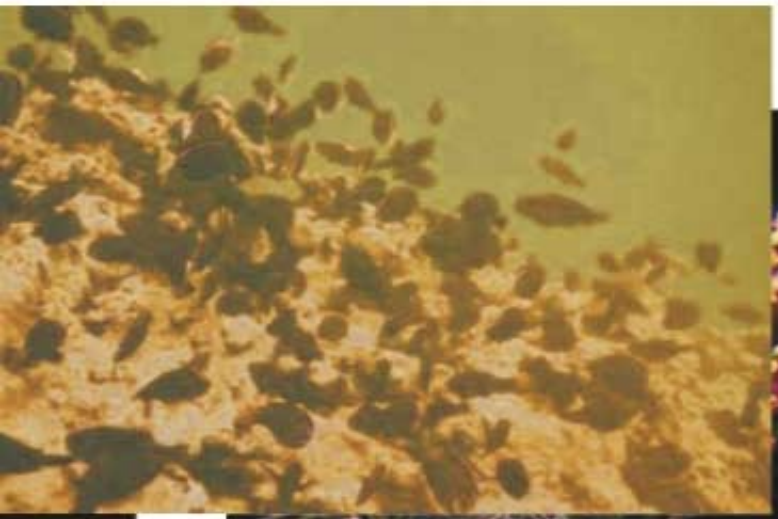
NEW AGE

ECOLOGY for MILLIONS

H.L. Kundu



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H. L. Kundu

PUBLISHING FOR ONE WORLD

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PREFACE

Ecology teaches us, how to lead a healthy and progressive life, while living in harmony with nature. In many countries however, despite its extreme relevance, Ecology is understood by very few. Lack of this understanding has resulted in many ills in such countries, particularly, impoverishment in the quality of lives of their citizens, as well as the environment they live in.

This book is a humble attempt to take the basic concepts of Ecology to the common man. Because it is the common man and woman who matter, as it is they who by their intelligent or unintelligent acts can make or mar the environment they live in. Much of the future happiness of mankind is hinged upon man's use of his environment.

Since the target population of this book is the common man I have deliberately avoided technicalities to explain the various concepts. Also my teaching experience of something over three decades in an University regarding Ecology has convinced me that the basic Ecological principles can be explained without the use of technical jargon.

The book is presented in ten small Chapters arranged in conceptual sequence. For interested readers, however, information regarding technical literature is given at appropriate places.

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ACKNOWLEDGEMENT

Although the seed of desire to wite such a book had lain dormant in me for years, I am not sure if this book would have ever seen the light of the day but for the encouragement which I received from certain people. First and foremost, Sadhana, my wife and life partner of forty years for her unrelenting support. Next come two very special friends, Professor RR Gulati for his persistent goading and faith which kept me going during all the years of toil and tribulations and Dr Vinod Jain whose friendly and forthright discussions helped shape the aim of this book; and also my children and their spouses, Sanghmitra and Suresh and Subroto and Shamita for their diligent search for relevant data, manuscript corrections and many useful suggestions. Last but not the least I would like to thank my father, the late Professor Surendra Lal Kundu and my brother, the late Mr J L Kundu who shaped my character and attitude.

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CONTENTS

	Preface	v
	Acknowledgement	vii
1.	Introduction	1
2.	The Ecosystem	15
3.	Productivity	33
4.	Bioenergetics	65
5.	Bio-Geo Cycles of Chemicals	83
6.	Populations	103
7.	Community	149
8.	Biomes	173
9.	Pollution	219
10.	Problems and Solutions	241
	Bibliography	280

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Chapter I

Introduction

(The Beginning)

Topics

I.1. History and meaning of the word Ecology

I.2. Ecological Consciousness in Ancient World

I.3. Renaissance and Anthropocentrism

I.4. Rebirth of Ecology and Its Multidisciplinary Nature

I.5. Aim of This Book

I.6. A Bird's Eye View of This Book

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CHAPTER I

INTRODUCTION

(*The Beginning*)

1. HISTORY AND MEANING OF THE WORD ECOLOGY

The Beginning

1.1. Soon after Charles Darwin wrote his revolutionary book, "The Origin of Species" in 1859, ecological thoughts began to hover upon the minds of biologists. In 1870 German biologist Ernst Haeckel coined the word **Oekologie** using two Greek words **oikos** meaning "home" and **logos** meaning "science". From Oekologie arose the word **Ecology** and it was first used in 1892.

1.2. Briefly, Ecology is that branch of biology which deals with the interactions between various living beings and their environments. Or more simply, Ecology is the art which shows us how to live in harmony with Nature.

Darwin's voyage in H.M.S. Beagle

1.3. The general concept of ecology however, is not post-Darwinian but definitely pre-Darwinian. While voyaging round the world in H.M.S. Beagle from 1827-31, Darwin was much taken by the glowing accounts tropical scenery of the Amazon river valley of South America by a much earlier German naturalist traveller Alexander von Humboldt (1769-1859). Like Humboldt, Darwin too was much struck with the varieties of animals and plants of different countries visited by him during this voyage.

1.4. So one can fairly say that Alexander von Humboldt laid the seeds of modern ecology in the minds of biologists. Humboldt's book "Personal Narrative" & Darwin's book "The Origin of Species" (1859) are classics of Natural History. These surely can be looked upon as the starting points of today's ecology.

1.5. Since Humboldt, Darwin and Haeckel, all over Europe and North America many ecological studies began. Gradually a general meaning of the word Ecology emerged. Today Ecology means the studies of the relationships of living beings with their non-living environments and **vice-versa**. Naturally ecological processes are complex varying from species to species and involving several factors according to the environments they live in. As a matter of fact ecology to-day has become so important that once a renowned biologist Thiodosius Dobjhansky said, "Nothing in biology makes sense, except in the light of ecology—that is,

in terms of interactions between organisms and their physical, chemical and biological environments" (Preface—pp. vii. of ECOLOGY by Begon, Harper & Townsend; Blackwell 1990).

2. ECOLOGICAL CONSCIOUSNESS IN ANCIENT WORLD

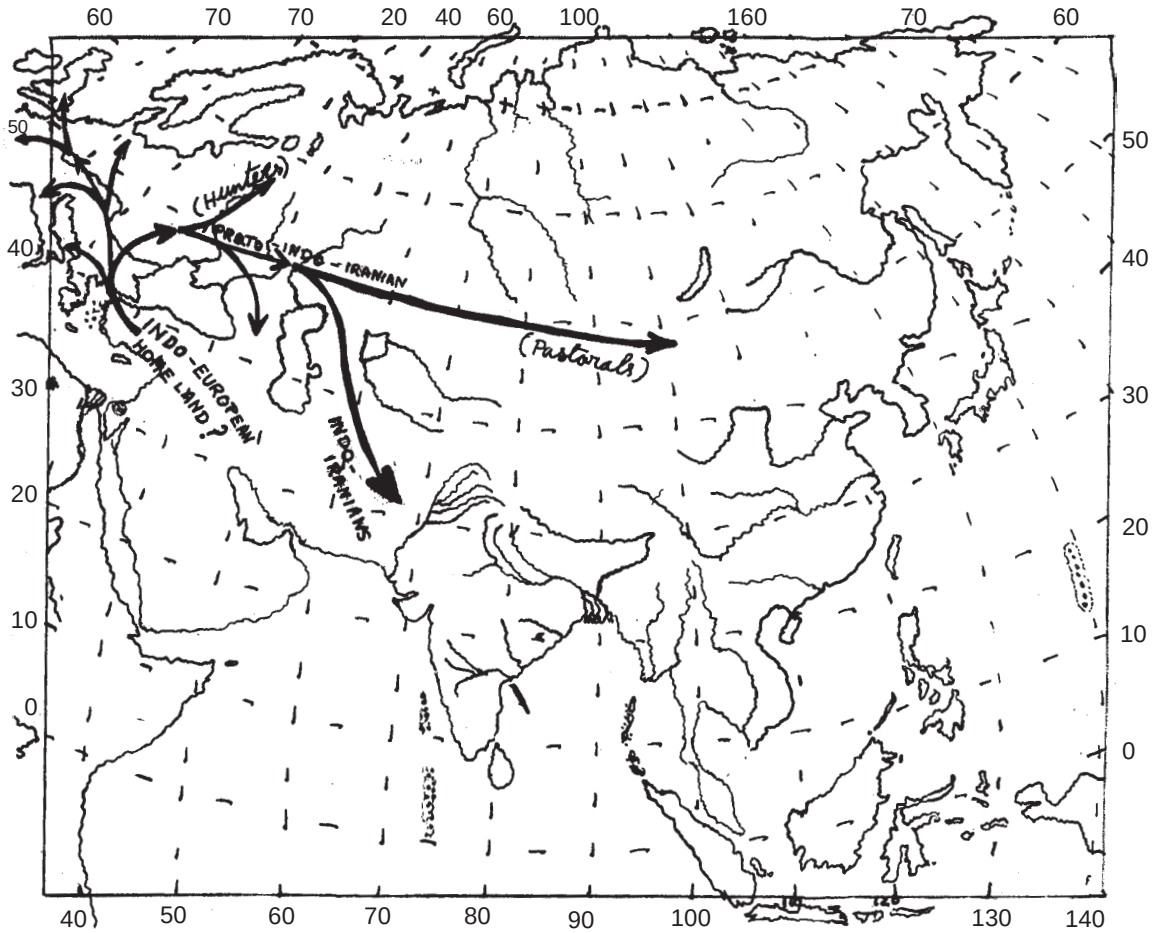
2.0. Wise men of the past were very much aware of the importance of plants and animals although they did not have any specific knowledge ecology so, they established traditions which when respected would automatically protect parts of their environment and thus ensure prosperity to their future generations. Following are a few such examples.

2.1. Ancient Egyptian Customs. In ancient Egypt animals played a very prominent role in the lives of its people. It is apparent from the paintings and etchings in the tombs of the Pharaohs. One animal—the jackal was given the status of God—"Anubis". Anubis the jackal-god was the protector to them. Crocodile was another God—the God of Fertility. There were other gods as well. They were all protected.

2.2. Hindu customs—ancient and present. (a) **Cow worship.** The Aryans—predecessors of Hindus who moved into India from Bacteria and Northern Iran during early second milllenium B.C. (Map - I.1), were hunters and herdsmen consuming both milk and meat of cows. During that time beef-eating was so much in vogue that a guest was particularly entertained by being treated with food prepared by sacrificing a young cow or calf. (Sanskrit was the language of the early Aryans. So in sanskrit literature there is a word 'GOGHNA' meaning a cow-killer. Thus a honoured guest was a 'GOGHNA'. The word 'GOGHNA' was used by the famous sanskrit poet Kalidasa in his book 'ABHIGYANA SAKUNTALAM').

2.2.(*a*) Origin of Cow-worship amongst Hindus. But in the Gangetic valley cattle suffered from high humidity resulting in premature death. So the Aryan scholars aiming to protect the cattle attributed holiness to cows so that cows would no longer be used as beef. Thus the cow-worship or at least veneration for cows amongst many Hindus (who are mostly discendants of Aryans and the local tribes of India who gradually adopted Aryan Culture, is really socio ecological adaptatian to protect the cows of India from premature death and thus help their owners (The Continent of Circe by Nirad C. Chaudhuri, 1966, Jaico, Delhi).

2.2.(*b*) Bishnois of Rajasthan. In some villages of Rajasthan, India, there lives a sect of people called Bishnois; Bishnois neither kill nor allow anybody else to kill an animal—even wild ones, in their village or its vicinity. Wild animals move very freely in Bishnoi villages. Recently a very popular filmstar from Bombay went into a forest in Rajasthan, near a Bishnoi village and shot two 'nilgais' (*Boselapus tragocamelus*; Bovidae; ARTIODACTYLA). This enraged local people, Bishnois so much that they



Map I.1 Dispersal of Proto-Indo-Iranians from north of Caucasus Mountains to the Gates of Western India (4th. - 1st. Millennium B.C.)

forced the police to take action against this film-star.

2.2.(*c*) Feeding ants by Jains. Jains a sect of Hindus who are not only strict vegetarians they even do not kill insects. Often, in the morning, they put sugar in front of the ant hills so that the ants can begin the day with a hearty breakfast!

2.2.(*d*) No-Fishing Day amongst Bengalee fishermen. During some specific days in June, fishermen of West Bengal (India), & Bangladesh would not cast their fishing nets in water so that fishes can breed uninterrupted and thus ensure abundance of fishes for the future.

2.2.(*e*) The monkey-god—'Hanuman'. According to 'Ramayana' the famous sanskrit epic, a langur (*Semnopithecus entellus*, Colibidae. PRIMATE) named 'Hanuman' and his friends helped Rama the hero of Ramayana to wage war against Ravana and finally defeat him. Since then

to Hindus the monkey god 'Hanuman' has become a most respected god and hence not killed. In many states of India, particularly Rajasthan there are numerous small temples dedicated to Hanuman. Also, wherever possible these temples are erected under a specific local acacia tree—*Prosopis spicigera.* These trees are very useful to the locals. The branches which are lopped before the winter, are used as fuel, and leaves as camel food. So along with this species of monkey this acacia tree also enjoys some amount of protection.

2.3. Noah's Arc and Christian Culture. The account of Noah's Arc in Bible is a very nice way of implanting the seeds for respect for animals and plants in the minds of people. Many excellent works, mostly by Christians, have now been initiated all over the world to protect wild life and Nature.

2.4. The Mongol Hunt and Ban on Hunting during Breeding Season of animals. During thirteenth century the great Venetian traveller Marco Polo travelled all over Asia, including China and India for nearly a quarter century. He stayed in the court of the of the famous Mongol ruler of China, Kublai Khan the descendent of Genghis Khan, for seventeen years and left a very picturesque description of the ways of the Khan's Court and the countries he travelled through as Khan's emissary. Mongols were very fond of hunting. The annual hunting expedition of Kublai Khan consisted of even 10,000 men and as many as 5000 hounds. (Travels of Marco Polo by Maria Bellonci; Tr. by Teresa Waugh 1984 pp. 83) A very vivid description of a Mongol hunt during Genghis Khan's reign is given by Harold Lamb in his book "Genghis Khan: "Emperor of All Men". (1927, 57). pp. 137-40. Nevertheless Mongols very well understood that unless the animals are allowed to breed uninterrupted during breeding season, their hunts would not last long. So the Great Kublai Khan decreed that no King or Nobleman throughout his empire can hunt hare, does, roebuck, stags or such like animals between the months of May to October as, this is their breeding season. Anybody violating this decree would be severely punished. So strictly this decree was observed by the subjects of Khan that even the animals understood this and hence during these months they would come near men without fear (Teresa Waugh 1984 vide supra p. 85). It is an irony of fate that after quarter century, when Marco Palo returned to venice and told people what he saw, nobody believed him. He ended his life belhind bars.

2.5. Surely there were and are many more worthy traditions all over the world which helped to protect the environment amongst the erstwhile and present communities of the world. An anthology of such traditions throughout the world would verily form an worthwhile theme of a book.

3. RENAISSANCE AND ANTHROPOCENTRISM

3.1. In the ancient world there existed a reasonable balance between men and their living environment. But with renaissance all these changed.

Renaissance had a dual effect on the course of human history. Men shook off the shackles of blind orthodoxy and took up reason and experiment as their guides. This soon led to an explosive growth of knowledge in all directions. Knowledge of Navigation, Mathematics, Astronomy, Physics, Chemistry, Natural History, Medicine and many other areas all grew very fast. Sadly though these people who did all these were, not only men of keen minds and indomitable courage but of insatiable greed as well. They not only crisscrossed the earth and discovered new countries (e.g. Americas, New Zealand and Australia) but soon found out which produce of Mother Nature—be it from any country—is economically most useful to them. Soon with the help of firearms and superior discipline in group-activity, these interpid people mastered the Earth and started a ruthless exploitation of Nature. They tore open the Earth and began looting her bounty. Almost the entire earth surface was curved out and distributed amongst the European nations— the renaissance countries. Never before Earth was ravished so ruthlessly, so thoroughly and in such a short time. The trend is still on. Handful of Europeans including Russians, directly or indirectly, colonised the entire North America, South America, Australia and New Zealand. The combined area of these Europe-colonised countries would be 2.11 times of Europe including Russia and Europe minus Russia 15 times (Table I.1).

Anthropocentric attitude & its consequence

Table I.1.
AREAS COLONISED BY EUROPEAN COUNTRIES SINCE RENAISSANCE *

Continents	*Countries*	*Areas (Sq. Km.)*	*Total Areas of Continents (Sq. Km.)*	
EUROPE	Chekoslovakia France Germany Italy Poland Russia Spain Sweden U.K.	78703 547030 356910 301230 312683 17075200 504750 449964 244820	(1) Total of Europe including Russia is 19871290 (2) Europe minus Russia is 2796090	
NORTH AMERICA	Canada Mexico U.S.A.	9976140 1972550 9629091	21577781	Total of these European colonies is 41853710
SOUTH AMERICA (Selected countries)	Argentina Brazil Nicaragua Venezuela	2766890 8511065 129494 912050	12320399	
AUSTRALIA NEW ZEALAND	Australia New Zealand	7686850 268680	7955530	

*Summary by author from C.I.A. data—1997-98.

3.2. Along with this exploitation of Nature, the growth of knowledge of modern medicine gave a spurt in the growth of human population. So since renaissance, human population of the world has grown very fast. Between 5000 B.C. and 1000 A.D. the growth in human population was quite slow. But from about 1500 A.D. or so (soon after renaissance) the rise in human population became spectacular and fearful (Fig. I.1.). This explosive growth of human population however, is not due to any rise in human fertility (as is commonly believed) but mostly owing to drop in child mortality as a result of modern medical care.

3.3. Gradually the native populations of North America, South America, Australia & New Zealand were almost decimated or withered away and replaced by more energetic and demanding people of European stock (The Oregon Trail Francis Parkman; 1967. Bantam Books pp.298). Other European colonies in Asia and Africa could not however decimate the native populations but the control passed on to European hands. Only China and Japan in Asia remained free of European control. A glance at pages 244/5 of Harper Collins Atlas of World History edited by Geoffrey Barraclough (1998) will corroborate the above statement. Here is one sentence form the same. "The late 19th century saw a new imperial outburst of an intensely competitive kind. In the scramble for territory, resources, markets and outlets for capital investment, an immense part of the world's total land area passed under European control" (p. 245) (Map I.2). North & South America have already passed under European hands (Map I.2).

3.4. Thus without perhaps conscious knowledge of the indigenes—native Americans, Africans, Asiatics and Australians, their lands became gignatic

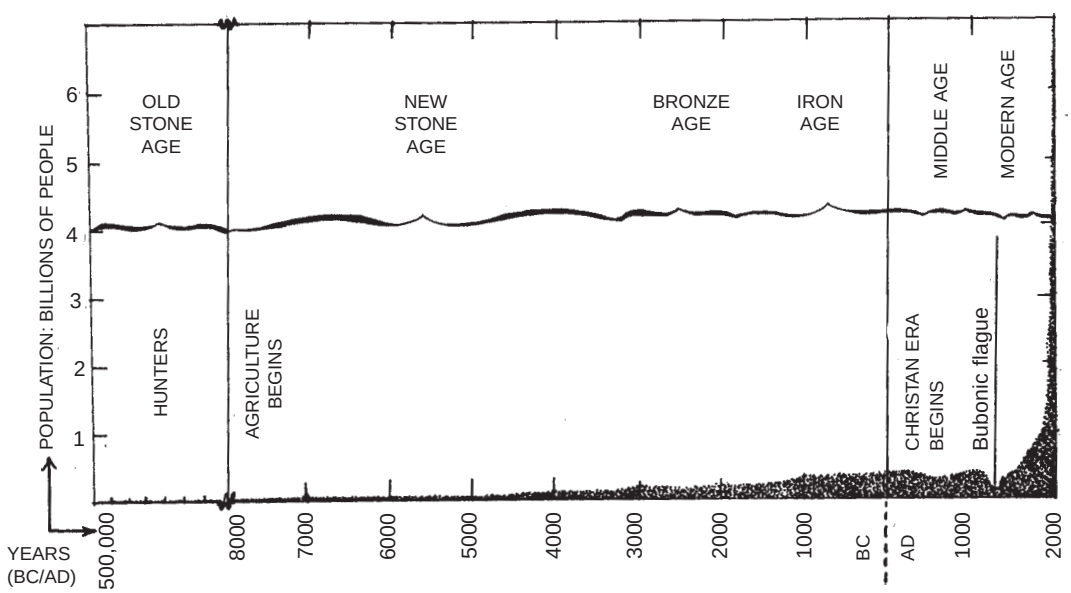
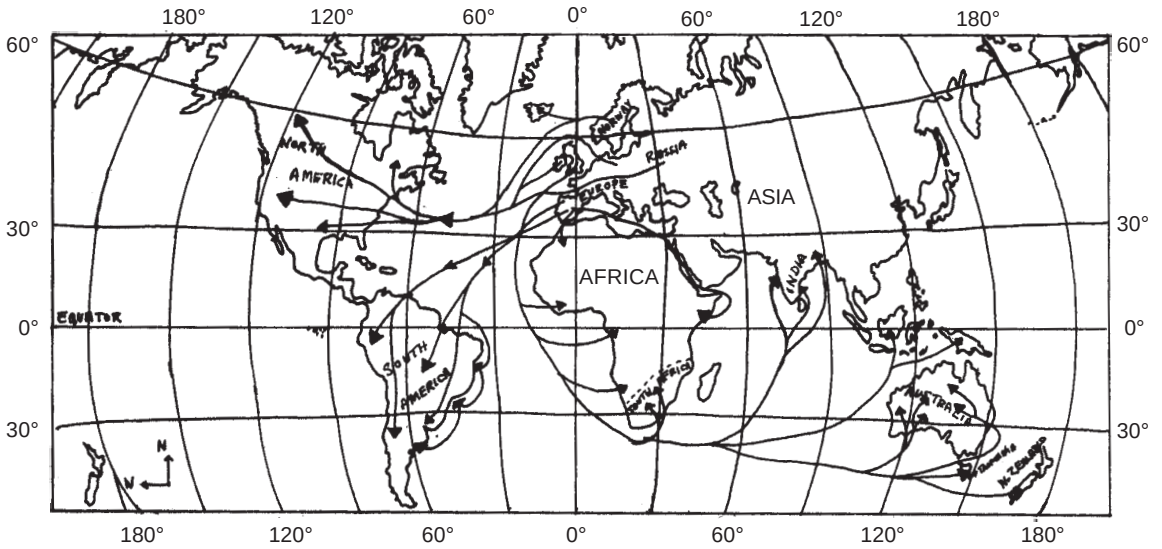


Figure I.1 Growth of human population in the past half a million years.



Map I.2 & 1.3 Growth of European Colonial Empires into different parts of the world (1535 – 1914)

hosepipes through which riches from these countries were sucked into Europe to provide the Europeans with unprecedented grandeur and comfort which is now termed as 'quality of life'. Save China, Japan and middle East there were perhaps no big country which could resist the canons and economic exploitation of Europe. So the inevitable happened. Gradually the natives of these colonies sank into a morass of poverty and ignorance. Both their wealth and population dropped and their cultures lost their vigour while the Europeans became richer and their populations rose very fast.

3.5. Before coming to the end of this topic we shall only cite two examples of exploitation of the same resource one pre-renaissance and another post-renaissance. According to the renowned Venetian traveller Marco Polo of 13th century, the island of Scotora in the mouth of Gulf of Aden was a great whaling centre. Large quantities of ambergis—a whale product was sold here. Whalers then used to kill sperm whales and other large whales by using tuna fish as baits and then hrapooning these by tying ropes with the harpoons. This method of whaling for centuries however, did not endanger the species but within the last few hundred years of so, when the harpooners used explosive tipped harpoons and huge factory ships with their pod of whaling boats so that they can whale non stop for mouths while roaming all the seas including the antarctic and artic, the inevitable happened. The whales who ruled the seas for centuries became so scarce during the last century, that to-day whaling is strictly controlled by International Whaling Commission. Thanks to efforts of the Commission, the number of whales are now rising again. Hope the whales will live and not share the same fate as dodos and Tasmanian Tigers (*Felis dingo*. MARSUPIALIA), i.e., become extinct.

Whaling: pre-renaissance and post-renaissance

3.6. There are many examples of accelerated eco-deterioration during 19th and 20th century including decimation of specific human populations. Those may not be relevent here. But one thing should also be admitted that 20th century also saw rebirth of man's interest in ecology and people started working for nature conservancy so that before it is too late all living beings of the world, other than human beings would have a place to live and breed in peace.

4. REBIRTH OF ECOLOGY & ITS MULTIDISCIPLINARY NATURE

4.1. Now let us come back to Ecology. Ecology although in spirit is as old as Egyptian culture, but is reborn in its modern garb after first World War when all the analytical tools of applied sciences were available to aid its pursuit. Ecology today is an applied science. It aims to unravel the complex relationships between animals and plants and each animal species and with each plant species and also the complex relationships which exist between each species and their non-living environments such as, soil water, light, heat and air etc. Hence Ecology has to draw upon various relatively pure sciences such as, morphology, taxonomy, behaviour, embryology, physiology, genetics, chemistry, physics, mathematics, geology, geography and metereology etc. Thus a true ecologist does not hestitate to draw upon any branch of knowledge which suits his need—particularly physics and chemistry and statistics. With time and experience ecologists are increasingly drawing from other areas of science besides these (as above). So the tree of ecology has many roots and many branches (Fig. I.2).

5. AIM OF THIS BOOK

5.1. Despite its relevance in today's context the basic oncept of ecology is still understood by only a few. The literature is full of technicalities and not easy to follow. Interestingly however, the basic principles of ecology can be presented to the general public without using technical jargon.

5.2. This small book is an humble attempt by the author to take the basic concepts of ecology to the common man. It is common man or woman who matter as, it is he and she alone who by their intelligent or unintelligent acts can make or mar their environment. Much of the future happiness of mankind is hinged upon how man uses his environment and habitat.

5.3. I have deliberately avoided technicalities lest these would limitise the size of the target population and thus the effectiveness of the book. Also my experience of teaching ecology in university has convinced me that the ecological principles can be understood without technical jargon. For interested readers however, information regarding technical literature is given in appropriate places.

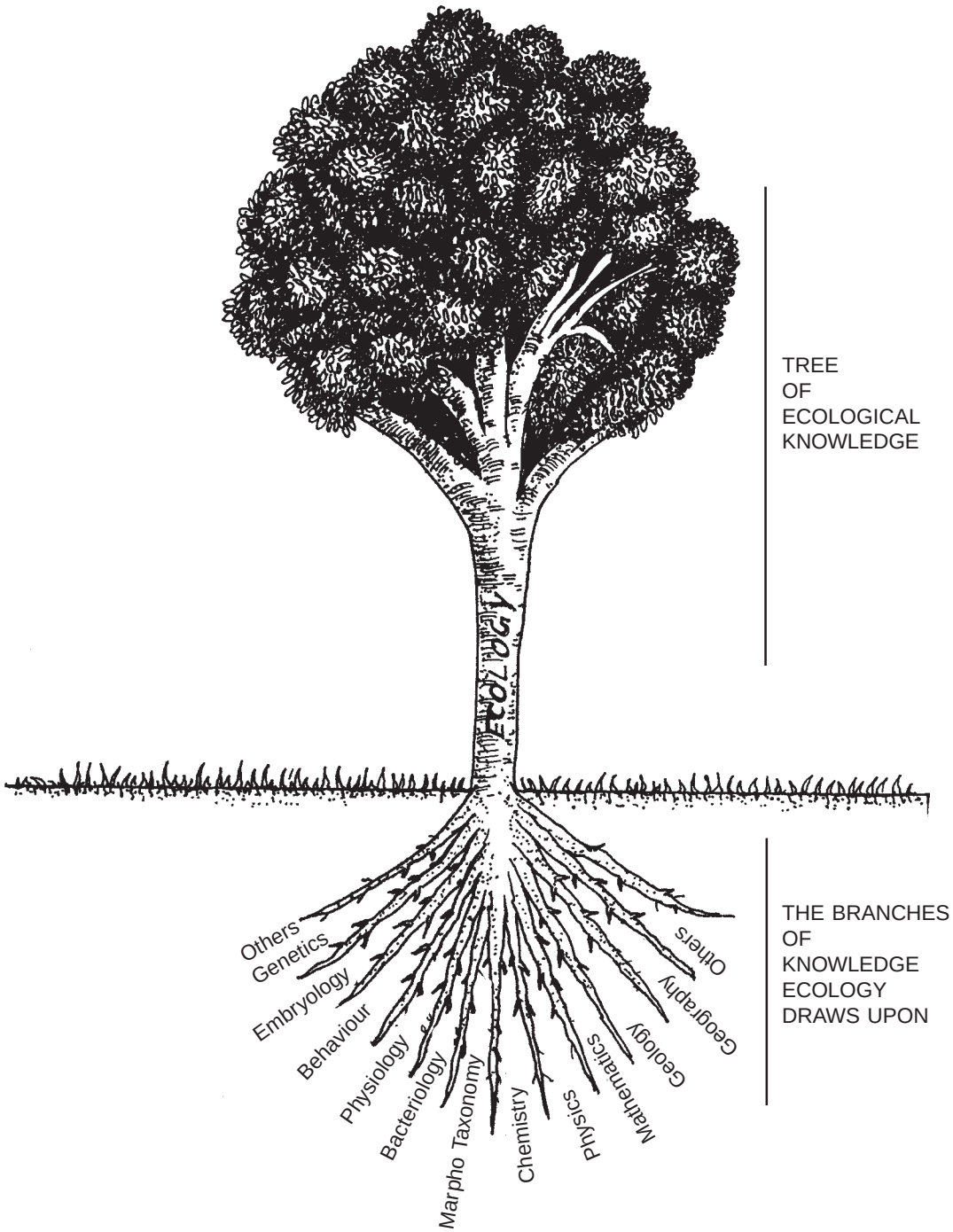


Figure I.2 Areas of Sciences which Ecology presently draws upon.

6. A BIRD'S EYE VIEW OF THIS BOOK

6.0. Efforts are made to explain step by step the basic principles of ecology and show our readers how these principles can be used for judicious use of the abundant resources of Nature for benefit of all and with detriment of none.

6.1. At the outset, a few words have been spent to trace the dawn of ecological consciousness amongst early human societies & also emergence of the formal word of "Ecology" amongst branches of sciences (Chapter I, INTRODUCTION : The Beginning).

6.2. Then it has been shown how, when a piece of "Nature" if left undisturbed, leads to a mutually-reactive but self-sustaining situation generally known as ecosystem. Thus a forest is an ecosystem, a lake is an ecosystem, a desert is an ecosystem and so on; (Chapter II, ECOSYSTEM : The Garden of Eden).

6.3. In the following chapter endevour has been made to show how bountiful Mother Nature is and how her bounty and blessings can be managed so that there is enough for all including animals (Chapter III, PRODUCTIVITY : Mother's Bounty).

6.4. Here it has been shown how the energy from sun, which is the ultimate source of energy of our planet Earth, is trapped by green plants for synthesising biomolecules which in their turn power all the activities of living beings. In the final analysis energy from sun is the fountainhead of the entire human civilisation since its dawn (Chapter IV, BIOENERGETICS : Sun the ultimate Source of Energy in Earth).

6.5. Following these chapters we have taken up the elucidation of the methods which Nature adopts to ensure the continuity of the flow of life on earth and how her bounty, or in other words how the cycle of birth and death are really supportive of each other and leads to the establishment of an eternal cycle (Chapter V, BIO-GEO CYCLES OF CHEMICALS : The Eternal Cycle).

6.6. and 6.7. Our next two chapters will lead us gradually into the areas which show us what regulate the increase or decrease of a population in a place and how skilful tending of Nature is primal for survival and growth of all living beings. These will also show us how application of this knowledge can help us to provide for all plants, animals and human beings (Chapter VI, POPULATIONS : The Milling Millions & Chapter VII, COMMUNITIES : The Noah's Arc).

6.8. After these a brief presentation has been made of the specialities and beauties of the various parts of Earth (Chapter VIII, BIOMES : Nature in Her Splendour).

6.9. Near the end of this small book an outline has been drawn up of the various types of disturbances in ecosystems, most of which are caused

by human activities. The various causative agents of such disturbances are broadly termed POLLUTANTS. These pollutants are gradually throttling our 'Garden of Eden' (Chapter IX, POLLUTION : Tortures to the Nature).

6.10. Finally before closing this book I have tried to put down to the best of my understanding of and in brief, what are our duties and obligations to Nature who nourishes all of us and how best we can discharge these duties and obligations in the light of our newly acquired perception of Ecology (Chapter X, PROBLEMS AND SOLUTIONS: Challenges and Rising to Them).

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Chapter II

The Ecosystem

(The Garden of Eden)

Topics

II.1. Ecosystem : Early Confusions in Meaning And Emergence of Present Definition

II.2. Main Types of Ecosystems

II.3. Human Interference And Damages to Ecosystems

II.4. Other Types of Ecosystems

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CHAPTER II

THE ECOSYSTEM

(*The Garden of Eden*)

"I went to the woods because I wished to live deliberately, to front only the essential facts of life, and see if I could not learn what it had to teach, and not, when I came to die, discover that I had not lived."

— Henry David Thoreau.

1. ECOSYSTEM : EARLY CONFUSIONS IN MEANING AND EMERGENCE OF PRESENT DEFINITION

1.1. With the birth of Ecology in late 19th century, as a distinct branch of Natural History, research on this baby science began in earnest in both sides of Atlantic. Soon useful information began to appear in journals. The area however being unchartered the observations were mostly descriptive. Methods varied from person to person and consequently their data were not easy to compare. There were ample scope of confusion as to exactly what a worker meant and how to compare one's observations with another's somewhat similar observations elsewhere. Rarely the parameters of two workers would mean the same. Indeed they did not. Clear and precise meanings of parameters with comparable data were necessary. Then only one could meaningfully compare the data of one with another.

Early works in Ecology and confusions in meanings

1.2. Gradually through various studies it became apparent that an area or habitat (i.e. a section of our biosphere) if it has to have stability in its nature, must have at least four distinct features. These are—

(*a*) Some green plants who produces food
(*b*) Some animals who live on green plants
(*c*) Some bacteria and fungi which live on dead (*a*) & (*b*)
(*d*) Some soil, water, air and sunlight which support the above.

Definition of Ecosystem

Plants produce food using sunlight and other components of (*d*), animals survive by sonsuming plants and after their death both animals and plants return all the materials locked up in their bodies back to (*d*) via decomposition through (*c*). Thus a self-sustaining environment is formed: from (*a*) to (*b*) from both (*a*) and (*b*) through (*c*) back to (*d*) and from (*d*) again back to (*a*). Thus the eternal cycle of life goes on and on (Fig. II.1.).

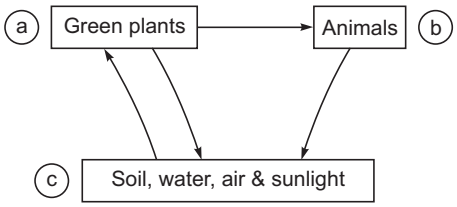

Figure II.1 The eternal cycle of Life in Ecosystem.

Ecosystem and Components of it

1.3. After several such descriptions of self sustaining habitats by ecologists both in Europe and in America, the definition of Ecosystem offered by English Botanist A.G. Tansley (1935) seemed most appropriate. According to Tansley all the living beings of a place (i.e. plants, animals and bacteria etc.) along with their habitat (i.e. physical and chemical components of environment) when interact and produce a recognisable stable entity, the place may be called an ecosystem (1935). An Ecosystem contains adequate amount of **Autotrophs*** (green plants—trees, grasses, algae etc. which can produce their own food), **Heterotrophs** (animals-herbivores, carnivores etc.), bacteria etc. which feed upon the matter produced by the autotrophs), **Saprotrophs** (bacteria, fungi etc.) and the **Abiotic Components** of surrounding environment (soil, water, air, light and heat—ingredients used by autotrophs to produce food). The above four factors or features autotrophs, heterotrophs, saprotrophs and abiotic components, interact with each other in such a fashion as to create a more or less stable and self sustaining unit of environment. Such a self-sustaining unit of Nature is an ECOSYSTEM. A large forest, a lake, a coral reef, a mangrove forest or a desert, all , if left undisturbed and remain self sustaining, are ecosystems. So henceforth we shall call these components namely, autotrophs, heterotrophs saprotrophs and abiotic components as the four basic components of all ecosystems.

2. MAIN TYPES OF ECOSYSTEM

2.1. With a little imagination we can easily see that ecosystems can be of various types. For example, a lake or a large pond can be an ecosystem as these are self-sustaining; so is a forest and so on. Human interference often robs ecosystems of their self-sustenance and thus kills them. A detailed examination of a simple ecosystem say, a large pond or a small lake, will help to understand the basic fetures of ecosystem. (Fig. II.2.).

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*TROPHISM concerns the method by which a living being procures food. A living being which produces its own food is an *Autotroph* such as a green plant. Similarly a living being which cannot produce its own food but instead, depends on food prepared by plants is an *Heterotroph* such as animals, and a living being which produce food by breaking down dead plants or animals is a *Saprotroph* such as fungi etc. We human beings are heterotrophs.

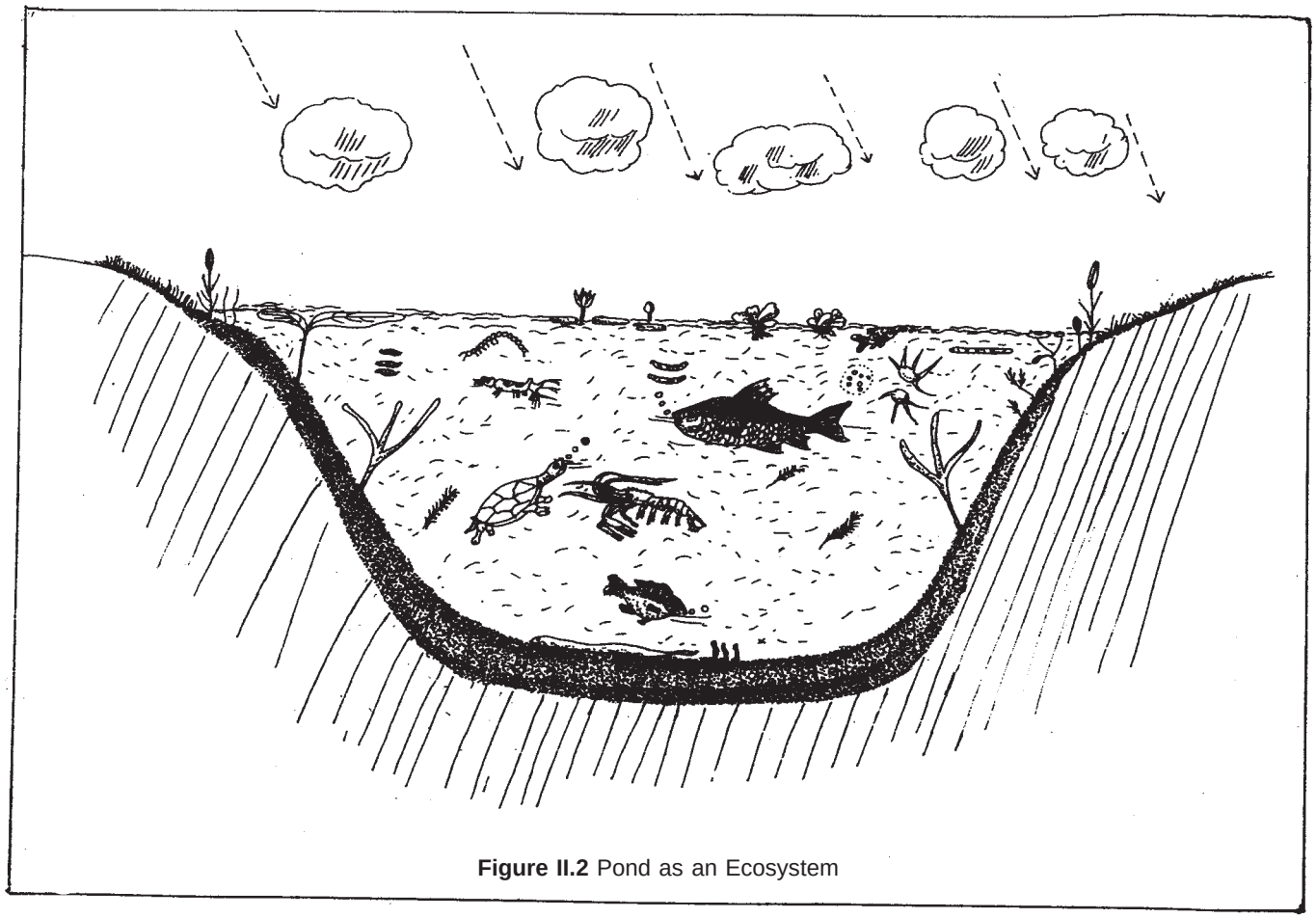


Figure II.2 Pond as an Ecosystem

Here it must be pointed out that often heterotrophs mean both heterotrophs and saprotrophs.

2.2. In a pond (or lake) we shall find algae, green weeds and phytoplanktons*. All these have chlorophyll (a green plant-pigment). With the help of chlorophyll and energy from sunlight these plants synthesise starch from simple raw materials such as CO_2 and O_2. So these green plants etc. are the first component or **autotrophs** of a pond or lake. Besides the autotrophs in a pond or lake there are fishes, insect-larvae, turtles, zooplanktons* and bacteria etc. None of these have chlorophyll so these cannot synthesise food (starch) as autotrophs can. So these must obtain food by consuming plants (as do fishes, cows, human beings, insects, zooplanktons etc.) or by consuming dead and decomposing bodies of plants and animals (as do bacteria and fungi etc.). Therefore fishes etc. and bacteris etc. both of which obtain food from plants either fresh of decaying beings form the second and the third components i.e. the **heterotrophs** and **saprotrophs** respectively of a pond or lake. Finally the non-living components of the environment, where the autotrophs live, i.e. soil, air, water and sunlight etc. and which the autotrophs utilise to synthesise food, form the third component or **abiotic components** of a pond or lake (Fig. II.2).

Pond: A Simple Ecosystem

2.3. This must also be remembered that besides providing raw materials to autotrophs for synthesis of food, the abiotic component of an ecosystem forms the bulk of the environment on which both auto hetero and saprotrophs depend. From a sentimental angle one can say that **abiotic components form the umbililcal cord of an ecosystem.**

2.4. These three main components i.e. autotrophs, heterotrophs and abiotic components are musts for any self sustaining ecosystem. Unfortunately in many instance men in power either through ignorance or being blinded with short-term gains, neglect one or more of these vital components and still want to create a 'garden' or 'reserve forest' or a 'national park'. Naturally they fail and not knowing the cause blame each other.

2.5. Here it would be worth while to emphasise once again that presence of autotrophs, heterotrophs and abiotic components all in ample i.e. balanced quantities are musts if an ecosystem is to be self-sustaining or more or less permanent. Large ponds, lakes, large forests, large rivers, large gulfs or seas are generally self-sustaining. So these are named as lake-ecosystems, forest-ecosystems and gulf-ecosystems etc. Examples of the above are Chilka Lake Ecosystem, Sundarbans Ecosystem of India and Gulf of Mexico Ecosystem of Mexico respectively. Lake Victoria of

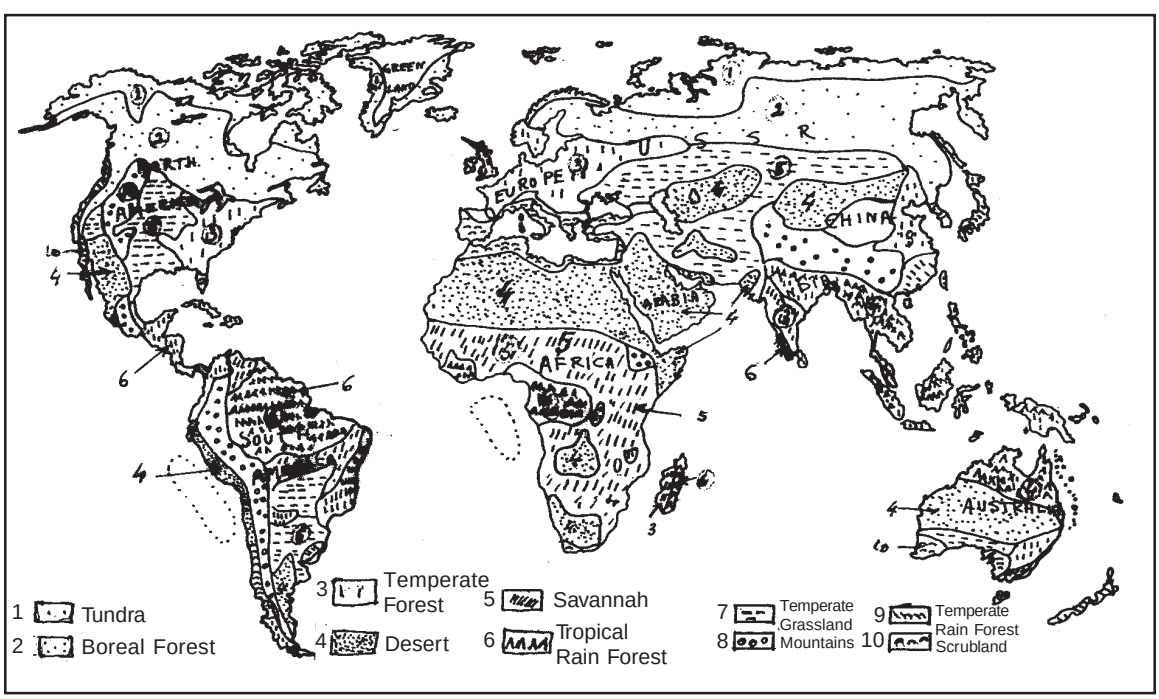
Some well known ecosystems

*PLANKTON are small mobile or passively flowing organisms in natural bodies of waters such as pond or lake or sea. Those who have chlorophyll and hence can manufacture food are called phytoplanktons and those who do not have chlorophyll and hence depend for food on phytoplanktons are called zooplanktons.

Africa, Mudumalai Forests, Corbet National Park of India, Amazon River Valley of Brazil, Lake Baikal of Siberia, Rain Forests of Amazon valley of Brazil and Great Barrier Reef of Australia are some of more spectacular ecosystems of the world offering challenges and rewards to any ecologist who works there. There are many more very interesting ecosystems found in different regions of the world. In the accomanying map the locations of some of the large and relatively undisturbed ecosystems of the world have been pointed out (Map II.1.).

2.6. Here it would be worth emphasising once again that the presence of autotrophs, heterotrophs and abiotic components all in ample quantities are musts for all self-sustaiing ecosystems. If any one of these three vital components are disturbed beyond the limit of tolerence (specific for each), the other two components are affected as well, mostly adversely. For instance until too many trees are cut down large forests are self-sustaiing. Similarly until too much pollutants poured in or dams are built or too much water is taken out for irrigation, large rivers are self-sustaining and so are large gulfs or small seas untill too muching fishing or too much dredging is carried out. Unfortunately to-day with many ecosystems such ills are happening.

On self-sustainance of eco-systems



Map II.1 Some well-known Ecosystems of the world

Role of Watershed and importance monsoon recharge

Rainwater and Water Management

2.7. For long-term survival a lake or even a pond or a small impoundment of water, must be **quite deep** and have a **large water-shed***—about 50 to 100 times of their actual areas. Rain-water from the surrounding land i.e. the watershed accumulates into the lake or pond and also percolates into the deeper layers of the soil of the watershed. If during monsoon enough rainwater is allowed to enter the watershed then, during the dry season this ground water accumulated during monsoon, gets gradually released into the lake or pond and keep then alive till next monsoon. If on the otherhand, the land surrounding a lake or pond etc. become covered with buildings, roads and pavements etc., then the rain water instead of entering the soil gets quickly washed into the drainage system and thence into the rivers. In such a situation the ground-water does not get a chance to get replenished during the monsoon. Consequently such impoundments of water (lakes, ponds all) gradually dry up and the dependant ecosystem lost.

2.8. That is exactly what is happening with the small ponds of Kolkata and the wetlands in the suberbs of Kolkata. Only the ponds of 'Maidan' area and 'Dhakuria Lake' are surviving. This is because their watersheds are still largely uncovered with buildings and roads etc. Summarily sustainability of any ecosystem depends upon a balance of all the main components of the ecosystem concerned i.e., a balance between the autotrophs, heterotrophs and abiotic components. Water is a vital abiotic component of any ecosystem. Small shallow ponds tend to dry up in summer when, their animals etc. i.e., fauna** either migrate away or die off. Hence most shallow ponds behave like temporary ecosystems. Large deep ponds or lakes however are more stable. Some examples of such stable ecosystems are Lake Victoria of Uganda, Great Lakes of U.S.A. and Lake Baikal in Siberia.

3. HUMAN INTERFERENCE AND DAMAGE TO ECOSYSTEMS

3.1. No lake however big is insulated from its surrounding basin or watershed. Aral Sea of erstwhile U.S.S.R. was a big land-locked lake (150 miles × 100 miles), fed by two rivers Syr Darya and Amu Darya, and hence was apparently permanent. But the Russians have taken out so much water from these two rivers for mega-irrigation schemes that today this huge lake has shrunk to nearly half of its original size. This has happened within a short span of 30 years (National Geographic Society).

3.2. Just as the lakes are susceptible to the abuse of their watersheds so are the rivers. The Ganga river ecosystem of India has suffered similar

*WATERSHED is the region or the area from where water is drained into a pond, a lake, a swamp or a river.

**Fauna & Flora : are the collective names of animals and plants of any place respectively.

damage owing to extensive irrigation canals and other causes such as, silt deposits and pollution. In a river ecosystem water supply depends mainly upon three factors—

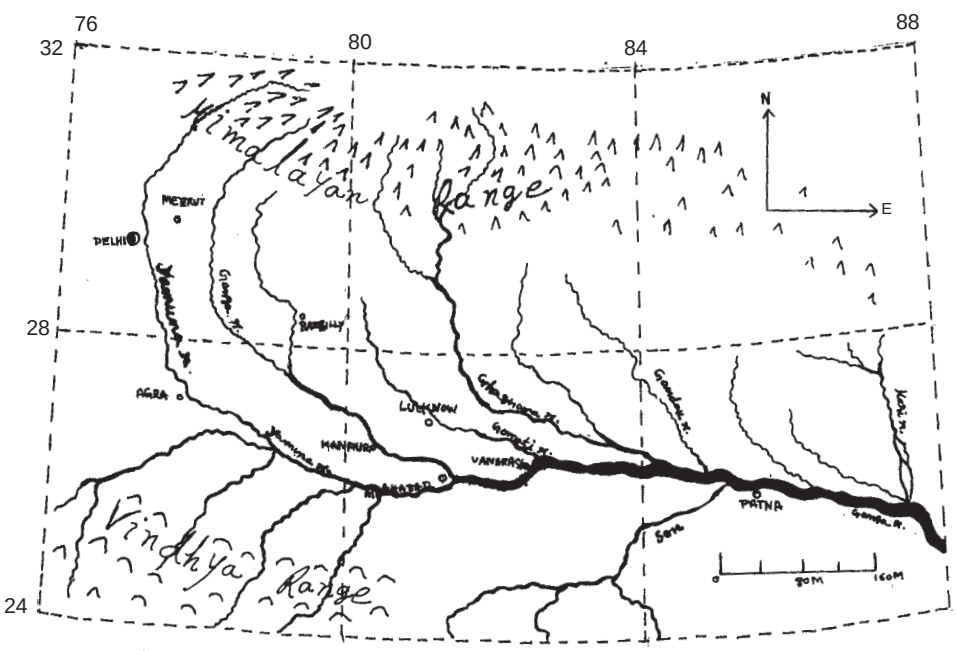
(*i*) adequate snow and glacier in its area of origin (when a river originates from snow capped mountains as Ganga does),

(*ii*) the regularity of rains upon its watershed and

(*iii*) the nature of vegetation which covers the watershed.

If any of these three factors are destabilised the river flow is affected. Let us examine these one by one using river Ganga of India as an example (Map II. 2.)

(*i*) **Snow and Glacier.** The Northern tributaries of Ganga such as Yamuna, Ganga and Gharghara and others all origin in the glaciers of Himalayan ranges. Therefore adequate snowfall in the upper mountain ranges and glaciers of Himalayas is necessary for healthy beginnings of Ganga and her tributaries. Hence unless plenty of snowfall takes place in Himalayas Ganga's owe may begin right at her origin. Nowadays owing to rise of CO_2 content and other gases of atmosphere there is a gradual rise of the atmospheric temperature of the world. This phenomenon is called 'global warming' (for explanation pl. see 'Carbon Dioxide and Greenhouse Effect' in chap V). Owing to this rise in CO_2



Map II.2 The watershed of river Ganga

content of atmosphere and consequent rise in atmospheric temperature the annual snowfall also gets reduced. This has a serious negative effect on the water supply of snowfed rivers such as Ganga and her tributaries. However for reasons not yet adequately understood, one year's low snow fall is ususally followed by high snow fall in the following year. Hence factor (i) is not yet identified as problematic.

(*ii*) **Rains on the watershed.** Here we have more information. The average annual rainfall of India, excluding Rajasthan, but including Himalayan region and Eastern India, fluctuates around 100″. Rainfall in Rajasthan varies from 5″ or so in district of Jaisalmer to 25″ or so in district of Kota; in Himalayan ranges the rainfall is around 150″ while in Eastern India particularly in and around Cherrapunji Hills the rainfall is highest in the world—around 500″.* This huge annual rainfall on the Himalayan ranges directly affects their watersheds and thus the rivers which origin thence. River Ganga and her Northern tributaries (Map II.2.) are direct beneficiaries of this rainfall.

(*iii*) **Nature of Vegetation and sponge effect.** Vegetable cover of the mountain ranges and hills and the rest of the watershed is extremely important for recharging the groundwater and thus the health of any ecosystem including river ecosystem, (such as Ganga). This is how this happens. Rainwater before reaching a river must roll down the surrounding slopes. In an undisturbed river ecosystem both the hills and the valley are normally covered with trees and ground vegetation. The roots of these keep the soil bound and the leaf canopy of trees and vegetation stop the rainwater from directly hitting the ground. Hence a good portion of rainwater gets opportunity for gradual penetration into the soil and the remaining water overflows into the rivers with only very low soil content as, most of the ground is bound with roots and covered with vegetation (Table II.1). This gradual absorption of rainwater by soil is comparable with sponges' absorption of water hence this concept is known as **'Sponge Theory'**. This penetration of rainwater into the soil helps in the survival of an ecosystem in at least six ways:

The Sponge Theory

(*a*) Recharges the aquifers i.e., the water-bearing strata of the ground.

(*b*) As a result of (*a*) the arsenic content of well-waters remains low.

*Alas even Cherrapunji could not escape the dark hand of human interference. To-day Cherrapunji suffers from draught in summer.

(*c*) Trees suffer less from summer draught.
(*d*) Keeps the silt load of river waters particularly in the monsoon, low.
(*e*) Consequent upon (*d*) the damages caused by floods are kept relatively low, and
(*f*) Keeps the ecosystem healthy by encouraging balanced survival of flora and fauna pertaining to the watershed.

The above points (*i*) to (*iii*) and (*a*) to (*f*) and the earlier principles delineated so far are the ecological bases of an healthy and balanced ecosystem. Violation of any one of the above causes havoc in the ecosystem and this we may not realise in the beginning and when we do, often only when too late. It is however very much possible for human beings to survive in any ecosystem if we only take prior notice of the nature of the ecosystem and determine how much it can be milched without detriment to its long-term health.

Table II.1.
EFFECT OF GRASS-COVER ON RUN OFF AND SOIL LOSS
(From State of India's Environment: A Citizen's Report–3, 1991. By Centre for Science and Environment, New Delhi)

S. No.	*Situation*	*Runoff as % of Rainfall*	*Soil Loss (t/ha/yr)*
1.	Bare fallow	71.1	42.4
2.	Bare and ploughed fallow	59.6	155.9
3.	Natural grass	21.2	1.0
4.	Grass cover	27.1	2.1

Here we shall present two examples to show how as a result of ignorance neglect of the above concepts the Ganga ecosystem of India has become much deteriorated.

Some major damages to Indian Ecosystem

(A) **Lions and tigers of India.** During the reign of emperor Asoka, lions were common all over India. The beautiful lion-heads of Asokan pillars—which form the seal of Govt. of India, were not figments of imagination of sculptors. As a matter of fact lions proudly strutted along throughout western Asia from Mediterranean to South Africa. Today the Indian share of these regal animals, are only a few left as 'protected animals' within the confines of Gir Forest of Gujarat. Now about the tigers. As late as beginning of this century (1900) tigers were abundant in Central India, Terai forests of Himalayas, Eastern India and Sunderbans of Bengal. Their number was around 50,000 or so. Today their number is so dangerously low that these royal animals had to be declared protected and their hunting prohibited. Credit goes to Late Prime Minister of India Mrs. Indira Gandhi for doing so. Still today they are found only in small pockets—reserve forests of India. This shocking decline of tiger population of India is quite clear from the following table (Fig. II.3). Here is what Zuber writes on this tragedy in his book (p. 47). "There have

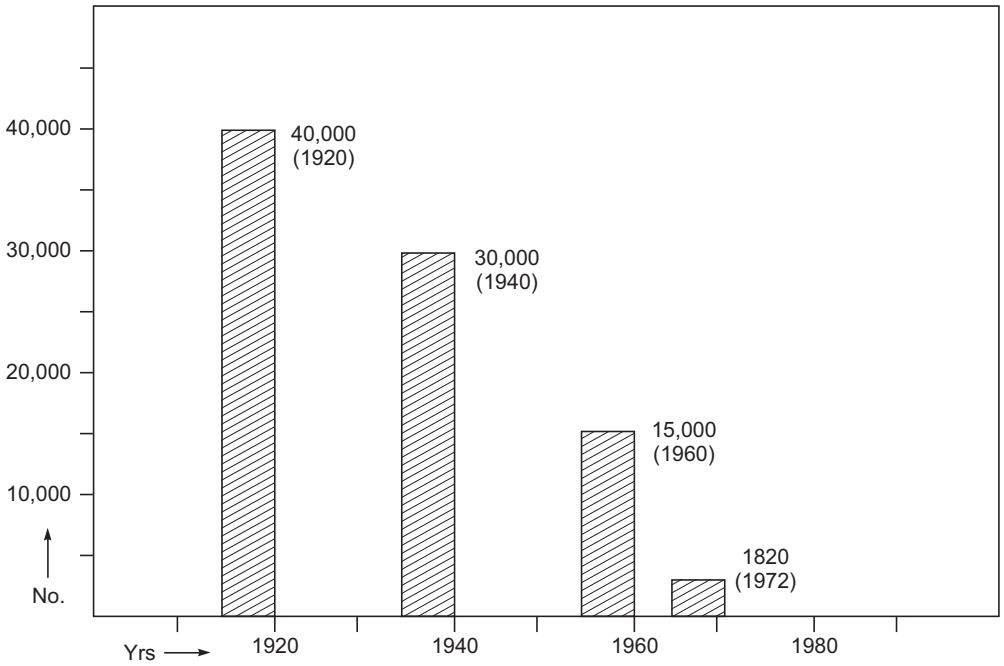


Figure II.3 Decline of Tiger population of India during this century

been Maharajas who have boasted of holding the world's record for the numbers of tigers they killed. Three of them have killed 1000 tigers spiece (1978).

They are like Indian counterparts of Buffalo Bill* of U.S.A. We feel sure there would be similar record holders' amongst the elephant and lion hunters of Africa. These are glowing examples of ignorance and vanity.

Increased soil-loss owing to ploughing & tree-felling

(B) **Soil loss through river-waters.** Soil loss during rains from grass-covered soil is considerably less than from bare soil (Table II.1.). Also, more water rushes into rivers from bare soil than from grass-covered one (table as above). The enormity of this loss of soil will strike us like a hammer if only we look at the following figure (Fig. II.4.). 'The river Ganga, Brahmaputra and Indus' together account for over half of the total silt load of Indian rivers' (Indus now mostly flows through Pakistan); but not even a fifth of their silt-load come from Himalayan mountains. The 'black soil' region of Central India alone generates an estimates 3,376 mil. ton of eroded soil—averaging a rate of 50 ton/ hectare year (State of India; Environment : a Citizen's Report - 3, p. 54). Details given in the above table and figure. This huge rush of soil during monsoons from river-valleys into the rivers—here Ganga and her

*Buffalo Bill—A folk hero of 19th century in U.S.A. who seems to have killed alone maximum number of bisons, partly as sport and partly to provide meat for men laying railway lines to open up the frontiers.

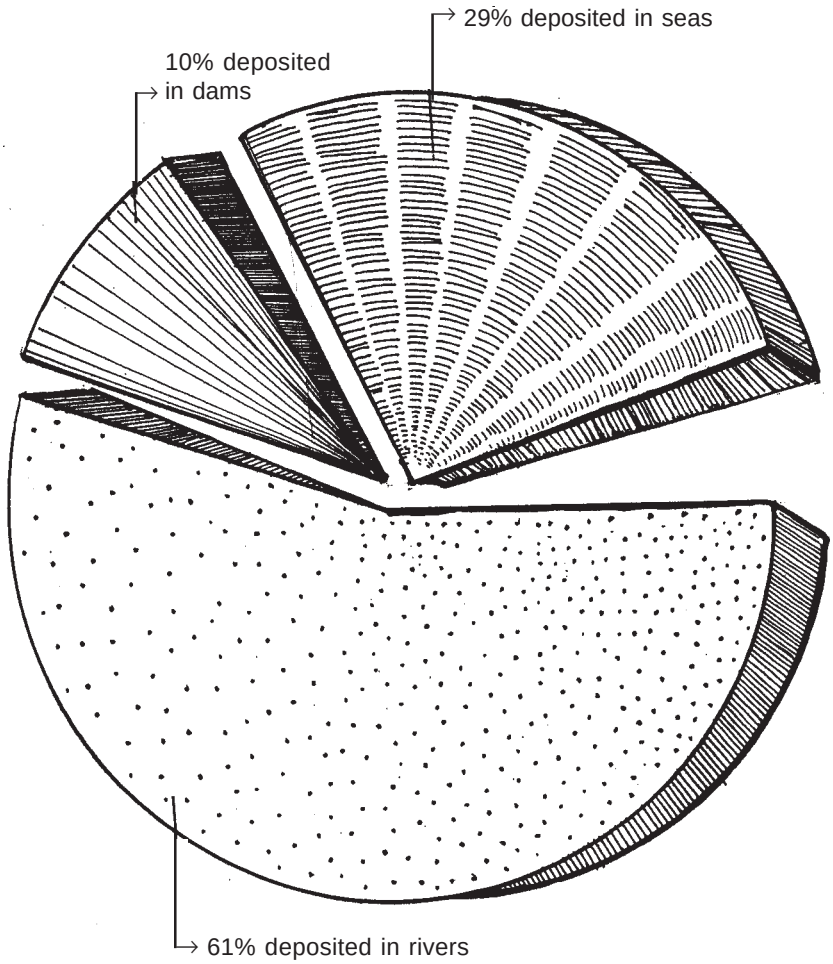


Figure II.4 India's annual soil erosion: About 5,400 million tons of soil of India is eroded every year—mostly during monsoons. Ganga and Brahmaputra alone contributed one-fourth of total ocean deposits.

branches, fill up their beds with silts as a result of which floods are becoming more frequent and more devastating every year. The following table (Table II.2.) and figures (Fig. II.4.) respectively show, how the area affected with floods and the consequent damages, on an all-India basis, have increased dramatically over the years.

Table II.2.
AREAS OF INDIA AFFECTED BY FLOODS IN SUCCESSIVE DECADES
(From State of India's Environment: A Citizen's Report–3, 1991. By Centre for Science and Environment, New Delhi)

Decades	*1950*	*1960*	*1970*	*1980*
Area Affected (in million ha)	6.86	5.86	11.19	16.57

Lowering of ground water level

Arsenic poisoning of well water and how that happens

(C) **Inadequate Recharging of Aquifers.** Another consequence of mismanagement of an ecosystem is **arsenic poisoning.** Unfortunately planners usually don't seem to understand this. Here is how it happens. Owing to the lack of tree/grass cover and poor management of monsoon rains, the rain-water runs off into Ganga too quickly, before adequate water can penetrate into the deeper layers of the soil and recharge the water-bearing strata of the soil i.e. the aquifers. Normally the recharging of aquifers also wash down the poisonous salts of soil such as arsenic into still lower levels from which water is isually not tapped. (This process of ground water sinking down to lower levels carrying along with it various salts in solution is generally known as **leaching**). However when there is good plant-cover, rain water gets enough time to penetrate into soil (through sponge action) before the surplus water is washed into the rivers (Tab. II.1). So leaching takes place. But in bare soil this does not happen. on the otherhand due to quick run-off of water from the ground surface, these natural processes of recharging the aquifers and leaching are thawarted. From the above two things happen.

One, the ground water level level goes more and more down and

two, the arsenic salts which are common in soils get slowly released into soil-water (and instead of being washed down by monsoon waters), rise above and mixes into the well-waters. This is the cause of recent frequent findings of arsenic in many well-waters which did not have arsenic earlier.

Wrong way of paving foot-paths

Paving of foot-path prevents penetration of rain-water into soil. In Kolkata most footpaths are already paved and in its suburban Salt Lake City the same is being done. Footpaths when paved should leave adequate entry points of rainwater into the soil and not let all water run off into the river Ganga. This simple precaution is not taken. The inevitables are happenning. The level of ground water is going further and further down every year, tubewells have to be sunk deeper and deeper for water, ponds are drying up, endemic fishes are vanishing and more and more trees are scccumbing to draught every summer. These are some common tragedies which can be easily prevented if the planners take into account the elementary principles of ground-water management and how to maintain the health of an ecosystem by linking proper ground water management, with town planning.

In the Ganga river watershed all the above tragedies are happening. We repeat, briefly these are

* Frequent landslides in the Himalayas owing to unbriddled deforestation;
* Frequent floods in the rainy season owing to silting of river beds from silt-loaded waters and;
* Frequent severe summer draughts owing to progressive lowering of ground water levels and

* Arsenic poisoning in well-waters due to reduced leaching (explained above).

In Rajasthan which is a semi-arid state of India, rainfall ranges from only 10-25″ inches annually, so the wells are very deep averaging 125 to 175′ feet each. Here owing to insufficient leaching many well-waters are poisoned with various salts particularly arsenic. Well-water is generally the only source of water for villagers in drier districts like, Jhun Jhunu, Barmer and Jaisalmer. A significant percentage of villagers who use well-water for drinking suffer from arsenic poisoning. But there is another source of drinking water available only to some residents of such dry places. Rich people who live in brick houses with paved courtyards store all the rainwaters washed down from roofs and courtyards into large underground reservoirs. Such rich people drink throughout the year only this stored rain-water and not the well-water. None of such people suffer from arsenic poisoning.

Drinking water in Rajasthan villages

3.3. Summing up, this may be safely said that the present state of Ganga River watershed is an excellent example of how an ecosystem should not be handled and this also shows that use of the basic concepts of ecology in planning and management of forestry, agriculture and town planning, can vastly improve the health of an ecosystem or watershed adding to economic gains as well pleasure to all inhabitants man, plants and animals.

4. OTHER TYPES OF ECOSYSTEMS

4.1. In the previous paragraphs we have outlined what are the basic features of an ecosystem (which are autotrophs, heterotrophs, saprotrophs and abiotic environment), using pond as an example, and following that were what calamities may result when an ecosystem is mismanaged using Ganga river watershed as an example. Besides pond (or lake) and river there are other ecosystems in our biosphere*. These are forests, seas, gulfs, coral reefs, mountains, islands and deserts. Each has its own specialities as well as susceptibilities to human abuse. At this stage we shall not delve into these details but rather talk more about these in a later chapter VIII - THE BIOMES (The Nature in Her Splendour).

4.2. Besides these natural ecosystems, there can be other types of ecosystems which are mostly small and of temporary nature such as, an aquarium for small fishes, an aviary housing small birds, a vivarium for small land animals or a dead tree lying on a forest floor with its host of boring insects and fungi or a bag of stored grain with insect pests. All these are like ecosystems in small scale. These are **Microecosystems.** A

Micro-ecosystem

*Biosphere—The this upper part of the earth's crust containing water and air, which contains all the living beings of earth. So all ecosystems are components of biosphere only.

microecosystem is like an ecosystem but not quite. An ecosystem is self sustaining but a microecosystem may not be so . From time to time many microecosystems may need inputs of one form or other for their continuance. Besides these are very small hence—micro. However within the confines of its limited space a microecosystem exhibits all the characteristic features (save self-sustainance) of an ecosystem. For instance an aquarium. A glass aquarium 1 metre wide, 1 metre deep and 2 metres long which besides water has 3-5 cm. thick floor of earth and gravel, some algae (autotrophs), a few small vegetarian fishes i.e., heterotrophs and presumably some saprotrophs, may easily form a microecosystem (Fig. II.5).

