECIATION IN INSECTS IN AN AGROECOSYSTEM

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ABSTRACT

Biological diversity is an integral aspect of Conservation Biology. The species and their populations constituting the biosphere are to be probed in detail to study this diversity. If an objective analysis is made of our progress in this direction, it could be seen that approximately 1.5 million living organisms have received scientific names of the 8 millions estimated. For most of these 1.5 million species, just brief descriptions and only localities have been recorded. Except for a handful of organisms, investigations on the intraspecific populations and speciation are lacking.

In agroecosystems the above gap in the knowledge becomes too wide, since many pest species which obstruct human progress are involved. No doubt one will be delighted to hear about extermination of pest species. But previous records have shown that extermination would be disastrous even if the species concerned is a pest. Thus it is essential that we answer the question "What species are to be conserved ?" and establish criteria for conservation of species. This is an essential requirement before planning strategies of Conservation Biology in an agroecosystem. The investigations on the intraspecific populations and speciation will be a crucial step in this direction and such investigations on few pest species are explained here.

The species studied include leaf cutter weevil *Deporaus marginatus* Pascoe (Rhynchitinae: Curculionidae: Coleoptera) and leaf eating ash weevils namely *Myllocerus undecimpustulatus* Faust and *M. dentifer* (Fabricius) (Otiorrhynchinae: Curculionidae: Coleoptera). The species *Deporaus marginatus* was extensively studied for its populations occurring at Kanpur and New Delhi, in the mango orchards. It was found that the populations of this species from Kanpur and New Delhi not only differ in their biological characteristics but are also reproductively isolated though structurally similar. The chief biological characteristics which showed differences are their damage potential, oviposition, incubation, larval and pupal periods, fecundity, longevity, percentage hatching and larval instars. It was seen that the populations at New Delhi have an edge over those of Kanpur in their line of evolution.

Studies on leaf eating ash weevil *Myllocerus undecimpustulatus* showed that there are five distinct populations in the cotton agroecosystem, differing in their elytral colouring patterns. It was seen that these coexisting populations are physiologically distinct and certain extent of reproductive isolation had also crept in among these populations. The population diversity is thus complex in this species leading to difficulties in explaining their present status. Further studies on their breeding and other behavioural characteristics will solve this problem. Similar situation exists in another ecosystem namely sorghum crop, where the species involved is *Myllocerus dentifer*. There are two distinct populations in this species which differ structurally and physiologically with restricted reproductive isolation behaviour. All these indicate that there is subtle process of speciation going on in these pest species.

Such investigations on the population diversity and speciation in pest species explained above indicate that there is great scope for such studies. There is a need to encourage such investigations for planning Conservation Biology strategies and formulation of Integrated Insect Pest Management strategy which centres around conservation of ecosystem.

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15. COMMUNITY STRUCTURE AND STABILITY

MADHAV GADGIL

15.1 Introduction

In this lecture we will address the question of how interactions amongst species and other community level processes modulate the effects of certain human impacts. The impacts of interest to us include : (a) enhancement of mortality rates of a species through harvests or pollution, (b) complete deletion of local populations of certain species from a community and, (c) addition of populations of new species to the community.

The consequences of such interference may be viewed in several ways. They could be measured in terms of numbers of individuals of different species in the community, or in terms of an ecosystem function like productivity. If the community returns to its original state after a perturbation, it would be said to be stable with respect to that perturbation. The more "resilient" the community, the more quickly would it return to its original state after a perturbation. Its "persistence" may be measured in terms of the time it continues in its original state following a perturbation. The less the change as a result of the perturbaiton, the more "resilient" may that community be considered.

Last three decades have witnessed a vigorous debate over how the "complexity"of a biological community relates to its "stability". Just like stability, complexity too has many facets. Amongst these are the number of species, the connectance amongst these species and the nature and strength of the interactions between the species connected with each other. The initial supposition was that complexity begets stability. Mathematical models of community dynamics however suggest that this need not be so. In fact, most models lead to less stability with an increase in the number os species, connectance amongst the species and in strength of interactions. These are however, Lotka-Voltera type of models. In a situation in which the "predator" does not affect the prey population, as with detritus feeders, stability may increase with an increase in the number of species. Dependence of birds on trees for nest holes or of monkeys for roosting places is also analogous to that of detritus feeders. Similarly, we need to explore more carefully the mutualistic interactions as with pollinators and seed dispersers. Where such interactions are important, complexity may indeed be expected to enhance stability on theoretical grounds (Pimm, 1982, 1986).

15.2 Response to harvests

An important issue in conservation biology relates to the response of biological communities to harvests. This is because most natural communities, be they forests, wetlands or grasslands are subject to harvests such as logging, fishing and grazing. The harvesters have seldom been concerned with conservation of diversity; rather they have tended to delete species of little economic value. Thus in south India early British forest management was entirely focussed on raising plantations of teak (Tectona grandis) to the exclusion of all else, including the evergreen species. Whole tracts of west coast evergreen forests were therefore destroyed by them by girdling, and bamboo was prescribed as a weed to be eradiated. Lianas were regularly removed in the so-called "climbercleaning" operations.

Outside of the teak plantations, timber was harvested from natural forest on a so-called "sustained yield" basis. The assumption was that only the increment to the stock was being harvested, and that the original species composition and structure of the community would change but little. There were serious flaws in this assumption for there was totally insufficient knowledge of the growth and dynamics of the forest to prescribe the appropriate harvesting regime. Moreover, recent theoretical work has demonstrated that there may be interactions amongst different species so that attempts to harvest individual species at the maximum sustainable yield levels may lead to a collapse of some of the harvested populations.

It is indeed quite clear that despite the attempts to regulate harvests to maximum sustainable yield levels, forests, seas, lakes, rivers and grasslands have very often been subjected to overharvests and depletion of diversity. Thus Indian forests have over large tract been opened up and become clogged with large populations of a few weedy species such as Lantana, Eupatorium and Mikenia.

15.3 Deletions

Apart from global extinctions, human impacts have resulted in deletions of many species from individual communities. How do the communities react to such deletions ? Pimm's (1982, 1986) models suggest that complex communities would be less sensitive than the simpler communities to deletions of primary producers, the plant species. Thus tropical humid forests may be less sensitive to the loss of plant species than less species rich communities such as tropical dry thorn scrub or temperate coniferous forests. At the same time, more complex communities are expected to be more sensitive to the loss of top carnivores. Deletion of the panther from the humid forests may then be a matter of more serious concern than, say that of the grizzly bear.

There is unfortunately little empirical data on the consequences of species deletions from natural communities. Some of the best studies have come from intertidal zones where the elimination of top carnivores such as starfish species enables some one species of herbivore to outcompete other species leading to substantial loss of diversity. This may be expected to happen, however, only if the predator preys more heavily on an otherwise competitively superior species.

15.4 Keystone Resources

How a species being deleted is linked to other species will obviously determine how far the effects of its deletion spread through the community, and whether it will result in a cascade of other local extinctions. Some elements of biological communities may be strongly linked to a large number of other elements and may therefore be critical for the persistence of many species in the community. Tergorgh (1986) terms such species "keystone resources". He has looked at these primarily in the context of tropical humid forests in largely aseasonal environments. A very significant proportions of birds and mammals in such forests feed on fruit, and contrary to the general belief, this fruit production is not year round. In the Cocha Cashu rain forest of Peru, for instance, studied by Terborgh, there is a shortfall of fruit production compared to the demand in the months of May-June-July. The survival of fruit eating birds and mammals making up over 75% of large animal biomass and numbering more than 100 species therefore depends on the few species producing fruit and nectar in these months. These include palm nuts and especially various species od Ficus. Ficus species produce fruit at irregular intervals round the year and at least some individuals are in fruit in the season of fruit famine. This genus is likely to serve as a keystone resource not only in Amazonia but in fact over much of the tropical forested areas. Its removal is therefore likely to strongely affect a very large number of species, perhaps leading to their extinction. It is notable therefore that Ficus is protected as a sacred tree over much of South Asia and Africa.

Gilbert (1980) suggests that another group of species, for instance, Englossine bees may similarly serve a critical role in the tropical forest ecosystems so that their deletion may lead to the extinction of many other species. He terms species like Englossine bees "mobile links", responsible for pollination of a wide groups of plant species over large areas. He also remarks on the specialization of a number of herbivores to specific plant species as a result of hostile coevolution. In fact Erwin claims that each species of tropical forest tree may have as many as 400 species of canopy insects specializing on it, and which would go extinct if that species were to be eliminated.

15.5 Additions

Finally, we may consider how biological communities react to additions of species. After all, humans have been moving species around wholesale in last several centuries. Rats, pigs, goats, crows and sparrows have all spread in the wake of humans all over the world, as have weeds like Perthenium and Eupatorium. Comparison of island communities with mainlands suggests that species rich communities are more likely to resist invasions than species poor communities. Thus bird communities of mainlands are more likely to resist invasions in comparison with islands, and bird communities of islands more likely to resist invasions than much poorer amphibian communities.

By and large additions do not lead to extinctions, except in special cases like goats on islands or diseases. Thus introduction of bird malaria has wiped out much of the lowland bird fauna of Hawai where the mosquito vector can survive. Diseases shared by man and his domestic livestock with wild ungulates pose a very serious problem in many areas. This, for instance, is the case with rinderpest, or the sleeping sickness. Rinderpest brought in by cattle has played havoc with the Bos gaurus populations in many South Indian sanctuaries; and programme of eradication of sleeping sickness have led to widespread slaughter of wild ungulates in Africa (Dobson and May, 1986).

15.6 Diseases in Zoos

When crowded, animals become more and more sausceptible to diseases, and zoo populations are therefore especially vulnerable. This poses particular problems when considering reintroduction of animals to the wild. In fact a group of Orang Utans slated for release in the wild was found some years ago to have contracted tuberculosis, leading to a cancellation of their release.

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16. IMMIGRATIONS EXTINCTIONS AND SPECIES DIVERSITY

RAGHAVENDRA GADAGKAR

16.1 Introduction

Islands are special in many ways. Following the tradition set by Darwin and Wallace islands as model systems have often attracted ecologists. The ease with which island ecosystems can be delimited, their relatively small size and compactness, and the obvious physical barriers they provide to the free movement of many species thus providing excellent opportunities to document allopatric speciation, are some of the reasons for this. Besides, islands are perhaps the only cases where a strictly equilibrium theory of biogeography is still very useful.

16.2 The theory of island biogeography

The essence of what has come to be knowm as the theory of island biogeography was put forward by Preston (1962) and MacArthur and Wilson (1963) and later developed into a formal theory by MacArthur and Wilson (1967). There are three essential statements of the theory (Fig. 16.1).

1. The number of species on an island is an equilibrium between the rates of immigration of new species to it and the rates of extinction of species already on it.

2. The rates of immigration decrease as the distance of an island to the mainland (which would be the source of immigrations) increases so that nearer islands have more species than corresponding farther

islands.

3. The rates of extinction decrease as the area of the island increases so that smaller islands have fewer species than corresponding larger islands. All the three statements of the theory have been repeatedly verified.

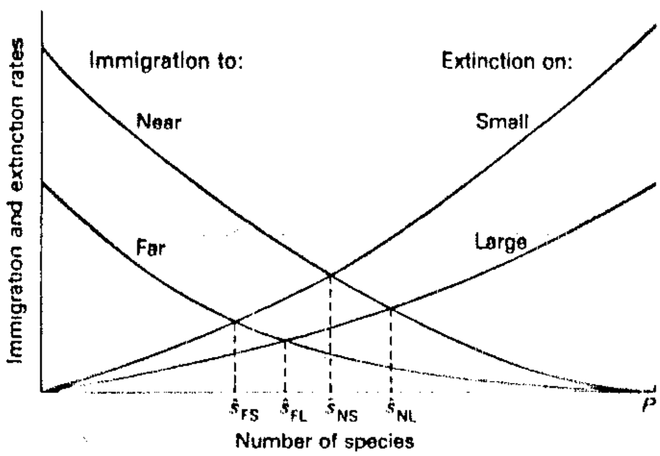

FIG. 16.1 Diagram of the MacArthur and Wilson theory of island biogeography. Equilibria occur at the intersections of the extinction and immigration curves, and are indicated by $\hat{S}$ with subscripts referring to different types of islands. P is the total pool of species

16.3 Defaunation experiments of Simberloff and Wilson

The most significant experimental verification of the theory comes from the studies of Simberloff and Wilson (1969; 1970; see also Wilson and Simberloff, 1970; simberloff, 1974; Williamson, 1981; MacArthur, 1972; Pielou, 1979) who used methyl bromide to defaunate four small but entire mangrove islands off the coast of Florida. Having made a complete inventory of the arthropod fauna of the four islands before defaunation, they systematically followed their recolonization. In about six months all the four islands recovered nearly the same number of species as they had before defaunation. Many species present before defaunation were now missing but many new ones not present before had replaced them. These findings lend strong support to the idea that the number of species on each island was in equilibrium. The pre-defaunation surveys showed that islands closer to the mainland had more species and this pattern was retained during recolonization (Fig. 16.2).

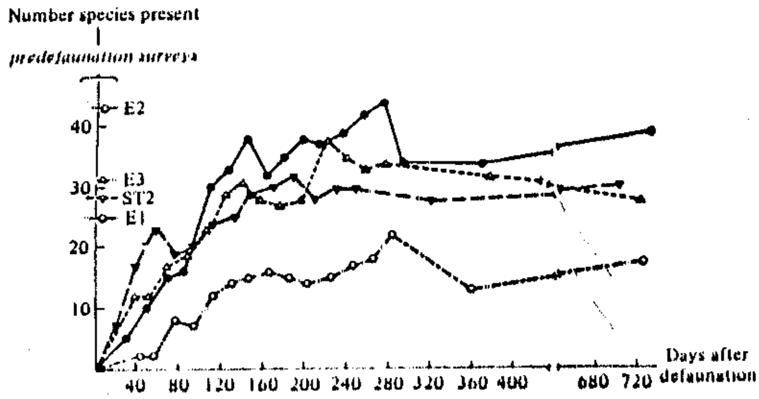

Fig. 16.2

The colonization curves of four small mangrove islands in the lower Florida Keys whose entire faunas, consisting mostly of arthropods, were removed by methyl bromide fumigation. The species numbers just before defaunation and at intervals following it are shown. The number of species is an inverse function of the distance from the nearest source. This effect was evident in the predefaunation census and was preserved when the faunas regained equilibrium after defaunation. Thus, the near island E2 has the most species, the distant island E1 the fewest, and the intermediate islands E3 and ST2 intermediate numbers of species. (From Simberloff and Wilson, 1970.)

16.4 Howell and Diamond bird surveys

A non-experimental but equally remarkable corraboration of the theory comes from Diamond (1969) who surveyed the breeding bird fauna of the Channel islands off the coast of California and compared his results with those of Howell who had previously surveyed the same set of islands 50 years earlier. Such a comparison (Table 16.1) shows that while many species recorded in 1917 were now missing, a nearly equal number of new species had colonised the islands so that extinctions had balanced new immigrations to maintain an equilibrium over the 50 year period. Dammermann's (1948) study of the recolonization of the Krakatoa volcanic island after its erruption in 1883 again shows a similar pattern.

The effect of distance from the nearest source of colonization can, as might be expected, demonstrated more easily for poorly dispersing groups such as mammals (Grant, 1970) and can often be masked by other variables (Connor and Simberloff, 1978).

Table 16.1
Avifaunal Turnover on the Channel Islands
(From Diamond, 1969)

	Area A	Distance B	1917 species C	1968 species D	Extinctions E	Additions F	Introductions G	Immigrations H	Turnover I
Los Coronados	1.0	8	11	11	4	4	0	4	36
San Nicolas	22	61	11	11	6	6	2	4	50
San Clemente	56	49	28	24	9	5	1	4	25
Santa Catalina	75	20	30	34	6	10	1	9	24
Santa Barbara	1.0	38	10	6	7	3	0	3	62
San Miguel	14	26	11	15	4	8	0	8	46
Santa Rosa	84	27	14	25	1	12	1	11	32
Santa Cruz	96	19	36	37	6	7	1	6	17
Anacapa	1.1	13	15	14	5	4	0	4	31

For each island, column A gives the area in square miles; B, the distance in miles from the nearest point on the mainland; C, the number of species of land and freshwater birds breeding in 1917; D, the number of breeding species in 1968; E, the number of species that were breeding in 1917 but not in 1968 and hence must have gone extinct in the interim; F, the number of species breeding in 1968 but not in 1917 ("additions"); G, the number of species present in 1968 that had been successfully introduced by man between 1917 and 1968 (all of these are game birds: California quail, Gambel's quail, pheasant, or chukar); H, the number of species present in 1968 but not in 1917 that had immigrated under their own power between 1917 and 1968, calculated as F minus G; and I, the turnover rate expressed in per cent of the species pool for 51 years, calculated as $100(E + H)/(C + D - G)$.

16.5 Species-area curves

A second kind of evidence for the theory comes from a corraboration of its prediction that extinction rates are inversely proportional to island area so that larger islands should have more species. The area effect is usually demonstrated using the species-area Arrhenius plot which is normally linear with a slope ranging from 0.15 to 0.40 (MacArthur and Wilson, 1967; Diamond, 1973; Terborgh, 1974; Cox and Moore, 1980).

16.6 Other isolated habitats

The theory of island biogeography can in principle be applied to a variety of other isolated habitats. Species-area curves have been demonstarted for insect pests in monoculture plantations (Strong, 1974; Strong et al 1977; Opler, 1974; Lawton and Schroder, 1977). Perhaps the most imaginative of these are the experiments of Maguire (1963; 1971) who set out beakers of water along a transect running from a fresh water pond in Texas and recorded the number of species of algae and protozoa colonizing these islands of water at various intervals of time.

16.7 Data that do not fit

Mountaintops may also be thought of as similar isolated habitats and Brown (1971) therefore decided to apply the equilibrium theory of island biogeography to distribution of boreal mammals on the mountaintops of the great basin of North America. His conclusions defy almost all the predictions of the equilibrium theory! The species-area curve is considerably steeper (slope=0.43) than the curves usually obtained for insular biotas suggesting that boreal mammals have an exceptionally low rate of immigration to isolated mountaintops. There is no correlation between the number of species and variables which are likely to affect rates of colonization, such as distance between island and mainland, distance between islands, and elevation of intervening passes. Thus Brown concludes that the today´s mammalian fauna of these mountaintops are true relicts of the Pliestocene period and do not represent an equilibrium between immigration and extinction. The moral of this story is that even isolated habitats cannot always be adequately described by simple equilibrium models.

16.8 Critique of the MacArthur-Wilson theory

Some criticism of the theory comes from naturalists who feel that the theory ignores important aspects of the biology of different species and is best illustrated in the following words of Berry (1979) "In the light of these many pressures, simple equilibrium theories of island biogeography are woefully inadequate; every species has to be considered on its own merits´. I suggest that these criticisms are best ignored because they reflect an *a priori* denial of any general patterns and probably come from a class of naturalists who "take refuge in nature´s complexity as a justification to oppose any search for patterns." (MacArthur, 1972). On the other hand there are clearly many limitations to the theory. The three main shortcomings are : 1. the theory only concentrates on numbers of species and completely ignores numbers of individuals of the different species, 2. the theory does not allow for any historical factors and thus runs into the kinds of difficulties exemplified by the distribution of borean mammals on mountaintops, and 3. there has been insufficient effort to incorporate the effects of evolution occuring on the islands. This last difficulty has been to an extent addressed by Wilson (1969).

17. MUTUALISTIC INTERACTIONS IN FOREST ECOSYSTEMS

KAMALJIT. S. BAWA

17.1 Introduction

Mutualistic interactions involve two or more species, each of which benefits from the resulting interaction. Examples of mutualisms abound in nature: plant-pollintor and plant seed disperser interactions are the most prominent types. Mutualisms occur in all terrestrial ecosystems, but they are most numerous and diverse in tropical forest ecosystems.

The role of mutualistic interactions in the structure and stability of communities has not received adequate attention(Gilbert, 1980). Here, I first describe some common types of mutualisms encountered in terrestrial communities, particularly in tropical forests, then discuss the concept of Keystone mutualists and finally explore the role of mutualistic interaction in the maintenance of diversity and stability in community.

17.2 Examples of mutualistic interactions

17.2.1 Figs and Fig wasps

The fig trees belong to the genus *Ficus* in the family of Moraceae. There are more than 700 species of the genus. All the species are pollinated by wasps. The pollinators are species-specific. Each species of *Ficus* is persumed to have its own species of pollinating fig wasp.

The process of pollination is complex. It starts with a female impregnated wasp carrying the pollen entering an unripe fig through an opening called ostiole (Fig. 17.1B). Once inside the fig, the female wasp lays eggs in the ovaries of the female flowers (Fig. 17.2). At the same time it pollinates the flowers with the pollen it is carrying on its body. The female flowers are of two types, some have short styles and the other long styles. Eggs are laid only in short style flowers. However all the flowers are pollinated. The wasp larvae consume the developing seeds inside the short style flowers and soon the next generation of wasps emerges inside the fig(The female wasp that originally entered the fig dies soon after eggs are laid and flowers are pollinated). This generation consists of males and females. The males emerge first and are wingless. They mate with the females and then together, males and females dig a tunnel through the fig wall. The mated females leave the fig via the tunnel; however before they leave the fig, they collect pollen from the male flowers that have now matured (Fig. 17.2E). The impregnated female wasp carrying the pollen now seeks another unripe fig on another tree to start the cycle again. The male pollinating wasps never leave the fig. Because fig wasps use chemical cues to locate their hosts and because they are extremely species specific, figs can persist in many tropical forests in low densities (Janzen, 1979).During the larval development of wasps, seeds continue to mature in long style flowers and soon after the female wasps emerge, the figs ripen and are dispersed by a wide variety of mammals and birds.

Note that the mutualistic interaction between figs and

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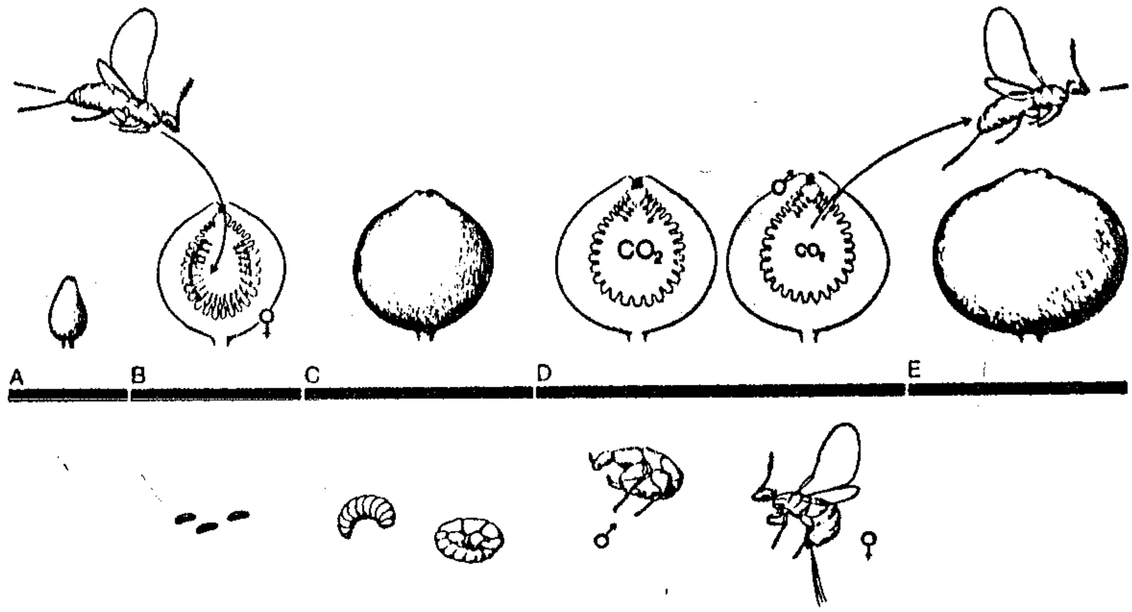
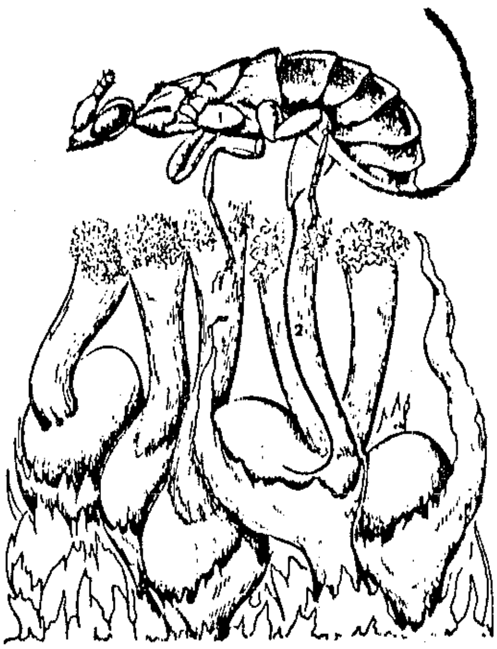


Fig. 17.1
Stages in the developmental cycle of the fig and its wasp.
[After Barth, F. G. 1985]

17.2a

Fig 17.2
The female of the fig wasp *Ceratosolen arabicus* laying eggs The forelegs are reaching into the pocket (1) at the side of the thorax to take out the pollen she carries. The long ovipositor (2) can reach the ovary of the flower only if the style is of the short type.
[After Barth, F G, 1985]



17.2 b

pollinating fig wasps is species-specific, but the interactions between figs and seed dispersers is not because seeds of figs are dispersed by a wide variety of animals (Janzen, 1979; Terborgh, 1986). We shall return to this point later.

17.2.2 Heliconia and hummingbirds.

Heliconia is a genus of vines in the Passifloraceae and occurs in tropical forests. In an atlantic lowlnd rain forest in Costa Rica, all the 12 species that occur in the forest are pollinated by various species of hummingbirds (Stiles, 1979). The interaction between hummingbirds and the species of Heliconia is not as specific as in the case of figs and fig wasps. In the cas of Heliconias a group of similar species are pollinated by a group of similar birds. The hummingbirds constitute a 'guild', which is defined as a group of species with similar feeding relationships, and, similarly the various species of Heliconia constitute a guild in the sense that they are exploiting a resource (hummingbirds) in a similar fashion. Of course not every species of Heliconia is visited by every species of hummingbirds. Rather a particular species is predominantly visited by one (or more) species which also pollinate other species contemporariously or, more often, sequentially.

An examination of the flowering phenologies of various species of the genus Heliconia reveals that their blooming periods are staggered in time. According to Stiles(1975) the hummingbirds shift from one species to the other during the flowering of Heliconia species.

'Guilds' such as those represented by Heliconia and hummingbirds are common in tropical forests and involve groups of pollinators such as bats, hawkmoths, scarab beetles, medium sized to large bees and others.

In the case of figs and fig wasps we are interested in determining the fate of one species of fig wasp following the extinction or elimination of its fig host, but in the case of 'guilds' like _Heliconia_ and hummingbirds we are interested in the effect of the extinction or elimination of one or more species of _Heliconia_ (or hummingbirds) on the populations of hummingbirds (or _Heliconia_ species). We shall return to this point later.

17.2.3 Rain forest trees and their pollinators - a community perspective.

So far we have considered species-specific relationships (figs and fig wasps) and relationships between groups of similar species (_Heliconia_ and hummingbirds). At the next level of organization, we can examine interactions between entire communities and the pollinators. Pollination systems of rain forest trees in a tropical lowland rain forest in Costa Rica, the site of Stile's studies are summarized in Table 17.1. The notable points of this data set are: 1. a wide variety of animals are involved in pollination of rain forest trees 2. different pollinators are distributed non-randomly, for example certain pollinators such as hawkmoths, beetles and hummingbirds are more common in the understorey than in the canopy, and 3. the diversity of pollination systems is higher in understorey than in the canopy. We shall return to the last point later.

Table 17.1

Relative frequency of different pollination species
(After Bawa et al., 1985)

Pollinator type	Number of species pollinated		% of all tree species pollinated
	canopy	understorey	
Bat	2	2	3
Humming bird	1	6	5
Small bee	4	14	14
Medium to large bee	21	22	30
Beetle	1	5	4
Butterfly	1	6	5
Moth			
Sphingid	1	11	8
Other	5	4	6
Wasp	2	5	5
Generalist insect	11	15	18
Wind		3	2

17.3 Keystone mutualists

The term keystone mutualists was first coined by Gilbert (1980) who defined them to include those organisms, usually plants, that provide critical resources to an assemblege of animals usually during periods of food scarcity. Plants can act as keystone mutualists by providing critical support to pollinators or to seed dispersal agents.

Among the examples discussed, Heliconia appears to be a keystone plant resource for some species of hummingbirds, which depend upon nectar of <u>Heliconias</u> all year around (Gilbert, 1980). Because one or more species of <u>Heliconia</u> is in flower at any given time of the year, hummingbirds are assured of a steady source of nector. Stiles (1975) also notes that some of the <u>Heliconia</u> species require light gaps in the forest for flowering to occur.

Figs constitute another example of keystone mutualist for a wide variety of fruit-eating animals that also act as seed dispersal agents of figs and other plants (Terborgh, 1986). In many tropical forests, more than 100 species of birds and mammals are dependent upon fruit for their food requirements, but the availability of fruit varies considerably from one season to another (Terborgh, 1986). Because, fig trees of various species are generally in fruit at any given time of the year, they act as important sources of fruit during the lean period. Note that asynchronous fruiting of fig trees in a population is consequence of their specialised mode of pollination. Probably as a result of selection for outcrossing, figs within a tree ripen synchronously so that the emerging wasps seek figs on other trees which are in a different stage of fig development (Janzen, 1979).

Many other examples of plants that act as keystone resources for pollinators or seed dispersal agents are described by Gilbert (1980) and Terborgh (1986).

17.4 <u>Implications for community stability and conservation biology</u>

There are many definitions of stability. According to a common definition, systems are considered stable if following a perturbation all species densities return to equilibrium (Pimm, 1986). A number of qualitative models exploring the implications of disruption in mutualistic interaction involving pollination and seed dispersal have been proposed (Janzen, 1973; Gilbert, 1980; Terborgh, 1986). However, there is little formal treatment of the effects of removal or addition of one or more species on the populations of the remainder species involved in a mutualistic interaction. Nevertheless a number of observations can be made.

1. Among the mutualistic interactions considered here, disruption of pollination systems is likely to perturb the community more than the breakdown of a seed dispersal system. This is due to the fact that plants and pollinators generally are more coevolved with each other than the plants and their seed dispersal agents (Janzen, 1985).

2. When the relationship is very species-specific as in the case of figs, it follows that elimination of one of the interacting species will lead to the extinction of the other species. Such an extinction so far has not been documented for any plant or its pollinators, but there is an example of the likely extinction of a plant species following the disappearance of its seed dispersal agent. In Mauritius, there is no evidence for regeneration in the populations of Calvaria major, a tree species, because its seed dispersal agent, the dodo bird, has become extinct(Temple, 1977).

3. Within a given forest, certain life forms and certain habitats may be more sensitive to disturbance than the others. As mentioned above, pollinator diversity seems to be maximum in the understorey. In many tropical forests, especially in India, the understorey has been severely degraded with possible deletereous effects on the

regeneration of the canopy species.

4. The elimination of the keystone mutualists is likely to have a ripple effect throughout the community (Gilbert, 1980). As Terborgh (1986) comments, the deletion of figs from a forest can lead to a "collapse" of the whole system. Incidentally, the religious and cultural practices to protect figs in India may have a deep ecological basis.

5. On a local and regional basis, the maintenance of certain habitat and vegetational types may buffer the system against perturbations in mutualistic interactions. Gilbert (1980) cites many examples of keystone mutualists requiring successional patches for their maintenence. Terborgh (1986) states that during periods of food shortages many frugivorous birds migrate to higher elevations. Thus the conservation of such species may require the maintenance of forest types at elevations other than where the target community is located. This may have implications for conservation of many tropical moist forests in Western Ghats and the eastern Himalayas in India.

17.5 Conclusions

Plants and animals in most tropical forests are involved in a myriad of mutualistic interactions. Both prevailing theory and intuition suggests that a disruption of such interactions will have a negative effect on community stability. However, we do not know the extent to which communities may (or may not) be able to withstand the breakdown of mutualistic interactions that are not species-specific. There is a great deal of scope for theoritical as well as empirical work in this area. The problem is particularly challenging for conservation biologists and resource managers in the tropics because the pace at which the tropical ecosystems are being altered is rapid and the knowledge about mutualistic interactions within such ecosystems is woefully inadequate.

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18. BIOLOGICAL CONSIDERATION IN ENVIRONMENTAL IMPACT ASSESSMENT

By:
Edy Brotoisworo

Abstract

Environmental Impact Assessment (EIA) is an activity to assess impact of proposed development project which is considered to have significant impact on environment. This activity comprises studies on various aspects which includes biological, physical, socio-economic and socio-cultural environments. The aim of the studies is to prepare an Environmental Impact Statement (EIS) which will be used as a tool in decision making process of the proposed development project. In this paper a discussion will be made on the biological aspect of the EIA.

Impact of development project on biological environment is very extensive. Particular consideration should be made when such proposed project will affect natural components of the environment, especially flora and fauna which have economic, scenic, cultural and scientific (in particular biological) values. Consideration of impact are based on several aspects, i.e. mobility of animal, site tenacity, social behaviour, space requirement, distribution in space, adaptability in new environment, ecological niche, etc. Evaluation of impact is done by analyzing the magnitude and importance of the above aspects, and may also be done by considering following factors, e.g. relative scarcity, change in status, endemicity, periferality, habitat specialization, etc.

The final study should aim on how to overcome or, at least, to minimize adverse impacts and to enhance the positive impacts.

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19. The Boundary Model: A Geographical Analysis of Design and Conservation of Nature Reserves

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ABSTRACT

It is widely recognised that nearly all parks and reserves are too small to protect their biological diversity. In response to this problem, we have been developing a multidisciplinary 'boundary model' that focuses upon the processes of exchange across the administrative edges of nature reserves. The model incorporates known dynamics from various disciplines and describes the interactions of these forces across the boundary. These disciplines include biogeography, ecology, and human effects, influences and attitudes in an understanding of reserve boundary vulnerability and effectiveness. The boundary model recognises the development of edges in association with the establishment of the administrative boundary. However, it discerns between 'natural' and 'generated' edges that are based upon the differing stimuli for their development and change. Segmentation of the boundary is recognised as a manifestation of environmental heterogeneity. The boundary model suggests that exposure of the reserve is a major determinate of potential vulnerability. Effectiveness of reserve protection is hypothesised to be more dependent upon what crosses the boundary than upon any internal processes alone.

20. Widespread use of Insecticides

Prof. Yosiaki Ito
Japan

Consequences of wide-use of chlorinated insecticides in Japan and other western countries and the way to reduce the amount of insecticides: I will first show some results of biological concentration of insecticides in ecosystems, and the harmful effects of these to wild animals. Then I will explain the changes of insect pest fauna by the wide-use of insecticides in Japan. In the last, I will introduce some of recent results of the application of the non-insecticidal control measures in Japan, such as sex-pheromones, silver vinyl films, and sterile insect technique, and an example of successful reduction of insecticide sprays by the analysis of pest damages on rice crop.

25. Tropical rain forests and herbicides

Prof. Yosiaki Ito
Japan

The basic structure of tropical rain forest ecosystems and its delicacy in relation to the consequences of wide military use of herbicides in Vietnam will be discussed.

23. BIOGEOGRAPHY

MADHAV GADGIL

The surface of the earth with its varied configurations of land and water, and temperatures ranging from -40^0 to 40^0 c poses a variety of challenges to living organisms. A whole variety of living organisms has evolved to tackle these challenges, with many broad similarities in the solution adapted to similar environnmental challenges. Thus the rocks in the intertidal zone buffetted by strong wave action harbour shelled animals cemented to the rocks, while tall trees dominate warm, humid tracts of land. Thus, different life forms are characteristic of the biological communities under different environmental regimes; such characteristic communities are called biomes. Since the plant life forms are the easiest to recognize and dominate the landscape, most biomes are distinguished by the dominant plant life forms. The eight major terrestrial biomes thus recognized are the Tundra, the Taiga or northern coniferous forest, the Temperate forest, the Tropical rain forest, the Tropical seasonal forest, the Temperate grassland, the Tropical savanna grassland and scrub and the Desert. In addition we may distinguish the Oceanic biome of open water, the Rocky shore biome, the Muddy shore biome, the Freshwater lakes and streams.

The biomes however do not specify the taxonomic distribution of the living organisms. Thus the dominant epiphytes in the tropical rain forests of Indonesia are orchids, they are bromeliads in those of Brazil. Similarly kangaroos and wallabies are the large herbivorous animals of Australia, bovids are their analogs in Asia and Africa.

Which taxa occur in a specific region is thus dependent on the evolutionary history, the barriers to dispersal, and the geographical and climatic changes. The distribution of living organisms from a taxonomic perspective is the subject matter of biogeography, which has obvious implications for conservation biology. This is because regions may differ from each other in their levels of diversity and of endemicity; an understanding of such patterns being of obvious relevance in efforts to conserve the total spectrum of biological diversity.

Ranges of distribution of terrestrial plants and animals would obviously tend to be governed by barriers to their dispersal such as oceans, deserts or mountain chains. Different groups of organisms would, of course react differently to such barriers; thus plants with windborne seeds can easily cross a small stretch of sea, frogs cannot. Nevertheless, a large number of taxa would tend to have common discontinuities in their distribution at such barriers which would serve to demarcate biogeographical regions. There is therefore a broad agreement in the main biogeographic realms of the world; and the Asian continent is part of two of these. The first is the Oriental, or Indo-Malayan; bounded by the Thar desert, the hill chain of Himalayas, and the deep ocean beyond the continental shelf that constitutes the Wallace line. The second is the Palaearctic region including the rest of the Eurasian continent.

How rich are these two regions compared to the rest of the world ? It is instructive to look at this issue with respect to the mammalian fauna (Cox and Moore, 1976).

TABLE 23.1

Taxon	Afrc	Ornt	Plact	Nrct	Ntrp	Astr
Rodents	+	+	+	+	+	+
Insectivora, Carnivora Lagomorpha	+	+	+	+	+	-
Ungulates, Elephants	+	+	+	+	+	-
Primates	+	+	+	-	+	-
Pangolins	+	+	-	-	-	-
Conies, aardvarks	+	-	-	-	-	-
Sloths	-	-	-	-	+	-
Marsupials	-	-	-	-	+	+
Monotremes	-	-	-	-	-	+
Total # of orders	12	9	7	8	9	3
Total # of families	44	31	29	23	32	11
Total # of endemic families	16	4	1	3	15	10
% endemic families	36	13	3	13	47	91

The Oriental and Palaearctic regions rank third and fourth, after African and Neotropical in the total number of mammalian families. They are at the very bottom of the scale with respect to the proportion of endemic families. This is clearly related to the geological history of the continents. Australia which split away from Gondavanaland before the origin of placental mammals has the highest level of families restricted to that biogeographic realm. Africa is richest in the total number of families for two reasons; firstly because it has a great diversity of environments, and secondly because its mammalian fauna was largely unaffected by episodes of glaciation that wiped out the mammalian faunas of Nearctic and Palaearctic regions.

The broad biogeographic realms are further divided into sub-regions or provinces, for they themselves are dissected by many barriers to dispersal, though of lesser importance. Thus McKinnons (1986) subdivide the oriental realm into Indian, Indochinese, Sundaic and Wallacean sub-regions; and these again into further provinces.

TABLE 23.2

Unit name	Plant		Mammals		Birds	
	spp.	%end	spp.	%end	spp.	%end
Indian Sub-region						
1. Western Ghats	high	high	32	12	57	9
2. Ceylon Wet Zone	high	v. high	20	10	39	15
3. Bengal	high	mod.	55	2	112	1
8. North India	mod.	low	42	–	66	–
11. Eastern Ghats	mod.	mod.	19	–	52	–
12. Coromandel	mod.	low	28	–	33	–
13. Ceylon Dry Zone	low	low	20	10	41	3
14. Deccan Plateau	mod.	low	28	–	47	4
15. Thar/Indus	low	low	26	–	64	5
H. S. Himalayas	mod.	v. high	48	–	124	6
Indo-Chinese Sub-region						
4. Burmese Coast	mod.	low	50	2	89	–
5. S. Indochina	mod.	high	59	–	113	–
6. S. China	low	mod.	35	10	95	1
9. Irrawaddy	high	mod.	55	2	144	3
10. Indochina	high	mod.	65	2	152	3
20. Andamans	mod.	c.10%	–	*	29	10
27. Taiwan	mod.	25%	18	16	44	5
Sundaic Subregion						
7. Malay Peninsula	820	15	208	3	480	1
21. Sumatra/Nicobars	820	11	221	12	466	2
22. Java/Bali	630	5	133	12	362	7
25. Borneo/Palawan	900	34	221	19	440	10
Wallacean Sub-region						
23. Lesser Sundas	510	1	41	12	242	30
24. Sulawesi/Sula	530	7	114	60	268	32
26. Philippines	700	27	127	66	367	39

* Andamans lack any native mammals in the selected groups but do have high endemism in the impoverished mammalian fauna

The table presents data on the relative richness and levels of endemism among plants, mammals and birds in the respective biogeographic divisions of the realm. The figures above the line (Indian and Indo-Chinese sub-regions) are not comparable to those below it (Sundaic and Wallacean sub-regions) which are calculated in a different way. Above the line, information on plants is only qualitative, data on mammals is based on selected groups (primates, ungulates and carnivores) and for birds is based on selected groups only (21 passerine families). Below the line, plant data are based on the total flora within all 118 families that have been revised in the Flora Malesiana, mammal data is for all mammalspecies and bird data is for all resident bird species.

In spite of these limitations of data, a number of interesting features do emerge. Thus the species richness, as well as endemicity can vary greatly. For instance, in the Indian sub region the S. Himalayan region is rich in diversity, but poor in endemicity because it shares most species with neighbouring regions of southeast Asia. On the other hand, the Western Ghats and the Ceylon Wet Zone, with their relatively isolated pockets of tropical humid forests display higher levels of endemicity. The highest levels of endemicity for birds and mammals, however prevail in the islands of Sulewasi and Philippines.

Such an analysis has obvious implications for deciding conservation priorities. But biogeographic information has another facet of relevance to conservation, namely, in assessing the extent of threat to the biota of any particular biogeographic region. A case study of this approach is provided by the appended report on the "Role of protected areas in conservation".

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Role of Protected Areas in Conservation

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TRADITIONS of conservation are deeply rooted in the Indian civilization. The subcontinent, therefore, harbours nature reserves that range in date from the hunting-gathering times to the 1980s and in size from a small serpent grove in the middle of a village to a national park of some thousands of square kilometres.

The rationale for the protection afforded to living creatures in these reserves has also been changing with time, from the need to propitiate divine forces to providing game for the royal hunt and lately for the preservation of wild animals for their own sake. It is only in the last few years, however, that we have come to realize that man must protect nature to ensure his own well-being and that his self-interest is tied in with the preservation of not just a handful of species of current economic utility, but of the biological diversity as a whole. The one person who has played a greater role than all others in India in spreading an awareness of this value of the total spectrum of biological diversity is Dr B.P. Pal. We therefore deem it a great privilege to be called on to pay a tribute to him in the form of this essay.

We thought it would be most fitting if our essay focusses on the extent, the distribution and the conservation of the biological diversity of the Indian subcontinent, particularly in terms of the role of protected areas in this context. The total number of animal species described so far from the India adds up to 80,000; of these 67,000 are insects, 4,000 molluscs,

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6,500 other invertebrates, 1,000 fishes, 140 amphibians, 420 reptiles, 1,200 birds and 340 mammals (Zoological Survey of India, 1980). Another 20,000 species of flowering plants have been described from India (Chatterjee, 1939). This implies that about 5 to 8% of the known species of animals and flowering plants occur in India with a land surface of only 2.2% of the world. It is certain that there would be many further additions when the little-studied invertebrates and lower plants are better investigated. Thus, Jain (1984) estimates that India harbours 20,000 species of fungi, 5,000 of algae, 1,600 of lichens, 2,700 of bryophytes and 600 of pteridophytes. The known 80,000 species of animals too would surely increase to 150,000 or so when invertebrates (especially those of smaller sizes and from habitats such as forest canopy), are more carefully looked at. It is therefore quite safe to estimate that India must harbour at least 200,000 species of living organisms. The challenge before us is to conserve this heritage of diversity for generations to come and the time for it is now. For any delay will only mean an irreversible loss of this precious biological heritage.

While we may save a few hundred, or at most a few thousand, of these species in botanical and zoological gardens and in deep freezers, it is clearly impossible to conserve the entire gamut of this tremendous variety through such artificial means. This can only be approached through the conservation of their natural habitats where they live as members of a community knit together in a web of life. Thus, the banks of fast-flowing Himalayan rivers, the rocks in the intertidal zone of the sea coast, and the north-facing slopes of Aravalli hills harbour their own assemblage of living organisms. These ecosystems are the natural units that go to constitute the biosphere, and the conservation of the total spectrum of our biological diversity has to depend on the conservation of these individual ecosystems over the subcontinent. Some of these ecosystems are very restricted in occurrence, as for instance the spray zones at the bases of large waterfalls, while others such as the flat arid plains of Rajasthan desert are very widely distributed. In order to reduce the tremendous complexity of pattern of distribution of ecosystems, we club together similar ecosystems into broad biome types such as tropical rain forests or hill streams. Of these, biomes such as tropical rain forests are zonal, i.e. coincide with broad climatic zones, while others like the hill streams are azonal. These latter, the azonal biomes, are almost always represented by elements in many distinct geographical regions of the country, as in the case of the hill streams in Nilgiris, Annamalais or Khasi hills. The zonal biomes may sometimes occur over a single contiguous region—for instance, the desert scrub of Rajasthan. In other cases, they may occur in more than one geographical region, as in the wet evergreen forests of the Western Ghats, the north-east India and the Andaman and Nicobar Islands. When representatives of a particular biome type occur in different geographical regions, they harbour species which may be different from each other because of divergent evolutionary

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histories. Thus, the rain forests of Western Ghats harbour the Nilgiri langur and the liontailed macaque, while those of the north-east harbour the golden langur and the hoolock gibbon. Conservation of the total spectrum must therefore be based on conservation of various zonal and azonal biomes in each of the geographical regions of the subcontinent

The current status of conservation of natural biological communities representing the different biomes, zonal as well as azonal, in the different geographical regions of the country then becomes the central matter of our concern in this essay. Operationally, this task is best approached by dividing the country in terms of coverage by different vegetation types to represent the zonal biomes of different geographical regions (Puri *et al.*, 1983). We can then investigate the extent of persistence of natural vegetation representing each zonal vegetation type, as also of azonal biomes, especially those related to water courses, freshwater and brackish-water bodies and marine coastal areas. This provides the basis on which we can then suggest a strategy for the conservation of the entire range of biological diversity of the country.

MATERIALS AND METHODS

One of us (VMMH) has been involved in a programme of mapping the vegetation of most of the peninsular India as a part of the team of the French Institute, providing an opportunity for extensive first-hand field observations. These have been supplemented by an analysis of these vegetation maps (Gaussen *et al.*, 1961 to 1973, 12 sheets), the maps of Himalayan vegetation by Schweinfurth (1957), the forest atlas of India (Das Gupta, 1976), the maps based on satellite imagery by the National Remote-Sensing Agency (1983), and Kawosa *et al.*, (1983). We have also had the advantage of access to as yet unpublished maps based on satellite imagery by Bellan (1985). The locations of protected and undisturbed areas of vegetation was determined on the basis of maps prepared by the Forest Survey of India (1982). Our suggestions on key areas of conservation are based on the extensive work of a committee of Indian Man and Biosphere programme (1982) and correspondence and discussions with a large number of knowledgeable naturalists, scientists and managers. Details of this data-base and its deficiencies will be discussed elsewhere in detail (Meher-Homji *et al.*, under preparation).

STATUS SURVEY

Arid Tracts

Calligonum Series and *Prosopis-Salvadora-Capparis* Series. This, the driest type of vegetation of India, covers regions of Rajasthan, Punjab

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and Jammu with less than 450 mm of annual precipitation and 9 to 11 dry months. It extends over large tracts of flat terrain (over 300,000 km^2) so that the environmental regime has a low level of heterogeneity. In this unfavourable, rather homogeneous regime, the levels of diversity are low, so that only 550 species of flowering plants have been recorded from this vast tract (Blatter and Halberg, 1918; Blatter, 1908; Jain and Deshpande, 1960; Kapadia, 1954). The flora has definite links with the north-African desert with 15% Saharo-Sindian, 18% Sudano-Rajasthanian and 9% tropical Indo-African elements. The element restricted to India is only 12% (Legris and Meher-Homji, 1968). This whole tract is quite unfavourable to human habitation, except where irrigation has been brought in But because of the low productivity of vegetation and the considerable grazing pressure, the natural vegetation has been totally wiped out. Only some degraded natural vegetation persists over about 0.5% of the area The two major nature reserves of this tract are the Desert National Park near Jaisalmer and the Wild Ass Sanctuary of the Rann of Kutch. These parks hold the key to the conservation of this biota and should emphasize recreation of the natural biota through protection, and if necessary by deliberate reintroductions. Apart from these the region also has a number of small wetlands in Jammu and Punjab with protection as wildlife sancturies.

Acacia-Capparis Series. This dry type of vegetation covers the semi-arid tracts of northern Karnataka, Maharashtra, Saurashtra and foothills of Aravallis in Rajasthan with 400 to 850 mm of annual rainfall and 7 to 9 months of dry season. It too extends over large tracts of flat terrain (170,000 km^2) with a rather homogenous environment. As with the previous vegetation series, the level of diversity in this unfavourable, homogenous environmental regime is quite low, so that only 500 species of flowering plants have been recorded from this large tract (Santapau and Raizada, 1955; Vaidya, 1967). This is a transitional zone constituting the eastern limit of distribution of many Sudanian species (11–14%) and western limit of distribution of the Indo-Malayan species (10–14%). The indigenous Indian element is about 28% (Legris and Meher-Homji, 1968). The natural vegetation of this series is, if anything, even more completely decimated than that of the previous series, in spite of moderate human densities, the degraded vegetation covering a measly 0.4% of the potential area. The only protected areas are the tiny Velavadar National Park (17.8 km^2), well known for its blackbuck population in Saurashtra, the coral reef and mangrove areas of the Pirotan island off the coast of Saurashtra, and the wetland of Nal Sarovar in Gujarat. These must become nuclei of recreating the biota of this region

Semi-Arid Tracts

Anogeissus pendula-Acacia senegal Series, *Anogeissus pendula-Acacia*

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catechu Series and *Anogeissus pendula-Anogeissus latifolia* Series. This dry vegetation extends over much of Rajasthan and north-western Madhya Pradesh with 400 to 900 mm of annual rainfall and 7 to 10 months of dry season It covers a wide extent of flat land as well as hill tracts of Aravallis of over 240,000 km^2, and the total number of species of flowering plants recorded is of the order of 700 (Kaushik, 1969; Majumdar, 1971; Maheshwari, 1963; Sharma, 1978). These series are also a meeting ground for the western and eastern elements, so that it has 10% Sudano-Rajasthanian, 8% Saharo-Indian and 17% Indo-Malayan elements. Elements peculiar to India make up 27% of the flora (Legris and Meher-Homji, 1968). This tract is moderately favourable to human occupation. This coupled with low productivity of vegetation and intense grazing pressures has left only about 2% of the potential area under forest cover and a further 1% under degraded natural vegetation. Traditionally, patches of such vegetation have received protection as "orans" or sacred groves dedicated to deities such as Jogamaya in the Aravallis, and many of these still persist. This biome is exceedingly rich in larger wild mammals such as antelopes, deer, panther and tiger and three of the protected areas--Sawai Madhopur, Sariska and Shivapuri--are old princely hunting reserves. So is the Keoladev Ghana National Park at Bharatpur, a wetland famous for enormous concentrations of waterfowl. This biome also includes the important Chambal wildlife sanctuary in Rajasthan and Uttar Pradesh, one of the few protected areas of riverine habitat. These five hold the key to the long-term conservation of this biota; but we should also keep alive the smaller traditional preserves like orans.

Acacia-Anogeissus latifolia Series. This so-called Deccan thorn forest of Maharashtra occurs in regions of 600–800 mm of rainfall and 7 to 8 dry months a year. In common with the dry zone series described earlier, this vegetation is almost totally gone with around 2% of the potential area of 98,000 km^2 remaining under degraded vegetation. There are no protected areas whatsoever representing this vegetation type, and it is imperative that at least one reserve be set up immediately in the hills of Marathwada region of Maharashtra to reconstitute this community.

Anogeissus latifolia-Hardwickia binata Series. This dry series, in regions with an annual rainfall of 500 to 1,200 mm and 6 to 8 dry months, occurs in two disjunct regions, on the dry plateau of Karnataka and Andhra Pradesh and in the Satpura-Mahadeo Hills and Vindhyas belt of Maharashtra and Madhya Pradesh. It covers an area of 120,000 km^2, but has a low diversity with only 475 recorded species of flowering plants; about 25% of these are Indo-Malayan, 45% being indigenous (Vajravelu and Ramakrishnan, 1967; Legris and Meher-Homji, 1968). It is somewhat better preserved than the other dry series described so far because of the hilly nature of some of the tract; thus 9% of the potential area is still under forest cover,

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with another 4% under degraded vegetation. The only major reserve representing this type is the Nagarjunasagar tiger reserve of 3,568 km² in Andhra Pradesh. One may also note the Tungabhadra and Ranebennur sanctuaries in Karnataka, both much smaller and with little natural vegetation. There is no reserve at all in the northern portion in Satpura-Vindhya-Mahadeo hills where at least one needs to be set up urgently.

Albizia amara-Acacia Series *Albizia amara-Chloroxylon-Anogeissus latifolia* Series and *Manilkara-Chloroxylon* Series. These three series of dry vegetation extend over parts of coastal plains of Tamil Nadu and Andhra Pradesh, as well as over the plateau regions of Andhra Pradesh and Karnataka where a rainfall of 500 to 1,500 mm has an annual regime with two distinct peaks during the south-west and north-east monsoon. In this unfavourable and fairly homogenous environment, the diversity is low, the number of angiosperm species recorded being only around 400. Of these about 20% are characteristic of the region and a further 20% are more widely distributed but restricted to India (Mathew, 1970; Sebastine and Henry, 1980; Balasubramanyan, 1975; Legris and Meher-Homji, 1968). As with preceding dry tract series the forest cover is utterly decimated with less than 1% of the potential area of over 200,000 km² being under degraded vegetation. The only nature reserves of note are related to the aquatic habitats. Thus there are three well-known heronaries--at Vedanthangal in Tamil Nadu, Ranganathittu in the course of Kaveri river in Karnataka, and the Pulicat lake in Andhra Pradesh. There are also smaller heronaries, often right in the middle of villages, as in the case of Kokre-Bellur in Karnataka. In all these cases the villagers have traditionally given full protection to the breeding birds, apparently in recognition of the value of bird guano as fertilizer. Another exceptional reserve is the Guindy Deer Park now inside Madras City, stressing the intimate relation between conservation areas and habitation that has been possible in this country. The Point Calimere coastal wildlife sanctuary is particularly valuable as a habitat for migratory birds. There is a proposal to conserve the coral islands of Gulf of Mannaar as a marine biosphere reserve. This is vital. The small but excellent patch of mangrove at Peechavaram near Pondicherry also needs protection. Finally, we must urgently set up some reserves embracing the hilly tracts of this region for protection and restoration of the terrestrial biota of this dry tract.

Other Deciduous Forest Biomes of the Peninsula

The deciduous forest biomes of the peninsula covering vast tracts are a little better preserved than the drier forests of arid and semi-arid zones considered above. Developed in a more favourable environmental regime and in many cases associated with a topographically more heterogenous terrain, they exhibit higher levels of overall diversity with 700-800 species of

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flowering plants in case of many series. A large proportion of these, 48–58% are restricted to India, while the Indo-Malayan elements make up 20–30% of the flora (Legris and Meher-Homji, 1968). The deciduous forest biome is rich in larger wild mammals and has thereby attracted considerably better protection. A number of the reserves were earlier hunting preserves of princes, and are now being protected as sanctuaries, tiger reserves and national parks.