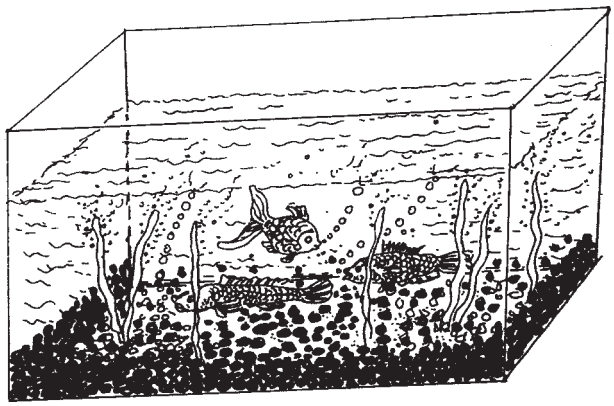


Figure II.5 A Microecosystem (glass aquarium)

4.3. If this aquarium with all the above components is placed near a window or a verandah where it can get some sunlight, this will behave like a microecosystem. With careful choice of fish and its number and proper management this aquarium may even be self-sustaining unit of biosphere i.e., an ecosystem but on a very small scale - in microscale. Similarly a small lawn of grass (autotrophs) with a few grasshoppers (heterothophs), soil, some small soil inhabitants (saprotrophs), water, air and sunlight as abiotic components may act as a microecosystem.

Microecosystems are very useful for experimental studies of various aspects of ecosystems within a laboratory or field. These are also excellent tools for teaching children ecology at home.

These microecosystems however mostly require supervision or monitoring so that none of the essential components become too much or too little.

4.4. In contrast with microecosystems large ecosystems such as forests, rivers etc. are called macroecosystems. All macroecosystems however house various microecosystems. Different areas of the same forest may vary qualitatively from location to location leading to pockets characterised

by their own microecosystems. For instance, the canopy of a large tropical rain forest and the undergrowth of the same forest will differ widely in their nature of the autotrophs, heterotrophs and in the amount of sunlight available to them. Hence it is always desirable for an ecologist to define precisely the nature, location, size and position etc. of the ecosystem he is referring to. Or in other words the ecologist is expected to define precisely the parameters of the ecosystem he is working with. Otherwise it may not be possible for another worker to repeat the experiment of the ecologist and check his observations. This repeatability is very important for ensuring the reliability of any observation and experiment.

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Chapter III

Productivity

(Nature's Bounty)

Topics

III.1. Meaning of Productivity

III.2. Types of Productivities

III.3. Measurement of Productivity

III.4. Factors Limiting Productivity

III.5. Some Interesting Examples of Productivities

III.6. Some Important Physical Factors' Role in Influencing Productivity

III.7. Ecological Niche—The Hutchinson Concept

III.8. Eras of Human Civilisation : Rise in Productivity and Population

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CHAPTER III

PRODUCTIVITY

(*Nature's Bounty*)

1. MEANING OF PRODUCTIVITY

1.1. Productivity is the rate at which biomaterials are being produced, by all the autotrophs (i.e. green plants) together and inhabiting a defined unit of biosphere (i.e. an ecosystem), within an unit of time.* Usually the amount is measured in kilo-calories and time in days, months or years. Again this 'defined unit of biosphere' depends upon the worker and his needs. The more biomaterial is produced in an unit of time the more productive the ecosystem is. For instance a forest is more productive than a desert. Here are the productivities of a few well-known ecosystems (Table III.1.)

Definition

Table III.1.
PRIMARY PRODUCTIVITIES OF SOME MAJOR ECOSYSTEMS
(Adapted from a Table of Ecology of Eyewitness Science)

S.No.	*Ecosystems*	*Productivities (Kcal/Sq. M/Yr)*
1.	Extreme Deserts	60
2.	Scrub Deserts	1200
3.	Open Ocean	2400
4.	Continental Shelf of Oceans	6500
5.	Lakes	9000
6.	Industrial Agriculture	12500
7.	Tropical Swamps and Marshes	35000
8.	Tropical Rain Forests	36000

2. TYPES OF PRODUCTIVITIES

2.1. A portion of the biomaterials produced by the autotrophs is used up by the autotrophs themselves for their sustenance. (By sustenance we mean all metabolic activities such as growth, reproduction and locomotion etc.). The surplus biomaterial only is available to the heterotrophs (i.e,

Gross and Net Productivities

*Productivity is a general term which means rate of production of any item, material or otherwise (such as intellectual). In this book however we shall concern ourselves only with the production of biomaterials.

plant eaters) of that ecosystem. The first quantity i.e. the entire biomaterial produced by the autotrophs of that ecosystem, i.e. including their own consumption, is known as **Gross Productivity** and the amount which remains for use of the heterotrophs is known as **Net Productivity**.

Primary, Secondary and Tertiary Productivities etc.

2.2. Just as autotrophs synthesise biomaterials, by using simple inorganic materials with the help of sunlight, the heterotrophs (i.e. herbivores, carnivores etc.) too, in their turn, produce biomaterials by consuming plant products or other animals respectively. To distinguish the production of autotrophs from those of heterotrophs, the productivity of green plants is termed **Primary Productivity,** of herbivores **Secondary Productivity** and of carnivores as **Tertiary Productivity.** By extending this logic further, the productivity of lice etc. which live by sucking the blood of carnivores such as, lions or tigers etc., can be termed **Quaternary Productivity.**

2.3. Now let us summarise all the types of productivities explained above as follows:

(1) Gross Primary Productivity (GPP)—the total amount of biomaterials synthesised by autotrophs.
(2) Net Primary Productivity (NPP)—that portion of GPP that remains to be available to the heterotrophs.
(3) Gross Secondary Productivity (GSP)—the total amount of biomaterial synthesised by herbivores.
(4) Net Secondary Productivity (NSP)—that fraction of the GSP that remains to be available to the carnivores.

Similarly (5) GTP and (6) NTP denote Gross and Net Tertiary productivities respectively and so are the meanings of (7) GQP and (8) NQP.

2.4. One more point. All productivities are measured as the amount of biomaterial produced within a fixed period of time. Hence both the amount of biomaterial produced and also the time period within which this amount is produced are the two essential parameters for measuring any type of productivity. Here are one example each of four types of producers.

(*a*) Grass — Primary producer
(*b*) Deer — Secondary producer
(*c*) Lions — Tertiary producer
(*d*) Fleas — Quaternary producer

All these four types of producers are found in any large ecosystem. Corbett National Park of India and Serengeti National Park of Afrika are two of many such ecosystems.

3. MEASUREMENT OF PRODUCTIVITY

3.1. We now have a broad idea about what productivity means to an ecologist. The next question that comes to our mind is how to measure

productivity. Here we shall present two simple methods of measuring productivity in two different situations.

3.2. As early as 1927, **T. Gaarder** and **H. H. Gran** devised a very clever experiment for measuring - both gross and net productivities, of an aquatic ecosystem. First the principle. During photosysthesis the plants produce biomaterials with the help of their green pigment i.e., chlorophyll, using carbon dioxide and water with energy from sunlight. During this process oxygen is released. So simply, photosynthesis can be shown as follows :

$$CO_2 + H_2O + \text{energy (from sunlight) and help of chlorophyll} \longrightarrow CH_2O + O_2$$

CH_2O is a very simple biomolecule from which other complex biomolecules are made. So the net direct outcome of photosynthesis is the production of CH_2O and O_2 (oxygen) and removal of CO_2. Therefore if we can measure how much CO_2 is taken up or, how much O_2 is released from the ecosystem we shall know how much biomaterial is produced. Here we must not forget that oxygen is also used by plants themselves in their own respiration. Therefore whatever oxygen that comes out of the ecosystem is that which is surplus after providing for respiration. This information is what Gaarder and Gran used. They measured the amount of oxygen released during a fixed period of time by a fixed amount of photosynthetic plants and also determined the amount of oxygen that was used up during the same period by the same plants. By adding one with the other they got the total amount of oxygen produced during photosynthesis by the same plants. From this sum total of oxygen produced, Gaarder and Gran determined the amount of biomaterial that was synthesised by these plants during that period. Following is the technique.

The Light and Dark bottle method of Gaarder and Gran

3.3. Three empty bottles of equal size were filled up with water from the same depth and preferably near the surface of a pond/ lake which is well-lighted and has normal phytoplankton flora, i.e., the water not crystal clear but rather somewhat greenish. The bottles are marked ‘A’, ‘B’ and ‘C’. The O_2 present in the bottle ‘A’ is immediately fixed with chemicals so that, both photosynthesis and respiration are stopped in this bottle. The bottle ‘B’ is thoroughly wrapped up in 3 layers of aluminium foil so that no light can penetrate into the bottle. This will stop photosynthesis but not respiration. The bottle ‘C’ is left as such i.e., unwrapped; so, here both photosynthesis and respiration will go on as usual.

3.4. Now all the three bottles i.e. ‘A’, ‘B’ and ‘C’ are stoppered and tied with three strings are left hanging in the same depth but near the surface of water, so that these can receive enough sunlight, and then left there for 24 hours i.e. one full day and one full night (Fig. III.1.). After 24 hours the bottles are lifted and their respective oxygen contents are fixed and measured. These amounts are marked ‘a’, ‘b’ and ‘c’ respectively. As per our assumption, ‘b’ should be less than ‘a’ as—

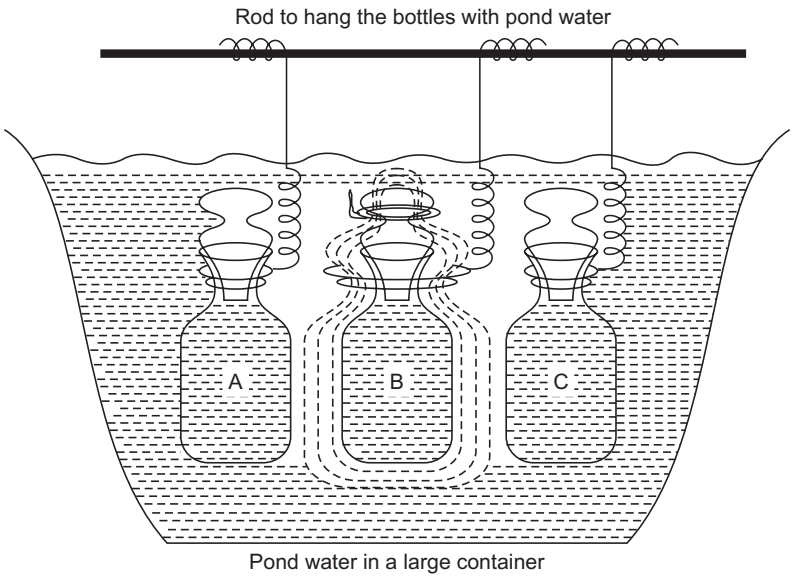

Figure III.1 Light and Dark Bottles suspended at same depth of water.

a – b = O_2 consumed due to respiration during this period and net
c – b = O_2 produced due to photosynthesis during this period, is obtained by deducing from the above.

Hence Net production + Consumption = Gross production
i.e. c – b = net production ... (1)
and (c – b) + (a – b) = gross production. ... (2)

So through this clever but simple experiment we can measure both the net photosynthetic production as well as gross photosynthetic production of a simple aquatic ecosystem. As the penetration of sunlight diminishes along with depth, production as well as consumption of O_2 depends upon the depth of water where the bottles are suspended (Table. III.2.).

Table III.2
CHANGES IN QUANTITIES OF OXYGEN IN DIFFERENT BOTTLES SUSPENDED AT DIFFERENT DEPTHS
(From Odum–Fundamentals of Ecology–3rd Edition, 1971)

S.No.	*Depth*	*Oxygen Change (gms/cu.m)*		*Gross Production*	*Community Respiration*
		Light Bottle	*Dark Bottle*	*(gms/O_2/cu.m)*	*(gms/O_2/cu.m)*
1.	Top cu.m	+3	–1	4	1
2.	Second cu.m	+2	–1	3	1
3.	Third cu.m	0	–1	1	1
4.	Bottom cu.m.	–3	–3	0	3

3.5. The same principle as outlined above can be employed to measure the productivities of any other type of ecosystem including microecosystems. We however shall have to make modifications in the techniques and, or indicators to suit the nature of the ecosystem and the aim of the ecologist. Also the techniques for autotrophs and the techniques for heterotrophs would not be same. Here comes into play the wisdom and skill of the worker. Anybody who has read the works of Louis Pasteur will understand this. Pasteur's experiments are wonderfully simple but precise and meaningful. In fact they are classic examples of well-desigined experiments.

The Quadrat Method

3.6. Now let us discuss another method of measuring productivity. This is **Quadrat Method.** This method is used to measure productivity of a forest or grassland or agricultural ecosystem. A fixed area such as 1 metre^2 or 2 metres^2 or more, as per the nature of the ecosystem and need of the worker, is fully fenced up so that no vegetable matter produced by the plants within this area is removed by wind or any other agency. The amount of vegetable matter produced (dry weight) by that area in a fixed period of time, is the **Net Primary Productivity** of that area during that period. (Fig. III.2).

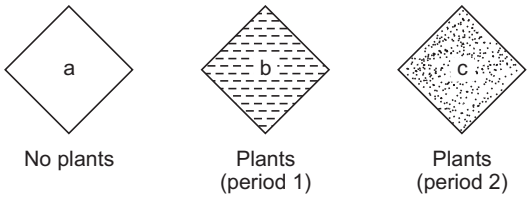

Figure III.2 The Quadrats for Quadrat Method.

3.7. It is rather difficult to know the Gross Primary Productivity through quadrat method as, a part of the bio-matter that is produced during this period is used up in maintaining the metabolic processes of plants themselves. So what we measure here is the net primary production. This net primary production is also called as Standing Crop. However by modifying the techniques employed and selecting parameters suitably it is possible to estimate both gross and net production of all types of producers—autotrophs as well as heterotrophs. For more on this topic one can see Southwood (Southwood, T.R.E., 1978, Ecological Methods, Chapman and Hall, London).

Biological Pyramid or Ecological Pyramid

3.8. Usually most of the plant materials consumed by animals (heterotrophs) is used up in their metabolic as well as locomotive activities. Only a fraction goes in building up their bodies. As a thumb-rule it is usually taken that not more than 5 to 10% of the plants consumed is converted into the body material of the consumers i.e., heterotrophs. So, if we arrange plants, herbivores and carnivores one above the other in the same order we shall get the following picture of

their quantities (Fig. III.3). This type of figure showing the successive trophic levels one above the other, and also indicating their respective amounts, like a pyramid is called **Biological Pyramid** or **Ecological Pyramid**. In such a pyramid order of production of food (i.e., biomaterials) are arranged with the top carnivores such as tigers occuping the top and the vegetation occuping the bottom position. We shall talk more about various ways of representing biological pyramids and their shapes in our next chapter (Chap. IV).

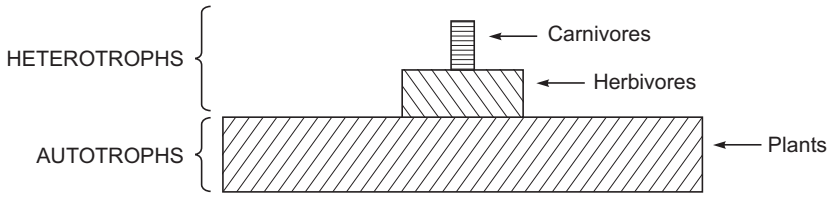

Figure III.3 The Biological Pyramid or Ecological Pyramid.

Web of Life (or Food Web) and Food-chain

3.9. Animals and plants are connected to each other through the food they eat. Here is a simple example. Deers feed on grasses and leaves of small plants and brushes etc. The tigers feed on deers and other herbivorous animals. Besides deers there are many other animals such, as insects, rabbits, cows etc. who feed on grasses and other vegetables. Similarly besides tigers there are many other animals such as owls, eagles, wolves etc. who feed on various hervivores including deers. When these relationships are shown graphically through a diagram we get a network-like figure which we call as **Web of Life** or **Food Web** (Fig. III.4). This

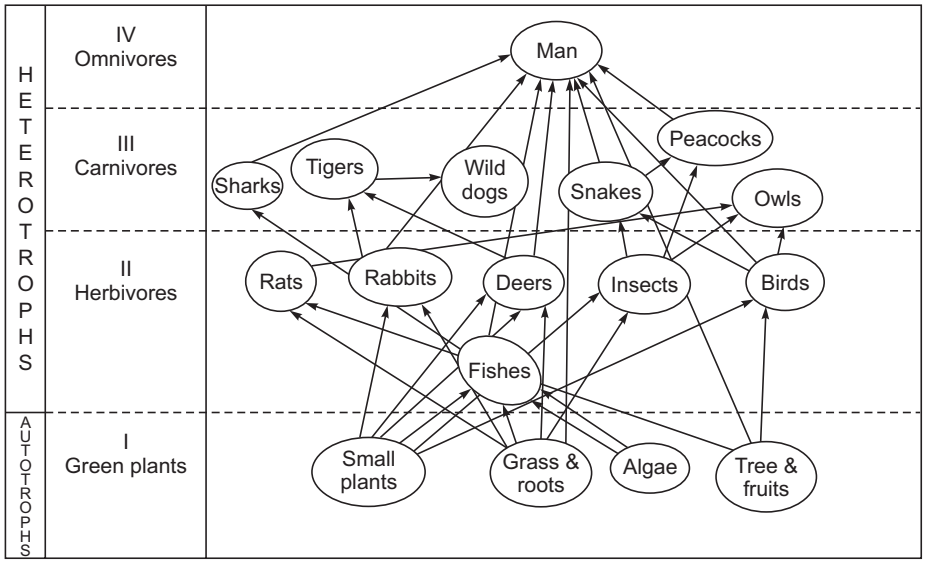

Figure III.4 Web of Life or Food Chain and the different levels of producers (a simplified example).

web of life or food web shows all the links in the feeding relationships in a community. This web is commonly worked out through the analysis of diets.

3.10. This simple diagram of an Web of Life illustrates may important features one of which is **Food-Chain.** Every animal, be it a deer or a rabbit or a man is bound with its environment through the food it takes. Also, ultimately all of them depend—directly or indirectly on green plants i.e. autotrophs for survival. This link of every animal through its foods to the ultimate producer of food in Nature i.e., green plants is called **Food-Chain.** If we ponder a little bit on this point we shall see how every man and woman on this earth is ultimately dependant on plants for his or her survival. **So protection to plants is verily protection to our lives.** We shall talk more regarding web of life and food-chain later.

4. FACTORS LIMITING PRODUCTIVITY (OF A POPULATION)

4.1. A potted plant if not watered regularly, first wilts then dries up and finally dies; grass if left covered for many days by something which light cannot pass through, will soon become yellow and finally die. What do we learn from these observations? **WATER** is a must for the survival of all plants. So also **LIGHT** is a must for survival of grass and all such green plants. So water and light are two very important factors on which survival and growth of plants depend. With more experiments and observations it was gradually found out that besides water and light there are other factors such as **heat, some gases** and **some chemicals** which are also vitally important for the life of green plants. All these factors are collectively called **Limiting Factors** for a population. Here is a brief account of Limiting Factors and their roles.

Importance of water, Light & other ingredients far sustenance of Life

4.2. As early as 1840 a German biochemist **Justus von Liebig** stated that the growth of a plant in any habitat is controlled by that essential raw material which is present in minimum quantity in that habitat. For instance, in a pond the growth of phytoplankton may depend upon the quantity of nitrogen salt present in water. This dependance on nitrogen will occur only if all other elements required for growth are available in plenty save nitrogen. Hence here nitrogen will act as the 'limiting factor' for growth of pond-phytoplankton. This means that factor whose paucity limitises further growth of phytoplanktons is the limiting factor in this habitat. If on the other hand, nitrogen is adequate but phosphorus (which is also essential) is not then, phosphorous is the limiting factor. Justus von Liebig summarised such observations by stating something as follows: To survive and prosper in a particular habitat an organism must have all the essential factors required for its growth and reproduction in ample quantities. Any element or factor which is not ample will soon approach the critical minimum for further growth. So **Leibig's Law of Minimum** states that no organism—plant or animal is stronger than the weakest link in its chain of requirements of nutrients (such as nitrogen, phosphorous etc.).

The Law of Minimum by Justus Liebig

4.3. Like many ecological concepts this Law of Minimum is a powerful concept with scope of application in areas far beyond mere chemical elements. Sometimes availability of space may be limiting as for humans and many other species today (for instance tigers). Sometimes supply of breeding opportunities may be critical as for some mammals of today. Here is an example from fish culture. This is not about breeding though. Often fishermen in order to increase productivity of fish, simply add cowdung in fish pond. Usually in many ponds nitrogen is a limiting factor for growth of phytoplanktons. When cowdung is added, phytoplankton growth spurts. Fishes live on phytoplanktons. So application of cowdung which is rich in nitrogen, leads to increase in the productivity of fishes by increasing phytoplanktons in pond. We shall touch upon these aspects once again later when, we talk about 'populations' of species.

The Law of Maximum by Victor E. Shelford

4.4. Now we shall discuss another law which also guides productivity. Just as too little of something may be the weakest link or limiting for growth of an organism so also too much of something may be limiting. For example, too much heat may be limiting or too much cold, or too much dryness or too much salt in water, all these factors in their own habitats and for the species involved may be limiting. **Victor E. Shelford** in 1913 summarised these observations in another simple law **Law of Maximum.** Shelford further linked the concept of minimum of Liebig with the concept of maximum of his and presented a combined law—**Law of Tolerence.** This Law of Tolerence may be simply stated as not only too little of something may be limiting but also too much of something else may too be limiting for survival, growth and breeding of a population.

4.5. With a little bit of thinking we shall easily visualise that :

(1) An organism which can tolerate an wide range of variation in its requirements will inhabit in a large area or have a wide geographical distribution. For example - Crow.

Law of Tolerence and Subsidiary Concept

(2) Conversely an organism whose capacity to tolerate variation in one or more of its vital requirements is very little, will be able to stay only in a small area or, have a narrow geographical distribution. For example—Trout, a fish found in cool waters of hill stream. These two important subsidiary concepts and the logical follow-up of these help us to understand the geographical distribution of many plants and animals all over the world. Hence these are important to understand biogeography.

The Prefixes steno and eury

4.6. The prefix ***'steno'*** and ***'eury'*** mean narrow range and wide range of toleration respectively, for any environmental quality. For example if, any organism can tolerate a wide variation in temperature, its temperature toleration will be called as **eurythermal** and if narrow it will be called as **stenothermal** (Fig. III.5).

This figure graphically represents the previous statement. One more point. Narrow ranges of toleration i.e., steno can either be in the low end

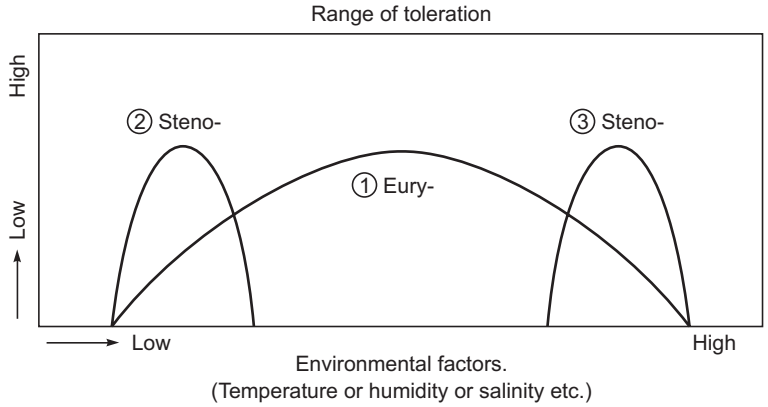

Figure III.5 Types of Ranges of Toleration of various organisms to a particular environmental factor such as temperature or humidity etc.

of the range or high end of the range. When at the low end it is called **oligo** and when at the high and it is called **poly.** Further to specify the factor concerned a suffix is used such as—

for **Temperature** one may use **Eurythermal** or **Stenothermal**,
" **Water salinity** " " " **Euryhaline** or **Stenohaline** and
" **Food habit** " " " **Euryphagus** or **Stenophagus**.

So workers are advised to use their own judgements and observations to decide about the prefixes to the factors whose effect on the species they may be studying.

5. SOME INTERESTING EXAMPLES OF PRODUCTIVITIES

1. When too much of a good thing is bad

5.1. Here are some examples of how small changes in the amounts of nutrients in soil/water can make significant changes in the presence of plants and animals in the habitat. Generally presence of adequate phytoplankton in water is good for fishes as they live on these. But when due to extensive use of fertiliser in agriculture, excessive amounts of nitrates reach the water system, this causes a sudden outburst of phytoplankton density in water. This phenomenon is known as **'algal bloom'**. This dramatic increase in the population of algae depletes the oxygen store of water so much that, most of the fishes die of asphyxiation. This is what happened in Lake Erie of U.S.A. in 1960s and 70s. Thus we find that too much of a good thing may at times be bad as well.

2. Ducks vs. Oysters

5.2. The great South Bay in Long Island Sound, New York, U.S.A. was a valuable breeding ground for edible oysters. They had a very profitable oyster fishery there. Recently large duck farms were established all along the tributaries leading to the Bay. This led to heavy fertiliser deposits in the Bay water from duck droppings. The sudden increase in the nutrients in water resulted into an outburst of some heretofore little known

flagellates*—*Nanochloris* sp. and *Sticoccus* sp. These completely replaced the indigenous diatom—*Nitzschia*—which is the normal phytoplankton of the Great South Bay and food for the famous 'blue-point' oyster—the edible oyster of this Bay. As a result the 'blue point' oysters literally starved to death although their stomachs were full of the new flagettates (*Nannochloris* and *Sticoccus*) which they took in but could not digest. *Nitzschia* the normal phytoplankton of this Bay takes in nitrogen from the watyer only when it is broken down to the state of inorganic nitrates but the newcomers i.e. *Nannochloris* and *Sticoccus* take up N_2 from the preeceding stages i.e. in the forms of urea, uric acid and ammonia. So nitrogen is picked up from the water before it become nitrate. Hence *Nitzschia* stood no chance. Thus while duck farmers thrived oyster fishermen starved.

5.3. Recently however (1998) there was a heartening report in The Washington Post, U.S.A., where they have claimed that resulting from extensive steps that are being taken to reduce the flow of agricultural wastes in the watershed, the water of the Great South Bay has regained some of its earlier pristine qualities. This has resulted in the reappearance of the 'blue point' oysters in the Bay raising the hopes of oyster fisherman. Here is a quotation from a news item in The Washington Post, 12th. Dec. 1998. "Chickens are big business on the Eastern Shore. So is sea food, bounty of the bay. Not untill a few years ago, however, did officials realise the connection. The health of this Chesapeake Bay and its tributaries—and the fish they yield—depends on the care and feeding of the poultry. Chickens—about 600 million a year—have been sources of serious nutrient pollution. Federal and State Government have been working on requirements for controlling poultry pollutants. These nutrients fuel algae that in turn choke off oxygen in the water and endanger fish and crabs. "The Washington Post 1998". Lawmakers have been seeking to hold big companies responsible for taking the necessary protective steps. This week to respond to these pressures and to prevent more government actions, national poultry industry representatives agreed on a voluntary plan to limit pollution. The industry's acknowledgement of at least some minimal responsibility for tougher antipollution requirements is welcome. But federal officials pointed out that the plan falls short of ensuring that the large companies, not small farmers, would bear most of the costs." The Washington Post 1998.

3. Big Chicken and Clean Bay

5.4. Some plants and animals respond to the presence of very small quantities of certain materials present in Nature. For example, pines and junipers if growing on uranium containing deposits, tend to contain uranium on the above-ground parts of these plants. If the foilage of such

4. Ecological Indicators

**Flagellates* are a type of one—celled animals (known as PROTOZOA) who are characterised by the presence of a tail-like structure called flagellum along with their bodies. Example-malarial parasite—*Plasmodium sp.*

plants are examined (fluorimetrically) and found to conotain more than 2 ppm uranium, the soil is considered to contain commercially exploitable deposits of uranium. Hence here pines and junipers can be called as **ecological indicators** of uranium in soil. Similarly, caged small birds are sometimes lowered into mine shafts to test the quality of air inside deep mines. These are very sensitive to oxygen depletion so, quickly dies if O_2 content of air is less than normal.

5.5. A general observation. From the above few examples and many other situations it may be broadly concluded that the 'steno' species, (and not the 'eury' species) i.e. those species whose capacity to tolerate changes in a particular factor in the environment is very narrow, or limited, are better indicators of environmental quality.

6. SOME IMPORTANT PHYSICAL FACTORS' ROLE IN INFLUENCING PRODUCTIVITY

Now we shall discuss very briefly the roles played by some very important physical factors on the survival and growth of populations.

6.1. TEMPERATURE

6.1.(1). Temperature is a very important regulatory factor for the survival and growth of all living beings on earth. The temperature on Earth can range from hundreds of degrees centigrade in magma (the fluid core of Earth) to –70/80°C in polar caps. But living beings as a whole can only live within a small part of this range, say + 90 to –190°C. Again no organism of any particular species can survive, grow and reproduce throughout this entire range of temperature but only within a much shorter band of this range which varies from species to species (Fig. III.6).

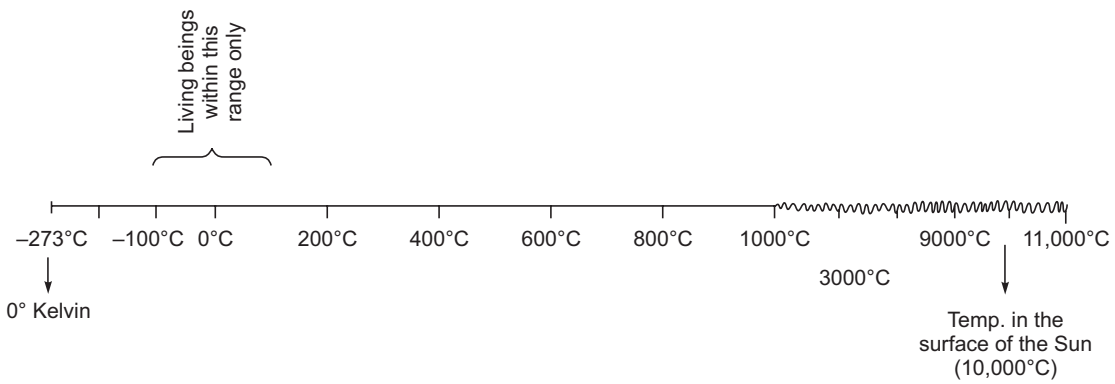

Figure III.6 Scale of Temperature within our Solar system.

6.1.(2). Interestingly the range of temperature which can be tolerated by a species not only varies from species to species but within the different stages of life cycle of the same species. Each stage of the life of a species can live only in a much narrower band of the overall range ot temperature tolerable to the same species. This fact often acts as limiting for the survival and growth of a species. Anybody who is observant and have some experience of Nature must have noticed that a sudden and unexpected rise or fall in atmospheric temperature will result in the abundance of some species of plants or animals of the place. There may be an outbreak of pests or disappearance of pests or flowering may be delayed or hastened. Owing to such fluctuations in the incidence of insect pests, the yield of cash crops which are affected by such pests, will also fluctuate. Generally metabolic activity is directly related with temperature. Stored grain pests particularly, grow faster in higher temperature. Larvae or *Tenebrio molitor*, (a stored grain pest) grow much faster in summer than in winter when the temperature drops considerably. Similarly development of eggs of grasshopper *Austroicetes cruciata* show almost a curvilinear relationship with the rise of temperature, from a threshold of 16°C till about 36°C (Fig. III.7).

Ambient temperature and survival

6.1.(3). When body temperatures of animals is compared with those of environments we find that some animals such as birds and mammals maintain a constant body temperature irrespective of the temperature of the environment while others such as, fishes, amphibians (frogs and toads) and reptiles' body-temperature rises and falls along with

Classification of organisms on the basis of their body temperatures. ENDOTHERMS and ECTOHERMS

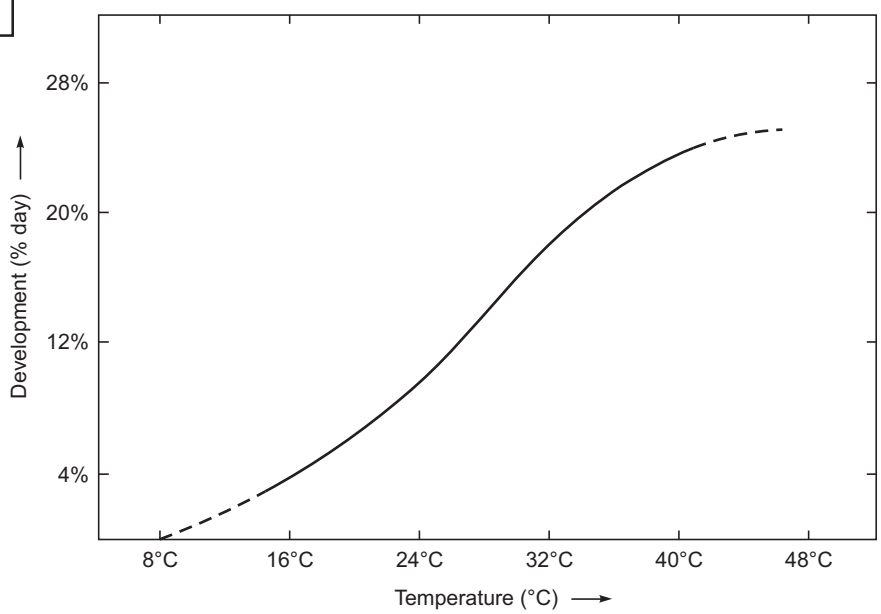

Figure III.7 Development of eggs of grasshoppers—*Austroicetes cruciata* is nearly linear between 16° to 36°C

temperature of the environment. The first group is called **endotherms** and the second group is called **ectotherms**.

"**Endotherms** regulate their temperatures by the production of heat within their bodies ; Ectotherms rely on external sources of heat." (Begon, Harper and Townsend, 1990, p. 48). (Quotes are author's). Earlier the endotherms were called **homoiothermic** and ectotherms **poikilothermic.** There are however some differences in the precise meanings between these two sets of terms. But the aim of this small book does not warrant such refinerments. We may even use a still simpler set of words without losing much. These are **wormblooded** for endotherms and **coldblooded** for ectotherms. (Recently biologists have found that some endotherms can alter their body temperature to suit their situations).

Devices for coping temperature variations

6.1.(4). Most places in Earth experiences seasonal changes in temperature. Organisms living in a particular place have to cope with its temperature. Generally this is done in one of the three following ways :

(*a*) Behavioural adaptations
(*b*) Anatomical changes and
(*c*) Physiological adaptations.

Here are a brief account of these.

a. Behavioural Adaptations. Animals tend to move into and away from places of favourable and unfavourable temperatures respectively. Basking in sun by grasshoppers, crocodiles and snakes etc. are temperature adaptations by cold blooded animals. Birds mostly fly about in mornings and evenings when the air is cool and rest in shade during mid-days which are hot. In winter mornings grasshoppers after crawling out from under the grasses, perch on the grass-tips placing their broad-sides towards sun and thus absorb maximum solar radiation. After absorbing enough heat they start hopping about. Again during mid-day, if it is very hot, grasshoppers will either hide under grass or sit putting their heads towards the sun so as to absorb minimum heat. In winter crocodiles mostly sit on the riverbanks basking. During spring and winter rattlesnakes in North America regularly bask on rocks. Trees however being rooted have little scope of such dynamic behavioural adaptations. The leaves of some plants hang down during mid-day to avoid too much heating and the resultant water-loss from transpiration through leaves. Most trees however have thick barks to protect these from extreme heat or cold.

b. Anatomical Adaptations (changes). The most dramatic anatomical adaptations are found in the hearts of vertebrates (animals with backbone). The endotherms (birds and mammals) have a four-chambered heart. The ectotherms have either a three-chambered heart (amphibians and reptitles) or a two-chambered heart (fishes) Figure—III.8. Here is a brief explanation. Broadly vertebrates can be either completely aquatic like fishes or partly aquatic or partly terrestrial like amphibians or fully

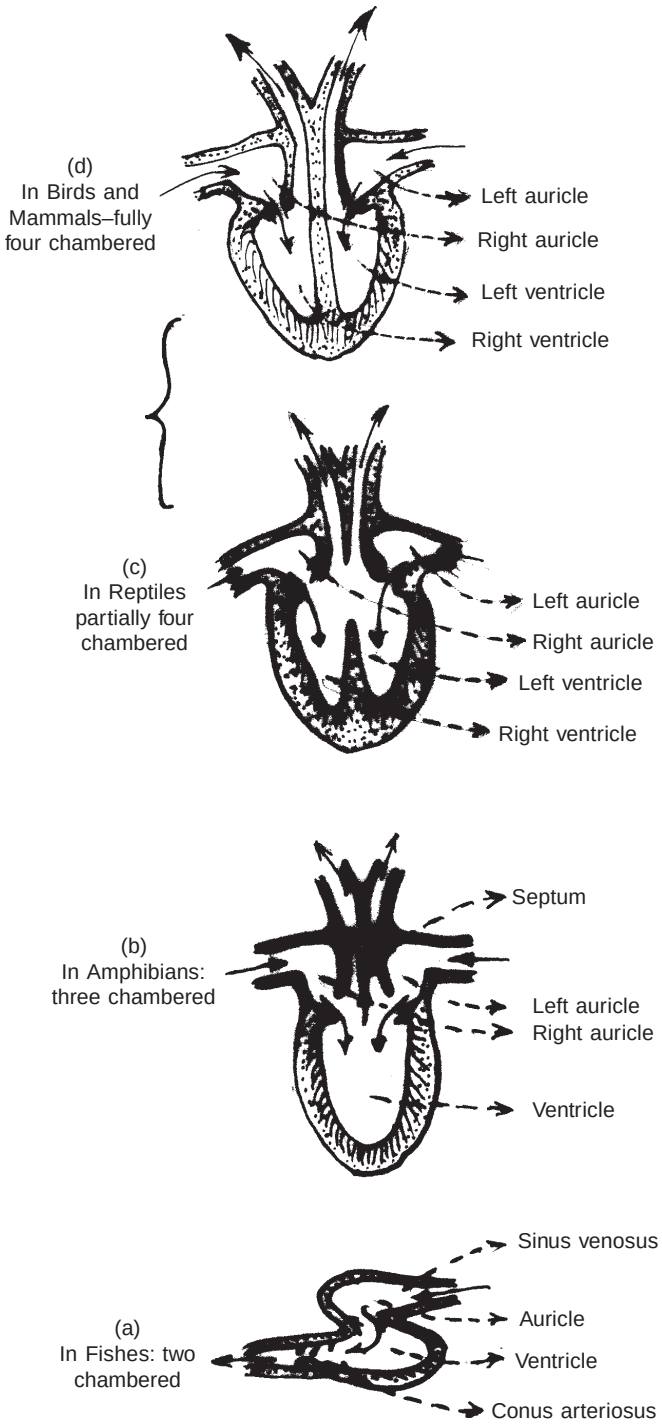

Figure III.8 Evolution of Heart in Chordata.

terrestrial like reptiles, birds and mammals. Fishes and amphibians are ectotherms while birds and mammals are endotherms. The reptiles are of intermediate type. The anatomy of the hearts of each of these group are also quite distinct.

Anatomy of Heart and Body Temperature

b.(*i*) The simple and small hearts of fishes consist of only a series of four linearly arranged chambers through which only non-aerared blood flows. These chambers are, starting with the fish—sinus venosus, auricle, ventricle and conus arteriosus (Fig III.8a). In fish deoxygenated blood from the entire body returns to the sinus venosus and moves on through the auricle to the ventricle. The ventricle pumps the blood through the conus to the ventral aorta from where blood flows into the gills for oxygenation. Then this oxygenated blood flows through the body providing oxygen to the tissues and finally returns to the sinus venosus deoxygenated. The cycle is repeated again and again as long as they live.

b.(*ii*) The next higher group are amphibians, who have lungs for aerial respirations, have developed a partition in the auricle making it two chambered—right and left auricles. So instead of one auricle and one ventricle, an amphibian heart has two auricles and one ventricle i.e., it is a three chambered heart. The right auricle receives the deoxygenated blood from the body while the left receives the oxygenated blood from the lungs. But in the next chamber—the ventricle as it is unpartitioned, the oxygenated and deoxygenated blood gets somewhat mixed but not fully (Fig. III.8.b.). When the ventricle pumps the blood forward, owing to a special septum* in conus arterious, the relatively less oxygenated blood is guided to lungs for oxygenation and the more oxygenated blood is sent into the body. Thus in amphibians we first come across the beginning of a double circuit heart which keeps the deoxygenated and oxygenated bloods somewhat separate and send these into two directions—deoxygenated to lungs and oxygenated to body. Still the amphibians' bodies do not receive fully oxygenated blood but only a mixture of oxygenated and deoxygenated. Hence they are cold blooded or ectothermic. That is why amphibians can stay only in warm places.

b.(*iii*) Amongst the **fully terrestraial** vertebrates such as reptiles, birds and mammals, the ventricle too is devided into two chambers. So now there are four chambers—two auricles and two ventricles and hence the oxygenated and deoxygenated bloods do not mix any more. Deoxygenated blood from the body enters the right auricle and thence to the right ventricle from which it is pumped into the lungs for oxygenation. The oxygenated blood from the lungs returns to the left auricle and from there to the left ventricle. The left ventricle pumps the oxygenated blood to the body from which the spent blood returns to the right ventricle. The cycle begins again (Fig. III.8.e). Owing to the presence of two auricles

*Septum—partition; a deviding wall

and two ventricles in the hearts of birds and mammals, the oxygenated and deoxygenated bloods remain separate throughout their flow through the heart. That is why such hearts are known as double circuit heart. This is the basis of their warm bloodedness and hence they are called endothermic. So they can stay both in cold as well as warm places. (Reptiles' hearts are only of intermediate type between amphibians in one side and birds and mammals in other side).

b.(*iv*) There are many other anatomical features which reflect remarkable adaptations to ambient temperatures. Here we shall briefly touch upon only two. **Blubber** : In order to retain the body-heat mammals living in the freezing arctic zones develop especially thick (3-6") layer of fat under their skin. This thick fat layer is called blubber. Polar bears, seals, whales living there all have bludder. These thick blubbers yield so much of oil that Eskimos use this oil to light lamps in their igloos. **Feather:** Bird feather is a specially structured insulating device. Feather not only prevent heat from escaping from the bodies of birds' in winter, these also keep the high heat of summer out. The soft belly feather of Eider ducks which are known as down feathers are used as stuffing for quilts and pillows for use in extremely cold places.

Insulation and Body Temperature

***c*. Physiological Adaptations.** Physiological adaptations to inclement temperatures are equally interesting and variegated. Neverthless for the sake of brevity and conforming with the aim of the book we shall mention only two.

***c*.(*i*) Hibernation :** This is a state of dormancy adopted by some vertebrates to tide over severe winter conditions. Some amphibians, reptiles and mammals hibernate during winter. Before the onset of winter such animals eat plenty to accumulate fat in their bodies. During winter amphibians and reptiles enter into a safe hiding place, become dormant and wait for the return of spring when their body become warm enough enabling them to move about. Mammals such as, bears, rabbits hamsters who live in places which become snow-covered during winter mostly hibernate. When snowfall sets in bears enter into specially prepared dens, curl up and enter into a deep winter sleep. They come out of their dens lean and hungry only in the beginning of spring. Other hibernating mammals also follow more or less the same pattern of hibernation. During hibernation to conserve energy store of body, both the heart-beat and body-temperature drops severely. For instance, the heart-beat of hamsters (a type of squirrel) drops from 110 to 10. Metabolic activity too is brought down to a minimum. This is just as well as, the lower the heart-beat etc. the lesser the need to generate heat by burning fat.

***c*.(*ii*) Aestivation :** While hibernation is a device to tide over severe cold, aestivation is a device to tide over severe summer heat and drought. Dipnois or fishes with lungs, adopt this. Lung-fishes are natives of Australia, South-west Africa and South America. *Protopterus* sp. a

lung fish live in the shallow swamps of Afrika. During summer most of such swamps dry up. So during summer Australian lung-fishes i.e., *Protopterus* sp. aestivate. Just prior to the onset of summer draught *Protopterus* enters into large egg-shell like cavities, well under the mud bottom, secrete senough mucilege and curl itself up within a cocoon of mucilege lodged safely under the mud bottom and wait till the return of rains (Fig. III.9). This over-summering device is aestivation.

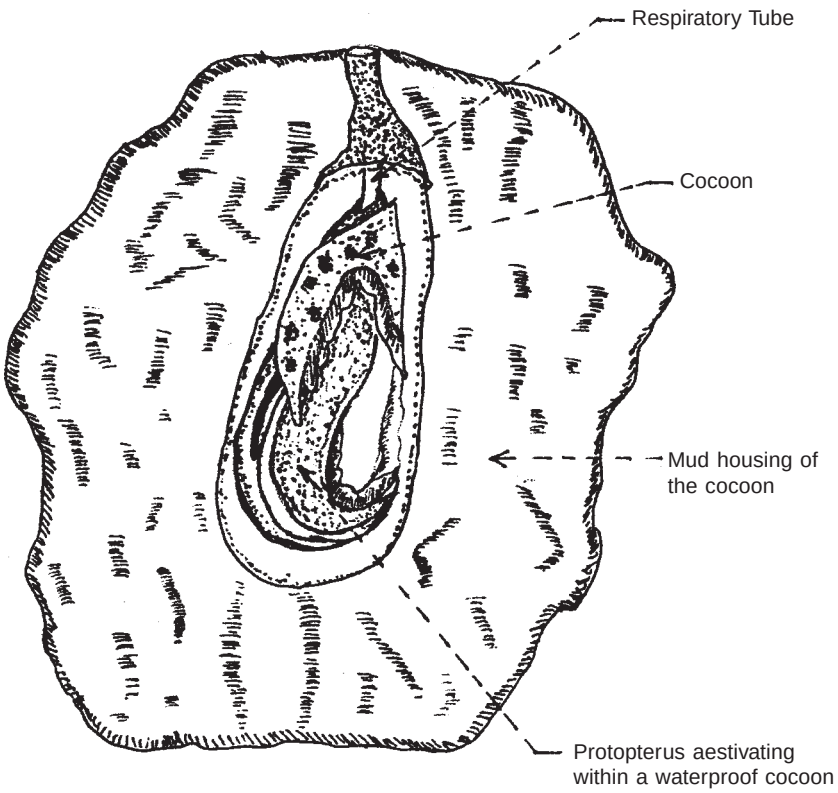

Figure III.9 A *Protopterus* (lung fish) aestivating during summer.

6.2. LIGHT

2.0. Sun Light is a crucial ecological factor. Without sunlight all the pulsations of life will cease and then in very short time our lovely and living Mother Earth will turn into a barren LIFELESS mass spinning around sun like other planets.

2.1. Sunlight supplies the energy required to synthesise biomolecules by green plants using simple inorganic molecules—CO_2 and H_2O. Green plants do so by trapping solar energy with the help of their green pigment—chlorophyll. This synthesis of biomolecules by green plants using solar energy is known as PHOTOSYNTHESIS. The quantity of

solar energy thus trapped by green plants is the ultimate source of all energy used by all other types of living beings including human beings, all over the world. Thousands of years ago the Vedic philosophers of India rightly understood the significance of SUN and praised him as the ultimate saviour of the world.

2.2. Here is a simple formula showing how much solar energy is trapped into a biomolecule through photosynthesis.

$$6CO_2 + 6H_2O + 709 \text{ kcal} \text{ ------- } 6O_2 + C_6H_{12}O_6$$

Here the quantities of inorganic compounds are in terms of moles* and energy is in terms of kcals** Green plants are the only group of living beings who can prepare their own food trapping sun's energy. This is why green plants are called **autotrophs.** These biomolecules when break down release the solar energy trapped inside which is then used to power all the subsequent biochemical reactions inside a living body. Thus sun is the ultimate source of all biological activities on earth.

Solar energy and visible light

2.3. The electro-magnetic waves which emanate from the sun are mostly lethal to life. Most of it is stopped by the upper layers of earth's atmosphere and only a fraction of it which is visible light reaches, the surface of earth. This visible light which again consists of only a small range, beginning with a fraction of ultraviolet and ending with fraction of infra red light, is the energy source of all the photosynthesis and other biological activities on earth (Fig. III.10).

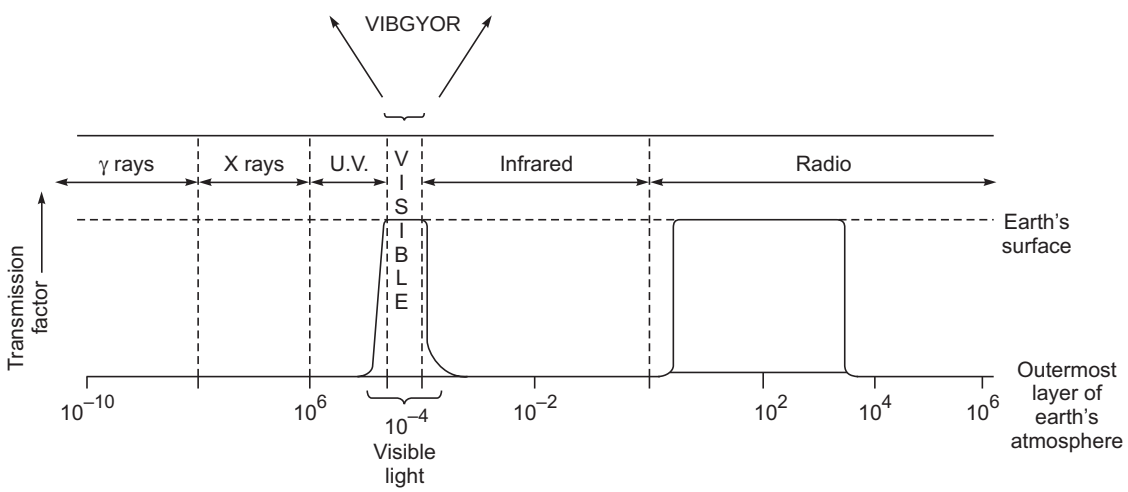

Figure III.10 The relative transmission of solar radiation from the outermost layer of Earth's atmosphere to the surface of earth.

*Mole: That amount of a substance whose weight equals to its atomic weight in grams.

**Kcal: One thousand calories (calorie is an unit of heat).

2.4. Photosynthesis is mostly limited to visible lights which has a wavelength range from 400 (near U.V.) to 750 (near I.R.) microns***. The rate of photosynthesis however varies somewhat with the wavelengths of visible lights (violet, iindigo, blue, green, yellow, orange and red). (This set of visible light is briefly named as 'VIBGYOR'). In terrestrial locations the colour composition of light does not vary much but in aquatic situations it is not so. In deeper waters reds and blues are filtered out and the resultant greenish light is left for chlorophyll for photosynthesis. So as an adaptation to life in deeper waters, the red marine algae have developed supplimentary pigments—*phycoerythrins* which enable these algae to live in deeper waters.

Wavelength of light and photosynthesis

2.5. Photosynthesis depends upon besides colour of light (wavelength), also on intensity of light (foot candle) and duration of light (day length). Unlike rainfall which may vary from year to year, in the same location, sunlight for a particular location remains unchanged from year to year. Both in land and in water photosynthesis increases with the intensity of light but only up to a point after which, it decreases. Actually at high intensities of sunlight photo-oxydation of enzymes reduces synthesis. **This is why in full sunlight, marine phytoplanktons move down from the surface of the sea to the deeper waters.** In forests as trees cannot move about, these adapt to different intensities of sunlight according to their locations in the forests. For example, young seedlings of pines are shade adapted but the older seedlings which are taller, are unable to survive under a canopy.

Photosynthesis Role of Light and Heat

2.6. Just as too much sunlight is limiting to photosynthesis so is heat. An interesting example are orchid flowers. In nature these grow in colder places under shades. But it has been found that orchids can grow quite well in sunlight, if temperature can be kept low. So now-a-days orchid-growing in temperature controlled green houses is a good business in many countries. In India too orchid growing can be a good business.

2.7. Duration of sun-light or day-length controls many biological events. Activities such as flowering of plants, seasonal migration of birds, laying of eggs by birds, insects etc., and many other activities are regulated by day-length (or in some cases the reverse of day-length i.e., length of dark-period). The reason behind this linking such biological activities with sun light is not difficult to understand. Sunrise and sunset are the most dependable natural qualities of a particular location of earth. So if, biological events are timed by day-lengths, rarely will these fail to meet the needs of Nature. For instance, birds time their egg laying in such a season when the fledgelings will have maximum chance of finding food and hence survival. So do insects, so do plants, so do fishes and many other living beings. Sir David Attenborough the renowned biologist in his

Photoperiodsm or Ecological clock

***A micron μ is 1/1000 of a mm. and a m μ (millimicron) is 1/1000 of a micron.

beautiful book 'The Trials of Life', 1990. page 11-14, has described very touchingly the phenomenon of egg-laying by land crabs (*Gecarcoidea natalis*) of Christmas Island in the Indian Ocean, during a particular season. Here are a few lines from him. "Soon the sea is fringed with a moving scarlet carpet of glinting shells, grappling legs and craning stick-like eyes. When at last the waves sluice over them, each shakes her body convulsively so that the brown eggs swill away in the water and, with a touching gesture of apparent exultation, lifts her claw above her head as if waving a salute."

2.8. With growth of our knowledge about photo-periodism many specific terms have been introduced to denote specific situations or responses for specific animals and plants. Diapause for insects, Aestivation for lung-fishes, Hibernation for mammals, reptiles and amphibians and Seasonal Migrations for birds and whales etc. are various types of physiological adaptations meant to synchronise Life with Rhythms of Nature. Such adaptations which are also known as Environmental Clocks are imprinted in the genetic make-up of animals and plants and animals who adopt these, can follow the pattern unerringly throughout their lives.

2.9. The study of photo-periodism is a relatively new but fast growing area of biology. Commercial breeders are programming the breeding seasons of fishes and poultry in such a way so that their profit margin goes up. This they do by manipulatiing day-length with artificial light (Fig. III.11). Now-a-days poultry owners routinely do this. Such techniques are now being adopted for flowering plants as well other animal species.

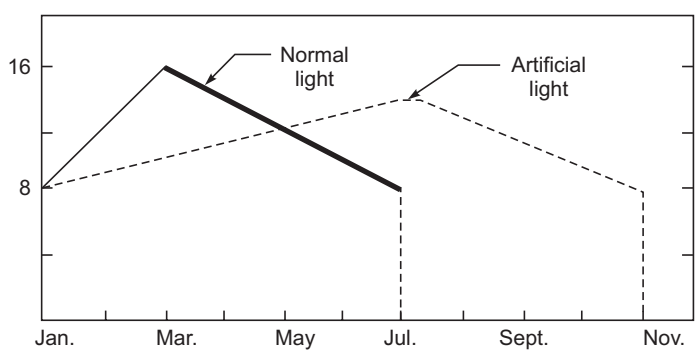

Figure III.11 Control of breding of brook trouts by artificial lighting.

6.3. WATER

3.0. Water or Moisture is another crucial ecological factor. Although essential for survival and growth nevertheless the quantity and quality of water available in different habitats poses various types of threats. Such

threats lead to adaptive radiations (i.e. adaptive changes in the structure and physiology leading to speciation*).

3.1. Animals living in fresh waters have to tackle the ingress of too much of water into their bodies while reverse is the problem in saline waters (seas). The Osmotic pressure of fresh-water being very low and that of body fluid much higher, water tends to enter into the bodies of fresh water animals while, the osmotic pressure of sea-water is higher than the body fluid of animal living there ; hence marine animals tend to lose water in salt water. So from the point of view of water-balance in the body fluid of animals, fresh water is too wet and sea is too dry. Sea may be likened with desert. Brakish waters (waters in river deltas opening into seas) present a situation intermediate between freshwater and marine. Such borderline habitats are usually very rich in variety of liviing beings as these have a variety of microecosystems.

3.2. In brakish water ecosystems, specially in river deltas, like Sundarbans of Bengal, where large tracts of inter-tidal zone with muddy soil prevail, a special type of plants grow. These have special air—breathing roots—pneumatophores, which stick out vertically from mud flats to breathe air when tidal water recedes (Fig. III.12.). This unique device is developed by a number of species of such habitats. Such species occupy and prosper in tidal zones. In this way hundreds of square kilometres of intertidal zones have been afforested all over the world. Thus grew mangrove ecosystems. The world famous abode of 'Royal Bengal tigers' the Sundarbans of West Bengal and Bangladesh is thus created by Nature in the mouth of the river Ganga. Mangroves are extremely rich in food materials and because of its intertidal nature and forests, the mangroves have become the breeding ground of many important species of prawns and fishes etc. Besides fishery and tigers, the Sundarbans is also the abode of deers, crocodiles, and many other important species of fishes and bees etc.

Mangroves and protection of sea coasts

3.3. These mangrove ecosystems not only protect the coastal areas from the severity of storms and cyclones but also help to extend the forests of the deltas. Unfortunately however human greed for quick profit has resulted in extensive destruction of mangroces in West Bengal and Orissa. The recent ravages suffered by Orissa from cyclone (Oct. 1999) is particularly aggravated by the destruction of the mangroves of Orissa coasts. This cyclone has harmed commercial breeding of prawns. In India, K.R. Naskar is engaged in an in-depth study of Sundarban ecosystem particularly its flora (2004, Manual of Indian Mangroves p. 1-220, Daya Publishing House, New Delhi—110 002).

*Speciation: The biological process of evolution of a new species. (Evolution and speciation of Darwin's finches in Galapogos Islands is is very good example of speciation. Even to-day new specis of finches are evolving there).

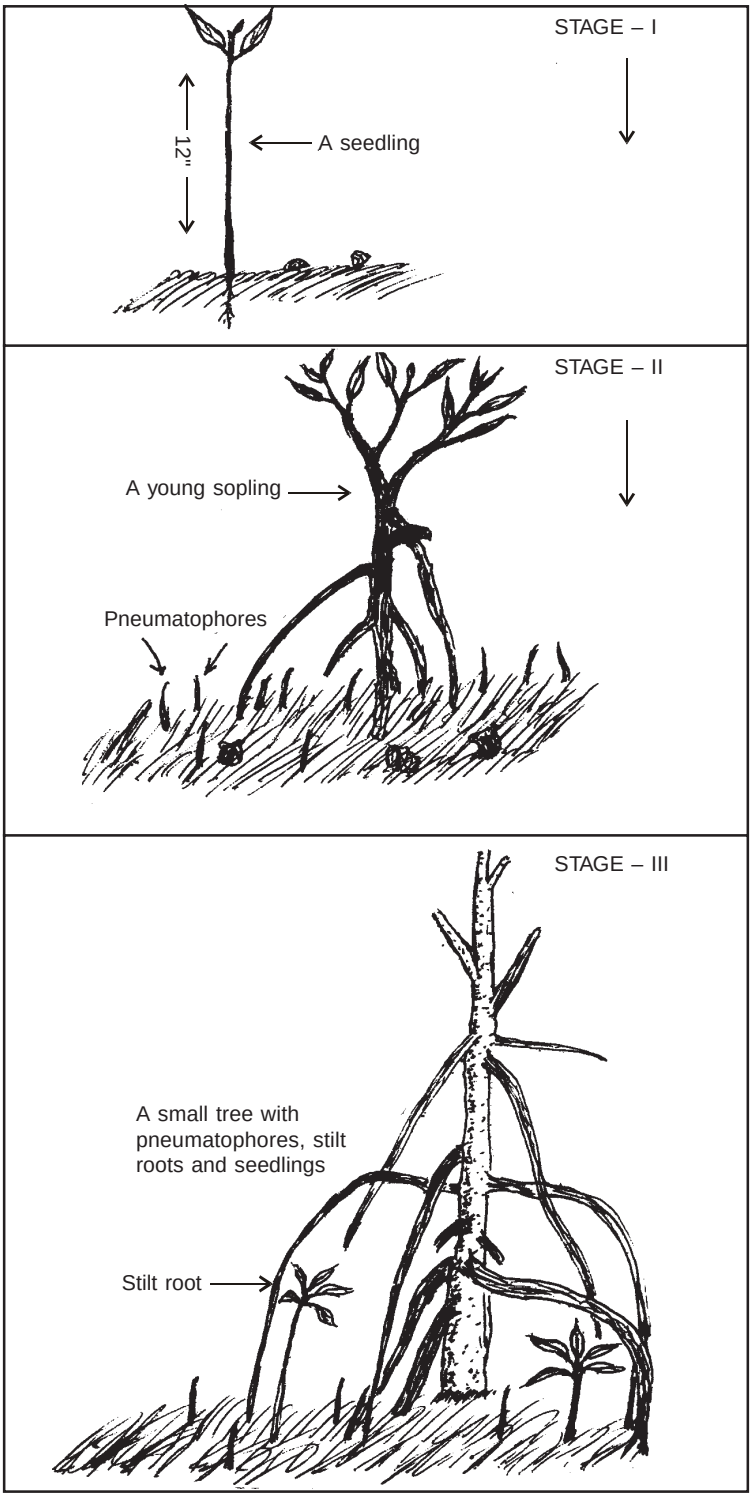

Figure III.12 Mangrove plants with their pneumatophores.

3.4. The nature of the terrestrial ecosystems mainly depends upon two things:

(*a*) amount of rainfall per year and
(*b*) how the rainfall is distributed over the year.

Roughly, depending on the total amount of rainfall per year, ecosystems can be grouped into four types.

I. Desert— 0-10˝ per yr. (Sahara of Africa, Thar desert of India and Pakistan)
II. Grassland/Savanna—10-30˝ per yr. (Serengeti National Park of Kenya)
III. Dry Forest— 30-50˝ per yr. (Rajasthan and Madhya Pradesh of India)
IV. Wet Forest— 50˝ and above per yr. (Congo watershed of Africa, Sub-Himalayan forests of India and Amazon forest of Brazil).

There are more example of each type. There is however one important point to remember. The above classification is based only on the total rainfall in a year, irrespective of distribution of this rainfall over the year. Rainfall, even relatively low—for instance 30" if distributed more or less evenly over the year can support a nicely woody ecosystems and beautiful glens as in Gt. Britain but if, it is concentrated to only 1 to 2 months of the year, this will invariably lead into a savanna type ecosystem as in Africa.

3.5. The retentivity of rainwater by soil is another important point for plant growth. Clay soil can retain more water than loam soil and loan soil more than sand soil. For agriculture loam soil is most suitable as, it is both porous and hence facilitates breathing of air by plant roots and also it can retain enough moisture for good plant growth while, clay soil tend to become too hard for roots and sandy soil looses moisture too soon.

Nature of Soil and Humidity & plant growth

5. RAINFALL AND TEMPERATURE ACTING TOGETHER

5.0. Right amount of water and right amount of heat are musts for every living being for its survival and prosperity in a place. The only exception to this rule are the human beings (*Homo spaiens*) who through their unique quality—the power of thinking, have created artificial environments which they can carry along with them (clothings) and thus occupied every corner of earth.

5.1. The effect of humidity and temperature are however interlinked. The effect of a particular amount of water in a place at a particular temperature say ‘x’ will be quite different in the same place with the same amount of water but at a different temperature say ‘y’. This is because the warmer a place is the quicker water tends dry up in that place. Here is an example.

Let us take four chambers all 1 litre each and all containing 20 cc of water each. Let us keep these four chambers at four different temperatures—. These are 10°C, 20°C, 30°C, and 40°C. Now let us examine the relative humidities in each of these four chambers (Fig. III. 13.).

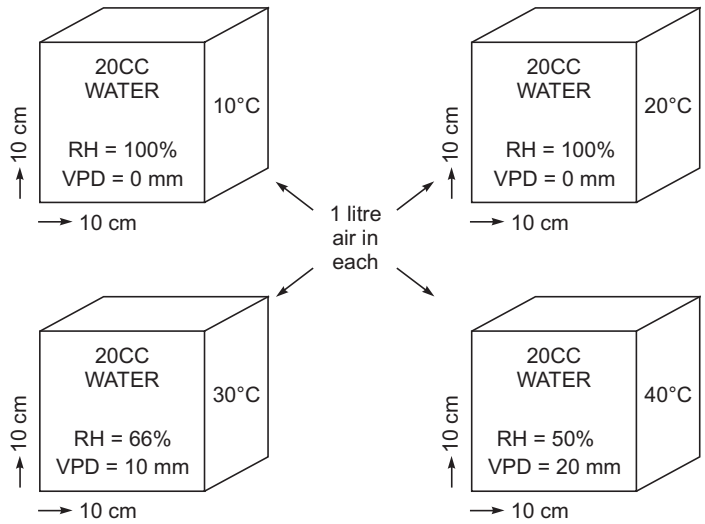

Figure III.13 Changes in the R.H. (relative humidity) and VPDs (vapour pressure deficits) of same enclosed spaces at different temperatures but containing same amount of water.

5.2. One litre of air at 20°C can hold a maximum of 20 cc of water when the relative humidity (R.H.) would be 100%. But at 10°C it can hold only 10 cc of water; so the R.H. will not only be 100% but the chamber will also contain 10 cc of liquid water as dew. Similarly to be at 100% R.H. the chamber at 30°C will need 30 cc and at 40°C will need 40 c.c. of water. Therefore the relative humidities of these chambers which all containt same amount of water i.e. 20 c.c. each, but are at different temperature i.e. 10°C, 20°C, 30°C and 40°C will be 100%, 100%, 66% and 50% respectively. This means that at lower temperature air with same amount of water will be saturated and the extra water vapour will settle as dew while, at higher temperature the reverse will happen—the air will be relatively dry so, the plants may suffer from draught. *Therefore the effect of water vapour on an ecosystem is intimately associated with the ambient temperature of that place.*

Climograph

5.3. Considering the above points it is now generally accepted that an overall combined picture of rainfall and temperature of a place would be a very useful guide for agriculturists. Climograph gives such a picture. A climograph is a two dimensional graph giving the rainfall and temperature of a place as monthly averages (Fig. III.14.). If the climograph of a

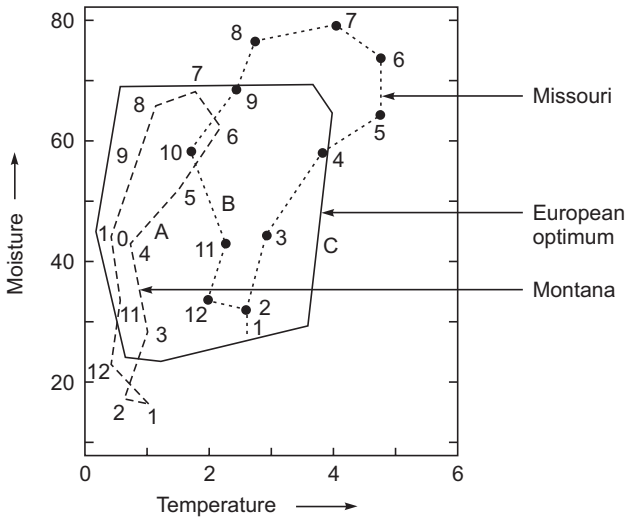

Figure III.14 Temperature-Moisture climographs of three places.

district is compared with that of another district one gets a very good idea regarding the suitability of a place about the cultivation of a particular crop. Thus climograph which sumarises two important parameters of climate of a place, over the year, helps us to guess intelligently the likelihood of success of an imported species to be established in a place or not.

5.4. Summing up: So far we have discussed very briefly, four important environmental factors which play crucial roles in determining success of a species—in fact any species—in a particular habitat. These factors are :

1. Temperature
2. Light
3. Water
4. Rainfall and Temperature acting together.

This list is not all. There are other factors which also play important roles. Some of these are soil and its pH, air current and pressure, microenvironments and pollutants etc. Although these are important considerations neverthless considering the scope of this small book we are leaving out this rather vast area of information. The book is for 'millions' so kept limited to basics.

6. *ECOLOGICAL NICHE* (THE HUTCHINSON CONCEPT)

6.0. We however have got enough exposure regarding the role of environment on population to introduce a very important ecological concept—**Ecological Niche.**

6.1. The term 'Ecological Niche' is in vogue for more than half a century but only much later a more precise definition emerged. *Broadly, ecological*

niche means the sum total of the limits of various environmental factors within which a species can successfully survive, breed and prosper to maintain a stable population.

6.2. Let us examine this statement a bit closely. A species may be able to tolerate a very wide range of temperature of which a relatively narrow band would be suitable for breeding, an wider band for growth and the entire range for the survival of the individuals (Fig. III.15). This is a simple graph—a line. But as we have discussed earlier, the combined effect of temperature and humidity would mostly result into a narrower range for survival (Fig. III.16). This is a two dimensional figure - an area. If another factor for instance current flow, is also brought into consideration than the range which would be found suitable would be even narrower (Fig. III.17). The situiation depicts a three dimensional figure—a volume.