Anogeissus latifolia–Terminalia and *Anogeissus latifolia–Terminalia–Cleistanthus* Series. These vegetation series with an annual rainfall of 700–1,500 mm and 5 to 8 months of dry season are distributed in a broad east-west base from Rajasthan through Madhya Pradesh to Andhra Pradesh and Orissa over an area of 220,000 km². About 11% of this remains under forest cover and 3% under degraded vegetation. There are a few reserves totalling about 2,000 km² protecting this vegetation type, the two notable ones being the Nawegaon National Park and the Nagzira wildlife sanctuary in the Bhandara district of Maharashtra, the two together covering only 270 km². These should obviously become nuclei for a stronger effort at conservation of this biome.

Terminalia–Anogeissus latifolia–Tectona Series. This dry deciduous forest biome extends in a north-south orientation over a large tract of 360,000 km² in a rainfall regime of 800 to 1,800 mm a year. It occurs in a narrow strip immediately to the east of the crestline of the Western Ghats, and in a broader strip to the east of semi-arid tracts of peninsular India from Kanyakumari in the south to a little north of the Vindhyas. In addition there are a few isolated occurrences, as on Girnar hills in Saurashtra. Occurring in a moderately favourable and moderately heterogeneous environment, it displays medium levels of diversity, the number of species of angiosperms recorded being 800 (Sharma *et al.*, 1978; Subba Rao and Kumar, 1967; Kapoor and Kapoor, 1973; Shah *et al.*, 1971; Shah, 1967; Malhotra and Moorthy, 1971). The natural vegetation in the strip near the Western Ghats is a little better preserved; that on the peninsula is largely destroyed except on a few hills here and there. A total of 7% occurs as forest, but a part of this is teak plantations, and another 7.5% is degraded vegetation. Important nature reserves flanking the Western Ghats include Mundanthurai near the southern tip, and Bandipur, Nagarhole and Mudumalai at the base of the Nilgiris. Gir, famous for its lions, in Saurashtra and Panna National Park in Madhya Pradesh are the other significant conservation areas. Bandipur, Nagarhole and Mundumalai along with the eastern slopes of the Nilgiri hills and Talamalai plateau will form a substantial area of over 1,000 km² that will be protected as part of the proposed Nilgiri Biosphere Reserve. Kolleru lake bird sanctuary is a wetland included within this tract.

Tectona–Terminalia Series and *Tectona–Terminalia–Adina–Anogeissus* Series. These dry deciduous forest biomes are distributed in a belt from the

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northernmost tracts of the Western Ghats to the central Indian plateau on the east of the sal forests with a rainfall of 1,100 to 2,500 mm, covering an area of about 190,000 km^2. Lying largely in hilly terrain this vegetation type is moderately preserved, about 25% occurring as forest and another 10% as degraded forest. The key areas for conservation of these vegetation types are the Indravati National Park and the Kutru wildlife sanctuary in Bastar, well known for their wild buffalo populations, and the Tadoba National Park in Chandrapur district of Maharashtra. The *Tectona-Terminalia-Adina-Anogeissus* series of the northern Western Ghats and Satpuras is protected in the Purna National Park in the Dangs; it is vital that the natural vegetation of this tract be preserved and not sacrificed on the altar of teak plantations.

Tectona–Dillenia–Lagerstroemia lanceolata–Terminalia paniculata Series. This moist deciduous forest biome of regions with an annual rainfall of 2,000–4,000 mm extends over parts of the west coast and eastern side of the Western Ghats from Kerala to Maharashtra. Developed in a favourable environmental regime in a tract of considerable heterogeneity, this region is rich in diversity with as many as 1,500 species having been recorded (Santapau, 1960); of these, 52% are restricted to the Indian region, while 30% are of Indo-Malayan affinity (Legris and Meher-Homji, 1968). It covers a potential area of 50,000 km^2, of which some 16% remains under forest, much of it teak plantations, and another 8% under degraded vegetation. The coastal vegetation is largely destroyed by the thick human populations, the only remnants being a few sacred groves in many parts. On the Ghats the key areas for its conservation include the Neyyar and Parambikulam sanctuaries in Kerala, Annamalai sanctuary in Tamil Nadu, parts of Nagarhole and Wynaad sanctuaries of the proposed Nilgiri Biosphere Reserve, the much-disturbed Dandeli wildlife sanctuary in Karnataka, and Radhanagari wildlife sanctuary in Maharashtra. Along with these, pockets of vegetation on coast now preserved as sacred groves should also continue to enjoy protection. There is, for instance, an excellent patch of mangrove preserved as a sacred grove in Sindhudurg district of Maharashtra, while the west coast mangroves have almost totally disappeared everywhere else.

Shorea–Buchnania–Cleistanthus Series, *Shorea–Syzygium operculatum–Toona–Symplocos* Series and *Toona–Garuga* Series. These moist deciduous forest biomes totalling an area of 144,000 km^2 in the rainfall range of 1,400 to 2,000 mm a year extend over parts of hilly, largely tribal tracts of Madhya Pradesh, Andhra Pradesh and Orissa. The level of diversity is moderately high, with 850 species of angiosperms having been recorded (Panigrahi and Chowdhury, 1964). About 25% of the potential area is still under forest cover, and 5% under degraded forest. The Simlipal Tiger Reserve of 300 km^2 is the key conservation area, which must be strictly protected, especially against forestry operations. There are no reserves representing *Toona–Garuga* vegetation series; these must be created.

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Shorea-Terminalia-Adina Series This moist deciduous forest biome in the annual rainfall regime of 1,000–2,000 mm extends over nearly 200,000 km^2 in the sub-Himalayan tracts from Uttar Pradesh to Assam and on the central Indian plateau through Madhya Pradesh and Bihar. The diversity levels are moderate, 700 species of angiosperms having been recorded (Sen Gupta and Ram Lal, 1973; Saxena, 1970). Of these, 45% are restricted to India, and 25% represent Indo-Malayan elements (Legris and Meher-Homji, 1968). Being hilly, and earlier malarial, this biome is moderately preserved with about 25% under forest cover and another 7% in degraded condition. The Corbett and Dudhwa National Parks in Uttar Pradesh, Jaldapara in West Bengal and Manas in Assam are important reserves of the sub-Himalayan tract, while the Kanha National Park in Madhya Pradesh and the Palamau Tiger Reserve in Bihar are significant in preservation of this type of vegetation from the central Indian region. Together these cover over 3,000 km^2. Also, Champaran in Bihar and Neora valley in West Bengal, are urgently in need of conservation.

Shorea-Cleistanthus-Croton Series and *Shorea-Dillenia-Pterospermum* Series. These series of deciduous sal forest with an annual rainfall of 1,000 to 2,000 mm extend over an area of 100,000 km^2 in the plains of Bihar, Orissa and West Bengal. These are thickly settled agricultural tracts and the natural vegetation has been thoroughly destroyed so that less than 4% of the potential area remains under forest and another 3% or so under degraded vegetation. Only 400 or so species have been described from this tract (Mallick, 1966; Rao and Banerjee, 1970). The Dalma wildlife sanctuary of 193 km^2 is the largest and the most significant nature reserve representing these vegetation types. There is a need to set up at least small nature reserves representative of the natural vegetation of the settled plains where the biome can be reconstituted. The estuarine ecosystems of this tract are represented in the Bhitar Kanika Sanctuary of Orissa, and most significantly in the Sundarban Tiger Reserve at the mouth of the Ganges in West Bengal. The latter, extending over 2,585 km^2, is vital to the conservation of the remarkable biota of the mangrove forests, as well as the moist deciduous forest in the hinterland.

Bridelia-Ficus glomerata-Syzygium Series This series of semi-evergreen forest vegetation in a rainfall regime of 2,000 to 5,000 mm with a dry period of 7 to 8 months extends over upper slopes of the Maharashtra Western Ghats and some ranges of Girnar and Aravalli hills. In this hilly terrain about 40% of the potential area out of a total of 2,750 km^2 remains under forest and another 30% under degraded vegetation. The floristic diversity is moderately high, 1,100 species of flowering plants having been recorded (Bhandari and Mehta, 1978; Jain 1967; Rao and Kanodia, 1962-63). Mount Abu wildlife sanctuary, with an area of 112 km^2, is the most significant nature reserve of this vegetation type.

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Evergreen Forest Biomes of the Western Ghats

The hill chain of the Western Ghats in peninsular India is notable for the high levels of rainfall ranging from 2,000 to 8,000 mm a year spread over 5 to 10 months. The result is a luxuriant evergreen forest developed in a regime of favourable and topographically highly diverse environment. The dry months are fewest and the hills highest in the southern portion of the Ghats, with rainfall being restricted to fewer and fewer months and the hills rising less and less as one passes north. This belt of evergreen forest is today isolated from the much larger belt of evergreen forest in south-east Asia; so also are the higher peaks of the Western Ghats from similar montane areas in the Himalayas. Favourableness of the environment, topographic heterogeneity and isolation have all encouraged high levels of species diversity coupled with a substantial degree of endemism in this biome. Thus as many as 2,000 species of angiosperms have been recorded from the southernmost series of *Cullenia-Mesua* and *Palaquium* with 26% of the elements being Indo-Malayan, 40% restricted to the Western Ghats and another 26% restricted to the Indian region. The montane shola forests possess over 60% restricted to the Western Ghats, with 20% tropical montane and 5% Indo-Malayan elements (Fischer, 1921; Vajravelu and Joseph, 1971; Legris and Meher-Homji, 1968). The levels of diversity tend to decrease in the northern series with only 1,700 species known from the *Dipterocarpus-Mesua-Palaquium* series and a mere 400 from the northernmost *Memecylon-Syzygium-Actinodaphne* series (Saldanha and Nicholson, 1976; Puri and Mahajan, 1960). The levels of endemicity also fall slightly with diversity in the northern series, with about 30% of elements endemic to the Western Ghats, and another 30% restricted to the Indian region. The evergreen forest biome of the Western Ghats with a total of some 3,500 species of angiosperms, 1,500 of them endemic, is thus a region of considerable value for the preservation of India's biological diversity (Mani, 1974).

Cullenia-Mesua-Palaquium Series. This series extends on the western side and along the crestline of the Western Ghats in Kerala and parts of Tamil Nadu. It has developed in a rainfall regime of over 3,000 mm a year, with less than 4 dry months. This is biologically the richest of the series; but has been depleted considerably through conversion to plantations of rubber, tea, cardamom, etc., and cultivation of tapioca, so that only about 15% of the potential area of 20,000 km^2 retains its forest cover. About 1,000 km^2 of this is protected in nature reserves, the most significant of these being Kalakadu in Tamil Nadu (223 km^2), Periyar (777 km^2) and Silent Valley (90 km^2) in Kerala. It is hoped that New Ambarambalam and Nilambur Kovilakam forests adjoining the Silent Valley will soon be protected as a part of the proposed Nilgiri biosphere reserve. Most of the river courses of this biome no longer possess natural biotas; Manimuthar in Kalakad, Kunthipuzha in the Silent Valley and Karimpuzha in New

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Ambarambalam being the important exceptions which must be preserved on a long-term basis

Montane Sholas. The montane evergreen forests and grasslands that occur above an altitude of 1,800 metres in the Western Ghats are a very special biome. Its typical representatives occur in the High Ranges, Palanis, Annamalais and Nilgiris; an analogous *Gordonia-Schefflera-Meliosma* series occurs on the high hills of Karnataka. This vegetation is notable for the occurrence of Sino-Himlayan elements such as *Rododendron*. It has been drastically altered by wholesale plantations of wattle, tropical pines and other commercial species so that no more than 5% of the potential area of 5,000 km^2 now retains its natural biota. The two major reserves protecting this biota are Eravikulam in Kerala and the Upper Nilgiri plateau in Tamil Nadu

Dipterocarpus-Mesua-Palaquium Series. This series extends along the west coast and Western Ghats of southern Karnataka in a regime of an annual rainfall of more than 2,000 mm and a dry period of 4 to 6 months. Of its potential area of 20,000 km^2 some 26% remains under forest cover. There are a few wildlife sanctuaries, namely Pushpagiri, Mukambika, Shettyhally, Someshwar and Sharavathy Valley, but these area afforded only minimal protection. A larger area of 620 km^2 near Kudremukh proposed to be set up as a satellite biosphere reserve should become the most significant conservation area for this series.

Persea-Holigarna-Diospyros Series. This series extends along the west coast and Western Ghats of northern Karnataka and Goa in a regime of annual rainfall of 2,500 to 3,000 mm with 6 months of dry period Of its potential area of 12,500 km^2 more than 35% appears under forest cover. However, this is a region of low hills where many of the interior valleys are under settlement, and therefore under human pressure, both of the rural population and of the forest-based industry such as plywood and matchwood There is therefore little of undisturbed natural forest and no significant nature reserves. This rich biota calls for serious protection at least in small patches as in the wildlife sanctuaries of Goa.

Memecylon-Actinodaphne-Syzygium Series. This series extends along the west coast and Western Ghats of northern Karnataka and Maharashtra in a region of more than 3,000 mm of rain a year with 6 to 7 dry months. As with the previous series, accessibility has led to substantial pressure on the natural vegetation throughout this region, so that although some 24% of the potential area of 5,000 km^2 is still under forest cover, there is little undisturbed forest and few nature reserves. A substantial area of at least 100 km^2 or more must be protected in the Koyna catchment as representative of this vegetation series. Another notable tract that needs continuing full protection is the sacred grove of Bhima-Shankar of 2 km^2 in Pune district currently threatened by the construction of road.

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Himalayas and Hill Tracts of the North-east

The great mountain chain of the Himalayas with its associated hill tracts in the north-eastern India is the biological treasure trove of the country. The tremendous altitudinal range of these hills and their wide expanse coupled with the large range in rainfall from very dry conditions at the western edge on Jammu and Kashmir and the wettest place on earth in Meghalaya have created an unparalleled diversity of environments in this region. Furthermore this region sits at the junction of several biogeographic realms so that it has amongst its biota elements with the mediterranean, temperate European, Sino-Himalayan, Sino-Indian and Indo-Malayan derivation (Legris and Meher-Homji, 1968). Given the dissected mountain topography and the scope for geographical isolation, it is not surprising that this region is rich in endemic elements. Chatterji (1939) estimates that it possesses over 3,000 endemic species of dicotyledons alone. Legris and Meher-Homji (1968) conclude that the indigenous element is dominant with 40%, as against 25% of the Indo-Malayan element. Furthermore they show that the indigenous element is somewhat less in the semi-evergreen and moist deciduous series, about 33%, with another 30% of Indo-Malayan elements.

Our data for the Himalayas is weaker, with little first-hand field experience. The vegetation maps available for this region are also much less detailed; and the topography renders the interpretation of the satellite imagery rather complicated. Nevertheless, we will summarize here the available information.

(a) The tropical moist deciduous and evergreen forests, in regions with an annual precipitation of more than 2,500 mm, spread over a potential area of 113,000 km^2 are restricted to the lower altitudes of the north-east. They have been extensively replaced by settled cultivation or affected by shifting cultivation. The traditions of conservation of this vegetation, once prevalent amongst tribals, have largely broken down and the increased pressure of the forest-based industry as well as population is playing havoc with it. About 25% of this vegetation remains as closed canopy forest and another 7% as degraded vegetation. There are no large well-protected areas representing the tropical wet evergreen forests. The important reserves of tropical moist deciduous forest include the Kaziranga National Park (430 km^2) in Assam, Intangki (202 km^2) in Nagaland, and Balaphakram in Meghalaya. Keibul Lamjo of Manipur (40 km^2) is an important wetland habitat. There are several smaller sacred groves.

(b) The subtropical forests of Himalayas range from the dry evergreen sclerophyllous forest of the north-west Himalayas in the rainfall regime of 500 to 1,000 mm a year and an altitude of 300 to 1,500 metres, and the subtropical chir-pine forest in the rainfall regime of 1,300 to 3,000 mm a year and an altitude of 1,000 to 1,800 metres over much of the entire Himalayan tract, to the subtropical broad-leaved hill forest of eastern Himalayas in a rainfall regime of over 2,200 mm a year and an altitude range of 1,000 to 2,000 metres. These forests are

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better preserved with 60% of the potential area of 65,000 km² being under forest and another 12% under degraded vegetation. There are however few good reserves protecting this biota, the largest being Govind Pashu Vihar of 320 km² in the Uttara Kashi district of Uttar Pradesh. Obviously serious attempts need to be made to conserve this biome

(c) The temperate forests of the Himalayas range in altitude from 1,800 to 3,000 metres. At the lower annual rainfall of 1,300–2,000 mm and altitudes of 1,800 to 3,300 metres it is a mixed oak and coniferous forest, while at an annual rainfall of 1,000–1,800 mm and higher altitudes of 2,000 to 2,800 metres it is a coniferous forest with a distribution stretching all the way from Kashmir to the eastern Himalayas. The wet temperate forest in the rainfall regime of over 3,000 mm a year and at altitudes of 1,700 to 2,750 metres is restricted to the outer ranges in the eastern Himalayas. The potential area under these forests is 61,000 km², of which 60% still persists. They are, however, quite inadequately protected, the major conservation areas being Kistwar (200 km²), Overa-Aru (212 km²), Gulmarg (180 km²) and Dachigam (141 km²) in Kashmir, Shikari Devi (213 km²) in Himachal Pradesh, Kedarnath (478 km²) and parts of Govind Pashu Vihar (total: 320 km²) in Uttar Pradesh. The rich wet temperate forest of the north-east must be totally protected in at least two or three reserves, the most significant being Namdapha, a proposed biosphere reserve of 233 km² in Arunachal Pradesh, and the Nagaland Central Forests of 104 km².

(d) The subalpine altimontane forests lie below the snow slides on sheltered slopes from Kashmir to the eastern Himalayas at altitudes from 2,900 to 3,500 metres. Of the potential area of 50,000 km², only about 15% retains forest cover. Clearly, this biome is in need of urgent protection. It is protected through the Henus High Altitude National Park (150 km²) of Ladakh, and Kedarnath sanctuary (478 km²) of Uttar Pradesh. The proposed Nanda Devi Biosphere Reserve must play an important role in conserving this biota.

(e) Apine scrub and meadows cover higher reaches of Himalayas in the altitude range of 3,500 to 4,900 metres. This biome suffers especially from overgrazing and tourism. The Valley of Flowers (90 km²) and the Govind Pashu Vihar National Parks of Uttar Pradesh are the only nature reserves protecting this biota.

(f) The alpine steppes over altitudes of more than 4,500 metres are a very fragile environment, included in several high-altitude reserves of Ladakh and Kashmir (Sang Gauri, Henus, Overa-Aran and Kistwar) as well as the Singalila National Park of West Bengal.

Island Ecosystems

India possesses two major groups of islands, those of Andaman and Nicobar and those of Lakshadweep. The former are crucial to our conservation effort,

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harbouring some of the best preserved wet evergreen, moist deciduous and mangrove forests of the country because of their isolation Thothathari (1960, 1962) has recorded a total of 1,000 species of flowering plants from this island group of 6,840 km^2. More than 220 of these species are endemic to these islands; and another 300 or so are restricted to the Indian region as a whole. About 15% of the species are elements shared with Burma and the north-east. Over 80% of the islands still retain their natural vegetation, but this is threatened by a whole range of pressures from forest-based industry, foreign trade, military and growing human settlements It is essential that we now decide to set aside the following as a nature reserve system of these islands Saddle Peak in North Andamans (32 km^2), Jarwa area in South and Middle Andamans (721 km^2), North Middle and South Button Islands in Middle Andamans (3.8 km^2), Mount Harriet Island (46.6 km^2), Interview Island, Tarmugli group of coral reef islands as well as the Narcodam Island (7.38 km^2).

The Lakshadweep groups of islands are notable for their coral reefs. Along with Pirotan Island in the Gulf of Kutch, Krusadai and other islands of the Gulf of Manaar, and the Tarmugli group in Andamans, several islands of Lakshadweep must be identified to conserve this most diverse and stable of marine habitats.

CONCLUSIONS

Nature conservation in India is an old yet vigorous tradition attempting to come to terms with the understanding and realities of the day. It is imperative that the programme should now address itself more forcefully to two priorities, namely, of preserving not just tigers, rhinos and blackbuck, but biological diversity as a whole, and of involving the local population positively in the conservation effort. To this end, we must develop a network of nature reserves properly representative of all the biological community types of the country. An assessment of this objective has been a major purpose of the material presented above; this is summarized further in Table 1. As this table brings out, nature reserves cover only 2.9% of the total area of the country; this should be increased to 5% at least. Furthermore, many reserves are only so in name, for instance the large Dandeli Wildlife Sanctuary in Karnataka is totally devastated by the giant Kali hydel project situated right in its centre We therefore need to qualitatively improve the kind of protection accorded to biological diversity in all the nature reserves, with an emphasis on conservation of the biota as a whole. Other features that emerge from this table are the sad plight of our arid and semi-arid tracts, and the urgent need to strengthen the network of nature reserves in the Himalayas and the north-eastern hill tracts

Apart from the larger reserves, we should not lose sight of the smaller ones down to tiny sacred groves which yet preserve rare species of plants. Thus

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Table 1. Extent of potential area, closed canopy forest, forest including degradation stages, and nature reserves in major zones over India Area is in thousand square kilometres Except in the last row, the percentage is to the total area of that column. The ratio is that of the percentage of the actual to the percentage of the potential. For India as a whole the percentage is given in terms of the total area in the last row of the table

Zone		Potential	Closed canopy	All forest	Nature reserves
Arid	Area	481.3	0	2 2	8 2
	Percentage	17 2	0	0 1	10.0
	Ratio	–	0	0 006	0.6
Semi-arid	Area	670 0	17 6	31.4	7.8
	Percentage	23.9	5 1	6.7	9.6
	Ratio	–	0.21	0 28	0.4
Peninsular deciduous	Area	1291.2	195.5	283.3	50.0
	Percentage	46 1	56.6	60.7	61.6
	Ratio	–	1 23	1 32	1.34
Peninsular evergreen	Area	62 0	14.1	16 4	3.6
	Percentage	2 2	4 1	3 5	4.4
	Ratio	–	1 86	1 6	2.0
Himalaya	Area	290.5	112 3	129.0	10.9
	Percentage	10 4	32 6	27 7	13 4
	Ratio	–	3 13	2 66	1 29
Andaman and Nicobar	Area	6 8	5.5	5.5	0.8
	Percentage	0 2	1 6	1 3	1 0
	Ratio	–	8 0	6.5	5.0
India as a whole	Area	2801 8	345 0	467 8	81.2
	Percentage	–	12 3	16.7	2.9

Mohanan and Nair (1981) described recently a new leguminous climber, the first record of its genus in India, *Kunstleria keralensis*, from a sacred grove in the thickly settled plains of Kerala. We must plan our nature reserve network to include a whole series of such protected areas necessarily smaller in size where population densities are higher, but nevertheless covering the entire countryside.

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REFERENCES

Balasubramanyan, K. 1975 Biogeographical studies on Marakkanam In: Research and Criticism, N. Radhakrishnan (ed.). Annamalai University

Bellan, M F. 1985. Eco-floristic maps of Peninsular India French Institute, Pondicherry

Bhandari, M.M. and M R. Mehta, 1978 Additions to the flora of Mount Abu. Indian J. For 1: 47-57.

Blatter E 1908. On the flora of Kutch. J Bombay nat. Hist. Soc 18: 756-777; 19: 157-176.

Blatter, E. and F. Halberg, 1918 The flora of the Indian desert J Bombay nat Hist Soc. 26: 218-246, 525-551, 811-818, 967-987

Chatterjee. D 1939. Studies on the endemic flora of India and Burma. J. Roy Asiatic Soc. Bengal 5: 19-67

Das Gupta, S.P (ed.) 1976 Forest atlas of India National Atlas Organization, Calcutta

Fischer C E C 1921. A survey of the flora of the Anamalia hills Rec bot. Surv India 9: 1-28

Forest Survey of India, 1982. Assessment and delineation of forests retaining primary characters (Mimeographed) Dehra Dun.

Gaussen. H. *et al.*, 1961a, 1961b, 1963a, 1963b, 1965a, 1965b, 1968a, 1968b, 1971, 1972, 1973 Vegetation maps of India Sheets: Madras, Godavari, Jagannath, Mysore, Bombay, Kathiawar, Satpura, Rajasthan, Wainaganga, Orissa, Allahabad. French Institute. Pondicherry Trav. Sect Sci., Tech Hors. Series Nos 1 to 4; 7 to 10; 12 to 15.

Jain S K 1967. Phytogeographic considerations on the flora of Mount Abu. Bull bot. Surv India 9: 668-78.

Jain, S.K. 1984 Flora of India: tasks before 2000 A D. J. Indian bot. Soc. 63: 325-334.

Jain, S.K and U.R. Deshpande, 1960 Further contributions to flora of Kutch in Gujarat State. Bull bot. Surv. India 2: 287-292.

Kapadia, G A. 1954. Statistical synopsis of the flora of Kutch Guj Res Soc 16: 90-107.

Kapoor, S.L and L D Kapoor, 1973 Further contribution to the flora of the Karimnagar district Bul Bot. Surv. India 15: 76-84.

Kaushik, J.P. 1969 A contribution to the flora of Shivpuri Bull. bot. Surv. India 11: 51-69

Kawosa, M A., H Lieth, and Esser, 1983 Vegetation map of Himalaya. 7 parts, FB Biologie. Universitat Osnabruck

Legris, P and V.M Meher-Homji, 1968 Floristic elements in the vegetation of India Proc. Symp. Recent Adv. Tropical Ecology 2: 536-543

Maheshwari, J.K. 1963. The flora of Delhi, New Delhi

Majumdar, R.B 1971. Synoptic flora of Kota division Bull bot Surv India 13: 105-146

Malhotra, S K. and S Moorthy, 1971. Materials for the flora of Chandrapur district, Maharashtra. Bull bot Surv. India 13: 292-318.

Mallick, K.C 1966. A contribution to the flora of Purulia district, West Bengal. Bull bot. Surv India 8: 45-59.

Man and Biosphere Committee, Department of Environment, Government of India, 1982 Minutes of the first meeting of the committee to review the inventory of potential areas for setting up biosphere reserve in India (Mimeographed), New Delhi

Mani, M S 1974. Ecology and biogeography in India. W Junk, The Hauge

Mathew, K.M 1970 A contribution to the flora of Narthamalai, Tiruchirapalli district Bull. bot. Surv. India 12: 80-91

Meher-Homji, V M, M. Gadgil, and R K Gupta, under preparation Vegetation of India: a conservation-oriented status survey

Mohanan, C N. and N C Nair, 1981. *Kunstleria* Prain: a new genus record for India and a new species in the genus Proc Indian Acad Sci *B* 90: 207-210

National Remote-sensing Agency, 1983 Nation-wide mapping of forest and non-forest areas Project Report, vol 1 Hyderabad.

Panigrahi, G and S. Chowdhury, 1964. A contribution to the botany of Orissa Bull bot Surv. India 6: 237-266

Puri, G.S. and S.D. Mahajan, 1960. The study of the evergreen vegetation of Mahabaleshwar area. Bull bot Surv India 2: 109-137.

Puri, G.S., V M. Meher-Homji, R K. Gupta, and S Puri, 1983. Forest ecology, Vol. I Oxford and IBH, New Delhi.

23 21

72

Rao, T.A., and L.K. Bannerjee, 1970 Vascular plants of the coastal Midnapore district, West Bengal. Indian For. 96: 668–677.

Rao, R.S. and K.C. Kanodia, 1962–63 Studies on the vegetation and flora of Jodhpur. Ann. Arid Zone 1: 16–46; 2: 35–60

Saldanha, C.J. and D.H. Nicholson (ed.), 1976. Flora of Hassan. Amerind, New Delhi

Santapau, H. 1960. The flora of Khandala on the Western Ghats of India. Rec. bot. Surv. India 16

Santapau, H. and M.B. Raizada, 1955 Contribution to the flora of the Gir forest in Saurashtra. Indian For. Rec 4.

Saxena, M.O. 1970. The flora of Amarakantak, Madhya Pradesh. Bull. bot. Surv. India 13: 79–93.