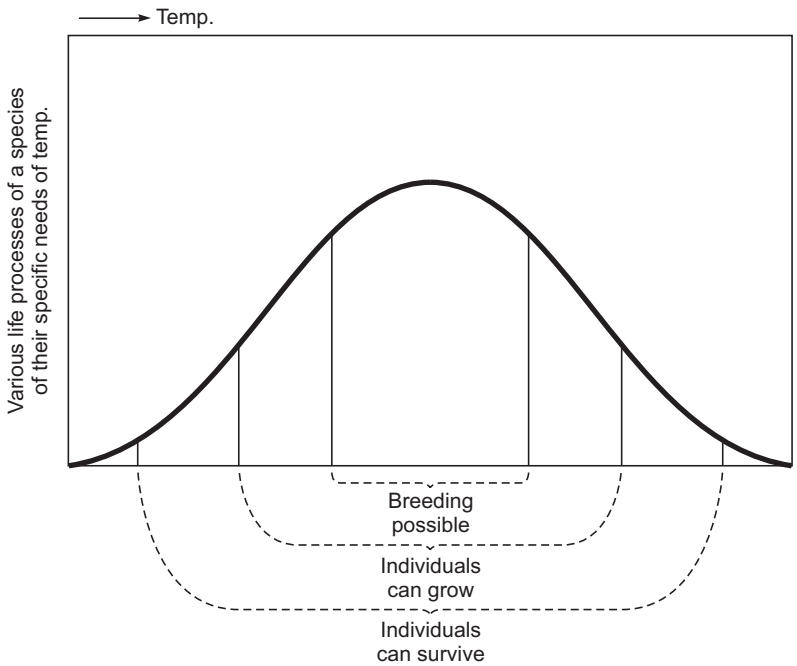

Figure III.15 Range of temperatures which a species can tolerate.

Hutchinson concept of Ecological Niche- a n-dimensional hypervolume

6.3. In Nature however in order to breed, survive and maintain a stable possible population a specied has to face several factors such as, temperature, humidity, air current, salinity of soils, minerals, sunlight and so on. Each factor will impose its own limitations on the range. The combined effect of all these factors determine the **effective or realised niche or ecological niche of a species.** *Therefore the true 'Ecological Niche' can be thought of as an n-dimensional hypervolume within which*

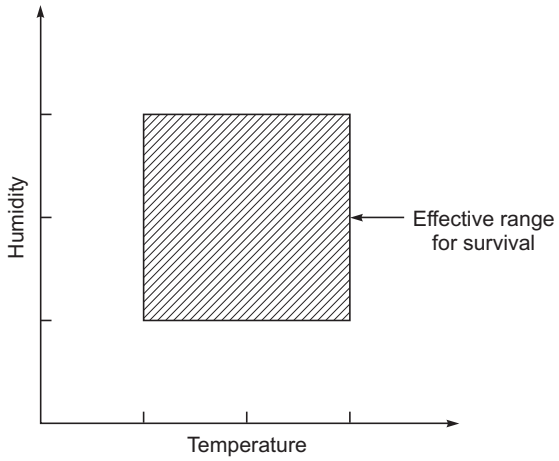

Figure III.16 Effective Range for Survival when temperature and humidity are considered together.

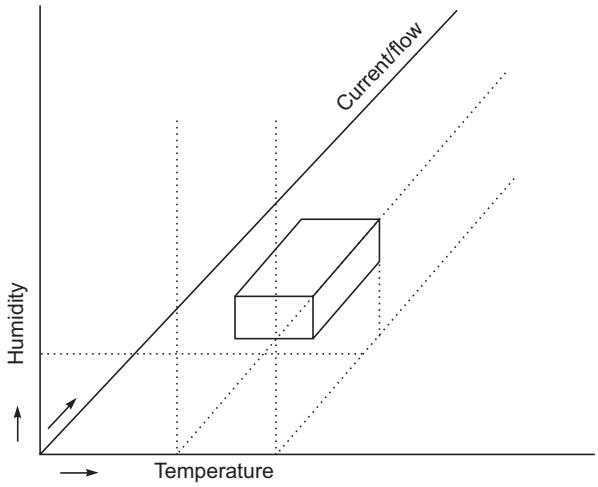

Figure III.17 A three dimensional Ecological Niche.

the species can maintain a viable population (Begon et. al. pp. 76). This concept was first proposed by G. E. Hutchinson in 1957. Since then it is known as Hutchinson concept of ecological niche. More about this will come later.

7. ERAS OF HUMAN CIVILISATION

Rise in Productivity and Human Population

7.0. Since the dawn of human civilisation plants are intimetely involved with its growth and spread. Civilisation has four distinct chronological phases. The earliest phase is the stage of the **Hunters;** the second phase

is the phase of the **Pastorals;** the third phase is the phase of the **Agriculturists** and the latest phase is the **Industrial phase** i.e. the phase of today.

The Hunters

7.1. The Hunters mostly lived by hunting animals and on fruits and roots. Meat was their main food and hide their raw material for clothings, huts and lining of the caves. The bones of animals were used as tools. Hunters also used to eat roots and fruits as and when they found these. Hunters scarcely affected forests. Even today some of the Australian natives live in this way. Hunters who drew the beautiful rock paintings of bisons in the caves of Altimara reindeer herds in Castelon, Spain are glorious example of their culture - which flourished about 20,000 years ago.

The Pastorals

7.2. The people of the second phase i.e. the Pastorals learnt to domesticate some animals mostly cows , horses and dogs. They used to own huge herds of such animals and moved then for grazing, from season to season over vast tracts of land. Even today there are some well-known pastoral people. Some people of Mongolia are horse herders; Bedouins of Arabia are camel herders ; Lapps of Northern Scandinavia are reindeer herders. Pastoral people follow their herds as these move from place to place in search of grazing ground. Pastoral people too did not fell forests. Such people meet most of their daily needs from their herds—but not all. Tea which is a product of agriculture is used regularly by many of presentday herdsmen.

The Agriculturists

7.3. The third phase people the agriculturists came next and formed bases of predominent human civilisations all over the world. The Agriculturists owing to their dependance on cultivating selected plants in continuous areas, had to fell forests extensively to do so. Today in some areas of U.S.A. and Canada there are miles and miles of continuous tracts covered with corn or wheat only. Most people today are dependant on agricultural products. Many of the beautiful edifices such as the magnificient pyramids of Egypt, beautiful temples of South India and gorgeous palaces of Europe are products of agricultural societies.

The Industrialists

7.4. The fourth and the latest phase is the Industrial age. In many places of today's world we find an admixture of agriculturists and industrialists. In fact these two phases have become interdependent. In this stage Mother Nature is being exploited most ruthlessly and most extensively by using highly sophisticated tools for both animal husbandry as well as agriculture. No part of Earth today, which were earlier left alone for their apparent inaccessibilities, be it freezing arctic, be it scalding desert, be it mosquito-infested swamp, are any more safe from the prying eyes and greedy fingers of today's men—*Homo sapiens*.

7.5. As one civilisation succeedes another, mens' power to extract more food from the same area increased and so did human population (Fig. I.1 and Fig. III.18 and Table I.1). Consequently from five million or less, about 10 to 12000 years ago—at the dawn of civilisation, today, human

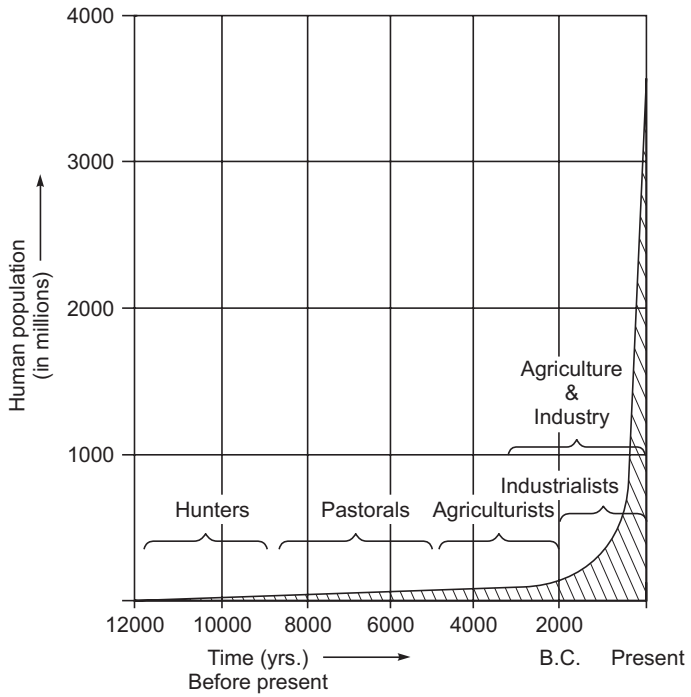

Figure III.18 Growth rate of human population over the last 12,000 years. (Partly from Atlas of World History Harper Collins 1978, p. 36 and Environmental Geology. A.E. Keller, 2002, p.10, Prentice Hall.)

population has surged to a staggering 5000 million or more ! No corner of Mother Earth is safe from loot by us. This horrendous growth of population of *Homo sapiens* must be stopped and our population should be reduced to a level, we believe, of 1000 million or so for the entire world. Otherwise our doom is not far. India for example, should reduce her (and also for all countries with such populations) to 200 million or so and China to about 300 million or so. Till this is achieved we fear, the quality of life of these densely populated countries would always remain low in comparison with land-rich Euro-American and Australian people. To-day the entire world must stand hand in hand to fulfil this aim.

Civilisation and growth of Human Population and the ills that are following

7.6. One of the several damages this spurt in human population growth has caused to Earth is disturbing of the water-balance of soil. Normally rainwater falling on forests or grasslands mostly gets absorbed into soil before the surplus water runs off into the rivers, lakes and seas. Owing to this, very little soil would be washed into the rivers. So the soil erosion would be minimal. But when trees are felled extensively to make way for vast agricultural tracts, rain water which hit the bare agricultural fields with loose and tilled soils, would quickly be washed into the rivers carrying huge quantities of top soil with it. (Table. II.1.). As a result of this washing off of the top soil into rivers and seas during monsoons, at

Agriculture and Soil Loss

least three damages occur. (*a*) As water quickly runs off into the sea, adequate rainwater does not enter into the deeper layers of the soil to recharge ground water. Hence ground water level gradually goes down, trees suffer, wells dry up and arsenic poisoning of well-waters shows up (explained earlier). (*b*) As top-soil from agricultural fields deposits into the river beds as silt, gradually the river beds become raised and so their water bearing capacity get reduced. Hence during monsoons rivers easily spill over the embankments and flood extensive areas. (*c*) As water bearing strata of soils (aquifers) slowly dry up even the forest ecosystems begin to suffer.

Importance of water management

Water is a precious commodity. Our planners must realise this and, take ecological principles into consideration while planning, carefully plan water-management and also ensure that the plans are implemented properly, regarding always water as a precious commodity.

Chapter IV

Bioenergetics

(Sun the Ultimate Source of Energy of Earth)

Topics

IV.1. Importance of Sun

IV.2. The Basic Principles Involved

IV.3. Light and Photosynthesis

IV.4. Energy Circuits

IV.5. Standing Crop, Carrying Capactity & Productivity

IV.6. Percentage of Solar Energy Used and World Productivities

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CHAPTER 4

BIOENERGETICS

(*Sun the Ultimate Source of Energy of Earth*)

" ওঁ জবাকুসুমসঙ্কাশং কাশ্যপেয়ং মহাদ্যুতিম্ ।
ধ্বান্তারিম্ সর্বপাপঘ্নম প্রণতোঽস্মি দিবাকরম ॥"

— from Vedas—a mantra on worship of sun

বৃক্ষবন্দনা

অয়ি ভূমিসখা হতে শুনেছিলে সূর্যের আহ্বান
প্রাণের প্রথম জাগরণে, তুমি বৃক্ষ, আদিপ্রাণ—
ঊর্ধ্বশীর্ষে উচ্চারিলে আলোকের প্রথম বন্দনা
ছন্দোহীন পাষাণের বক্ষ-'পরে ; আনিলে বেদনা
নিঃসাড় নিষ্ঠুর মরুস্থলে ॥

* * * * * *

ওগো সূর্যরশ্মিপায়ী,
শত শত শতাব্দীর দিনধেনু দুহিয়া সদাই
যে তেজে ভরিলে মজ্জা মানবেরে তাই করি দান
করেছ জগৎ-জয়ী, দিলে তারে পরম সম্মান,
হয়েছে সে দেবতার প্রতিস্পর্ধী— সে অগ্নিচ্ছটায়
প্রদীপ্ত তাহার শক্তি বিশ্বতলে বিস্ময় ঘটায়
ভেদিয়া দুঃসাধ্য বিঘ্ন বাধা ।

— from the poem "Ode to Trees" in the book "Banabani"
by Rabindra Nath Tagore.

1. IMPORTANCE OF SUN

1.1. Sun is the ultimate source of all energy of our Mother Earth. Not only the photosynthetic productions of all biomaterials of all ecosystems are powered by solar energy, but such spectacular sights such as, the giagantic Niagra Falls of U.S.A. pouring down 800000 gallons of water per second or the devastating hurricane like Mitch near South America or the horrible cyclone in October 1997 hitting the Orissa coast of India or the chilling landslides in Himalayan glaciers or the scalding and massive volcanic eruptions of Pina Tibu etc. all are powered by solar energy.

1.2. This section of this simple book will be devoted to an attempt to understand how solar energy powers ecosystems. A proper understanding of this process is vital for the survival and prosperity of mankind without causing irrevocable damages to our ecosystems.

1.3. Untutored though they were of modern experimental sciences, the ancient sages of humanity rightly guessed the importance of Sun in their lives. Sun was the most benevolent god to them and they wrote beautiful verses in praise of Him. The Sanskrit verse given in the begining of this chapter is from 'Vedas' (which is one of the two important books on Hindu philosophy)—written well over 4000 years ago. This sanskrit verse is recited even today in all Hindu religious ceremonies. This verse describes the resplendent beauty of Sun and His effects on our lives in just four exquisitely beautiful sentences.

1.4. The ancient Egyptians of the days of Pharaohs worshipped Sun as a god - the god RA. To them it is the sun-god RA who through his benevolent hands constantly showers blessings on his devotees in the form of food grains, cotton and all other things that they need (Fig. IV. 1.). Such beliefs were shared more or less by most ancient civilisations. The Hindus called the Sun god as / 'ARKA' / Or SURYA DEVATA, (there are

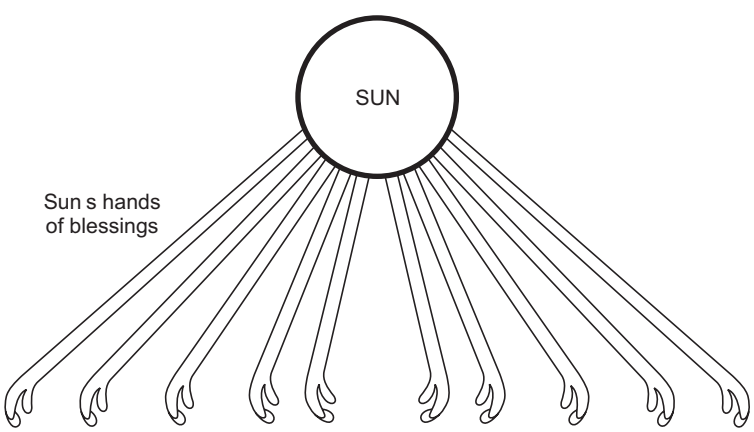

Figure IV.1 The sun god– "RA" of ancient Egyptians with his hands of blessings.

many other names as well). The religion of ancient Persians grew around Sun. In fact still today, Persians who are not converted to Islam, call themselves sunworshippers.

2. THE BASIC PRINCIPLES INVOLVED

2.1. First the solar energy is picked up by green plants. This energy locked into plants' bodies is passed on from them into animals providing energy for all their biological activities. Again as wood, coal and petroleum, plants provide energy for all other activities responsible for sprouting up and spread of human civilisation in its breath-taking splendour of today. This phenomenon has been beautifully described by the Indian poet Rabindra Nath Tagore in the second poem quoted in the beginning of this chapter. He said "Oh trees, by lending the power which you have drunk from the Sun, to men, you have made them so strong that they have conquered the Earth and now they are trying to challenge God himself". (The preceeding lines within italics are author's own translation of a part of this poem in an attempt to depict the spirit of this superb poem). This forms part of the 2nd poem in the begening of this chapter.

2.2. The properties of energy can be understood by following the basic laws of thermodynamics.

2.3. The First Law of Thermodynamics states that energy can neither be created nor destroyed; it can only change from one state to another. For example, from light to heat etc. When sunlight falls upon a surface it warms up the surface, which means light is converted to heat. There are many such examples.

1st Law

2.4. The Second Law states that at every step of conversion i.e. change from one state to another some energy will be invariably lost (or dissipated) into the environment. Consequently energy will always flows from a higher level to a lower level (Fig. IV. 2.).

2nd Law

2.5. The Third Law states that Nature if left to herself tends to lose energy and thus gradually sink to more and more disorder. In thermodynamics this is known as entropy i.e. a "hypothetical tendency for the universe to attain a state of maximum homogeneity in which all

3rd Law

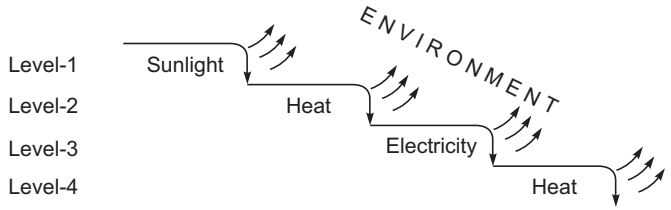

Figure IV.2 Loss of energy to environment (also called 'heat sink') at every change of its form.

matter is at a uniform temperature" (Webster's College Dictionary). In short, third law implies that without constant input of energy order tends to disorder. (It seems to me this is the likely reason of our finding so much of chaos and disorder and decay in societies where men are not very energetic, disciplined and orderly).

Death and Decay

2.6. The decay of bodies after death can be easily understood through this third law. To remain alive a living being requires constant input of energy. This energy is obtained through respiration followed by several subsequent metabolic processes. If the respiration is stopped then, soon the animal dies. The same thing happens with waterlogging of plant roots. After death when no longer energy could be supplied hence decay i.e. breakdown of tissues take over. So death simply means sessation of energy input.

Thermodynamics and Society

2.7. It may sound a bit queer but if we are prepared to think without bias we shall easily understand how a society's condition can be explained thermodynamically. Let us take two simple examples. To keep a road neat and clean the trees by its side must be pruned in time, roads must be swept regularly, sewerage lines must be kept free etc. All these require constant input of energy. Now if the persons who are entrusted with these tasks do not work enough i.e. not enough energy input is made in time for these tasks, gradually the roads will become dirty and dirtier, trees will become too big and sewerage will become choked etc. Soon in the monsoons water logging of the roads will take place and many other calamities will follow. Then everybody will raise hue and cry and finally seek monetary help from other countries. people are generally shy to admit that all these sufferings are due one simple preventable mistake—'a stitch in time'—maintainance of the roads in time. Thermodynamically this means not putting in enough energy in time to maintain order. Hence disorder takes over.

2.8. Same is true with the education system of many third world countries. For instance the poor state of education in many places of India to day, be it in schools, be it in colleges, or be it universities everywhere the energy input is far less than required for maintenance of order and relevence. There are instance where the syllabi and the methodologies of teaching and evaluation are standing still for more than quarter century. The inevitables are happening.

Enough of these social problems. Let us now move on to ecology.

Passage of Solar Energy through Ecosystem

2.9. In all ecosystems the Primary Producers or green plants trap solar energy into their bodies in the forms of roots, trunks, branches, leaves and fruits. These trapped energies are used by various secondary producers i.e. herbivores such as deers, cows, rabbits etc. to form in turn their bodies. The Tertiary Producers i.e., carnivores, such as tigers, cheetahs, hawks etc. consume the secondary producers to form in turn, their bodies.

2.10. Thus solar energy first trapped by Primary Producers (green plants) is passed on successively through Secondary Producers (herbivores), Tertiary Producers (carnivores) and so on until all the trapped energy is completely used up.

2.11. This transfer of solar energy from plants to animals however, is always partial (cf. 2nd Law of Thermodynamics), the unused energy being lost to atmosphere as heat. As a matter of fact in all such cases of transfers of energy from one form into another (here from plants to animals) are always accompanied with some loss of energy in the form of heat (cf. as above). This is shown in figure (IV. 2).

2.12. This progressive attrition of energy captured by plants, during its passage from plants through others such as herbivores, carnivores etc. till the energy is completely dissipitated, has led to the emergence of a very useful concept known as **Pyramid of Life** (or Ecological Pyramid) shown in Fig. IV 3. This concept of pyramid of life is graphically presented in a sequential order in which energy is passed on through all categories of living beings of any ecosystem. Such graphical presentations may use either **energy** or **mass** or **number** as parameter. Let us take as an example—the Indian forest of Nilgiri Mountains in State of Chennai. Here grasses, creepers and trees are the primary producers ; the deers, elephants, monkeys, birds and insects etc. are the secondary producers ; and the tigers, wolves, wild dogs and snakes etc. are the tertiary producers. If we draw three ecological pyramids of this forest using the above three parameters, the shapes of the pyramids will vary according to the parameter used and the nature of the ecosystem (Fig. IV. 3a, b and c).

Ecological Pyramid

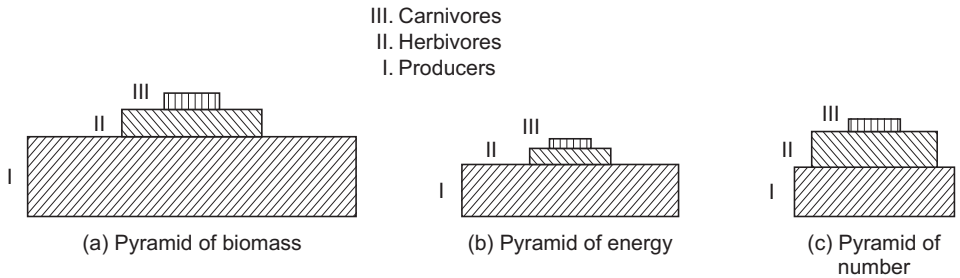

Figure IV.3 a, b, and c Ecological pyramids or pyramids of life.

2.13. Normally one may expect that an ecological pyramid will have the shape of an usual pyramid i.e., a tetragonal cone with a wide base like "Pyramids of Egypt". But this is not always so. The shape of the pyramid i.e. Pyramid of Life depends upon both the parameter and also the nature of the ecosystem (as mentioned earlier). For instance, if the parameter is **number** but he ecosystems are different—one a **forest** and another a **grassland**, their pyramids would be somewhat like this (Fig. IV. a and b).

Parameters and the shape of the Pyramids

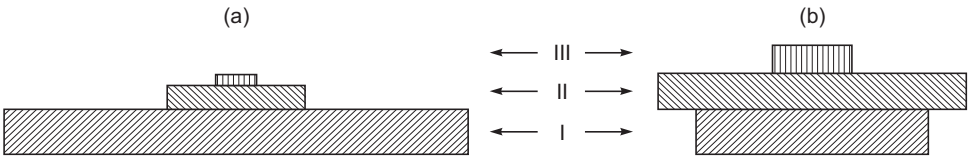

Figure IV.4 a & b Pyramids of number of two different ecosystems
(a) Grassland (African savannah) (b) Forest (Congo river basin).

2.14. In both the figures the stages I, II and III are arranged on the basis of their numbers. In (*a*) i.e. grassland the number of grasses are far more numerous than the herbivores—mainly antelopes, deers and wildebeests but in (*b*) i.e. forests the number of trees and shrubs are less than the total number of herbivores which include birds and host of insects etc. So here we get an odd-shaped pyramid with base being narrow, middle wide and top narrow again. Now, if we take **biomass** as parameter, the shape of the pyramid for same ecosystems may not always be cone-shaped. With **energy** as parameter however, the shape of the pyramid irrespective of the nature of the ecosystem, will always be conical as, the energy utilised by any step will always be less than energy utilised by the preceeding step. This is a very important law of Nature which can be used to solve our chronic food shortage.

2.15. Summing up, the solar energy which autotrophs trap, become progressively dissipated as it passes through the successive stages of heterotrophs in an ecosystem. We shall come to ecological pyramids once again later in this chapter.

3. LIGHT AND PHOTOSYNTHESIS

3.1. Solar radiation which is vital for photosysthesis consists of a range of electromagnetic waves whose wavelengths vary from very short and high energy gamma rays (10^{-10} cm) to very long radiowaves (10^{4} cm). But most of it which is lethal to protoplasm is screened off in the Earth's upper atmosphere. Only the visible lights ($\pm 10^{-4}$ cm) and a little of ultra violet, a little of infra red and a good deal of radio-waves reach the surface of earth.

3.2. The white sunlight that we see is formed by blending seven distinct colours ranging from 400 to 750 µm. Each colour of sunlight is characterised by light of a distinct wave length. If we pass a beam of sunlight through a prism (triangular shaped optical glass), the sunlight will break up into its original seven colours and we shall get what physicists simply call a **solar spectrum** (Fig. IV. 5.).

3.3. This spectrum of sunlight has seven colours. These are, from one end, violet, indigo, blue, green, yellow, orange and red. In short this is named 'VIBGYOR'. Beyond violet there is ultra-violet (U.V.), and beyond red there

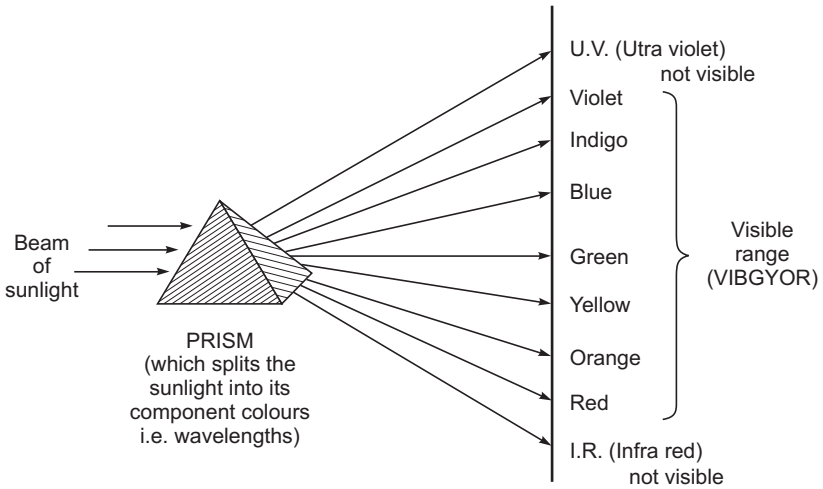

Figure IV.5 Solar spectrum i.e. spectrum of sunlight, reaching Earth's surface and visible to us.

is infra-red (I.R.) both of which are invisible to us. The colour of the light will depend upon the wavelength of the light. For photosynthesis the green plants use only a portion of the visible spectrum (given before) i.e. some colours only and not all (Fig. IV. 6). This figure should be seen along with the previous figure i.e. solar spectrum (Fig. IV. 5).

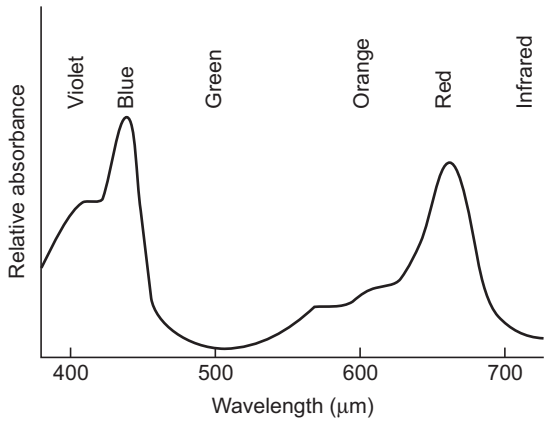

Figure IV.6 Absorption spectrum of chlorophyll a.

3.4. It is quite obvious from the above absorption spectrum that blue and red are the two colours whose relative absorbance for photosynthesis by chlorophyll are highest. Green is least absorbed hence forest are green. There are however other pigments such as carotenoids which use green colour for photosynthesis. Sea water does not absorb the blue colour. So sea is blue.

How much sunlight is used in Photosynthesis and what the rest do?

3.5. Leaves etc. i.e. phosynthetic areas of plants absorb only 50% of the sunlght that impinges on them. Of this only about 2% is utilised in synthesising biomaterials. This means that the gross efficiency in producing biomaterials by plants by using energy of sunlight is only 1%. The remaining 99% of solar energy which is not used up in photosynthesis, is however, not wasted but indirectly keeps the planet alive. Some uses may be given here. Solar energy heats up sea surface causing water to evaporate leading to formation of clouds. Air currents again created by air warmed up by sunlight, carry these clouds all over the earth causing rainfall and snows. Snows in turn feed the rivers and so on. So besides photosynthesis, causing rainfall, wind current and snows are some of the most important life-saving roles of sunlight.

3.6. There are many more such uses which need not be elaborated here. Suffice it to say that sunlight is not only responsible for photosynthesis and rainfall but also the entire weather system of Earth and many other roles. Recently it has been shown mathematically by Edward Lorenze that a very small change in the weather in one corner of Earth may lead to a big change in weather elsewhere (Butterfly Effect or Chaos Theory, 1972). Sunlight is really life to us. Later in the chapter on POLLUTION more on this will come.

3.7. The intensity of sunlight depends upon its nearness to tropics. The further a place is from tropics the lower is the intensity of sunlight. Also, in the same ecosystem a plant that grows under a tree will receive less sunlight than the top of the tree (i.e. canopy) which gets sunlight directly. From this angle of light and shade, a forest has at least two storyes, — **Canopy** i.e. the tree tops which is fully exposed to sun and **Understorey** i.e. the area under canopy which does not get much of direct sunlight (Fig. IV. 7.).

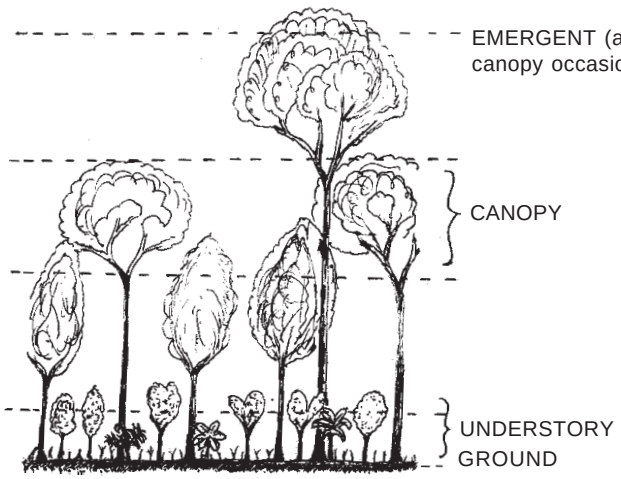

Figure IV.7 Forest with canopy and understorey.

3.8. Thus plants belonging to the same ecosystem become differentially adapted for photosynthesis according to the intensity of sunlight at their exact locations. So some plants become shade adapted while others become light adapted.

4. ENERGY CIRCUITS

4.1. The energy synthesised and stored by autotrophs (i.e. green plants) during photosynthesis, gradually passes through various heterotrophs (i.e. herbivores and carnivores) i.e. secondary and tertiary producers and so on till the entire quantity of solar energy trapped by the plants is released back into the environment. This particular pathway of stored energy through an ecosystem is called **Energy Circuit** or **Energy Pathway** (Fig. IV 8.).

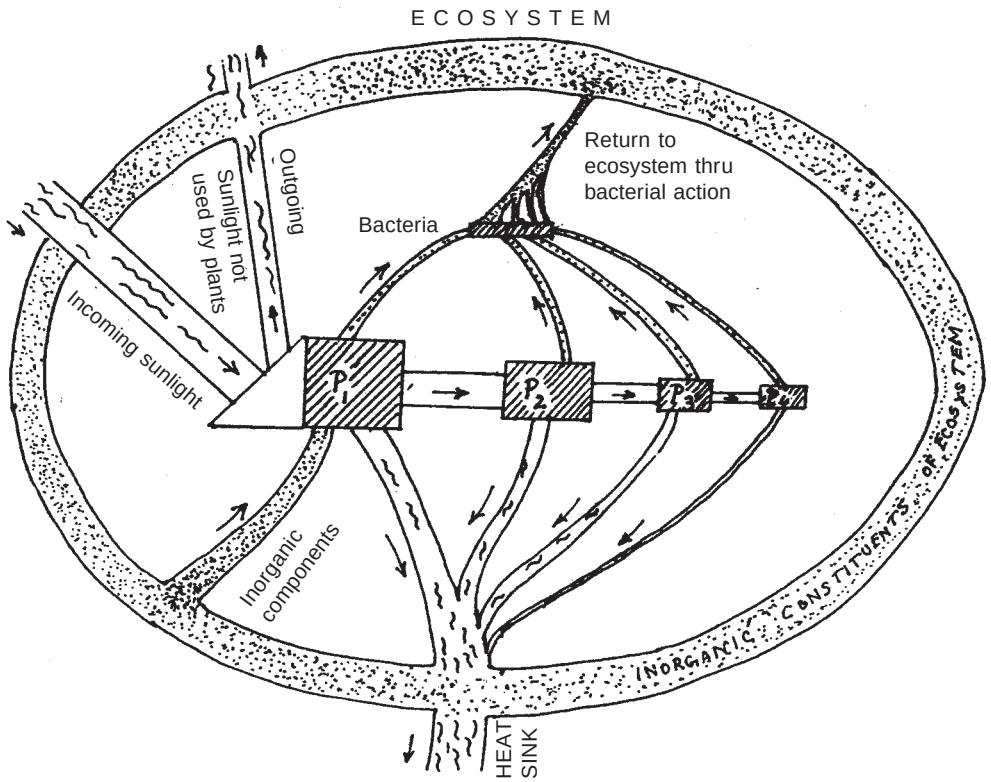

Figure IV.8 A schematic diagram of energy-circuit and material circuit in an ecosystem. (P_1, P_2, P_3 and P_4 are the producer$_1$ i.e. green plants, producer$_2$ i.e. herbivares, P_3-carnivares and P_4 i.e. the top carnivares such as parasites etc.).

4.2. From the above figure it will be apparent that food materials synthesized by green plants (P_1) pass from them to the herbivores (P_2) and from these to the carnivores (P_3) and finally to top carnivores (P_4) such as lions and tigers on land and sharks in sea and parasites. Such

Grazing Circuit and Detritus Circuit

passage of energy through stages P_1 to P_4, through successive states of eating and being eaten is known as **Grazing Circuit**. When energy, instead of passing through successive stages of grazers, pass mostly through bacterial actions on dead and decaying bodies, then such an energy circuit is known as **Detritus Circuit**. Such circuits occur in sea beds or beds of deep lakes where the beds become muddy owing primarily to accumulation of dead and decaying organic bodies. Dead bodies of plants and animals constantly fall like shower upon the bottom dark surface of sea-bed from the top sunlit surface of the sea, to be broken down by bacterial action.

4.3. Other features of ecosystem apparent from the figure (IV. 8) are as follows :

3.(1) Only a part of the biomaterial produced by one producer is available to the next producer. Rest of it is directly used up by the producer itself for its own various metabolic needs and decomposition after death by bacterial action. As a result most of the biomaterials produced are quickly broken down and returned to the abiotic component of the ecosystem to be recycled again.

3.(2) The energy component of each stage i.e. P_1, P_2 etc. is partly passed on into the ecosystem through their successive stages—(just like biomaterials) but rest of it is directly released into the ecosystem without the intervention of the bacteria (Fig. IV. 8). Still there is a difference between the two. Unlike biomaterials which are recycled again and again the energy however once released into the ecosystem cannot be recycled. It is lost irrevocably. This method of loss of energy from ecosystem is called **passage into heat sink** just as water poured into a kitchen sink is no longer available. This important difference in the behaviour of energy and mater is to be remembered.

4.4. Our Sun is the constant and unending source of energy which is keeping our ecosystem going on and thus the ultimate provider of all our requirements. Thus food, fuel, household items, fire, weather, ocean current, rains and other glorious and beautiful features of our Mother Earth all of which have come through solar energy, have made Earth a unique planet in our Solar System. Ancient sages rightly guessed the importance of Sun in our lives. Here lies the root cause why Egyptians worshipped Sun as a most benevolent god—Ra. Persians too worshipped Sun as their principal god (Chap. I) and Hindus worshipped Sun as Sun God or **Surya Devata**. These examples tell us of the excellent power of observation and understanding of our forefathers about the important roles of Sun and Nature in our lives. [Please see the poem in the beginning of this chapter (IV)].

Role of Sun and Clairvoyance of ancient sages

4.5. If we measure the amounts of energy fixed by one producer against another, preceeding or succeeding, according to a descending order i.e. parent producers occupying the lower rungs and the consumers the

upper, we shall get an usual conical structure i.e a conical tetrahedron—the pyramid of energy. This means the base would be widest with the upper tiers successively narrower (Fig. IV. 3). While the pyramids of energy of any ecosystem will always look normal i.e. base wide and the tip narrow, but other types of ecological pyramids of the same ecosystem such as, pyramid of biomass and pyramid of number may not always look so (Fig. IV. 9).

Ecological Pyramids (a follow up from IV.2.11)

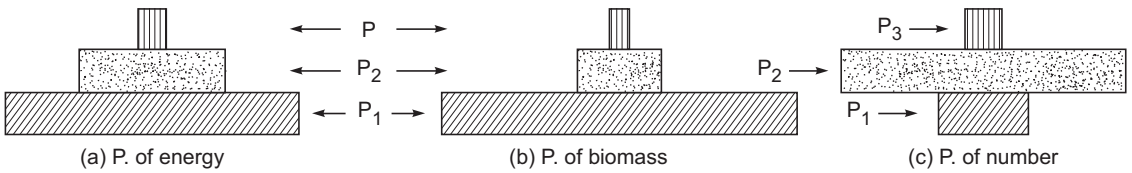

Figure IV.9 Ecological pyramids of the same ecosystem–i.e. a tropical rainforest but using three different parameters—a. energy, b. biomass and c. number.

4.6. In this ecosystem (tropical rainforest) P_1 are trees, P_2 are insects and P_3 are birds. While the pyramid of energy (*a*) for any ecosystem will look normal i.e. like a conical tetrahedron but the pyramids of biomass (*b*) or number (*c*) however may not look normal for all ecosystems. For example here the ecosystem being a forest the P_1 are trees, P_2 are insects (mostly) P_3 are birds mainly. So here necessarily the pyramid of number (*c*) is an inverted one. In another type of ecosystem say, the Afrikan savanna the P_1 mainly consists of grasses and a few trees, P_2 of deers, wildebeests and zebras and P_3 of Lions, Cheetshs and Hyenas. Here the Pyramids (*a*), (*b*) and (*c*) all look normal i.e. will have a normal pyramidal shape (conical tetrahedron). Therefore it should be remembered that for a comparative study of one ecosystem with another, the pyramids of energy are most reliable.

5. STANDING CROP, CARRYING CAPACITY AND PRODUCTIVITY

5.1. In shallow ponds for artificial fish culture, we shall have only 2 or 3 varieties of producers. The P_1 would mostly constitute of phytoplanktons and P_2 mostly of small fishes and some zooplanktons. Here if we weigh P_1 and P_2 separately, we shall find P_2 far outweigh P_1. Although it may seem odd to see how so small amount will of P_1 can support so large amount of P_2, the following consideration will help to understand. The time required to mature and duplicate for a species may vary from species to species. A phytoplankton may require less than a day to duplicate itself but a fish may require more than a year to mature and breed. In this case the fishes might have grown for months to acquire their weights but the phytoplankton in the same pond might have multiplied more than hundred times within the same period. That is how apparently small amount, by

Standing Crop

weight, of P_1 can support or carry an apparently large amount, by weight, of P_2.

5.2. This also helps us to understand the concept of Standing Crop. The **Standing Crop** is a measure (by weight, volume or else) of any particular species or any group of species in a particular ecosystem at a particular point of time. This is a very helpful concept. This gives us a quantitative assessment of a particular type of biomaterial (ex. crop, fish, food grains, cubic feet of wood or Kg. of beef etc.) that is available as **standing crop**, for harvesting or some other need in a particular ecosystem at a particular point of time. A forestryman may talk of how many cubic feet of commercial wood per acre a particular forest may give or, an animal husbandry man may talk about how many kg. of beef per acre a pasture can yield at a particular time.

Carrying Capacity

5.3. The **Carrying Capacity** of an ecosystem means the capacity of one level of producers to support the growth and survival on a more or less permanent basis of another, higher group or producers. Here is an example from pond ecosystem. The standing crop of only a small amount of phytoplankton can support a much larger quantity of fish population (explained earlier). Hence this is the carrying capacity of the phytoplankton of this pond for this fish population. Naturally the nature of both the groups of species (P_1 and P_2 or P_3) i.e. the species supporting and the species supported will determine the carrying capacities of an habitat or an ecosystem for the species one is interested in. The nearer a species is to the autotrophs, the more will be the carrying capacity of that habitat for that species. Here is an example from Kendeigh (p. 167). A density of 100 deers is required to support one wolf (after Pimlett 1967). Perhaps one thousand acres would be needed to feed 100 deer. In this way one can estimate how much land would be required to support one community of deers (of P_2) or wolf (of P_3). We shall descuss more on this theme later in chapter on POPULATION.

6. PERCENTAGE OF SOLAR ENERGY USED AND WORLD PRODUCTIVITIES

Only 2% of sunlight utilised by autotrophs

6.1. Before concluding this chapter it would be interesting to examine how much solar energy is really used by autotrophs. Average solar energy impinging upon per square metere of land is about 200 calories per day (world average) and autotrophs absorb only 2% of usable light energy of which only half (i.e. 1% of impinging light energy) is utilised in photosynthesis. This is the world average. The entire bioproductivity of the world comes only from this 2% of solar radiation absorbed by plants. With this mere 2% of solar radiation absorbed, the primary producers of the world (P_1) manufacture **170 billion tons of biomaterials annually**. This includes the entire biosphere i.e. lakes, forests, deserts, seas and so on. The productivity of all places are naturally not same. It varies from one ecosystem to another depending upon the presence or absence and

quantity and nature of +ve and –ve factors for production. For example, presence of adequate nutrients is a positive factor. Ample sunlight is a positive factor. Reasonable amount of wind current or water current are positive factors as currents help the supply of oxygen and remove unwanted metabolic products. Also up to a point, temperature is helpful for growth. On the other hand too much of heat or, too much or cold or too high winds all are negative factors for productivity.

Ecological basis of Agriculture

6.2. Agriculture is essentially creation of an artificial ecosystem where, for certain selected species such as, rice, wheat , maize or cows, sheep and poultry etc. the specific positive factors for productivity are boosted such as, fodder and minerals for cows, sheep etc. and nutrients and water for crops and also the elimination of competitive species such as weeds, pests etc. in order to ensure a very high productivity of grains or standing crop as the case may be, from the point of view of the requirements of humanity. Still it would be well-worth to remind ourselves of the fact that the world average of utilisation of solar energy for primary production (P_1) is only 2%.

Certain observations on this Table on World Net Productivity

6.3. A look at the following table (Table IV. 1.) will give us an idea about the net annual primary productivities and biomass of all major ecosystems of the world. This compilation by R. H. Whittaker (1975) is a very useful one. For example it can help planners to focus on such ecosystems where investments to augment primary production to yield maximum output vis a vis capital invested. It would also help to do the opposite i.e. help to decide for which ecosystems paying attention may wait. Also it should be noted that the net annual world primary production is 170 billion tons from which all our and the requirements of other consumers such as fishes, deers, tigers, elephants, birds etc. etc. are met. And all this 170 billion tons come from only 1% of solar energy that reaches the ecosystem. Rest 99% of solar energy absorbed by plants goes for other things such as weather regulation, creating ocean currents, rains etc. all of which collectively keep the biosphere alive.

6.4. It seems it would be an interesting mathematical speculation to work out a computer model and estimate what would be the likely fall-out if, say, through genetically enginered plants we succeed to utilise instead of present 1%, 1.25% or even 1.5% of solar energy that reaches the earth surface. Would the meteorological ripple that would result may, through butterfly effect (Chaos Theory), bring havoc in our earth through changes in weather? Would this lead to serious tampering with Nature? Off course tampering with Nature in small ways have already started long ago. When we became herdsmen instead of food gathers (Paleolithic Age) we tampered with ecosystem. Again when we became agriculturists instead of herdsmen (Mesolithic Age) we once again tampered with Nature. Electricity, damming of rivers, deforestation, atom bombs, genetic engineering etc. all are forms of tampering with Nature's Ways. Some of

Table IV.1
NET ANNUAL PRIMARY PRODUCTIVITIES AND STANDING CROP BIOMASSES OF VARIOUS ECOSYSTEMS OF THE WORLD.
(After Whittaker, 1975; from Begon, Harper and Townsend, 1990. p. 652)

Ecosystems	*Area covered* (10^6 *Km*)^2	*Net primary productivity per unit area*		*Biomass (standing crop)*	
		Mean Productivity $gm/m^2/area$	*World Net Production* (10^9 *ton*)	*Per unit area wva* ($Kg\ m^{-2}$)	*World biomass* (10^9 *ton*)
Tropical rain forest	17.0	2200	37.4	45	765
Tropical seasonal forest	7.5	1600	12.0	35	260
Temperate evergreen forest	5.0	1300	6.5	35	175
Temperate deciduous forest	7.0	1200	8.4	30	210
Boreal forest	12.0	800	9.6	20	240
Woodland and schrubland	8.5	700	6.0	6	50
Savanna	15.0	900	13.5	4	60
Temperate grassland	9.0	600	5.4	1.6	14
Tundra and alpuse	8.0	140	1.1	0.6	5
Desert and semi-desert schrub	18.0	90	1.6	0.7	13
Extreme desert, rock, sand and ice	24.0	3	0.07	0.02	0.5
Cultivated land	14.0	650	9.1	1	14
Swamp and marsh	2.0	2000	4.0	15	30
Lake and stream	2.0	250	0.5	0.02	0.05
Total Continental	149.0	773	115	12.3	1837
Open ocean	332.0	125	41.5	0.003	1.0
Upwelling zones	0.4	500	0.2	0.02	0.008
Continental shelf	26.6	360	9.6	0.01	0.27
Algal beds and reefs	0.6	2500	1.6	2	1.2
Estuaries	1.4	1500	2.1	1	1.4
TOTAL–MARINE	361	152	55.5	0.01	3.9
TOTAL–WORLD	510	333	170	3.6	1841

the consequences are already making us worry. It is time planners pay more attention to ecological consequences before initiating large scale manipulations with Nature.

6.5. Finally, it may be worthwhile to consider as below. God has created all of us—men, women, animals, plants, birds, fishes, insects, earthworms and all. ALL are God's children and hence ALL have a right on this Garden of Eden—Mother Earth. We have now admitted women's right; is it not time we also admit rights of plants and animals for a safe corner in this "Garden of Eden"? The present day Nature Parks are too small. What makes men think that we are the undisputed owners of this Earth? Never before the Earth has been violated so much through plundering of her resources and ravaging her body by the ever growing lust of

populations of *Homo sapiens*, as it is being done today. It is time we tarry a while and ponder about the rights and requirements of the other citizens of Earth—plants and animals. It is time enough we concede their right to live and allow them the citizenship of this planet. Hindu sages perhaps meant this when they announced

"সর্বং খল্বিদং ব্রহ্ম"

'All are Manifestations of God'

— translation - author's

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Chapter V

Bio-Geo Cycles of Chemicals

(The Eternal Cycle)

Topics

V.1. The Principle

V.2. Various Types of Cycles

V.3. Various Aspects Related to Bio-Geo Cycles of Chemicals

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CHAPTER V

BIO-GEO CYCLES OF CHEMICALS

(*The Eaternal Cycle*)

"I was, I am and I shall be"

— *Geeta.*

(A part of Krishna's advice to Arjuna described in the epic Mahabharata)

1. THE PRINCIPLE

1.1. In the preeceding chapter we have seen that energy passes through the ecosystem in a constantly diminishing manner until it is irrevocably lost into the environment. Thus in ecosystem energy does not recycle but flows on.

1.2. Here we shall see it is not so with materials. Materials in ecosystem, do not get lost but recycle again and again. Materials locked up in living bodies return to the abiotic environment after the death of the living beings. These materials are again picked up by plants to produce new biomaterials. This cyclic passage of inorganic materials from the abiotic environment into the biotic bodies and return from these to the abiotic environment again is known as **Bio-Geo Cycle of Chemicals**. This process is repeated again and again in nature as an unending cycle.

1.3. In the end of this chapter we shall see how clairvoiantly the author of the Vedic scripture "GEETA" (sage Veda Vyas) perceived the essence of the 'bio-geo cycle of chemicals' and put it so effectively in so few words which is given in the verse in the beginning of this chapter. We shall come to this verse or 'Sloka' again in the end of this chapter.

1.4. Besides solar energy which is a must, plants also require certain specific chemical elements in order to synthesise biomolecules. These elements are specific and many of them are abundant in Nature, but not all. These elements are needed in varying proportions by all plants and animals while some elements particularly sodium is needed by animals only but scarcely by plants. Following is a table listing these elements and showing their relative amounts in the bodies of plants (maize) and animals (man) (Table V. 1).

The Chemical Elements Living beings Require

Table V.1.
MOST CHEMICAL ELEMENTS REQUIRED BY PLANTS AND ANIMALS, (%) OF DRY WEIGHT.
(From Ecology – ed. by Moore – 1986, p. 12)

Elements	*Plants (Maize)*	*Animals (Man)*
Oxygen	44.4	14.6
Carbon	43.6	56.0
Hydrogen	6.2	7.5
Nitrogen	1.5	9.3]
Silica	1.2	0.005
Potassium	0.9	1.1
Calcium	0.2	4.7
Phosphorus	0.2	3.1
Magnesium	0.2	0.2
Sulfur	0.2	0.8
Chlorine	0.1	0.5
Aluminium	0.1	–
Iron	0.1	0.01
Manganese	0.04	–
Sodium	–	0.5
Zinc	–	0.01
Rubidium	–	0.005
Total	98.94	98.33

(Here three points are worth mentioning. The totals of neither maize nor man adds up to100% implying that there are other elements which may be required in trace amounts. For example, some animals need vanadium. Secondly, the proportion of the main elements substantially vary between plants (e.g. maize) and animals (e.g. man). For example, maize require 44% of oxygen but man only 14.0%. Thirdly, certain elements such as sodium are needed by animals and not by plants. Sodium is crucial for nerve transmission hence animals must have it. As sodium is scarely present in many plants many forest animals and birds must specially supplement sodium in their food by licking sodium-rich soils. Forest Rangers sometimes specially provide sodium salt for animals to come and lick when needed).

2. VARIOUS TYPES OF CYCLES

2.1. Movement of each element, (such as, Carbon, Hydrogen, Iron, Phosphorus, Calcium etc. etc.) within living bodies has a specific cycle of its own. Each cycle is characterised by various steps. One part of this cycle is spent within living bodies as constituent of biomolecules and the other part in the abiotic environment as inorganic molecules.

2.2. In Nature some elements stay, in a gaseous state. For example, Nitrogen (N) before being picked up by plants, i.e. outside living bodies stays in the form of gas—a constituent of air. Other elements such as Phosphorus (P) and Sulphur (S) when outside the living bodies stay in solid state as phosphates and sulfides respectfully. There are still another group of materials such as water and carbon dioxide (H_2O and CO_2) which pass through both a gaseous and a solid state when these stay as non-living components of the environment. So these have a dual state i.e. a combination of gaseous and solid state. Outside living bodies water stays both as gas (water vapour in air) and as liquid (water in soil, rivers and lakes) or as solid as ice in polar caps and mountain tops) while carbon dioxide stays either as gas (in air) or as solid (as carbonates).

Three types of Bio-Geo Chemical Cycles

2.3. So we have generally three types of Bio-geo Cycles of Chemicals.

(*a*) Gaseous cycle e.g. nitrogen.
(*b*) Sedimentary cycle e.g. Phosphorus and sulphur,
and (*c*) Dual cycle e.g. water and carbon dioxide.

Let us examine one example of each of these three types of cycles.

2.3.(*a*) A Gaseous Cycle

(i) Nitrogen is an essential component of protein molecules. When living beings die and their bodies get decomposed by bacteria, nitrogen is converted, through stages, into nitrate salts and later released into the atmosphere as the gas NO_2. The NO_2 component in the atmosphere is the main nitrogen storehouse of earth. This gaseous nitrogen through various agencies becomes reconverted into nitrate salts or ammonium ions which green plants (autotrophs) pick up to synthesise biomolecules.

The Nitrogen Cycle

(ii) This cyclic passage of nitrogen from living beings to soil and water to atomsphere and return from atmosphere again through soil and water, into the the bodies of living beings is called THE NITROGEN CYCLE (Fig. V.1). As when outside living bodies, nitrogen stays in the atmosphere in the form of gas the nitrogen cycle is called **gaseous cycle**.

2.3.(*b*) A Sedimentary Cycle

(i) Phosphorus is another essential element of living beings. Molecule of DNA, RNA and ATP must have it. After decomposition following death, phosphorus compounds enter the soil and become phosphate salts and stay there till these are picked up again by autotrophs (green plants) so that the cycle may restart. Plants use phosphorus as orthophosphate ions ($H_2PO_4^-$). If however plants can't pick up phosphorus soon enough, it runs down along with rainwater and gets sedimented into sea-beds from where its return to biocycle is very slow. There is however a phenomenon in sea called **upwelling** (for explanation see later in this chapter) through which part of this phosphorus, which has found its way into sea beds, returns again to land and thence into the bio-geo cycle.

The Phosphorus Cycle

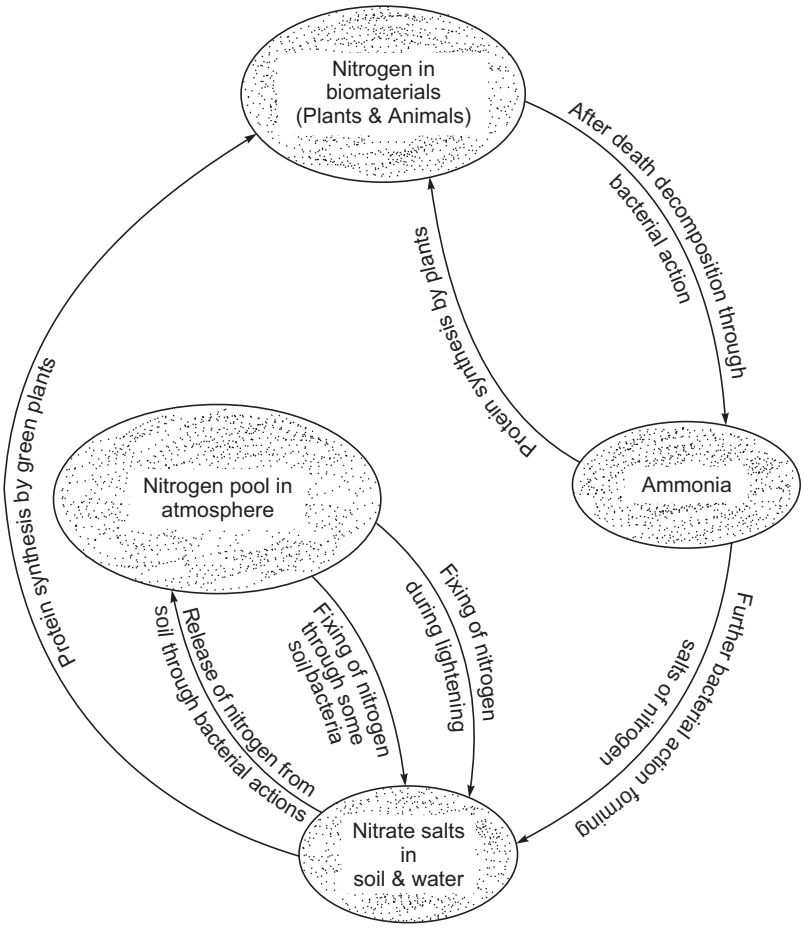

Figure V.1 The nitrogen cycle.

(*ii*) When plants and plant products such as, wood, coal and petroleum (the latter two are only fossilised wood), are burnt as fuel, phosphorus goes into atmosphere as gaseous compounds. With rain this phosphorus comes down to soil and become phsophates again. When plants do not pick up all phosphates from soil soon enough, gradually the unutilised phosphorus moves along with soil-water into the river and thence into the sea. From sea only a small portion of phsophorus is brought back to land through food-chain (vide infra). A large portion of phosphorus in sea however settles down as sediments in deeper water whence its return is extremely slow and little at a time.

(*iii*) Phosphorus recovery from sea-water through food-chain is effected in the following way. Both phytoplankton and zooplankton pick up phosphorus very quickly from sea-water. From planktons this soon finds its way into the sea fishes who live on planktons. From fishes

Phosphorus retrieval from Sea through Food Chain

phosphorus is brought back to land through two pathways. One via trawlers who harvest sea fishes extensively for our dinner table. The other route is via sea birds. Sea birds who spend the day in sea catching and eating fishes, return to coast in the evenings to roost for the night. Their droppings are extremely rich in phosphorus. So this is the other route for return of phosphorus to land (Fig. V. 2.).

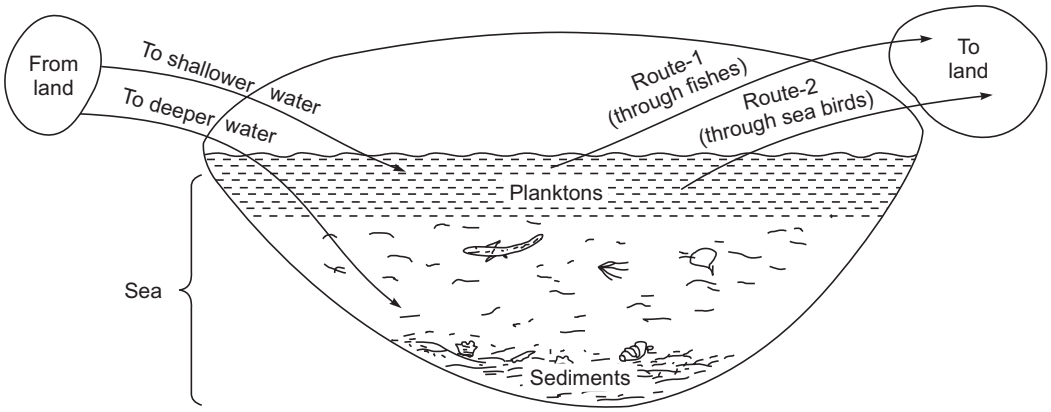

Figure V.2 Phosphorus retrieval from sea.

(*iv*) Here we would like to mention an interesting thing. Generally bird droppings are rich in plant nutrients. Chicken droppings, pegion droppings, even bat droppings, are used by farmers in Sumatra as plant manure. Excrements from sea-birds are even more so as these are formed from extremely phosphate rich food—fishes, which these birds live upon. Sea birds have a habit of roosting at nights in the same spot throughout their lives and this goes on for generations—hundreds of years—forming mountainous heaps—several metres thick layer of an extremely phosphate rich material commercially known as GUANO. In the western coast of Chilli there is so extensive stock of Guano that the country has been exporting Guano as fertiliser and earning good revenue.

Guano

(*v*) Similarly there are some small unihabited islands West of Africa which are used by sea birds for roosting at nights. Over the years these islands too have become so rich in Guano deposits that some people from mainland Afrika make their living by collecting and selling this harvest of Guano—a bird product. There is a novel "Bridge of the Magpies" (Geoffrey Jenkins 1975) depicting the activities of some questionable characters in such uninhabited, Guano rich West Afrikan islands.

(*vi*) Ocean beds are not always flat. In some places there are mountains running North to South. Recently National Geographic Society (of Washington D.C., U.S.A.) has published very good maps of ocean floors. There are some such elevations west of South America and West

Upwelling and retrieval of phosphates

of Africa. When the ocean currents moving from West to East strikes such submerged mountains the cold deep sea currents move upwards carrying phosphate rich sediments along with them. This physical process of cold deep sea water welling-up is known as UPWELLING (Fig. V. 3.) In seas such zones where upwelling takes place are very rich with phosphates and hence abounds with planktons and hence fishes which feed on these. Such areas of are full of sea birds and now-a-days with fish trawlers as well. In this way, formation of guano deposits, are direct consequences of sea birds droppings on land.

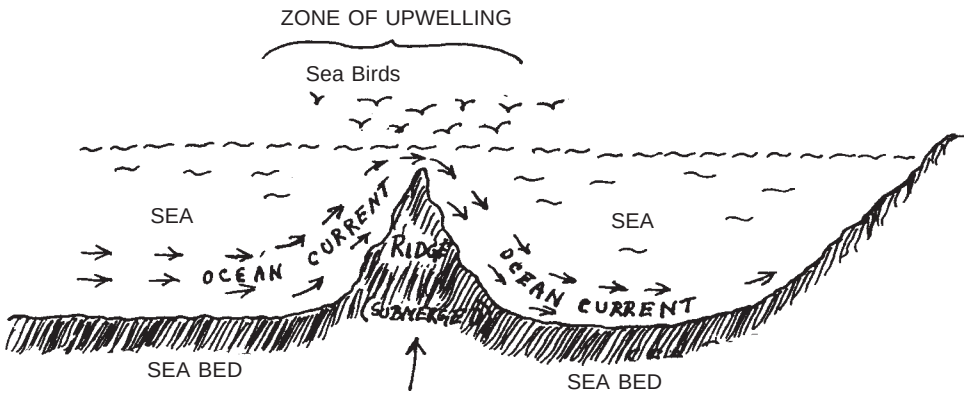

Figure V.3 Upwelling.

Pegion droppings- a free source of manure

(*vii*) Thus phosphates return to land from sea by two pathways. First, through sea-fishes harvested from sea by trawlers and fishermen using small boats. Second, through guano deposits formed by droppings of birds who live on sea fishes mostly from upwelling zones of sea. The entire phosphorus cycle is being summarised in the following figure (Fig. V.4.). As outside, living bodies, Phosphorus stays in land in the form of solid phosphate salts, the phosphorus cycle is called a **semimentary cycle**.

(*viii*) In this connection it occurs to us that keeping a few pegions, by towns people who maintain kitchen garden or potted flowers in their houses would provide them a free source of garden manure. This would be both an environment-friendly as well as handy source of manure.

2.3.(*c*) A dual Cycle

(*i*) Water is a mojor content of the bodies of living beings Water contents ranges from 50% or so in hardwoods to 95% or more in jelly fishes. Without water life would not be possible.

The Water Cycle

(*ii*) Most of the water content of earth is in huge reservoirs like seas, lakes, polar ice and underground. Water in transit is in the form of clouds, rainwater and rivers. This is not much in quantity and the water locked up a biological systems is ludicrously tiny. However one must hurry to add

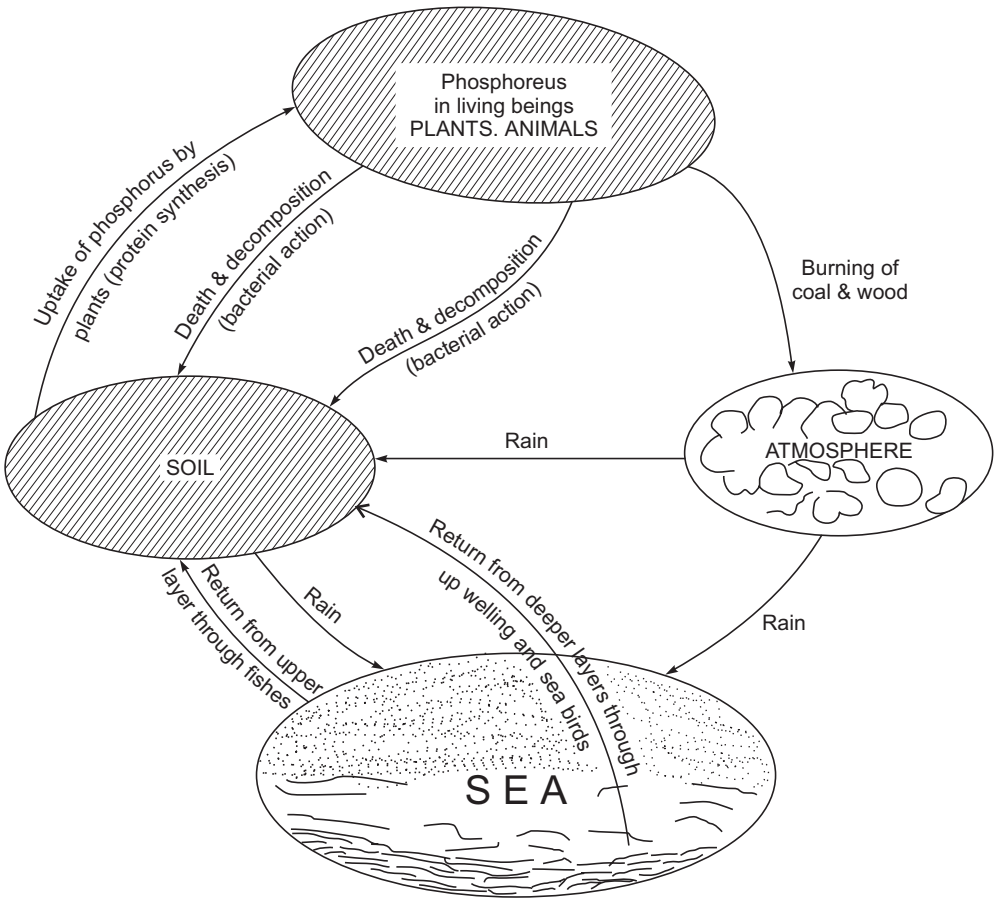

Figure V.4 Phosphorus cycle.

that in Nature's designing nothing is 'ludicrous'—everything is programmed and relevent. Here is the water-content of the various sections of biosphere (Table V. 2.). The information given in this table is a very thought provoking one. We may have to refer to it again at the end of this book.

(*iii*) The journey of water from the living to the non-living and back to living takes the following route. Water comes out from the living systems through respiration, transpiration, perspiration, metabolism and decomposition after death. Water from these evaporate, go into the atmosphere and form part of the cloud formations. In the meantime simultaneously due to solar radiation, water constantly evaporates from sea, land, rivers, lakes etc. to form the bulk of the clouds. These cloud masses are carried along with wind currents and when situation favours (mainly due to drop of temperature) condense into water droplets and come down to earth either as rain or snow. Rainwater moistens the earth.

Table V.2.
WATER CONTENTS OF VARIOUS SECTIONS OF BIOSPHERE
(After Data of R.L. Nace from Colinvaux)

Sections	*Amounts (million cubic kilometer)*	*% Total*
Oceans	1322.0	97.21
Glaciers and Polar Ice	29.2	2.15
Ground Water	8.4	0.62
Soil Water (part of life)	0.067	0.005
Freshwater Lakes	0.125	0.009
Inland seas and Salt Lakes	0.104	0.008
Rivers and Streams	0.001	0.001
Atmosphere (clouds and vapours)	0.13	0.001

From moist soil, plants take in water and other nutrients so that biosynthesis continues. Not all clouds rain on lands. In fact most clouds rain on seas, some only on lands and the remaining come down as snows on mountain tops, polar regions and cold temperate zones. Mountain snows melt in summer and feed the rivers. Part of the water from snow percolates into the soil and nourish the ground water. Not all rainwater that falls on land enters the plants. Most of it however enters the soil to recharge the ground water system or aquifers and some evaporate to feed the clouds and the rest feed the rivers. Ultimately all the ground water flows into seas. Thus gradually with time, all water in the clouds find their way back into the seas. From sea the cycle starts again (Fig. V. 5.).

(*iv*) Rainwater on land is the lifeline for vegetation, agriculture, forests and their animals. All rainwater however do not go into these. A considerable part of it percolates down into the deeper layers of soil, a process called leaching carrying down with it the harmful salts like arsenic etc. Ultimately however all water finds its way into the sea. Another very important function of rainwater is to recharge the water-bearing strata of the soil—the aquifers.

Deep Tubewells: Depletion of Ground Water

(v) When we sink deep tubewells and suck out large quantities of water for housing projects in towns and intensive agriculture, we deplete the aquifers more than the normal recharging during the monsoons and consequently the water table gets lowered. Unless we recharge the aquifers adequately during monsoon with proper water management, the groundwater will be further depleted with consequent havocs in various areas and countries. India is already suffering for neglecting the above principle.