Schweinfurth, U. 1957. Die horizontale und Vertikale Verbreitung der vegetation im Himalaya. Bonner Geogr. Abhandlungm Helft 20. Bonn. Ferd. Dummlers Verlag.

Sebastine, K.M. and A.N. Henry 1980. Studies on the flora of Singamatti R.F. in Tirunelveli. Bull. bot. Surv. India 2: 24–42.

Sen Gupta, G. and Ram Lal, 1973. Flora of Sidhi district, M.P. Bull. bot. Surv. India 15: 182–188.

Shah, G.L. 1967 A preliminary contribution to the flora of Rajpipla forests in Gujarat. Indian For. 93: 627–676.

Shah, G.L., A.I. Patel, and V.K. Singh, 1971 Additions to the flora of Rajpipla forest division. Bull. bot. Surv. India 13: 203–211

Sharma, S. 1978 Studies in the floral composition of Jaipur district. Indian For. 55: 189–203.

Sharma, S. *et al.*, 1978. Flora of Mudumalai wildlife sanctuary, Tamil Nadu. J. Bombay nat. Hist. Soc. 75: 133–42.

Subba Rao, G.V. and T.R. Kumar, 1967 Contribution to the flora of Karimnagar district. Bull. bot. Surv. India 9: 95–113

Thothathari, K. 1960. Botanical exploration in Car Nicobar and Nancoury islands. Bull. bot. Surv. India 2: 341–346.

Thothathari, K. 1962. Contribution to the flora of the Andaman and Nicobar islands. Bull. bot. Surv. India 4: 281–296.

Vaidya, B.S. 1967. Flora of Ahmedabad. Ahmedabad University School of Science.

Vajravelu, E. and J. Joseph, 1971. Additions to the flora of Anaimalai hills. Bull. bot. Surv. India 14: 264–273.

Vajravelu, E. and N.C. Ramakrishnan, 1967 A contribution to the flora of Dharmapuri district. Bull. bot. Surv. India 9: 31–48

Zoological Survey of India, 1980 State-of-art report, Calcutta

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24. GENETIC RESOURCES OF TROPICAL RAIN FORESTS: BIOLOGICAL ISSUES *

KAMALJIT S. BAWA

24.1 Introduction

Tropical rain forests, which constitute the core of tropical forests, are the most diverse and complex of all the terrestrial ecosystems. Tropical rain forests contain thousands of plant and animal species of actual and potential economic importance. The rate of tropical deforestation is so high that many species face imminent extinction. It is estimated that the tropical rain forests at the current rate of exploitation will be largely devastated by the end of this century (Myers, 1979). It is ironic that the plundering of nature´s bountiful genetic resources continues unabated at a time when the number of agricultural crops, on which we ourselves are dependent, has been reduced to less than 20 (Wilkes, 1983). The situation is even more serious for tropical forest tree crops. Decimation of scores of species every year in tropical rain forests is being coupled with homogenization of once diverse forest stands by plantations of exotic eucalyptus and pines.

Although there has been considerable debate about the rate of tropical deforestation and the consequences of this deforestation on extinction of plant and animal species (Simberloff, 1986), there has been very little discussion of the type of biological knowledge we

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might need to conserve and manage the vanishing genetic resources of tropical forests. In this lecture, I outline some key areas that require attention for adequate management and conservation of forest genetic resources.

The type of biological information required depends upon the extent to which a resource is utilized. For species that are underutilized, used on a limited scale or are of only potential value, we need to document their distribution and the the way they might be effectively conserved in biological reserves. For species that are being intensively used, the primary need is the information about reproductive biology and genetic variation.

24.2 Resources of limited or potential value

24.2.1 Inventories

For trees in the north temperate zones and traditional agricultural crops throughout the world, the genetic resources that require conservation and management have been identified at the speices level. Thus much of the work in management of these resources is at the intra-specific level with a major emphasis on defining and protecting genetic diversity within and between populations.

In contrast, the situation for subtropical and tropical zones is very different. First, the number of species involved and the range of habitats they occupy are enormous; the number of species that constitute forest genetic resources run into thousands. Second the forest communities containing the multitude of species have not been adequately described and explored. As a result there is no complete inventory of genetic resources at the species level.

The unevenness in the inventory of the world's plants has been compared by Prance(1984), who points out that at places like Britain every species has been mapped on a 10Km^2 grid in a computerised system, whereas tropical areas have not been mapped even on a 100Km^2 grid. Prance states that for many areas in Indonesia, only 10.5 herbarium specimens have been collected per 100Km^2. Thus many forest plant species, especially in the humid tropics remain undescribed. For example, <u>Licania</u> (Chrysobalanaceae) is a large genus (approximately 150 species) of trees distributed in central and south American tropics. Approximately 25 of the 150 species were described only during 1972-1982, the period during which Prance did most of his monographic work on the family(Prance, 1984). Even in some well studied groups such as the Meliaceae to which belong such well known species as the mahagony and neem, a complete inventory of species remains an elusive goal. At the La Selva Biological Field Station of the Organization for Tropical Studies in Costa Rica, there are more than 8 species of <u>Guarea</u>, a genus of small to medium sized trees. These species differ in their phenological patterns. Yet the taxanomists have been reluctant to recognize more than 3-4 species, because in the absence of field data, the few herbarium specimens look alike. The situation of course is now being rectified with the systematic compilation of the La Selva Flora.

How cumbersome and elusive a complete inventory of flora can be is demonstrated by two well studied sites. Barro Colorado Island in Panama with an area of 1560 hectares and the La Selva Biological

Field Station of the Organization for Tropical Studies in Costa Rica with 1,400 hectares are among the two biologically best known tropical rain forests. The flora of BCI took almost 10 years of work and was published only recently. The work towards a complete flora of La Selva was initiated 6 years ago and it will be 2-3 years before the flora is published. Despite the fact that both the areas have been thoroughly collected over the last 25 years, new species are being continuously discovered. Thus 15 new species have been found at BCI since the publication of the flora(Gentry, 1986), and at La Selva a new species is added to the list every few months(B.Hammel, pers. comm.).

Unfortunately the pace at which the inventories are being undertaken or completed is not commensurate with the rate at which the subtropical and tropical vegetation is being decimated. In Western Equador, 100 new species described during the preparation of the flora of the Rio Palenque Field Station in Los Rios Province are now known only in the field station forest which is less than 1 Km^2; the most important timber tree of the region, Persea theobromifolia, now has a relicit ´population´ of only 12 trees at the station(Gentry, 1986).

24.2.2 Biological reserves

Once genetic resources of potential and actual use are identified by means of adequately designed biological inventories, the next step is to formulate plans for their ex situ and in situ conservation. Ex situ conservation involves collection of seed and the maintenance of seed in its original state or in the form of plants raised from the seed. Often ex situ conservation is not a practical way to conserve underutilized resources because the number of species involved is generally large and there is not enough biological information about the timing, availability, processing and storage of seeds. Furthermore, ex situ conservation requires an infrastructure for exploration, collection, maintenance and evaluation of the material. The infrastructure is often lacking, in other cases its creation is not justifiable considering the realized economic value of the resource. Moreover in situ conservation has several advantages over ex situ conservation. These include a more efficient and wider use and greater evolutionary stability of the in situ as compared to the ex situ material. Thus in situ conservation is usually the strategy adopted for the maintenance of genetic resources that are either not intensively utilized or are of potential use. In many tropical and subtropical areas in situ conservation is the only viable option for resources that are very intensively used.

In situ conservation generally involves the establishment of a biological reserve to conserve populations of target species. It is generally recommended that such reserves be established in those areas which also serve as repositories of other resources such as wildlife (FAO, 1984a). The two primary issues in the creation and management of these reserves are the minimum viable population sizes of the target species and the maintenance of diversity in the reserve(FAO, 1985)

24.2.2.1 Minimum viable population size:

The concept of minimum viable population size implies that a population in a given habitat cannot persist for a certain amount of time if the number of organisms is reduced below a certain threshold. It is a complex concept because there is no fixed minimum viable population size for most species. Whether or not a population of a given size can persist, depends upon a number of demographic, genetic and environment stochastic events(Gilpin and Soule, 1986). Moreover, Gilpin and Soule argue that population size varies with such attributes as life history, particularly generation time and the breeding system and spatial distribution of resources.

Nevertheless minimum viable population sizes have been estimated for several groups of organisms on the basis of genetic criteria (Franklin, 1980; Soule, 1980). In general effective population size N_e, which is defined as the average number of individuals that contribute genes equally to the next generation, below 500 individuals is assumed to result in reduced genetic variance and a decreased likelihood of population responding to selection (Franklin, 1980). Assuming that the ratio between census number, N and N_e is 3 or 4 (Soule, 1980), the minimum viable population size comes to 1,500-2,000 individuals. Both N and N_e specified above are for outbreeding species.

There is ample evidence that canopy trees in most forests, including tropical lowland rain forests are strongly outbred (Ashton, 1969; Bawa, 1974; 1979; Bawa, Perry and Beach, 1985; Ledig, 1986). However, population densities of large trees, which constitute the most important forest genetic resources, in tropical lowland wet forests are extremely low. For example, in a tropical lowland wet forest in Panama, Hubbel and Foster (1986) found that one third of all plant species with individuals larger than 1cm dbh (diameter at breast height) were represented by only one adult per hectare in the 50 hectare plot they sampled. Assuming that these species are evenly distributed (many are not), an area of 20 Km^2 will be required to include 2,000 individuals. For the rarest tree species in south-east Asian tropical wet forests, Ashton(1981) estimates that an area of $20Km^2$ will be required to contain 200 individuals. By extrapolation, $200Km^2$ may be required for 2,000 individuals.

In summary, it appears that reserves of $20Km^2$ to $2,00Km^2$ are required to maintain minimum viable populations of most tropical forest trees. Unfortunately in many regions areas earmarked for conservation of certain vegetation types or forest genetic resources are below the minimum sizes estimated above (Elaborate by giving examples from India and FAO reports).

24.2.2.2 Ecosystems dynamics:

Although much of the literature on <u>in situ</u> conservation is couched in terms of conserving particular populations, <u>in situ</u> conservation in reality largely involves preservation of whole communties. The number of populations and species that require some protective measure in the wild is so large that it is impractical to consider and design <u>in situ</u> conservation programs for most species at the population-species level. Thus the emphasis is usually on conserving whole communities in areas particularly rich in genetic resources so that a number of species can be simultaneously conserved in a nature reserve.

A key requirement in the management of nature reserves is the knowledge of ecosystem dynamics. The minimum viable population size may assure genetic density through generations only if the structure and stability of the ecosystem is maintained. This is true regardless of the number of species that is the target of conservation. Among the many biotic forces that impinge on community structure and stability is the integrity of food web in an ecosystem(Pimm, 1986). The organization of food webs is particularly important for the maintenance of forest genetic resources in subtropics or tropics, where an overwhelming majority of forest plants have both pollen and seed dispersed by a wide variety of animals. The diverse feeding relationships between a multitude of animals and numerous plant species add extraordinary complexity to the food web. Thus, one is confronted with the problem of knowing not only the pollen and seed vectors of target species but also of finding what other resources are exploited by these animals. Species-specific relationships between pollinators or seed dispersers and their host plants are rare in the tropics. Rather, it is a common observation that a group of pollinators or seed dispersers shift from one plant to another plant as flowering and fruiting progresses in a community. A number of plant species may not be important targets as significant forest genetic resources. But by providing food resources in the form of pollen and nectar and fruits to pollinators and seed dispersal agents when the food resources are scarce, such species may play a critical role in maintaining the structure and stability of the community(Gilbert, 1980; Terborgh, 1986). Furthermore in some areas, pollinators may be recruited from distant sources and seed dispersers may migrate from one place to another on an elevational gradient. For example, in south-east forests, Asian forests, bats may fly over many kilometers to pollinate their host plants. In Amazonia, frugivorous may migrate to other elevations during periods of food shortages (Terborgh, 1986). In brief, the maintenance of pollinators and seed dispersers in a community is contingent upon a very thorough understanding of spatial and temporal distribution of their resources.

The link between pollinators and seed disperser and their host plants is not the only critical element in the maintenance of community stability. The role of pollen and seed vector is highlighted because they play a vital part in the reproduction of plants. Other processes such as edge effects and the part they play in maintaining community integrity is considered in a series of articles in Soule (1986).

24.3 Intensively used Resources

Information about genetic diversity within a species is of critical importance in the management of genetic resources. At a very basic level, if most of the variation within a given species is to be within all of its populations then one or a few population is all that is needed to utilize the population for present and future uses. If on the otherhand, populations show much genetic divergence, then the maintenance of multiple populations is necessary. Biologists concerned with conservation have increasingly emphasised the need for information about the genetic architecture of populations (Frankel and Soule, 1981; Schoenwald-cox et al., 1983). There is considerable variation among species with respect to the total amount of genetic variation and the way such variation is spatially organized within and among populations. In plants, both the amount and the pattern of genetic diversity are strongly regulated by mating systems and gene flow. Below our knowledge of mating systems and gene flow is reviewed before a discussion of genetic variation in tropical plants.

24.3.1 Mating Systems

The extent of selfing or outcrossing is dependent upon the breeding system such as the presence or absence of genetic self-incompatibility, self-sterility and the floral features such as monoecy and dioecy, all defined below.

Most tropical forest trees have hermaphroditic flowers, that is the flowers contain both male and female reproductive organs(Ashton, 1969; Bawa, 1974, 1979), but many are monoecious, that is the flowers are unisexual but both types of flowers occur on the same plant. A very large number of species are dioecious, that is they are characterized by the presence of seperate male and female plants.

Selfing is possible only in hermaphroditic and monoecious species, but is usually prevented by a wide variety of genetic mechanisms and differences in maturation of male and female floral parts.

Most tropical species with hermaphroditic flowers are genetically self-incompatible; there is no or little seed set following self-pollination(Bawa, 1974; Bawa, Perry and Beach, 1985).

Mechanisms like self incompatibility, self-sterlity and dioecy eliminate the possibility of selfing, but do not necessarily preclude inbreeding. The level of inbreeding is determined not only by the nature of the breeding systems, but also family structure which itself is influenced by pollen and seed dispersal characteristics. Limited dispersal of pollen and seed can increase the genetic relatedness of individuals in a population and reduce effective population size. Asynchronous flowering among conspecifics and biased seed ratios can further reduce population size and increase the level of inbreeding.

The degree of inbreeding can be quantified by measuring the rate of outcrossing. Using genetic markers, outcrossing rate has been estimated in two rain forest tree species. Both estimates reveal a very high outcrossing rate.

24.3.2 Gene flow

Gene flow together with population size determines the extent to which populations may be differentiated from each other. Of course, population differentiation can also occur in response to strong selection exercised by the local environmental factors despite gene exchange(Ehrlich and Raven, 1979).

Gene flow occurs via the movement of pollen and seed. Both are dispersed by a wide variety of abiotic and biotic mechanisms. All temperate-zone conifers and many hardwood species such as oaks and populars are wind-pollinated. Although most pollen dispersed by wind falls near the paternal tree, much is carried further away, upto several hundred meters or more(Levin and Kerster, 1974). This in combination with high density of the temperate-zone wind-pollinated species results in pollen exchange among hundreds of individuals distributed over a large area. A substantial number of the temperate-zone trees are animal pollinated, but virtually nothing is known about the extent to which these pollinators move among trees. In fact, in most cases even the pollen vectors have not been identified.

In contrast to the temperate-zone trees, tropical forest trees are largely animal-pollinated. Wind-pollination is restricted to a few species that mostly occur in the understorey(Bawa et al., 1985). The diversity of animal pollinators is immense, ranging from bats with a wing-span of 2m to tiny wasps, 1-2mm. in size. However, most species are pollinated by medium sized to large bees (Bawa et al., 1985). Other pollen vectors in the order of importance are generalist insects(the category includes a wide variety of small bees, beetles, butterflies, wasps and flies that collectively visit flowers, though only one or more of these groups may act as pollen vectors), small bees, moths and beetles (Bawa et al., 1985). Relatively few tree species are pollinated by bats, birds and butterflies; however these groups may pollinate a large number of other species in the same forest commonly.

The extent to which animal pollen vectors move pollen between plants is largely dependent upon the foraging behaviour of pollinators and the spatio-temporal distribution of floral resources. In general, pollen carried by animals is more precisely directed at receptive surfaces of stigmas than the pollen carried by wind. Consequently, animals can bring about extensive exchange of pollen among individuals scattered over a wide area. This is particularly true in cases where specificity between pollen vector and the plant is high. An example is the genus Ficus in which approximately 700 species are pollinated by a different species of wasp. The high specificity allows the fig trees to reproduce and persist in very low densities (Janzen, 1979). However, the type of specificity found between figs and fig-wasps is not common among tropical forest trees.

There are few data about the distances over which animal vectors move pollen. In hummingbirds, territorial birds are more sedantary than non-territorial no consequently pollen dispersal is extremely limited in space (Linhart, 1974). Bats on the otherhand are known to forage over a range of several kilometers. Similarly, medium sized to large bees can move pollen among plants that are several kilometers apart.

In general, our knowledge of pollen flow within and among populations of tropical forest trees is extremely limited. Given the diversity of dispersion patterns, wide variation in stand density and number of vector types involved might expect tremendous differences among species.

In tropical forest trees, seed dispersal by wind is common in deciduous forests, but in evergreen forest, most species have their seeds dispersed by birds of various sizes and classes; mammals, especially bats is another common group of dispersers. Few species have their seeds dispersed by wind. There are virtually no experimental data about the distances over which dispersers transport seeds in the temperate zone or tropical regions.

24.3.3 Genetic variation in population

Two approaches have been used to study genetic diversity. One is to study genetically based variation in morphological fruits. This is done by gathering seed from different populations and observing variation in several characters in plants grown from these seed lots under uniform environmental conditions. The populations sampled are genrally from different geographical regions exposed to divergent climatic conditions. This approach constitutes the well known provenance testing in forestry. The second, more commonly used, approach is based on the survey of genetic diversity as revealed by variation in allozymes at specific gene loci by means of gel electrophoresis. Provenance testing and electrophoretic surveys are undertaken with different objectives in mind and the results obtained from the two approaches also have different applications in theory and practice.

Information about genetic variation within populations is largely based on surveys of allozymes variability. In such surveys two measures used to estimate variability are the average level of heterozygosity and the proportion of polymorphic loci.

24.4 Deforestation and loss of genetic variability

. (Discussion of the types and estimates of loss and the condition that might reduce the loss).

24.5 Conclusions

In tropics, hundreds of species are used in a variety of ways. To both the manager and the biologist, the diversity of genetic resources pose a tremendous challenge. On one hand, we must complete inventories of our diminishing biological resources and gain a better prespective of ecosystem dynamics in biological reserves designed to conserve genetic resources. On the other hand, we must initiate studies of the population biology of the most intensively used resources. In population biology, the key areas aré of concern are the mating patterns and population genetics.

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26. Beijing Botanical Garden -- its Contribution to the Utilization and Conservation of Plant Resources

Jin Xiaobai

Over the past 32 years since its establishment, the Beijing Botanical Garden has been introducing wild and cultivated plants, especially those of immediate or potential economic and ornamental value, for breeding and research, for their conservation, further distribution and utilization.

Pyrus and Malus species and cultivars have been collected and classified. The affinities and interactions between different scions and rootstocks have been tested. Specialists from the Garden went to Xinjiang Uighur Autonomous Region to investigate the genetic resources of wild apple woods and proposed methods of their reasonal utilization. Fruit trees of Actinidia, Elaeagnus, Diospyros, Prunus and Vitis FROM DIFFERENT sources are all grown here. Breeding work has produced new cultivars, among which is the hardy hybrid grape from the cross made between Vitis amurensis and grape cv. Muscat Hamburg.

Gastrodia elata, an orchid growing in association with a honey fungus, is used in traditional Chinese medicine. To meet the increasing demand and to ease the pressure on its wild populations, its cultivation was first studied in the Garden. Now the herb is grown commercially to supply the market.

Metasequoia glyptostroboides , the well-known Chinese relict species now protected by the country, was propagated from seeds and has grown into a woodland in the Garden.

Staff members of the Garden have contributed to the preparation of the China Plant Red Data Book, which is to include information on the morphology, ecology and biology of rare and endangered Chinese plant species, as well as on their usages and cultivation techniques. A research team is introducing many of these plants, including Camellia crysantha, to establish an exhibit area, in order to educate the public on the importance of conservation, and to form a centre of research on their biology.

On the basis of these research results, the Garden distributes good plant material to various growing industries, parks and landscaped sites and buildings.

As part of the Gardens work, the author went on an expedition this summer to collect Begonia species in Sichuan and Yunnan Provinces, and observed their vulnerable habitats. Some of the species have narrow distribution areas, and attention should be paid to their conservation.

29. CONSERVATION STRATEGIES FOR THE ARID ZONE

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ABSTRACT

The perpetually moisture-deficient arid zone, parched due to prolonged solar radiations, exhibits a spectacular diversity of flora and fauna partly because, 'east meets west' in this eastern most fringe of the Great Saharo-Rajasthani desert. The Thar desert is not a recent, man-made creation as is often conceived. It is a result of geotectonic activities and climatic changes. But it is true that man is not only maintaining the desert but is also deteriorating it. Two major processes have been assigned to this ensuing debacle :

(a) Escalation of human and livestock population
(b) Developmental activities

Cultivation of marginal lands, unsuitable for cropping, to feed the escalating human numbers, results in the decline in crop production, soil fertility and increase in the soil erosion processes. The over-exploitation of food, fuel and timber resources has degraded the woodlot,

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forests have vanished and the natural regeneration has been suppressed. All these activities have a negative impact on the wildlife. Overgrazing by 23 million livestock heads in western Rajasthan has denuded the vegetation resources almost to bare sand.

The creation of Indira Gandhi Canal, which has brought excellent quality water - a boon in the desert - has resulted into water logging, salinity development and a large number of new weeds and pests have colonised the zone. As a consequence the desert is being further desertised.

A very large number of cost-worthy strategies for combating these processes and for conserving and augmenting the productivity of aridland and for conserving flora, fauna, especially wildlife and the scant water resources have been standardised by the Central Arid Zone Research Institute, and other organisations.

29.2.

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31. Conservation of the Fauna of the River Ganga Eco-system in and around Patna (Bihar), India.

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ABSTRACT

The River Ganga has the largest river basin in India which drains eight states and one Union Territory covering 861,404 square kilometers. It has served as the cradle of the Indian Civilization. With the increase in the population along the bank of the River, this Holy River has been subjected to intense pollution from various sources resulting in extinction/endangering of a log of endemic fauna.

In the present investigation a detailed Biological and physico-chemical monitoring of the River water has been made to ascertain the possible causes of the depletion of the fauna in the River Eco-system and to suggest certain ways and means to conserve the Eco-system. During the biological monitoring of the River a large number of polychaetes belonging to three different species were encountered which has not hither to been reported so far from any freshwater body in India. Possible causes of depletion of only aquatic mammal of the River, the gangetic dolphin and reptilian fauna, gangetic gavialis have also been fraced.

Due to heavy pollution load on the city side (south bank) of the River at many places monoculture of indicator species like Tubifex sp. Limnodrilus hoffmeisteri etc. was noticed. The extent of pollution at these sites has further been confirmed by the physico-chemical conditions of the water. On the other hand the River water quality at the north bank and midstream was less polluted sustaining diverse fauna. The River's tremendous self purifying capacity was another interesting finding of the investigation which was confirmed by the observation of water quality at the entry and exit points of the River at Patna. It was noticed that at both the points the River water is almost free from pollution.

RKSinha 6/10/87
(R. K. Sinha)

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32. NANDA DEVI BIOSPHERE RESERVE

B S LAMBA

The proposed Nanda Devi Biosphere Reserve in U.P. includes parts of three civil districts, viz. Chamoli, Pithoragarh and Almora. The main portion of the Biosphere falls in Chamoli district of Garhwal Himalayas. It includes on its Eastern side, some portion of Pithoragarh district and, on its southern side, some portion of Almora district.

The area of the Nanda Devi Biosphere Reserve is approximately 1560 Sq. Kms. including 630 sq. kms. of the present Nanda Devi National Park which forms the core zone of the Biosphere. About 930 sq.kms. area surrounding the Nanda Devi National Park from all directions forms the Buffer Zone of the Nanda Devi Biosphere.

The Biosphere is situated between latitude 79°40' E and 80°5' E and longitude 30°17' N and 30°41' N. The altitude of the Biosphere area varies from 1000 in to 7816 m. The mountain rim of the core Zone includes several major peaks, the most, important ones being Dunagiri (7066 m.), Chang bang (6864 m.), Kalanka (6931 m.), Rishi Pahar (6992 m.), Nanda Devi East (7434 m.), Nanda Khat (6611 m.), Mrigthuni (6855 m.), Trisul (7120 m.) and Nanda Devi (7816 m.). Nanda Devi is India's second highest mountain.

FAUNA : The proposed Biosphere area is very rich in animal life. 86 species of Mammals, 534 species of Birds, 45 species of Reptiles and Amphibians have been reported from the area. The proposed Core and Recreation Zone alone holds as many as 11 species of Mammals, 67 species of Birds and 18 species of Reptiles and Amphibians (Lamba et al). The following endangered and threatened species of Mammals and Birds find refuge in the Core Zone :

Mammals :

1. Snow Leopard
2. Black Bear
3. Brown Bear
4. Musk Deer
5. Himalayan Tahr
6. Bharal
7. Serow

Birds :

1. Monal Pheasant
2. Koklas Pheasant
3. Western Tragopan
4. Snow Cock
5. Golden Eagle
6. Stepp Eagle
7. Black Eagle
8. Bearded Vulture

There is no record, published or other-wise, of the invertebrates, including insects, of the area. If the richness of flora is any indication of the insect life, the entomological component of the Fauna should be tremendous. It is hoped that the study of invertebrate fauna will be given a top priority in the bench mark studies to be undertaken in the Biosphere Reserve.

FLORA

The area is equally rich in Flora. The information compiled from

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the working plans of the Forest Department of Uttar Pradesh, publications of the Botanical Survey of India from time to time, and other expedition reports from the area reveal the presence of 341 species of trees etc. 552 species of herbs & shrubs and 18 species of grasses in the proposed Biosphere area.

Out of these as many as 9 species of tree, 120 species of herbs and shrubs and 2 species grasses are met with in the proposed Core Zone itself. These lists are by no means exhaustive. Bench-marck studies to be undertaken in the area may reveal the presence of many more species in the Core and Recreation Zone. It may be mentioned here that as many as seven species of threatened and endangered plants grow in this Core and Recreation Zone in good numbers especially the 'Brahm Kamal' Sisoria sps. the greatest concentration of which is found here.

THE PEOPLE

There is no human habitation in the proposed Core and Recreation Zones. In the proposed Buffer Zone sixteen odd villages exist. These villages are mostly inhabited by people of :

(1) Indo-Mangoloid and (2) Indo-Aryan origin.

1. The people of Indo-Mangoloid origin are known as Bhotias. The Bhotias are further divided into following sub-divisions :

Bhotias :

(i) Tolcha
(ii) Marchcha
(iii) Nitiwal
(iv) Johari
(v) Darmi
(vi) Chandansi
(vii) Byansi

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The Bhotias inhabit the higher valleys, belong to Tibeto-Burman language group and follow religious practices akin to Budhism. All Bhotias are now classified as scheduled castes.

(2) The people of Indo-Aryan origin have two main sub-divisions.

1. Biths
   - (i) Brahmins
   - (ii) Rajputs

2. Domes
   - (i) Artisans
   - (ii) Schedule Castes

In addition to these two major ethnic groups a small tribe of Indo-Mongoloid origin known as "Rajis" inhabits the area borderning Nepal. The Rajis are nomads, numbering about 400. They have free mating relationship with a larger population of their own tribe aceross the border in Nepal.

Of course there exists a good sprinkling of admixture of the two bigger ethnic groups throughout the area.

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33. DIVERSITY : CULTURAL AND BIOLOGICAL

MADHAV GADGIL

Early human populations utilized a wide range of biological resources in a tremendous diversity of environments. As a result, they possessed high levels of cultural diversity dependent on and supportive of high levels of biological diversity. This pattern changed drastically with technological innovations enabling certain human groups to break down territorial barriers and to usurp resources of other groups. The dominant groups have gone on to exhaust a whole range of resources, depleting both biological and cultural diversity. Traditions of resource conservation can however re-emerge with the dominant cultures spreading over the entire area and the innovations diffusing to other human groups. This could change once again as genetically engineered organisms become an economically viable proposition with the accruing advantages concentrated in the hands of a few human groups; this may lead to further drastic reduction in biological and cultural diversity.