The duality of hydrologic cycle

(*vi*) The duality of the nature of water cycle is owing to the following reason. The water that is used by the living beings (biota) is the liquid water which plants take in from soil. Soil gets liquid water from rains and snows. Rains and snows owe their origin to the clouds which in their turn are the products of evaporation from sea and land. Therefore

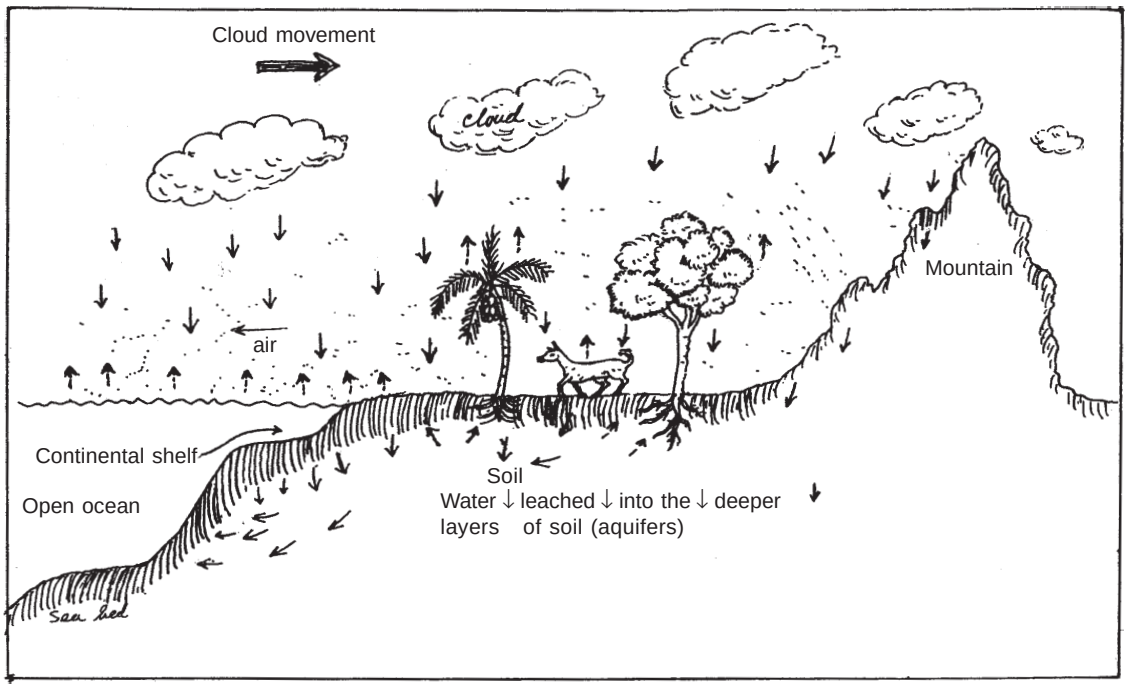

Figure V.5 The water cycle.

outside living bodies both the gaseous as well as the liquid stage of water are musts for an ecosystem. Hence the hydrologic cycle is called a **dual cucle**.

2.4. By the above few pages we have tried to explain to our readers the concept of bio-geo cycle of chemicals with the help of three examples illustrating three different types. First a gaseous type i.e. the atmosphere acting as the main storehouse of the nutrient (e.g nitrogen), secondly a sedimentary type where the soil acts as the main storehouse of the nutrient (e.g. phosphorus) and thirdly a dual type meaning thereby that here both atmosphere (and sea) and soil act as the storehouses of the nutrient (e.g. water).

Summing up

3. VARIOUS ASPECTS RELATED TO BIO-GEO CYCLES OF CHEMICALS

3.0. Now we shall briefly touch upon a few selected topics on bio-geo cycles of chemicals a brief information of which might be useful to most readers.

3.1. Besides its requirements for biosynthesis, water acts as carrier for nutrients. It is now clearly understood that wanton deforestation and poor land management causes havoc with nutrient cycling. Here is an example through phosphorus cycle in Indian grasslands (Fig. V. 6.). The phosphorus is carried into plant bodies through the root system in the form of

V.3.1. Importance of water for Nutrient Cycling

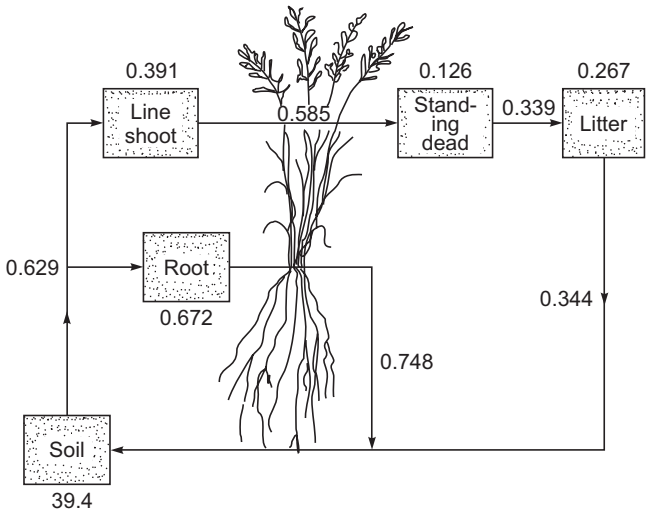

Figure V.6 Phosphorus cycle in Indian grasslands.

orthophosphate ionic salts dissolved in water. Just as haemoglobin carries oxygen into animal blood stream so does water carries nutrients into plant sap. Therefore unless adequate liquid water is available in soil near the root system of plants, this phosphorus cycle is seriously interfered with. As a matter of fact water acts as the carrier for most inorganic nutrients to plants. Hence water is a must for survival of forests.

V.3.2. Moderating Effects of Forests on Temperature

3.2. Forests help to keep the weather relatively moderate. Bormann (1976) has shown that nearly 42% of solar radiation received by a forest is used up for powering transpiration of water by plants. And it is only through transpiration that plants get their nutrients for biosynthesis. If there were no plant-cover this 42% of solar energy would have gone into heating up the bare ground. So one can easily perceive how important is vegetation in moderating the local climate. Deforesters would do well to heed this.

V.3.3. Standing Stock, Turnover Time and Turnover Rate

3.3. The amount of bio material of a plant/crop present at a particular time in a area is called **Standing Stock.** For instance, one can measure the cubic feet of wood present in a forest in a particular time. This would be the standing stock of wood of that forest at that time. Similarly, the kilograms of fish in a pond at a particular time would be the standing stock of fish in that period at that time. Now if in a pond the standing stock of fish is 20 kg. per square metre and if the annual growth rate is 1 kg. per square metre than the turnover time is 20/1 i.e. 20 years and following this, the turnover rate is 1/20 i.e 5% per year. Therefore simply speaking **Turnover Time** is the time required to replace the entire amount of standing stock and the **Turnover Rate** is the rate of replacement of standing stock taking place in relation with the amount of the entire standing stock present at that time. Hence the the turnover time and the turnover rate are very useful criteria for assessing any parameter of an ecosystem.

3.4. After death and decomposition the elements or constituents, which are locked up in the bodies of plants and animals, all return to their non-living environments. This simply means everything that is locked up within the biota return to abiota after their death. From abiota, after some time-gap, these elements or constituents are again picked up by autotrophs for biosynthesis and thus these enter the biota once again. This period of waiting by any element or constituent in the non-living environment (abiota), before being picked up again by the autotrophs, is called the **Residence Time** for that element or constituent. This residence time varies from element to element or constituent to constituent depending upon the nature of the element or constituent and also the pathways these follow during their bio-geo cycles.

V.3.4. Residence Time

3.5. Nowadays by using radio-active substances or tracers the pathway of movement of an element or a compound, through an ecosystem can be quite accurately mapped. (This is a big area for studies to Indian ecologists). Through such methods it is also possible to measure the residence time and turnover time of any chemical or an element through an ecosystem. For instance **DDT**. DDT an important insecticide retains its toxicity for at least ten years, but its residence time in abiota may not be more than one year or so. Hence within ten years this—poison may circulate through an ecosystem several times causing severe damages to the biota. This is affected in the following way. DDT when sprayed in the fields to control insect-pests, soon reaches the soil and from there gets picked up by grass etc. When cows eat grass containing DDT, DDT enters the cow's bodies and then finds its way into the milk of the cows. When human beings drink such milk containing DDT, DDT reaches human bodies (Table V. 3.). Thus DDT which was used in agricultural fields to kill insect pests, ultimately finds its way into the human bodies—i.e. from grass to cows and from cow's milk to human bodies. This transit of DDT—a poison for insect pests to human bodies need not take more than a year while DDT's toxic properties last for ten years. This is a startling observation. The earlier governments make use of such information and put restrictions on use of such chemicals whose toxicity lasts more than a year, the better it will be for all of us. Soon after this finding U.S.A. has banned use of DDT.

V.3.5. Poisoning the Ecosystem: DDT

3.6. Raechel Carson was the first person to point out this dangerous side effect of use of DDT. Carson in her now famous book "The Silent Spring" (Houghton Mifflin, Boston, 1962) showed most convincingly as to how DDT from agricultural fields travelled through the rivers into the bodies of sea-birds. These sea birds who have DDT into their bodies lay eggs with very thin shells. Naturally such thin-shelled eggs broke when the parent birds tried to sit upon these to incubate. Egg fatalities became so extensive that populations or some sea-birds dropped almost to the verge of extinction. Thanks to Miss Carson's beautifully written book

V.3.6. Rachael Carson: DDT and sea birds

Table V.3.
MEAN CONCENTRATION OF DDT IN HUMAN BODY FAT IN SOME COUNTRIES
(Abridged from Ehrlich and Ehrlich – 1973. p. 133)

Country	*Year*	*No. of Samples*	*DDT (ppm)*
U.S.A.	1942	10	0.0
U.S.A.	1963	282	10.3
Alaskan Eskimo	1960	20	3.0
Canada	1966	27	3.8
U.K.	1964	100	3.3
Germany	1959	60	2.2
Hungary	1960	50	12.4
Israel	1964	254	19.2
India (Delhi)	1964	67	26.0

with convincing arguments and her tireless campaign against use of DDT, U.S.A. banned use of DDT in 1972.

The famous bald eagles *(Haliacetus leucocephalus)* of North America suffered severely from DDT and their number plummeted to only 400 breeding pairs in the lower 48. But soon after 1972 they made a remarkable spring back in population. Now they have more than 6000 breeding pairs (N G S, July 2002). This ban was followed by other developed countries as well. Thereafter populations of other affected sea-birds also have risen. But India and other underdeveloped countries are still using DDT and such long lasting insecticides. It seems consciousness about the latent hazards of synthetic chemicals used in agriculture and in households is still inadequate in most developing countries.

V.3.7. Cultural Eutrophication: Oyster Fishery in Cheasapeake Bay, U.S.A.

3.7. DDT is a poison. One would easily understand that accumulation of too much of any poison or even nutrient in any ecosystem, anywhere is harmful. The process that leads to such harm is termed ***Cultural Eutrophication.*** Here is an example. There is a bay known as Cheasapeake Bay near Washington D.C. which receives water from Potomac river. The watershed (vide V. 3. 9) of this river has many cultivations which uses heavy doses of chemical fertilisers. Use of chemical fertilisers is supposed to be good for agriculture. But residual fertilisers from the fields however are washed into Potomac river enriching the waters of Cheasapeake Bay so much that, its native plankton was soon replaced by an entirely new species of plankton. This lead to near extinction of the valuable oyster fishery of the Bay. This caused a terrible loss of income to the local fisherman. So we see how a good thing such as use of fertiliser for agriculture can lead to a bad thing elsewhere such as loss of a valuable fishery. Fortunately U.S. Govt. took vigorous corrective measures to ensure that nutrient rich water do not get into Potomac river and thus upsets its ecobalance. Now they are hopeful to be able to restart the valuable oyster fishery of Cheasapeake Bay, U.S.A. (The Washington Post 1999).

3.8. Recently a Calcutta daily (Bartaman : 21.02.001) reported that **poisonous effluents** from a paper mill at Darshana, Bangladesh, flowed into the river Mathabhanga there. This river soon split into two tributaries one of which is the river Churni which mostly flows through India (Nadia district, West Bengal) and finally joined Ganga. So much of the poison entered the river Churni that plenty of fishes died and people who bathed in the river suffered from skin problems.

V.3.8. Direct poisoning of fishes of a river

3.9. The area of land from which water is drained into a river or lake (or pond) is the watershed of that river or lake (or pond). For example, the watershed of the river Ganga is spread from Kashmir to Bihar and West Bengal covering vast areas of Himalayas and Siwalik Ranges, parts of the states of Delhi, Rajasthan, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Bihar and West Bengal as well as the neighbouring state Nepal. This area is equivalent to roughly 1.4 million square kilometres. (Map. II.2). This is quite a big area with extremely variagated environments ranging from snow-capped mountains of Himalayas to hot semi-arid ravines of Chambal and also tropical forest of Southern Himalayas as well as flat alluvial plains of Uttar Pradesh and West Bengal. Monsoon water from this vast watershed and also water from molten snow of Himalayas all move towards Ganga—some directly and the rest indirectly though forests, agricultural fields and some by percolation through soil. Still only a part of the monsoon showers reach the river Ganga, rest either evaporate away from the surfaces of the arid regions or lost through transpiration from forests and agricultural fields and the rest percolate down into the soil to replenish the stock of ground water. All these processes play importance roles in maintaining the health of the watershed i.e. the ecosystems which forms the Ganga watershed.

V.3.9. Watershed and its Importance

3.10. Like big rivers such as Ganga, small rivers or even brooks have their watersheds. So have the lakes or ponds. All have their watersheds (or catchment areas) and naturally their ecosystems. The quantity of the water that flows into the rivers, brooks, lakes or ponds is very much influenced by the conditions of the watershed. When an watershed is disturbed by human interference such as deforestation, agriculture of creation of cities, roads etc. one or more of the followings happen.

V.3.10. Recharging of Aquifers

(*a*) Deforestation leading to temperature rise of the exposed area. This is because nearly 42% of the energy of the incident sunlight on a forest is used by plants to provide energy for transpiration of water. If plants are removed this unutilised energy heats up the place further.

Ills from Deforestation

(*b*) In a deforested place as there are no trees to use water and stop its flow, so rainwater quickly runs off to the nearest river or lake causing several damages to the ecosystem such as—

(*i*) soil erosion,
(*ii*) raising of the river beds or filling up of the dams,
(*iii*) causing more frequent floods,

(*iv*) loss of nutrients from the top soil impoverishing the soil,
(*v*) impeding the recharging of the water table leading to summer draught,
(*vi*) lowering of the water table,
(*vii*) arsenic poisoning of the well-waters,
(*viii*) drying up of the lakes and rivers in summer.

(*c*) Deforestation causes another type of damage to the ecosystem. When top soil is washed off carrying with it most of the nutrients, the waters of rivers and lakes become abnormally rich with nutrients. This causes explosive growth of phyto-planktons and zooplanktons leading to depletion of oxygen in water. Consequently soon fishes start dying of suffocation. Thus excessive nutrients in water have a negative effect (also see V. 7.).

3.11. Importance of Watershed in keeping the Lakes and Ponds alive. Here we would like to seek a few minutes of townspeople to talk about their ponds. With town population soaring, and land price sky rocking the estate developers are now eying the town-ponds as easy target areas for filling up and constructing apartments. Naturally local people—the so called environmentalists protest. But these protests are mostly, of no avail. By various unholy combinations of people with vested interests ponds are filled up and the inevitable apartments spring up.

A word About Town Ponds

This surrpetitious land—filling is done mostly in the following way. first the houses are built-up to the edge of the pond, leaving only 10 to 20 feet of land in the margin mostly as road. The locals however promise to preserve the pond for the beauty of the locality etc. Soon however the pond is used as a handy dumping ground of garbage by the locals. Even the images of most earthen idols worshipped by people are regularly thrown into this pond. So the bed gradually rises. This two pronged attack on the pond—first by depriving it of its watershed and secondly by filling it up with garbage soon kills the pond. Only 50 to 100" of annual rain on its surface is not adequate to keep a pond alive. Soon the dry bed to the pond is used by the local boys as playground after which the house builders take over. There were several beautiful ponds in Kolkata which are now going through such death-spasms. For example, Lake No. 2 of Lake Town and the pond behind the office of Geological Survey of India, Chowringhee, Kolkata). [Photo V.1(a) and (b)] Even the ponds of Kolkata Maidan do not seem very safe. Uniformed public, apathetic government and greed of estate developers have formed a unholy trinity which is gradually throttling Kolkata ponds. Soon the park trees may die off for lack of water in soil.

Thus the watershed which is vital for pond is gone

3.12. If forest cover of a watershed is adequately maintained then rainwater gets time to enter the soil and thus recharges the water bearing strata or aquifers and so replenishs the ground water. Such recharged aquifers help in the following ways—

Summing Up

(*i*) Provide water for the trees in summer.
(*ii*) Keep the waterholes in the forest alive throughout the year.
(*iii*) Keep the village wells free of arsenic poisoning
(*iv*) Encourage leaching i.e. poisonous chemicals in soil to go deeper down as dissolved solutes in water.
(*v*) Keep the silt load of river waters low and thus keep the rivers deep and hence reduce the severity of monsoon flooding.

V.3.13. Forests in U.S.A. vs. India

3.13. Since 1930's United States of America initiated vigorous steps to maintain and replenish their own forest resources. Today that country has more trees than before. Their reserve forests are so well stocked with herbivores that they regularly cull animals such as deers to maintain health of the forests.

In India the position is reverse. Though Forest Research Institute of India at Dehta Dun was established as early as 1906, the forest cover of India has only shrunk and shrunk. The relative health of the forests ecosystems of U.S.A. and India would be evident form the following. U.S.A. has 30% of her land covered with forests while India has only 23%. Again U.S.A. has only 19% of arable land but India has 56% (both are from C.I.A. data, 1998).

The Comeback of Bisons but Decline of Tigers

The magnificient herds of bisons of U.S.A. which neared extinction through hunters with rifles, are now well protected. Their number is swelling. The story of the royal Bengal tigers is reverse. Following figure is revealing (Fig. V. 7.). Obviously the Government of India inspite of her efforts to stem this alarming decline of tiger population, has scarcely succeeded. Immediately much more is needed.

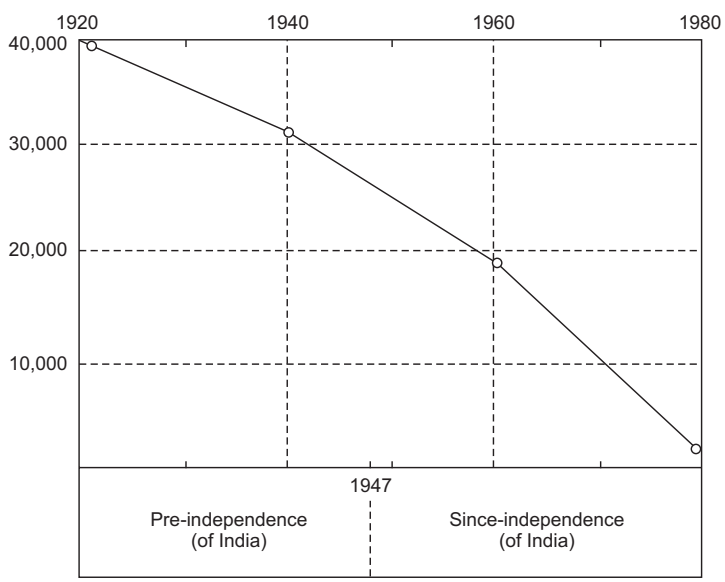

Figure V.7 The decline of "Royal Bengal Tigers."

3.14. One must also remember the land requirement of an animal depends upon its size as well as food habit. A predator like a tiger needs vast area but a herbivore can manage with a fraction of it. A single spotted deer may need only 10-15 acres of land for food but a single tiger would need at least 10 to 15000 acres of land to provide it with enough prey animals (Col. Keshri Singh, Jaico Publishing House, 1967) required to survive and breed. Again although vegetarian nevertheless owing to their large size elephants too require very large areas to support them. An adult elephant consumes 3 to 400 pounds of vegetables every day. That is why small game preserve are unsuitable for tigers and elephants. Besides large mammals migrate considerable distances from season to season for either suitable pasture or climate. Migrations of wildebeests of Africa and reindeers of North Europe are classic examples. (The annual migration of wildebeests and zebras from Serengeti to Masai Mara in Tanzania is a spectacular scene covering a distance of 400 kilometres). African elephants too travel long distances. Elephants in the reserves in Northern bank of river Brahmaputra and tigers of Sunderbans of Assam and West Bengal respectively regularly tresspass into neighbouring habitations of men. For these reasons if game preserves or national parks are to be made very effective, these should have not only plenty of space but these should be, as far as possible, connected with neighbouring reserves through corridors. If these can be achieved the animals would have much better chance of prospering. These corridors should also facilitate north—south migrations. A north south migration helps animals to tackle rigours of weather.

V.3.14. Space requirement of animal and Importance of Corridors between Game Preserves

3.15. Earth's atmosphere is a very extraordinary mixture of gases. Besides water vapour it contains 79% nitrogen, 21% oxygen (nearly) and a mere 0.03% carbon dioxide and traces of other gases. Earth is the only planet we know of which has free oxygen in its atmosphere. Next remarkable feature is CO_2. Plants get their carbon during photosynthesis in the form of CO_2 from atmosphere. Plants again release CO_2 into atmosphere during respiration and decomposition. So essentially carbon cycle is a simple gaseous cycle—atmosphere $\rightarrow$ plants $\rightarrow$ atmosphere. But the story does not end here. Atmospheric CO_2 absorbs infra-red radiation from ground. Therefore rise of CO_2 level in atmosphere is followed with increase in air temperature. This is known as **Green House Effect**. It has now been shown that since 1955 till 1995, the atmospheric CO_2 level has steadily risen from 315 ppm to 355 ppm with annual peaks and troughs (Fig. V. 8). This gradual rise of atmospheric carbon dioxide is worrying many. They think if temperature rises steadily arctic snow will melt, sea level will rise, vast areas near coastline will go under sea and many other calamities may follow.

V.3.15. Carbon Dioxide and Greenhouse Effect

3.16. The above group of people are alarmists. There are however people who believe otherwise. Before delving into their views let us have a look on the earth's pool of carbon and its movement through biosphere (Fig. V. 9.).

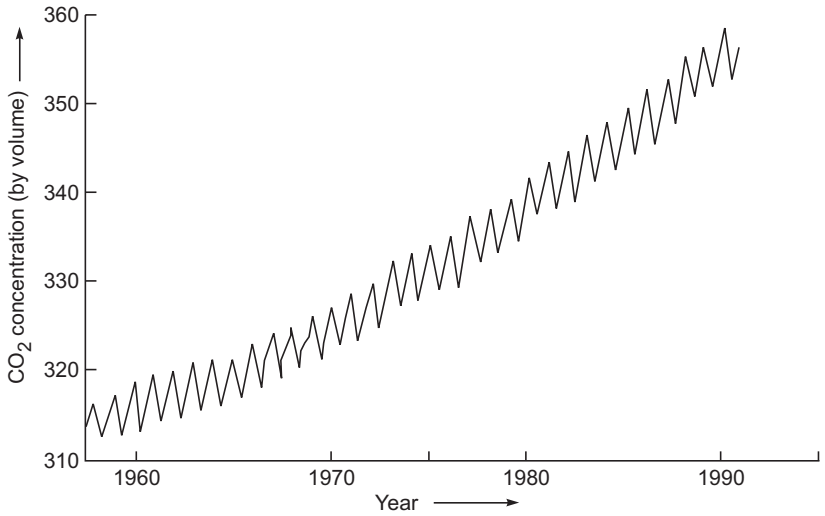

Figure V.8 Rise of Carbon dioxide level in atmosphere.

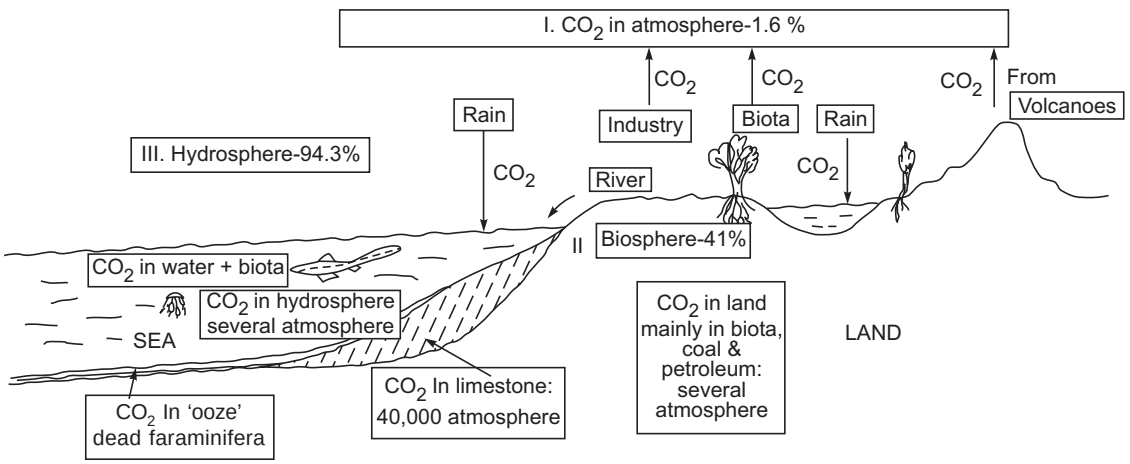

Figure V.9 Earth's pool of Carbon dioxide and its movement through biosphere.

As mentioned earlier carbon cycle is a gaseous cycle. Plants absorb carbon dioxide from atmosphere during photosynthesis and releases it back into atmosphere during respiration. Most of the atmospheric CO_2 however finally finds its way into sea. Sea surface acts as a huge sink for atmospheric CO_2. Surplus CO_2 of sea tends to settle down as limestones in the sea-bottom. CO_2 content of sea water is 50 times of atmosphere and of limestone 40,000 times! Sea is a huge sink for atmospheric CO_2. So the latter group feels that emissions of CO_2 due to industrial activity is too meagre to offset the role of sea as a CO_2 sink and change weather.

V.3.16. We need not be so alarmed after all

The present author inclines to agree with the latter view. The rise of atmospheric CO_2 level is a temporary fluctuation which is very likely owing to extensive deforestations and draining off of swamps and bogs all over the world. On this issue Colinvaux says as follows. "This is because a more massive and suden release of CO_2 which might be affected by the agricultural activities than by burning and mining of coal" (p. 593, Yr. 1993).

V.3.17. "I was, I am, I shall be"

3.17. Before closing this chapter let me refer again to the opening 'sloka' from the religious book GEETA—"I was, I am and I shall be". From our understanding of Bio-Geo Cycles of Chemicals we can now easily comprehend that all that we see around us—both living and non-living, had been in existence on the earth since its beginning, only their forms and hence activities are changed from time to time. This is the essence of Bio-Geo-Cycles of Chemicals. Thus the above sloka of Geeta seems very apt.

Chapter VI

Populations

(The Milling Millions)

Topics

VI. 1. The Definition

VI. 2. Characteristics of Population

VI. 3. Seasonal and Annual Changes in Populations

VI. 4. Territoriality

VI. 5. Population Age Pyramids

VI. 6. Population Interactions

VI. 7. Some specific Responses of Populations to meet the Challenges of Environment

VI. 8. Byorhythm

VI. 9. Specific Responses of Populations to Factors of Weather

VI.10. Measurement of Populations

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CHAPTER VI

POPULATIONS

(*The Milling Millions*)

"There is no exception to the rule that every organic being naturally increases at so high a rate, that if not destroyed, the earth would soon be covered by the progeny of a single pair. Even slow breeding man has doubled in twenty-five years, and at this rate, in a few thousand years, there would literally not be standing room for his progeny."

— *Charles Darwin - The Origin of Species*

(Avenel Books, New York, 1976, p. 117)

1. THE DEFINITION

1.1. So far we were busy in acquainting ourselves with the elementary concepts of ecology such as, basic features of a normal ecosystem (Chap. II); how food materials pass from one level of producers to the next (Chap. III); how solar energy travels through the entire ecosystem in an ever depleting manner (Chap. IV) and finally how chemical elements travel in a cyclic fashion from the living to the non-living and back to the living in ecosystems (Chap. V).

1.2. Arming ourselves with these elementaries of ecology we shall now turn on our attention to the lives and activities of groups of individuals in an ecosystem i.e. **Populations**.

Definition and Characteristics of Population

1.3. The word **Population** means an assemblage of all members of the same species living in the same ecosystem. For example, tigers of Sunderbans of India and tigers of Siberia of U.S.S.R. from two different populations though they both belong to the same species-*Panthera tigris.* The population of Sunderban tigers is so far placed from the Siberian tigers that they cannot interbreed. This genetical isolation of one set of members of the same species from another is an essential requirement for eventual evolution of a species.

1.4. From this angle Darwin's observation given in the opening of this chapter is very valuable. It seems to us, just as for animals, such concepts for population increase is relevant about human species *Homo sapiens* as well. More about this later when we talk about territoriality of populations.

2. CHARACTERISTICS OF POPULATION

There are some biological traits which are shared by all populations as a group but not as individuals. There are—

(1) Birth Rate or Natality,
(2) Death Rate or Mortality,
(3) Density,
(4) Growth Rate,
(5) Biotic Potential,
(6) Territoriality,
(7) Bio-rhythm, and a few more.

Of these the first four are universal. The rest are although interesting but more relevant in certain specific situations and populations. So we may refer to those if and when required. Now we shall examine these one by one.

Birth Rate or Natality

2.1. Birth rate is the rate at which new individuals are born to a population in an unit of time. This unit of time, depending upon the nature of the population, may be as small as an hour or less (for instance yeast), to as big as an year or more (for instance elephant). Birth rate is naturally quite different from birth.

2.2. Birth is a biological process of producing one new individual from another individual at a particular point of time. There may not be any more repetition of such process for several succeeding points of time. Biologists distinguish birth from birth rate by calling the latter **Natality**.

2.3. Natality of a population is a very important information regarding it. For example, birth rate of dear population and birth rate of rabbit population although both are herbivores and both inhabit the same forest, may not be same. While natality of a population of 1000 spotted deers in one year may be 250, that of rabbits of same number might be no less that 500. Forest rangers use such data in the management of forest and parks.

2.4. The capacity of producing new individuals by an individual is however called **fecundity.** Fefundity varies enormously from species to species. An elephant may produce one baby in two years, a human being one in one year, a rat several within a few months and a cod fish may release one million eggs in a river in one season! In this measure of facundity however the unquestionable winner is the Pacific giant calm *Tridacna*.

2.5. Like spewing of a white cloud from a volcano, one single calm releases more than a billion eggs in water at one go—a truly "Guiness Book of Record" performance (Fig. VI. 1)!

2.6. Later we shall see that mere size of litter or, number of eggs laid per season do not ensure the survival of species. Much more is taken to achieve that. Attenborough in his remarkable book (The Trials of Life:

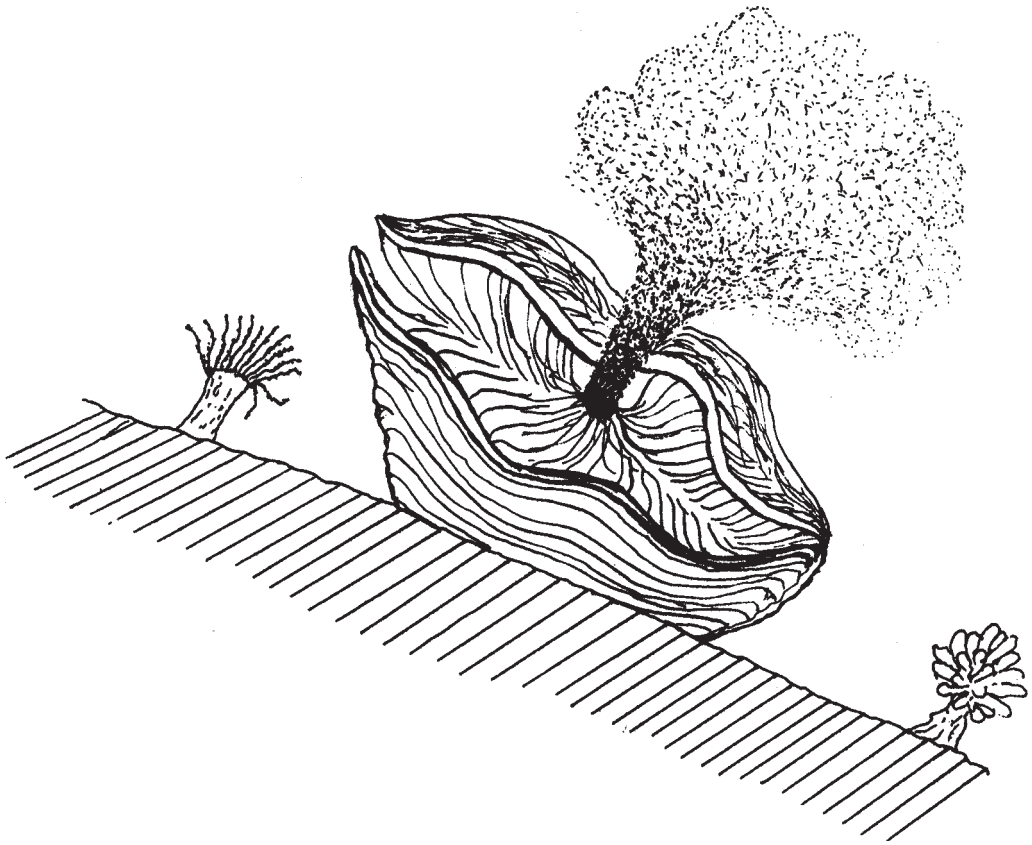


Figure VI.1 Billions of eggs being released from a single giant pacific calm *Tridacna sp.*

Little, Brown and Co. 1990) has beautifully shown some of the struggles a species has to undertake to survive and breed.

Physiological Natility and Ecological Natality

2.7. All the thousands of eggs released by a fish in water or even a few eggs laid by a bird in a breeding season do not survive. Hence natality can be of two types. First is the maximum production of new individuals that is possible for one individual under ideal conditions. This is called **absolute or physiological natality.** The second is the **realised or ecological natality** which means the actual population increase under specific ecological conditions. Naturally ecological natality of a species is much smaller and varies from place to place depending upon how encouraging or discouraging the habitat is for the birth of the offspring of that species.

Death Rate or Mortality

2.8. Just as we have talked of birth-rate now we shall talk about death-rate or mortality. Death-rate is the rate at which a certain number of individuals belonging to a population, die within an unit of time. Naturally this unit of time varies according to the nature of the species. Like natality here too this unit may be as small as one hour or less for a being like

yeast or as big as a year or more for a being like elephant. We know that animals or plants which produce too many young ones or eggs or seeds will lose most of these before they reach maturity and reproduce. Otherwise before long, the earth will be overrun by one species population-the one species which produce the maximum number of eggs or seeds.

Theoretical Mortality and Ecological Mortality

2.9. The following table will illustrate the consequences of unrestricted growth on two relatively slow breeding populations-man and elephant (Table VI. 1.). In just four hundred years there would be thirty thousand five hundred and seventeen crores of human beings and in just eight hundred years, three thousand fiftyone crores of elephants on earth. But this does happen not so. In any undisturbed ecosystem the relative sizes of different populations of species remains nearly unchanged. Normally mortality in a population is more than what it might have been under ideal conditions ie unlimited food and space etc. This means that there is a minimum or **theoretical mortality** and an actual or ecological mortality for that species population. **The theoretical mortality is always less than ecological mortality.**

2.10. Natality adds to a population and mortality subtracts from it. Also sometimes some members of a population migrate away reducing the size of the remaining population or, by a reverse operation ie by immigration some new members may join the population increasing its size. So the

Table VI.1.
UNRESTRICTED POPULATION GROWTH OF TWO SLOW BREEDING SPECIES–MAN AND ELEPHANT.
(Assumption is that man has 25 years and elephant has 50 years of reproductive period but both pair will produce 10 offspring each, during this period.)

After year	*(a) Man (25 yrs × 10)*		*(b) Elephant (50 yrs × 10)*
25	10	50	10
50	50	100	
75	250	150	50
100	1250	200	125
125	6250	250	625
150	31250	300	3,125
175	156250	350	15,625
200	781250	400	78,125
225	3906250	450	3,90,625
250	19531250	500	19,53,125
275	97656250	550	97,65,625
300	488281250	600	4,88,28,125
325	2441406250	650	24,41,40,625
350	12207031250	700	122,07,03,125
375	61035156250	750	610,35,15,625
400	3055175781250	800	3051,75,78125

Status of a population

status of a population at any time therefore is the result of four processes operating simultaneously on the population, prior to that time. Ecologists show this by a very simple equation.

$$N_{now} = N_{then} + B - D + I - E$$

When N_{now} = number now

N_{then} = number then

B = birth

D = death

I = immigration

and E = emmigration

The sum total of all these processes determine N_{now}. When N_{now} is expressed against the area the population is occupying, we call it Density. Density is usually expressed as number of individuals per unit area. The following table shows the densities of human populations and the land available per individual in some selected countries of the world (Table VI. 2).

2.11. From the above table it is quite clear human densities varies widely from country to country. Gaza strip is the most densely populated country of the world and Australia the least, with 2744 persons per square km. or

Table VI.2.
RELATIVE DENSITIES OF HUMAN POPULATIONS OF SOME COUNTRIES AND LAND AVAILABLE PER CAPITA THERE, ARRANGED IN DESCENDING ORDER OF DENSITY
(By H.L. Kundu from C.I.A. Data – 1999).

S. No.	*Country*	*Population (per sq. km.)*	*Square Metre (Per head)*
1.	Gaza Strip	2744	364
2.	Bangladesh	871	1150
3.	Japan	333	3003
4.	India	294	3401
5.	Israel	267	3745
6.	U.K.	241	4149
7.	Pakistan	164	6098
8.	China	127	7874
9.	Syria	87	11494
10.	Egypt	65	15384
11.	Iraq	51	19608
12.	Kenya	50	20000
13.	U.S.A.	28	35714
14.	Brazil	19	52631
15.	Saudi Arabia	10	100000
16.	Russia	9	111111
17.	Canada	4	325216
18.	Australia	3	416883

364 square metre of land per person in gaza and 3 persons per sq. km. or 333333 sq. metre of land per person in Australia. This is remarkable indeed. Later we shall discuss about the reasons of this. Now let us spend some time on Malthus who was a pioneer regarding studies on human population ecology (demography).

Thomas Robert Malthus

2.12. Thomas Robert Malthus (1766-1834) was born of a middle class english family, educated at Cambridge and spent early part of his life as a curate. At 38, he joined East India Company's College at Hertfordshire as Professor of History and Political Economy. His seminal book **Principle of Populations** was first published in 1798. Immediately it drew worldwide attention of scholars. The main theme of the book was whether human society is perfectible or not. He thought not, as, the tendency of human population is to grow exponentially while the food supply can grow at best arithmatically. Hence this will lead to misery and vice. This contention of Malthus was a cornerstone of Darwin's theory on 'The Origin of Species'. In Darwin's language: "A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase.....". "Hence as more individuals are produced than can possibly survive, there must in every case be a struggle for existence".... "It is the doctrine of Malthus applied with manifold force to the whole animal and vegetable kingdoms;" ... So we feel one can fairly say Malthus was a precursor of Darwin. (Interestingly Malthus had only two surviving children i.e. zero growth family—at a time when most of his contemporaries used to have several children. Most Europeans who colonised Americas soon after Columbus's discovery of America (1492), used to have very large families—most had more than six children).

2.13. As shown before, the status of any population i.e., N_{now} is a result of $N_{then} + B - D + I - E$ (for explanation of symbols see para 10). All the above processes which influence the status of a population ie birth, death, immigration and emigration are called demographic processes.

Patterns of Growth of Populations

2.14. Any population when unhindered, tends to grow. When the size of a population is plotted in a graph, depicting the growth of the population from the time of its introduction to a place, at successive points of time, we get a curve which is called as growth curve (Fig. VI. 2).

Sigmoid Growth Curve

2.15. The above graph shows how in a favourable habitat the population of a species tends to grow on and on until the habitat becomes fully saturated. This means that this environment now can no longer support a bigger population of that species. This type of growth curve which looks like a slanted capital 'S' is called Sigmoid Growth Curve or, 'S' shaped growth curve. This sigmoid type of growth pattern is likely to happen with large predators in a forest or savannah—such as lions in African savannah and also for small animals in special situations; for instance barnacles in sea. Barnacles are a type of small invertebrate (belonging to the groups of prawns and crabs), who remain attached with sea-side logs,

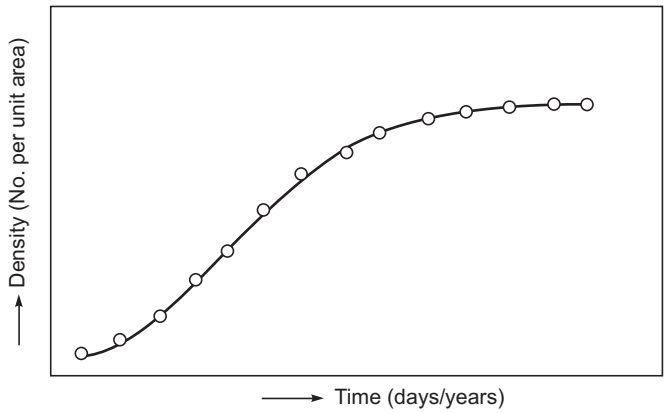


Figure VI.2 A simple growth curve (sigmoid curve) of population.

or stones and such stable foot-holds (Fig. VI. 3.). (The young ones of barnacles swim about in sea, looking for a foot-hold. Once these find one such as stone, pillar or wood etc., these quickly settle upon it and grow. In this way when all the available space is occupied, no new barnacles can settle upon. So here the population growth is a sigmoid one.)

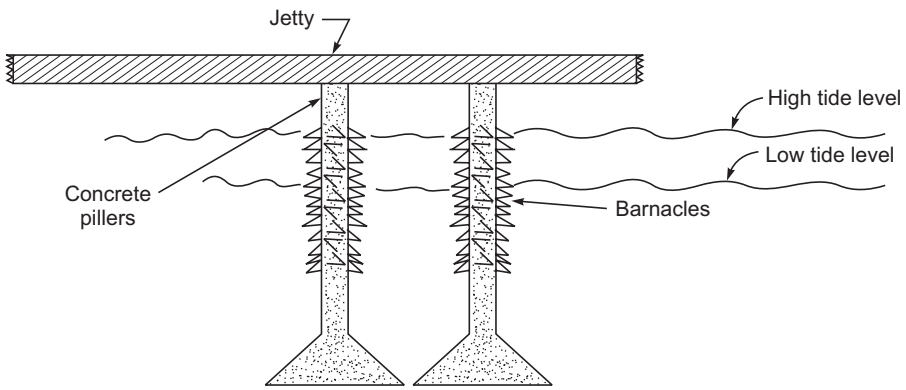


Figure VI.3 Barnacles attached and covering a foothold.

2.16. There is another pattern of growth where the population rises very fast until all the available resources of the habitat is used up and then the population plummets down or crashes (Fig. VI. 4). This type of quick rise followed by sudden crash is found amongst many invertebrates such as planktons in a lake. In a lake in cold place say Dal Lake in Kashmir or lakes in Scotland, winter is so cold that planktons can no longer grow. When summer comes and water temperature rises suddenly there is a spurt of plankton-growth; they grow very fast and quickly use up all the available nutrients. Soon due to lack of nutrients plankton population almost drops to nil. As the bodies of dead planktons decompose and the nutrients are released into water, the plankton number spurts up again.

"J" Shaped Growth Curve

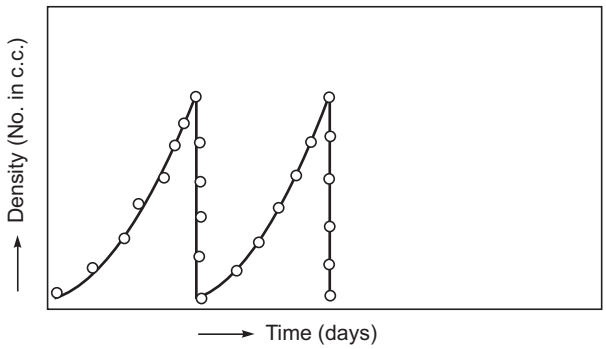


Figure VI.4 A "J" shaped population growth curve.

2.17. This type of quick rise followed with a sudden fall of population is known as 'J' shaped population growth-as this rise and fall roughly looks like the letter capital. Besides plankton such type of growth pattern is generally exhibited by small animals like insect larvae, stored grain pests etc.

Specific Mortality Life Table and Cohort

2.18. There are standard mathematical equations available for describing such patterns of growth and for comparing the growth patterns of one species with another. We may come to such equations in future, if need be.

2.19. When the mortality of the members of a population "is expressed as a percentage of the initial population dying within a given time" this is called **Specific Mortality.** If the entire life-span of a species is devided into several successive and equal periods and we work out the specific mortalities of each period and put this information in a tabular form, we get a table called **Life Table**.

The Life Table is a table which gives the mortalities of a species population at each age-group. Adolf Murie an U.S. National Park Ranger very painstakingly collected such information on the mortalities of Dall Mountain Sheep *Ovis D. Dalli* of Mt. McKinley National Park of Alaska (1944). Soon after from these data of Murie, Edward S. Deevey (1947) prepared a life-table of these sheeps (Table VI. 3). Perhaps this is the earliest and one of the best prepared life-tables. The symbols x, x', d_x, I_x, 1000 qx, $^e x$ etc. are now standard notations for life-tables and accepted symbols in demographic works. There are more such standard notations. We are just exposing the readers with the meanings of most common of these.

(1) **'Specific Mortality'.** The meaning of the term 'Specific Mortality' is already given earlier (see para 18).

(2) **'Cohort'.** The meaning of the term 'Cohort' is as follows. A group of individuals sharing a particular demographic or statistical characteristic is called a 'Cohort'.

Table VI.3.
LIFE TABLE OF DALL MOUNTAIN SHEEP, *OVIS D. DALLI*
(From Odum 1959, p. 166)

x	x	d_x	I_x	1000_{qx}	e_x
Age (years)	*Age as percent deviation from mean length of life*	*Number dying in age interval out of 1000 born*	*Number surviving at beginning of age interval out of 1000 born*	*Mortality rate per 1000 alive at beginning of age interval*	*Expectation of life, or mean life-time remaining to those attaining age interval (years)*
0-05	–100	54	1000	54.4	7.06
0.5-1	–93	145	946	153.4	–
1-2	–85.9	12	801	15.0	7.7
2-3	–71.8	13	789	16.5	6.8
3-4	–57.7	12	776	15.5	5.9
4-5	–43.5	30	764	39.3	5.0
5-6	–29.5	46	734	62.6	4.2
6-7	–15.4	48	688	69.9	3.4
7-8	–1.1	69	640	108.0	2.6
8-9	+13.0	132	571	231.0	1.9
9-10	+27.0	187	439	426.0	1.3
10-11	+41.0	156	252	619.0	0.9
11-12	+55.0	90	96	937.0	0.6
12-13	+69.0	3	6	500.0	1.2
13-14	+84.0	3	3	1000.0	0.7

Survivorship Curve, its meaning and usefulness

2.20. Reverse of mortality is survival. When the number of individuals survived from the same age-group or cohort, at fixed time-intervals/of their lives, are put against the time-intervals in a two dimensional graph, we get a curve - the **Survivorship Curve.** Such survivorship curves can provide valuable information about a species population such as—

(*a*) It can tell us at which age-group that population is most susceptible to death,
(*b*) It can tell us at which age-group the population is least susceptible to death ie strongest against environmental pressures like predators, etc.
(*c*) It can also tell us at which age the vigour of youth gives way to old age so senility begins to set in, and finally death takes over,
(*d*) It tells us the average life-span of members of that population.

2.21. By judicious use of such ecological information we can discourage a pest like an insect by hitting it at its most vulnerable stage in life or, patronise an animal or plant (which we consider useful to us) by reverse tactics ie protecting it at its most vulnerable stage of life.

Here is an example—mosquito. Pouring kerosene oil occasionally into pools of stagnant water where mosquito lays eggs is a very effective way to reduce mosquito population. In order to breathe the larvae have to visit

water surface at regular intervals. When at surface air enters the trachea (air breathing tubes) of the larvae thus enabling these to respire. When kerosene is poured on water it covers the water surface as a thin film and enters the tracheae of the larvae and choke them whenever these visit the surface to breathe. So they die of asphyxiation. Visiting water surface by the larvae for breathing, is the most vulnerable stage in the life of mosquito. So any control measure at that stage would be most effective. So far kerosene is perhaps the cheapest and environmentally least harmful tool for controlling mosquito populations.

2.22. The following figure gives the survivorship curves of a certain species population (Fig. VI. 5). The figure depicts, based upon the respective life-tables, the survivorship curves of Dall Mountain sheep *Ovis. D. Dalli,* men from rich countries, men from poor countries. *Hydra,* fishes and oysters. Each curve reflects many valuable information about the life of that species population. In nutshell the convex curves mean well-cared for childhood, vigorous youth and death takes over only when the natural life-span is over. The concave curves indicate the reverse situation ie scarce parental care so, sharp infantile mortality which continues with lessening severity during youth and old age. Attrition starts long before the natural life is over. Curves in between these two extremes, indicate high mortality at all stages owing to various environmental pressures such as, paucity of food, predation, lack of space etc. etc.

2.23. Fishes usually have very high mortality at egg and fingerling stages-mostly due to predators. Once the fingerlings acquire a certain size these

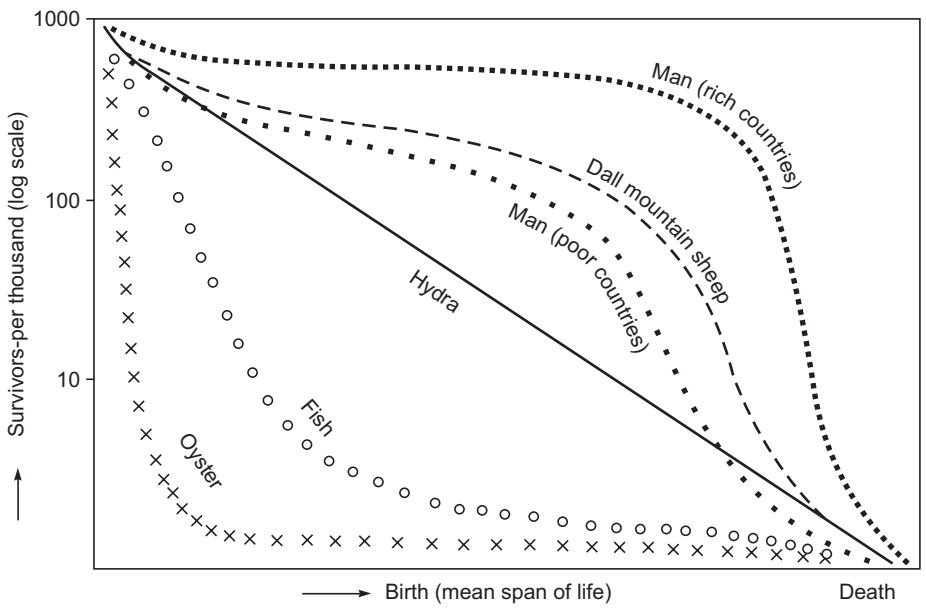


Figure VI.5 Survivorship curves.

enjoy a considerably hazard-free existence till mature age. Oyster larvae float around in sea as a part of plankton population looking for a foothold. During this period these suffer very heavy mortalities. That is why their survivorship shown almost a vertical decline until these secure a foothold. Once this is achieved the sessile oysters suffer few casualties. Most grow to maturity. *Hydra* on the other hand, suffer from mortalities at every stage of its life. Dall Mountain sheep whose most natural hazard is wolf predation, suffer premature mortalities mostly at infant and young ages, but once they attain youth these can tackle wolf and hence do not suffer too much till they become old and weak and hence can no longer fend off wolf attack.

Use of Life Tables and Survivorship Curves in Planning

2.24. Life-Tables, Survivorship Curves and fecundity schedules prepared for discrete populations such as members of one religion or one community or one locality etc. will yield valuable information for planners. Interestingly such information can easily be obtained by school boys as part of their school projects with no or little cost. Such data are of utmost importance as these contain the raw material of 'ecological facts of life'. Without these we can neither understand N_{now} nor hope to predict N_{future} of human beings or specific human populations and their needs.

VI.2.5. Biotic Potential and Struggle for Survival

2.25. "There is no exception to the rule that every species of organic being naturally increases at so high a rate, that if not mostly killed, the earth would soon be covered by the progeny of a single pair." (Charles Darwin—1859). Please refer to Table VI. 1. This natural propensity to increase at a very high rate is now-a-days called by ecologists as Biotic Potential. Chapman (1928) first proposed this term and defined it as "the inherent property of an organism to reproduce, and survive i.e. to increase in numbers".

Living beings require four conditions to survive. These are:

(*a*) food,
(*b*) space,
(*c*) breeding facility and
(*d*) proper weather.

If the first three are unlimiting and the fourth one is favourable then, any living being will grow in number as fast as its physiological capacity (i.e. physiological natality) permits. This maximum reproductive capacity for a species in ideal situation is the Biotic Potential and is denoted by a standard symbol 'r'. Or in other words the symbol 'r' is the difference between instantaneous specific natality rate and instantaneous specific mortality rate. Simphy speaking r = birth – death or, r = b – d.

2.26. Though one may presume 'r' to be constant for a species this not really be so. Depending upon **reproduction of the component age-groups** and their sizes, 'r' may vary from population to population of the same species even though other factors such as food etc. may be unlimiting. Hence there may be several values of 'r' for the same species population depending upon the population structure (i.e. age groups).

Variability of 'r'

When a **stationary and stable age-distribution** exists then the specific growth rate is called the **intrinsic rate of natural increase** and denoted at "r_1". At any rate whether 'r' or "r_1", Nature can support neither for long. Competition must take over to maintain balance.

2.27. Unrestricted breeding inevitably leads to catastrophe. Here are some examples, some estimated, some actual. Carl Linnaeus has calculated that if, an annual plant produce only two seeds each year, even then in twenty years it will leave a million plants! Charles Darwin estimated that an elephant, one of the slowest breeder amongst animals, will leave in five hundred years, from one initial pair, a population of fifteen million elephants (pl. see Table VI.1, as well). Following table gives how houseflies would multiply in one year, if unchecked (Tab. VI. 4). Eggs layed by houseflies *Musca domestica* in just one year starting from one pair of housefly and assuming it will lay 120 eggs in one generation of which 50% will be females and it will have seven generation in a year and all will live only for one year then one pair will lead to the production of nearly 5000 billion eggs of houseflies in just one year, (E. J. Kormondy- P. 76. Concepts of Ecology 1978. Printice Hall. New Delhi). Here is our estimation for human beings *Homo sapiens* (Table VI.1). Normally one healthy human female can produce ten children in her reproductive life of twentyfive years of these half may be females. If they can breed unrestricted, in a short span of 325 years, one pair of human beings will lead to a human population of 2.44 billion human beings-double of today's population of China (Table VI. 6). Obviously **Nature can never permit such unrestricted breeding to any species.** When Nature is prevented from acting freely then conscientious human intervention is the next best thing. Today human beings are the most powerful manipulator of Nature. But limited human intervention is not enough. Human population has never grown as fast as its physiology permits (i.e. 'r'). There was always some pressure on it to grow slowly.

Havoc from full play of Biotic Potential

Table VI.4.
GEOMETRIC INCREASE IN THE GROWTH OF A POPULATION OF ONE PAIR OF HOUSEFLIES (MUSCA DOMESTICA), IN JUST ONE YEAR, IF UNRESTRAINED AND RESOURCES ARE UNLIMITED
(Kormondy – p. 195)

Generation	*Eggs laid for year*
1	120
2	7,200
3	432,000
4	25,920,000
5	1,551,200,000
6	93,212,000,000
7	5,598,720,000,000

Still depending upon the prevailing social customs and financial leverage, human densities vary very widely in different countries (Table VI. 2). Today, Gaza strip and Bangla Desh are the two densest countries in the world, the earlier having 2744 and the latter 871 persons per square kilometre. It seems this alarming situation is due to prevalent social custom and access to modern medical facilities. Most Ladies have 4-8 children but owing to availability of better medical facilities now than ever before, infantile mortality has been drastically reduced. Earlier many children used to die off before becoming adults from malaria, cholera, small pox and malnutrition etc. But not today. Hence this 'so called' population explosion. We shall come to these issues again the last chapter of this book.

Need for Intervention with Biotic Potential

2.28. Here are two examples of active human intervention. In Zambia they have big elephant reserves where hunting and poaching is completely halted. Except occasional poachers-who hunt elephants for tasks, meat, hide and trophy, elephants have little to fear from other animals. Only lions occasionally kill one or two calves. So in Zambian game preserves, where rangers are mostly British or, locals trained by British, the elephant population has risen so fast and so much that these are destroying the forests they live upon. So, now Zambian Government regularly culls (kills off selectively) elephants in their reserves to keep the elephant population down to a healthy level for the ecosystem i.e. the reserves. In U.S.A. the Fish and Wildlife Department opens up their reserve forests once every year to permit a 2 to 4 week hunting season for deers. In November 1998 hunters in Maryland alone, killed 39,466 deers during a two-week hunting season (Washington Post. 19-12-98). Thus **a well-managed forest is not only a pleasure to visit but can also be a source of revenue** for the forest departments. This is equally applicable for the lakes, rivers and coral reefs of coastal waters.

Need of periodic culling and Well Managed ecosystems are sources of revenue

2.29. "A struggle for existence inevitably follow from the high rate at which all organic beings tend to increase" (Darwin-Origin of Species. p. 116 Avenel 1979). In a normal large ecosystem, uninterrupted from human intervention, various internal competitions for food, space etc. always operate. Through these mechanisms of checks and balances, Nature prevents a species from growing as fast as its 'r' or 'r_1' would allow. These mechanisms are collectively called **Environmental Resistance.** As a result of this i.e. environmental resistance, the actual growth of a population that we find in Nature is called **Ecological Potential** and may be denoted as 'r_e'. If 'r_e' is one, then the population remains stable i.e. neither increases nor decreases, if more than one than the population would grow with time. Here are the 'r_e's of some populations worked out by the ecologists (Table VI. 5.).

2.30. From the above table it seems that, the population of whites in U.S.A. will grow slowly, *Calandra* (a grain weevil) will grow astronomically fast, *Chorthippus* (a grasshopper) will vanish soon and

Table VI.5.
THE GROWTH POTENTIALS OF POPULATIONS OF SOME SPECIES.
(Prepared by author from Odum 1963, p. 181 and Begon et al. 1990, p. 133 and 136)

	Species	*Yardstick and its meaning*	*No.*	*Author and year*
1.	*Homo sapiens* (man) (Whites in U.S.A. in 1920)	'r_e': (no. of times the population would multiply in a year)	1.0055	Dublin and Lotka (1925)
2.	*Calandra orizae* (a beetle) (Rice weevil at 29° C)	"	1.58×10^{16}	Birch (1948)
3.	*Chorthippus brunneus* (Grasshopper)	"R_0" (No. of offspring produced for original individual by the end of the cohort.*	0.51	Richards and Waloff (1954)
	Phlox Drummondis (an annual plant)	"R_0"	2.41	Leverich and Levin (1979)

**Cohort:* A set of offspring born during a short and fixed period.

Phlox (a flower) will grow very fast indeed. In reality however none of these ever happened. There are many reasons and specific reasons for the realities of life not conforming to the figures. Here suffice it to say that these data at arrived are only from small samples; to get a realistic picture one needs much bigger samples and data over several years.

2.31. In the following sections we shall discuss some of the various ways with which a population meets the challenges of environment ("environmental resistance").

Carrying Capacity

(*a*) Generally any big ecosystem would be able to support a population up to a particular size and not above it. The upper limit of this size (or capacity), in a particular ecosystem beyond which no major increase can occur, is termed as the **Carrying Capacity** of this ecosystem for that species population. Unfortunately however we do not have many reliable data in this area. Following is one of the few available.

(*b*) Around 1810 the British immigrants introduced sheep in Tasmania. Initially the sheep population rose very fast but later growth rate slowed down gradually till it became nil. The sheep population reached its maximum around 1850 after which the population remained more or less stable (Fig. VI. 6). It is a typically sigmoid growth—initially slow, then fast but constant and then again slow and finally nil (Fig. VI. 6). The population density at the final stage is the carrying capacity of this ecosystem (here Tasmania) for that population (here sheep) under the then prevailing conditions.

(*c*) This case of sheep in Tasmania is a special case. Here men looked after them and there was no death from predation. As a matter of fact to ensure the safety of their sheeps, the British immigrants to

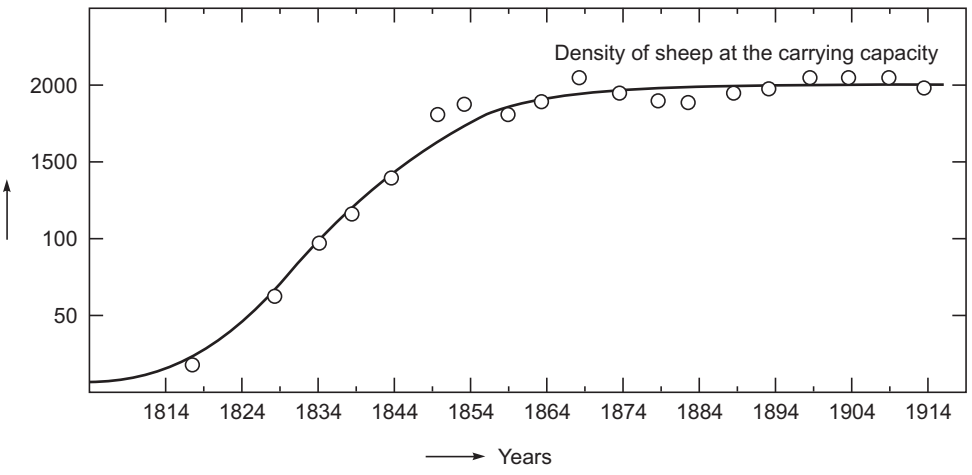


Figure VI.6 Growth of sheep population in Tasmania and its carrying capacity.

Tasmania decimated the local predator—'Tasmanian tiger'—*Canis dingo*, the only predator of Marsupial stock. (Today tragically Tasmanian tiger is extinct). So, save the area available for grazing, nothing deterred the growth of sheep population. For herbivores in forests there are predators to effect their numbers. Even then forest animals unless interfered with, exhibit sigmoid growth. Figure VI. 7., shows how in Serengeti region of Tanzania and Kenya, population of wildebeests *Connochaetes taurinus* devastated from an outbreak caused by the disease—rinderpest, rose and levelled off in a sigmoid pattern/(Fig. VI. 7.).

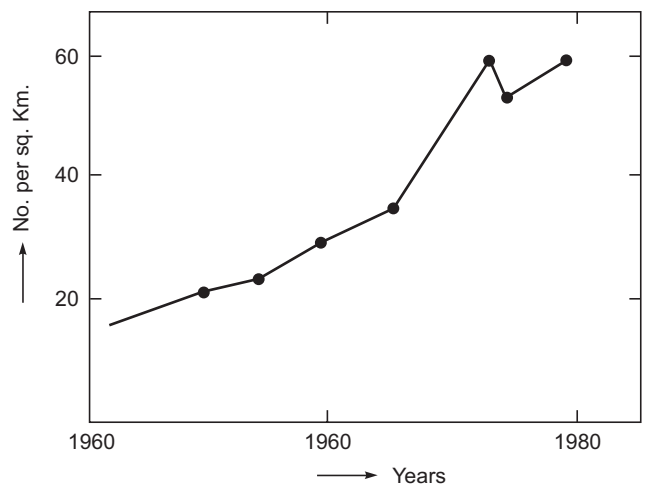


Figure VI.7 Sigmoid growth pattern of 'wildebeests'-a common wild animal of Tanzania and Kenya.

Food Habits and Carrying Capacity

2.32. Any ecosystem which does not suffer too much from human greed, for instance, a large reserve forest, would be able to support more or less, stable densities of different species of animals. The level of density of a species however, depends on its food habit which means the trophic level the species occupies in that ecosystem. Here are the densities of some common forest animals. (Fig. VI. 8).

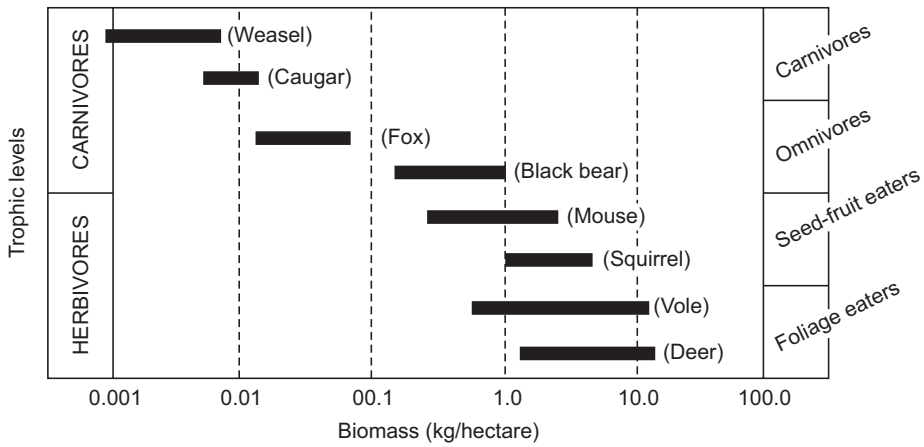


Figure VI.8 Densities of some common forest animals.

Food Habits and Space Requirements

(*a*) One very important lesson can be learnt from this table. The same area of land can support much more of herbivores animals than carnivores. For instance, one hectare can support 1.0 to 10.0 kg of deers who are foliage eaters i.e. herbivores but the same area of land can support only one hundreth (0.001 kg.) of caugars (animal like a leopard) as it is a carnivore (which means it has to feed itself by killing herbivores such as deers, rabbits etc.). For the same reason a Royal Bengal tiger *Panthera tigris*—a carnivore, requires about 30 to 40 sq. miles of land to support itself. That is why tigers live alone, save breeding season when they pair, and ferociously guard their territories. It seems to us Indian reserve forests are mostly too small in size to support healthy and genetically sound tiger populations and large herbrivores such as elephants.

Poverty and food-habit

(*b*) There is another point we would like to stress upon. For a poor and overpopulated country like India, Bangladesh etc. vegetarianism is both ecologically better and financially less strenuous. One hectare of land can produce much more food grains than meat. The other urgent eco-sociological need for countries like India, Bangladesh, Nepal and Gaza Strip etc. and such grossly overpopulated countries is to halt further growth of human population by bringing down "r_e" to 1. More about this later.

3. SEASONAL AND ANNUAL CHANGES IN POPULATIONS

Seasonal Changes Fluctuations and Blooms

3.1. The densities of populations of many species vary widely from season to season and for some species, from year to year.

When the densities vary regularly from season to season, such variations are termed fluctuations for example mosquitoes, planktons etc. Many of us have suffered from mosquito bites and have noticed how the mosquito numbers change with season.

3.2. In temperate countries such as Europe and North America, during winter planktons almost vanish from waters but as soon as spring returns there is a sudden outburst of planktonic activities and their number rises so fast that this phenomenon is called **plankton bloom** (or plankton pulse). As there is little biological activity, nutrients in water usually accumulate in winter. At the onset of spring when temperature is warmer biological activity erupts and abundance of nutrients (accumulated in water during winter) leads to plankton "bloom". Soon the planktons use up most of the nutrients and die; so again before the summer is over there is some accumulation of nutrients which sets in another "bloom" just before winter i.e. in autumn (Fig. VI. 9).

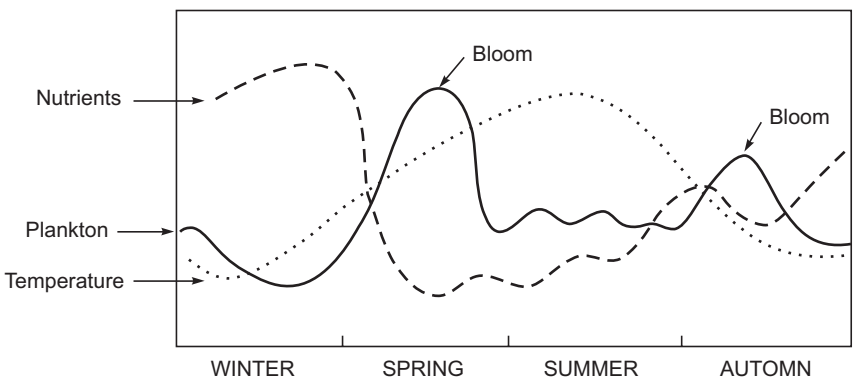


Figure VI.9 Plankton 'Blooms' in spring and autumn.

Annual Changes Population Oscillations

3.3. In relatively simple ecosystems such as tundra, where both the numbers of species of herbivores and carnivores dependant on them are few. Hence densities of both populations that is predator and prey rise and fall in a cyclic manner spanning several years. This regular and cyclic rise and fall in the population size of a species is termed **Population Oscillation.**

3.4. Interestingly this significant ecological discovery was made not through patient population surveys by biologists, in inclement weathers and spread over several years, but from the well kept account books of a famous business house in Canada. From 1800 onwards Hudson Bay Company maintained accurate records of pelts (of fur bearing animals)

they purchased from trappers. Their records showed clearly a cyclic pattern in rise and fall of densities of snowshoe hare and their predator Iynx with peaks in every 9 to 10 years (Fig. VI. 10). This is a classic case of popu-lation oscillation.

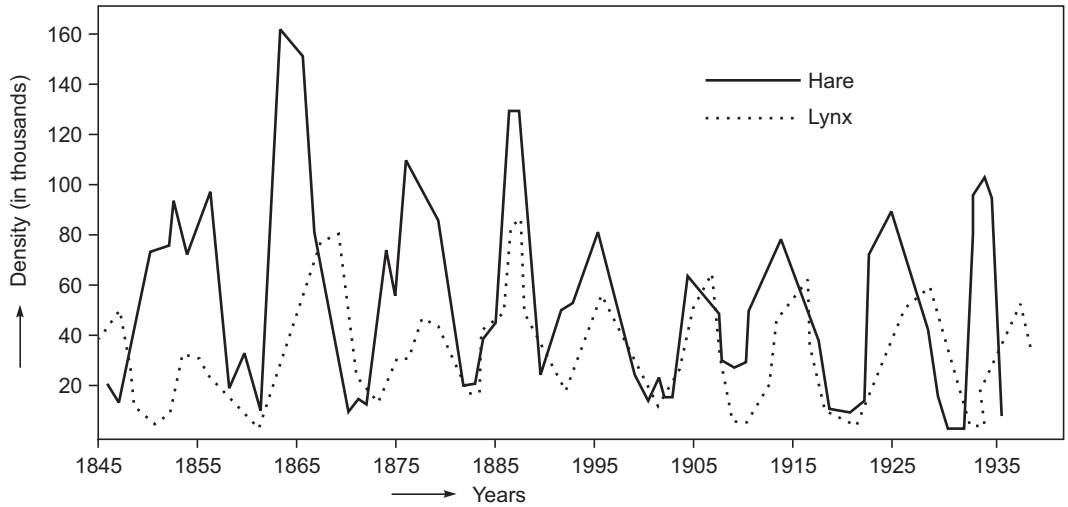


Figure VI.10 Population oscillation as exhibited by Snowshoe hare and their predator Lynx.

3.5. North Canada is a rather cold place—having tundra climate. So its ecosystem has fewer numbers of autotrophs and heterotrophs. There is a distinct 10.5 to 10.6 year cycle within which the population of snowshoe hare rises and falls sharply. The population of lynx whose main food is snowshoe hare, also rises and falls with hares' population—closely following it.

4. TERRITORIALITY

Tendency of one Population to eliminate another

4.1. Requirement of space is a must for many if not all, living beings. Some animals such as tigers fiercely protect their territories (see earlier), while others as some trees quitely suppress the growth of other plants in their vicinity. Tigers claim their territories by leaving scent marks (by urinating) on important landmarks such as trees, stones. A tree *Prosopic spicigera* which is endemic in semi-arid regions of Rajasthan achieves this by secreting some chemicals from its roots which prevent growth of other trees near it. Basically these are some of the ways by which living beings try to eliminate or reduce competition. More about competition follows.

4.2. What is competition? If we think a bit we shall realise that competition simply means the struggle between two individuals or two populations to grab the same resource such as, mate or food etc. If the

object for competition is scarce then some competitor will lose in the struggle and be eliminated. For instance, in the mating season stags fight each other to possess the herd of hinds around them. The loser runs away and do not get any hind to mate with and produce offsprings. The same thing happens with many other animals. Same thing applies with many populations. If two populations occupy the same ecosystem and depend on the same source of nutrition then sooner or later, the population which is even slightly stronger will eliminate the weaker one.

Gause's Competition Exclusion Principle

4.3. G.F. Gause (pronounced 'Gauser') demonstrated this principle of competition elimination through a simple elegant experiment. Gause took two nearly identical looking one-celled Protozoans. (Protozoa is the general name for all single celled animals). Ex. 1. *Entamoeba hystolytica*—the protozoa which causes amoebic dysentery. Ex. 2. *Plasmodium vivax*—the protozoa which causes malaria. Most protozoans however are harmless to us. Gause took two species of Paramecium—*Paramecium aurelia* and *Paramecium caudatum.* Both grow well in same type of culture—oatmeal medium. When grown separately both showed sigmoid growth curve. If however *aurelia* and *caudatum* are grown together in the same culture medium, *aurelia* soon eliminates *caudatum* (Fig. VI. 11).

4.4. From this and other similar experiments Gause concluded that when two species or two populations of same species having same requirements are placed together in the same environment, then the one having slight edge over the other will eliminate the other. This is exactly what happened with *P. caudatum* and *P. aurelia.* Obviously *P. aurelia* is a shade superior in competition to *P. caudatum*.

4.5. This elimination of one species or population by another allied species or population when are in the same environment is named by G.F. Gause as **Competition Exclusion Principle** (1934). So far this principle is found to be valid in all situations of competition. This is why the more variegated an ecosystem is from the point of view of its biotic and abiotic components - the more variety of plant and animals it would be able to support. This is because each species or population be it a plant or an animal will fit within a specific ecological niche within the same ecosystem, where it would be the most suited to survive and prosper.

Gause's Principle and Human Societies

4.6. There are strong social evidences to believe that Gause's principle is valid for human societies as well. All men want money but the supply is not unlimited. Therefore sooner or later, in a locality of human beings which is a social ecosystem, those group of men who are bit smarter than the other in earning money will soon eliminate the other group. This has happened in eastern India. Over the last two centuries or so, businessmen from western India have gradually but steadily squeezed out the locals from most business. Today in Calcutta-the capital city of a state in India, West Bengal where majority speak Bengali, the moneymarket is in the hands of people whose vernacular is anything but Bengali. This

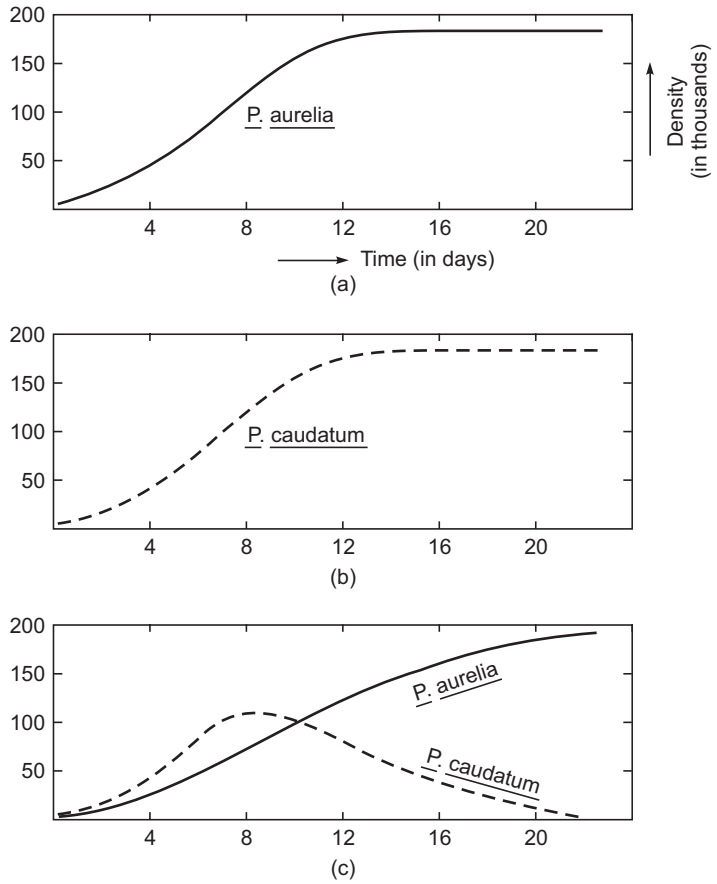


Figure VI.11 The principle of competitive exclusion as exhibited by *Paramecium aurelia* and *P. caudatum.*
(a) Culture of *P. aurelia* alone.
(b) Culture of *P. caudatum* alone.
(c) What happens when they are grown together.

silent revolution is creeping into U.S.A. as well. Since Second World War businessmen from western India and other developing Asiatic countries are emigrating to U.S.A. in good numbers. After a few years in various small jobs, most of the emigrees have quit jobs and plunged into business by banding together, pooling their resources and buying out small business. Through hard work, perseverance and parsimony they are making steady progress. This would soon become an economic force to reckon with in U.S.A.

5. POPULATION AGE PYRAMIDS

So far about competition. Now let us come to nature of population age groups and their significance.

5.1. When members of a population are arranged in age groups such as, infants or children, pre-breeding, breeding and post breeding groups and are placed one above the other, starting with infants at the bottom, we get a pyramidal structure called **Population Age Pyramid** (Fig. VI.12).

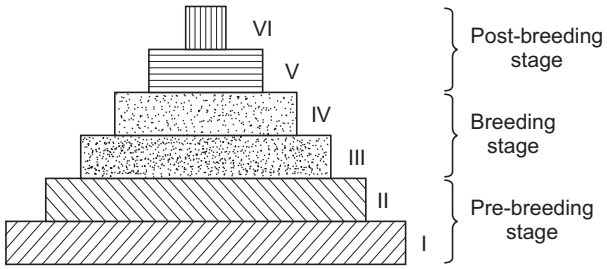


Figure VI.12 Population age pyramid.

5.2. Generally this pyramid looks like an usual pyramid having a wide bottom and a gradually tapering tip. Nevertheless depending on the relative sizes of the three stages i.e. pre-reproductive, reproductive and post-reproductive, the pyramids may be of three types—(*a*) with very wide base, (*b*) a tall conical one with not too wide base and (*c*) with a fat middle and narrow bottom (Fig. VI.13).

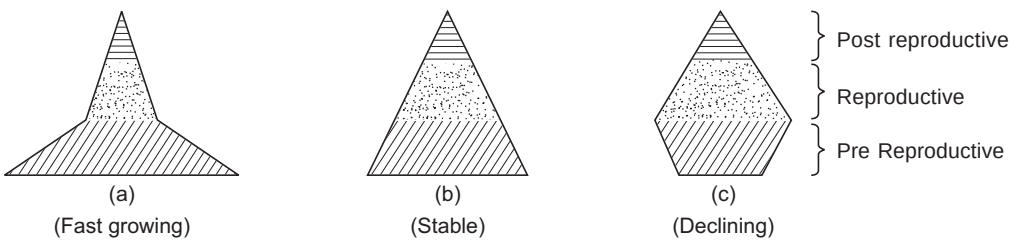


Figure VI.13 Types of population age pyramid.

5.3. Such shape of age-pyramids are indicative of the future growth patterns of the populations. Broadly if the pre-reproductive population is much larger in comparison with the reproductive one then, the population is a fast growing one (type a), if the pre-reproductive population is only slightly bigger than the reproductive one then the population will tend to remain stable (type b) and if the pre-reproductive population is smaller than reproductive population then the population will shrink with time (type c). Thus age-pyramids provide valuable insight about the future growth of a population. Three sets of information are however needed for accurate forecasting of the growth of a population. These are—

(*a*) age—pyramid,

(*b*) specific growth rate and
(*c*) life-table.

Such information are very valuable for any country which wants to plan in advance, for future vital requirements of its population such as, food, houses, schools, jobs, hospitals etc. and also the area of forest which may remain available to its animals and plants, in order to maintain a healthy ecological balance between man and Nature. Any country which instead of hard thinking and acting in time, only takes add hoc decisions based on wishful thinking, or looking at vote bank will remain perpetually poor and won't have much prestige in the comity of nations. It seem to us that developing countries like Bangladesh, Palestine, Ethiopia, Pakistan, India, Ceylon and many others need to pay more attention to their population age groups and future projections from these. Otherwise such countries will remain forever poor. China and Singapore have set up good examples to learn from.

Poor & developing countries & lessons from China and Singapore

5.4. If such population age pyramids are prepared for specific human populations based on parameters such as economic groups, religious groups, ethnic groups and such, one can learn a lot about the future of such specific populations and how these will affect the future of others. This should be a very useful area of sociological research. Interestingly, collection of such data is neither difficult not expensive. With a little bit of imagination and knowledge the teachers of schools and colleges may collect and analyse such data as part of their student-projects. Such data would be valuable aids to planners. Charles Darwin used local boys to help him collect specimens as early as 1831—34, during his voyage in H.M.S. Beagle to South America. Here we quote from Alan Moorhead's Darwin and the Beagle (Penguin, 1971, p. 106). "In one of his notebooks he catalogued fifteen hundred and twentynine specimens, from fishes to fungi, sent home in spirits of wine. 'My collection of the fishes and quadrupeds of this place is becoming very perfect. A few Reales has enlisted all the boys in the town in my service, and few days pass in which they do not bring me some curious creature'". British people are nothing if not ingenuous. Darwin too although a square fully shared this quality.

5.5. Now let us come back to the issue in hand. Here is a Table (VI. 6), prepared by the author from C.I.A. data, regarding area, population, population density, population age structure, female fertility, population growth rate, main religion and income per capita of some countries of the world. The table should be extremely useful to anybody who would like to know more about the status of human population of a country and its likely use from a socio-economic point of view. It can help us in identifying the countries with densest and sparsest populations, the richest and the poorest countries or the countries with highest female fertility and lowest female fertility and many other useful features.

Table VI.6.
POPULATION, POPULATION DENSITY, RATE OF POPULATION GROWTH AND PER CAPITA INCOME OF SOME COUNTRIES OF THE WORLD.
(From C.I.A. data 1998)

Country	*Area (Sq. Km)*	*Population*	*Population density (No/Sq.Km)*	*Population Age. Structure 0-14; % 15-64; % 65+ %*	*Dominant Religion of population*	*Fertility per female*	*Population Growth (%)*	*Income Per Capita ($)*
Afganistan	647,500	24,792,375	38.29	43: 54: 3	Sunni Muslim	4.21	6.01	800
Bangladesh	144,000	125,340,261	870.42	38; 59; 3	Muslim	1.82	3.45	1,200
Cambodia	181,040	11,113,861	61.39	45; 52; 3	Buddhist	2.72	5.81	710
China	9,596,960	1,221,591,778	127.29	26; 68; 6	Buddhist	0.93	1.81	2,800
Gaza strip	360	987,869	2744.08	51; 46; 3	Sunni Muslim	6.59	7.68	1,100
Indonesia	1,919,440	209,774,138	109.29	31; 65; 4	Muslim	1.51	2.66	3,770
India	3,287,590	984,003,683	299.31	34. 61; 5	Hindu	1.71	3.24	1,600
Iraq	437,072	22,219,289	52.44	47; 50; 3	Siya Muslim	3.62	6.26	2,000
Israel	20,770	5,534,672	266.47	28; 62; 10	Buddhist	2.01	2.74	16,400
Japan	377,835	125,752,794	332.77	15; 69; 16	Buddhist	0.23	1.44	22,700
Jordan	89,215	4,324,638	48.47	44; 53; 3	Sunni Muslim	2.6	4.94	5,000
Nepal	140,800	23,107,464	164.12	42; 55; 3	Hindu	2.53	4.96	1,200
Pakistan	803,940	132,185,299	164.42	42; 54; 4	Sunni Muslim	2.22	5.08	2,300
Saudi Arabia	1,960,582	20,087,965	10.25	43; 55; 2	Muslim	3.42	6.41	10,600
Sri Lanka	65,610	18,721,178	285.34	28; 66; 6	Buddhist	1.14	2.15	3,760
Syria	185,180	16,137,899	87.15	46; 51; 3	Sunni Muslim	3.3	5.73	6,300
Ethiopia	1,127,127	58,732,577	52.11	46; 51; 3	Muslim, Christian	2.67	6.94	430
Egypt	1,001,450	64,824,466	64.73	36; 60; 4	Muslim	1.89	3.5	2,900
Kenya	582,650	28,803,085	49.43	44; 53; 3	Christian	2.13	4.26	1,400
Nigeria	923,770	107,129,469	115.97	42; 52; 3	Muslim, Christian	3.05	6.17	1,380
South Africa	1,219,912	42,327,458	34.70	35; 61; 4	Christian	1.51	3.22	5,400
Brazil	8,511,965	164,511,366	19.33	30; 65; 5	Christian	1.1	2.29	6,300
Argentina	2,766,890	36,265,463	13.11	27; 62; 11	Christian	1.3	2.68	9,700
Mexico	1,972,550	87,563,374	49.46	36; 60; 4	Christian	1.84	2.97	8,100
U.S.A.	9,629,091	270,311,756	28.07	22; 66; 12	Christian	0.87	2.07	32,200
Canada	9,976,140	30,675,398	3.07	20; 68; 12	Christian	1.09	1.65	21,700
France	547,630	58,609,285	107.14	19; 65; 16	Christian	0.35	1.66	20,900
Russia	17,075,200	147,305,569	8.63	20; 67; 13	Christian	0.29	1.35	5,200
U.K.	244,820	58,970,119	240.87	19; 65; 16	Christian	0.25	1.7	21,200
Spain	504,750	39,133,996	77.53	15; 69; 16	Christian	0.08	1.21	16,400
Australia	7,686,850	18,438,824	2.40	22; 66; 12	Christian	0.96	1.83	23,600
New Zealand	268,680	3,625,388	13.50	23; 65; 12	Christian	1.04	1.91	17,700

6. POPULATION INTERACTIONS: (When one Population meets Another)

6.1. Whenever we come across a plant or an animal the first question that comes to our mind is what is it and next how many are there and then, is it useful to us and so on. Assuming we know its name (naming is an altogether different subject—Taxonomy), the next question we would address ourselves to is the theme of our present subject Ecology.

6.2. Basically the abundance of a population in an ecosystem is decided by two factors. First, its response to other species and secondly, its response to the rest of the environmental conditions. Or, in other words, the responses of the concerned population to the biotic and abiotic factors of its environment. Now we shall deal with the first—when one population meets another.

The Predator Prey and Parasite Host relationships

6.3. When population A meets population B then A either be benefitted (+) or harmed (–) or need not be affected at all (0). Odum (1963, p. 226) has elegantly summarised such reactions through a table. Here is an abridgement of that (Table VI. 7). When population A lives on population B by attacking and killing them by sheer physical force and then eating them, the members of A are called the *predators* and the member of B the *prey.* The tiger is a predator and the deer is a prey. Similarly in sea, the shark is a predator herring fish is a prey. Also one species of prey may be predated upon by several species of predators. As predators mainly depend upon muscle power for hunting down the prey, so it is usually a bigger, strong and clever animal.

6.4. On the other hand when members of population A are tiny beings which live inside the bodies of population B, which are much bigger in size, the A are called *parasites* and B *hosts.* The parasites gain entry into the bodies of the hosts by various clever devices. Once inside the host the parasites live and multiply at the cost of the host. *Plasmodium vivax / falciperum* the protozoans which cause malaria are, parasites and human beings on whom these parasites live upon, are the hosts. These malarial parasites—*Plasmodium vivax* or *falciparum* are one celled animals (or

Table VI.7.
RESPONSES OF EACH WHEN TWO POPULATIONS COME ACROSS EACH OTHER

Population A	*Population B*	*Relationships that emerge*
+	–	A predatare and B Prey. Ex. Tiger and Deer
+	–	A Parasites and B Host. Ex. Malarial Parasites and human beings
+	0	Commercial – must for A, B not affected
0	–	Ammensal – harmful for B, A not affected
+	+	Symbiosis – both need each other
–	–	Compelition – one most affected is eliminated
0	0	Neutralism – neither affects the other

protozoans) who enters the human blood stream through mosquito bites. Once inside human body these reproduce very fast consuming the red blood cells. Soon the affected person is down with malarial fever and unless treated in time the parasites may cost him his life.

Predator Prey mutually conuctive

6.5. In an ecosystem, predator-prey relationship is mutually beneficial. Predation helps to keep prey population physically fit (by removing mostly the old and weak ones) and also by keeping its size small the predator reduces overgrazing of the forest/grassland. The prey population too by its paucity, helps to keep the predator population fit.

Commensalism

6.6. In commensalism, population A is benefitted but population B is unaffected. Such one sided gain is found both in plant world as well as in animal world. A climbing plant on a forest tree is an example of commensalism. The climber gets sunlight while the tree is unaffected. Hermit crabs in sea-shore are examples of commensalism. Hermit crabs are crabs whose main body has no protective armour. So to protect its delicate body it must do something. If it hides into a stationary tunnel or burrows it may secure protection but it wont get food. So instead it looks for a movable house. This is provided by the empty shell of a whelk (a type of sea snail). But a mere house is not enough for a hermit crab, it must also have caretaker. As caretaker the crab gets hold of some sea anemones which it gently places upon the upper side of the whelk shell. Now the hermit crab can move about safely—it has a strong house in the form of whelk shell and guards in the form of sea anemones. In this way the hermit crab gets protection from the sea anemone but the sea anemone is scarcely affected (Fig. VI. 14.a). This is commensalism—the hermit crab is the commensal.

6.7. Another interesting example of commensalism are some small fishes which live inside the so called mouth, with rings of armoured thentacles, of sea anemones. Such a fish is clown fish (Fig. VI. 14.b) which darts in and out of sea anemones without any harm. This is because the mucous that covers the skin of this fish lacks the chemical which evokes attack from sea anemone. So here the fish gets protection from its enemies through its host—the sea anemone. But he host gets nothing in return. (The tentacles of sea anemones are covered with stinging cells which stings to unconsciousness any prey—small fishes, shrimps etc. that may come within its reach and help the anemone to devour its prey. Clown fish elicits no such attack reactions from the tentacles of the anemones).

Ammensalism

6.8. In ammensalism population A remains unaffected but the population B is harmed. A classic example of ammensalism is bread mould *Penicillium.* This fungus secretes a chemical penicillin which kills off all other fungi which may come in contact with this chemical.

6.9. By chance **Sir Alexander Flemming (1881-1955)** noticed that some of the culture slides he was discarding have spots where the microbes, which were supposed to grow, did not. Flemming, thanks to

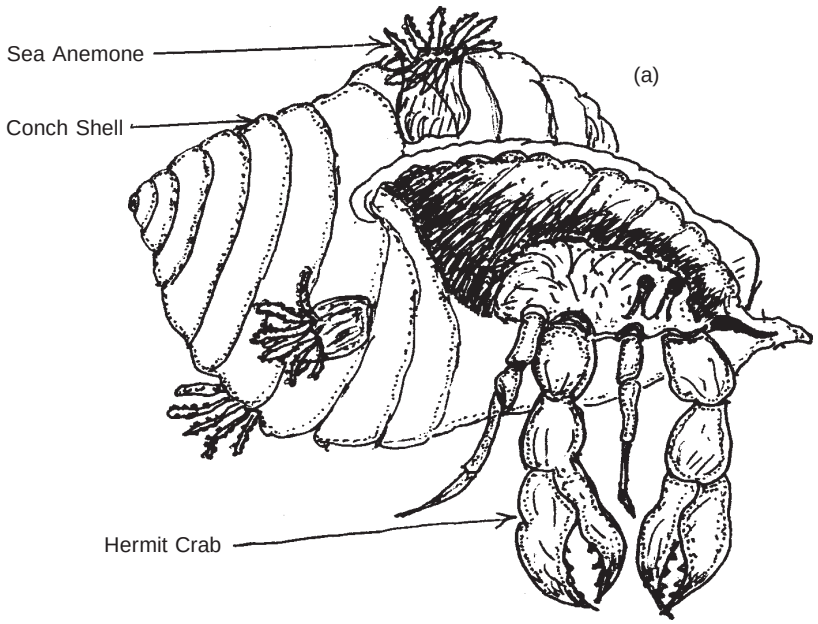


Figure VI.14(a) Commensalism: Hermit crab inside the shell of a conch with sea anemones on the shell.

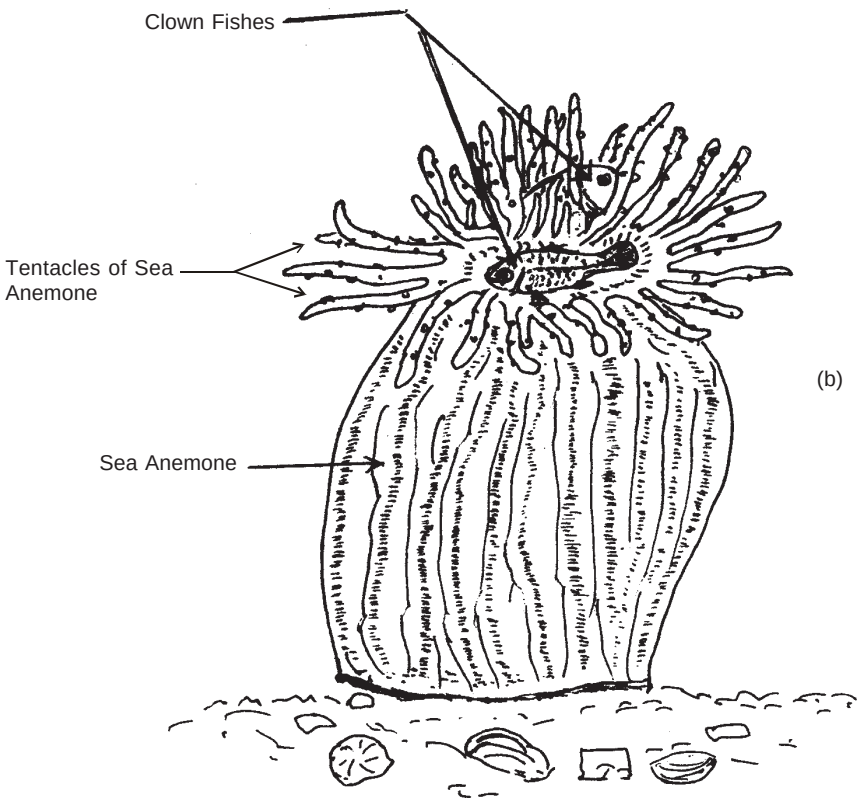


Figure VI.14(b) Commensalism: A large sea anemone with small fishes inside its so called mouth.

his knowledge, wisdom and fore sight could immediately grasp the significance of this observation. He pursued this observation and soon discovered that this mould secretes a chemical which inhibits the growth of any other microbe within the ambit of this chemical. This chemical, as it is secreted by a fungus Penicillium, he named Penicillin. Later with the help of biochemist **Sir Howard Florey** and others penicillin was purified and successfully tested on human patients. Thus Flemming's chance observation, and his ability to grasp the significance of this and perseverance to follow it up opened up a new chapter in medical science and saved millions of life.

Sir Alexander Flemming and Penicillin

(It is an irony of fate that Sir Alexander Flemming—the discoverer of penicillin died of pneumonia in his home, without getting penicillin which was a sure cure of pneumonia at that time.)

It is however worth remembering that "chance observations" yield, their secrets only to prepared minds. People armed with adequate knowledge, keen power of observation and capacity for deep thinking only, can grasp the inner meanings of chance observations. Alexander Flemming and Isaac Newton were such men. The "Vedic Rishis" of India were such men.

6.10. We have now discerned many instances of ammensalism in Nature. In semi-arid places trees secrete a chemical from their roots to the surrounding soil which prevents the growth of other trees near it. Such chemicals are called ectocrines (opposite to endocrines which affect the inside of the body). In semi-arid tracts of Rajasthan / India such as district of Jhun Jhunu, there is a tree *Prosopis spicigera,* which grows widely but always sparsely. Whereever they are, they are scattered—15 to 30 feet apart (Fig. VI. 15). The chemicals secreted by its root system discourage other *Prosopis* to grow near it. The environment to *Prosopis* is dry (rainfall 10 inches or so, water table 75—125' down, and soil is sandy) and resources are limited so, this is an adaptation for survival for the plant. Interestingly leaves of *Prosopis* is the main food of camels.

6.11. Here both A and B need each other for survival as, as they supply each other with some vital necessities of their lives. Basically in symbiotic relationship one species becomes dependent on the other. There are many examples of symbiotic relationships. **Lichen** is one such. This is an association of an alga with a fungus. The alga provides food and the fungus—protection. The algal cells get so intimately associated with the fungal filaments (hyphae) that the whole thing looks like a continuous greenish-white patch. The greenish-white encrustations which we often come across upon the trunks of palm trees particularly, betel-nut palms in West Bengal and Assam of India, are lichens (Fig. VI. 16).

Symbiosis or Mutualism

6.12. Symbiotic relationships are also known as mutualism. There are numerous examples of symbiosis or mutualism. Here is another. **The nitrogen fixing microbes.** Plants cannot fix atmospheric nitrogen but

Figure VI.15 A rural landscape of district Jhunjhunu, Rajasthan, India, portraying the distribution of the dominant tree *Prosopis spicigera*.
((Locally this hillok is known as "Pahari" which is 5/6 Km. from Birla Institute, Pilani, (Raj.) INDIA.))

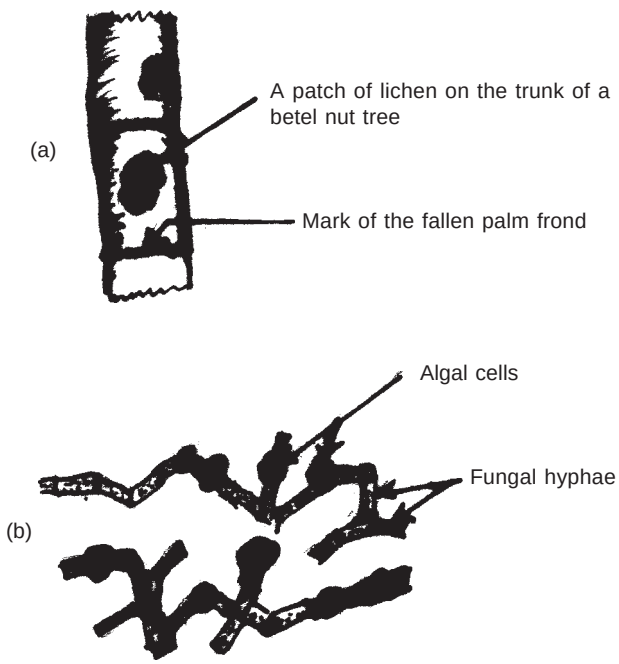


Figure VI.16 Lichen upon the trunks of betel-nut palms.
(a) Two patches of lichens upon the trunk.
(b) A microscopic view of algae-fungi association.

some microbes can. One such microbe is *Rhizobium* of the family Rhizobiaceae. These fix nitrogen within the root nodules of leguminous plant (i.e., peas, pulses etc.). These bacteria/microbes which are free-living in soil, multiply when these come in contact with root-hairs of a host plant. Apparently there is some chemical stimulant which exudes from the root-hairs to stimulate multiplication of the bacteria. Soon the root-hairs engulf the bacterial colony within the root tissue and as the bacteria continues to multiply, the point of bacterial infection on the root becomes a nodule (Fig. VI. 17).

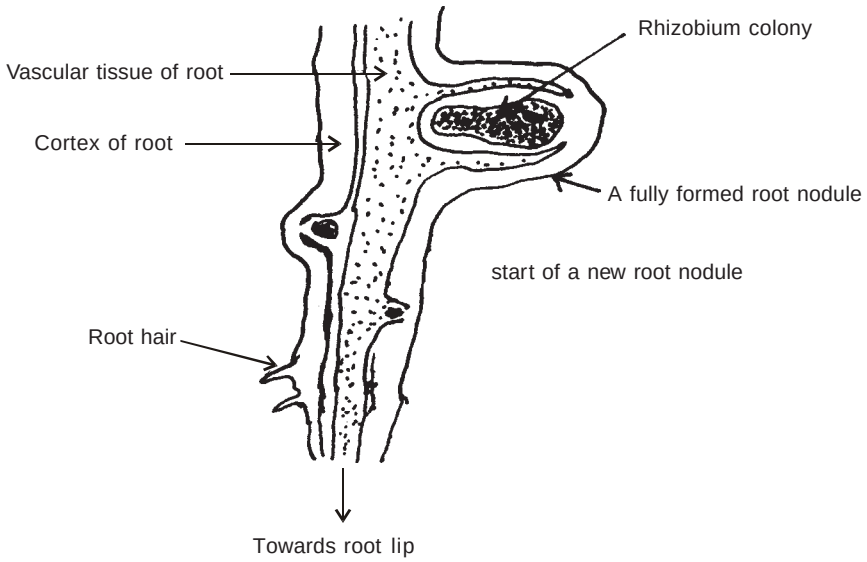


Figure VI.17 Root nodules formed by the infection by symbiotic bacteria on root hairs of certain plants.

There are symbiotic bacteria in the rumen of mammals, alimentary canal of termites and many places. Let us now close the topic on symbiosis in a lighter vein. Symbiosis is like the marriage of two physically different beings. They may be different but they depend on each other until "death does them apart".

Competition

6.13. In competition population A compete for the same thing as population B. Consequently that population which has a slight edge over the other, however slight it might be, will ultimately eliminate the other population from the ecosystem. The relationship between *Paramecium caudatum* and *P. aurelia* is example of competition (see Competition Elimination Principle or Gause's Principle p.). If put together in same culture medium, *P. aurelia* will ultimately eliminate *P. caudatum.* (For more see VI. 4. paras 3, 4 and 5).

6.14. There is however one point which deserves special attention. The competitive edge of a population is a joint product of physical and physiological specialities as well as the specific environmental conditions of the ecosystem which the population finds itself in. In one set of environmental conditions population A may win and in another set of environmental conditions population B may win. Here is a classic example from Tansely (1917). English botanist A. G. Tansley, who introduced the word 'ecosystem', found that two species of bedstraw *Galium hercynicum* and *Galium pumilum* would grow in both acidic as well as alkaline soil, if grown alone. If however these are grown together then only *G. hercynicum* will grow successfully in the acidic soil and *G. pumilum* in alkaline soil. Thus the winner is decided by the nature of the habitat where competition occurs.

Later many such instances are found particularly, amongst the intertidal fauna and flora of sea.

7. SOME SPECIFIC RESPONSES OF POPULATIONS TO MEET THE CHALLENGES OF ENVIRONMENT:

7.1. All species of populations of living beings struggle to survive and increase in number. Obstacles to this road to success are many. First is **interaction with other populations.** These we have already discussed. The second is **unfavourable weather.** These we shall now address ourselves to. Third is finding a **suitable mate**.

7.2. There are several options for tackling inclement weather. **Migration** is one such. Migration can be of three types. One can be moving out from a place with the onset of bad weather and return when the weather becomes good again. Another can be coming into a place permanently where the weather is more suitable and the third one can be moving away from a place permanently where the conditions are no longer suitable. These types are called respectively: MIGRATION (two-way movement); IMMIGRATION (moving in permanently) and EMMIGRATION (moving out permanently) respectively (Fig. VI. 18).

Migration and its Types

7.3. For instance, when a person goes to U.S.A. from India, and settles there for good, he/she may be called an immigrant to U.S.A. and emmigrant from India. Now-a-days we know of many species of animals-ranging from insects to mammals, who in order to take advantage of climatological changes or in search of fresh pasture etc. migrate long distances travelling from hundreds to thousands of miles. We shall briefly touch upon these.

(1) Insect – Locusts of Sind, Pakistan.
(2) Fish – Eels of Great Britain.
(3) Reptile – Ridley's turtle of India.
(4) Birds – Arctic terms.
(5) Mammals – Wildebeests of Africa.

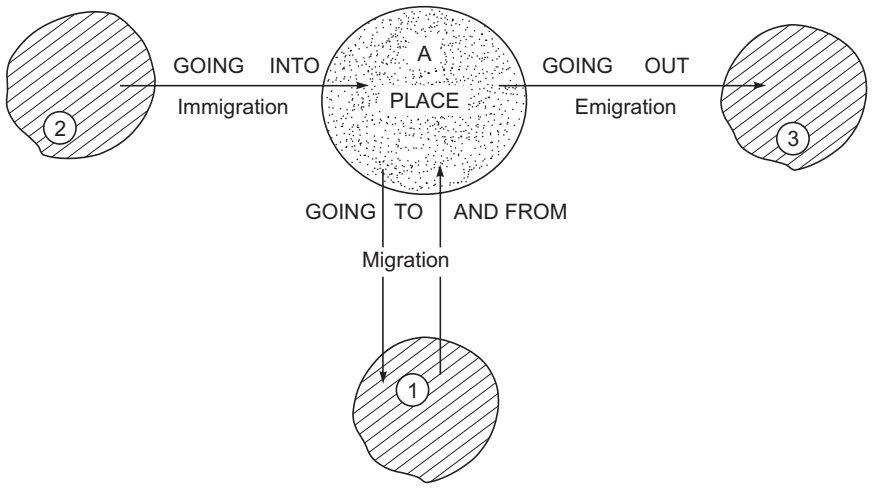


Figure VI.18 Three possible types of movements of living beings between two places.

7.4. Locusts *Schistocerca gregaria*

Locusts are a species of large grasshoppers (3″ or so long), (Fig. VI. 19), often met with in small numbers in agricultural plains throughout Asia and Africa. Since ancient times, both in Egypt as well as in China, epidemics of locusts outbreaks have been recorded. During such outbreaks these fly as huge marauding swarms flying over large tracts of

Migration of Insects: Locusts.

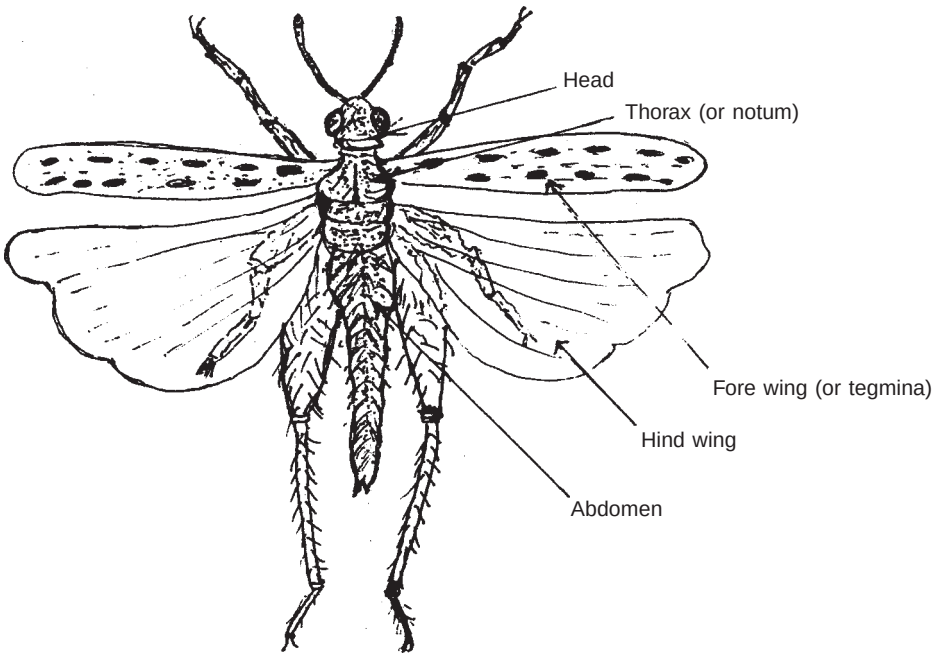


Figure VI.19 A locust *Schistocerca gregaria* and his external features.

agricultural lands defoliating all vegetation that come in their way and leaving famines in their wake.

Sir Boris Uvarov (1921, 28) has made a detailed study of locusts and unravelled many aspects of their biology. Locusts have two distinct phases *solitary* and *gregarious.* These are characterised with conspicuous physical differences. Uvarov showed that non-migratory locusts have swollen thorax whereas the thorax of migratory ones are somewhat constricted like the waist of a lady (Fig. VI. 20). There are differences in colours as well. This explanation is known as Phase Theory of Uvarov.

Phase Theory of Uvarov

The solitary phase locusts are residents in their normal breeding areas but if in some year, owing to various conditions, such as meteorological or flooding etc. the breeding ground (also called outbreak area), gets restricted or disturbed or crowded etc. the young locusts develop into gregarious phase, and their populations burst into thousands of times—literally into hundreds of millions and start their migrations of thousands of miles. While on flight these locusts halt frequently to rest, feed and breed. Any greenery that comes into their path—leaves, grains, crops—all is eaten up. When locusts migrate these leave at their wake only devastations and even famine. Here is a map of one such outbreak and migration of locusts on Indian sub-continent in recent times (Map. VI. 1). The outbreak centre is in Sind of Pakistan hence these migrate to northern India and finally return to the area of outbreak.

Nobel Laureate, **Pearl Buck** in her novel "Good Earth" (1931) has given a striking description of a locust migration in China. Here is how she writes".

"There came out of the south one day small slight cloud, ... except it did not come hither and thither as clouds blown by the winds do, but it stood steady until it spread fanwise up into the air."

.....

.....

Then the sky grew black and the air was filled with deep still roar of many wings beating against each other, and upon the land the locusts fell, flying over this field and leaving it whole, and faling over that field, and eating is bare as winter. .....

Wang lung was furious and he beat the locusts and trampled on them and his men flailed them with flails and the locusts fell into the fires that were kindled and they floated dead upon the waters of the moat that were dug. And many millions of them died, but to those that were left it was nothing."

.....

(Pearl S. Buck – The Good Earth; 1931 Pocket Books – New York, London, Singapore; pp. 168–169.

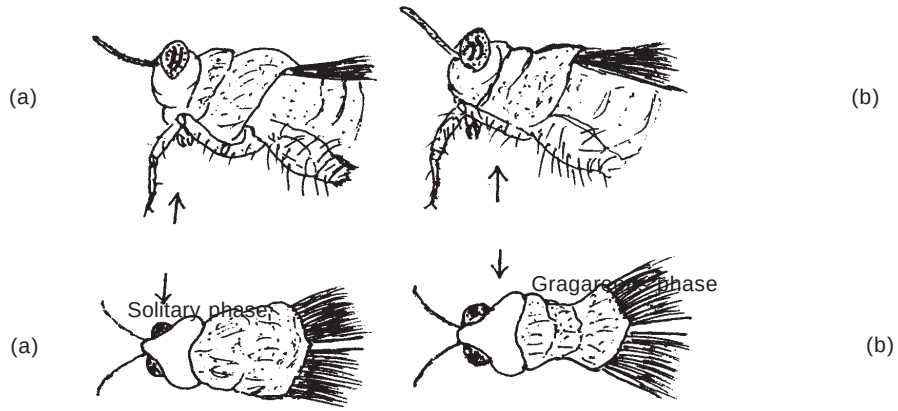
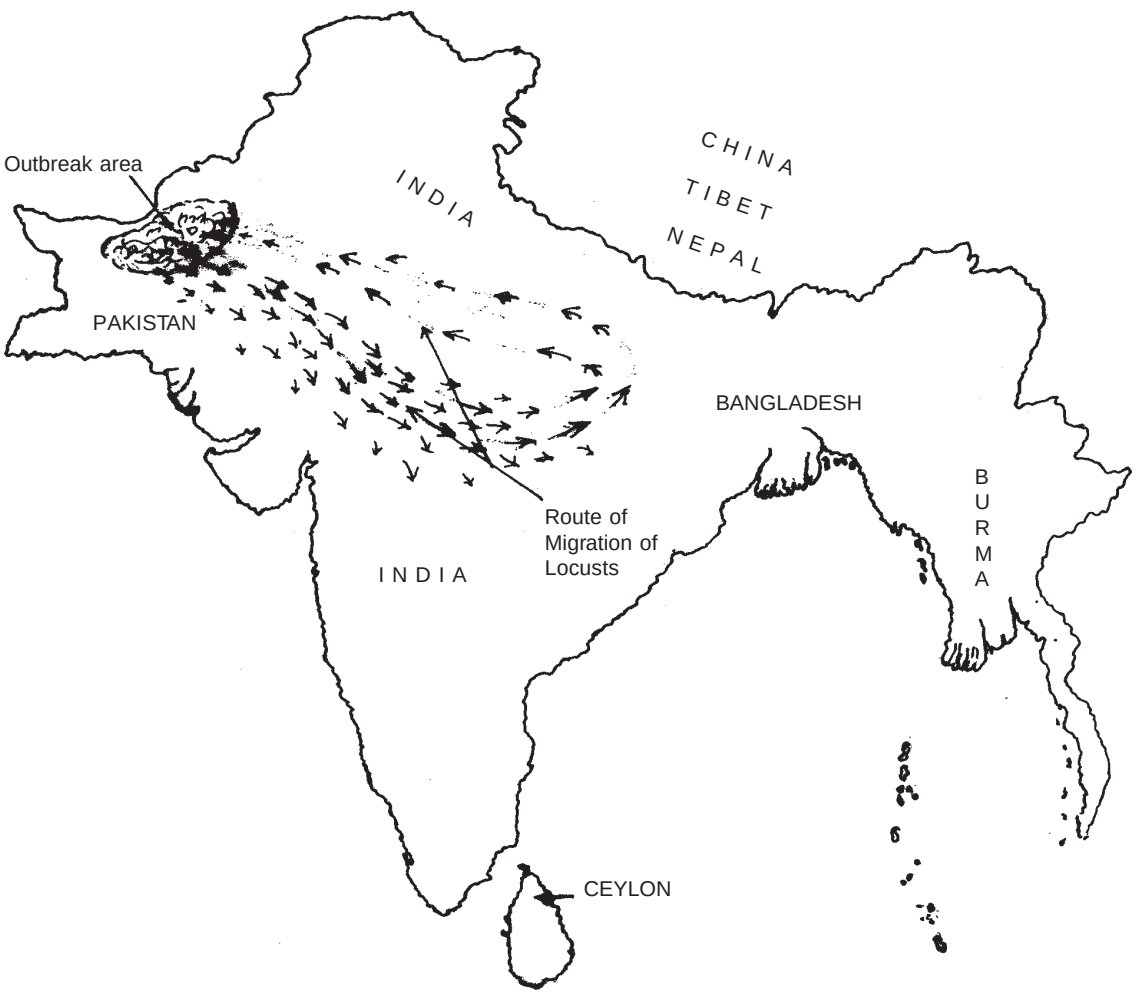


Figure VI.20 The external differences between a solitary phase locust and a gregarious phase locust.



Map VI. 1 Map of one outbreak and migration of locusts in recent times in India.

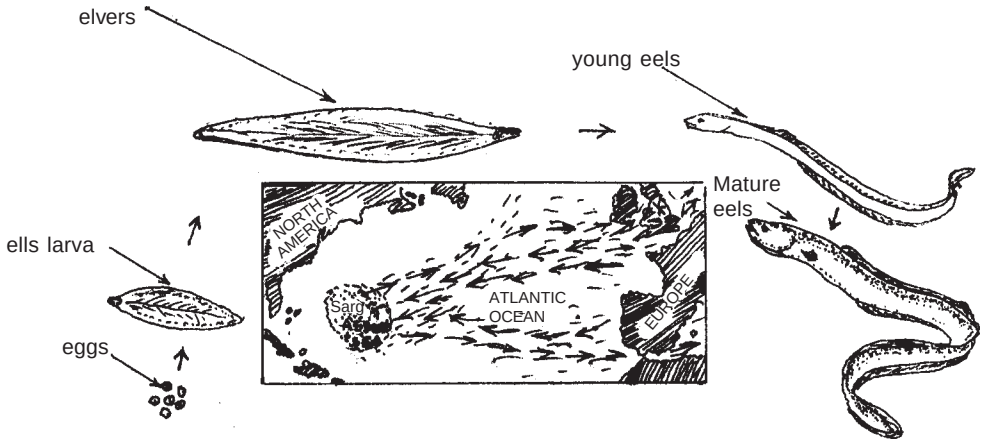


Figure VI.21 Lifecycle and migration of European cells, *Anguilla* viridis.

Migration of fishes: Eels

7.5. Some of the fishes migrate hundreds of miles to feed, grow and spawn. Eels, Salmons and Tunas are some famous examples. European eels (*Anguila viridis*) live in rivers and lakes of Europe but migrate through the deep waters of the Atlantic into the warm waters of Sargasso Sea near Florida, to lay. The hatchlings are about half an inch long, leaf-like semi transparent *larvae.* These feed, elongate and swim along with the warm waters of Gulf Stream towards Europe. Within 2-3 years the larvae become long (20-25") slim *elvers.* The elvers swim into the rivers and lakes of U.K., Europe and Black Sea. There these feed for another 2 to 3 years and grow into tall 3 feet or so, thick dark and mature *eels.* The mature eels then embark on the perilous return journey through the Altanic to Sargasso Sea only to lay eggs and die (Fig. VI. 21). The odyssey of the Salmon is equally exciting.

Perhaps through a combination of genetic information-pool and the quality of water and environment (and may be smell of their parents' bodies) something gets imprinted into the memory of the young eels, which guide them unerringly, from its birth place in sargasso sea through their entire path of migration three the seas la kis and risurs high in the mountain valleys and back to the sargasso sea to spawn just as their mother did—a perilous and marathon round trip of 14,000 miles in 6-8 years. This is indeed a most remarkable phenomenon of Nature.

Migration of Reptiles: Olive Ridleys

7.6. Ridley's sea turtles also called Pacific olive Ridley *Lepedochelys olivacea,* make a spectacular annual migration for laying eggs, from pacific ocean to Bhittarkanika in Orissa, India. Every year mearly 200.000 or more Ridleys swim up, to nest and lay eggs, in a 5 km. beach at Bhittarkanika, for a period of only one or two days. Now Govt. of Orissa has declared Bhittarkanika beach a protected area so that, Ridleys can lay eggs without interference.

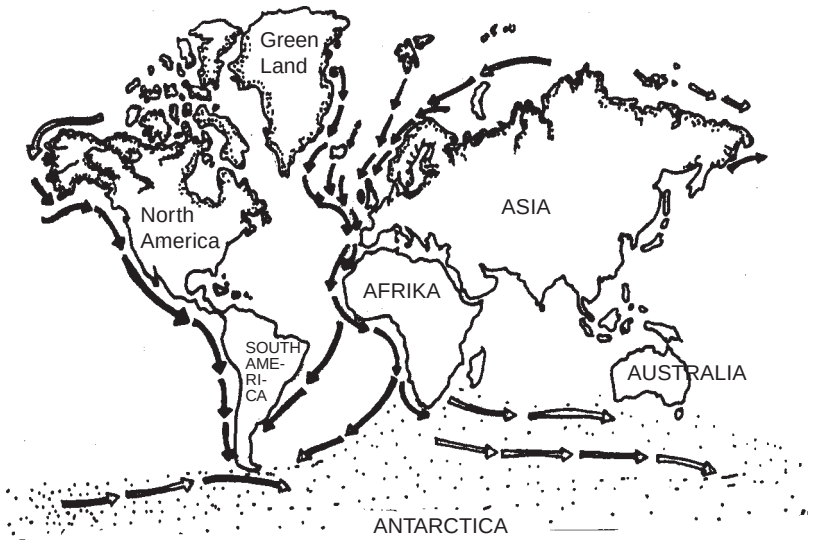


Figure VI.22 Migration of Arcitc Tems *Sterna paradisaea*.

Migration of Birds: Arctic tern, Golden Plover and Snipe

7.7. Birds on wings are freest of all. Who is not enthralled watching the leisurely effortless soaring of vultures high above the sky? Still all these have a purpose.

Landsborough Thompson describes bird migration as "Changes of habitat periodically recurring and alternating in direction, which tend to secure optimum environmental conditions at all times." Many birds migrate. In India snipes, ducks, geese, cranes and others are common visitors in winter. Bharatpur bird sanctuary and Calcutta Zoo are some of the delightful places to visit in winter for birds.

Amongst migrating birds the most spectacular is the Arctic Tern *Sterna paradisaea.* This bird travels from its arctic breeding grounds to the antarctic pack ice and back each year—10,000 miles each way! (Fig. VI. 22). Arctic Terns however, unlike many other migratory birds, feed on their way. The eastern Golden Plover *Pluvialis dominica* which is a winter visitor to India flies **non-stop** at least 3200 km. across open sea. Another is the Snipe *Capella hardwickii* which breeds in Japan and spends the winter in Australia travelling non-stop 4800 km. over the sea.

Migration of Mammals: Wildebust of Africa

7.8. Mammals also migrate, long distance, from season to season, in search of suitable astures. One classic example of such scasonal migration is that of wildebeests—*Chonnochaetes taurinus.* These are a type of large deers (like "Nilgais" of India), which travel long distances between Serengeti plains in north-west Tanzania to Masai Mara steppes in north-east Tanzania and south-east Kenya a distance of about 400 kms. En route wildebeests swim through the ferilous Mara river full of large crocodiles and throughout this journey they are harassed and killed by lions and cheetahs. This annual odyssey consisting of hundreds of

thousands of wildebeests and zebras *Equus burchelli*, is a spectacular event which attracts tourists from all over the world. This may be noted here that from tourists who come from all over the world to witness this spectacular migration. Tanzania and Kenya Govts. earn handsome foreign exchange.

7.9. Unlike animals which can move plants are sessile—i.e. fixed to a place. So these depend on others for movement. For example air is the carrier of cotton seeds; pasture animals carry seeds of grass and weeds along with their fur, water currents of sea carry cocoanuts far and wide, birds carry the seeds of plants along with their food and drop them elsewhere along with their droppings. Many seeds have special coats which can withstand digestive juices of birds. To facilitate such type of movements plants have developed various adaptive devices as well. In fact some plants have coated their seeds with such coverings that such seeds won't germinate till these pass through the digestive canal of a mammal or a bird.

Migration vs Vagility

7.10. Such movements by plants through their seeds etc. which depend on others is called VAGILITY in contrast with movements of animals, which are self-dependent, is called MIGRATION. Anyway whatever is the purpose the aim is the same—movement from here to there.

8. BIORHYTHM

(Adaptive devices other than Migration and Vagility)

HIBERNATION: Ectotherms, Endotherms.

8.1. Besides moving out when the weather in inclement and returning along with good weather, animals and plants resort to various other adaptive devices to tackle inclement weathers without moving away elsewhere. Collectively these are termed Biorhythm. Here are some of such devices.

8.2. Hibernation is a physiological device adopted by vertebrates (animals with backbones) to tide over winter cold. During winter when cold sets in and land is, at places, snow covered, many warm blooded animals such as rabbits, bears etc. enter into specially constructed burrows and undergo a deep winter sleep. Such winter sleep is called hibernation.

(During 1998 when I was visiting my daughter in South Riding. North Virginia, U.S.A., there was a family of five rabbits which used to stay in an adjacent wooded spot, behind her back garden and feed on the grass of the lawn. When winter came and snowing began they all vanished. Presumably these were all hibernating in their warrens. When the spring came they were seen capering about. There is one point however which is worth mentioning. During winter once in 15 days or so the rabbits used come out, run about for a while and then vanish for another 15-20 days). Like rabbits other mammals such as hamsters (a type of squirrel), bears, foxes and all those who live on cold, snow-clad places like north

U.S.A., Canada and northern Europe hibernate. During hibernation the heartbeats of animals go down remarkably. For hamsters the heartbeats drop from more than a hundred a minute to merely ten or so. The hibernating bears do not even defecate or urinate—the entire body waste is recycled. Thus the hibernating animals conserve energy.

Cold blooded animals such as frogs, snakes etc. also hibernate during winter.

Warm bloodedness and Cold bloodedness. Animals whose body temperatures remain constant in all seasons are called warm-blooded animals or **endotherms.** These are mammals and birds. Animals whose body temperatures fluctuate along with that of air are called cold-blooded animals or **ectotherms.** These are amphibians and reptiles. That is why in winter crocodiles come out of water and busk in sun. This is the reason why frogs, lizards and snakes are active in summer and during winter these hide in their burrows or holes and remain inactive.

8.3. Just as hibernation is for tiding over winter cold similarly, aestivation is a physiological device to tide over summer heat and drought. Lung-fishes (fishes which besides gill also have lungs) of Australia has adopted this device. *Protopterus*—a lung-fish of Afrika, live in ponds which dry up in summer. So when summer comes *Protopteruses* make cocoons whose insides are made waterproof through their own mucilage and remain curled up within these cocoons till rains begin (Fig. III. 9).

AESTIVATION

8.4. Diapause is an overwintering device frequently adopted by invertebrates (animals without backbones) particularly insects. Eggs of Chinese silk worm *Bombyx mori* do not hatch out in winter. Instead these become dormant-undergoing only various internal developmental changes—and hatch out in the spring. This phase of winter-dormancy is known as diapause. Also, the internal changes during diapause (which is must for successful hatching of eggs after winter) is called *diapause development*.

DIAPAUSE

8.5. This overwintering device is so compulsive for Chinese silk worms that, even in a warm country like India, Chinese silk-worm eggs have to be put in frigidaire so that these can undergo proper diapause. If this is not done the larvae will be defective. Besides silk worms many other insects undergo diapause—some as eggs, some as larvae and some as pupae.

8.6. In dry seasons small aquatic invertebrates such as Rotifers form **CYSTS—**small granular things with a thick strong shell, and stay in such dormant state for months, even years till proper weather returns. Cysts are small and so resistant to weathering that, these easily get windborne and carried from one water hole to another.

ENCYSTMENT

The above are only some of the adaptive devices. There are many more.

9. SPECIFIC RESPONSES OF POPULATIONS TO FACTORS OF WEATHER

9.1. Soil, Atmospheric Gases, Light, Temperature and Humidity are five important environmental factors. Of these soil and atmospheric gases are relatively stable for a locality but the other three are not. Here is a brief discussion of the effects of these three variable factors on populations.

LIGHT SEE 3.1

9.2. LIGHT particularly sunlight is the single most important factor on which life depends. If sun is not there life on earth will cease to be. Elsewhere in this book (Chap. IV.) we have already discussed in some details the relationship between sunlight and productivity. Here we shall mention a few of the interesting behavioral and physiological adaptations which living beings have evolved to co-ordinate rhythms of their lives, using sunlight as guide.

Diurnal, Nocturnal and Crepuscular activity

9.3. Generally some animals are active during daytime, some during nighttime. Those which are active during day are **diurnal** and those during night are **nocturnal** animals. Deers, monkeys and crows are diurnal and tigers, jackals and bats are nocturnal. There are others of both groups. Again there are some who are in between the two i.e. these are active only in the early mornings or at sun-downs. These are **crepuscular.** Rabbits and partridges are some of this group.

Circadian Rhythm

9.4. There is still another group of small animals who show vertical movement between night and day. This is called **circadian** rhythm. For example, planktons in the sea come to the surface layers only during night; during day these move down to the much deeper layers of water. Similarly in grassfields, grasshoppers move up to the top layers and hop about during daytime but in the nights these crawl down to the ground surface and rest.

BIOLOGICAL CLOCK

9.5. Have you ever thought what guides the cyclic rhythm of activities of living beings? What guides the forest to prepare for the fall? Who instructs the cuckoos to begin his search of mates by calling? Who informs the birds—terns in the arctic zones that winter is coming, you better get ready to migrate to the south. What brings the tasty 'hilsha fish' *Clupea ilisha* unerringly from the sea into the river Ganga of Indian peninsula in every monsoon. There are many many such animal activities which are repeated with meticulous timings every year.

9.6. Some stimulus from Nature which follows a constant rhythm from year to year must be the guiding agent. This is SUNLIGHT. All living beings must have a cycle of biological activities which guide their lives. This is **Biological Clock.** This biological clock is powered by **Light** which is the most dependable stimulus from Nature. The rising and setting of sun at each point of earth is pre-determined and calculable. The period of daylight or, the reverse of it ie night length, is the spring of all biological clocks. All rhythms of biological activities of all living beings such as, migrations, egg layings, flowerings etc. in all places of Earth are hitched upon this most dependable guide of Nature **sunlight.**

9.7. Sunlight through the photoreceptor eye, activates pituitary glands of animals. From pituitary a chain reaction starts which finally initiates activities such as, migration, egg laying (oviposition for insects) etc. Pituitary however cannot be the only receptor. Plants do not have pituitary glands. So plants and others have other photoreceptors which we need not go into here.

9.8. Besides sun moon also initiates biological rhythms. Some marine worms (invertebrates) which live inside tunnels in mud on the floor of shallow seas come out of the mud regularly following the lunar cycle, to mate. This mating period has been imprinted in heir genetic make-up so much so that, if kept in aquarium within laboratory where there is no moon, these still follow the same lunar rhythm according to the dictates of their genetic make-up. Rachael Carson put has this beautifully in her book "The Living Tide".

LUNAR CYCLE

9.9(*a*). Relative Humidity (RH) or better still Vapour Pressure Deficit (VPD) is a very important factor in determining the locations of animals particularly those who are susceptible to desiccation. All readers however may not follow the relations between RH and VPD. Hence the following. See also III 6.5.2.

MOISTURE
SEE 3.2

Here a few words about atmospheric moisture would be relevant. One litre of air at 20°C will require 20 gm. of water to be fully saturated when its relative humidity (or RH) will be 100%. At 10°C the same 1 litre of air will need only 10 gm. of water to saturated (i.e. 100% RH) and similarly at 30°C, 30 gm. of water for RH 100% of so on.

Relative Humidity (RH) and Vapour Pressure Deficit (VPD)

(*b*) If however the reverse situation arises i.e. the temp. is 10°C and the water is 20 gm. then the air will not only have 100% RH but 10 mg. water will be surplus so this will be deposited as dew. This is why sometimes in the morning when the temperature is low there is dew on grass. If no the other hand, the temperature of air is 30°C and the water content is 20 mg. then the RH of the air will be 2/3rd. of 100% ie 66% or so. This is the relationship of relative (RH) with the temperature (temp) and moisture content of air.

(*c*) The water vapour of air, like other gases , exert pressure. This is vapour pressure. 20 gm. of water vapour exerts (about) 20 mg. pressure; 10 gm. 10 mm. and so on. This means the more the vapour content, the more is the vapour pressure. Or in other words, the vapour pressure and water content bears a direct relationship with each other. The air at 10°C can hold a maximum of 10 mg. of water; at 20°C 20 gm. of water and at 30°C 30 gm of water as water and so on. consequently if any sample of air contains less water vapour than what it can hold, liquid water in this air will tend to evaporate. On the other hand, if any sample of air contains more water vapour than what it can hold, the surplus water vapour will condense in the form of dew. Vapour Pressure Deficit (VPD) is the difference between the pressure of maximum water that a sample of air can contain

and the pressure that is being actually exerted the amount of water that it holds. For example if a sample of air at 20°C holds only 10 cc. of water then its VPD is 10 mm. of mercury (Fig. III. 13).

(*d*) Consequently the higher the VPD of a sample of air is, the faster will be the evaporation of water in that sample of air. Hence in hot and dry climate clothes dry quickly as the VPD is high, but not so in wet season as VPD then is very low or nil.

9.10. After the above paragraphs explaining RH and VPD, we are coming back to the effect of moisture i.e. 3.2. Toads and frogs (amphibians) do not stay in desert sand—dunes and similar dry places. This is because their skins (technically known as integument) are soft and very susceptible to draught. Lizards and snakes on the other hand, can easily live in dry sandy places. Their skins are covered with waterproof scales. So amphibians can live only in places with high RH or low VPD but the reptiles distribution is not tied up to such factor.

Adaptations of Plants and Animals living in dry places

9.11. Hence in desert or semi-arid areas (i.e. areas with high VPDs) water dries up so quickly. Consequently there, plants and animals in such places often suffer from desiccation. In response to such environmental pressure these life forms develope, according to their natures, physiological, morphological and behavioural adaptations. **Plants** reduce the leaf surface and some convert leaves into thorns such as cactus. **Animals** develop water-proof skins. Reptiles and birds have developed waterproof scales and feathers respectively to cover their bodies. Amphibians who have no such devices available are scarce in semi-arid areas. Mammals however through their superior intelligence, have developed special behavioural adaptations to take care of VPD problems. The common land invertebrates such as insects and spiders have developed waterproof layers on theirs skin (also called integument). This layer is a special type of wax. So abrasion of their skin exposes these to the hazards of desiccation (or VPDs). Rest of invertebrates such earthworms and snails etc. who cant resist desiccation stay only in the moist places such as soil or, under the bark of trees. Thus living beings tackle challenges of desiccation.

9.12. There are various other challenges living beings have to face and so develop equally variegated ways to handle them. David Attanborough in his book "The Trials of Life" (Little Brown and Co. 1990) has described these beautifully with excellent photographs.

Here is a summary table of the responses that animals adopt to meet the various challenges of environment (Table VI. 8).

10. MEASUREMENT OF POPULATIONS

(Also see III. 3.6.)

10.1. No study of population can be very meaningful until the size of the population can be assessed. Only after knowing the size of a population

Table VI.8.
RESPONSES AND ADAPTATIONS OF ANIMALS (AND SOME PLANTS) TO MEET SOME OF THE CHALLANGES OF THE ENVIRONMENT TO ENABLE THEM TO SURVIVE AND BREED

Challenges/Stimuli	*Adaptations — Behaviour and Anatomical*
Food	Migrations – Fishes (eels, salmons, tuna, etc.) etc. – Birds – Arctic terns, etc. – Mammals – Wildebeests, etc.
Temperature	Hibernation – Rabbits, Hamsters, Bears of North America etc. Diapause – Silk worm Aestivation – Lung fishes
Water	Encystment – eggs of wireworms – eggs of rotifers
Humidity	Microenvironments – Earthworms, frogs, fishes with accessory respiratory organs, Wilting of plants; Leathery and waterproof (glabrous) leaves; Thick water storing trunks of large desert cacti, etc.
Light *(a)* Sunlight	– Biological Clock (Day length or Night length) – Initiates migration of birds, egg laying of birds, flowering of plants. – Vertical migration in grasshoppers and planktons
(b) Moonlight (moon phase)	– Initiates egg laying of many marine invertebrates.

we can assess as to how much it is contributing to the primary productivity (if autotrophs) of the ecosystem or, costing the ecosystem to sustain it (if heterotroph) and so on.

10.2. For example, a single banyan tree *Ficus bengalensis* which is an autotroph and require only 1000 sq. m of land as so can support dozens of birds, thousands of insects and thousands of worms. But one single tiger *Panthera-tigris* which is an haterotroph require about 30 or more square miles of land to provide it with enough food such as, deers, boars, etc. Similarly one elephant *Elephas loxodonta/indica* will require nearly 5 or more square miles of forest to provide it with enough vegetation to live. Hence an ecologist needs to know the size of a population, its food habits and other essential requirements, to assess the impact of the population on the ecosystem it belongs to. For forest rangers such information are very vital. If in a forest there are too many predators, the prey population will be so much depleted that the forest will overgrow leading to the starvation and death of predators. Again if there are too much prey and too few predators, soon the forest will be overgrazed and destroyed. So a harmonious balance between the two is essential for healthy ecosystem. Hence the measurement of the populations are must.

10.3. The techniques of measurement of a population will naturally depend upon the nature of the species concerned. For instance if one counts tigers the way one counts trees, the consequence will be very unpleasant indeed if not tragic. So the techniques would have to vary. Here are some common techniques.

10.4. Quadrat Method. This is generally used for primary producers such as grasses, shrubs and trees—which are stationary. A quadrat is an area of 1 m^2, 2 m^2 or even 5 m^2 or more in size (Fig. III.2). The actual size of the quadrant will have to be decided by the ecologist taking into account the nature of the species population and also his own angle of study. After deciding the size of the quadrat the number of specimens within that quadrat is counted. Several such quadrats in different locations, within the same ecosystem, are taken at random and the number of individuals within each are recorded. By manipulating all these data statistically the population is measured.

QUADRAT METHOD

10.5. Capture—Recapture Method. For populations with very large number of individuals particularly mobile ones such as, insects, birds etc. this method seems more suitable. Here all insects that can be captured in a day (through nets) or in a night (through light-traps) are marked and released. Next day again these insects are captured from the same spot in the same method. Some of these would be marked. Now through simple calculations one can work out the size of the population. Those who want more information on such techniques may consult T.R.E. Southwood (Ecological Methods, Chapman and Hall. 1978.).

CAPTURE RECAPTURE METHOD

10.6. Indicators e.g. Pug Marks, Spoors etc. For large animals which are both mobile and aggressive, indicators such as foot prints (pug marks) or spoors (tracks) etc. are usually employed by forest rangers. Tigers, Lions and Elephants are mostly studied in this way. This naturally requires courage, patience and very keen power of observation. Experts in this line can not only distinguish marks of one from the other even they can tell the age, sex, state of health of the animals and time of the marks.

INDICATORS e.g. PUG MARKS, SPOORS etc.

10.7. When **Charles Darwin** was travelling in South America as a naturalist in H.M.S. Beagle in 1830s, he gave an accurate description of such capabilities of some South American soldiers along with the very cruel end of individuals thus tracked (Darwin and the Beagle—Alan Moorehead. Penguin. 1971. p. 122-3). Here is an example. One General Rosa of Argentina a very competent horseman was in charge of subduing the hostile Indian tribes of pampas (Argentine grasslands).