The diversity of life on earth is currently under serious threat; so is the diversity of human cultures. Since the now dominant technological culture is often perceived as a major cause of loss of biological diversity, there is serious interest in understanding how the diversity of human cultures relates to the conservation of biological diversity, and whether the attempts to conserve biological and cultural diversity could go hand in hand (McNeely and Pitt, 1985).

Biological diversity has increased through evolutionary time, presumably because much of it arises through diversity of adaptations to environmental heterogeneity, which itself has been continually enhanced by the activities of living organisms (Benton, 1987; Whittaker, 1972). Part of the adaptation of organisms is behavioural, with behaviour becoming increasingly flexible in higher animals. Thus birds and mammals take to new food sources by imitating other members of their social group (Bonner,1980). Biologists define culture as such acquisition of behavioural traits from conspecifics through social learning; and man's close relatives such as chimpanzees have progressed further by introducing deliberate teaching (Lumsden and Wilson, 1981). The capacity for tool use and symbolic communication has however, enabled the human species to far outstrip all others in the complexity of its culturally transmitted behaviour. This has rendered possible a tremendous variety of cultural behaviours in the different human populations across the world (Boyd and Richerson, 1985).

Human cultural behaviour encompasses a great range of traits, but we are concerned here only with those pertaining to the biological environment; information regarding and patterns of behaviour relating to other living species and artifacts fabricated from or meant to deal with them. Any given human group may possess a wealth of culturally transmitted behaviour in this context; and just as we talk of α - species diversity or ecological species packing, such within-group diversity of elements of cultural behaviour patterns may be termed α- cultural diversity. These cultural patterns also differ from one human group to another, and this may be termed β - cultural diversity in anology with β - species diversity or ecological species turnover (Whittaker, 1972)

33.1 Human niches

When populations of Homo erectus learnt to make and use tools two million years ago, they could greatly expand the range of food items accessible to them. They could then not only consume small animals and berries, but also dig for roots and tubers and cut through tough hides of elephant and rhinoceros caracasses (Harris, 1980). Techniques of making tools from stone, wood and bone and information on what to eat and what to avoid eating would become a vital component of the culture of these hominid groups. For instance, a 1.5 million year old fossil of H erectus from Kobo Fera in Kenya shows signs of suffering from a poisonous overdose of vitamin A, probably caused by consumption of large quantities of raw liver. As Richard Leakey remarks, such consequences were expected when meat eating was a novel pursuit, and could be avoided only when a lore was built up of what was good to eat and what was to be avoided (Leakey, 1981). Since African savannas are exceptionally rich in biological resources and the early hominids occupied a particularly varied environment comprising a mosaic of grassland, woodland and gallery forest (Harris, 1980). These groups must have possessed high levels of α- diversity of elements of cultural behaviour patterns relating to biological diversity.

When control over fire and effective group hunting was added to tool using abilities hominid groups could colonize all but the most arid zones. Survival in such a wide range of environments by populations equipped with relatively simple technologies depends on a tremendously detailed knowledge of the local environment and of appropriate ways of dealing with it (Fig 33.1). Biological resources would be significant to such populations not only as food and raw materials for tools, but also as bait, drugs and so on. This importance of a diversity of biological resources is reflected in the wealth of folk systematics of present-day primitive societies which as a rule discriminate between 500 to 800 different kinds of living organisms (Berlin, 1973). The different human groups in early days must have diverged culturally in their adaptations to the use of biological resources, exhibiting high levels of β-diversity. For instance, two different groups of Neanderthals living in close proximity in France are believed to have maintained specific cultural identities, with one group specializing in preying on reindeer and the other in hunting horses (Leakey, 1981).

33.2 Ecological Prudence

At what rate would humans have used the variety of biological resources they depended on? The resources could have been foraged for at rates that would maximise immediate energy or nutrient returns, and this might have caused extinction of some biological populations, at least locally. Of course, even while foraging optimally the human predators may not have exploited the prey populations to extinction, switching to other patches or other species when lowered prey population levels reduced the returns from utilizing any given population below a threshold. It would often be quite difficult to distinguish such behaviour from behaviour designed to conserve the various "prey" populations on a long term basis (Smith, 1983).

There are however certain patterns of human utilization of biological resources which cannot be so interpreted as part of optimal foraging responses. For instance, many biological communities may receive total protection as for example, sacred groves or sacred ponds and function as refugia. Keystone species such as Ficus trees may receive total protection over a wide area and may serve to support a whole range of insects, birds, primates and other organisms. These practices suggest that human populations may indeed have developed traditions that would specifically serve to conserve a whole diversity of biological resources of value to them.

It is possible to think of scenarios favouring the cultural evolution of such deliberate conservation measures. Many hunter-gatherer societies, as well as shifting cultivator or horticultural societies significantly dependent on foraging, are known to have been highly territorial, with each endogamous group constantly struggling with neighbouring groups (Vayda, A.P.). Being a K selected species with a long generation time, humans cannot quickly convert resources into increased population size. Well being of a human group therefore requires the availability of resources, and possibly a wide diversity of resources, at a minimal level over periods of several years. For territorial groups, this implies the need to sustain resource levels on a long term basis within their own territory. Any group that failed to achieve this would find itself weakened and subject to the territorial aggression of neighbouring endogamous groups, and become culturally, even if not genetically, exterminated. Cultural group selection which may be quite effective under these special conditions, might then favour behavioural traits that would ensure sustainable use of the biological resources of the territory (Boyd and Richerson, 1985). In addition, within group co-operative behaviour promoting prudent resource use is also expected to prevail in endogamous groups where a relatively small number of individuals repeatedly interact with each other over long periods (Berkes, in press; Berkes and Kence, in prep.). Such practices may be particularly common in groups inhabiting stable, productive habitats where territoriality is likely to be strong.

It is then not surprising that some of the best documented examples of conservative use and protection of a wide spectrum of biological diversity come from human groups of small Pacific islands and of New Guinea rain forests (McNeely and Pitt 1985; Johannes, 1978; Ruddle and Johannes, 1985; Rappaport, 1968; Eaton, 1985; Nietshmann, 1985). Such groups possess a variety of practices apparently leading to sustainable use of a wide range of biological resources and conservation of biological diversity as a whole. These include total protection to certain biological communities or species; protection to certain life history stages, or during certain seasons; restrictions on methods and amounts of harvest, and on certain social, age or sex groups from harvesting certain species; and restriction of access to certain localities to certain groups or individuals.

Of course, some of these practices may be a consequence of optimal foragers reducing the rate of exploitation in response to local depletion of a given prey population (Smith, 1983). We may so interprete the moratoria on hunting of certain birds imposed by New Guinea chiefs when their populations appear to have declined, or the ban on certain methods of fishing by Pacific islanders following the decline of fish populations (Ruddle and Johannes, 1985; Eaton, 1985). However, these decisions do appear to be taken and enforced by the group as a whole, suggesting that what is being ensured is long term group interest in resource conservation which may be against the short term interest of individual foragers.

33.3 Sequential exploitation

Cultural traditions of conservation would confer no advantage on human groups under a variety of conditions:

(a) When the resource level fluctuates independently of the extent to which the resources are harvested, for instance with populations of migratory prey species. This might also be the case in highly seasonal or unpredictable environments such as deserts where the human user group is also likely to be nomadic.

(b) When a conquering human group is able to move into new areas displacing the earlier territory holders. As the resources of any locality are exhausted, the group may derive no advantage from conservative use if the option of moving into a new locality is open to it. At the same time, subordinated groups would also fail to derive any advantage from practices of conservation.

(c) When humans have developed the technological abilities to deploy newer and newer resources to meet their various requirements, they may find little advantage to conservative use of any particular resource.

(d) When a human group is unable to ensure co-operative behaviour on part of its members.

Technological innovations must then have played a vital role in affecting the patterns of resource use by human populations. Some such as the use of horse or gunpowder significantly affect the relative coercive abilities of different human groups. Others, like the iron axe or snowmobile, increase the rate of resource harvest and thereby enhance the possibilities of resource exhaustion unless there is persistent motivation for conservative resource use. Yet others, for instance the ability to convert any kind of woody matter into a variety of paper and polyfibre products, eliminate the motivation for the conservation of a diversity of species. Finally, technology can dramatically increase the sizes of human groups having access to particular resources, thereby rendering difficult the enforcement of co-operative behaviour on the part of all group members so necessary to ensure conservative resource use.

By and large, technological innovations would thus tend to favour non-conservative use of biological resources. In particular, whenever a technologically superior group moves into a region occupied by groups at more primitive levels of technology, the dominant group would have the option of moving on to fresh pastures as resources of any locality are exhausted, and would derive no advantage from traditions of sustainable, conservative use. At the same time, groups now subordinated would lose any advantage from traditions of conservative use that might have been favoured in times when they could exclude other groups from their territory (Fig. 33.1). The result would be a relatively rapid use of resources, with the wave of resource exhaustion spreading outward from localities first affected by the dominant group. Such a pattern of resource use has been termed as the <u>fishing-up sequence</u> in the context of fisheries and <u>sequential exploitation</u> in a broader context (Berkes, 1985). This process would tend to deplete biological diversity. It would also diminish cultural diversity, for two reasons. First, a significant component of cultural diversity relating to fine-tuning of cultural behaviour to the local biological environment would lose its functionality. Secondly, many subordinated groups may begin to imitate the culture of one or few dominant groups, thereby losing part of their cultural diversity. Indeed, there is abundant historical evidence of such a process accompanying the two major technological revolutions in the human history. Thus colonisation of the Gangetic plains by the dominant agricultural-pastoral people of the so-called Aryan culture from about 1200 to 600 B.C. was accompanied by systematic destruction of natural biological communities and breakdown of cultures of indigenous populations as they were subjugated (Gadgil and Malhotra, 1985). Similarly, a wave of overfishing and overhunting swept over North America along with the depletion of cultures of indigenous people at the time of the colonization of that continent by European populations (Berkes, 1985).

33.4 Reassertion of conservation ethic

This process could cease however, when dominant groups no longer have "virgin" territories to take over and when the technological innovations of the dominant group have been absorbed by other human groups. It is then likely that local populations of subordinated, as well as dominant groups may assert restricted access to certain localities and/or resources (Fig. 33.1). Practices of sustainable resource use may then again confer advantage on the local group involved, and may become reestablished (Berkes, in press; Berkes, 1985). With groups tuning in to the use of local resources, cultural diversity relating to biological diversity may partially reappear. This seems to have been the case with the caste society that emerged at the conclusion of the wave of agricultural colonization of the Indian subcontinent around 500 A.D. This society was made up of tens of thousands of endogamous groups, each with its own, often highly specialized, mode of subsistence. Its sympatric endogamous groups had so partitioned the use of specialized biological resources that a particular resource tended to be monopolised by a particular endogamous group in a given region (Gadgil and Malhotra, 1983). For example, three major groups of nomads indulging in extensive hunting in semi-arid tracts of Maharashtra had so elaborated their hunting techniques that one of them had virtual monopoly over antelopes and deer, another over small carnivores and a third over small herbivores and wild pig (Malhotra, Khomne and Gadgil, 1983). In addition, resources more commonly in demand such as fuelwood and bamboos were controlled by multi-caste village communities on village common lands. The result was the persistence of cultural practices of sustainable resource use and conservation of diversity on the Indian subcontinent right down to the present day. Thus today a turtle, Trionyx nigricans survives only because it is protected in a single pond sacred to a moslem saint in Bangladesh, and a new species of a leguminous climber, Kunstleria keralensis was described a few years ago from a sacred grove on the otherwise thickly settled west coast of India (Gadgil, 1985; Gadgil and Malhotra, 1985; Gadgil, in press).

33.5 World conservation strategy

The colonization of the world by the dominant technological culture pouring out of Europe is now nearing completion, and with this, traditions of sustainable use of biological resources and conservation of diversity are reappearing. They have reemerged most readily in regions where the technological revolution was first completed. Thus the Japanese have successfully established highly

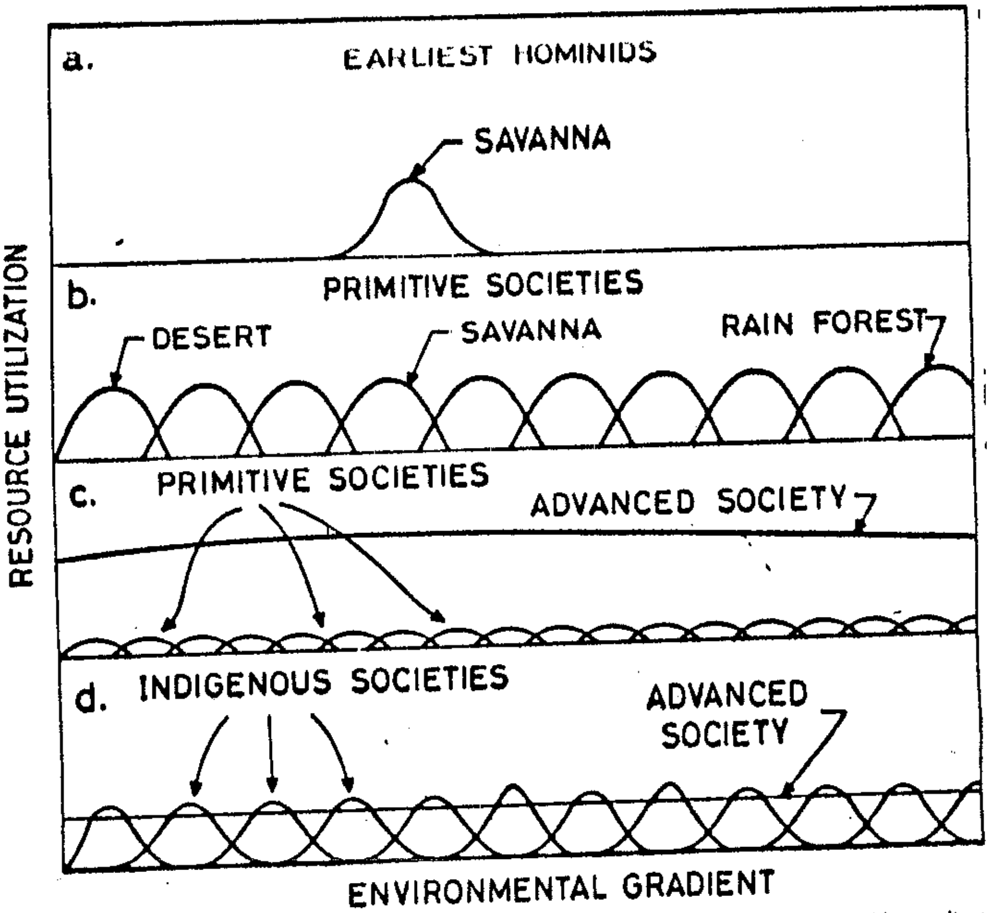

Fig. 33.1 Historical changes in patterns of resource utilization by human societies (a) The earliest hominids were genetically and culturally adapted to utilize the biological resources of tropical savannas (b) Cultural adaptation then enabled hunter–gatherer societies to occupy a wide range of environments, with each local society fine-tuned to utilize the biological resources of its own environment. (c) Technological advances enabled a few societies to usurp the bulk of resources from the more primitive and culturally more diversified societies. Technologically advanced societies initially maintained rather high levels of resource utilization, while the availability of resources to more primitive societies was markedly depressed (d) With diffusion of technologies and depletion of the resource base, the advantage enjoyed by the technologically advanced societies is reduced, so that the less advanced indigenous societies can begin to reassert some control over resources

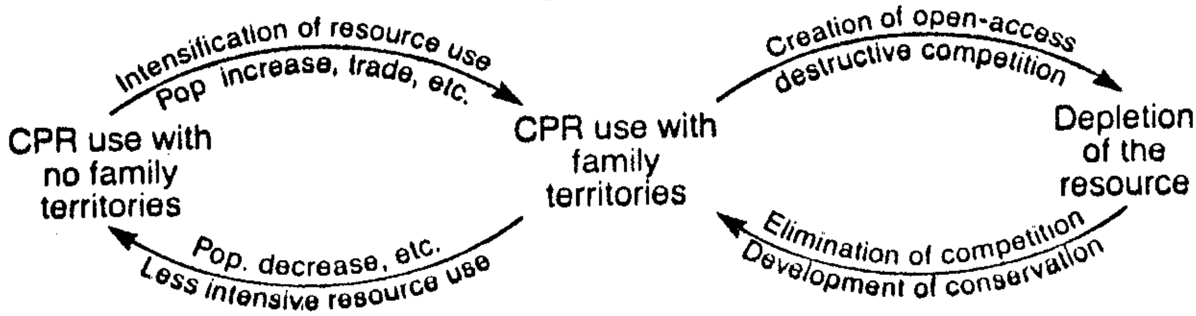

Fig. 33.2 The cycle of utilization of a potentially common property resource (CPR), the beaver, in Eastern subarctic Canada occupied by Cree Amerindian people At relatively low levels of use, the resource is owned and used communally With increasing levels of exploitation, the resource is still used communally but under a system of family-controlled territories White trappers broke down this system in 1920–30, resulting in resource depletion. Under conservation laws introduced after 1930, outsiders were banned from trapping in this area, and Cree communal and family territories were legally recognized, resulting in productive harvests after 1950 *Redrawn from Ref* 12.

sustainable use of their inshore fisheries, basing it on earlier communal controls by artisanal fishermen although Japanese fishermen practice exploitative fishing in the open access ocean areas (Ruddle, 1985). Even outside of these regions the control over local resources is reverting to local people as resources are reduced to levels too low for profitable exploitation by those employing more sophisticated and hence more expensive technologies (Fig. 33.1). Thus in the Canadian North the Amerindians are reasserting territoriality in areas once depleted of fur bearing mammals (Fig. 33.2), in the Torres Straits of Pacifics the indigenous islanders are reestablishing control over islands now depleted of pearl bearing oysters and in the Garhwal Himalayas the local peasants are claiming rights over once forested hill slopes now rendered largely barren through overexploitation by the urban-industrial sector (CSE, 1985; Nietschmann, 1985; Berkes, in press).

The intriguing question is this: apart from establishing rights over resources, will the local communities bring back some of their earlier cultural traditions of conservation of biological diversity? There are some signs of this happening; for instance with the Valley of Flowers in Garhwal Himalayas and sacred groves on the Western Ghats of India. In fact in the Uttara Kannada district of the Western Ghats tract local farmers have taken lead in establishing new sacred groves (CSE, 1985; Gadgil and Vartak, 1975; Gadgil, et.al., 1987). The same forces appear to be partly responsible for the newly emerging concepts and practices of conservation of biological diversity, such as the World Conservation Strategy and the Biosphere Reserve Programme.

These are complemented, however, by an entirely new awareness in technologically advanced cultures of the value of biological diversity. This awareness seems to be related to new developments in biology, especially the ability to create organisms of novel genetic constitutions. These possibilities suggest that genetic material in all sorts of apparently totally insignificant organisms may turn out to be of great utility. Conservation of biological diversity has therefore become a major new interest of technologically advanced cultures as well.

33.6 Prospects

Creation at human hands of genetically engineered organisms could revolutionize the world's stock of biological diversity. These technological developments may motivate profit-making enterprises wishing to establish monopoly over genetic diversity to promote destruction of natural populations once the genetic material of interest to them has been added to the gene banks under their own control. The new, engineered organisms could also convert all lands and waters, however unproductive they may appear today, into highly profitable bases of resource production. This would tremendously increase the pressure for converting all habitats into sites for man-made production, perhaps, in the end totally wiping out all natural biological communities and thereby a great deal of natural biological diversity. As the concerned technological advances provide a competitive edge to the technologically sophisticated societies, there is likely to be further erosion of cultural diversity as well (Janzen, 1986).

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34 PRACTICAL PROBLEMS IN CONSERVATION

R. SUKUMAR

Implementation of conservation strategies often runs into difficulties because of the conflict between people and wildlife. Some animals are a threat to human life and property, while people hunt animals and affect their habitat. In this lecture I shall deal with some practical problems of conservation involving conflict between people and large mammals.

34.1 Manslaughter by animals

No one has seriously argued for preserving the small pox virus or even disease-transmitting mosquitoes in the human environment. When it comes to man-eating tigers or rogue elephants the issues are somewhat different, but nevertheless there is a social obligation to selectively eliminate the offending animals. Tigers kill up to 50 people in northern and eastern Indian sub-continent, elephant kill 100-150 people and rhinos a few each year. Difficult decisions on the management of such endangered species have to be taken. In Dudhwa National Park and Royal Chitwan NP many tigers have been shot by park authorities. More than 80% of human killings by elephants in southern India are male elephants.

34.2 Crop Depredation

Mammals such as elephants, rhinos, wild pig and deer cause significant damage to agricultural crops in some regions. Rhino damage upto 90% of crops in villages surrounding the Royal Chitawan NP (Misra, 1982). Elephants damage cereals, millets and other crops in Asia and Africa. The economic loss to oil palm and rubber plantations in Malaysia due to elephant depredation amounts to about 25 million US dollars annually.

A study of crop depredation in southern India (Sukumar, 1985, 1986) revealed interesting patterns which have implications for management. Adult male elephants raided far more frequently than did female-led family herds. Bulls damaged the more economically valuable crops such as coconut and also consumed more crops per raid due to their large body size. In the final tally a bull destroyed crops worth $670 (at 1982 prices) annually compared to $32 by an average elephant in a herd.

Thus, the selective removal of a notorious bull elephant would have a far greater effect in reducing crop damage and manslaughter than culling a member of herd. This culling of males will result in an unequal sex ratio; but it will not seriously affect the population growth rate in a polygynous species.

Of course, methods of excluding elephants from human settlements will also have to be established. Trenching is expensive and fails under wet condition. The high voltage electric fence of a non-fatal type seems to have considerable potential in keeping elephants and other mammals out of settlements.

34.3 Wildlife poaching

Illegal hunting of animals is a widespread problem in Asian countries. The musk deer, the snow leopard and the Indian one-horned rhinoceros are examples of mammals that are under severe pressure from poachers. Male Asian elephants are hunted for ivory. The trade in wildlife products is a complex economic issue linked to market forces in various countries. The Convention on International Trade in Endangered Species (CITES) has succeded in partially regulating the legal trade but has little control over the illegal trade. Conservation biologists can help administrators decide their strategy against poaching by providing them objective assessments about a population's demography and its chances of surviving under hunting pressure.

34.4 Human impact on the habitat

I shall refer to three problems faced in most Asian countries - shifting cultivation, fire and grazing.

a) Shifting cultivation : Slash-and-burn shifting agriculture is a traditional practice of people inhabiting tropial moist forests over much of Asia. In some north-eastern Indian states upto 50% of the forest area is under shifting cultivation. Short rotation periods, often less than five years has degraded the forest cover over large tracts. Studies by Mishra and Ramakrishnan (1983a, 1983b, 1983c) have shown that nutrient levels under a 5-year cycle are significantly lower than under 10-15 year cycles. Short cyles also result in rapid soil erosion and desertification of sites in high rainfall areas. Plant succession may be arrested with weeds such as *Eupotorium adenophorum* and *Imperata cylindrica*. Cycles above 20 years may allow the vegetation succession to proceed to secondary forest types which attract many mammalian herbivores.

b) Fire : Human induced fires have already altered a substantial portion of the earth's landscape. There evidence for 6000-year old fires in the Amazon rain forests (Sanford *et al.* 1985). A regular fire regime alters the composition of a community to one of primarily fire-resistant species. The ground layer is usually dominated by grasses whose underground stolon is not affected by fire. In a community such as an evergreen forest which has not experienced fires, the onset of regular fires may reduce the plant species diversity. However, in a dry forest already subject to fires, regular burning may not lower diversity. Edroma (1981) found that fire actually increases the diversity of grasslands.

Protecting a dry forest from fire for a few years would increase the grass biomass. A fire at this stage would burn at a high temperature destroying not only ground vegetation but also the trees. In regions where human pressure on forests is high, it would not be possible to keep out fire permanently. Such forests may be best managed by early cool burning or rotational burning of a block every few years. Fire management may also depend on other objectives. For instance, large mammalian herbivores prefer regenerating grass from burnt clumps to umpalatable umburnt clumps.

c) Grazing : The impact of intensive livestock grazing on the habitat is well known and will not be elaborated here. The soil is compacted due to trampling, infiltratation of water into the ground is low and surface runoff is high. Plant growth is poor in heavily trampled ground.

Livestock compete directly with wild mammals such as gaur and spotted deer for food resources. They also harbour diseases such as rinderpest, anthrax and foot-and-mouth which may be transmitted to wild ungulates. The rinderpest outbreak among gour during 1968-69 in the Western Ghats is an example.

Such practical problems in conservation cannot be tackled by force or legislation alone. Ecological sound socio-economic programmes and education programmes will have to be promoted if conflicts between people and conservation are to be minimized.

35. MAN'S IMPACT ON CLIMATE

J. SRINIVASAN

35.1 Introduction

Human being began to influence climate of the earth with the advent of agriculture. The destruction of forest changed the wind speed, temperature and humidity in the lowest layers of the atmosphere. The earth's surface without vegetation cover is strongly heated by solar radiation. This decreases the relative humidity of air near the surface and hence can reduce the amount of precipitation. With the advent of industrialization large scale urbanization took place. The climate in large cities are quite different from surrounding rural areas. The temperature in these cities is atleast 3 to 5 ^{o}Centigrade higher than the surroundings. The examples cited above refer to the effect of human activities on local climate. In this lecture we will, however, concentrate our attention on the effect of human activities on the global climate.

The anthropogenic influences on the global climate can occur in various ways. The influence which has been pervasive is the increasing level of carbon-di-oxide in the earth's atmosphere. In the recent years there has been an increase the amount of chlorofluro carbons, nitrous oxide, sulphur dioxide and aerosols. The rejection of large amount of heat by industries to the atmosphere and the ocean can also influence global climate.

35.2 The 'greenhouse' effect

Most of the gases in the earth's atmosphere do not absorb solar radiation. Water vapour and carbon-di-oxide absorb about 20% of the solar radition. About 80% of the solar radiation reaches the earth's surface. The radiation emitted by the earth is in the infrared while the solar radiation is primarily in the ultraviolet and visible. Both water vapour and carbon dioxide are very good absorbers of infrared radiation emitted by the earth. Thus the earth's atmosphere permits most of the solar radiation to go through while absorbing most of the radiation emitted by the earth. This makes the earth warmer than it would be if it had no atmosphere. This is known as "greenhouse effect". In a greenhouse the glass permits most of the solar radiation to pass through but absorbs most of the radiation emitted by the plants. The earth's surface temperature is, therefore, dependent upon the amount of carbon-di-oxide, clouds and dust in the atmosphere. Clouds and dust generally tend to reflect solar radiation and hence cool the earth's surface.