"One day it was reported that one of Rosa's outposts on the route to Buenos Aires had been wiped out by Indians. So a commandant named Miranda was ordered to go out and take reprisals"... "In the morning the men were set off for the scene of murder, with orders to follow the **rastro** or track even if it had led them to Chile. They were experts at deciphering a track; from examining the prints of a thousand horses they could tell how many were mounted, how many loaded; even by unevenness of the hoof marks, how tired they were. These men would penetrate to the end of the world". He heard later that the raid was successful. "In the end some hundred and ten men, women and children were rounded up. All the men who were not likely to be useful as

informants were shot. The better looking girls were set aside to be distributed amongst the soldiers and later on the older women and the uglier girls were murdered. The children were taken off to be sold as slaves." "Among the prisoners who were spared there were three particularly fine looking men, all very fair and over six feet in height. They were lined up for interrogation and when the first refused to divulge the whereabout of the rest of the tribe he was shot dead. So was the second and the third had no hesitation either. 'Fire' he said 'I am a man, I can die'. "Darwin was horrified, but there was little he could do except to confide to his diary the thought that these Christian soldiers were much more savage than the helpless pagans they were destroying."

10.8. Tagging. Tagging the individuals members of a population with special markers such as, rings on legs, radio collars, implementing radio-active device under the skin etc. etc., are some of the devices resorted to by ecologists and behaviour scientists. These techniques have proved very useful in studying migrations of birds, marine turtles etc. There are many other methods which are being constantly developed and used by ecologists of today, depending upon the nature of the target population and level of resources available and above all their knowledge, ingenuity and wisdom. So **ingenuity and common sense of the ecologist are most important aids in measuring or assessing a population.**

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Chapter VII

Community

(The Noah's Arc)

Topics

VII.1. The Definition

VII.2. Dominance

VII.3. Succession

VII.4. Ecological Niche

VII.5. Balance In Community

VII.6. Approaches To Community Study

VII.7. Space and Carrying Capacity

VII.8. Phases of Human Civilisation

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CHAPTER VII

COMMUNITY

(*The Noah's Arc*)

"Two hermits can live on the same blanket but two kings cannot stay in the same Kingdom."

..... *an old Indian proverb*

1. THE DEFINITION

Definition of Community

1.1. So far we were talking about the individual populations i.e. members of a single species. An ecosystem however is never made of a single population but consists of an assemblage of several interacting and interdependant populations and the sum total of whose functions determine the personality of a community.

1.2. All the populations of an ecosystem—both autotrophs and heterotrophs when taken together, form a **COMMUNITY**.

1.3. Different ecosystems would therefore appear to be different from one another in looks. For instance, an African savanna mainly has grasses and a few trees whereas the rainforest of Mudumalai hills of Kerala, India, consists mainly of trees and undergrowth. This means a savanna is dominated by grasses and a few scattered trees while a rainforest is mainly dominated by a dense assemblage of trees.

2. DOMINANCE

Naming of a Community and Dominant Populations

2.1. Any community when taken an overview of, will appear to be dominated by one or a few species of autotrophs and heterotrophs, either by their number or size or both. Basically this means any species or group of species which plays a major role in flow of energy in community is considered the dominant species or the dominant group of species of that community. These dominant populations tend to lend a personality to that community and hence the community is named that way. For example, the tropical savanna of Africa may be named as **Grass-Tree Community** while the rainforest of Mudumalai Hills, Kerala, India may be named as **Tree-Undergrowth Community** (Fig. VII. 1).

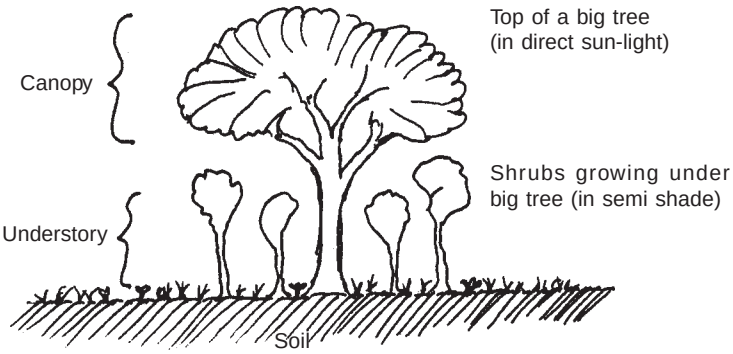

Figure VII.1 A tree-undergrowth community.

Mangrove Community

2.2. In India, the Gangetic delta, where the river Ganga meets the sea, has an extensive mangrove forest of around 2585 sq. km. This is a zone with vast tracts of intertidal areas having only a few plant species most of which have air breathing roots or pneumatophores. These trees are generally called mangroves and the community **Mangrove Community**.

Pine-Deodar Community

2.3. The Himalayan hill region however ranging from 5000 to 8000 ft. altitudes, are mostly covered with pine and deodar trees as the dominant trees. So these can be called **Pine-Deodar Community**.

Other Communities

2.4. In between these two communities i.e. the mangrove community in the delta of river Ganga and the pine-deodar community of the Himalayan hills, lie the vast tracts of plain lands and other hill regions of India. These are dimonated by various other types of communities. We shall come to these later if, and when necessary.

3. SUCCESSION

Invasion of Life and Evolution of a Community

3.1. Nature abhors vacuum. Any place on earth if, for some reason is devoid of life, will, at the first opportunity, be filled up with living beings. Here is an example. During volcanic eruption hot molten lava comes out from the volcano and covers the slope around it. Because the lava is a hot molten liquid it is not only devoid of life, it also kills off all living beings around the rim of the volcano and all the slopes covered by this hot liquid volcanic lava. So after such a volcanic eruption the sides of the volcano become a lifeless and barren landscape—no grasses, no trees, no insects—nothing. But as soon as the lava cools down it starts getting covered with various life forms—first plants and later animals. This is an invasion of life into **a lifeless but life-supportable** environment. There can be many such examples. Here is another. When a new island comes up in a river delta, it is just a flat alluvial land very near the level of the surrounding river water but lifeless. But soon this new lifeless and deltaic island start becoming covered with living forms—first by plants followed by animals.

3.2. Most of the southern part of West Bengal of India and Bangladesh have been formed in this way—i.e., by deposition of millions of tons of alluvial soil brought down through thousands and thousands of years by the mighty rivers Ganga and Brahmaputra, from Himalayan mountains.

3.3. All the plants and animals which thus occupy a new area, together form a **COMMUNITY**. Such newly established communities do not remain same for long. Changes in the ecosystem brought in by the first community will lead to the replacement of the original community i.e., this first community by a new set of plants and animals i.e., a new community. With time this second community will also give way to a third comunity and even more till, after many years, a stable ecosystem gets established in that area. This stable ecosystem has a tendency to maintain its structure (i.e., nature of its plants and animals association) for a long time afterwards (unless disturbed by man or other natural calamities). This invasion of an area by living beings through distinct and successive communities of living beings is called **SUCCESSION**. This succession leads to evolution of communities.

Stages in Invasion or, Succession and Community Evolution

3.4. The first stage of evolution of a community is called the PIONEER and the final stage of evolution i.e. the stage—where the ecosystem has become a self sustaining and relatively stable one, is called the CLIMAX. The stages in between are called the SEERS. So the pioneer, the seers and the climax are the three definitive stages in the evolution of a community and also ecosystem (The word ecosystem however, means much more than a community. A community is only a part of an ecosystem.) This evolution of a community is a long and slow process taking at least 150 years or more and hence not very easy to observe and study. However, the shorelines of a big natural lake which is gradually drying up offers an excellent opportunity for such study (Fig. VII. 2.). In the shoreline of such a lake an ecologist can visualise all the stages of community evolution—i.e. from the pioneer, through the seers till the climax—all simultaneously. So in ecology succession means the process of evolution of communities.

Succession Seers and Climax

3.5. The shores of Lake Michigan, U.S.A. offer an opportunity for such study. Once, long ago, Lake Michigan had a much bigger area than today. As the lake shrunk with time, more and more shore areas got exposed and became available for invasion by plants and animals. Hence here an ecologist can observe all the stages of succession. The tier of flora and fauna which are nearest the water-line is the area most recently invaded by living beings. So this is the pioneer stage and as the ecologist moves away from water-line he comes accross the first seer, then second seer and so on till the ecologist reaches the tier of flora and fauna which merges indistinguishably and permanently (i.e. without any further changes) with the neighbouring large ecosystem. This is the climax (Fig. VII. 2.).

3.6. Another place on earth-where one can find such stages of evolution of an eosystem is the volcanic lava slope created by the recent huge

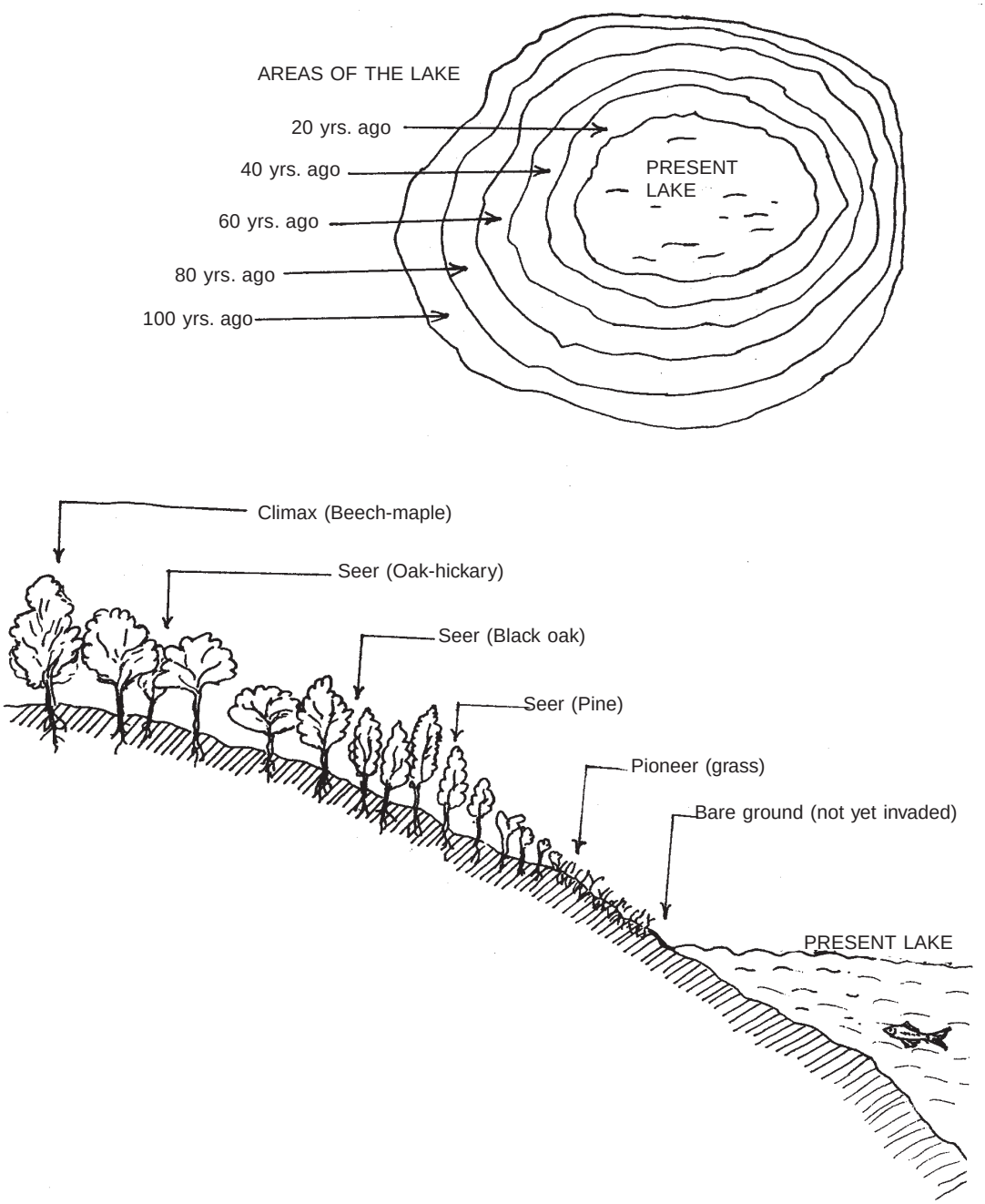

Figure VII.2 Evolution of a community as evidenced in the shoreline of a gradually drying lake.

volcanic eruption at Pina Tibu. A third place where at least the pioneer and some of the early seers can be observed, are the freshly formed river deltas such as; the delta regions of the rivers Ganga and Brahmaputra of India and Bangladesh.

3.7. It is also possible to simulate succession experimentally and thus study the evolution of an ecosystem by the following method. Thoroughly plough a piece of land then remove carefully all orgnic matters—both plants and animals after which fence up the land. After this the ecologist can follow up the successive stages of invasion of flora and fauna into this piece of land. Care has to be taken however to ensure that nothing is removed from such an experimental plot nor anything is put into the plot from outside. It must be left alone to change on its own. Changes in flora and fauna from one stage into another would be initiated by the changes in the local microenvironments caused by the presence of the earlier set of plants and animals.

3.8. Succession can even be studied by school boys and girls if they have some knowledge and interest in biology. Here class- teachers can help. Here is a case study. In villages in deltaic regions of Ganga often ponds are dug. Fresh earth from the lower levels of pond are usually dumped on a nearby suitable place. This earth is clean and has no plants or animals in it. If a school student fences up one such a dump of fresh earth—the dump will be an experimental plot. Now one can start observation of succession. Soon the bare dump will be covered with one or two types of grasses and small animals only. Then these will be gradually replaced with shrubs and later more permanent plants. All these changes should be carefully noted. This observation will form a good case study of succession.

Succession can be studied by school students

3.9. The young ecologist should however be prepared to come accross unexpected results. These are additional excitements of work and should never be neglected or ignored. An observant student may discover new facts hitherto not reported in books. Thus was discovered penicillin, by Sir Alexander Flemming—the antibiotic which saved millions of lives. The class-teacher of the student may be able to help him in interpreting such findings and also in developing his power of observation. A competent class-teacher can help in developing curiosity and hunger for knowledge in the minds of his students.

3.10. In succession one set of plants and animals which inhabit a particular place cause so much changes in the micro environment of that place that, soon these plants and animals are replaced by another set of plants and animals. Similar things happen inhuman societies as well. Here is an example. There is a small town Birnagar, in Nadia district, West Bengal, India, about 95 kilometers east of Kolkata. Before independence of India in 1947, this was a sparsely populated village inhabited by poor farmers. After independence farmers from Bangladesh migrated here and settled down. It was still a agricultural community and in whole day only two trains stopped near that village. Soon however Birnagar progressively became better connected with roads and trains with other towns including Kolkata. Its population too swelled. To-day (1998-2000) Birnagar is no

Succession in Human Societies

longer a village—it is a small town with municipality of its own. Agriculturists of yesterday are being replaced by town dwellers.

3.11. Even within the metropolis Kolkata this is happening. When Kolkata was founded by English traders about 300 years ago, the Burrabazar area was mostly inhabited by local business men mostly Bengalees. Soon however smarter businessmen from outside Bengal flocked into Kolkata and ousted most of the local businessmen. Today Burrabazar area of Kolkata is 90% occupied by non-local businessmen and the language prevalent in this area is not Bengali. All these social changes can be easily understood if we consider Gause's principle (Chap VI.). Another example from Kolkata. Soon after independence, when Kolkata was very much overburdened with influx of refugees from Bangladesh, the then Chief Minister of West Bengal, Dr. B.C. Roy decided to fill up a large swamp in east of Kolkata with alluvial soil from the river Ganga and then distribute this reclaimed land at a very cheap rate to poor middle class Bengalees. So was the plan and so was the action. Soon something new happened. This was not the plan. As the land prices started soaring up, the poor middle class Bangalee land owners of Salt Lake plots succumbed to the temptation of quick money, and by various not so straight means, passed on these lands to rich, mostly non-Bengalee businessmen. Now Salt Lake Bengalees are again becoming landless and are moving further away from Kolkata. These processes are also cases of succession in operation—succession in human societies. All these and many such situations in human societies, past and present, are examples of Gause's Principle in operation. According to Gause's principle no two populations having the same demand on the habitat (ecosystem) can live together. It seems the earlier the social planners take cognisance of such biological forces and plan for these as well the better it will be for us and our children.

Gause's principle in understanding changes in human societies

4. ECOLOGICAL NICHE

4.1. The term **ecological niche** or simply **niche** is a very important but relatively new term introcuced by ecologists. Oxford ecologist Charles Elton (1927) gave a clear meaning to this word which is now broadly accepted. It is the **"functional status of an organism in its community"**. Or, "The niche means the mode of life, and especially the mode of feeding of an animal" (Elton—1933). It is like the profession of a person in our society. Every person plays a definite role in a society. For instance, a doctor plays an important role, a teacher another role, a mason still another and so on. It is the proper functioning of all such persons and others that keep the society working in harmony.

Definition by Charles Elton

4.2. So is in the animal world. In a forest just as herbivores are important so are the carnivores. For instance, in a forest the presence of sufficient numbers of deers and rabbits etc. is a must for the survival predators like

tigers and leopards. Again, unless the deer polulation in the forest is kept in check by predators like tigers etc. the deer population will grow explosively and soon the forest will be defoliated and destroyed. Ultimately deers in a predatorless forest will face starvation and extinction. This is exactly what happened once with Kaibab National Preserve in U.S.A. They removed all the predators from Kaibab to promote deer population and pleasure of tourists. The deer population grew so fast that this almost killed the forest. So the predators have to be reintroduced for survival of the forest as well as the deers. The presence of predators is healthy for both the herbivores as well as the forests. (Also see 5. 2) Similarly hawks serve a very helpful role in keeping the population of dove and other preys healthy. Thus the scavengers like vultures and hyenas help in keeping the forest clean of dead and decaying caracasses. Otherwise the forests would reek with stench from carcasses. Plants also exert similar pressures on the community.

Kaibab Preserve: Need of both Prey and Predators

4.3. Thus each species in an ecosystem plays a particular and important role in balanced functioning of the ecosystem. This role that a species plays is the ecological niche of that species. In short, ecological niche indicates the "profession or job" of a species in its ecosystem. Hence each species of animals as well as plants occupies a niche in its ecosystem. Consequently removal of a species from an ecosystem always disturbs it. The above is a simple definition of niche, but this meaning of niche, in the light of further studies however, has acquired more precision. So it would be worthwhile to dwell awhile on this point.

4.4. Any species can only tolerate only a certain range of temperature and humidity and not anything beyond it. If we take temperature and humidity for consideration regarding the survival of a species, we shall get a two-dimensional graph only (Fig. VII 3.a.). However if the species lives in a windy place it would naturally be influenced by air current as well. So besides temperature and humidity, air current will be another dimension of the niche of that species (Fig. VII. 3. b.). As a matter of fact niche of a species involves not only food but several other factors—some biotic some abiotic. G. Evelyn Hutchinson an Yale ecologist studied various such factors which influence the niche of a species and drew up the conclusion that **niche is an abstract n-dimensional hypervolume**. This definition however is no contradiction to that of Elton (VII. 4. 1) or, that in VII. 4. 3. Hutchinson merely added more precision to the definition. It seems that verily a species requires several factors—each factor within a particular range, in order to survive, grow and reproduce and maintain viable population in an ecosystem—i.e. its habitat.

Ecological Niche Hutchinson's concept

4.5. In Nature everything has a purpose. If we come accross a hummingbird with a thin, long and curved beak, we may wonder what could be its purpose. In Costa Rica of South America there are some flowers such *Heliconia* which are shaped like curved trumpets. There are

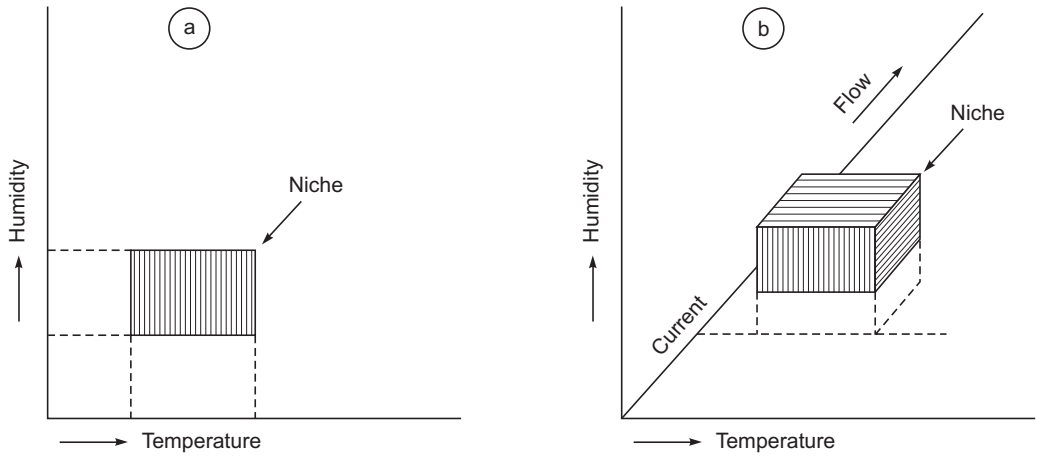

Figure VII.3(a and b) A two-dimensional and a three-dimensional niche.

some humming birds who also live in Costa Rica whose beaks are curved exactly to fit such flowers. These flowers are pollinated by these hummingbirds and the hummingbirds in return get their nectar from these flowers (Fig. VII. 4.). Celebrated Charles Darwin went even further. He predicted the presence of such a pollinator, when some botanists battled as to how it could be pollinated, and showed Darwin a Madascaran orchid *Angraceum* which secretes its nectar in the bottom of a green tubular spur a foot long. Darwin after examining the flower, particularly its colour and size, told that a night flying moth would be its pollinator. And lo, 40 years later exactly such a moth was discovered which has a foot long proboscis. Darwin's prescience was honoured by giving part of the scientific name of the moth as *forma predicta* (Attenborough. Trials of Life, 1990, p. 65).

Niche - an abstract n-dimensional hypervolume

4.6. If we patiently examine living beings and find out how and where they live, we shall realise that in Nature nothing is a waste. In her master plan Mother Nature has a job and place for every living being. All fit into their respective niches. It is we human beings out of our insatiable greed coupled with ignorance, 'throw a spanner', now and then, into her this otherwise perfect machine and thus put it out of balance. This is what is colloquially known as disturbing the ecosystem or upsettig the ecobalance. Some people out of excess of sentiment and lack of ecological concepts try to save all the cats and dogs they come about. This is a mistake. Regular culling is a must to keep these populations healthy and the ecosystem balanced.

Some occupants of various niches and the roles they play

4.7. Three Indian carps beautifully illustrates how each species fits the niche it occupies. In east Indian ponds there are three common carps. These are *Labeo catla*, *Labeo rohita* and *Labeo calbasu.* Overall these all stay in the same ecosystem namely ponds. But *Labeo catla* feeds on the

Figure VII.4 A Hummingbird visiting a flower.

surface planktons, *L. rohita* feeds upon the planktons in the middle depths of the pond while *L. calbasu* feeds only upon the dead and decaying organic mater settled in the bottom of the ponds. So there is no competition between them as they occupy different niches of the same ecosystem i.e. the pond. Because of difference in food habits these carps differ in their facial features as well. *L. catla* has a wide mouth and *L. rohita's* mouth opening is narrow but the mouth opening of *L. calbasu* is subterminal i.e. opens downwards and has short barbels guarding the rim of the mouth. These barbels help in search of food at the bottom of the pond where light is scanty. These bottom feeding *calbasus* play the important role of recycling the organic nutrients which would have otherwise remained locked up in detritus in the bottom layer of the pond and thus unavailable for recycling into bio-geo cycle of chemicals for a very long time.

4.8. This special role played by a species in ecosystem is its niche. In simple analogy one can compare the niche of an animal living in an ecosystem, with the exact address of a person as the niche and the postal pin code as the ecosystem.

5. BALANCE IN COMMUNITY

Disturbances in Community Balance

5.1. In a balanced and stable community that is climax community, each species has a specific and important role to play. These roles are the niches these are occupying. Let us compare this with a large human family. Here somebody might be only earning, somebody cooking, somebody maintaining the house, somebody tending the children and so on. In such a balanced family if somebody stops doing his or her duty properly, the whole family would be thrown out of gear. This is exactly what happens if suddenly in a stable community (climax) a species is removed or a new species is introduced. Here are some example.

Kaibab plateau: Prey-Predator balance

5.2. The Kaibab plateau of Arizona, U.S.A. has an area of more than half million acres. Prior to 1907 it had good populations of deers, wolves and pumas. It was a stable community. At that time there were about 4000 deers. But between 1907 and 1923 most of the predators were deliberately removed. Within this short period the deer population being free from predator pressure, exploded to about 100000, almost decimating the forest through overgrazing. Consequently deer population crashed and the forest became poor. Subsequently the forest department had to reintroduce predators establishing a much smaller but sustainable deer population in Kaibab (see also art 4. 2). This is a vivid example of what may happen if all on a sudden a species is removed from an ecosystem. From this the dove-lovers and hawk-haters may rethink about hawks and decide if hawks are really so bad after all.

Introduction of a Species: Water-Hyacinth in India and Bangladesh

5.3. The water hyacinth which is today most common in ponds and rivers of India and Bangladesh, is a native of South America. It is said that some European lady, to decorate her garden-pond brought it from South America to India. Oh what a havoc it has created ! It disrupted the entire fresh-water community. It has choked the canals and ponds, encouraged malaria which has become an everlasting epidemic and spawned many other human miseries in the entire eastern India and whole of Bangladesh. Really this has been a calamity. Indians and Bangladeshis still do not have any effective solution to water hyacinth problem.

Cactus in Australia

5.4. Here is another example. This is different from the above in the sense that here they could find a solution. The cactus *Opuntia* was taken by a British coloniser from India to Australia to decorate his garden. In no time it jumped over the fence and covered hundreds and thousands of acres of grasslands spoiling valuable pastures. Fortunately, after lots of efforts though, Australian entomologists could find in India a moth *Cactoblastis cactorum* which keeps the *Opuntia* in check in its in its native land. When introduced into Australia *Cactoblastis* cactorum soon brought down *Opuntia* infestation to a managable level, much to the relief of the pasture owners. There are more such examples.

5.5. All species belonging to a community are, in some way or other, connected to each other. Right from the imperial tigers to the lowly and

shy earthworms, all play important roles in the game of life. While the roles of tigers may be easily understandable to most of us but that of earthworms requires unbiassed and discerning eyes. Let us spend some time on this. Tigers (*Panthera tigris*) are carnivores which depend only upon meat as food. Depending upon its size a tiger needs 10-15 kg. of meat a day. Deers, hogs, porcupines etc. are its main food. So a tiger kills lots of animals for food. It has been estimated that nearly 30-40 square miles or forest area is required to provide a single tiger with food (Col. Keshri Singh, Jaico, Bombay, 1967).

Prey-Predator relationship: Tigers and Deers

One may think it is a waste to allot so much of forest area for a single tiger. But tigers and similar predators are very useful for the health of a forest. Without the presence of a powerful predator like tiger, the prey population such as deers will soon outgrow the capacity of a forest and destroy it by defoliating the trees and nibbling away the barks. Secondly, a predator usually predates upon the old and the weak and the young ones. Thus the predator helps to keep the prey population healthy and their number in check. Besides these the imperial majesty a tiger imparts to its forest is surely undeniable. Tigers are also great tourist attraction and have potential for good revenue.

5.6. Now let us examine the shy and self-effacing earthworm. *Pheretima posthuma* is a common Indian earthworm. These are small (8"-12" long) backboneless (INVERTEBRATES), tubular, legless and blind creatures belonging to the phylum **Annelida**. Their bodies are made of a series of rings with mouth and anus situated at the two extrimities of the body tube. They are nocturnal and live in forest floors or agricultural fields where one may occasionally come accross these crawling about upon moist earth. Usually earthworms' presence is indicated through earthworm mounds. Prior to 1850's biologists did not think that earthworms play an important role in the economy of forests. It took the genius of Charles Darwin to understand the important role that earthworms play in ecosystem. Darwin published a monograph on earthworms (The Formation of vegetable Mould throuch the Action of Worms. C. Darwin. 1888. John Murray. London), which is still a masterpiece. Earthworms live in tunnels, dug by these, within soil. Earthworms are vitally important for the health of forest and agriculture. They live on dead and decaying vegetable matter and thus break down leaves etc. which cover the forest floor. In this way earthworms hasten the return of organic matters to soil so that these can be reused by plants for biosynthesis. The earthworms also play a significant role in turning over soil by making mounds, ouside their burrows, of soil which has passed through their alimentary canals (Fig. VII. 5.). Today earthworms are considered so useful that, many farmers deliberately bring and put earthworms in their fields and gardens.

Detritus feeders: Earthworm

5.7. The snakes are another member of community which have suffered very much through us due to our misconception about them. Bible has

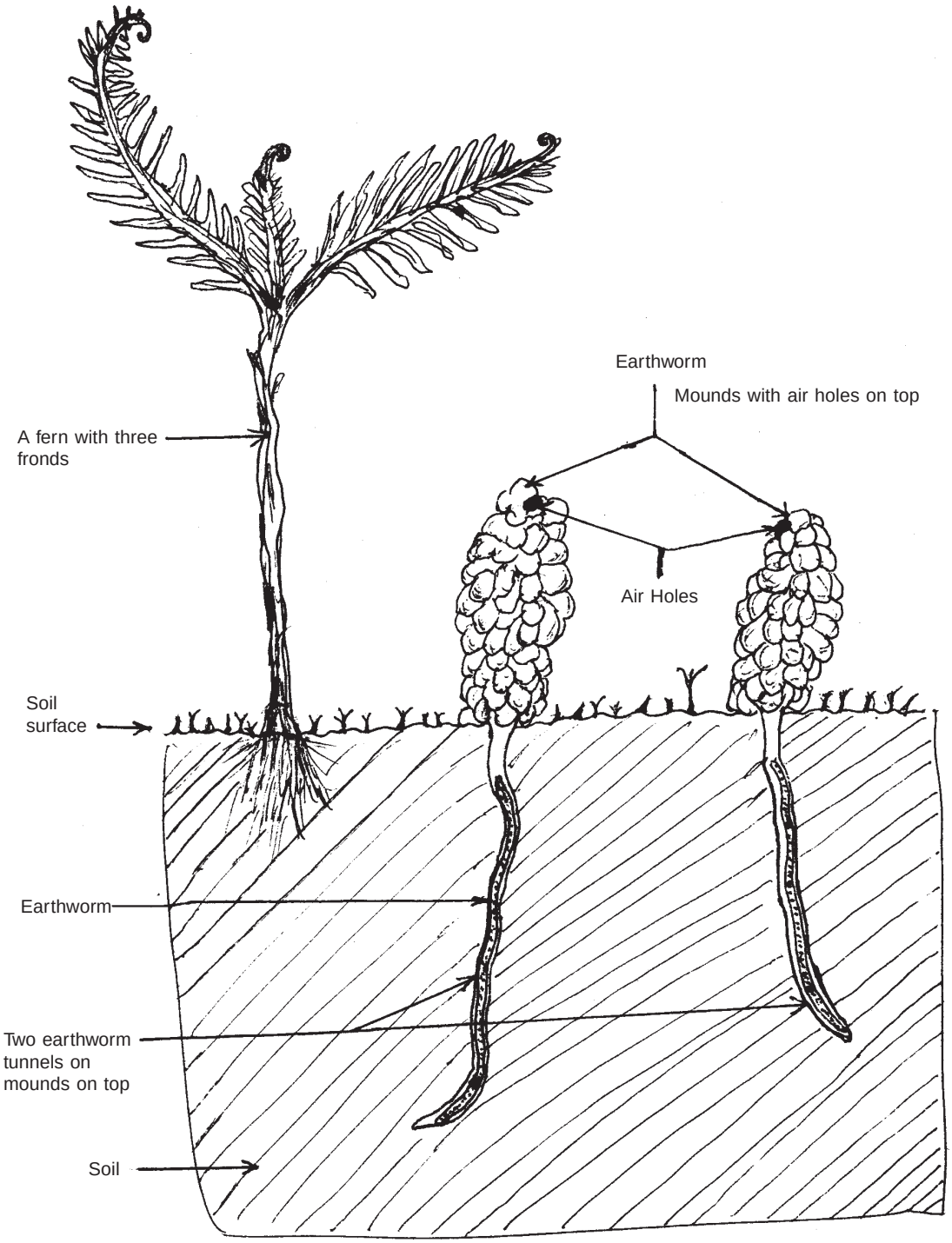

Figure VII.5 The mounds of earthworms.

depicted snakes as representative of Satan which it certainly is not. It is a predator and lives on small animals—such as insects, rats, birds and frogs. As the main terminator of field-rats snakes help the agriculturists. Like tigers as predators, snakes too keep their prey in check and thus help to maintain the ecosystem in balance. General public in most places have a tremendous fear of snakes as bite of some snakes can be lethal, so they try to kill them, one and all, whenever they can. In this way we not only do injustice to snakes but also upset the local eco-balance. Most snakes are harmless and shy, even cobras avoid encounter with human beings. It seems save African mamba no snake attacks unprovoked or unless threatened. None should kill snakes unless it is a must. Just because a few snakes can kill us by their bites we try to kill them all. It is very unfair. Just as we have, snakes too have their right to live. We ecologists think that unless it is a must a snake, whatever the species, should never be killed. Snakes are firends and not foes. They eat rats and thus directly help the farmers. Also unless threatened they do not bite.

The Friendly Snakes

5.8. Here are some of my own experiencec. At Pilani, Rajasthan, India, where I spent most of my academic career, once I came upon a large cobra (*Naja naja*) about 5' or so, busking in sun. Without noticing it when I walked to about 8' of it, it raised its head and spread the hood. Then I noticed it. I believe it was afraid and felt cornered—so in desperation threatened me. I stopped then and there and watched it. When it felt I am not going to attack it, it felt assured. Then slowly it moved away and I moved on. Another cobra, this one a young one, used to come, now and then, into the courtyard of our house, presumably trailing some rats. It never tried to attack us nor we harmed it.

My experiences of snakes

5.9. A large, balanced and self-sustaining ecosystem consists of a climax community and its abiotic environment. The functioning of the community of such an ecosystem is comparable with the orderly functioning of household. Here every member has a definite role to play. Similarly each species in a balanced ecosystem, is important. Each has a role to play.

Biodynamic forces and Eco-balance

5.10. Earlier we have seen that the consequences of interactions between two species may be + ve, – ve or 0 (i.e. neutral). So also are the nature of the various ongoing biodynamic processes within the community of an ecosystem. Looked from one angle one discrete biodynamic process may appear + ve and another – ve but when we take a totalistic view of the function of the entire community we find that collectively i.e. in sum total, all interactions lead to the sustenance of the health of a natural community.

6. APPROACHES TO COMMUNITY STUDY

6.1. Very often people use the term totalistic in their discussions. Ecologists use two other words—holistic and meristic. Holistic means looking at the whole complex of things that constitutes an ecosystem or

the community or similar interconnected assembly of things. Here are two simple examples. Suppose we have a small undisturbed forest valley as a self sustaining ecosystem along with a rivulet which origins and flows out of the forest then, by examining the water of this rivulet at regular intervals we can arrive at a pretty good picture about the health and nature of this ecosystem. This is a holistic study. Similarly, if we monitor carefully the inputs into a town i.e. the merchandise that goes into it for sell, we can make a pretty good idea about the financial capability and social tastes of the people who live in that town. This is also a holistic approach. But in meristic approach an ecologist would rather take one species i.e. a population and try to work out in details the various aspects of its biology—such as energy requirement, nature of food consumed, breeding habits, territoriality etc. Such detailed study on one single species may take the whole life of a biologist. Jane Goodal (1980). Spent her life studying primates of Africa and Karl Von Frisch spent his life studying bees in Germany (The Dancing Bees. An Account of the Life and Senses of Honey Bees. Methwn and Co. London. 1954). Still the significance of their findings went far beyond primates or bees. Their data helped enormously in holistic studies—Goodal's in understanding the behaviour and evolution of all primates and Frisch's in understanding the mechanism of foraging and pathfinding of bees and many other insects. Charles Darwin was a pioneer biologist who simultaneously used meristic studies and holistic approach to interpret biological processes. Thus he reaped ample harvest and presented the world, along with Alfred Russel Wallance, the single most important work in biology in ninteenth century—mechanism of origin of species (1859). Therefore holistic and meristic approaches are complimentary to each other. A synthesis of both yields maximum information in understanding the processes of life. In a community every single species is connected with heavy other species however remotely they may appear to be so.

Holistic and Meristic views: Are they different?

7. SPACE AND CARRYING CAPACITY

Here let us repeat some of the basic terms used so far.

(1) AUTOTROPHS : Green plants. They are also called **Primary Producers** and the symbol is .....$\mathbf{P_1}$.

(2) HETEROTROPHS : Animals of all types. Those which are herbivores are called **Secondary Producers** and the symbol is .....$\mathbf{P_2}$.

Those which are carnivores are called **Tertiary Producers** and the symbol is .....$\mathbf{P_3}$.

Those which are parasites are called **Quaternary Producers** and the symbol is .....$\mathbf{P_4}$.

(3) SAPROTROPHS : Bacteria and Fungi. Those which feed on dead organisms—plants and animals and the symbol is .....S.

Saprotrophs are the ones which break down and decompose any and all producers—P_1, P_2, P_3, and P_4, after their death and release the nutrients locked into their bodies back to abiotic environment for recycling. As these absorb nutrients at liquid state only, these are named sap-feeders or **Saprotrophs.**

7.1. Therefore Plants (P_1), Herbivores (P_2), Carnivores (P_3 and P_4) and Bacteria and Fungi (S) are present in all self-sustaining ecosystems. These sustain the ecosystem and are in turn sustained by the ecosystem. Hence P_1, P_2, P_3, P_4, and S are the fundamental biotic components of any healthy ecosystem. Removal of any of these, would throw the ecosystem out of gear (Chap. II.)

Land Requirements of Heterotrophs

7.2. Now let us examine how much land is required by a herbivore and a carnivore. Generally weight by weight, a carnivore requires 50 to 100 times of land that a herbivore requires. This would be obvious if we check the amounts of biomass of animals of various trophic levels which are supported by one acre of forest land (Figs. VI. 8 and 6). From these one can easily understand that the supportive capacity of land or a forest for an

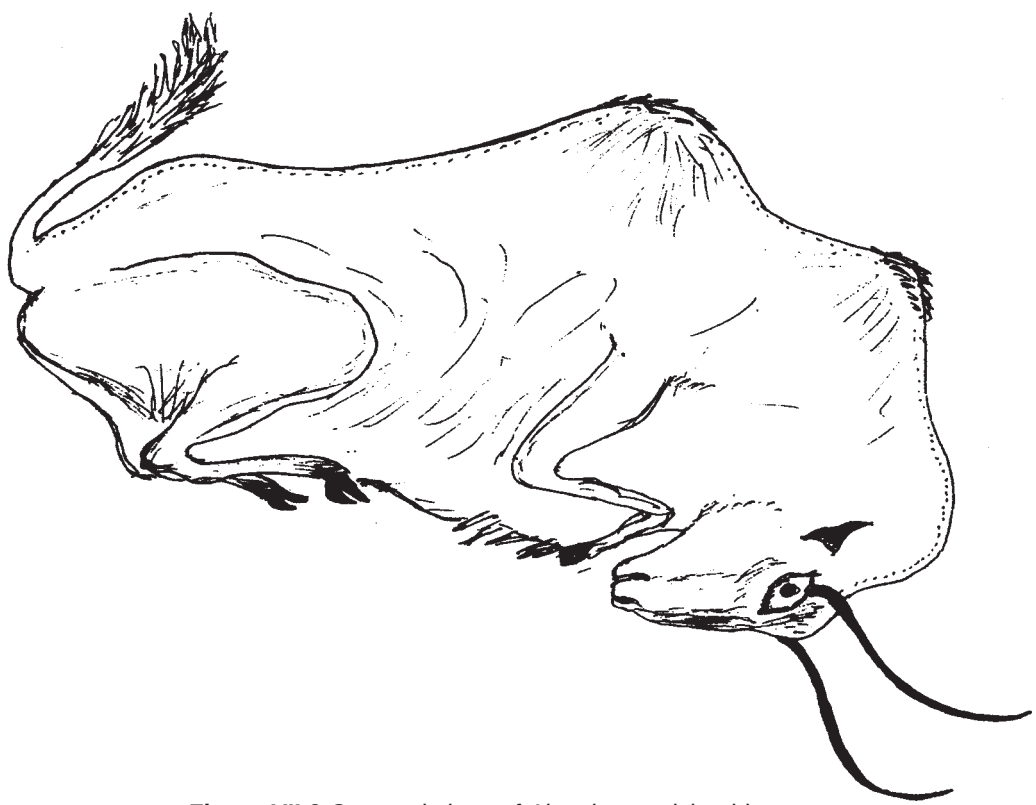

Figure VII.6 Cave paintings of Altamira—a dying bison.

animal depends upon how far away the animal is from the primary producers (P_1) i.e. the plants. So Land can support more herbivores than primary carnivores (C_1) and more primary carnivores than secondary carnivores (C_2). That is why a tiger in land or shark in sea both of which are top carnivores, require huge areas to support them. Estimated requirement of forest land, depending upon the nature of forest, to support one tiger varies from 30 to 40 square miles. For shark however we do not have any definite data but, it seems being top carnivore a shark too would need lot of sea area to support it. Sundarban forest in the Ganga delta of West Bengal, has an area around 2585 square miles. So it can support only about 85 tigers. Whether such a small number of tigers form a genetically viable population is not quite clear. We believe, our planners, as a thumb rule, should always provides for at least 250 numbers of any species of large size as a viable and genetically healthy population. Owing to poor planning and greed of unscrupulous people India's majestic tigers *Panthera tigris* and grand one horned rhinos *Rhinoceros unicornis* are almost at the brink of extinction. It would be a black day for Indians and India's ecosystems if these lovely and majestic animals are gone.

7.3. From the above figures and Table VI. 6 one can work out approximately, depending upon food habits and size, how much space an animal may require. Another lesson that can be drawn from this figure is also vary crucial. Same area of land can support more herbivores than carnivores. Therefore for overpopulated countries like Gaza Strip (2744 p. sq. km.), Bangladesh (870 p.sq. km.), Japan (332 p.sq. km.) and India (299 p. sq. km.), vegetarianism would be less eco-taxing (refer Table no. VI. 6 of Chap. VI). It appears to maintain an healthy environment all countries should aim to keep their population densities within a target aim of 100 to 200 p.sq. km. This number however may vary somewhat according to the rate of primary productivity of the ecosystem concerned. For instance 200 p.sq. km. for a desert is too high and too low for a tropical rain forest respectively. Here ecologists can help the planners. (Also it is now established in ethology that availability of open space helps healthy growth of human minds).

Over-populated Countries

7.4. The basis of the above statement is related with a concept called production efficiency. **Production Efficiency** (PE) is the percentage of the food that is assimilated by a producer (A_1) to that which is converted into new biomass of the producers (P_1) and efficiency as (E_1)

Production Efficiency

$$\text{Production Efficiency or PE} = \frac{P_1}{E_1} \text{ (when expressed as percentage)}$$

Generally invertebrates have a rather high production efficiency (30-40%), cold blooded vertebrates (10% or so, and warm blooded vertebrates including humans have a PE of only 2—5% or 20: 1 or so. This means warm blooded carnivores make a much higher demand on the food resources of the ecosystem they live in than the cold blooded imertebrates.

(Some require evenmore. For example, hummingbirds who are nectar feeders, require nectar about 50% of their body weight per day).

Culture and Land Requirement for human beings

7.5. Human beings are also animals—warm blooded animals (endotherms). But being exceptionally intelligent animals, who can think, learn and plan, their conversion ratio of 20 : 1 could not contain their ascendancy over all other living beings within a very short time. (Dr. J. Bronowski has given a very captivating account of this in his book—The Ascent of Man, 1973, B.B.C.)

There are two reasons for this.

(*i*) They can manipulate their environments end, depending upon their culture, get more out of the same land than other animals,

(*ii*) Their requirements are not mere food—depending upon the "quality of life" they aspire for, men of to-day not only need much more land but many other items to sustain them than other animals of comparable weights and food habits. Because of these two extra-ordinary qualities human beings to-day are posing a serious threat to the stability and health of all ecosystems of the entire world.

7.6. When English farmers introduced sheep in Tasmania, their number rose rapidly with time till, the number reached a level of density beyond which it could not be sustained profitably (Fig. VI. 6). Apparently that is the carrying capacity of Tasmanian pastures for sheep. Bus this would not work for human beings—*Homo sapiens.*

7.7. Human populations rose very very slowly during the early phases of human culture. In recent ages however the populations rose very fast (Fig. I.1 and III. 18). This rise is linked with the food procurement systems developed by people of different cultures. From the beginning of civilisation till now, human societies have passed through three successive distinct phases of cultures and now is poised at the doorstep of another. These cultures and their characters are as follows (Also, improvement in medical facilities contributed heavily in population rise).

8. PHASES OF HUMAN CIVILISATION

1. The Hunting Phase

8.1. First was the **Hunting Phase.** This is the earliest and pre-historic phase of human civilisation. People used to live in small groups or clans wandering about from place to place, living off from land and water mainly by hunting animals and eating whatever wild fruits, fishes and roots they could gather. In this way whenever the food supply of an area would get depleted, they would move on to another. These hunters did not have any written language but some of them developed superb painting and sculpting skills. The cave painting of hunting scenes at Altamira, Spain are examples of their superb talents. These cave painters of Altamira certainly achieved the acme of the hunting phase of human culture (Fig. VII 6).

8.2. The hunting era ended about 10—8000 years ago. There are a few scattered tribes who still live by hunting. Some of these are Bushmen of Australia, Jarwas of Andaman Islands and a few scattered tribes. World's human population was very low at that time. The best estimate seems to be less than 5 million (Ehrlich and Ehrlich, 1970. p.6) as, it required a lot of land to support a hunting tribe who would produce nothing but live off the natural produce of land. Also population growth was very very slow because many people died before reaching mature age owing to hunting accidents, diseases, starvation and inter-clan fights for mates and hunting grounds. Life was a never-ending struggle with no holiday.

2. The Pastoral Phase

8.3. Next came the **Pastoral Phase.** During this phase men learned the technique of domesticating animals. Cows, horses and dogs were domesticated and bred. These domesticated animals provided an year-round assured supply of food and clothing (from animal hides). With food and clothing assured, human population saw a faster rate of growth (Fig. III. 18). Such people whose life depended on domesticated animals are called pastoral people and their culture-pastoral culture.

8.4. Pastoral people have given humanity two great religions—Judaism and Christianity and one great—perhaps the greatest military genius the world has ever seen—Chenghis Khan. Alone he conquered, with his mounted archers, land spread from Mongolia in the east to Persia in the west (Genghis Khan : Emperor of All Men, Harold Lamb, Bantam Books, New York, 1957). Never in human history such a superb military genius has been seen—before or since . Pastoral people are still found in scattered pockets of the earth. Most notable of them are the herdsmen of Mongolia. Besides these people still migrate from place to place along with their herds of cattle and horses and their yarts (collapsible tents of felt). Besides there are Bedouins of Arabia who still live live off herds of camel and stay in tents and the Lapps who are Reindeer herders of Northern Sweden. During pastoral phase, because food supply was more assured and steady, humanity saw a spurt of rise in population (Fig. III. 18).

3. The Agricultural Phase

8.5. The phase which is present phase is the **Agricultural Phase.** Soon after the rise of pastoral culture, in different pockets of the world, rose the next phase in evolution of human culture—the agriculture phase. People noticed that seeds of some grass are eatable—so they tried to cultivate these. Soon in Africa and Asia they learnt how to cultivate wheat, rice, millet etc. In South America they cultivated maize.

Agriculture gave two things—settled life and more food. From agriculturists rose some of the most remarkable civilisations—one of them is Egyptian. This is the civilisation which flowered upon the valley of Nile river of Africa—the civilisation of Pharaohs—from around 5000 to 3000 B.C. The awe inspiring pyramids of Giza, Egypt and the stone carvings of Luxor and Abu Simbel also of Egypt, still bear silent witness of the glory and grandeur of that age (VII. 7).

Figure VII.7 One of the stone carvings of Luxor—a Pharaoh.

8.6. Besides, pyramids, Egyptian culture gave us hieroglyph (picture writing) and a very advanced agricultural civilisation which spread far and wide such as in valley of river Indus, Pakistan. There we find evidences of planned city life with underground sewage canals etc. From other agricultural civilisations such as in the valley of the river Ganga, India, we got a most beautiful and thought-provoking philosophy of life, the Vedic philosophy. The valley between the rivers Euphrates and Tigris, Iraq, gave us another powerful culture which produced besides great kingdoms beautiful stone carvings and the valley of Yangtze Kiang, China, gave us another remarkable way of life—Taoism. The Egyptians migrated to and spawned the early civilisations of South America. These are only a few of the vast cultural, scientific and architectural outpourings of agricultural societies. It is still flowering. But let us stop here. Our theme is ecology.

Cultural Phase and Boost in Population

8.7. The agricultural life is a settled life and assured supply of food, gave a further boost in the rise of human population (Table-VII. 1 and Fig. VII. 8). These three successive cultural phases of human development increased the productivity of land and thus its carrying capacity (for

Table VII.1.
CULTURES AND RISE IN HUMAN POPULATION DURING THE LAST TEN THOUSAND YEARS. EACH CHANGE IN CULTURE AND ADVANCE IN KNOWLEDGE IS ALWAYS FOLLOWED BY AN INCREASE IN THE RATE OF POPULATION GROWTH

Period BC/AD	*Population (In millions)*	*Civilization, methods of food gathering and other factors*
2000 AD	6000	Agriculturists; Industrialists, use of Modern Medicine to reduce pre-reproductive deaths and discovery and occupation of huge continents – Americas and Australia
1000 AD	900	Agriculturists and Pastorals
00 AD	700	Agriculturists and Pastorals
1000 BC	500	Agriculturists and Pastorals
2000 BC	400	Agriculturiests, Pastorals and Hunters
3000 BC	300	Agriculturists, Pastorals and Hunters
4000 BC	200	Agriculturists, Pastorals and Hunters
5000 BC	175	Agriculturists Pastorals and Hunters
6000 BC	150	Hunters and Pastorals
7000 BC	125	Hunters and Food gatherers
8000 BC	100	Hunters and Food gathersrs

human beings) by approximately 10 times in each phase. For instance, if 100 acres of land could support only 1 hunter, the same would support 10 pastorals or 100 agriculturists. Thus the carrying capacity of land, for human beings, is very dependant upon the technology people employ to obtain food from their ecosystems.

Effect of Industrial Revolution on Agriculture

8.8. In the later eras of agricultural phase, particularly industrial revolution in Europe (16th century onwards), men acquired new innovative tools for agriculture. These are mainly, machine ploughs, harvesting machines and chemical fertilisers. These artificial energy inputs to agriculture gave a further boost to cultural growth as well as numerical growth of human beings. People also had time to think and innovative. Consequently agricultural production went up even further. In to-day's world the agricultural productivity of land and economic clout of a country is very much linked with the level of technology the agriculturists there employ (Table. VII. 1).

8.9. Simultaneously growth in our knowledge of horticulture and animal husbandry, has contributed substantially to achieve all these. As a matter of fact five species of plants played a significant role to change the face of earth. These are :

(*i*) Quinine—a bitter alkaloid obtained from the bark of *Cinchona* tree, which cures malaria and thus helps human population growth.

(*ii*) Sugar—a very sweet chemical obtained from the sap of a tall grass *Saccharum officinarum.*

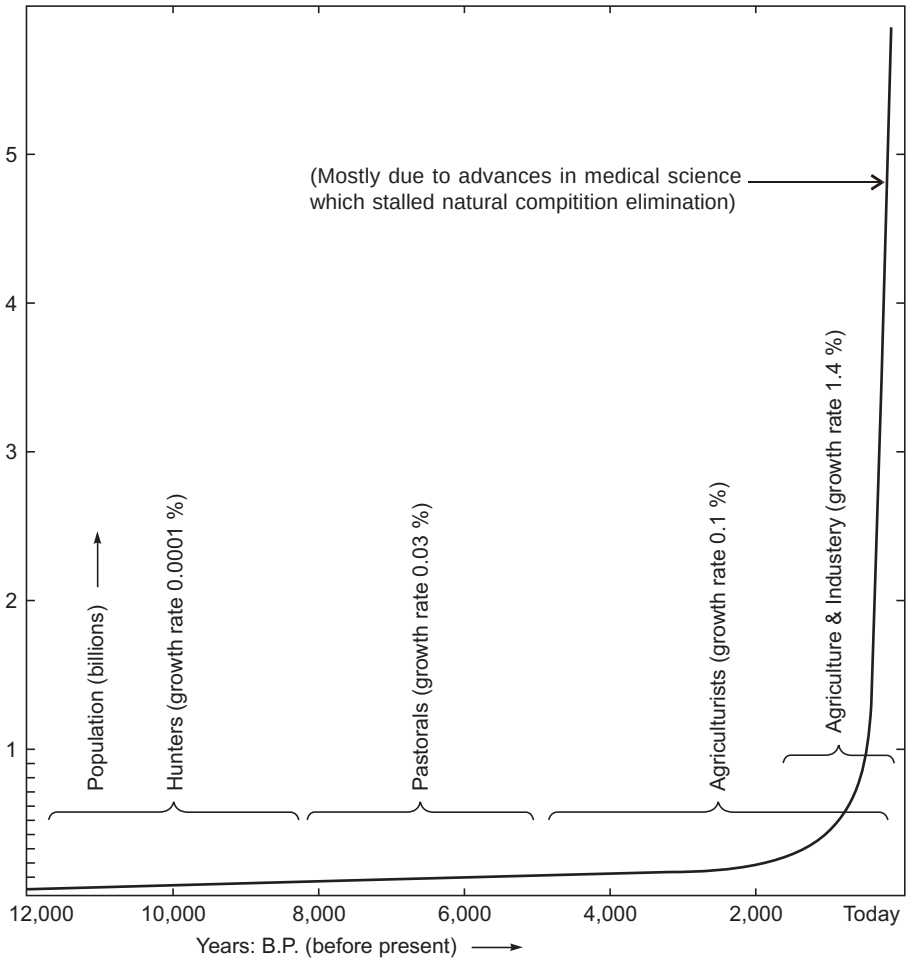

Figure VII.8 Growth rate of human population over the last 12,000 years.

(*iii*) Tea—a mild stimulant obtained by processing the bud and young leaves of a shrub *Thea sinensis.*

(*iv*) Cotton—white downy fibres obtained from the seed pods of shrub of *Gossypium sp.*

(*v*) Potato—white edible underground tubers of a small plant *Solanum tuberosum.*

Henry Hobhouses's account of all these is very attractive (SEEDS OF CHANGE : Five plants that transformed mankind. PAPERMAC. 1992).

Explosive Growth of Human Population and Survival of Ecosystems

8.10. Carrying capacity of land for human beings therefore, depends upon the techniques men employ to extract food from land. Now population growth is being boosted by two factors—first, by obtaining more food from same land and secondly, by reducing child-mortality through better medical care. The resultant explosive growth in population is now posing

a severe threat to the very survival of our ecosystems. To-day we are 6 billions, hurtling towards 9! We are just too many for Mother Earth to hold. This must be halted.

The Silver Lining

8.11. Still there seems to appear a silver lining in the horizon. Human beings today are at the threshold of another techno-cultural phase—**the Phase of Genetic Engineering and Information Highway.** These two powerful tools will enable human beings to increase the production of food manyfold—perhaps ten fold once again. Simultaneously through vigorous family planning even more will be achieved. But like Aldus Huxley's interesting book "Brave New World" that road may not be 'roses roses all the way' More about these in Chapter X.

Chapter VIII

Biomes

(The Nature in Her Splendours)

Topics

VIII.1. AQUATIC BIOMES

(where the environment is predominently water)

1.1 Swamps

1.2 Ponds & Lakes

1.3 Streams & Rivers

1.4 Estuaris or Deltas

1.5 Coral Reefs

1.6 Continental Shelf

1.7 Open Ocean

1.8 Upwelling zones

VIII.2. TERRESTRIAL BIOMES

(where the environment is predominently land)

2.1 Tropical Rain Forests

2.2 Temperate Evergreen Forests

2.3 Temperate Deciduous forests

2.4 Boreal Forests

2.5 Scrubland

2.6 Savanna

2.7 Tundra

2.8 Deserts

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Bed of the Pond has become so shallow that it is covered with grass in summer.

Photo V.1 (a) A dying lake.
(The Lake No. 2; Lake Town, KOLKATA, INDIA)

Photo V.1 (b) A dying lake.
(The lake behind the office of Geological Survey of India, Chowringhee, KOLKATA, INDIA)

Photo VIII.1
A garden plant in South Riding, Virginia, U.S.A. showing fall colours. South Riding is very near to Blue Ridge Mountains. (Author in background)

Photo X.1(a)
A piece of ungrared after one monsoon, KOLKATA, INDIA.

Photo X.1(b)
A piece of grared land (for gardening) in the same locality as X.a.

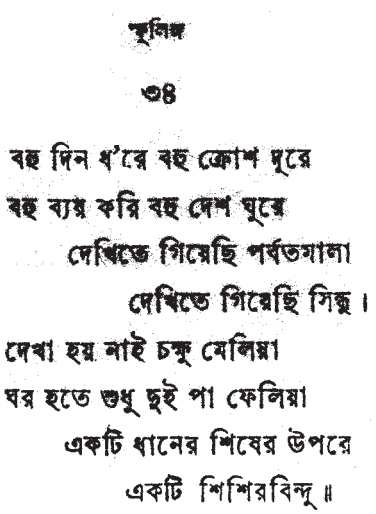
CHAPTER VIII

BIOMES

(*The Nature In Her Splendours*)

Nature abhors vacuum. Unless a place is absolutely uninhabitable, each and every corner of this biosphere is colonised by living beings. We shall begin this chapter by quoting from three extraordinary persons—one a poet, another a philosopher and the third one a naturalist, all praising and wondering at marvels of Nature.

The Indian poet Rabindra Nath Tagore wrote—



The American philosopher Henry David Thoreau wrote—"I went to the woods because I wished to deliberately, to front only the essential facts of life, and see if I could not learn what it had to teach, and not, when I came to die, discover that I had not lived."

This is what Alan Moorehead wrote about Charles Darwin's ecstatic reactions to Brazil's rainforest which he visited in 1832. "They (i.e. Darwin and his companions) were a party of seven, all mounted on horseback, ... they followed the coast for the first few days and then turned inland into the tropical rainforest.....he was

enthralled, enraptured. All around them vast ceiba trees and cabbage palms, as slender and tall as ships' masts,..... From the topmost branches Spanish mosses and long rope-like lianas trailed down through the green light ..... incredibly brilliant birds : the toucans (*Rampastos toco*) and the green parrots..... The blood curding cry of the howler monkey erupted through the silence .....".

Who has not shivered in pleasure and excitement at the first sight of the georgeous beauty of the snow clad Himalayas ? Whose soul has not been lifted at seeing the breaking out of sun through the crests of ocean waves or, who is not charmed at the resplendent fall-veil of the Blue Ridge Mountains of U.S.A.? Photo VIII.1. Or think of the awe inspiring sight of Niagra Falls where every second 800,000 gallons of water is hurtling down from a rock ledge forming an arc of half a mile. Such and many more are the bounties of our universal mother—MOTHER EARTH.

Our Earth is so variegated, so beautiful and so bountiful that, if we handle her with a little bit of care and love, she will ever remain a source of endless beauty and bounty to us all. It is time we address ourselves to this noble and urgent task. This chapter will be devoted to presenting a brief account of the varieties of our ecosystems and the following chapter on how we are damaging these precious ecosystems and the chapter after next i.e. the last chapter of this book on how we can rectify our mistakes and blunders before it is too late.

Main Ecosystems of Earth

From the ecologists point of view **the main ecosystems of the earth can be broadly grouped into land and water ecosystems or Biomes** with sub-divisions in each of them according to their dominant physical and biological features. Here is a table enlisting the main biomes of the world (Table VIII. 1.).

Each of these biomes pose their distinctive environmental challenges which lead to various adaptations. However even a mere enlistment of the challenges and adaptive responses of living beings of those, will occupy too much of space and time. Besides this is not the aim of this simple book. We shall therefore try to confine ourselves to the most salient features of these biomes and a few striking examples of adaptations. (The recent trilogy by David Attenborough—Life on Earth 1979, The Living Planet 1984 and The Trials of Life 1990, published by Little, Brown and Company, has beautifully presented some of these themes). Here is a world map indicating broadly the locations of the principal biomes (Map II. 1).

1. AQUATIC BIOMES

These are ecosystems where the environment is predominantly water. Naturally these ecosystems are of considerable variety. Here are the main ones.

Table VIII.1 Main Biomes of the World

Principal Biomes

Aquatic				Terrestrial			
(1)	Swamps (Fresh water)	→	Shallow waters on large areas	Mostly in warm areas and some in Siberia	(1) Tropical Rain Forests	→	Humid, dark and dense forests	Mostly in some tropical water-sheds
(2)	Lakes and ponds (Fresh water)	→	Permanent land locked body of water	All over the world	(2) Temperate Evergreen Forests	→	Forest with Broad leaf and evergreen trees	
(3)	Streams and rivers (Fresh water)	→	Running water systems	All rivers and streams	(3) Temperate Deciduous Forests	→	Deciduous forests where leaves fall off in winter	Mostly in cold temperate regions
(4)	Estuaries or Deltas (Brackish water)	→	Where rivers meet the seas	Mouth of Amazon, Ganga etc.	(4) Boreal Forest	→	Cold temperate regions with conifers	Pre-arctic areas
(5)	Caral Reefs (saline water)	→	Reefs formed of layers of dead shells of small sea anemones	In continental shelves in tropical and sub-tropical areas	(5) Scrubland	→	Semi-arid areas with thorny plants and shrubs	
(6)	Continental shelf (saline water)	→	Shallow (200 m.) areas of seas fringing all continents	Shores of all continents	(6) Savanna	→	Wide expanse of grasslands scattered with a few trees	
(7)	Open ocean (saline water)	→	Vast expenses of open seas	All oceans	(7) Tundra	→	Sub-arctic areas with seasonal grasslands	
(8)	Upwelling zones (saline water)	→	Special areas of seas where ocean currents push up some of rich sediments	A few special areas	(8) Desert	→	Mostly covered with sanddune with no or sparse rainfall.	

1.1 Swamps or Freshwater Wetlands

Swamps or Fresh-water Wetlands

a. Whereever a considerable body of water accumulate over a large area in modest depth, it forms a swamp or a wet land. Such swamps are mostly associated with fringes of lakes as with African rivers or in rivers in Amazon valley or river Ganga of India. The swamps in Florida, and Eastern part of Kolkata, India, are now-a-days very much talked about. We shall come to these later. Generally swamps enjoy heavy rainfall (100" or more) and warm climate (20—25°C). These wetlands are mostly situated in the warm parts of the globe i.e. from the tropics to about 40° North and 40° South latitudes (except the swamps in northen Siberia). So the climate is rather warm—around 18/20 to 20/25°C, humid and with plenty of rooted plants. Also the bottom of swamps are rather muddy and silty.

Flora and Fauna

b. The flora and fauna of swamps have characteristic features. As the water is nutrient rich, nearly stagnant and shallow such wetlands encourage growth of rooted plants, giant water lily such as the lilies with leaves about 1.8 m. long in Amazon swamps and the beautiful floating lake-gardens of Dal Lake in Kashmir. Water hyacinth is another plant very common in wetlands all over the world (Fig. VIII. 2.).

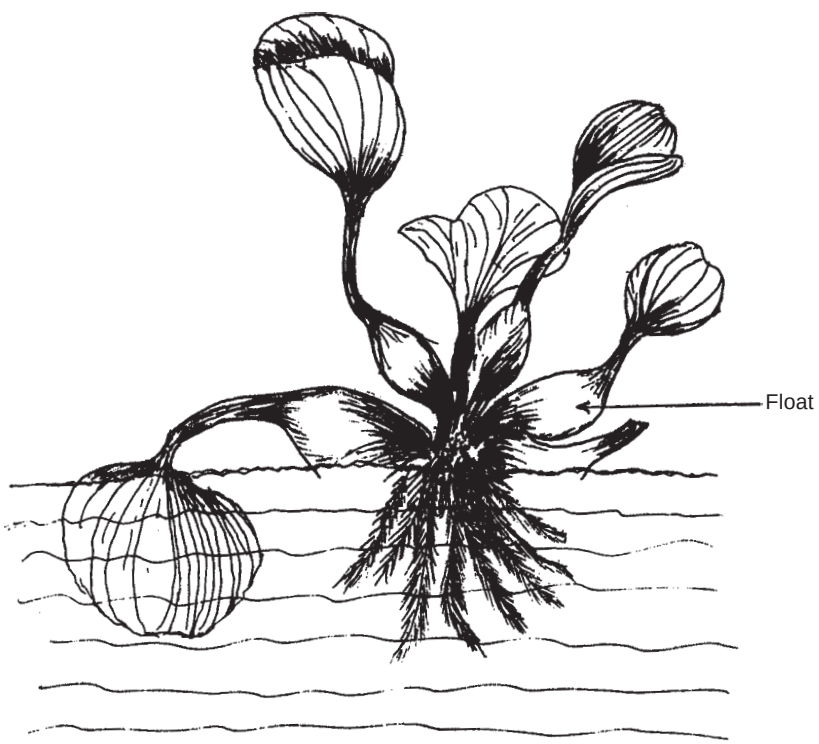


Fig. VIII.2 A clump of water hyacinths.

Fauna of wetlands too, like flora, have some characteristic features. They are generally suited to highly humid and warm climate and home of some large aquatic animals such as Anacondas (a species of water python), Crocodiles and Alligators of Americas, Hippopotamus in Africa. This is because in water body weight becomes much lighter (owing to buoyancy). The anacondas of South America may become as long as 10 meters weighing 230 kg. or so ; the crocodiles may becomes as big as 7—8 meters and hippo may weigh 2.5 tons and consume 175 Kg. of aquatic plants and grasses daily. Naturally these large animals' faecal matters add a lot of nutrients to the swamps. Besides, nutrients are further added along with the run off of water from the watershed of the swamps. Hence the fast silting is a conspicuous feature of most swamps. The silted up rims of swamps gradually get occupied with lowland forests.

Swamp Adaptations

c. The birds of swamps usually have long legs and splayed feet to facilitate walking in shallow waters and muddy surface. In some swamps of South America, Afrika and Australia, which dry up seasonally every year, three species of fishes have developed accessory respiratory organs in the form of lungs—to enable them to breath in air and thus tide over the dry season (Fig. III. 9 and Fig. VIII. 3).

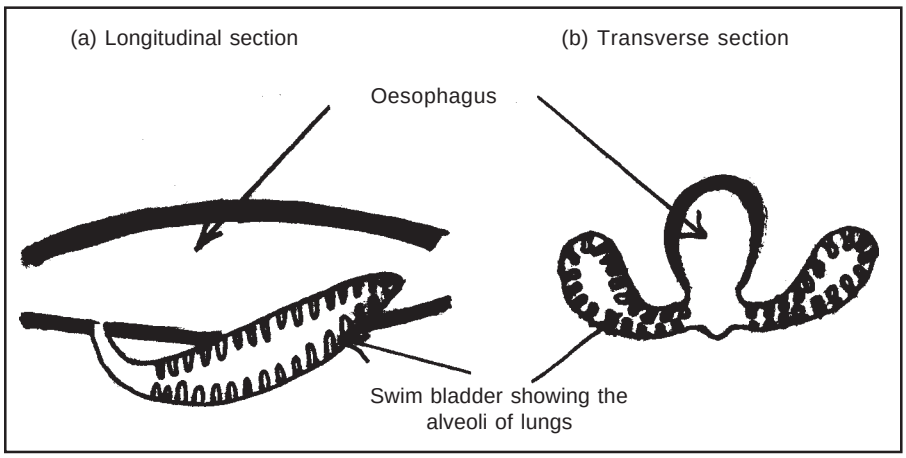


Fig. VIII.3 The lung of a lung fish–*Protopterus sp.*

1.2 Ponds and Lakes

a. A lake is a permanent land-locked body of water whose water supply may be maintained either by the aquifers (water-bearing strata of soil) or, run-off from the watershed during monsoons or, through rivers which open into this or both. A pond is an artificial impoundment of water made by men to serve their needs. Naturally being manmade, ponds or impoundments are small in size, Recent river-dams however have created huge artificial impoundments.

Ponds and Lakes

b. The main abiotic component of lakes is water or rather excess of it. Water though vital for life, poses challenges if it becomes more than necessary. Every living being must have water in their tissue but only in a particular proportion. Deficit or surplus of water both pose problems.

Animals get rid of excess water either through urine or perspiration or both (in rare cases such as tears of crocodiles and saliva of dogs serve the same purpose). Where and when water is insufficient animals move away from such places but plants which are stationery develop special dessiccation resisting features like converting leaves into thorms or developing thick barks etc. That is why semi-arid places have mostly thorny plants like cactus etc. When water is in temporary short supply, plants wilt i.e. the stomatal openings* of the leaves narrows as the stomatal cells become flaccid, so the leaves sag down. This helps in reducing the loss of water-vapour through leaves.