35.3 The effect of carbon dioxide and aerosols

The amount of carbon-di-oxide in the earth's atmosphere has been increasing monotonically for the past 130 years. During this period the amount of CO_2 in the atmosphere has increased from about 280 ppm (parts per million) in 1860 to about 350 ppm today (see Figure 35.1). Since the beginning of industrial revolution we have been taking carbon out of the earth in the form of coal, petroleum and natural gas and burning it to make carbon-di-oxide and water vapour. There have been several model calculations to show the influence of increased

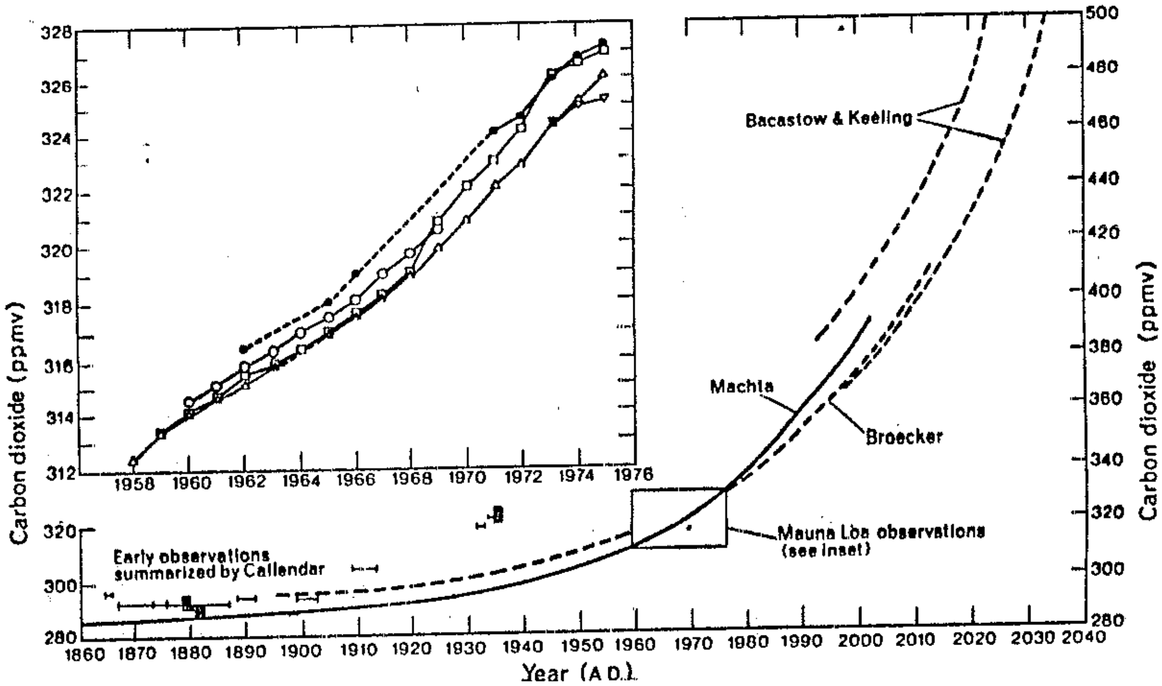

Fig.35.1. The record of carbon dioxide concentration (parts per million by volume, ppmv) from 1860 to 1975, measured at several locations, and some estimates of future trends. The early data were critically reviewed by Callendar (1958).

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carbon-di-oxide on the surface temperature. These models have shown that the doubling of CO_2 concentration in the atmosphere can increase the global mean surface temperature by 1.5 to 3 ^{o}C (see, for example, Schneider, 1975). The surface temperature changes in the polar region is about three to five times larger than the global average change. Most of these models have, however, assumed a fixed cloud cover. Newell and Dopplick (1979) have argued, however, that variation in cloud cover might reduce the tendency for the surface temperature to increase. The observed variation of the surface temperature of the globe in the past hundered years show a 0.6 ^{o}C temperature increase from 1880 to 1940 and a decrease of 0.3 ^{o}C from 1940 to 1965 (see Figure 35.2). From 1965 the surface temperature of the globe has been increasing again. Climatologists generally agree that the global warming observed during this century is on account of a increase in CO_2. What caused the cooling after 1940 inspite of an increase in CO_2? The amount of solar radiation reaching the ground is strongly influenced by the number of particles in the atmosphere. These particles have diameter around 1 micron (10^{-6} meters) and are called aerosols. Aerosols scatter and absorb radiation and hence can cause cooling of the earth's surface. Large quantities of aerosols can be produce by volcanic eruptions and human activities. The reduction in solar transmittance on account of volcanic eruption in Mt. Agung is shown in Figure 35.3. The aerosols injected into the earth's atmosphere by volcanic eruption are removed slowly by atmospheric circulation and precipitation. Natural aerosols injected by volcanic eruptions tend to cool the earth's surface. Gilliland (1982) has proposed a model which includes the effect of varying CO_2, aerosols and solar irradiation. This model predicts surface temperature variations which

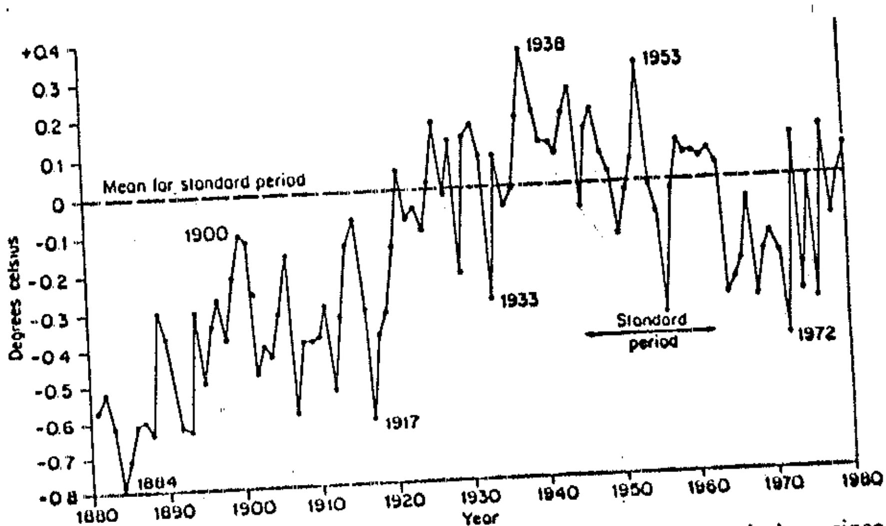

Fig. 35.2 Variation of surface air temperature for northern hemisphere since 1881, to show the recent fluctuation. (After Jones *et al.*, 1982)

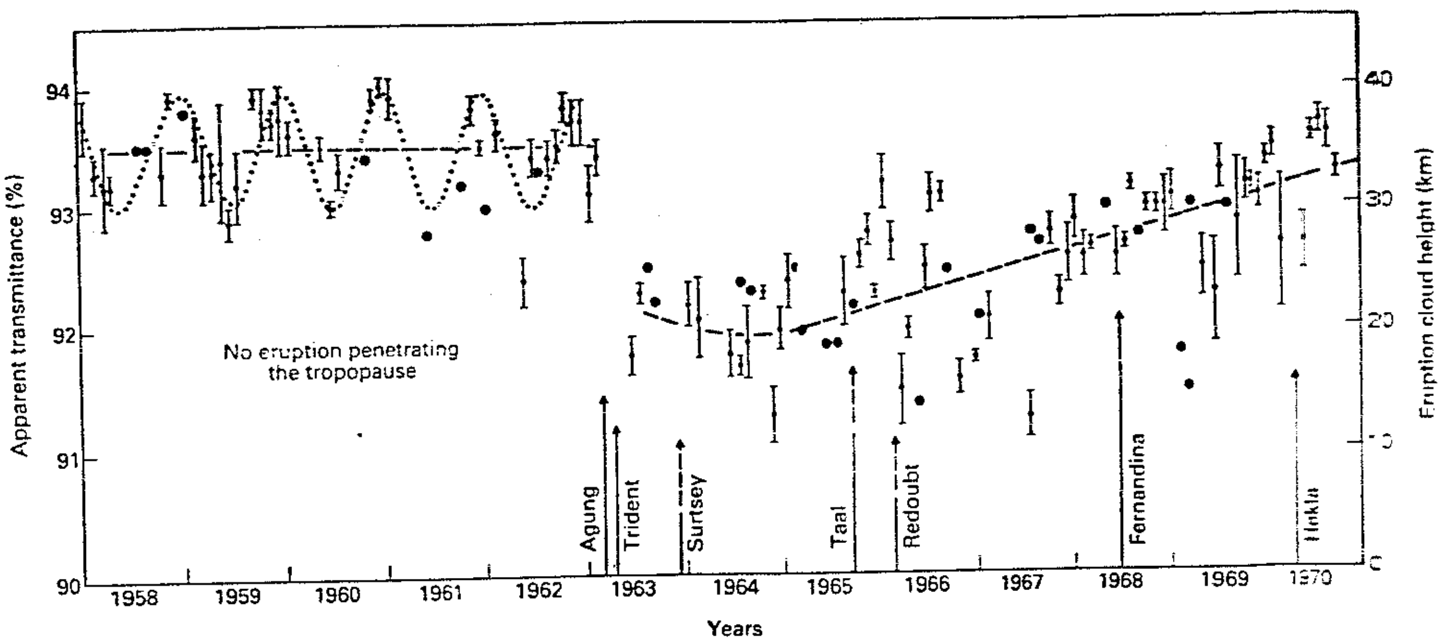

Fig 35.3 Variation of monthly means of solar transmittance (*Ellis and Pueschel, 1971*) and heights of volcanic eruptive clouds. (*Cronin, 1971*).

compare well with observations (see Figure 35.4). If there are no major volcanic eruptions in the next 50 years the surface temperature of the earth is bound to increase on account of increase in CO_2 in the atmosphere. The large increase in surface temperature that occur in the polar region will result in a melting of the ice caps. This can cause large scale flooding of cities in the coastal regions. The warming of the earth will also cause a dramatic changes in precipitation patterns. One way to predict the precipitation patterns on a warm earth is to look at the conditions on the earth during the Altithermal period (4000 to 8000 years ago). During this period the earth was warmer than present by about $1^{o}C$. Kellog (1977) has shown (see Figure 35.5) that during this period Europe, North Africa, India and China were wetter than present while North America, Canada and Greenland were drier. Hence a global warming may make the tropical regions more favourable for agriculture.

35.4 The effect of trace gases

The combustion of fossil fuels is an important source for sulphur-di-oxide. Agriculture and industries contribute to the formation of Nitrous oxide (N_2O). These gases have resulted in the problem of acid rain. Acid rain causes damage to crops, forests, aquatic organism and corrosion of materials. The sulphur-di-oxide is ultimately converted to sulphate aerosol which can cause a decrease in temperature of $0.05^{o}C$. Nitrous oxide can cause a warming of $1^{o}C$. Chloro-fluro carbons, used in spray cans and refrigerants, can cause a temperature increase of $1^{o}C$ through "greenhouse" effect.

Chloro-fluro carbons diffuse into the stratosphere and are broken

35.4 a

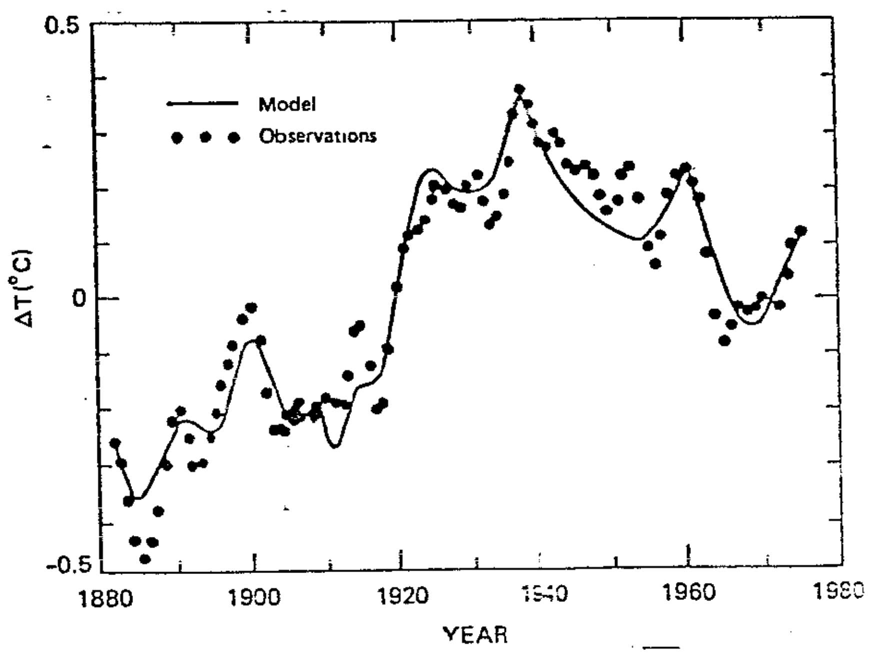

Fig.35.4. Comparison of the observed change in surface air temperture and model predictions of the change in temperature when considering the increase of CO_2 concentrations and changes in solar irradiance and stratosperic aerosol loading. Gilliland (1982).

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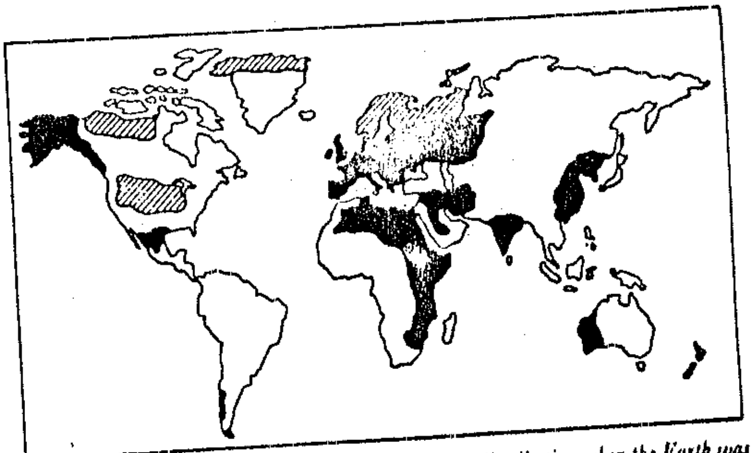

Fig. 35.5 *Will Kellogg's reconstruction of rainfall distribution when the Earth was warmer than today, during the Hypsithermal between 4,000 and 8,000 years ago. Some parts of the world* (black) *were wetter than today, others* (shaded) *were drier. Information is lacking for blank areas. (Based on Figure 13.6 of W. W. Kellogg, 'Global influences of mankind on the climate', in* Climatic Change, *ed. J. Gribbin, Cambridge University Press, London and New York, 1978.)*

35.4 b

down by ultraviolet radiation. The products of these reactions can reduce the amout of ozone in the stratosphere. The reduction of ozone in the stratosphere can increase the incidence of cancer in human beings and cause genetic damage in other living organisms. In the region between 8 microns and 13 microns the earth's atmosphere is somewhat transparent. This is known as the atmospheric window. Any trace gas which can absorb infrared radiation in this region can have dramatic impact on global warming. Hence gases such as ammonia, carbon tetrachloride, chloro-fluro carbon and sulphur-di-oxide whose concentration is only in parts per billion can cause global warming because they absorb infrared radiation in the atmospheric window.

35.5 The effect of waste heat release

In many urban areas the heat released by human activities is becoming comparable to solar radiation incident in the area. With increasing energy consumption and rapid population growth, the heat release in many urban areas will exceed the incident solar radiation. Such a situation will result in global influence on climate. Model simulations have shown that concentrate heat release in megapolises can cause temperature rise of 5 to 10 ^{o}C near the heat source and temperature falls of 5 to 10 ^{o}C in other areas of the globe.

35.6 Conclusion

We have seen that human activities can influence global climate in a variety of ways. Natural phenomena such as volcanic eruption can also cause large variation in global climate. The dramatic increase in energy consumption and population in this century has made human activities as important as natural causes.

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36. CONSERVATION TRADITIONS AND SOCIAL JUSTICE

RAMACHANDRA GUHA

This lecture analyses the different traditions within the conservation movement. Taking the United States and India as case studies, it argues that the evolution of a conservation ethic in the First World is likely to be quite different from a conservation ethic in a Thirld World context. As a consequence, an uncritical tradition may have far reaching social and ecological consequences. As a first step towards a synthesis of what is best in both traditions, the lecture identifies diversity, sustainability and equity as the building blocks of an environmental ethic that successfully integrates conservation with social justice.

At one level, the United States and India have a great deal in common. They are both countries of a continental size, exhibiting a bewildering ecological and cultural diversity. Moreover, they both have thriving environmental constituencies. Whilst, the American movement is the oldest and perhaps best organized, the Indian environmental movement, though more recent in its origins, is one of the more effective in the Third World. Yet the countries do exhibit sharp differences as well. They have had radically different settlement patterns, India has been a complex and sophisticated agrarian society for several millenia. The United States was thinly populated until the arrival of white colonists, whereupon it has experienced a dramatic spurt in levels of population growth and economic development. India has also had the experience of two centuries of British colonial rule. Higher population densities, the colonial experience and the fact that it is still predominantly an agrarian society all distinguish India from the most powerful country in the industrial world.

It is these differences in ecological, economic, and demographic history that are crucial in explaining the different traditions of conservation that have emerged in the two countries. The dominant tradition in American environmentalism has been that of the wilderness ethic. At the turn of the century, early naturalists like John Muir (founder of the Sierra club), appalled at the destruction of the spectacular American wilderness by commercial and economic expansion, made a strong case for the setting aside of protected wilderness areas. Their attempt was successful, and over the years, the United States has created what is unarguably the most extensive and best managed system of National parks in the world. Moreover in recent years the craze for the wilderness has truly become a mass movement; with the rapid rise in leisure time in the "post industrial" economy, millions of Americans go yearly to enjoy the beauty and solitude of the wilderness.

Ostensibly, therefore, the American wilderness movement is an outstanding success, and is indeed claimed as such by its official and non-official votaries. Yet underlying this victory of the wilderness ethic is a disturbing paradox. If within its borders, America has been remarkably successful in the cause of environmental protection, as the most consumption oriented and wasteful society in the world, it simultaneously has had by far the most negative impact on other ecosystems with 6% of the world's population, it consumes close to 40% of the world's resources - in order to do so, it must draw upon the physical resources of a large portion of the globe, fostering in the process unsustainable and ecologically imprudent economic practices. This inconsistency between an ecological wisdom at home which is abandoned when a society goes beyond its borders, is replicated in their daily lives by many wilderness lovers, who see nothing discordant in driving 1000 miles in that ultimate ecological villain the private automobile, to experience the ultimate symbol of ecological harmony - undisturbed wilderness.

One final word on American environmental traditions while the wilderness ethic may be the dominant trend, it is by no means the only one. Another important strand in the environmental movement has been chiefly concerned with the control of industrial pollution and toxic wastes yet this trend has remained in very much a minority, and the wilderness movement has been far more effective in claiming public support and influencing government policy.

The dominant thrust of the Indian environmental movement has been quite different. It is perhaps best exemplified by the chipko (Hug the Tree) movement, a present initiative in the Himalaya directed against commercial forestry and its devastating impact on hill ecology. Yet chipko is only one among several movements in different forest belts of India, where conflicts between peasants and the commercial sector on the proper ecological and social function of the forest, have taken a sharp turn. These movements have arisen in response to the transformation, largely for the worse, of peasant and tribal society, first under colonialism and more lately as a consequence of the policy of industrial development followed by the Indian government. These movements have challenged the massive state subsidies in providing natural resources to the industrial sector, as well as the privatization of common property resources. Outside the sphere of forests, there have been several movements of villagers displaced by large dams, and a major movement of small fishermen in Kerala in opposition to encroachment and overshing by large trawters.

While these movements are as yet small scale and localized, the intervention of voluntary groups and activists have helped bring them together. Underlying these movements is a sharp critique of the energy, capital and resource intensive model of industrialization presently followed in India. This critique is based on the criteria of sustainability - viz that present patterns of economic development are ecologically unsustainable in the long run - and equity - viz. that the utilization of natural resources has been principally directed in favour of the urban-industrial sector, while restricting access to large sections of the rural population.

In the last decade, this grass roots based environmentalism has emerged as the dominant tendency in the Indian movement. Yet such has not always been the case. For several decades following Indian independence, conservation was the preserve of a tiny elite who in part emulation of the American National Park System, helped set up an analogous system of parks and sanctuaries oriented around large mammals such as the tiger and rhinoceros. This uncritical transplantation of an alien ethic, without adequately tailoring it to local conditions, has been rightly criticized for the negative impact it has had on rural communities living in and around the reserves. More recently, it has been eclipsed by the emergence of the new environmental movements, which has repeatedly raised the issues of sustainability and equity neglected by the wilderness movement in both India and abroad.

As this brief analysis suggests, what we have here are very different traditions of conservation. While respecting local differences, one can nevertheless strive for a working synthesis, at the level of principle, of what is best in both traditions. From the American wilderness movement we draw the key concept of diversity, with the following caveat : it must be enlarged ecologically, so as to constitute the retention of overall biological diversity rather than focus exclusively on a few spectacular "game" species, and socially, to include the fostering and retention of cultural diversity. The other two building blocks of a global conservation ethic come from the experience of Third World environmentalism. The first is sustainability, defined as ecologically sustainable economic development at all levels; local, regional, national and global. The second is equity (or social justice), which must incorporate political as well as economic justice.

37. ENVIRONMENT AND DEVELOPMENT

A.P. GORE

Abstract

This talk comments on conflict and complementarity between conservation and development in the Indian context from a lay viewpoint. Conflict is manifested in issues such as land encroachment, traditional rights of rural communities vis-a-vis natural resources and damage caused by protected animals. Complementarity is seen in programs of rural employment, soil and water conservation and need for development of common property resources such as village grazing lands. Some comments are also offered on processes of diffusion of ecologically desirable technologies.

38. BIOTECHNOLOGY AND THE FUTURE OF BIOLOGICAL DIVERSITY

RAGHAVENDRA GADAGKAR

It is now a widely appreciated fact that there has been an explosion of genetic engineering technology. The key discovery that really started it all was that bacteria have certain enzymes called restriction endonucleases which break up foreign DNA to protect the cell from invasion. These enzymes cleave DNA at very specific sequences called palindromes so that the the broken ends have complimentary sequences and may thus be called sticky ends. Moloecular biologists have learned to use these restriction endonucleases to cleave DNA molecules and then use the sticky ends to join DNA fragments from widely different sources and hence engineer hybrid DNA molecules of the desired kind. The rather extensive elaboration of this technique has made it possible to introduce DNA molecules from one organism to another and in many cases it has also been possible to have the foreign DNA transcribed and translated. Most commonly DNA from higher organisms is introduced into bacterial cells so that large quantities of desired proteins such as hormones can be synthesisd in the bacteria. In more recent times we are very close to introducing foreign DNA into higher organisms also. There is for instance a tremendous effort underway to introduce bacterial nitrogen fixing genes into the genome of higher plants so that they no longer have to dependend upon symbiotic relationships with bacteria. The possibility of producing improved varieties of plants by incorporating disease resistance and other "good genes" is really around the corner.

What if any are the implications of this technology for conservation efforts? This question is as interesting as it complicated. On the one hand genetic engineering technology can, in principle at least, have very favourablr consequences for conservation efforts. With improved varieties of crops and horticultural plants land use can be much more efficient therby decreasing the pressure on new land to be brought under cultivation. Genetic engineering technology can sufficiently simplify the task of engineering suitable organisms for effective biological control thus reducing the problems due pollution of the environment by pesticides. It is very intersting that it is at present entirely legitimate to argue that genetic engineering will have exactly the opposite consequences. Cheap and efficient production of vanilla, cocaine and opium in other parts of the world will certainly ruin the economies of Mexico, Bolivia and Turkey, very likely leading to conversion of the remaining forest into agricultural land to grow food for their starving inhabitants. What are the chances that "good" species will accidentally be converted into pest species requiring the use of more pesticides than we do today? These possibilities appear to be very real (Regal, 1986).

There is a different and even more intersting kind of implication of genetic engineering technology for conservation efforts. It would be foolish to deny that molecular biologists are learning very rapidly to resurrect whole plants from tissues and single cells and to resurrect viable genes from DNA banks . The day is probably not very far off when knowledge of the sequence of a DNA molecule alone will be sufficient to synthesise it and introduce it into a living cell and make it work. The inevitable consequence of this is that slowly and steadily, our arguments for the preservation of entire habitats and large populations of wild plants for the sake yet to be discovered drugs and "good genes" are becoming impotent. There is a great deal that molecular biologists can do with frozen material in seed banks, tissue banks and DNA banks not to mention mere DNA sequences. A recent triumph of molecular biology has been to clone and sequence portions of a DNA molecule extracted from an Egyptian mummy (Paabo, 1986). True, such triumphs will sometimes lead to unwise destruction of habitats even when not absolutely essential or when the claims of molecular biologists are not fully substantiated. But I would like to inderscore the other side of the coin. In my opinion, conservationists should accept the fact that not all species need be or, more importantly, can be preserved in their pristine habitats. Conservationists should therefore devote a lot more effort to defining their priorities. It is time we realised that our conservation efforts can be directed at the levels of complex biological communities, large populations of certain species, small and maybe, captive populations of some special organisms as well as at the level of organs, tissues, cells and gene banks (Swaminathan, 1984). Conservation efforts at all these levels are justified and acceptance of tissue banks or gene banks as the mode of conservation of some species should not be construed as betrayal of the cause of conservation. It should be our effort to identify the sufficient and practical levels at which conservation can be achieved for different species.

39. WILDLIFE CONSERVATION IN BANGLADESH

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Institute of Life Sciences
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Bangladesh, a small country, has a total human population of over one hundred millions in an area of 144,054 km^2 of which 8300 km^2 are water areas. Only nine percent area is covered by forests. We do not, unfortunately, have any exact figure on wildlife, we had about a hundred years ago. Over last few decades Bangladesh lost about a dozen species such as Rhino, Nilgai, Wild Buffalo and the Pinkheaded Duck. Bangladesh has, at present, 19 species of amphibians, 124 species of reptiles, 578 species of birds and 119 species of mammals. Of these, 23 species have been enlisted by the IUCN in its Red Data Book as endangered. About a dozen species, including Common Langur, Serow, Whitewinged Wood Duck, Comb Duck, King Vulture, Bengal Florican, Gharial are now on the verge of extinction.

Habitat destruction, monoculture of teak, tea, rubber and oil palm and the increase in water salinity in the rivers of the Sunderbans are causing threats to the wildlife.

With a view to conserving wildlife, the Government of Bangladesh constituted four national parks, nine wildlife sanctuaries and one game reserve. A Wildlife Advisory Board was also formed in 1976. With the abolition of Wildlife Circle in 1982, wildlife conservation has now been placed in the hands of Divisional Forest Officers. This means, no scientific wildlife management prevails in the country. A task force (formed in 1985) recommended a few conservation actions in June 1986 which, however, failed to bring attention of the government. These lapses could be remedied by securing the existing forest areas, by stopping monoculture forestry practice, by the revival of the abolished Wildlife Circle and by amending the Bangladesh Wildlife (Preservation) Amendment Act, 1973.

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Lorenzo C. Agaloos

40. Status of National Parks in the Philippines

Traces the legal and institutional history of national parks in the Philippines. It also gives an overview of the system, the policies affecting the system, the management and development programs, the multifarious problems, and the actions that we are taking to remedy these problems.

40.1

41. ELEPHANT CONSERVATION IN NORTH-EAST INDIA

D.K. LAHIRI CHOUDHURY

Abstract

1. Present distribution of population and estimates of population of elephant in North-East India

2. Analysis of status of individual populations

3. Analysis of threats including elimination figures

4. The area is best seen in terms of two biotic provinces : north bank of the Brahmaputra and South bank of the Brahmaputra. On the north bank the tract concerned is the sub-Himalayan belt from West Bengal to the river Siang (Brahmaputra) in the east and the foothills of the Himalayas in Arunachal Pradesh between the rivers Dhansiri (border between Bhutan and Arunachal Pradesh) and Siang (Brahmaputra). Protection problem here concerns the core habitat of elephant in the foothills of Siang East and West Civil Districts of Arunachal Pradesh and the fragmented habitat in West Bengal, west of the river Torsa. On the south bank of the Brahmaputra the picture is grim. The possibility of consolidation of habitat remains only in Meghalaya and in Assam, in Kaziranga-Karbi Anglong area. A third possibility is the consolidated Jainti Hills (Meghalaya)-North Cachar reserved forests of Assam.

5. Existing sanctuaries on the north bank and proposed extended protection areas. Existing protected area on the south bank and proposed extended area including proposed new areas.

6. The problem of shifting cultivation and its present position.

7. The problem of protection of some associate species in these forests.

8. The present legal status and its mode of enforcement are questioned. Should elephant be treated merely as a wild animal which is best left in the wild or should it be given the special status it has always enjoyed in India's history : that it is a wild animal taken from the wild to serve and befriend man ? Should there be merely a all-India status evaluation or a state-wise status evaluation, as permissible under Wild Life (Protection) Act, 1972 ?

First Asian School On Conservation Biology

41. A Brief Introduction On Nature Reserves Of China

by

Zhao Xianying

(National Committee of the People's Republic of China for MAB)

Abstract

347 nature reserves of various different types had been set up in China by the end 1986. China's reserves can be divided roughly into the following six categories depending on the nature and goal of protection:

1. Conservation of an intact comprehensive ecosystem;
2. Conservation of the source of certain rare animals;
3. Protection of rare relict plants and characteristic types of vegetation;
4. Conservation of nature landscape;
5. Preservation of characteristic geological sections and special geomorphological features;
6. Protection of the natural environment and natural resources of the coastline.