Lentic and Lotic habitats

c. Let us now come back to lakes. Before going into details of lake ecosystems the understanding of two terms are necessary. These are Lentic and Lotic. Lentic means standing water habitats such as swamps, ponds and lakes. Lotic means running water habitats such as springs and rivers.

Problem of surplus water for freshwater beings

d. Animals and plants in lakes have no shortage of water; in fact it is excess of this they have to deal with. As the body fluids of animals is more concentrated (hypertonic) than the surrounding water (hypotonic), water always tend to enter the bodies of the animals. The fresh water animals get rid of this excess water by producing plenty of urine (which is hypotonic).

Vertical Zonations in lakes

e. Waters of lakes which are deep—20 metres or more, have two types of zonations—one according to light penetration and the other according to thermal stratification. The upper layer where light penetrates is known as **Photic zone** and the lower layer where the light does not penetrate is called **Prefundal zone.** The photic again has two sub zones. Shore areas where light penetrates easily and have rooted plants is called **"Littoral zone"**. The area next to this where light penetrates but the zone is too deep for plants to strike roots is called **"Limnetic Zone"**. Fig. VIII. 4. As the photosynthetic activity is likely to be progressively less as one goes deeper, one should note depth of the place when he/she takes a sample of lake water to measure productivity.

f. Besides the above photosynthetic stratifications, lakes which are deep enough (20 metres or more) show thermal stratification in their waters. In a lake in temperate region during summer as the water is warm, it will form the top layer and the cold heavy water will stay in the bottom. There

*Stomatal openings (from stomata, pl. of stoma). Minute openings on the under surface of the leaves, in between two guard cells, regulating diffusion of gases into and out of the leaves for respiration.

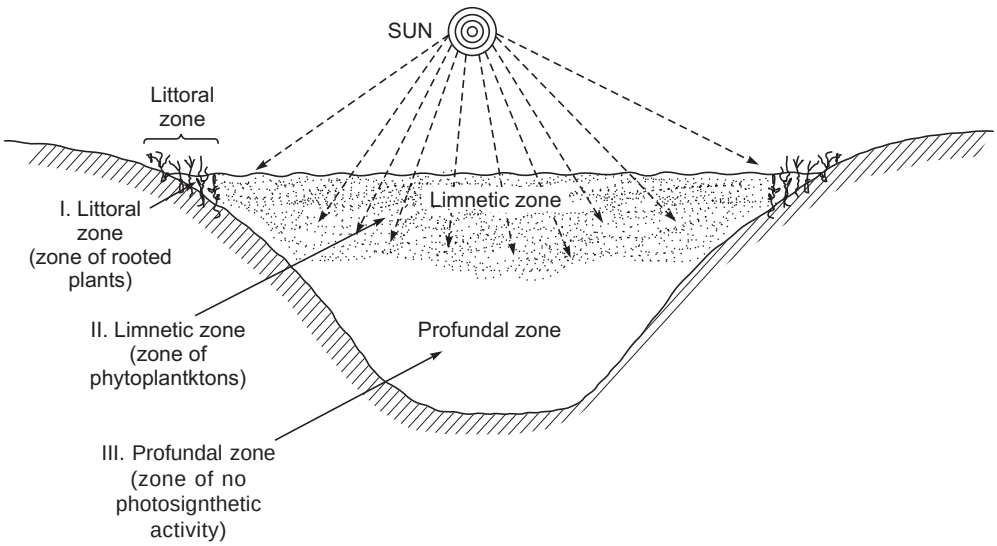


Fig. VIII.4 Vertical zonations of a Lake.

will be no mixing between the two. The top warm layer is **Epilimnion,** the bottom cold layer is **Hypolimnion** and the intermediate layer is **Thermocline** (Fig. VIII. 5.). As there is no photosynthetic activity in the cold heavy water of the hypolimnion so gradually this zone becomes the repository of nutrients.

Thermal Stratification of a Lake

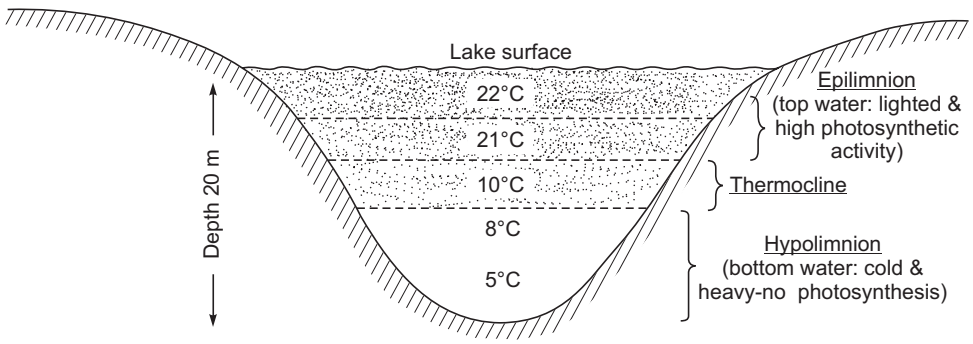


Fig. VIII.5 Thermal stratifications of a Lake.

g. As the winter approaches (in colder climates) the temperature of the upper water cools down. When it touches 4°C (i.e. when the water is heaviest) the upper cold and heavy water sinks to the bottom and the lower warmer and lighter water rises up. This is fall overturn. This bottom water which now comes up is however loaded with nutrients. Soon with further drop of temperature the surface water of the lake freezes and covers the lake as a hard protective coat. No further movement of water takes place. In spring when the ice melts there is a

Fall Overturn and Plankton Bloom

sudden spurt of plankton multiplication in the epilimnion—as now the water is loaded with nutrients and the temperature is favourable. So there is an explosive multiplication of planktons. This is known as plankton bloom (Fig. VIII. 6.). Just like a bloom as soon as the nutrients are used up it subsides. So plankton bloom is essentially a rhythmic affair linked with the season and temperature changes. Following the surge in plankton number, the density of fishes which feed on these planktons also rises up.

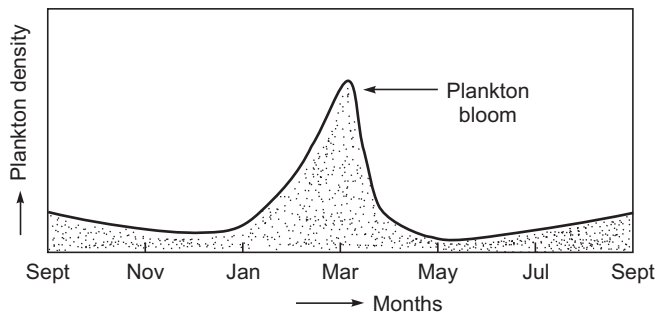


Fig. VIII.6 Plankton bloom in spring.

Adaptations and Evolution

h. Each environment has its own characteristic demands which lead to evolution of adaptive features. Such as, a brook is characterised with swift-flowing water while a lake may scarely have any current. So a brook-living fish would very likely have suckers on its lower surface (i.e. ventral surface) to stay put at a particular spot as long as it needs while, a lake fish would need only good fins to swin about. Thus demands of environment encourage adaptations.

Here we shall present a few special adaptations in sedentary water or lake-dwelling (lacustrine) beings:

(*i*) **Aerial respiratory organs:** Some of the pond fishes like *Anabas sp*. (in eastern India) migrate from one pond to another when the monsoon rains comes in June. This overland journey is frought with dangers— dehydration as well as asphyxiation. To avoid dehydration these migrate only in the nights, after rains when the grass is wet. To deal with asphyxiation these fishes have developed a pair of spongy structures behind their gills. These structure facilitate respiration in air (Fig. VIII. 6). These are called **accessory respiratory organs.** Also these fishes have spines on the rims of their gill covers (i.e. operculum) which help them to move about in wet grass.

(*ii*) **Lungfishes** (Dipnoi). In Australia, South America and Africa where they have many shallow ponds/lakes which regularly dry up in summer. A group fishes living is such situations, besides having their normal gill, have developed a **pair of lungs** as well which, enables them to respire in air and thus tide ever the summer months. *Protopterus* is one

of such fishes. These live in Africa where during summer they dig holes in the muddy bottom, exude copious mucilege to build cocooms around their bodies. *Protopterus* stay inside these cocooms in a curled-up posture and enter into a phase called **aestivation** (like of diapause of silk-worms during winter). In this position the fishes breath air and wait for the return of monsoon and water (Fig. III. 9).

(*iii*) **Barbicules** amongst detritivores. Bottom dwellers, such as catfishes like *Clarias batrachas* or carps such as *Labeo calbasu* are usually detritivores. These fishes are mostly bottom dwellers of ponds and hence detritivorus (i.e. those who eat detritus i.e. decomposing biomaterials). Also the bottom area is usually dark. So these denizens of dark have developed specially sensitive thread-like 'feelers' on their snouts to feel their way about in search of food. These feelers are called barbicules or barbicels (Fig. VIII. 7).

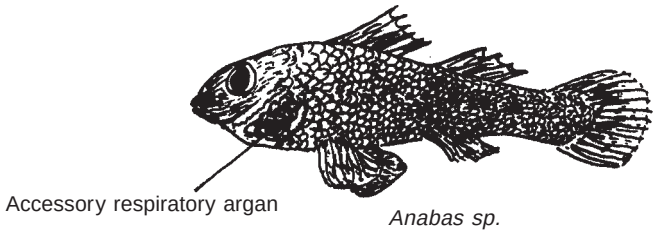


Fig. VIII.7 Accessory respiratory organ of a fish.

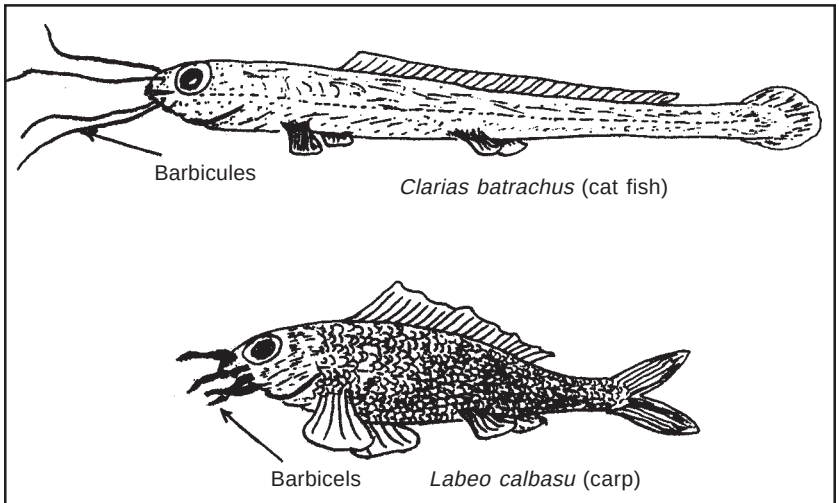


Fig. VIII. 8 Barbicules and Barbicels of a catfish and a carp.

These are some instances of how the demands of environments lead to specific adaptations. Every ecosystem has its own demands which leads to the matching morphological, physiological and behavioural adaptations to enable its inhabitants to survive there. Thus begins speciation.

Origin and Size of Lakes

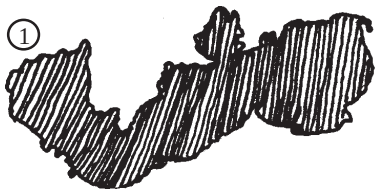
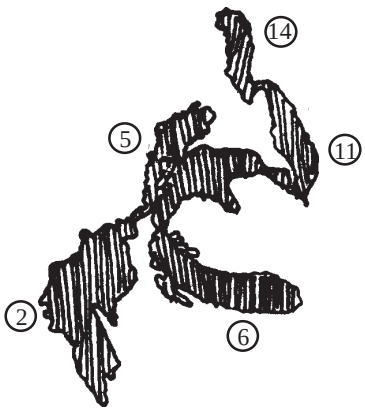
i. Lakes origin in several ways. Some begin by accumulation of water from surrounding places (called water-shed of lake) into depressions created by movement of soil layers (tectonic movements) over millions of years. Some are formed within the volcanic craters—which are large mouths of volcanoes cooled and solidified as large cup-like depressions. Now-a-days men are creating lakes within river valleys by damming rivers for irrigation and power generation. Some such river lakes are very large. For instance, Lake Kariba on Zambesi river of Africa is 30 km × 75 km and Lake Nasser on river Nile is 300 km. × 50 km.

j. Here are the names, locations of 15 biggest natural lakes of the world (Table VIII. 2a, b & c). Amongst the huge lakes a few perhaps deserves special attention. (1) **Lake Baikal.** It is the oldest (25 million years) and deepest (1260 m.) in the world. It has its own characteristic fauna found nowwhere else. 70—80 % of its fishes are unique. Baikal's fauna is as special amongst lakes' as is Australia's fauna amongst the continents. 98% of the arthropods (prawns, crabs and such creatures) and 80% of the fishes of Baikal are endemic (not found anywhere else). (2) **Aral Sea.** It is a huge one nonetheless, the erstwhile U.S.S.R. has drawn so much water out of it for giant irrigation projects that the lake has shrunk to almost 1/4th of its original size with all harmful consequences. The present status of the Aral Sea is a good example of how Nature should not be handled. (3) Canada and U.S.A. are extremely fortunate to have five huge interconnected lakes—**Superior, Michigan, Huron, Eerie** and **Ontario.** Between Eerie and Ontario there is that huge and spectacular

Table VIII.2(a)
FIFTEEN BIGGEST NATURAL LAKES OF THE WORLD
(Adapted from various sources)

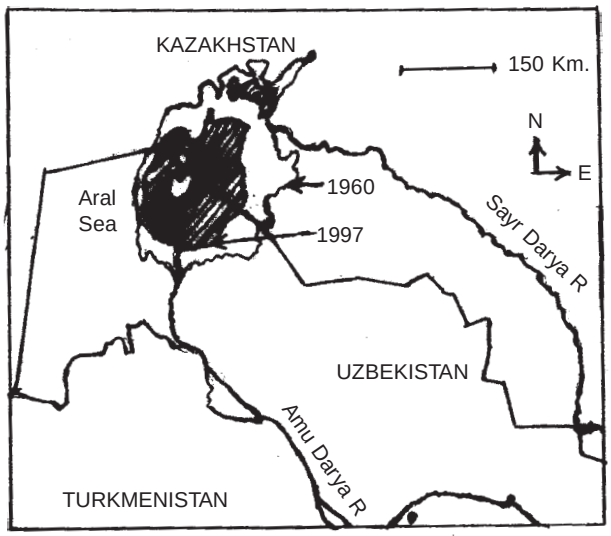
Rank	*Name*	*Area (Km^2)*	*Country*	*Remarks*
1.	Caspian Sea	371,000	USSR	Salty
2.	Lake Superior	82,900	Canada	
3.	Lake Victoria	68,800	Africa	
4.	Aral Sea	65,500	USSR	Now drying up (owing to mega-irrigation projects)
5.	Lake Huron	59,580	Canada	
6.	Lake Michigan	58,020	USA	
7.	Lake Tanganyika	38,900	Africa	
8.	Lake Baikal	31,500	USSR	Deepest (1260 m.) and oldest (25 million years)
9.	Great Bear Lake	31,330	Canada	
10.	Great Slave Lake	28,570	Canada	
11.	Lake Erie	25,680	Canada/USA	
12.	Lake Winnipeg	24,890	Canada	
13.	Lake Malawi	22,490	Africa	
14.	Lake Ontario	19,400	Canada/USA	
15.	Lake Ladoga	18,390	USSR	

Table VIII.2(b)
THE 15 LARGEST NATURAL LAKES OF THE WORLD

	*No.**	*Area*	*Name*	*Country and Comments*
	1	371,000	Caspian	USSR Main source of sturgeon fish and cavier-their eggs.
	2	82,900	Superior	Canada
	5	59,580	Huron	Canada
	6	58,020	Michigan	USA
	11	25,680	Erie	Canada and USA
	14	19,400	Ontario	Canada and USA
				All the 5 lakes are interconneated fed with ice melt from north Canada and open to Atlantic sea via Niagra falls at the end of Lake ontario and then St. Lawrence river.
	3	68,800	Victoria	Africa
	4	65,500	Aral	USSR Now owing to too much with drawal of water for irrigation it has shrunk to 40,000
	7	32,900	Tanganyika	Africa
	8	31,300	Great Bear	Canada
	9	31,300	Baikal	USSR Oldest (25 million years) and deepest (1260 m) Lake
	10	28,570	Greal Slaue	Canada
	12	24,890	Winnipeg	Canada
	13	22,490	Malawi	Africa
	15	18,390	Ladoga	USSR

*According to size (area in Km^2)

Table - VIII.2(c)
DEATH SPASM OF ARAL SEA. IN 1960 ITS AREA WAS 67,000 SQ. KM. AND IN 1997 ONLY 39,000 SQ. KM.



Niagra Falls pouring down 800000 thousand gallons of water per second. All the surplus water from these five lakes come via Niagra Falls to Lake Ontario and from here through St. Lawrence river to Atlantic Ocean. Seeing Niagra Falls is an unforgettable sight.

k. Amongst the artificial lakes the two largest ones we shall touch upon. first is the **Lake Nasser** created by dammging Nile at Aswan. It has created a huge artificial lake about 300 km × 50 km. This lake has submerged the huge and famous stone images at Abu Simbel. Fortunately Egypt with international aids, has been able to cut these idols into managable sizes and remove them to safe places before these were drowned. The other one is the **Lake Kariba**—another leviathan of 300 km × 75 km created by damming Zambezi river at Kariba. Interestingly another spectacular falls—the **Victoria Falls** lies at the other end of Lake Kariba—also on Zambezi river.

Consequences of damming the rivers

l. Damming a river makes water available for power generation and agriculture. These are economic gains but not without a price. A dam creates extensive changes in the local ecosystem and also in the flora and fauna of the river. Unfortunately such changes are not being given enough attention. In india owing to poor maintenance, most of the river dams are being silted up. Also owing to melting of snow, deforestation and the annual monsoon floods are increasing in ferocity. Still they are erecting another huge dam—Narmada dam, the ecological fallout of which may be far from welcome. Public is generally ill informed and Indian ecologists' voice is too feeble to be heard.

m. Lake fauna can be divided into three main groups. (1) **Plankton.** These are tiny beings—both plants (phytoplanktons) and animals (zooplanktons) who stay on the upper surface, photosynthesise, and are not very mobile. (2) **Nekton.** These are mostly fishes and other animals such as turtles, prawns, etc. who can swin about on their own. (3) **Benthos.** These are organisms which are attached with the bottom or live on the bottom sediments. For instance, Chironomid larvae* or bloodworms, Tubifex **—a red annelid—commonly used as fish food in home aquaria and *Unio*—a common pond bivalve *** etc.

Lake Fauna

n. The quality of the water of lake naturally depends upon the surrounding area or the watershed from which water comes into it and also the depth of the lake. Young lakes are deep and hence have a much larger hypolimnion than epilimnion. The nutrient content is also relatively low. Such lakes are called **oligotrophic** lakes. As nutrient content is low so is plankton density. Such cold oxygen rich clear water lakes are preferred by such fish as trout **eutrophic** lakes are older, shallower and are richer in nutrient content. These therefore have high plankton density. Kashmir's Dal Lake is an eutrophic lake. Trouts cannot live in such lakes. They prefer oligotropic lakes.

Productivity of Lakes: Oligotrophic and Eutrophic Lakes

o. A lake is nourished with water from its watershed#. The watershed nourishes the surrounding ecosystem including humanity. Consequently any change in the watershed will effect the lake as well. With time, through sediments from watershed, all lakes gradually get filled up and ultimately the aquatic flora and fauna of a lake are replaced by terrestrial flora and fauna. This however takes thousands, if not hundreds of thousands, of years. A lake may also dry up owing to depletion of its water (as in Aral sea). So a careful and alert observer may be able to discern stages of succession in the shore of a lake. Such successions from aquatic to terrestrial systems are known as **hydroseral successions**.

Death of a Lake and Hydroseral Succession

p. Nowadays the following factors, created by human intervention, are adversely affecting many lakes.

(*i*) When trees in the watershed of a lake, are cut down the rain drops falling directly upon the exposed forest floor will loosen the soil and hence the rain water will carry more of silt with it than before. This silt will untimaetly settle in the bottom of the lake raising the bed every year. If this concontinues unabated i.e. unless corrective measures are taken in time, soon the lake will meet its doom. The Dal Lake in Srinagar, Kashmir, India, is a good example. This beautiful shallow lake, one of the

*from *Chironomus*—an insect.

**A species of Annelid—a group allied to earthworms.

***Bivalve—the group which oysters belong to.

#A watershed broadly means the area of land, from which rain water according to gradient or slope, accumulates into a lake or river or swamp and thus maintains it.

attractions of Kashmir is doomed to death within next 100 years or so, unless vigorous preventive measures are taken now.

(*ii*) Besides natural beauty lakes and swamps are very valuable in recharging ground water. If lakes and swamps get silted up rain water will very quickly roll away elsewhere leaving the groundwater unrecharged. This is one of the reasons why in many densely populated areas and tubewell-irrigated agricultural areas, the level of ground water is going down every year. In U.S.A. parts of Florida Swamps have been drained off by estate developers for making houses and villas. Now they are having second thoughts. Situation in Kolkata, India is equally saddening. For instance they are sinking a deep tubewell capable of lifting 35,000 gallons of water per hour in CD park of Salt Lake (Laban Hrad Sambad, 21.04.2004). This will very likely lower the ground water level further.

***q*.** Kolkata a metropolis in eastern India, although receives more than hundred inches of rain every year, suffers from water shortage in summer. When the British colonialists created this town by buying out a few villages, they established many parks, left many ponds untouched and dug a few new ones—partly for beauty and partly to face summer draught. Since 1947 i.e. Independance, the Kolkata people started filling up the ponds to construct houses. Parks were nibbled here and there for Government uses. The Government owned ponds are neglected, neither their water is cleaned regularly, nor the sediments dredged out to maintain their depths. On the contrary, the Kolkata people usually look upon a pond as a convenient dumping ground for rubbish. Slowly the ponds are dying. Roads and footpaths are being paved up. So when rain comes Kolkata gets water logged. The sewarage canals are choked and parks are few and the footpaths are all paved up. So the rain water has no chance to percolate into the soil and recharge the ground water. Hence as soon as the rainy season is over, Kolkata faces draught. Wells dry up as the water level gose down. Trees on foothpath die—as they have paved the footpath right up to the base of the tree—so the base of the tree has not received any water during monsoon. Most of the city canals do not have running water any more—although they were planned so; so these become cess-pools and happy breeding grounds of mosquitoes and sources of other problems of hygiene. A once-beautiful lake in Lake Town is slowly being killed to make way for houses (Photo V.1a).

Plight of Kolkata Ponds and Swamps

Now they are even filling up the swamps around Kolkata for housing projects. None who counts seen to understand the value of swamps. The entire Salt Lake City of Kolkata is made that way. Now they are planning to reclaim more such swamps around Kolkata. It seems that more miseries lie ahead. The only consolation seems to be that people are unaware of the ominous future—so for the time being they seem to be happy. In short, Kolkata is a good example of mismanaging nature.

1.3 Streams and Rivers

Streams and Rivers

Streams and Rivers are stages of the same system—drainage system for water of watersheds. The water may come from melting of ice from snow capped mountains (as in Himalayas) and or from rains. As water always flows in streams and rivers the communities living in such waters are called **Lotic** or running water communities.

a. Basically there are three important differences between a pond / lake community and a stream / river community. First is the—**Water Current:** Here in lotic systems, water always flows. So all organisms have to adopt themselves to a life in flowing water or, they would be carried away to altogether different places. So among lotic organisms some have hooks, some suckers, some strong claws, some digging apparatus and some are very strong swimmers etc. Such adaptations are required to keep them where they need to stay. The second differences is oxygen content : As the water is always flowing and depth is not much, **Oxygen Content** in lotic water is uniformly high. Consequently unlike lentic communities (i.e. communities in ponds or lakes) which can tolerate oxygen fluctuation to a considerable degree, the lotic communities (i.e. communities in streams or rivers) are very susceptible to oxygen depletion. This suseptibility is successfully used by forest rangers to test the quality of waters of streams and rivers (more about this in next chapter when we shall talk about BOD). Thirdly, as all streams and rivers are shallow water and running water systems there is **no Hypolimnion** in lotic waters. So the entire water contains photosynthetic and heterotrophic organisms.

b. Streams and rivers differ from each other mainly in gradient, speed of water current and width of the valley. At her origin, a river is more like a stream; her sides are steep, water flow high and the valley is narrow and steep. As the river flows forward she widens, her water speed reduced and she joins up with other such sister rivers, who bring waters from different part of the same valley or adjacent valleys. Gradually this river moves forward, and strengthened by unions with sister rivers, so the river becomes wider, her gradient gentler and the water speed is further reduced. In the final stage when the river reaches its lowest level and its speed becomes slow or sluggish, the silt deposition is high as a result deltas are formed.

Zones in a River Watershed

In short there are three distinct zones in the watershed of a river. First the steep-gradient, high-speed and cold water zone in the mountainous areas, second the medium gradient and medium-speed and relatively warm zone in the plains and in the third or final stage a river has a very low gradient, low-speed and fairly warm water zone. Here is the confluence of the river with sea or a lake. Also here **deltas** may form.

c. Streams and rapids in cool high mountain, where the water is clear and the current is high, there are boulders which create small pools.

Importance of streams and rapids in fish breeding

These are favourite breeding grounds of fishes such as salmon. These fishes, which spend most of their adolescent and adult days in seas when breeding season comes, return swimming all the way up from the sea into the river and from the river mouth to nearly the origin of the river—rapids in high mountains to lay their eggs. These eggs are laid in nearly the same spots where they were born a few years ago. The Atlantic sock-eye salmons which spend most of their lives in various locations of Atlantic return to lay eggs in the source areas of rivers in western Alasca. Here, in small rock pools of cold clean water these fishes spawn (Fig. VIII. 9). It is a wonder how they perform this perilous return journey of thousands of miles following only the dictates of their genes. When men dam up the rivers and thus prevent such fishes from swimming up to their breeding grounds, the fish population plummets. So now they have added fish-ladders to enable such fishes to move up the dam and breed as before in their normal spawning grounds (Fig. VIII. 10).

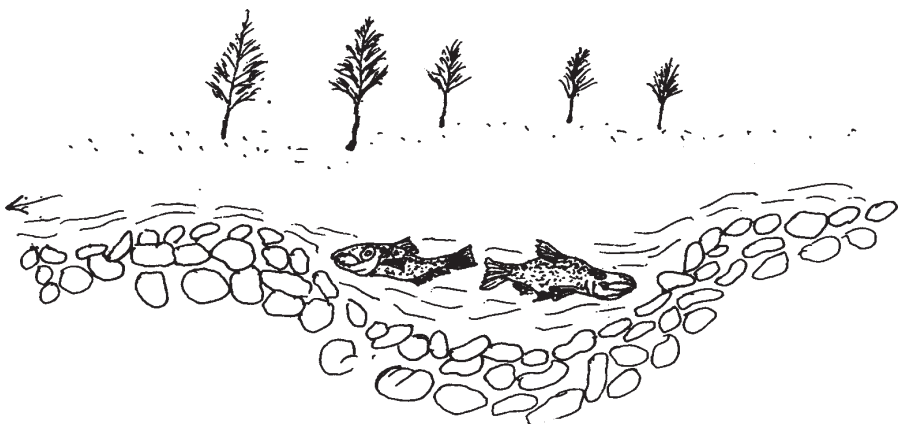


Fig. VIII.9 Spawning bed of Atlantic salmon-*Salmo* sp. (schematic).

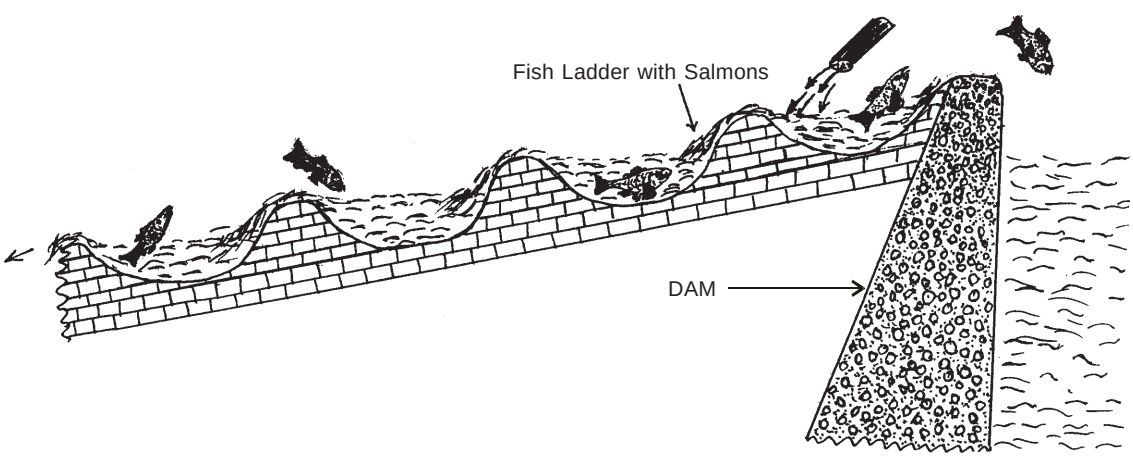


Fig. VIII.10 Fish ladder for river fishes to negotiate dams and continue their swim upwards.

d. Recently it has been found that whereever in a rivershed there has been logging, the enhanced soil erosion has made the waters somewhat turbid and silt loaded. Fishes do not lay eggs in such rock pools there any more. Owing to deforestation so much damage has taken place in spawing areas that salmon population has dwindled and so salmon fishing suffered. This is a poignant example how even an apparently small change in one part of the ecosystem can swell up into a major upheaval. Many such things are happening in Himalayan forests and the snow lines above them where lies the sources of three major rivers of Indian subcontinent—Indus, Ganga and Brahmaputra. Unfortunately as yet not much is known about the consequences of such actions. Things must be happening only people are blissfully unaware.

Logging in watersheds and its effects on fish spawning

e. In many aquatic systems a new but deleterious factor has been introduced by men. This is **eutrophication.** Broadly eutrophication means enrichment of the environment with nutrients in such a way that productivity (i.e. production of biomaterials) is increased. This begins with the increase in phytoplanktons. A consequential biological phenomenon of eutrophication is increase in biological oxygen demand. By Biological Oxygen Demand (BOD) we mean the amount of oxygen needed to completely oxidise all the organic and chemical wastes in the water until the water is clean again.

Eutrophication, BOD and treatment of waste water

f. The sewerage water which is full of organic and chemical wastes (which are, in-a-way, nutrients) is cleaned in the following way. Before being released into the rivers or recycled for gardening and agriculture, all the large particulate dirt is sieved out. This is first treatment or primary treatment. Then water is transferred to secondary treatment plant where microorganisms carry out the breakdown and assimilation process till most of the organic matters and chemical nutrients are used up. This is facilitated by supplying oxygen to the waste water by aeration. Primary treatment removes about 35% and secondary treatment about 55% of BOD so these two treatment together have about 90% efficiency in reducing BOD. To make the water usuable in homes however requires further treatment or tertiary treatment which involves various processes such as electrodialysis, and chlorination etc.

g. In poor countries like India, Pakistan, Bangladesh etc. water supplied by most municipalities may not always be very good in quality. Dysentry, cholera, jaundice, ptyphoid, all are caused by water borne carriers. It seems to us the best thing to do is to either treat the municipality—water, in small home water—treatments plants where special filters and U.V. lights are used or better still to boil the water or, use solar-distillation plants to distil water before using it for drinking purpose. Then most of the above ailments will vanish.

1.4 Estuaries or Deltas

Estuaries

The region of a river where it opens into a sea covering an extensive shallow tidal area is called estuary. The rivers here are shallow, wide and many have split out from the main river. The water is brackish i.e. the salinity is in between sea water and fresh water.

High productivity of estuaries

a. The estuarine water is very rich in nutrients. This is because the lighter freshwater from the river flows outward forming the top layers while the heavier salt water from the sea flows inwards forming the bottom layers. (Fig. VIII. 11). This counter current forms a sort of nutrient trap enriching the estuarine water and raising its productivity. Besides the enrichment of estuarine water through nutrient trap, most estuarine water is also enriched from accumulation of dead and decaying products (i.e. detritus) from mangrove vegetation (described earlier III6.3) of estuaries. Consequent upon all these the estuarine biomes are one of the highly productive biomes of our biosphere. Their average net primary productivity is of order of 200-3500 gm/m^2/year. In the end of this chapter a comprehencsive table showing the productivities of all biomes discussed here are given (Table VIII. 3).

Estuaries in Ganga delta and its pitiable fate

b. In the South Bengal—both of India and Bangladesh there is an extensive estuarine biome formed by Gangetic delta. This is Sunderban. In not too distant past—about 100 years, it was a large and lovely biome—home of one of the most regal animals of the world—the Royal Bengal Tigers (*Panthera tigris*) and innumerable other attractive animals and plants. The well known amongst then are deers, honey bees and prawns, shrimps, crabs, and many fishes and trees like 'Sinduri' 'Goran' etc. etc. It is still a much smaller but a lovely biome—and a visit to it would leave pleasant memories with any one. But to-day its future is dark. From the beginning of this century however Sundarban is slowly being chipped off; first by middle class 'Bengali' 'babus for making "bheries"—a system of impoundment of tidal water for fishery, and by poor Bengalis as easy source of wood as fuel. After independence i.e. since 1947 things have aggravated so much that Sunderban is simply being raped. The greed of

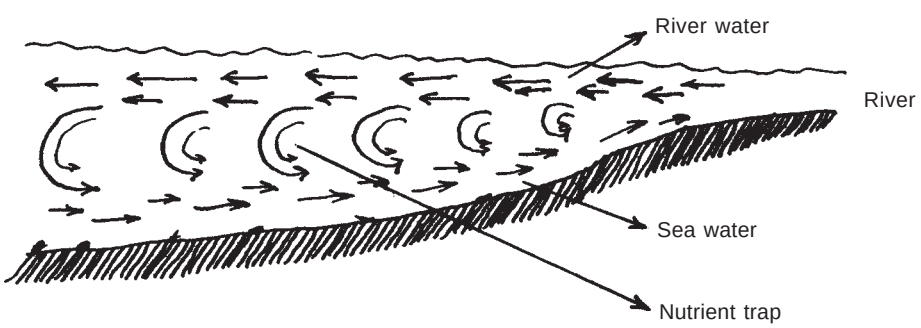


Fig. VIII.11 Two opposite currents in estuarine water forming a nutrient trap.

Table VIII.3.
BIOMES AND THEIR PRIMARY PRODUCTION AND SUCH RELEVANT INFORMATION
(Adapted from Colinvaux, – Table – 24.3. p. 508)

Biomes	*Mean Net Primary Productivity (g.c/m^2/yr)*	*Area (10^6 Km^2) [% in bracket]*	*Total Net Primary Production (10^9 metric ton.yr.) [% in bracket]*
1. Tropical Rain Forest	900	17.0 [11.765]	15.3 [33.579]
2. Temperate Evergreen Forest	585	5.0 [3.460]	2.9 [6.368]
3. Temperate Deciduous Forest	540	7.0 [4.844]	3.8 [8.344]
4. Boreal Forest	360	12.0 [8.304]	4.3 [9.442]
5. Woodland, Shrubland	270	8.0 [5.536]	2.2 [4.831]
6. Savanna	315	15.0 [10.380]	4.7 [10.320]
7. Tundra	65	8.0 [5.536]	0.5 [1.098]
8. Desert	32	18.0 [12.457]	0.6 [1.317]
9. Others (incl. agri.)	298	54.5 [37.370]	11.24 [24.681]
TOTAL LAND (28.333%)	374	144.5 (99.580)	45.54
1. Swamps	112.5	2.0 [0.547]	2.2 [7.942]
2. Ponds, Lakes and Rivers	225	2.5 [0.684]	0.6 [2.166]
3. Open Ocean	57	332.0 [90.834]	18.9 [68.231]
4. Upwelling Zones	22.5	0.4 [o.109]	0.1 [0.361]
5. Continental Shelf	162	26.6 [7.278]	4.3 [15.523]
6. Coral Reef	900	0.6 [0.164]	0.5 [1.805]
7. Estuaries	810	1.4 [0.383]	1.1 [3.971]
8. Others	–	–	–
TOTAL WATER (71.666%)	500.6	365.5 (99.998)	27.7
TOTAL OF EARTH	437	510.0	73.24

money of industrialists and craze for vote bank by politicians together are choking Sunderbans almost to death. Now they are even talking of erecting an Atomic Power Station there. That will be the last nail in the coffin of India's pride—the Royal Bengal Tigers. The ecological backlash of the destruction of Sunderban we shudder to think of. More has been discussed on this issue in IX.

***c*.** Sundarban's survival needs serious serious ecological works and vigorous administrative actions which are unfortunately scarce. As far as we are aware of two scientists are working. Dr. Kumudranjan Naskar and his team are working on Sunderbans mangrove flora (2004) and Prof. Amalesh Roy Choudhury (1987) has established, through his own initiative, a small Marine Biological Station at Sagar Island in the mouth of Ganges. These are very heartening efforts but not enough.

1.5 Coral Reefs

***a*.** Coral Reefs, continental shelves, open oceans and upwelling zones are four biomes which are parts of sea. These share certain common

Common features of all seas

features. (1) **Salinity:** Sea water has a very high salt content, about 3%. This is more than what sea animals have in their bodies. Consequently water tends to get out from sea animals bodies into sea. Therefore to sea animals sea is a dry place. This is reverse of what happens to fresh water animals. (2) **Depth:** Depths in sea vary from 5 metres in coastal waters to 8000 metres or more in really deep portions of sea (trenches). Naturally marine animals are subject to extreme variations of pressure. Those who inhabit shallow water can't stay in deep waters and vice versa. Sharks, whales and a few other marine animals however, can bear enormous variations in water pressure. So these can easily roan about in deep waters and again come up and swim about in shallow waters. (3) **Light:** Sunlight cannot penetrate effectively beyond 300 metres in water. Therefore, out of a total possible depths of 8000 metres or so only the top thin layer of 300 metres or so is productive i.e. the autotrophic zone. (4) **Current:** Owing to rotation of earth on its own axis, sea water is constantly moving. Hence there is a constant, fixed and worldwide ocean current (Fig. VIII. 12).

Coral Reef

b. Coral reefs are shallow and relatively warm areas of sea where corals grow in abundance lending a beautiful under-water colourscape like look to the whole area. (Corals are small marine polyp—like animals who have a calcaroous skeleton. After death of these polypes' skeleton get deposited one above the other—gradually forming what we know as coral reefs). These areas are very rich in nutrients as coral reefs are within autotrophic zone of sea and act as resting, hiding, feeding and breeding places of many marine animals—particularly fishes. Coral reefs abound with beautifully coloured fishes, such as sea horse, butterfly fishes, crabs, sea-anemones, sea stars, corals, cray fishes, mussels, octopuses, small fishes

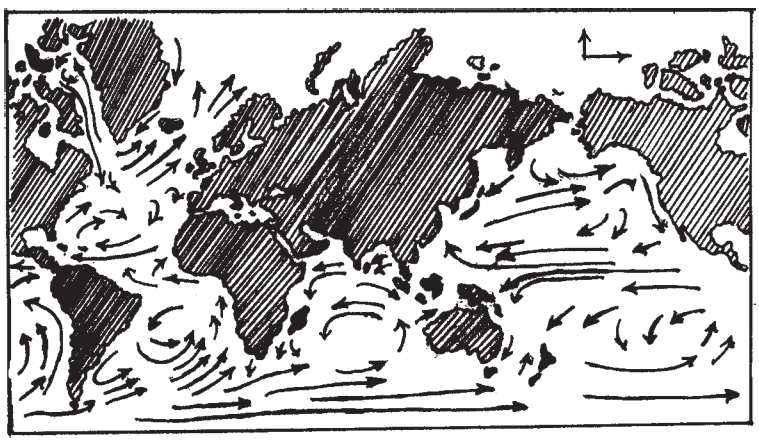


Fig. VIII.12 Continents, oceans and major currents of the oceans. (In northern hemisphere currents are clockwise and in the southern hemisphere anticlockwise).

and many more. In fact diving into a coral reef in a divers' suit and seeing the throbbing life of coral reefs is an unforgettable experience.

c. The most famous coral reef of the world is the Great Barrier Reef of Australia skirting almost half of eastern coast of Australia like a huge tiara stretching 1500 miles from Brisbane in South to the Cape York Peninsula in North. Others are found nearly in almost every Pacific Islands and other shallow warm water areas. In India there are a few excellent coral reefs—Andaman and Nicobar Islands, Palk Straits and Gulf of Kutch. Gulf of Kutch is particularly interesting as this is a small gulf spreading from east to west and has tidal height of 13 feet or so. Hence it is extremely rich in diversity of marine fauna. The author and his students have found living conch shells, small octopuses and small dog fishes (a species of shark) in puddles of water left in low tides amongst the coral reefs.* The entire Gulf of Kutch should be made a "reserve marine forest" by Govt. of India as soon as possible. Some steps have already been taken. Also this Gulf can be safely used to generate electricity from tide when water rises about 12-14'—a clean source of power and a permanent one.

Great Barrier Reef and other famous coral reefs

Gulf of Kutch

d. Coral reefs are one of the most beautiful spots of Nature. Anybody who is a good swimmer can enjoy them. One however must never venture into a coral—reef without supervision of a local expert diver or else, pleasure may soon end up in pain. The most frequent dangers in these places are sharks, sting-rays, poisonous jelly-fish, electric cels and coral snakes (Fig. VIII. 13a, b & c).

Pleasure and pains in visiting them

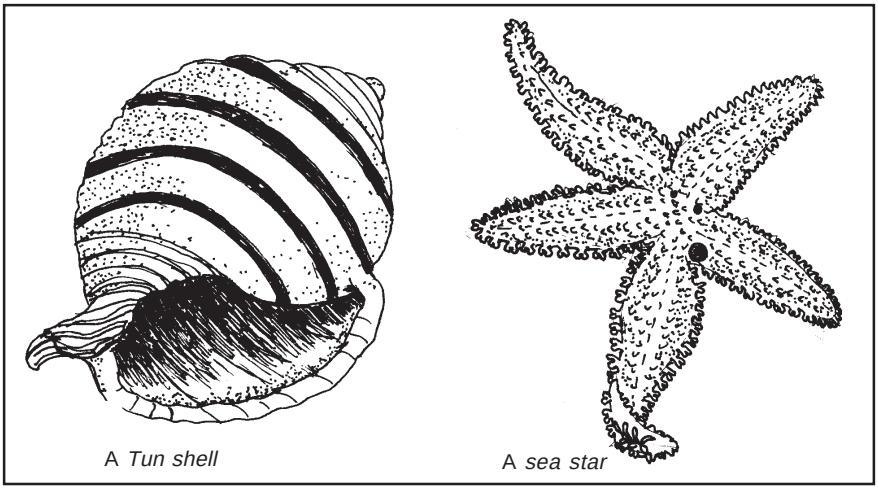


Fig. VIII.13a Some animals of coral seas. A snail and a starfish.

*The author has published a detailed study on the Pelecyphods (musssels) of Gulf of Kutch (J.B.N.H., 62, 1 and 2).

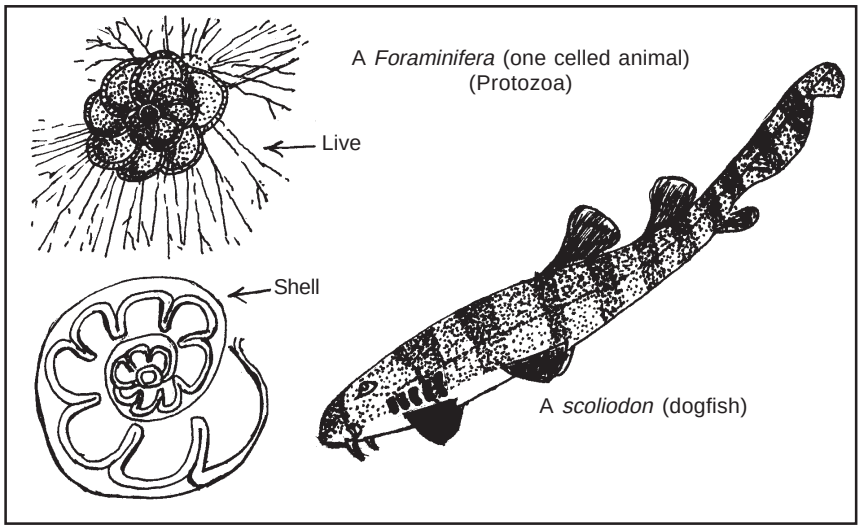


Fig. VIII.13b A Protoroan and a Dogfish.

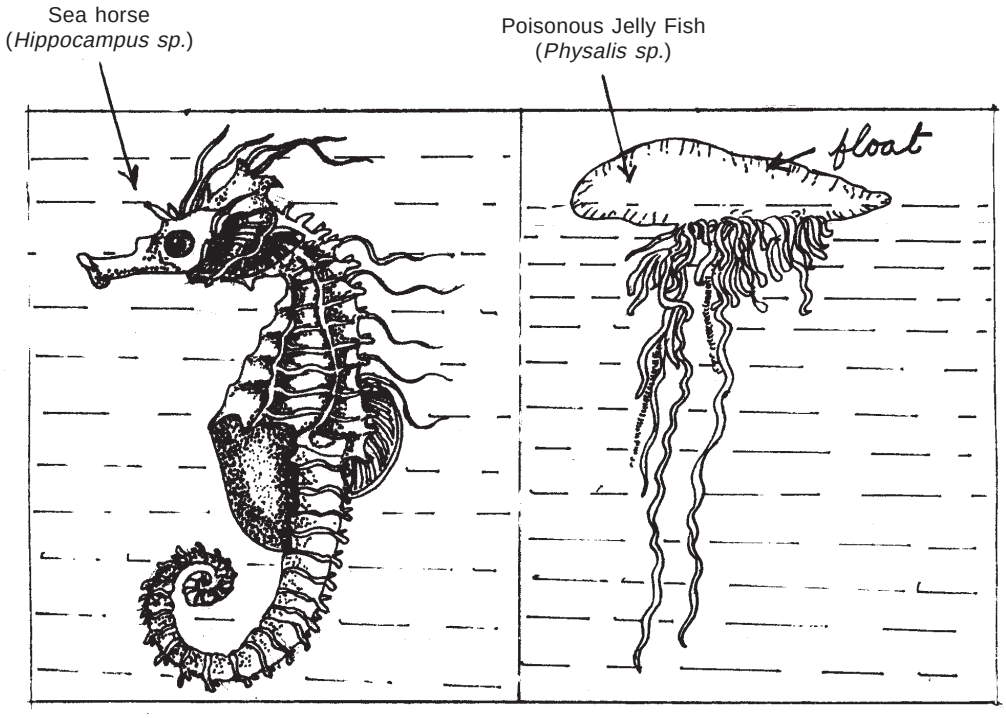


Fig. VIII.13c A sea horse and a poisonous Jelly fish.

e. Unfortunately however, the advancement of fishing techniques particularly dredging by trawlers which scoop up the whole bottom biota —corals, star-fishes, algae and all and killing fishes by poisoning the

water and using explosives are posing grave dangers to marine ecosystems. Some species are facing extinction. One such is seahorse (*Hippocamous sp.*) and small beautiful horse-like fish which has a mouth like a horse and prepensile tail with which at attaches itself to algae (Fig. VIII. 13a, b & c). Most Governments are yet slow to grasp the gravity of the situations and act.

1.6 Continental Shelf

Continental Shelf and different zones of the sea beyond continental shelf

a. Continental shelf, open ocean and upwelling zones, although all these three form parts of a continuous environment namely oceans, still they are remarkably different from one another in their areas, depths and productivities. A summary table given here will illustrate this point (Table VIII. 3).

b. The above table we shall come to later. First let us summarise the outstanding features of continental shelf. The **continental shelf** is that segment of ocean which skirts all the continents as a shallow water zone extending as a step 10-150 miles wide and not deeper than 200 metre. This area is within the penetrable zone of sunlight, hence euphotic. But this is beyond the **Littoral zone** which is washed daily by tides.

After the continental shelf there is a sharp drop of ocean floor i.e. rise in depth from 200 to about 3000-4000 metres. This zone forms the bulk of the ocean floor. The lower part of this zone is called the **Bathyal Zone** and the upper part—the euphotic—the open ocean. In some zones the ocean floor suddenly drops further till 8000 to 11000 metres. These are called **Hadal zones** with individual names such as Maryana Trench in the Pacific ocean. Maryan trench is the deepest trench of the world (11,600 metre). In fact it is the reverse of the Mount Averest (highest mountain in the world). Mount Averests' top will be more than 1/2 mile under the sea if it is dipped in Mariana trench. There is an excelent article on ocean floor in a recent issue of National Geographic Magazine.

Flora and Fauna of continental shelf

c. Now about the continental shelf. **First : Light.** Some of the sunlight is reflected away from ocean surface. However red, orange and ultraviolet lights are mostly absorbed in the first 25 metres of the surface. Green, yellow and blue penetrates further till about 125 metres or so. Because only green, yellow and blue colours penetrate deeper waters, sea-weed in the deeper waters of continental shelf have a red colour pigments instead of Green chlorophyll, for photosynthesis. Hence occasssionally we find red-coloured weeds in the sea shores. Due to its shallow depth the continental shelf receives sunlight and hence this zone is euphotic (see Fig. VIII. 14) and photosynthetic **Second : Biota.** As continental shelf is photosynthetic it has good density of diatoms (one celled plants), foramifera (one-celled animals), and copopods (small prawn like animals), jelly fishes, starfishes, fishes, sea-shells and worms etc. who feed upon the smaller ones (Fig. VIII. 13). Diatoms contain silicon in their bodies—

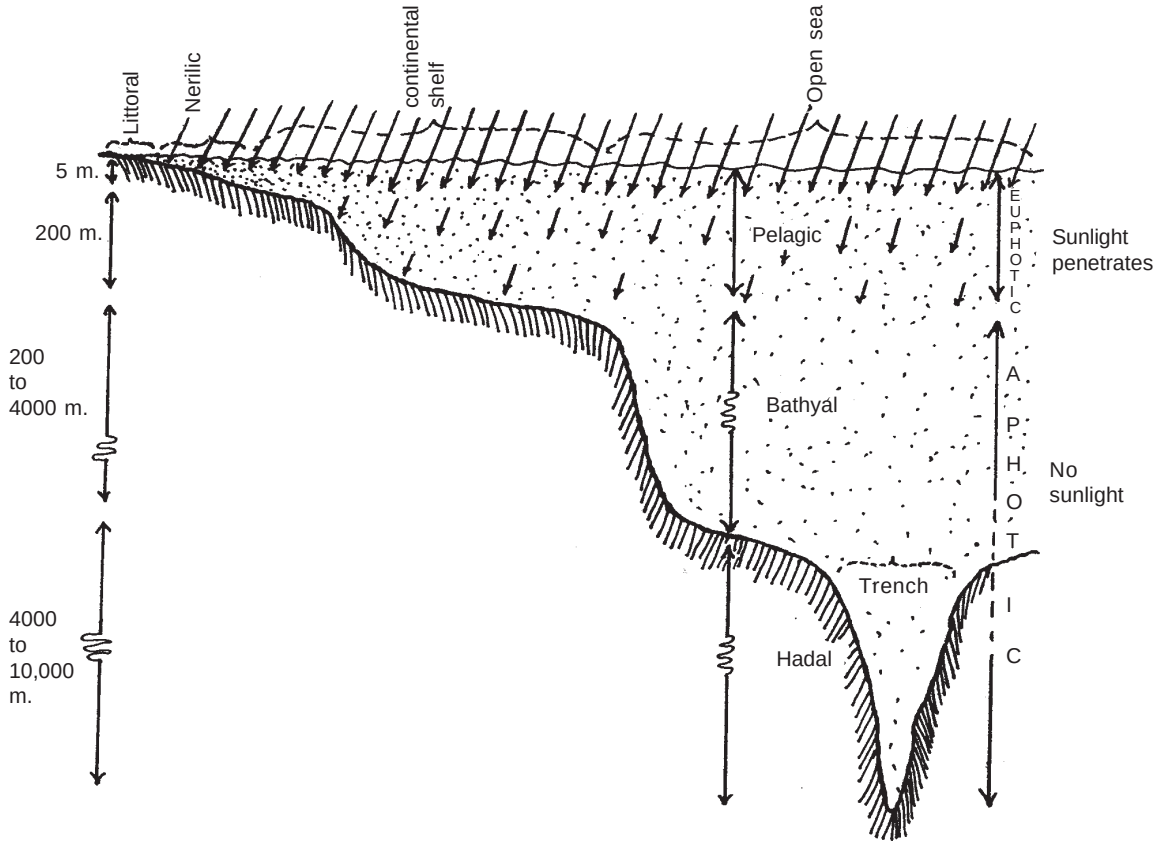


Fig. VIII.14 Zonations of oceans: based upon—(a) tidal effect, (b) depth of water and (c) penetration of sunlight.

hence these are siliconaceous and as Farminiferams contain calcium in their bodies these are calcareous. When these die and their bodies settle and rot upon the ocean floor these form a soft whitish mud called "ooze". Tides and wave action however at times, stir up the waters of continental shelf. So the water of Continental shelf is fairly rich in nutrients, and hence constitutes one of highly productive areas of sea (Table VIII. 3).

d. Fishing vessels of most of the countries operate mainly in continental shelf. One very interesting fish of continental shelf is tuna (*Orcynus thynnus*). This fish is so large (2-3 metres), so delicious and so expensive (5-10 thousand dolars a piece) that American fisherman use helicopters to locate them, harpoon to kill them and big trawlers to lift them from sea and then immediately freeze and fly these to Tokyo fish market—the greatest fish market of the world. Japanese love to eat 'suci' a delicacy made from tuna. So the ultimate destination of most tunas of the world are the Japanese kitchens.

1.7 Open Sea

a. Open sea is the vast expanse of sea beyond the continental shelf, whose average depth is 2000-4000 metres. Its upper part receives sunlight hence euphotic but lower part does not—hence aphotic (Fig. VIII. 14). The euphotic area is known as pelagie and aphotic area as bathyal. Open sea covers around 70% of earths' surface and interconnected throughout the world and holds 97% of earth's water. Columbus rightly thought that as the seas are interconnected so if he sails west he will arrive at the east. It is dreamers like him with courage to act change the world. The folowing table gives some information about the oceans and major seas of the world. This includes continental shelves as well, as these are part of seas. (Table VIII. 4).

Open Sea

b. The tidal waves and oceanic currents mixes the upper waters about 300 metres or so, rest of the deeper waters remains unaffected and cold—about 3°C. The productive zone of the open sea is only the thin top layer of 200 metres or so which receives sunlight and so is photosynthetic. The detritus settled in the bottom of the open sea, which is 3-4000 metre below and hardly has any current. There this remains locked up for hundreds of years. Only a fraction fo it comes up to the surface through upwelling (see later). So the concentration of nutrients in open sea is rather low and consequently is the productivity (Table VIII. 1). In fact open sea is comparable to the deserts of terrestrial systems.

Poor productivity of open sea and its cause

c. Notwithstanding, open sea harbours some very spectacular large swimmers (nectoms) such as blue sharks, blue whales, baleen whales and rorquals, turtles, great white sharks, large octopuses, cuttlefishes, porpoises and flying fishes etc. (Fig. VIII. 13). Whales are the laviathans of the ocean. They are a large group of aquatic mammals classified into three families and consisting of 76 species some toothed some toothless.

Table VIII.4.
MAJOR OCEANS AND SEAS OF THE WORLD AND THE WATER THEY HOLD
(From – Colinvaux, p. 373, Table – 15-1.)

Name	*Area (10^3 Km^2)*	*Volume of water (10^3 Km^3)*
Pacific Ocean	165,250	707,600
Atlantic Ocean	82,440	324,600
Indian Ocean	73,440	291,000
Arctic Ocean	14,090	17,000
South China Sea	3,685	3,905
Caribbean Sea	2,755	9,585
Mediterranean Sea	2,515	4,250
Bering Sea	2,270	3,300
Gulf of Mexico	1,555	2,230
TOTAL	348,000	1363,470

The Leviathans of the ocean

There are 66 species of toothed whales (Odontoceti) some of these are small 4 to 8 feet long such as river dolfins and are somewhat bigger-such as the marine dolfins and porpoises who are very intelligent and playful. Dolphins are easily trainable and star attractions of marine aquaria all over the world. The largest of this group are the sperm whales. There are 10 species of toothless whales (Mysticeti) which are also called baleen whales. Some the pacific grey whales and all the remaining species of this group has baleen which consists of fine bony plates arranged in the form of two combs hanging from the upper jaw (Fig. VIII. 15). Baleen whales feed by opening their mouth wide and then rush through water so that all small fishes, prawns, jellyfishes etc. get into their mouth along with waters and then get trapped into their mouth only to be eaten by the whale. Because they have to feed by sieving a lot of water at ago all whales are good swimmers with sleek bodies and characterised by small dorsal fins. The famous blue whale (*Balenoptera sp.*)—the biggest animal of earth (100 ft. long) is a baleen whale and a denizen of open seas (Fig. VIII. 15).

The famous novel "Moby Dick" by Herman Melville is a captivating story of a blue whale and his heroic struggle for survival.

1.8 Upwelling Zones

a. There are certain areas in sea where deep ocean currents of cold water striking upon a submerged range of mountains wells up towards the warm surface carrying along with it all the rich nutrients accumulated into the sea bed. Such areas of sea surface where water of the surface mixes with the rich cold water welling up from the bottom are called upwelling zones. These places are very rich in plankton and fishes. Sea birds always swarm over such areas. Such up-wellinig zones are the

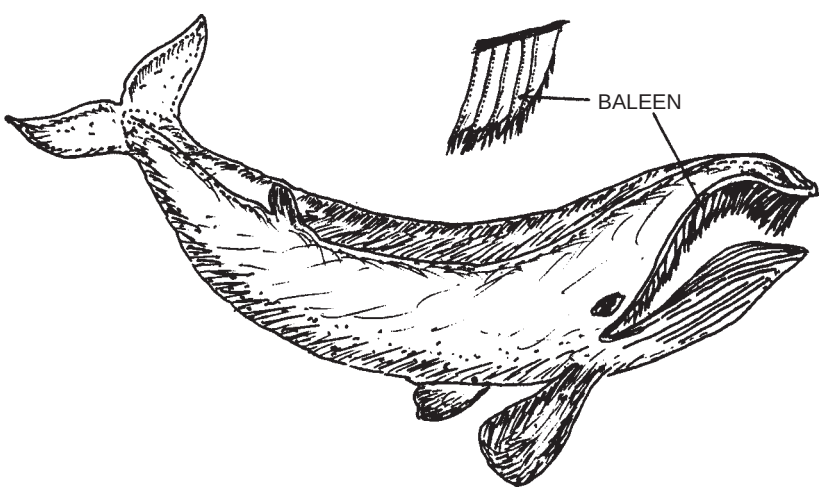


Fig. VIII.15 Baleen of Baleen whales.

happy hunting grounds of marine birds and now trawlers. One such area is in the west of south America and another in the west of Africa. More has been given about upwelling in

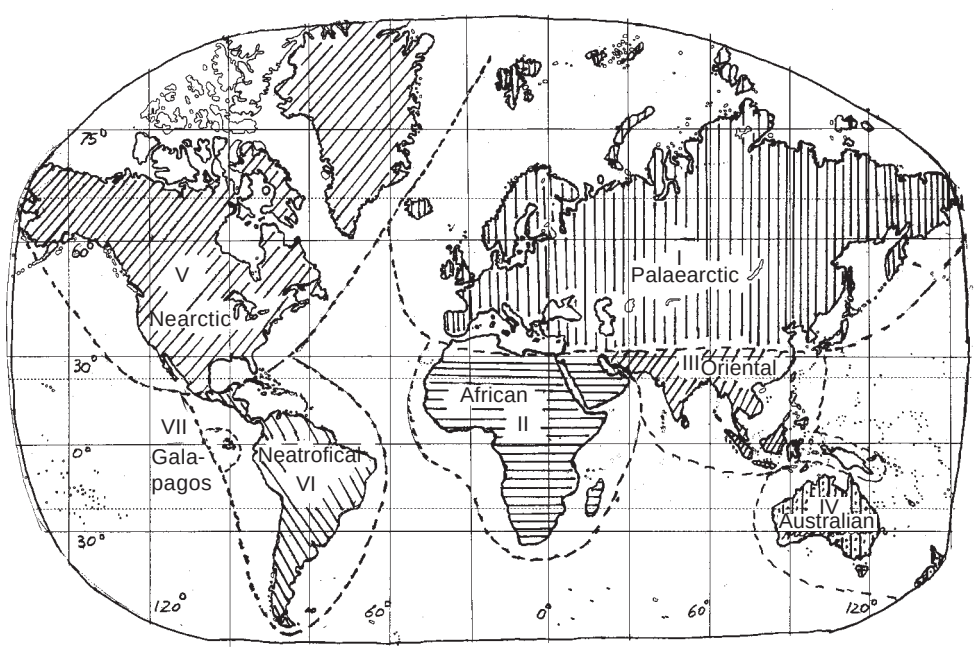
There is story book "A Bridge of Magpies" by Geoffrey Jenkins, 1975, written about the guano deposits (sea-birds droppings) owing to this west African upwelling zone.

b. The summary table VIII. 3, shows the primary productivities and productions of all the main biomes and their areas of earth. This should be a very useful information to all concerned.

2. TERRESTRIAL BIOMES

a. Just as we have water as the constant abiotic component of the environment in all aquatic biomes similarly, for all terrestrial biomes soil or land is the constant abiotic component. Also, unlike sea which is continuous land is more fragmented into continents and islands with vast expanses of sea standing as nearly impassable barriers for animals and plants. As a result of this isolation, land biota* of different continents have evolved into somewhat distinctive types in each continent or area. These areas characterised with distinctive flora and fauna are called Biogeographic Regions with names as follows (Map VIII. 1).

Special features of Terrestrial Biomes



Map. VIII.1 Biogeographic regions of the world, indicating Galapogos Islands as a distinct region.

*Biota = flora (i.e plants) and fauna (i.e. animals).

Biogeographic Regions and some distinctive animals

(1) Nearctic (North America)
(2) Neotropical (South America including Mexico)
(3) Palearctic (Europe and Asia)
(4) Oriental (India, Pakistan, Afganistan, Myanmar, Thailand, Combodia, Malay, Sumatra, Borneo and Philipphines)
(5) African (Africa and Madagascar)
(6) Australian (Australia, New Zealand Tasmania and New Guinea).

b. These Regions are separated from each other for millions of years. So each region have some remarkable animals and plants not found in any other regions. Here are a few such.

Nearctic	—	Caribou, Bison and Mountain goat
Neotropical	—	Monkeys with prehensile** tail (such as howlers, spider monkeys), Ostriches, Armadillo, Rhea and Condor.
Palaearctic	—	Reindeers, Giant pandas and Wild horse.
Oriental	—	Tigers, Baboons and Flying Lemurs.
African	—	Zebras, Giraffes and Gorillas and 2 horn Rhinos.
Australian	—	Kangaroos, Dingo dogs (now extinct) and Platypus (egg laying mammal).
Galapogos Island	—	Giant Land Tortoises, Darwin's finches, sphenodon etc.

A word about Galapogos Islands and Darwin's Voyage

c. It seems injustice would be done to our readers if we move on without dwelling for a while on **Galapogos Islands**—a biological wonder land. Galapegos is a set of 12 small valcanic islands in Pacific ocean and is situated at the crossing of equator with 90° longitude about 1000 miles west of Ecuador. These islands were discovered in 1535 by Fray Thomas de Berlanga, Bishop of Panama. Charles Darwin, the author of the single most famous book on biology "Origin of species", 1859. set his foot on Galapogos Islands 300 years later on 16th September 1835, travelling as an unpaid gentleman biologist in H.M.S. Beagle with its Captain Robert FitzRoy.

d. During these 300 years Galapogos was a usual stopover for ships particularly whalers who picked up the huge land tortoises from there to replenish their meat store. None noticed any specialty there for these 300 years. It is Charles Darwin with his keen power of observation backed up with knowledge of Biology and Geology and almost uncanny ability to take in both analytical as well as synthetic view on the same set of observations, immediately noticed that Galapogos biota is very different from the biota of rest of the continents. Darwin also possessed a mind that was unusually free from orthodoxy prevalent at that age. The seed of doubt that was laid them in the fertile mind of Charles Darwin (he was only 23 then) soon crystallised and resulted in that celebrated theory on

**Prehensile = adapted for holding something by entwining it.

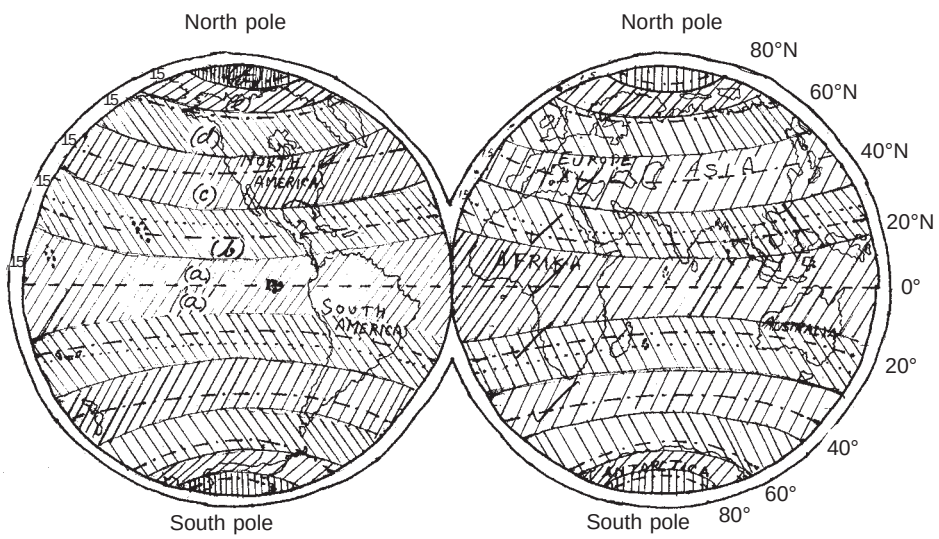
"The Origin of Species by Means of Natural Selection" made public in 1859. After publication of this book Biology has never been same as before. (Later it became known that another British naturalist Alfred Russel Wallace was working at the same time in the jungles of south east Asia and arrived as the same conclusions as Darwin. So now this Theory of Natural Selection is known as **Darwin-Wallace Theory of Organic Evolution Through Natural Selection**). So albeit its tinyness this cluster of islands of Galapogos is fit for honour of a separate Biogeographic region.

e. Anybody who wants know more about Darwin's voyage in the Beagle and his fateful visit to Galapogos may read. "Darwin and the Bengle" by Alan Moorehead (Penguin Books 1971). Indeed the book is a biological thriller. Darwin's host i.e. skipper of HMS Beagle, **Captain Robert FitzRoy** who was a devout christian, and earnestly believed in Special Creation declared in Bible, was so shocked at Darwin's heretical theory that, many ascribe Darwin's theory as the reason for which Captain FitzRoy committed suicide even after promotion as Rear Admiral. FitzRoy felt had he not taken Darwin as his guest in Beagle such a heretical thought would have never seen the light of the day. Darwin was neither knighted nor given an F.R.S. Thus one pays the price for challenging tradition and faith.

f. Now let us come back to the point—the terrestial biomes. The terrestrial biomes have three features which vary.

Main features of Terrestrial Biomes

(1) **Climate.** Depending on its distance from the equator i.e. latitude. Broadly there are five different climates for terristrial biomes (Map VIII. 2).



Map. VIII.2 Terrestrial biomes (a) Tropical, (b) Subtropical, (c) Temperate evergreen, (d) Temperate deciduous, (e) Bareal, (f) Arctic (limits are approximate only)

(2) **Plants.** Depending upon the position of its renewal organs i.e. organs with which a plant renews itself (also called prenating organs), plants of the world are grouped into six different classes by a Danish botanist Christen Raunkiaer (1934), Fig. VIII. 18. These are

Epiphytes—stay and flower on other plants–no roots to soil.

(*i*) Phanerophytes—Plants whose renewal buds are well above ground as trees, shrubs etc.
(*ii*) Chaemophytes—plants whose buds are near the ground.
(*iii*) Hemicryptophytes—plants whose buds are just below the surface of the ground.
(*iv*) Geophytes—plants where buds are well below the surface as rhizomes or buds.
(*v*) Therophytes—plants which are annuals and survive only as seeds.

(3) The third feature is the **Soil.** Besides moisture and temperature soil is the third most important feature of a terristrial biome which influences the nature of its biota. Hence soil needs some attention. All soils are products of long-term (millons of years) weathering of parent-rocks and accumulation and layers of silt (due to the actions of wind, water and ice) and by-products of plants and animals living above and within soil. These are arranged in the form of layers one above the other with the parent rock forming the bottom layer and organic litter the top layers. These layers are collectively called soil profile the quality of which varies widely from place to place. The basic features of soil profile are shown in the following (Figure VIII. 16).