In order to promote international co-operation and exchange of information with other countries, Changbaishan, Wolong, Dinghushan, Fanjingshan, Wuyishan and Xilingguolei nature reserves were included in the international network of biosphere reserves under the framwork of MAB, UNESCO.

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12. THE VEGETATION OF THREE NATURE RESERVES IN NORTH CHINA

(Chen Ling-Zhi)

(Institute of Botany, Academia Sinica, Beijing China)

About 330 nature reserves widely distribute in various provinces and cities of China. Three types of nature reserves are introduced in this paper.

Changbai MT.nature reserve is one of the largest reserve in China. It was established in 1960. The mountain extends from 40°58' to 42°6' N, 127°56' to 128°6' E belonging the temperate climatic zone in the northeast part of China. The secondary oak forests and its coppics appear on the montane base belt. The core of nature reserve is covered with mixed coniferous and broadleaved forests between 500-1100m. It is zonal vegetation in this region. Taiga forests appear at 1100-1700m in altitude. The elfin forests present on the upper forest line. The peak of the mountain is covered with the tundra. The vegetation distribution on Changbai MT. represent the altitudinal zonation in temperate climatic zone in Northeast China.

Baihua MT. nature reserve was set up last year. It is situated in the warm-temperate climatic zone near Beijing. The deciduous forest as a zonal vegetation occur on the base belt of the mountain. Unfortunately, most of them were replaced by shrubland. Oak,birch,poplar forests limitely present on the remote area. It is the core of the naure reserve, man-made coniferous forsets such as spruce, larch and pine forest distribute at 1100-1900m on the mountain. The top of the mountain is covered with beautiful subalpine meadows.

Guandi MT.nature reserve was set up in 1980, it is located at 37°45'-37°55' N, 111°22'-111°33' E in province Shanxi. The conservation of the brown eared pheasant and Taiga forest ecosystem are aims of the nature reserve. The original deciduous broadleaved forests on the montane base belt were replaced by shrubland and farmland. The natural larch forests occupy large area at 1800-2500m in altitued including some natural spruce forests. The peak of the mountain are covered by subalpine deciduous scrubs and meadows. The vegetation distribution of Guandi MT. represent the altitudinal zonation of warm-temperate climatic zone in North China.

H2.1

43. REVIEW OF NATURE CONSERVATION EFFORTS IN INDIA

R. SUKUMAR

The traditions of nature conservation in India have been dealt with in an earlier lecture. This talk will be confined to conservation efforts by the state.

During the mid-19th century the British organized the Forest Departments in the country. Large tracts of forest were declared as Reserve Forests for management by the government. However, the exploitation for timber was disorganized until 1920-30 as admitted in the Forest Working Plans. Sport hunting of animals was also permitted in most of the Reserve Forests.

The large scale slaughter of elephants in the Madras Presidency was reduced after the Elephant Preservation Act of 1873. The British set up the first National Park (now called Corbett NP) in 1936. The princely rulers of various states also had their own reserves, primarily for hunting big game. Some of their hunting preserves such as Gir and Bandipur are important National Parks today.

This nexus between hunting and conservation meant that the majority of protected areas in the country were set up in deciduous forests where large herbivorous mammals and carnivores occur at high densities. The initial emphasis was also on endangered and endemic mammals such as rhino (Kaziranga and Manas Sanctuaries), hangul deer (Dachigam) and Asiatic lion (Gir). A few refuges for water birds were also created, notably Bharatpur and Point Calimere Sanctuaries. In 1973, the government with the help of WWF launched "Project Tiger" to save this species which had declined to an estimated 1800 animals in the country. This is estimated to have increased to over 4000 by 1986. Though there are uncertainties about the population figures, it is certain that Project Tiger has been successful in saving the tiger from immediate extinction.

The national parks and sanctuaries catering to large mammals did protect other components of the ecosystem. But the emphasis on deciduous forests and grasslands meant a general neglect of other biomass and the overall biological diversity of the country. There were a few exceptions; for example, the Sunderbans Tiger Reserve had a significant proportion of mangrove habitat. During the Seventies the importance of conserving the entire spectrum of biological diversity was gradually realized. Based on the classification of Udvardy (1975), 12 sites were identified as potential candidates for Biosphere Reserves in accordance with the concept evolved by UNESCO. These included the Nilgiris (representing Western Ghats), Nanda Devi (Himalaya), Rajasthan Desert (Thar desert), Gulf if Mannar (Marine) and Namdapha (N. E. India). Apart from emphasizing conservation of biological diversity, the biosphere reserve concept also seeks to reconcile conservation with sustainable development. India's first biosphere reserve, the Nilgiri Biosphere Reserve, was officially declared in September 1986. Covering a forested area of 5520 km^2, the NBR encompasses a diversity of vegetation types (including dry thorn, deciduous and evergreen forests) and numerous endemic mammals such as Nilgiri tahr, Nilgiri langur and lion-tailed monkey. During the Eighties the public involvement in conservation also came of age with the successful battle in saving Silent Valley from a dam project.

In 1980 there were 17 national parks and 95 wildlife sanctuaries in India (UN List of Reserves). By 1986 this had jumped to

1 biosphere reserve, 53 national parks and 247 sanctuaries, covering over 90000 km^2 or 3% of India's total land area or 12% of India's forest area.

There have been two recent attempts to relate the network of nature reserves with the biogeographic zones/biomes/vegetation types of India. Mackinnon and Mackinnon (1986) have reviewed the protected area system in the Indo-Malayan Realm. Their review of the Indian sub-continent is based largely on the biogeographic classification of Rodgers (1985) which, in turn, is a modification of the widely used Udvardy system. A summary of their review is given below (Table 43.1). For each "biounit" they have also given a detailed break up by vegetation type.

Table 43.1

Biounits	Original area km^2	Remaining natural area km^2	% original area protected	% remaining area protected
1. Western Ghats	186000	61380	5.6	17.2
2. Bengal/Assam	442700	84110	1.1	6.2
3. North India	1532000	245120	2.8	17.6
4. S. Himalayas	331600	159170	3.6	7.6
5. Eastern Ghats	94600	34060	4.9	13.8
6. Coromandel	26000	2860	3.9	36.0
7. Deccan plateau	284000	45440	0.3	1.9
8. Thar/Indus (incl. Pakistan)	618920	123780	4.7	23.8
9. Laccadives	?	?	0	0
10. Andamans	6430	4370	4.1	6.2

Gadgil and Meher-Homji (1986a, 1986b) have identified the conservation status and key localities in 43 major vegetation types described by other sources. A summary is provided below (Table 43.2).

Table 43.2

Zone	Potential area km^2	Area of primary forest km^2	Area of all forest km^2	Area of Nature Reserves km^2	Nature Reserves as percentage of all forest
Arid	481300	0	2200	8200	a
Semi-arid	670000	17600	31400	7800	a
Peninsular deciduous	1291200	195500	283300	50000	17.6 %
Peninsular evergreen	62000	14100	16400	3600	21.9 %
Himalaya	290500	112300	129000	10900	8.4 %
Andaman and Nicobar	6800	5500	5500	800	14.5 %

a - The Desert National Park includes a large area without any vegetation cover.

The present network of protected areas covers more evenly the major vegetation types, compared to the situated a decade ago. There is scope for improvement in the N. E. Indian states, South Himalayas, Deccan plateau, Laccadives and Andamans. However, it must also be realized that a major proportion of forests in India are Reserve Forests (unlike in many other Asian countries) and, hence, protected even if these do not have the status of a national park or a sanctuary.

45. POLICIES AND PROGRAMMES OF ENVIRONMENTAL REHABILITATION IN INDONESIA

MOHAMAD SOERJANI

The plight of human beings in less developed countries, including Indonesia, is a continuous existence of poverty. The first thing that the national development should aim at achieving is to meet the basic needs like oxygen to breath, water to drink and food to eat, for which people will have to find a spatial, trophic and qualitative niche to live.

Consequently the national effort in development has to face the following problrms :

1. The imbalance in distribution of the population among different areas with different resources, coupled with the fast rate of population growth

2. The increasing pressures on the environmental resources for a high economic growth in order to meet the rising demand of the rapidly increasing populaiton.

3. The inappropriate and incomplete adoption and development of technologies in supporting the high economic growth, creating certain degradation of the environmental quality.

This paper deals with the main policy in national development, the population problems in Indonesia, the various areas of development, its important impacts on the environmental quality that need both environmental conservation and rehabilitation, and analysis of posterity to find additional components for conservation in our future developments.

46. INDONESIAN WILDLIFE RESOURCES AND THEIR CONSERVATION

AGUSTINUS W. TAUFIK
Directorate of Nature Conservation

ABSTRACT

Indonesia has all the natural factors in its favor to make the country very rich in natural resources, but people has already squandered much of their natural wealth through their ruthless exploitation and lack of conservation in resource utilization.

The present discussion of the Indonesian experience is also applicable in many ways to what has happened and is still happening to the wildlife resources in the other countries of Southeast Asia.

Steps should be taken to manage wildlife species in order to protect them from extinction. The role of the Indonesian government is very important and effective in this conser - vation efforts.

Wildlife, as discussed in the present paper, is restricted to the mammals including their present status, distribution, threats, conservation efforts, and also the public attitudes toward wildlife conservation are discussed; and details of the present game law are also given.

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47. COUNTRY WIDE REVIEW OF NATURE CONSERVATION EFFORTS

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Indonesia

The problem of conservation cannot be solved by studying biophysical components only. We have also to study the complex interactions between biophysical components and the humans (and their societies and cultures), who attempt to manage the systems. As such, its solution cannot be achieved by biologists or ecologists alone but requires the anthropologists with an ecological perspective. It is in this respect, I think there appears to be a great opportunity for an ecological anthroppologists to understand problems, especially people problems more fully dealing with conservation.

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48. HOLISTIC APPROACH IN THE MANAGEMENT OF CONSERVATION AREAS IN DEVELOPING COUNTRIES

By:

Edy Brotoisworo

Abstract

Nature reserve is an area set aside for conservation of particular ecosystem or unique plant and animal species. Depending on its allocation, but this area is usually set to be free from human exploitation or other development activities. But in most developing countries we can find that one major problems in managing conservation area is due to the population pressure. Safeguarding the conservation area is usually done by patrolling the boundaries and preventing any interference from outside. Such management practice is commonly would not be effective, since the population keeps on growing, while on the other hand the carrying capacity of the land in the surrounding of the reserve is limited. This made that in many cases, safeguarding a reserve area by preventing human interference is an endless effort. To solve such a problem would not be able been done by only curative methods. The root of the problem should be found and analyzed.

If we see in a larger scale, a nature reserve in a particular location is actually a component of a larger ecosystem, so called "rural ecosystem". In the case of in western Java, this ecosystem consists of four components, i.e. village, farmland, river, and forest; which are interacted with each other. Thus, to save the forest environment from human interference, we should manage the other components of the ecosystem.

Population pressure is the main problem of this case. This pressure should be reduced by creating alternative source of income which needs a more narrow land requirement. If better source of income can be created for the people, the conservation of reserve area in that area could be more ensured. This paper will discuss population pressure on conservation areas and alternative solution of the problem.

* Abstract submitted for ***The First Asian School on Conservation Biology***, Bangalore, India. 16-31 December 1987.

** Member of research staff at the Institute of Ecology, and educational staff at the Biology Department, Faculty of Mathematic and Natural Sciences, Padjadjaran University. Bandung, Indonesia.

49. The vegetation regions of China and establishment of natural protected areas

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Abstract

The thirteen vegetation regions of China are described in the following paragraphs.

1.The coniferous forest occupies the extreme north of China. Considerable area of forest is still preserved, there are four natural protected areas with an area of some 540,000 hectares.

2.The mixed coniferous and deciduous broadleaf forests are situated in the northeast corner of northeastern China. This is the main forest region of China. Thirty reserves have been established and the matter of vegetation conservation can not be delayed.

3.The deciduous broadleaf forest is principally the broad area stretching from the southern portion of the Manchurian plain to the northern shore of the Huai River and the northern stope of Qinling. This region has 94 reserves, but the work of effective management must be strengthened.

4.The mixed deciduous and evergreen broadleaf forest, the transitional region between the deciduous and the evergreen broadleaf forests, belongs more to the subtropical category from the viewpoint of vegetation analysis, so we call it northern subtropics. 29 Reserves have been established. It is very necessary to strengthen vegetation conservation. 5.The evergreen broadleaf forest, which has a climate typical of the moist subtropics of eastern Asia, occupies a vast expanse in China. It may be divided into two subregions--- the eastern and western. The former subregion is mainly influenced by the pacific monsoon, and its climate is moist and warm, the dry and wet seasons not being distinct from each other. The latter is affected by the Indian monsoon, its dry and wet seasons are very marked. There are 169 protected areas in this region. These will be of great advantage to biological research applied to meet the needs of industry and agriculture.

6.The tropical seasonal rain forest lie in the northern margin of the Tropics (The "Northern Tropics"). They include the southern part of Kuangdong, Kuangxi, Yunnan, the extreme southern corner of Tibet, the islands of Hainan and southern Taiwan. The task of nature protection is large and very urgent in this region. 86 areas have been set up for the protection of tropical forests, rare animals and plants.

7.The coral islands of the South China Sea experience frequent typhoons and strong wind. The typical vegetation consists of tropical shrubs growing on coral islands, such as Pisonia grandis, Guettarda speciosa and Scaevola serices. Two reserves were established.

8.The forest steppe is a transional zone between the forest to the east and the steppe to the west. It may be divided into two subregions, the northeastern and the northwestern. Their common features are large patches of woodland alternating with grassland There are 25 protected natural areas in the region. Task of nature conservation is very important.

9.The steppe occupies dry area of northern part. The climax community is stipa steppe. Because of inadequate management, the grassland is being very

severely denuded. It is urgently necessary to strengthen vegetation protection by rational utilization and restoration of the grassland. 12 reserves have been established in this region.

10.The desert steppe and desert include the western part of Mongolia, the northern part of Gansu, the Talimu and Zhungeer basins of Xinjiang and Chaidamu basin of Qinghai. Although 22 reserves have been established, but it is urgent need to strengthen effective management.

11.The mountains of northwestern China consist of three sections: a).the Tianshan;b).the Qilianshan; and 3).the Aertaishan. There are 10 protected areas in this region. They play very important role in economic construction.

12.The mountain and plateau of East Tibet encompass the eastern part of Tibet, northwestern Sichuan, and northwestern Yunnan. The region is heavily wooded, ranking second only to northeastern China in this regard. The establishment of protected areas cannot be delayed. Recently 7 reserves have been established.

13.The Tibetan plateau is a lofty plateau rimmed by even loftier mountains ---the Kunlun to the north, the great Himalaya range to the south. There are 9 reserves in this region.

The task of nature conservation is a problem throughout the world. We would like to strengthern our cooperation with other countries, and to learn from the advanced experience of them in order to do the best.

H

ABSTRACTS OF POSTER SESSIONS

i) A STUDY ON THE SIBERIAN WEASEL (*Mustela sibirica*) POPULATION OF JIANGSU PROVINCE AND THE RELATION TO ITS RODENT PREY

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ABSTRACT: This paper is a summary of the study on population ecology of the Siberian weasel (*Mustela sibirica*) in Jiangsu Province during 1984-1986. The mean sex ratios (♀:♂) of the weasel were 1:1.71 (Nov. 1984), 1:1.2 (June 1985), and 1:1.33 (Nov. 1985). The mean population densities of weasel ranged form 0.61-3.05 individul/sq.km in northern Jiangsu and 1.64-5.29 individual/sq.km in southern Jiangsu. The mortality in the census areas averaged about 78% from Nov.1984 to June 1985. The population size was 258,000-334,000 individuals in Jiangsu Province.

A life-table for the Siberian weasel was constructed through age criteria procedures. skulls (n=320) and bacula (n=74) which were collected during the winter hunting season 1985/86. Maximum longevity was less than 5 years, under the present high hunting pressure.

To evalute the effect of weasel predation on its rodent prey, a calculation was made from field data. The converting rate (0.23±0.072 mouse tissue weight(g)/weasel tissue weight(g)) for the weasel's daily food requriment was obtained by captive feeding experiment, together with published data on reproduction of local dominant rodent species: the striped field mouse (*Apodemus agrarius*) and the striped hamster (*Cricetulus barabensis*). The annual predation rates were 21.9 % and 30.8 % respectively. Results showed that the Siberian weasel may bear no important role in rodent control in the cultivated land ecosystem of Jiangsu Province.

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(ii) Predation Ecology of the Asiatic Lions *(Panthera leo persica)*- an interim report

Ravi Chellam

This report deals with the results obtained from field work for a period March 1986-October 1987. It concentrates on the predation ecology of the lion, even though the ongoing research project- The Gir Lion Project of the Wildlife Institute of India- covers other aspects of wildlife in Girforest Gujrat.

Results obtained from scat analysis have shown that nearly 67% of the collected scats had wild prey remains. This is a dramatic turn about when compared with the results obtained by Joslin (1973).

Results from kill examination shows a strong seasonal preference for domestic stock during the monsoon and within the wild prey a strong seasonal choice for sambar during the dry hot summer (March-mid June). The reasons for this seasonality are discussed.

Observation on hunts, both successful and unsuccessful are presented to give an idea of how the lions operate and to contrast with the known African situation.

Data on leopard predation is presented to compare it's predation ecology with that of the lion.

Data on wild ungulate population: their relative numbers, age and sex structure and their breeding periods is also discussed.

As it is an ongoing project and since analysis is not complete the results expressed indicate only trends and are provisional.

(iii) Influence of cattle grazing on the food and feeding habits of Blackbucks, *Antelope cervicapra*, at point calimere wildlife santuary.

K. Thiyagesan, R . Nedumaran and G. Rajashekaran
Tamilnadu

Blackbuck and cattle diet compositions were studied in two areas of distinct vegetation types viz. Ocean vegetation and Dry evergreen vegetation, at point calimere wildlife sancturary, during January to March 1987 the blackbucks principally fed on 29 species of plants comprising of 8 species of graminoids, 17 species of forbs, 2 species of browse and 2 species succulent plants. Cattle used the same 8 species of graminoids, 17 species of forbs, 2 species of browse in addition to 4 other species of browse. The percent overlap between the blackbucks and cattle diets ranged from 57.8% to 78.1% during that period. During the hotter season i.e., August to September 87 the blackbucks principally fed on a total number of 15 species of plants comprising of 6 species of graminoids, 8 species of forbs and 2 species of succulents and the percent overlap between the blackbucks and cattle diets ranged from 6f2.49% to 92.7% during that period. The influences of water and nutrient contents of those food plants on the diet selection had been discussed. The results obtained suggested that the cattle competed quite severely with the blackbucks and the impacts of this acute competition for food on the management of the sanctuary towards the conservation of blackbucks had been discussed.

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(iv) Ecological threat to the Nilgiri Laughing Thrush *Garrulax cachinnans* in their natural habitat

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The Nilgiri Laughing Thrush *Garrulax cachinnans* is endemic to the Nilgiris. An intensive study (between 1982 and 1984) shows that the main habitat of *G. cachinnans* is shola with dense undergrowth and shrubs on the edges, preferably above 1900m. The roosting behaviour of seven pair of *G. cachinnans*, showed that all the pairs roosted in shola species. Out of 26 species of food plants, only five are exotic. During the study period 26 species of plants were used for nest building, of which only four are exotic. The birds invariably use moss to build the outer layer of the nest; mosses grow in shola and evergreen scrub. The preferred nest height varies from one to two metres. The above observations suggest that *G. cachinnans* is pre-eminently a bird of the shola.

Deforestation and urbanisation have definite effect on this laughing thrush. The foremost is the loss of habitat. During my study this bird could not be seen in any garden at Ooty, not even in the Ooty Botanical Gardens. The local people are indiscriminately clearing the original shola forests for planting cash crops; they use wood for fuel and other purposes. A good many of shola species have a peculiar significance in the ritual ceremonies of Toda tribes. The regeneration of shola species is very slow even in favourable localities. Unless these clearings are stopped immediately, the existing shola forest will vanish in the near future which in turn will shrink the habitat of the Nilgiri Laughing Thrush. An extensive campaign be organised among the local people, who are unaware of the importance of the shola in order to generate greater awareness.

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ABSTRACT

(V) BENGAL FLORICAN - THEIR STATUS AND CONSERVATION PERSPECTIVE

By

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Bengal Florican (Hourbaropsis bengalensis) probably the most endangered bustard, is found in Assam, West Bengal, Utter Pradesh and possibly Bihar in India, and in Nepal. Originally an inhabitant of grassland in a large part of undivided India including present Bangladesh, it has been restricted to Himalayan "terrai" grasslands in dismally small numbers. The vanishing grasslands and continuous destruction of its habitat by increasing human and cattle population are the main factors responsible for the decline.

Habitat utilization studies show that the Bengal Florican prefers totally undisturbed grassland for breeding. Observation on their ecology and behaviour at Manas Wildlife Sanctuary throws light on some hitherto little known, facts including description of nest and chick. Major emphasis has been given on the territorial behaviour of the males in breeding season; the females were found extremely elusive. The birds were not seen after cessation of the season and their non-breeding habitat is not known.

It is certain that their survival will depend on the survival of protected grasslands. Introduction and expansion of large scale grass cultivation is one of the eco-development schemes for their restoration.

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(vi) Lyonia ovalifolia: An endangered species of Nepal.

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The plant Lynonia ovalifolia has its distribution in the middle hills of Nepal. In the region, it was extensively distributed few years ago but within very short period its existence is on alarming stage as it has become very difficult to have a look upon the tree nowadays. One can see only the stumps of prexisting trees of that species even within the dense and so called virgin forest.

(vii) MANGROVES OF SRI LANKA AND THEIR CONSERVATION

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ABSTRACT

Mangrove formations or mangals, which are important components of the coastal ecosystem, have been exploited by man for a very long time in Sri Lanka, in most instances with a severe detrimental effect to them. As a result, only about 6,000 ha of mangroves are left and even these are highly interfered with. The low tidal amplitude and man's persistent interference appear to be major factors that led to the poor development of mangroves and the disappearence or non-establishment of proper ecological zonation of mangrove trees. Rhizophora spp., Bruguiera spp., and sometimes Sonneratia spp. are usually present at the edge of water followed by a zone containing other core species.

Five types of mangroves, namely, fringing, riverine, scrub, overwash, and basin are present in Sri Lanka. The macroflora and most of the macrofauna of these are known. Twenty core species and about 17 associate species of macroflora are known in Sri Lankan mangroves. Mangrove macrofauna is dominated by grapsid crabs and cerithidean gastropods, but in general, a paucity of fauna, numerically as well as species-wise, was observed.

Various ecological aspects of mangroves are presently under investigation and these studies will hopefully lead to the formulation of a proper management plan for the mangroves which in turn will help to conserve this important resource.

(viii) UTILIZATION POTENTIALS AND CONSERVATION STRATEGIES OF SEAGRASS SYSTEMS IN INDIA

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Seagrass systems constitute the most conspicuous communities along the estuarine and near shore marine regions. The ecological importance of seagrass beds has been well recognized globally, in recent times, but poorly researched in India. About 13 species of seagrasses were enumerated along the eastern coast of India, which depict the diversity of seagrass species in the Bay of Bengal and Gulf of Mannar. In most coastal belts, co-occurrence of various seagrass species was observed. But in estuarine regions, species such as *Halophila ovalis*, *H.beccarii* and *Halodule uninervis* were prevalent.

Seagrass beds are known for their multi-faceted utilization potentials, such as high bioproductivity and sediment stability besides providing multiple food resources for various marine organisms. The bottom area of seagrass beds, with also the protection offered by their canopy serve as a breeding ground for various marine fauna. The lamina provides substrate for a diverse microflora and fauna. Seagrass beds are observed to promote sediment deposition and efficiently modify currents.

Evidences also abound as to the consequences encountered due to the seagrass destruction since 1930s. Hence the *in situ* conservation of these coastal resources becomes essential for maintaining ecological balance. Propagation of seagrasses to bare sediments by transplantation techniques and the eco-restoration of seagrass meadows are suggested as conservation measures for these delicate bioresources.

IX. BIOLOGICAL SPECIES DIVERSITY OF SOME SELECTED SITES IN WESTERN GHATS OF KARNATAKA, INDIA

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Conservation biologists in India have voiced serious concern over the lack of any rigourously collected quantitative data on biological diversity in different habitats of the country. Such data are necessary for formulating a conservation strategy to save the multitude of habitats on the sub-continent from total destruction. The Centre for Ecological Sciences, Indian Institute of Science, Bangalore initiated several such studies in 1983 in tropical monsoon forests in a few selected sites of the western ghats in Karnataka, India, to obtain such baseline data on species diversity of plants, insects and birds. Twelve study sites, each comprising three replicate plots of one hectare, located in coastal lowlands and at an elevation of about 600m in the ghats were selected for the study. The sites also differ in the levels of human disturbance and climatic conditions. Plant, Insect and Bird communities were sampled using standardized methodologies to obtain qunatitative data on numbers of species and their relative abundance. Shannon-Weiner diversity indices were computed for all the study sites. A preliminary analysis of data suggests that in general sites with higher levels of disturbance have higher species richness than similar sites with lower levels of disturbance. Disturbed sites however, are not necessarily more diverse. The shannon-Weiner diversity indices for such sites are lower since a few species account for disproportionately large number of individuals. Current investigations also suggest that such an increase in species richness in sites with high levels of disturbance may be related to habitat heterogeneity. No correlations have been found between the diversity and abundance of plants insects and birds.

(X) DELHI RIDGE

Ms. Subhadra Menon

The metropolitan city of Delhi has a unique attribute rarely found in modern, urban areas: the Ridge, a spur of the Aravathis. This typical rocky area has a semi-arid, scrubby vegetation type which forms a green area within the city. This scrubland has a complex, living community, comprising a variety of plants, animals and avifauna.

The primary aim of this presentation is to bring across the importance of the Ridge and the need to conserve it in a form as close to its original nature as is possible. Two project reports, done by Advanced Ecology students at the M. Sc. level at the Department of Botany, University of Delhi, in the years 1985-86 and 1986-87, have thrown some light on the ecological status of the Ridge, the North Delhi Ridge, in particular.

Soil and vegetation analysis using simple ecological techniques have been carried out to assess the edaphic and vegetational condition of the area, within a specific time-frame. From these data, the status of the Ridge has been analysed and our desire now is to utilize this information to save the Ridge from total devastation, and to stop the unlicensed hegemony that is being established over this forest.

The talk of Sugardjito that will be presented in the School on Conservation Biology

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(xi) ORANG-UTAN REHABILITATION IN CONSERVATION BIOLOGY POINT OF VIEW.

ABSTRACT

Orang-utans (<u>Pongo pygmaeus</u>) are one of man's closest relatives and an essential element in the tropical rain forest ecosystems of Borneo and Northern Sumatra. They have been threatened by habitat destruction, hunting, and capture for trade.

Concerning the actions necessary to tackle the problem of hunting and trade in orang-utans, the returning confiscated animals to the wild (rehabilitation) is one of the management steps that have been undertaken so far. While the orang-utan rehabilitation having most value for conservation, its biological relevances are discussed.

ABSTRACT

(xii) PROBLEMS OF WILDLIFE CONSERVATION IN THE NORTHEASTERN REGION OF INDIA AND THE NEW CONSERVATION STRATIGY

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The North eastern region of India constitute seven states coveri ing an area of 255183 sq.km. having unique ecological individual ity.The forest types varied from dry alpine scrub to tropical ev er green.Flood prone areas of Brahmaputra and Borak valley interspeared by weetlands of different dimention,temporary and permanent alluvial lands coupled with mesothermal muggy climate have created an habitat mosoic which harbours one of the richest wildlife fauna of India.Urban wildlife is also a reality in the region.The tribal population constitute 10 to 93 per cent of the population in different constituent states with 103 important ethnic groups.The nature oriented life style, the inter-ethnic cinflicts,the mounting pressure ofdevelopment,apart from the population pressure,have createdtypical problems of conservation of wildlife in the region.The problems associated with conservat ion originated out of the conplexities of the situation in the region are discussed.,Important new stratigies for the conserva tion seems suitable are discussed.

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XIV. ACID RAIN ECOLOGY : AWARENESS OF THE PROBLEM, ITS EVALUATION AND THE NEED FOR CONSERVATION.

By

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ABSTRACT

Any precipitation that has a pH value of less than 5.6 is defined as acid rain. It results mostly from the increased emissions of sulphur and nitrogen compounds into the air. This problem is prevalent in countries such as NW Europe, N America, Canada and Japan. Developing countries in Asia, Africa and South America have started receiving identical threats recently. Acid rain may affect soils, waters, plants, animals and humans.

Two short-term studies were conducted by the author in Klang Valley, Malaysia to see the effects of acid rain on (i) leaf litter decomposition, (ii) the growth of mung bean plant, and (iii) the chemical composition of the underlying soil subjected to it.

Simulated rain using sulphuric acid at pH 5.6, 4.5 and 3.5, and a control at pH 6.2 were used in quantities equivalent to the mean annual rainfall.

The decomposition and carbon mineralisation rates of leaf litter decreased with increased acidity. At lower pH, metal elements such as Ca, Mg and particularly Mn were increasingly leached while P stayed. K was not much affected by the acidity.

At low pH, the mung bean plants became stunted and the grain yield decreased. Further, there was a 25% reduction in the crude protein content of seeds. K and Fe decreased as well.

With increasing acidity, the soil cation exchange capacity (CEC), carbon mineralisation rate and total N content decreased, while the base cations, particularly Ca, Mg and Na were increasingly leached. Increased availability of the micronutrients Fe, Mn and Al was detected across the pH gradient. Plant-available P decreased significantly whereas the total P content was higher at the stronger acid concentration.

Studies in all regions, irrespective of the latitude and longitude, appear to emphasize the need for efficient management of the environment. Increasing the pH of lakes, soils and forests, and a few other measures suggested in literature warrant earlier attention.

REFERENCES

ASHTON, P.S. 1969
Speciation among tropical forest trees : some deductions in the light of recent evidence
Biol. J. Limn. Soc., 1, 155-196

AYALA, F.J., VALENTINE, J.W. 1979
Evolving the Theory and Processes of Organic Evolution.
The Benjamin / Cummings Publishing Company, California, p.452

BACASTOW, R., KEELING, C.D. 1973
Atmospheric carbondioxide and radiocarbon in the natural carbon cycle
I. Changes from A.D. 1700 to 2070 as deduced from geochemical model
In : Carbon and the Biosphere, G.M. Woodwell and P.V. Pecan (ed.), pp.86-135, US Atomic Energy Communications, CONF-720510

BAWA, K.S. 1974
Breeding systems of tree species of a lowland tropical community
Evolution, 28, 85-92

BAWA, K.S. 1974
Breeding systems of trees in a tropical wet forest
N.Z.J. Bot., 17, 521-524

BAWA, K.S., PERRY, D.R., BEACH, J.H. 1985
Reproductive biology of tropical lowland rain forest trees. I. Sexual systems and incompatibility mechanisms
Am. J. Bot., 72, 331-345

BENTON, M.J. 1986
The Evolutionary Significance of Mass Extinctions
Trends in Ecology and Evolution, 1 (5), 127-130

BENTON, M.J. 1987
The History of the Biosphere : Equilibrium and Non-equilibrium Models of Global Diversity
Trends in Ecology and Evolution, 2 (6), 153-156

BERKES, F., KENCE, A. (IN PREP.)
Common Property Resource Management and the Prisoner's Dilemma Game : Application to Fisheries

BIRKS, H.J.B. 1980
British trees and insects : atest of the time hypothesis over the last 13,000 years
Am. Nat., 115, 600-605

BOLIN, B., BIRCHOF, W. 1970
Variations in the carbondioxide content of the atmosphere of the northern hemisphere
Tellus, 22, 431 442

BONNER, J.T. 1980
The Evolution of Culture in Animals
Princeton University Press

BOYD, R., RICHERSON, P.J. 1985
Culture and the Evolutionary Process
Chicago University Press

BROECKER, W.S. 1975
Climatic change : are we on the brink of a pronounced global warming ?
Science, 189, 460-463

BROWN, J.H. 1984
On the realtionship between abundance and distribution of species
American Naturalist, 124, 255-279

BROWN, J.H., 1971
Mammals on mountain tops : nonequilibrium insular biogeography
Am. Nat., 105, 467-478

BROWN, J.H., LIBERMAN, G.A. 1973
Resource utilization and coexistence of seed eating desert rodents in sand dune habitats
Ecology, 54, 788-797

BROWN, J.H.,1975
Geographical ecology of desert rodents
In : Ecology and Evolution of Communities, M.L. Cody and J.M. Diamond (ed.) Harvard University Press, Cambridge, Mass. pp.315-341

CALLENDAR, G.S. 1958
On the amount of carbondioxide in the atmosphere
Tellus, 10, 243-248

CENTRE FOR SCIENCE AND ENVIRONMENT 1985
The State of India's Environment, 1984-85
C.S.E. New Delhi, India

CODY, M. 1986
Diversity, Rarity and Conservation in Mediterranean - Climate Regions.
In : Conservation Biology, M.E. Soule (ed.). Sinauer Associates, Inc., Publishers, Sunderland, Mass. pp.123-152

CODY, M.L. 1973
Coexistence, coevolution and convergent evolution in seabird communities
Ecology, 54, 31-43

CODY, M.L. 1974
Competition and the structire of bird communities
Princeton University Press, Princeton, New Jersey

CONNELL, J.H. 1978
Diversity in tropical rain forests and coral reefs
Science, 199, 1302-1310

CONNELL, J.H. 1983
On the prevalence and relative importance of interspecific competition : evidence from field experiments
Am. Nat., 122, 661-696

140

CONNELL, J.H., ORIAS, E. 1964
The ecological regulation of species diversity
Am. Nat., 98, 387-414

CONNOR, E.F., SIMBERLOFF, D. 1978
Species number and compositional similarity of the Galapagos flora and avifauna
Ecol. Monogr. 48, 219-248

COX, C.B., MOORE, P.D. 1976
Biogeography, an Ecological and Evolutionary Approach
Blackwell Scientific Publications, p.234

COX, C.B., MOORE, P.D. 1980
Biogeography : an ecological and evolutioanary approach
Blackwell, Oxford

CRACRAFT, J. 1985
Biological diversification and its causes
Ann. Misc. Bit. Gard., 72, 794-822

CROAT, T.B. 1974
Flora of Barro Colorado Island
Stanford University Press, Stanford, California

CRONIN, J.F. 1971
Recent volcanism and the stratosphere
Science, 172, 847-849

DE BOER, L.E.M. 1982
Karyological problems in breeding owl monkeys, Aotus trivirgatus
Int. Zoo yearbook, 22, 119-124

DIAMOND, J.M. 1973
Distributional ecology of New Guinea birds
Science, 179, 759-769

DIAMOND, J.M. 1973
Distributional ecology of New Guinea birds
Science, 179, 759-769

DOBSON, A.P., MAY, R.M. 1986
Disease and Conservation
In : Conservation Biology, M.E. Soule (ed.). Sinauer Associates, Inc., Publishers, Sunderland, Mass. pp

EDROMA, E.L. 1981
The role of grazing in maintaining high species composition in Imperata grassland in Rwenzori National Park, Uganda
Afr. J. Ecol., 19, 215-233

EHRICH, P.R., RAVEN, P.H. 1969
Differentiation of populaitons
Science, 165, 1228-1232

EMMONS, L.H. 1980
Ecology and resource partitioning among nine species of African squirrels
Ecol. Monogr., 50, 31-54

FAO, 1984a
A guide to in situ conservation of genetic resources of tropical reswoody species (based on work of L.R. Roche and M.J. Dourojeanni)
FORGEN/MISC/84/2. FAO, ROME, PP.196

FAO, 1985
Status of in situ conservaiton of plant genetic resources
CPGR/85/5, 1st session of commission pn plant genetic resources, FAO, ROME

FENCHEL, T. 1975
Character displacement and coexistence in mud snails (Hydrobidae)
Oecologia, 20, 19-32

FISCHER, A.G. 1960
Latitudinal variations in organic diversity
Evolution, 14, 64-81

FRANKEL, O.H., SOULE, M.E. 1981
Conservation and Evolution
Chicago University Press

FRANKLIN, I.R. 1980
Evolutionary change in small populations
In : Conservation Biology, M.E. Soule and B.A. Wilcox (ed.) Sinauer Associates Inc., Sunderland, Mass. USA pp.135-149

GADGIL, M. 1985
Social restraints on resource utilization : The Indian experience
In : Culture and conservation : The human dimension in environmental planning J.A. McNeely and D. Pitt, Croom Helm, pp.135-154

GADGIL, M., HEGDE, K.M., BHOJA SHETTY, K.A. 1987
Uttara Kannada : A case study in hill area development
In : Karnataka state of environment report 1985-86, C.J. Saldanha ed. Centre for Taxonomic Studies, Bangalore, India pp.155-172

GADGIL, M., IYER, P. (in press)
On the diversification of the common property resource use by the Indian society
Proceedsings of workshop on common property resources, IV International congress of ecology (Berkes, F. ed.)

GADGIL, M., MALHOTRA, K.C. 1983
Adaptive significance of the Indian caste system : An ecological perspective
Annals of Human Biology, 10, 465-478

GADGIL, M., MALHOTRA, K.C. 1985
Ecology is for the people
South Asian Anthropologist, 6(1), 1-14

GADGIL, M., MEHER-HOMJI, V.M. 1986a
Role of protected areas in conservation
In : Conservation for productive agriculture, V.L.Chopra and T.N. Khoshoo (ed.), Indian Agricultural Research Institute, New Delhi, pp.143-159

GADGIL, M., MEHER HOMJI, V.M. 1986b
Localities of great significance to conservation of India's biological diversity
Proc. Indian Acad. Sci. (Animal Sci. / Plant Sci.) Suppl., 165-180

GADGIL, M., VARTAK, V.D. 1975
Sacred groves of India : A plea for continued conservation
Journal of Bombay Natural History Society, 72, 314-320

GENTRY, A. 1986
Endemism in tropical versus temperate plant communities
In : Conservation Biology, M.E. Soule (ed.), Sinauer Associates Inc., Sunderland, Mass. USA. pp.153-181

GENTRY, A.H. 1986
Endemism in Tropical versus Temperate Plant Communities
In : Conservation Biology, M.E. Soule (ed.). Sinauer Associates, Inc., Publishers, Sunderland, Mass. pp.153-181

GILBERT, L.E. 1980
Food Web Organization and Conservation of Neotropical Diversity
In : Conservation Biology, M.E. Soule (ed.). Sinauer Associates Inc., Publishers, Sunderland, Mass. pp.11-34

GILLER, P.S., McNEILL, S. 1981
Predation strategies, resource partitioning and habitat selection in Notonecta (Hemiptera / Heteroptera)
J. Anim. Ecol., 50, 789-808

GILLILAND, R.L. 1982
Solar, volcanic and carbon dioxide forcing of recent climatic changes
Climatic Change, 4, 111-132

GIPLIN, M.E., SOULE, M.E. 1986
Minimum viable populations : processes of species extinction
In : Conservation Biology, M.E. Soule (ed.), Sinauer Associates Inc., Sunderland, Mass. USA pp.19-34

GRANT, P.R. 1970
Colonization of islands by ecologically dissimilar species of mammals
Can. J. Zool., 48, 545-555

GREIG, J.C. 1979
Principles of genetic conservation in relation to wildlife management in S.Africa
S. African J Wildlife Res. 9, 57-78

HALLAM, A. (Ed.) 1977
Patterns of Evolution as illustrated by Fossil Record
Elsevier Scientific Publishing Company, Amsterdam, Oxford, New York, p.591

HARRIS, D.R. (Ed.) 1980
Human Ecology in Savanna Environments
Academic Press

HARTL, D 1981
A primer of population genetics
Sinauer Associates, Inc., Publishers, Sunderland, Mass. USA

HORN, H.S, MAY, R.M. 1977
Limits to similarity among coexisting competitors
Nature, 270, 660-661

HUBBEL, S.P., FOSTER, R.B. 1986
Commonness and Rarity in a Neotropical Forest : Implications for Tropical Tree Conservation
In : Conservarion Biology, M.E. Soule (ed.). Sinauer Associates Inc., Publishers, Sunderland, Mass. pp.205-231

HUSTON, M. 1979
A general hypothesis of species diversity
Am. Nat., 113, 81-101

HUTCHINSON, G.E. 1959
Homage to Santa Rosalia, or why are there so many kinds of animals ?
Am. Nat. 93, 145-159

JANZEN, D.H. 1970
Herbivores and the number of tree species in tropical forests
Am. Nat. 104, 501-528

JANZEN, D.H. 1971
Escape of juvenile dioclea megacarp (Leguminosae) vines from predators in a deciduous forest
Am. Nat. 105, 97-112

JONES, P.D., WIGLEY, T.M.L., KELLY, P.M. 1982
Variations in surface air temperatures. Part I. Northern hemisphere, 1881-1980
Monthly Weather Review, 110, 59-70

KEELING, C.D., ADAMS, J.A., EKDAHL, C.A., GUENTHA, P.R. 1976b
Atmospheric carbondioxide variation at South Pole
Tellus, 28, 552-564

KEELING, C.D., BACASTOW, R.B., BAINBRIDGE, A.E., EKDAHL, C.A., GUENTHA, P.R., WATERMAN, L.S. 1976a
Atmospheric carbondioxide variation at Mauna Loa Observatory, Hawaii
Tellus, 28, 538-551

KELLOG, W.W. 1978
Global influences of mankind on the climate
In : Climatic Change, J.Gribbin ed., Cambridge University Press, London

KIMURA, M. 1984
The neutral theory of molecular evolution
Cambridge University Press

KRZYSIK, A.J. 1979
Resource allocation, coexistence and the niche structure of a stream bank salamander community
Ecol. Monogr. 49, 173-194

LAWTON, J.H., SHRODER, D. 1977
Effects of plant type, size of geographical range and taxonomic isolation on number of insect species association with British plants
Nature, 265, 137-140

LEAKEY, R.E. 1981
The Making of Mankind
Abacus

LEDIG, F.T. 1986
Heterozygosity, heterosis and fitness in outbreeding plants
In : Conservation Biology, M.E. Soule (ed.), Sinauer Associates Inc., Sunderland, Mass. USA pp.77-104

LEIGH, E.G. 1981
The average lifetime of a population in a varying environment
J. theo. Biol. 90, 213-239

LEVIN, D.A., KERSTER, H.W. 1971
Neighbourhood structure in plants under diverse reproductive methods
Am. Nat., 105, 345-354

LIVINGSTONE, D.A. 1975
Late quarternary climatic changes in Africa
Ann. Rev. Eco. Syst., 6, 249-280

LUMSDEN, C.J., WILSON, E.O. 1981
Genes, MInd, and Culture
Harvard University Press

MACARTHUR, R.H. 1965
Patterns of species diversity
Biol. Rev. 40, 510-533

MACARTHUR, R.H., MACARTHUR, J. 1961
On bird species diversity
Ecology, 42, 594-598

MAEHTA, L. 1973
Prediction of carbondioxide in the atmosphere
In : Carbon and the Biosphere, G.M. Woodwell and E.V. Pecan (ed.), pp.21-31, US Atomic Energy Communications, CONF-720510

MAGUIRE, B. Jr.1963
The passive dispersal of small aquatic organisms and their colonization of isolated bodies of water
Ecol. Monogr. 33, 161-185

MALHOTRA, K.C., KHOMNE, S.B., GADGIL, M. 1983
Hunting strategies among three non-pastoral nomadic groups of Maharashtra
Man in India, 63, 21-39

MAY, R.M. 1973
Stability and complexity in model ecosystems
Princeton University Press, Princeton, NJ. USA

MISRA, B.K., RAMAKRISHNAN, P.S. 1983a
Secondary succession subsequent to slash and burn agriculture at higher elevations of north-east India. I. Species diversity, biomass and litter production
Acta Oecologica / Oecologia Applicata, 4, 95-107

MISRA, B.K., RAMAKRISHNAN, P.S. 1983b
Secondary succession subsequent to slash and burn agriculture at higher elevations of north-east India. II. Nutrient cycling
Acta Oecologia / Oecologia Applicata, 4, 237-245

MISRA, B.K., RAMAKRISHNAN, P.S. 1983c
Slash and burn agriculture at higher elevations in north-eastern India. II. Soil fertility changes
Agriculture, Ecosystems and Environment, 9, 83-96

MONK, C.D. 1967
Tree species diversity in the eastern deciduous forests with particular reference to north central Florida
Am. Nat. 173-187

MOORE, J., ALI, R. 1984
Are dispersal and inbreeding avoidance related ?
Anim. Behav. 32, 94-112

MUKAI, T., YAMAGUCHI, O. 1974
The genetic structure and natural populations of Drosophila malanogaster XI Genetic variability in a local population
Genetics, 76, 339-366

MYERS, N. 1979
Conversion of tropical moist forests
National Academy of Sciences, Washington, D.C., pp. 240

MacARTHUR, R.H. 1972
Geographical ecology
Harper and Row, New York

MacARTHUR, R.H., WILSON, E.O. 1963
An equilibrium theory of insular zoogeography
Evolution, 17, 373-387

MacARTHUR, R.H., WILSON, E.O. 1967
The theory of island biogeography
Princeton University Press, Princeton

MacKINNON, J., MacKINNON, K. 1986
Review of the protected areas system in the Indo-Malayan realm
International Union for Conservation of Nature and Natural Resources, Gland, Switzerland

McKINNON, J., McKINNON, K. 1986
Review of the Protected Areas System in the Indo-Malayan Realm
International Union for Conservation of Nature and Natural Resourcesp.284

McNAB, B.K. 1971
The structure of tropical bat faunas
Ecology, 52, 352-356

McNEELY, J.A. PITT, D. (Eds.) 1985
Culture and Conservation
Croom Helm

NEVO, E., BEILES, A., BEN-SHOLMO, R. 1983
The evolutionary significance of genetic diversity : Ecological, demographic anf life history consequences
In : Evolutionary dynamics and genetic diversity, G.S. Mani ed., Lecture notes in Biomathematics, Vol. 53, Springer Verlag

NEWELL, R.E., DOPPLICK, T.G. 1979
Question concerning the possible influence of anthropogenic carbon di-oxide on atmospheric temperature
Journal of Applied Meteorology, 18, 822-825

NILSSON, N. 1965
Food segregation between Salmonoid species in north Sweden
Rep. Inst. Freshw. Res. Drothingholm, 46, 58-78

NOAA 1975
Geophysical monitoring of climate change, No.3, Summary report-1974
J.M. MIller (ed.), Environmental Research Laboratories, National Oceanic and Atmospheric Administration, Boulder, Colorado

OPLER, P.A. 1974
Oaks as evolutionary islands for leaf mining insects
Am. Sci., 62, 67-73

OSMAN, R.W., WHITLATCH, R.B. 1978
Patterns of species diversity : fact or artifact ?
Paleobiology, 4, 41-54

OWEN, D.F., OWEN, J. 1974
Species diversity in temperate and tropical Ichneumonidae
Nature, 249, 583-584

PAABO, S. 1986
Molecular genetic investigations of ancient human remains
In : 51st Cold Spring Harbor Symposium on Quantitative Biology : Molecular Biology of Homo sapiens, May-June 1986, Abstract only. p. 38

PACKER, C. 1985
Dispersal and inbreeding avoidance
Anim. Behav. 33, 666-668

PAINE, R.T. 1966
Food web complexity and species diversity
Am. Nat. 100, 65-75

PEARSON, D.L., MURY, E.J. 1979
Character divergence and convergence among tiger beetles (Coleoptera; Cincindelidae)
Ecology, 60, 557-566

PIANKA, E.R. 1969
Sympatry of desert lizards (Ctenotus) in western Australia
Ecology, 50, 1012-1030

PIELOU, E.C. 1977
Mathematical Ecology
John Wiley and Sons

PIELOU, E.C. 1979
Biogeography
Wiley, New York

PIMM, S.L. 1982
Food Webs
Chapman and Hall, London. p.219

PIMM, S.L. 1986
Community Stability and Structure
In : Conservation Biology, M.E. Soule (ed.). Sinauer Associates Inc., Publishers, Sunderland, Mass. pp.309-32

POLLARD, J.H. 1973
Mathematical models for the growth of human populations
Cambridge University Press

PRESTON, F.W. 1962
The canonical distribution of commonness and rarity
Ecology, 43, 185-215, 410-432

PRICE, P.W. 1975
Insect Ecology
Wiley, New York, London

RABINOVITZ, D., CAIRNS, S., DILLON, T. 1986
Seven forms of Rarity and their Frequency in the Flora of the British Isles
In : Conservation Biology, M.E. Soule (ed.). Sinauer Associates, Inc., Publishers, Sunderland, Mass. pp.

RALLS, K., BRUGGER, K., BALLOU, J. 1979
Inbreeding and juvenile mortality in small populations of ungulates
Science, 206, 1101-1103

RALLS, K., HARVEY, P.H., LYLES, A.M. 1986
Inbreeding in natural populations of birds and mammals
In : Conservation Biology, M.E. Soule ed. Sinauer Associates Inc., Publishers, Sunderland, Mass. USA

RAPPAPORT, R.A. 1968
Pigs for the Ancestors
Yale University Press

REGAL, P.J. 1986
Genetic Engineering : implications for the conservation of nature
Proc. Symp. Conser. Biol., M.Soule (ed.)

RODGERS, W.A. 1985
Biogeography and protected area planning in India
In : Conserving Asia's Natural Heritage, J. Thorsell (ed.), IUCN, Gland, Switzerland

ROUGHGARDEN, J. 1979
Theories and population genetics of evolutionary ecology : an introduction
MacMillan

RUDDLE, K., JOHANNES, R.E. (eds.) 1985
The Traditional Knowledge and Management of Coastal Systems in Asia and the Pacific
UNESCO

SANDERS, H.L. 1968
Marine benthic diversity : a comparative study
Am. Nat. 102, 243-282

SANFORD, R.L. et al. 1985
Amazon forest fires
Science, 227, 53-55

SCHAFFER, M.L.
Minimum population sizes for species conservation
Biosciences, 31, 131-134

SCHNIEDER, S.H. 1975
On the carbon-di-oxide-climate confusion
Journal of Atmospheric Sciences, 32, 2060-2066

SHOENER, T.W. 1983
Field experiments in interspecific competition
Am. Nat. 122, 240-285

SIMBERLOFF, D. 1974
Equilibrium theory of island biogeography and ecology
Ann. Rev. Ecol. and Systematics, 5, 161-182

SIMBERLOFF, D. 1986
Are we on the verge of mass extinction in tropical rain forests ?
In : Dynamics of extinction, David K. Elliot (ed.) John Wiley and Sons, New York pp.165-180

SIMBERLOFF, D.S., WILSON, E.O. 1969
Experimental zoogeography of isalnds : the colonization of emptu islands
Ecology, 50, 278-296

SIMBERLOFF, D.S., WILSON, E.O. 1970
Experimental zoogeography of islands : a two year record colonization
Ecology, 51, 934-937

SIMPSON, E.H. 1949
Measurement of diversity
Nature, 163, 688

SIMPSON, G.G. 1964
Species diversity of North American recent mammals
Syst. Zool., 13, 57-73

SOULE, M.E. 1980
Thresholds for survival : maintaining fitness and evolutionary potential
In : Conservation Biology, M.E. Soule and B.A. Wilcox (ed.) Sinauer Associates Inc., Sunderland, Mass. USA pp. 153-169

STEHLI, F.G., DOUGLAS, R.G., NEWELL, N.D. 1969
Generation and maintenance of gradients in taxonomic diversity
Science, 164, 947-949

STRONG, D.R. Jr., 1974
Rapid asymptotic species accumulation in phytophagous insect communities : the pests of cacao
Science, 185, 1064-1065

STRONG, D.R. Jr.,SIMBERLOFF, D., ABELE, L.G., THISTLE, A.B. (EDS.) 1984
Eclogical communities : conceptual issues and the evidence
Princeton University Press, Princeton, New Jersey

STRONG, D.R., McCOY, E.D., REY, J.R. 1977
Time and the number of herbivore species : the pests of sugarcane
Ecology, 58, 167-175

SUKUMAR, R. 1985
Ecology of the Asian elephant (Elephas maximus) and its interaction with man in South India
Ph.D thesis, Indian Institute of Science, Bangalore, India

SUKUMAR, R. 1986
Elephant-man conflict in Karnataka
In : State of Environment report-Karnataka, C.J. Saldanha (ed.), Centre for Taxonomic Studies, Bangalore, India

SWAMINATHAN, M.S. 1984
Genetic conservaiton : microbes to man
In : Genetics : New frontiers, Proc. XV Internatl. Congr. Genet., V.L. Chopra, B.C. Joshi, R.P. Sharma and H.C. Bansal (eds.), Vol.1, pp.xxix-lxi, Oxford and IBH, New Delhi

TEMPLETON, A.R. 1986
Coadaptation and outbreeding depression
In : Conservation Biology, M.E. Soule ed., Sinauer Associates Inc., Publishers, Sunderland, Mass. USA.

TEMPLETON, A.R., SING, C.F., BROKAW, B. 1976
The unit of selection in Drosophila mercatorum I. The interaction of selection and meisois in parthenogenetic strain
Genetics, 82, 349-376

TERBORGH, J. 1973
Chance, habitat and dispersal in the distribution of birds in the West Indies
Evolution 27, 338-349

TERBORGH, J. 1974
Preservation of natural diversity : the problem of extinction prone species
BioSci., 24, 715-722

TERBORGH, J. 1986
Keystone Plant Resources in the Tropical Forest
In : Conservation Biology, M.E. Soule (ed.). Sinauer Associates, Inc., Publishers, Sunderland, Mass. pp.330-344

THOMAS, C.D., MALLORIE, H.C. 1985
Rarity, Species Richness and Conservation : Butterflies of the Atlas Mountains of Morocco
Biological Conservation, 33, 95-117

UDVARDY, M.D.F. 1975
A classification of the biogeographical provinces of the world
IUCN Occasional paper, 18, 1-48

UETZ, G.W. 1977
Coexistence in a guild of wandering spiders
J. Anim. Ecol. 46, 531-542

VARIAVA, D., SINGH, S. (ED.) 1985
Directory of national parks and sanctuaries in India, Mimeo.
Directorate of Wlidlife Preservation, New Delhi

WHITESIDE, M.C., HARMSWORTH, R.V. 1967
Species diversity in Chydorid (Cladocera) communities
Ecology, 48, 664-667

WHITTAKER, R.H. 1977
Evolution of species diversity in land communities
Evo. Biol. 10, 1-67

WILKES, H.G. 1983
Current status of crop plant germplasm
Critical reviews in plant sciences, 1, 133-181

WILLIAMSON, M. 1981
Island populations
Oxford University Press

WILSON, E.O. 1984
Biophilia
Harvard University Press, Cambridge, Mass., London. p.157

WILSON, E.O., SIMBERLOFF, D.S. 1969
Experimental zoogeography of islands. Defaunation and monitoring techniques
Ecology, 50, 267-278

WILSON, E.O. 1969
The species equilibrium
In : Diversity and Stability in Ecological Systems, G.E. Woodwell and H.H. Smith (ed.), Brookhaven Symp. in biol., 22, 38-47

WOLF, E.C. 1987
On the Brink of Extinction : Conserving the Diversity of Life
World Watch Paper, 78, p.54

WRIGHT, S. 1978
Evolution and the genetics of populations, Vol. 4 Variability within and among natural populations
University of Chicago Press

WRIGHT, S. 1977
Evolution and the genetics of populations Vol. 3 Experimental results and evolutionary deductions
University of Chicago Press, Chicago, USA

YODA, K. 1967
A preliminary survey of the forest vegetation of eastern Nepal II. General description, structure and floristic composition of the sample plots chosen from different vegetation zones
J. Coll. Arts. Sci., Chiba Univ. Nat. Ser., 5, 99-140

ZARET, T.M., PAINE, R.T. 1973
Species introduction in a tropical lake
Science, 182, 449-455