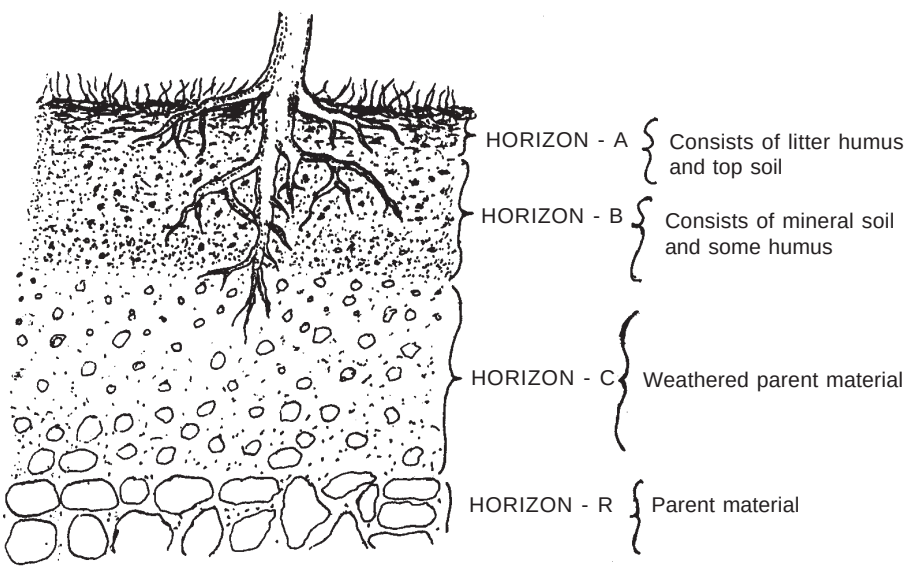


Fig. VIII.16 Soil profile (schematic).

g. Climate (temperature and rainfall) and soil (depth and richness of the profiles) are the two features which guide the destiny of a terrestrial biome—i.e. if it is going to be a rainforest or a desert etc. Now let us examine the terrestrial biomes one by one.

2.1 Tropical Rain Forests

a. Tropical Rain Forests are the jewels of terrestrial biomes. These as the name implies are situated in tropical regions and enjoy frequent rainfall and warm weather throught the year. Their productivity is one one of the highest of all the biomes (Table VIII. 3). They have an extremely variegated flora and fauna and average temperature is of the order of twenty five—thrity degree centigrade and annual rainfall of 100" or so. The primary productivity can easily exceed 2 kg/sq/m/yr and sometimes can even reach a fantastic value of 3.5 kg/ sq/m/yr! For their main locations please see the Fig. VIII. 17.

High Productivity and rich flora and fauna

b. Tropical rain forests are dense humid and dark forests. These forests is so dense that in a vargin rain forest not much of sunlight reaches the ground—so the ground remains pretty clear of grasses and shrubs. Such forest has three distinct layers or canopies. The top canopy consists of very tall trees (34-40 metres), a middle canopy of shorter trees and a bottom layer of a few scattered fern type plants. Besides these, there are a lot of thick climbers in such forests. (Refer to downwords discription in Benglis journey).

c. Tropical rain forests are also the habitat of a host of very interesting animals. For example—army ants (*Echiton burchelli*), gibbon (*Hylobatis lar*), large and spectacular butterflies, 3 toed sloth (*Bradypus variagatus*),

Fauna of Tropical Rain Forests

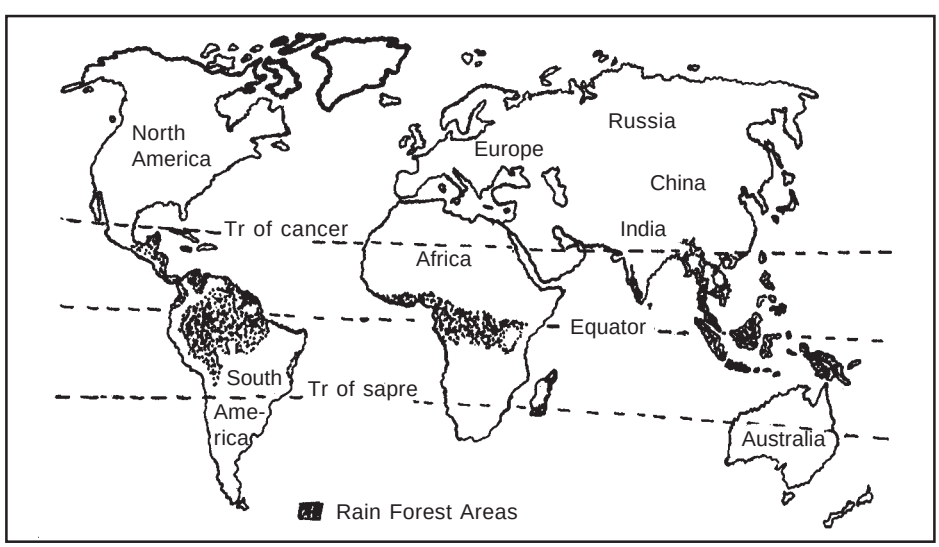


Fig. VIII.17 Present rain forests of the world.

Harpy eagle (world's largest eagle), poison arrow frog (*Dendrobates auratus*), anacondas or reticulated pythons (*Eunectes sp.*) who mostly live in water and can be very huge (9 metres or so) etc.

d. Tropical rainforests are also a rich store house of medicinal plants. One example is *Cincona* tree. The famous anti malaria drug quinine is a product of *Cincona* tree from South America. The *Cincona* plant is known as one of the few plants that have profoundly affected the course of human history (the others, are Cotton, Potato, Sugar and Tea). The natives of South America used to drink the bitter water of ponds into which leaves from the surrounding *Cincona* trees fell and rotted, to cure them of malaria. Jesuit preists of Spain noticed this and extracted quinine. They kept this knowledge as a closely guarded secret and used quinine as an incentive to convert the native Indians to Christianity and also sell the quinine in Europe at the price of gold. Adventerous and clever Britishers when they learnt of this secret, brought some saplings of *Cincona* plants to manufacture quinine. Thus quinine has not only saved innumerable lives all the world but also contributed to explosive growth of human population. There are many other plants of medicinal value in both old and new world about which we have only just began to understand.

Now researchers from both sides of Atlantic are roaming all over Afrika, South America and India looking for such plants and their properties.

e. Trees valuable as timber such as teak (*Tektona grandis*) and sal (*Shorea robusta*) are found in east of India, Myanmar, Malayasia, Philipines and Borneo. There are many other valuable timbers in the rainforests of Africa and Brazil. Unfortunately good rainfall throughout the year and presence of excellent timber have also caused their doom. Large tracts of rainforests have been cut down in South American and elsewhere to make way for agriculture/animal husbandry and to obtain timber. To-day we do not have even half of rainforests we had 100 years ago. The situation is really alarming. I pray rich people to do something to halt this stide.

f. Now-a-days many organisations particularly United Nations is trying to save the remaining reinforests as sites of "World Ecological Heritage." But progress is poor, and in the meantime relentless pressure on reinforests by various multinationals continue unabated. Poverty and population pressure are the two major threats to rain forests. Governments of these countries are selling their invaluable rainforests to various multinationals just for money—particularly dollar. In Kolkata one frequently comes across trailer-trucks carrying huge logs of sal (*Sherea robusta*), 3' of more in diameter and 30' or more in length all from Malayasia. It is a painful to see such pathetic ends of these magnificient kings of forests. Most of the Pacific island between Northern Australia and Singapore are selling their

Plunder of Rainforests

timbers. As a result of this denudation of rainforests those countries are suffering from more floods and other calmities. Loss of rainforests will not only harm these countries but will also deal a terrible blow for global ecobalance. India's rainforests are mostly gone only a little is left in the eastern and some in the southern tip of India. India is as tardy in taking effecting steps to stop this plunder as other underdeveloped countries are.

2.2 Temperate Evergreen Forests Or Temparate Rain Forests

a. Beyond tropic of cancer and capricorn as one moves towards the poles the weather becomes cooler but not too dry. Rainfall is good, around 40-80". It is well distributed during the year—so there is no real dry period. The prominent trees in these latitudes are usually broad leaved evergreens. Such as oaks, beeches and the magnificant world famous Californian red woods *(Sequoia gigantica*)—the tallest trees of the world, 90-100 metres in length with a basal diameter of 5 metres or so!

b. Such temperate rain forests are now mainly confined to California, Uruguay, East of China, Japan, south East Australia, Tasmania, Newzealand and some small pockets (Fig. VIII. 17). Temperate forests mostly have only two layers—a high tree canopy and a tree form understorey (Fig. VIII. 17).

The productivity of such forest is high (Table VIII. 3) around 1 to 1.5 kg/sqm/yr. Here the temperature is lower than tropical rainforests. So many of the common decomposers/such as earthworm are absent. Consequently these forest floors are usually covered with thick leaf litter, dry twigs etc. this is quite a contrast with tropical rainforest where because of faster decomposition of litter, the forest floor is usually much clearer.

c. A characteristic animal of these forests are the black bears (*Ursus sp.*) in palaerctic and nearctic ones and in Australian zone (New Zealand) the Kiwis—the flightless birds (*Apteryx australis*).

2.3 Temperate Deciduous Forests

a. In temperature regions where there is prolonged spell of cold (lower than freezing), trees are deciduous i.e. their leaves fall off in winter. These biomes however enjoy good rains. annual precipitation ranges between 20-50". Weather, considering the latitudes of these forests, is relatively mild/ with real winter of about three months when the daily mean minimum is around 0°C. Most plant forms here are hemicryptophytes (Fig. VIII. 18). These are perennial plants of which upper parts die off in winter leaving buds just above ground to germinate in early spring. Those bud remain protected from frost by a thick layer of leaves which fall off from trees in autumn. In fact the leaves just before falling from the trees in autumn, take a beautiful reddish-brown hue rendering the same colour to the entire deciduous forest belt. This is the famous ‘fall colour’. The Blue Ridge

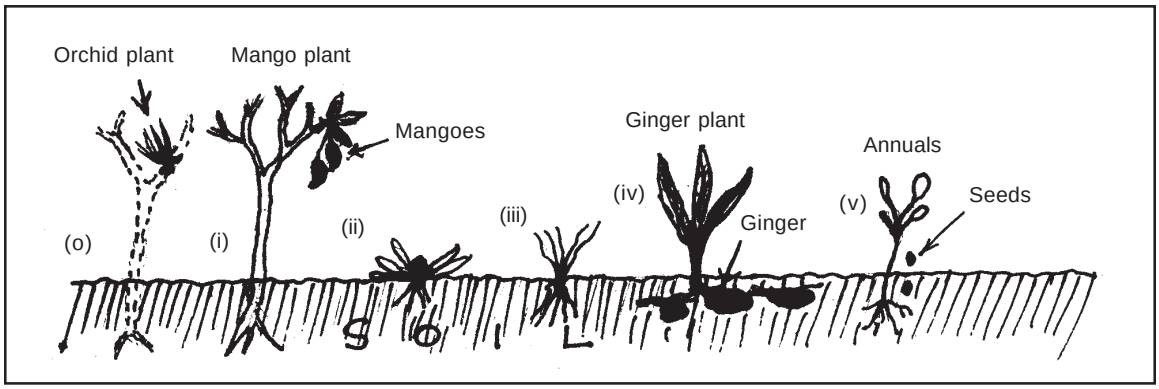


Fig. VIII.18 Classification of plants according to the positions of their renewal organs (for explanation see text).

Mountains near Washington (capital of U.S.A.) looks picturesque with fall colour during autumn. Here is a photo of fall colour in Virginia, U.S.A. (Photo VIII. 1). The structure of temperature deciduous forest is rather simple. It has two strata—the upper canopy of tall trees (50—100') and the lower canopy of short trees (15—40') (Fig. VIII. 16).

b. The productivity of these forests ranges from 0.5 to 2.5 kg/sqm/yr. Neither flora nor fauna is very diverse and the winter being rather long (though may not remain below freezing for more than 3 months or so), biological activities are confined mostly to spring and summer. Such biomes remain mostly inactive during winter but spring to activity as soon as spring arrives. Here a mention of Hopkin's Bioclimatic Law would be worthwhile. Hopkins said that spring events occur about 4 days later per degree of North latitude i.e. about 17 miles northward per calender day. For instance if a temperate deciduous forest spreads about 250 miles between its North and South ends the spring will come about 20 days earlier in the South end than in the North end. Throughout summer the biological activity gathers momentum reaching its peak just before fall when all beings prepare to face winter. Plants prepare for their winter-buds and animals reserve food in their bodies to go into hibernation or torpor.

Hopkin's Bioclimatic Law

c. At present temperate deciduous forests are mainly found in the Eastern U.S.A., Europe—North of Alps till Scandinavia and Eastern Asia including China. It seems much of such forests of Europe and Asia were continuous before the last ice-age*. About 50 to 15 thousand years ago.

*Ice Age: During its geologic history earth has periodically undergone cooling and warming. During cold phase the North polar ice cap expanded tremendously covering most of Europe and North America and such areas. The cold age is called Ice Age. The most recent ice- age abated about 10000 years ago. Change in temperature braught changes in flora and fauna as well.

Squirrels, Rabbits, Hedgehogs, Bears and Badgers are common animals of American Temperate Forests. Japanese forests have a very interesting denizen—Japanese macaque (*Macaca fuscuta*)—the only species of monkey known to occupy such temperate deciduous forests.

2.4 Boreal Forests

a. These forests are in cool temperate regions (Map. VIII. 2) characterised by chilly inhospitable climate. The word boreal has come from the name of the Greek God Boreas—God of the North wind. Here summer is very short and winter is very long—mostly covered with snow. The dominant plants are conifers, spruce, fir and birch. Their needle like evergreen leaves have better heat retentive capacity and the conical shape of the trees help in shedding off snow more easily. The boreal forests almost form a ring in the Northern hemisphere—spanning North America, North Europe and North Asia. Southern hemisphere has no such luxury—save a few scattered pockets such as Southern tip of South America, South Patagonia and Tierra Del Fuego. The structure of the boreal forest is rather simple—mostly conical shaped firs and birches with one emergent upper storey and one under storey but no clear demarcation between the two (Fig. VIII. 19).

Nature of Boreal Forests

b. Under snow cover of ground mosses grow providing food during winter months, toherbivores like Caribou* and Moose** in North America and Reindeer*** in North Europe. In Lappland of North Europe a group of people—the Lapps live by hording only reindeers. The life and cultures of Lapps are very interesting. There are four groups of in today's world—a world of computers—who are still retaining their pastoral culture. (1) Masais of Kenya (tend cattle); (2) Mongols of Mongolia (tend horses); (3) Bedouins of Arabia (tend camels) and (4) Lapps of Lappland (tend reindeers).

Some pastorals of To-day

c. The Boreal Forests being mostly cold—long winter and short summer—holds very few species of plants and animals. Hence the productivity is low as well—ranging from 0.2 to 1.5 kg/sqm./yr. As the productivity is low hence is the carrying capacity (explained earlier IV. 5.2). Here is an example. The Indian tigers need only 20 to 30 square miles of forest per head but the Siberian tigers need more than 100 sq. miles each. *So whenever we plan to manage an ecosystem to protect some species the carrying capacity of the ecosystem concerned needs to be matched with the space requirement of that species in that ecosystem*. Most of the reserve forests of India suffer from this drawback. Some animals however manage with extremely clever adaptations. Most birds

Animals of Boreal Forests

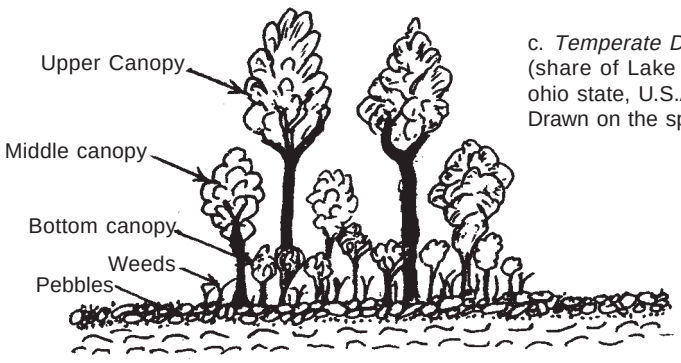
*Caribou (*Rangifer tarandus*)—reindeer of North America,

**Moose (*Alces alces*)—a large deer: the males have enormous palmate antlers

***Reindeer (*Rangifer tarandus*)—caribou of North Europe, both and have antlers.

a. *Tropical Rain Forest*

b. *Temperate Rain Forest*



c. *Temperate Decidrous Forest*
(share of Lake Isabella, Hamilton county, ohio state, U.S.A.)–view from Boat House. Drawn on the spot

d. *Boreal Forest*

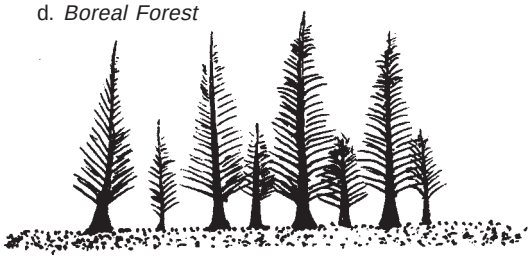


Fig. VIII.19 The main storeys of different types of Forests.

being fliers migrate southward to avoid winter cold (About this we have written earlier (VI. 23). Beavers (*Castor canadonsis*), a member of rat family which live in Canadian boreal forests have a fascinating way of living. These live in colonies near stream in forested areas. They collect twigs and when necessary cut down small trees by gnawing off their bases and use these twigs and trees very ingenuously to dam up these small streams. It is a wonder to see how big a dam these small animals can construct this way. When the water level is high enough and so the dam deep enough, they make a network of warrens in the shore, making sure that the levels of warrens are higher than that of the top level of water in the dam but the entrance into the warrens are always within the dam and well under the level of water so that no enemy can reach them unless they know swimming and also the locations of these under-water entrances into the warrens (Fig. VIII. 20). Indeed beavers demonstrate how resourceful and adaptive an animal can be in order to survive in a harsh and competitive world.

Beavers: Their fascinating way of life

d. Because the life is very harsh and inhospitable in boreal forests, variety of animal species here are much fewer so the 'web of life' (i.e. the number of species available as food to one another) is much simple and short. One species may depend solely on the presence of another species. So the density of one (i.e. no. per unit area) became dependant on another. This leads to, in some cases, in regular **oscillation of population.** For example, lynx and snowshoe hare in Northern Canada. The earlier one is the predator and the latter one is the prey. This phenomenon has already been discussed earlier in the chapter on Populations (Fig. VI.).

Population Oscillation

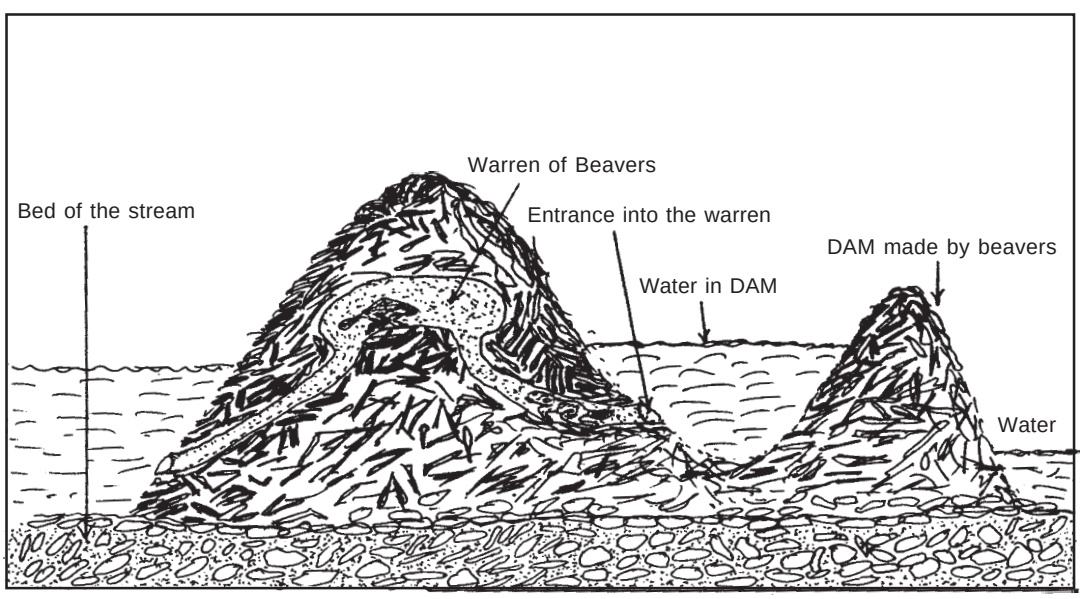


Fig. VIII.20 Underwater entrance into the warren of beavers.

2.5 Scrublands

a. Scrubland biomes are often formed where rainfall is rather low (10—15" per year) and mostly concentrated within one short period and temperature is usually high—more than 20°C in average. Naturally productivity is also rather low and depending upon the exact amount of precipitation and average temperature , and may range from as low as 0.05 to 0.75 kg/sqm./yr. Scrubland biomes are now found mainly in Mediterranean, California, Chili, South Africa and south of Australia (Fig. VIII. 21). Perhaps the semi-arid regions of Eastern Rajasthan, India, may also be termed scrubland.

b. In scrublands trees are mostly short, thorny perennials—such as 'Jatti' (*Prosopis spicigera*) in eastern Rajasthan the leaves and soft twigs of which are used as fodder of camels. Some scrubland plants such as, sagebrush of California are rich in volatile chemicals. Many plants here are however are annuals or therophytes*. Scrublands are also fairly rich in fauna. The famous predator puma or mountain lion (*Felis concolor*) and the poisonous rattle snake (*Crolatus viridis*) and the jackrabbit (*Lepus alloni*) etc. are found in Californian scrublands. Similarly scrublands of Africa, Australia and India have their own interesting fauna. For example, scrublands of Rajasthan, India still has—"blue cows" a species of antelope. Locally these are called 'nil gais' as from a distance they appear to have a bluish tinge in look.

Plants and Animals of Scrubland

2.6 Savanna Grass Lands

a. These are large tropical grass covered plains with scattered trees. The rainfall is rather scanty (10-30" per year) and concentrated more during summer months. Consequently the grasses of savanna have very deep penetrating roots—around 6' or so. This help them to survive the long dry season. Some of the trees of African savanna particularly the famous baobob tree (VIII. 21) has a massive water holding trunk which can hold up to 10,000 litres of water)! An wonderful adaptation indeed. Savannas played a special role in human evolution. Is was in open savanna lands where the ancestors of human beings who were tree dwelling apes, left the tree and ventured out in the open. Here they learnt to walk erect and developed skills for hunting in groups. The African savannas are really the cradle of ecolution of today's humanity.

b. Savannas occur in both sides of the tropics—in Africa, South America, India, South East Asia and Northern Australia (Fig. VIII. 29). With their wide expanses and easy visibility savannas are one of the most attractive places on earth to visit and photograph. African savannas still hold such splendid animals like elephants, lions, wildebeests, zebras, cheetahs and

*Therophytes—plants which are annuals and survive only as seeds

Fig. VIII.21 A savanna landscape (in Afrika).

many species of deers. Many of us have been seen in TV those wonderful films on wildlife of Africa and their annual migrations.

c. The productivities of the savanna grasslands are quite high—ranging from 0.2 to 2.0 kg/sq.m./yr. Originally grasslands of vast expanses were in all the continents. But unfortunately most of have yielded to the man's need and greed and got replaced with agricultural fields or ranches (The Oregon Trail. Francis Parkman 1966. Bantam Books). However thanks to the early European settlers particularly the British administrators, the remaining African savannas of today are amongst the best maintained ones of the world. These abound with wildbeests, zebras, deers, lions, cheetas, hyenas, eagles, elephants, giraffes and rhinos etc. Olduvai gorge of Kenya/Tanzania is one of the most breath taking savannas of the world. To be able to see the migration of wildbeests of Serengeti National Park to Masai Mara of Tanzania is an experience of a lifetime. In dry season when they move from one pasture to another, their movement is spectacular. Huge trotting herds of more than 10,000 individuals are no rarity. National Geographic Society (NGS) has rendered a singular service in photographying these migraions and showing them through T.V. throughout the world. NGS has helped to wake up men's curiosity and respect for Nature.

Contribution of British Biologests and NGS

d. Grazing by herbivores in savannas is both orderly and beneficial. The cycle of grazing begins with zebras who takes in the top layers only; This

Cycle of Grazing and its Utility

is followed by wildbeests (also called gnus) who cut down the grass swards further. Finally Thompson's gazelles move in. These feed only on the short grasses now exposed. In an experimental study where one area is allowed to be grazed and the other area is not; the grassland of the ungrazed area declined in quality and biomass. This shows *normal grazing by wildlife is healthy for an ecosystem and also for maintaining the fine balance between fauna and flora*.

Temperate Grasslands

e. There are grasslands in temperate areas too. Both in South and North America there are huge savannas abounding with ostriches and pumas in south and and bisons and grizzly bears in north America. South American savannas which are mostly in Argentina are called pampas. Charles Darwin during his voyages with H.M.S. Beagle, 170 years ago, travelled widely through Argentine pampas. With an escort of six gauches (horsemen) Darwin took to the pampas and went exploring. They (including Darwin) mainly lived off the land i.e. ostriches (called Rheas now), ostriches' eggs, armadillos and pumas etc. and whatever other eatables they could lay their hands on.

f. Most of these beautiful savannas along with the resident native Indians are all gone—sacrificed to give way to ranches of early European colonialists. Here is a chilling description of the beginning of this process by Charles Darwin.

Extermination of the Indians

"Buenos Aires lay some 600 miles to the North, and all the intervening plains- the Pampas—was unexplored territory over which tribes of Indians (Patagonians) roamed and hunted. They were fierce and aggressive people when aroused and great horsemen" ...." "But now they were fighting for their lives against the Argentinians who wanted their lands in order to graze their expanding herds of cattle; in fact it was the story of the America's middle west all ever again except that here the struggles were even more primitive and more ruthless. The Indians were of course fighting a losing battle against a war of extermination. ....." Once there had been villages of two or three thousands of them but by the time of Darwin's visit the tribes now mostly wandered homeless accross the Pampas: (Darwin and the Beagle. Alan Moorehead, pp. 107—8, Penguin).

2.7 Tundra

Weather Productivity

a. Tundra is the **arctic grassland.** In the Palaerctic region (North of North America and North Eurasia) it covers a large area but in Neactic it is confined only to the Southern tip of South America, Falklands and a few small islands. In tundra the ground remains frozen throughout the year save a few summer months. The average temperature however varies considerably depending however whether the tundra is a **oceanic***

*Oceanic—near a sea or ocean

or **continental*** one. The tundras in West of Eurasia may have a winter minimum of –10°C but the winter minimum of Alaska and Canada (which are continental) may reach –30°C and in Northern Siberia –50°C! Rainfall too varies from 6" to 12".

Ordinarily productivity is limited to the short summer of 60 days or so…. Still when we remember the shortness of the period, the productivity is fairly good (0.1 to 0.4 kg/sqm/yr).

b. The tundra ground is permafrost i.e. frozen throughout the year. Only in the summer the top few inches melt lending it a slushy or muddy appearance with puddles and shallow swamps here and there. The flora is mostly arctic grassland—consisting mainly of lichens, some grasses, sedges and a few dwarf woody plants. The perennials are generally hemicryptophytes** and chaemophytes***. During summer when there is liquid water in soil, tundra abounds with mosquitos and black flies whose bites make living there in summer miserable. Other remarkable animals are caribou, mask ex, arctic hare, arctic fox, lemmings, ptarmigan and some migratory birds. While the mammals stay put during winter, (save caribou/ reindeer who migrate south), the birds migrate. Amongst the birds, while the goose and the honkers are the most renowned migrants (as their formation flights and honking is a common sight and noise autumn skies of U.S.A.), it is the arctic terms (*Sterna paradisaea*) who have earned most respect. These amazing birds nest during summer in arctic tundra but migrate to antarctica during winter of arctic. This annual migration of 25000 miles makes these birds indeed the most remarkable flying machine amongst animals.

Soil, Flora and Fauna

c. Because of the preserving capacity of ice, tundra soil (which is permafrost) holds fossils of some animals in a very well-preserved state. Most famous of these fossils are mammoths. Mammoths (*Mammuthus primigenius*) the ancestors of today's elephants, used to roam in Northern temperate forests and tundras even in late Pleiostocene age—around 20-15000 years ago. Because of low temperature, frequent snowing and slow bacterial action, Siberian tundra still holds many mammoth-fossils in extremely well-preserved state. The whole bodies of some are preserved in ice with muscles, hide, fur and all. One such fossil is in Spitsberg Museum of Russia. To-day fossil hunting in Siberian tundra is a big business.

Mammoth's Fossils

d. As the weather is very harsh (cold, freezing etc.), floral and faunal diversity of tundra is low. This being so the food-chains of animals are also very short. Many have only two or three species of prey as food. So

*Continental—deep within a continent with no ocean nearby.

**Hemicryptophytes—plants whose buds are just below the surface of the ground.

***Chaemophytes—plants whose buds are near the ground.

Population Oscillation in Tundra

if the number of one goes down the predators' number too will go down. Following to this and owing to this, the prey population will rise very fast. This will soon be followed by a rise in predator population. consequently such rises and falls will go on in a cyclic pattern. Such violent rises and falls in populations of prey andpredator is known as **Population oscillation.** Such oscillations are of common occurance in tundra ecosystems. Lemmings' populations in tundra exhibit such oscillations spread over a 4 year cycle (for more on 'population oscillation' see chap. VI).

The Lemmings' Suicide: Truth behind it.

There are stories of Lemmings of Norway migrating en masse towards the sea and finally jumping over the cliffs only to commit suicide. But the truth is something else. In their 4-year cycle of population oscillation when the population density of lemmings is at its peak, these migrate in search of better pasture elsewhere. Norway being full of fiords they find highways to migrate. But they are good swimmers. So when faced with such situation these jump into the sea and swim accorss to find new pastures. So Lemmings' jump over the cliff is not suicide but an endeavur to survive.

2.8. Deserts

Main Features of Deserts

a. We began our presentation on terristrial biomes with tropical rain-forests, we shall end this with the antithesis of that—the deserts. Tropical rain forests are too wet, humid and warm while the deserts are too dry, hot and at times cold. Lack of water is the dominant ecological factor in deserts. Areas where annual rainfall ranges from 0-8" are called deserts or arid regions; and areas with more rainfall as semi-arid regions. Central Sahara is the absolute desert i.e. the area which receive no rainfall. During daytime most deserts are either hot or very hot . Daytime air temperature may reach 50°C and sand surface temperature 90°C ! Gobi of cenral Asia however is a cold desert. The large deserts are mainly in Asia—Gobi and Tibet, in Africa—Sahara and Namibia and in Australia—central Australia. Deserts of North and South America are relatively small. Such small deserts are many.

b. In deserts draught is the main restrictive factor for productivity; lower the rainfall—lesser the productivity (Table VIII. 3). Many desert plants are therophytes—passing the draught as seeds for months and then sprouting, growing and flowering all within a few weeks after rains. Deserts look beautiful then. The perennials which are mostly shrubs have very little above-ground biomass but very extensive and deep underground root systems. The productivity of above-ground biomass ranges only between 250 to 500 gm/sqm.yr. but of the underground one is much more, reaching in some extreme cases to 24 kg/sqm/yr.

c. Considering their low precipitation and high drought, many deserts still have a variety of plants and animals. Some plants as we said before,

maintain a large amount of **underground biomass** while some others convert the leaves into **thorns**—to reduce loss of water, and some develop **succulent trunks** to store (e.g. cacti in Arizona deserts., Fig. VIII. 22). Because of scarcity of resources particularly water, desert plants, whereever they are tend to tend become **spaced apart** (Fig. VI. 15). To achieve this these plants secrete some root hormones—ectocrines which discourage growth of another plant near it (e.g. *Prosopis spicigera* in Rajasthan, India).

Desert Plants

d. Desert fauna also show characteristic adaptations. The integument of desert insects is waterproofed by a coat of **wax,** reptiles all possess **waterproof skin** armoured with scales and birds are helped by their general **higher body temperature** (about 104°F) and a coat of **feathers** which are highly insulative. Feathers are so good at insulation that that the soft down feathers from the belly of eider ducks are used, instead of cotton for pillows and quilts. Such pillows and quilts are very comfortable for use in cold countries. Desert mammals too show various adaptations. Many are **nocturnal** in habit and thus avoid the extreme heat and draught of daytime. In night temperature falls but humidity rises. This diel rhythm* (of humidity and temperature) helps desert animals to move

Desert Animals

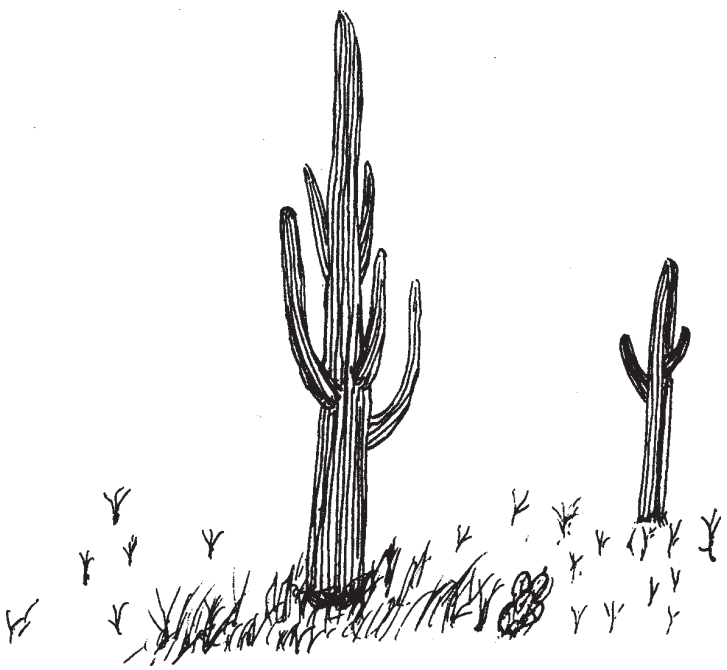


Fig. VIII.22 Canon cacti of arizona desert.

*Diel Rhythm: When a change in a biological activity becomes associated with the change from day to night and vice versa, it is called a diel rhythm. For example, vertical migration of flanktons—upwards during night and downwards during day, is a diel rhythm.

around and hunt in more favourable environments. The **desert scorpions** which are large and very poisonous hunt only in night. There is another large predator, a spider found in many West Asian deserts including Western India. Amongst the desert mammals camels deserve special mention. These are large animals who can travel long distances, without drinking water carrying huge loads on their backs and for several days (with night halts). Camels are so useful for survival to desert nomads that they are popularly called 'ships of desert'. Australians have introduced camels into their country to exploit their deserts more profitably. Besides camels, most desert vertebrates—mammals, reptiles etc. have developed *water-efficient urine producing mechanism*. Some secrete urine in a very concentrated form with little water in it while others completely recycle the water and secrete in the form of solid white granules of uric acid (like house lizards).

Beautiful Desert

Deserts with their wide expanse of rolling sand dunes and majestic herds of camels striding along in a string on the top of sand dunes, do lend a special attraction to any visitor who loves Nature.

Chapter IX

Pollution

(Torturing the Nature)

Topics

IX.1. Introduction and Definition

IX.2. Types of Pollution
- A. Chemical
- B. Physical
- C. Biological
- D. Psychological

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CHAPTER IX

POLLUTION

(*Torturing The Nature*)

1. INTRODUCTION AND DEFINITION

1. By now we have acquired a broad idea about the basic principles which guide the relationships of living beings with their environment and vice versa. Also, we have a glimpse of the enormous varieties and breath taking panoramas of different regions of our Mother Earth. She is verily wrapped with a many splendoured robe. Here we see how either through our ignorance or, through greed aided by modern technology or both, we are tearing up this beautiful Earth's robe into rags. One of the main culprits for these damages is pollution. What pollution is and how is it affecting the environment is the issue of this chapter.

2. What is pollution? Is some unwanted chemical in environment a pollution? What about too much sound? Sound is not a chemical. Is unwanted sound a pollution? When forests are cut down and as a consequence river beds get silted up during monsoons, what is that—a pollution? If a child's mind is exposed to such things that, when adult he becomes a criminal—shall we call such exposures pollution? When political and social outlooks encourage one group of people to treat another group as inferior or as enemies—what shall we call such outlooks—pollutions? Pollution is a word which deserves a very wide definition. It seems to us an appropriate definition of pollution could be as follows. Any Interference with the Normal Rhythm of Nature Through Human Intervention is Pollution. The agents for such initerference could be many, a chemical agent such as DDT, a physical agent such as radiation, or a cultural agent such as social upbringing and teaching. By interference we generally mean some sort of detrimental intervention.

Definition of Pollution

2. TYPES OF POLLUTION

1. Unfortunately however only such interferences are considered pollutants which harm our interests. This is an anthropocentric definition i.e. a definition which generally takes into account only man's interest. This should not be so. The interest of all species of living beings should be taken into account. We all are children of God and interdependent.

Fortunately, wise people all over the world are becoming aware about the needs of other living beings and are initiating steps to protect them. This is very laudable. In this endeavour the British, the Americans and the Europeans are in forefront.

Pollution causing agents can be grouped into four broad categories.

Types of Pollution

A. **CHEMICAL—**such as DDT.; Alkyl mercury; Chlorofluorocarbons; Smog; SO_2; Crude oil; Radio active isotopes; Detergents; Dusts; Fertilisers insecticides and; a host of other chemicals.

B. **PHYSICAL**—such as Noise; Heat; High Energy Radiations from radio-active isotopes; Ultra-Violet ray; Ultra-Sonic sound etc.

C. **BIOLOGICAL—**such as explosive growth in number of any species—plants or animals (including humans); Genetically engineered species; and Disappearence of endemic species etc. The explosive growth of a single species of living being—*Home sapiens* is, we believe, the single most damaging polluting agent today.

D. **PSYCHOLOGICAL**—such as various educational, social and religious practices of man which result in developing a bias in the minds of one group of human beings against another group.

Out of these four categories the last one we shall not deal with here as, that constitutes the material of an entirely different type of book—unrelated to the basic theme of this small book.

2.A. CHEMICAL POLLUTANTS

2.A.0. Now-a-days so many chemicals have been identified as polutants and there are so many different techniques developed to measure them that discussing them all, or even most of them, would be too much for the aim and scope of this small book. Here we shall refer only to a few of the most common chemical pollutants, how these are generated, what harms these cause to our ecosystems and what should we do to reduce the use of these. Here are some:

2.A.1. D.D.T.

2.A.1. The first one is **Dichloro-diphenyl-tetrachloroethane,** in short DDT. **DDT** is a very powerful and very hard-to-destroy insecticide first developed during Second World War. Initially it was extensively used during war, against various insects in battle-fields to get rid of these from the camps of Allied Soldiers. Then everybody was happy. Soon however the negative sides of DDT. began to come into notice. Negative sides are mainly two.

***a*: First,** the acquirement of resistance to DDT. by insects which are subjected to frequent DDT. spraying. This happens in this way. Every time DDT. is sprayed—a few—only a few—of the insects sprayed, do not die. These a few survivors are individually more vigorous and

resistant to DDT. When these survivors reproduce they produce a slightly more vigorous strain whose general level of DDT resistance is higher. Now if these are again subjected to same dose of DDT spraying, there will be more survivors than before. In this way, after several generations, the DDT resistance (or DDT tolerence) of these insects will be so high that none of these will die if, DDT is sprayed at the same dose as before. This is DDT resistance. This means as time passes one has to use a higher and higher dose of DDT, to kill insects of same species. Soon DDT spraying will be too costly. This is how Malaria Eradication Programme of Govt. of India spearheaded by National Institute of Communicable Diseases, New Delhi, although initially successful, ultimately failed to eradicate malaria from India.

***b*: Secondly,** persistence of toxicity of DDT (i.e. the poisonous effect) may last as long as ten years. This is a very serious matter. During this long period DDT travels from the target insects, through food chain (for Food Chain see IV) and soil to human bodies and others such as sea birds. There owing to biological magnification (for biological Magnification see V. 3) DDT becomes lodged in a much higher concentration. In some cases DDT concentration in milk is so high that it is positively harmful (Table V. 3). Now about the sea birds. Through food-chain and rainwater most of the DDT sprayed for crop protection finds its way to the sea. From sea again through food chain, DDT climbs up into the bodies of sea birds. In sea-birds' bodies DDT concentration reaches so high level that such birds lay very thin-shelled eggs which break easily when the birds try to sit upon them for incubation. This egg-failure reached so high proportion that the populations of some sea birds declined alarmingly. The national bird of U.S.A. — bald eagle (*Haliacetus bucocephalus*) almost faced extinction. Now owing to timely vigorous measures their number is rising.

***c*: Rachel Carson** (1907-64) An American Marine Biologist from Woods Hole Marine Biological Station and Johns Hopkins University, who with her love for nature, knowledge, wisdom and grim determination first brought to light this lethal link of DDT with the alarming decline of sea-birds' populations. As expected her discovery was not easily accepted. Interests of the producers of insecticides were involved. But ultimately she won. She has written two remarkable books on such matter—(1) Silent Spring (1962. Houghton Mifflin, Boston), (2) The Sea Around Us (1952. Oxford University Press). Besides these she wrote many valuable technical papers on this issue. Ultimately due to her persistent lobbying U.S. Govt. banned the use of DDT—the first country to do so.

Rachel Carson (1907-64)

d: Before we move to other pollutants here we would like to introduce briefly, some important concepts about the use of insecticides/ drugs etc. The first concept is **Lethal Dose 50%** or **LD-50.** The amount of insecticide (or any other poison) which is required to kill 50% of the insect population (or any other pest population) which is the target of the

LD-50

insecticide, is called lethal dose 50% of LD-50. This is shown in Figure IX. 1. where the mortality (of the target population) is plotted against the dose in a graph. From such graphs based on laboratory experiments dose for LD-50 of an insecticide etc. are determined and recommended to farmers for their use. There is a presumption behind recommending LD-50 as field dose. The surviving population after recurring LD-50 uses will no longer be able to do any appreciable damage. Otherwise they would have to recommend a much higher dose to ensure LD-100 or 100% kill. This would have become too costly to be practical. The second concept is **Drug-Fastness** or **Drug-Resistance** (see earlier in this chapter). This use of LD-50% for agricultural purpose however has an inherent hazard. Some offsprings of the population surviving LD-50, is likely to have a resistance level slightly higher than the parent stock. In this way, after a few generations this pest will be resistant to this insecticide if applied at this dose. This acquirement of resistance of an insect to an insecticide when treated with the same insecticide over generations, is called **drug-resistance** or drug fastness. The third concept is the **Persistence of Chemicals in Nature.** The problem with applying chemicals in field is the long time which some of these chemicals take to be broken down into simpler and harmless components. This is called **persistence of toxicity of a drug/chemical in nature.** For DDT it is ten years or so. During this long time this chemical passes through the bodies of many other harmless and useful species of living beings (through food-chain), which were not its targets, and become increasingly concentrated into the bodies of these creatures and ultimately cause their death—a most unforseen and unwanted consequence—some of such unfortunate creatures are bees and

Persistence of Toxicity of Drug

Chemicals in Nature

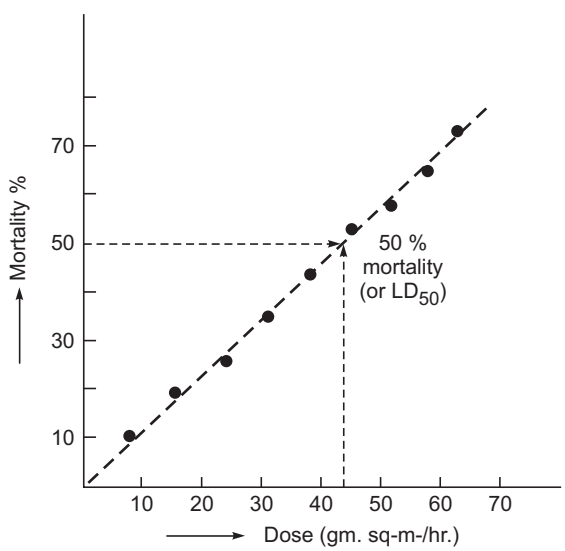

Figure IX.1 Lethal Dose 50% (or LD_{50})

wasps. Bees pollinate flowers and wasps iradicate insect—pests by eating their larvae. This is what happened with sea-birds which was first shown by Rachel Carson. (Recently there was a news item in the Bengal daily 'Bartaman', Oct/Nov. 2001, that the vulture population of West Bengal (INDIA) has gone down remarkably. It seems to us perhaps the vultures of West Bengal are also suffering like sea birds). Most of the carcasses they eat might have too much of DDT in them.

2.A.2 CO_2 (Carbon dioxide) is another common pollutant. CO_2 is released into air when we burn wood or any product of wood such as coal or oil. Therefore with increasing industrialisation all over the world, CO_2 production is steadily rising. Hence more and more CO_2 is being released into atmosphere. This is hapening with an increasing rate, since the beginning of industrialisation i.e. for the last two hundred years or more. Also CO_2 is a normal constituent of air (0.03%). It has been discussed and shown earlier (Chap. V) that within past 20 years (1960-80) CO_2 concentration of air has increased about 7%, of 0.03% (Fig. V.8).

2.A.2. CO_2

***a*:** CO_2 however has a special property. It allows sunlight to pass through it easily and while doing so absorbs heat (infra red radiation) both from sunlight as well from earth.s surface. So higher concentration of CO_2 in air tends to warm up the atmosphere faster. The same thing happens with a greenhouse. (A greenhouse is a glass enclosed room in which cold-suceptible plants are grown). The glass cover of greenhouse allows the sunlight and heat to pass into it easily but retards their escape readily. So a greenhouse remains relatively warm in winter). Just as the glass cover keeps the greenhouse warm so does the CO_2 content of atmosphere. It keeps the atmosphere relatively warm. This phenomenon is known as the Green House Effect of CO_2 on atmosphere. This is exactly what is happening now. During the last 100 years or so, as the CO_2 content of atmosphere is slowly risesing (Figure V.8), the average temperature of earth's atmosphere has also risen. It has risen by 1/2°C. This has resulted in severe drought in some places (ex. Sahel areas in west-south of Africa (and devastating cycones elsewhere (ex. El Nino, Mitch) and melting of some of the heretofore permanent polar ice chelves. Only recently one huge permanent iceberg (of several hundred square miles) has split out from antarctic ice shelf and started floating away and melting.* People are worried. Sea level may rise worldwide.

Green House Effect

Hazards of Green House Effect: Is it serious?

*On March 17, 2000, through satellite they found a very unusual thing. A huge chunk of ice, about 200 mile long, 25 mile wide and 800 feet thick, broke out from the Ross Ice Shelf of Ross Sea. They named it B-15. Slowly it splintered into smaller bergs, floating around the Ross sea and melting. At first B-15 was 1900 square miles in area. The Antarctic Peninsula has warmed about 4 degrees in the past 50 years. "The winter sea and area has been so reduced in recent years that krill populations—which feed on algae that initially grew in the ice—are in danger of crashing. As krill are the basis of almost the entire Antarctic food web, seal, whale and penguin populations could follow." (N.G.S. December 2001).

***b*.** This seems to us however a rise in CO_2 content will induce increased photosynthesis and that in turn will ultimately take care of extra CO_2 in atmosphere. At any rate our Mother Earth has already passed through four ice ages - Grand Canyon, Lauramide, Cascadian and Appalatian - the last one being only 15 to 20 years back. During Appalatian half of Europe was under ice and North Afrika cool and forested. That was the time when the cave dwellers of Altamira (Spain) drew those excuisite cave paintings of bison hunt. (Fig. VII. 6).

2.A.3. As_2O_3

2.A.3. As_2O_3 **(Arsenic Oxide),** is a harmful salt found in deeper layers of soil—in rocks. This chemical dissolves in water and tends to seep into the upper layers of soil. In this way it contaminates the waters of some wells. In semi-arid places such as Rajasthan of India people draw water from wells—oftern 125 feet or more deep. Such waters are frequently found contaminated with arsenic and other harmful salts which seep into the well. That is why people from some vilages of Rajasthan, India, suffer from arsenic poisoning. Unknowingly they use such waters for drinking as well. Interestingly it is noticed that the rich people of the affected villages- "banias" (businessmen) and "thakurs" (land holders) do not suffer from arsenic poisoning. Such people live in brick /stone houses with flat roofs and paved courtyards. Rainwaters from roofs and courtyards of these houses are not allowed to seep into the soil but all are channelled into large brick reservoirs. The houseowners use this stored rainwater solely for drinking, throughout the year. So they escape arsenic poisoning. The remaining villagers however who have to use well-water for drinking often suffer from arsenic poisoning (also pl. see II. 3.2.(C)).

Arsenic poisoning in Rajasthan Villages

***a*:** Recently arsenic poisoning is reported from some villages of West Bengal, India as well. This was not so earlier. It seems the reason lies in the recent disturbance of its ecosystem. Earlier when Bengal (of India before 1947) was well forested adequate rainwater could enter into the soil due to sponge effect of the forest floors and also through many swamps and ponds. Forests, swamps and ponds were much more extensive and numerous then than now. Thus rainwater entering the soil would leach down the arsenic into the deeper layers of it. So the upper layers from which drinking water was drawn remained relatively free of arsenic. Nowadays, in many places, trees have been cut down for agriculture and swamps and ponds have been drained off to make way for housing complexes. Consequently monsoon waters, instead of entering the soil and reacharging the aquifers, quickly run off into the rivers. Along with monsoon water a lot of top-soil also finds its way into the rivers raising their beds. (Also see. II.3.2).

Arsenic poisoning in West Bengal Villages

***b*:** Two ills result from all these—first, arsenic seeps up from the lower levels to the upper levels contaminating the wells and secondly, the raising of river beds cause extensive and frequent floods during monsoons. Annual monsoon floods are much more extensive and severe

today than 25 years before. Recently, a local fortnightly ("Laban Hrad Sangbad", Dec. 19, 2001), has reported as follows. A comparison between 22 years prior to 1964 and since 1964 shows that the drought during the latter 22 years is 9 times more than during the earlier 22 years. We now know that drought is partly caused by lack of ground water. We also know that deforestation, draining off of swamps, filling the ponds are are the main causes for inadequate recharging of groundwater. It seems (according to the above report) in India alone, every year 1.5 million hectar of forest are being cleared to meet the demands of the exploding human population. If true it is horrendous. I hope it is not so or the Govt. would wake up and do something to halt population growth.

***c*:** Thoughtless deforestation is an ecological disaster. We are afraid, the full significance of this damage, neither the planners nor the general populace are aware of. **Afforestation, water management** and **family planning** (to reduce pressure on land) all these three need be attended to on war footing.

2.A.4. Ozone (O_3) is a gas present in trace amount in our atmosphere. However it stays mostly as thin film in the upper layers of our atmosphere —stratosphere, 10 to 30 miles from the earth surface. Sitting over there like a thin protective blanket it protects us by cutting off most of ultra violet light (of solar rays) which is harmful to living beings. Unfortunately nowadays the gas used extensively for refrigeration in most of the countries of the world is chloro-fluoro-carbon (C.F.C.). This gas when leaks out interacts with ozone and destroys it, thus creating gaps in the protective ozone coat of earth's atmosphere. Through those gaps the U.V. rays of solar radiation hit the earth's surface at much higher intensity than elsewhere and harm the living beings thus exposed. Such gaps are called Ozone-Holes.

2.A.4. Ozone layer and ozone holes

4.*a*. Ecologists have already noticed signs of damage in the ecosystems of some parts of the earth owing to over exposure to U.V. rays. This and other consequences of overexposure to various other pollutants have been discussed by ecologists and planners who gathered from all over the world in recent International Ecological Conferences in Brazil, Japan and South Afrika.* The participating countries including India, have signed a resolution outlining what they would do, in a phased manner to reducing pollution of biosphere. But none have stressed upon population control which is the most basic issue.

Ecological Conference in Brazil

2.A.5. Smoke is a suspension of fine particles of carbon in air. Burning of materials such as coal, oil, wood or wood products all produce smoke and ash. Smoke pollutes the air of cities particularly where there are too many cars such as Delhi. In winter smoke and fog together form smog.

2.A.5. Smoke and Smog

*(INTECOL in Rio de Janeiro (1992), on Global Warming in Kyoto (1997) and Earth Sumit in Johannesburg (2002).

Smog is extremely harmful to lungs. A few years ago the senior citizens of London suffered from heavy mortality owing to lingering dense smog in winter. Improvement in emission control of automobiles is vital to solving this menace. Many countries, including Indias are now taking steps to reduce emission from cars.

2.A.6. SO_2 and other air-borne pollutants

2.A.6. Sulphur dioxide (SO_2) and many other air-borne pollutants which result from industrial and mining activities are very harmful to plants. Lichens—a type of delicate plants* have almost vanished from neighbourhoods of most cities and mining areas owing to SO_2 and other air borne pollutants. The naked hills around Queenstown, Tasmaina, stand as mute witness of the ravages of sulfur fumes. SO_2 fumes from a nearby copper mine has completely denuded an once-densely-forested area spread over several square miles in Tasmania. To-day the bare grounds stand purple with sulfur fumes a mute evidence of torture to nature.

2.A.7. Land-Fills

2.A.7. A growing city mostly faces acute land shortage. So now-a-days many city planners are using city garbage to fill up the surrounding swamps and ponds etc. and thus create land for housing-complexes, parks and roads. This is happening all over the world. Bombay and Kolkata are doing this extensively. In fact some city-planners look upon swamps and ponds as manna for them.

Recently however, ecologists have started worrying about this method. First, dangerous chemicals are getting into the ground through land fills which will very likely contaminate ground water and cause health problems for long time to come. The other immediate problem that worries us is the sealing off of the entry points of rain water into ground to recharge the aquifers (the water bearing strata of the ground). Sooner or later the ground-water-level will go down and then the trees too will be affected. Recently in U.S.A. they have raised serious doubts on the propriety of such land-fills (Washington Post 2004).

2.B. PHYSICAL POLLUTANTS

1. Radio-active Isotopes

So far we had been discussing of chemical pollutants which harm through their interferences with the normal biochemistry of living bodies. Now we shall discuss about physical pollutants which harm living beings by the entry of, either high energy radiations emitted by radio-active substances or, extra-ordinary mechanical disturbances generated by external agencies such a sound, heat etc. Radio-active Isotopes (RAI) top this list.

***Lichen:** A group of plants whose bodies are made of symbiotic combination of algae and fungi. These are found in rural and forest environments as light-green crusts on rocks and tree-trunks.

2.B.1. Radio-Active Isotopes

a. RAIs are the most dangerous of all physical pollutants. An isotope is one of the two or more forms of an element which has the same atomic number i.e. the same number of protons but different atomic weight i.e. different number of neutrons. For example, the element carbon which is an essential constituent of most biomolecules, has an atomic number of 6 but atomic weight of 12.*

But there is an isotope of carbon which has an atomic weight of 14. This C_{14} is a radio-active isotope of carbon. This radio-active carbon automatically emits high energy radiations which are harmful to living beings. Similarly there are isotopes of many other elements. Some of such isotopes automatically produce high energy radiations such as alpha, beta and gamma.

The cause of harm from Radio-Active Isotopes

b. Radio-active-isotopes or RAIs automatically and continuously produce alpha, beta and gamma radiations (generally symbolised as α, β and γ rays). Of these beta and gamma are extremely high-energy radiations hence when these enter into the bodies of organism, occassionally these remove electrons from some atoms and attach these free electrons to other atoms. In this way such radiations produce positive and negative ion pairs and so these high energy radiations are known as ionising radiatons. Ionising radiations are the chief causes of injury to organisms from RAIs.

The ionising capability of alpha, beta and gamma rays

c. Generally radiation-damage to the tissues and organisms is proportional to the number ion-pairs produced within the irradiated tissue in an unit of time. Again the capability of producing ion-pairs is dependant on the energy of these rays. Alpha and beta rays are corpuscular (i.e. particles) but the gamma rays are electro-magnetic waves (related to X-rays). Alpha particles are parts of Helium atoms and hence huge in atomic scale. These can travel only a few centimeters from the source and can easily be stopped, even by a sheet of paper. Beta particles are high speed electron beams and can travel several feet in air or penetrate a few centimeters in the tissue. In contrast to these two, the gamma rays are extremely high energy electro magnetic rays which can travel long distances in air or tissue producing ionisations throughout their path. Gamma rays can even go through thin concrete walls. So of these types of radiations, alpha particls cause least and gamma the most damages to the tissues.

d. Some elements go on continually emitting high energy radiations. For instance Radium (Ra), Uranium (U), Plutonium (Pu) etc. For some

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*__Atomic Number__ and __Atomic Weights__ of elements are shown in this way. Atomic number is written above the abbreviated form of element and the atomic weight under.

Thus Hydrogen = H_1^1 ; Carbon = C_{12}^6 ; and Cobalt = CO_{59}^{27} .

The radio active element of these isotopes are H_3^1 ; C_{14}^6 and CO_{60}^{27}

others the common forms do not emit high energy radiations but some of their isotopes do such as Hydrogen (H), Carbon (C), and Cobalt (Co). There are many such elements which have radio active isotopes. Radiations from such RAIs (mainly beta and gamma) cause ionisations within the protoplasm. Such ionisations may lead to mutations (explained later in this chapter), cancer and death. However it should be remembered that cancer is also found in people who are not exposed to any known source of ionisation. Exposure to some chemicals such as coal tar has been found to cause cancer. With passage of time, other carcinogenic agents (cancer causig) are being identified. To day cancer is a high priority research area all over the world. A break through in this area will sure be a Nobel Winning work. Exposure to high doses of radiation from RAIs is extremely dangerous to life. The first known victim from radiation is Madam Curie herself—the discoverer of radium. Unknowingly she received a fatal dose of radiation while handling radium. She developed blood-cancer or leukemia and succumbed to it. Later many more have died. Measurement of doses or radiation to which a living being may be exposed to without harm is although important to many but somewhat technical and outside the scope of the small book.

Damages from Radiation

e. These high energy particles and waves particularly beta (β) and gamma (γ), destroy some body cells (somatic cells) and our gonadic cells (germ cells). That is why when X-raying a patient, doctors keep the testicular or ovarian parts of the body covered with a thick lead sheet through which X-ray can't pass. When extensive damages of body cells take place—owing to radiation, the patient, after stages of illness, dies. If however, the gonadic cells (germ cells) get damaged, the being may produce offsprings with unexpected features—mostly bad. These deviations are called mutations. Prof. H.J. Muller 1947 first demonstrated that X-ray irradiation can alter genetic material leading to permanent changes in the offsprings. Such changes owing to irradiation are permanent and hence called mutations. Prof. Muller's discovery was such a break through in the growth of knowledge of Genetics that he was awarded Nobel Prize for this.

Mutation and H.J. Muller

f. None of these high energy rays are visible. So RIAs like $Cobalt_{60}$ or $Uranium_{238}$ etc. are like invisible killers. Atom bombs not only kill thousands of people directly (as at Hiroshima and Nagasaki) but also releases in the form of 'fall-out' a variety of RAIs such as $Cobalt_{60}$ and others which retain their lethal property for years. In fact some retain their lethal property for thousands of years. Half-Life of $Carbon_{14}$ is 5568 years and of $Cobalt_{60}$ 5.27 years. (Half-Life is the time required by a radio active isotope to lose 50% of its original radioactivity.). That is why world is now trying to ban the production and use of such horrible weapons as atom bombs.

Danger from Atom Bombs

g. There are other RAIs which may be injected into the ecosystems from sources other than atom bombs. Nuclear Power Stations are very

prominent examples of sources of RAIs These power stations are sprouting up all over the world like mushrooms and more so in the so called developed countries. Some of their by products are RAIs. These have to be stowed away extremely carefuly, in safe and sealed containers and placed deep inside the earth or sea-bed till their radio-activities come down to harmless levels. This is the practice now but nobody is too sure about the reliability of these measures as time required to check these is to long and none of us will remain alive then. (Recently in N G S. July 2002, issue there is a very important article on storage facilities in U.S.A. for RA wastes from Nuclear Power Plants).

Hazards of Atomic Power Plants

h. Sometimes due to human errors, the radio-active fuel rods in a nuclear power station, which normally generates heat in a controlled way to produce steam in boilers for power generation, may become uncontrollable. Consequently all on a sudden so much of heat is generated that the entire power plant may explode with all the horrible consequences folowing swiftly. Such accidents are however very rare. Still recently one did happen at Chernobyl, U.S.S.R. (Year 1986). It was a terrible disaster. Thousands have died. After the accident the Russians have sealed up the whole power plant with thick concrete shroud. Several hundred square miles of land around Chernobyl have the banned for human habitation. (So dangerously high was the level of radiation—mainly rays, that a Russian helicopter pilot sent several days after the explosion, to survey the extent of damage from his helicopter, whose floor was covered with a thick lead sheet (to protect him from beta and gamma rays) nowithstanding, received so heavy dose of radiation that after a few months, he developed leukemia—blood cancer, and died. He could not be saved although some American pilots and doctors tried to save him through bone marrow transplantation. The explosion of the atomic power plant at Chernobyl is comparable with a nuclear volcano that has erupted. From that angle all nuclear plants are inherently very very risky.

The Chernobyl Accident

Atomic power plants need constant vigil and monitoring. With them nothing should be left to chances. The first atomic power plant of the world is that of Windscale of U.K. Now they have several all over the world. So far India has two—one at Trombay near Mumbai and another at Kalpakkam near Chennai. Recently they are planning to erect one more in India at Sundarbans—the only mangrove ecosystem of India and perhaps the only reserve forest in India with a reasonable number of tigers. To destroy Sundarbans would be an ecological disaster and not having tigers would be a matter of great loss and shame for all Indians. Ecologically and ethically this is very very wrong. Tigers too have a right to live. Also, mangroves ecosystem of Ganga delta is too precious to be trifled away. If mangroves of Sunderbans is gone the survival of entire Ganga delta will be threatened. Putting a Atomic Power Plant in Sunderbans will be an ecological folly of gargantuan proportion. Tigers will vanish. The very existence of Haldia and Kolkata will be at stake.

Atomic Power Plant in Sunderban-a dangerous idea

Prawn culture will be destroyed. Mangroves will go, and soil erosion will assume dangerous proportion. Hilsa fish will almost vanish and many more irreversible ills will follow. Then no amount of 'Foreign Aid' will be able save Sunderban and West Bengal from calamities. Desire to employ "higher Technology" without carefully assessing the price for it is indeed a very wrong way of planning. People in power, if they really love India should desist from doing this. Ambition with little knowledge is a dangerous thing. If an atomic plant is erected there one of India's few proud possessions will be gone forever.

k. Besides it is time now we start working for solar power, wind power and tidal power and no more for thermal plants or atomic plants. Rajasthan desert is a huge untapped source of clean power. It is time we turn our attention to such sources of power. If we can only tap 1% of solar energy for power generation India will be flooded with power.

Solar Power station in Rajasthan Desert

2.B.2. SOUND

Sometimes noise may be a source of pollution. Too much noise is positively harmful to hearing and health. People who are constantly exposed to too much noise of machines as, pneumatic drils, railway engine whistle, aircrafts, pneumatic horns, crackers, mikes etc. (without adequate protection to ears) sooner or later, all suffer from impaired hearing. Some may even become deaf. A new-born baby's hearing may suffer permanently. Too much sound may disturb sleep and thus cause health and healing problems. Human beings can hear sound form 60 to 75 decibel (an unit of sound). But sounds above 70 decibels are harmful to hearing.

2.B.2. Sound

a. Many animals can produce, hear and communicate through such sounds (ultra and infra sounds) which we can't hear. Such animals are bats, elephants, porpoises and whales. There may be many more such animals endowed with such capabilities. Recently it has been proved even ants when in pain scream.

Sounds in animal world

b. It is extremely important therefore that, the permissible level of sound production near human dwellings and public places be determined and enforced. This is an area where more information are urgently required. These however can be easily found out through simple laboratory experiments. People of Europe, North America and other rich countries are fairly conscious about the pernicious effect of too much sound so, they have strict laws regarding permissible range of sound production in public places. Unfortunately in India and such underdeveloped countries such awareness is far from adequate. Only recently some courts of India have ordered to keep the sound level in public places within 65-70 decibels.

2.B.3. HEAT

Our universe has a very wide range of heat starting from 10,000°C on the surface of the sun to minus 100°C or less in polar ice caps and some planets. Life however can exist only within fraction of this vast temperature scale that exists in this solar system (Fig. III. 6). This small range is approximately from + 90°C or so to – 60°C or so i.e. a span of only 150°C. Of this 150°C any individual species can tolerate a still smaller range say, around 30°C. Protoplasm (the semi-liquid content of a cell) of an individual species however cannot tolerate any temperature fluctuation—it can stay alive only at a fixed temperature such as of birds and mammals or with very little fluctuations of temperature such as of fishes, amphibians and reptiles. To survive in an habitat with fluctuating temperatures, a species develops various adaptations—some structural, some physiological and some behavioural. For details pl. see III.

2.B.3. Heat

***a*.** When the ambient temperature of a habitat or a breeding place changes, due to pollution, the population of the species concerned, suffers severely. For instance the population of salmon fish drops if the temperature of their breeding grounds namely, pools in the rock streams in cold mountains, rises owing to deforestation. (Also the turbidity matters. Cool and clean water in their breeding grounds is a must for salmons and eels.)

Pollution: Temperature of Habitat

***b*. The toleration range of a species** depends upon the ecosystem it lives in i.e. its niche. For instance a yak (a variety of cow) which lives in Tibetan plains, can live only in cold climate (say –10°C to +15°C)—alpine climate*; Similarly a good cow from northern plains of India say a Haryana cow prefers warm and dry climate of western India (Say 5°C to 30°C). Again, the different stages of the life—cycle of an animal or plant, may require even a still narrower band of temperature to survive and grow. Here are two examples—one a fish (Salmon—*Salmo fario*) and another an insect (Silk worm—*Bombyx mori*).

***c*.** The famous commercial fish **salmon** spends most of its life in seas but for laying eggs it must swim up the rivers in the colder regions of the earth, all the way to nearly the source of the river and lay eggs in cold clear water pools. If these waters are not so cold or turbid spawning will suffer and consequently there will be crash in the salmon population of the seas. So a good catch of salmon during fishing season in seas may very well depend upon, among other things, the coolness and clearness of the waters of the breeding grounds of mountain rivers.

Spawning of Salmon

***d*.** Now the silk worm. The **Chinese silk worm** lays its eggs in Autumn. These eggs do not hatch immediately. Instead those will enter into a winter phase—a dormant phase—technically known as diapause. In

*Alpine Climate : Pl. refer to 'Terrestrial Ecology' in Chapter VIII.

Diapause of Silk Worms

early spring, after undergoing diapause development the eggs will hatch and then the normal larval activity will be resumed i.e. feeding, moulting etc. Undergoing diapause in winter is a compulsory requirement for the eggs of Chinese silk worms. If for some reason or other, the period of exposure and intensity of cold the diapausing eggs are subjected to are different from the normal, the silkworm population will suffer. Pollution of the native environment, owing to human interference sometimes causes such situations.

e. Thus although as a physical factor temperature is vital but pollution may adversely affect temperature and thus cause catastrophic rise or fall of a population. The same is true for other physical factors. for instance, dust may diminish sunlight and effect photosynthesis.

2.B.4. MOISTURE

2.B.4. Moisture

Not only liquid water is a must for the sustenance of life, the nature of liquid water, as well as relative humidity (i.e. percentage of water vapour in air), are also crucial for living beings particularly animals. Those animals who live in fresh water all face one comon challenge—too much water tend to enter into their bodies through endosmosis and those who live in salt water face the reverse situation i.e. too little water tend to stay into their bodies due to exosmosis. Again, those animals who live in land other than deserts, face a variety of other challenges regarding relative humidity, according to their niches and character of their skin (integument). Thus a toad whose skin can't stop evaporation of water through it, can move about only during monsoon season when the air is humid. During dry season toads hide within burrows. So anything that drastically changes the quality of water or relative humidity of a place damages the local ecosystem. Also human activities, at times, adversely affect ecosystems. For instance, release of warm waters into the rivers from nearby factories and power plants etc. damages the river ecosystem.

The river Ganga of India and its Pollution

The river Ganga of India is a victim of triple pollution—heavy silting due to deforestation and agriculture in her watershed secondly, the pouring of factory affluents and city sewage and the third cause is a religious practice of Hindus. Many Hindus believe that if, after death, their bodies are burnt on the banks of Ganga their soul will go to heaven. So after cremation the ashes and other related items all are thrown into Ganga. Today the water of river Ganga is heavily polluted. These are adversely affecting the fish population as well as the mangrove ecosystem of Sunderbans in the mouth of Ganga.

The other instance is the 900 miles long canal that has recently been taken from Ganga into the Ganganagar district of Rajasthan. This has increased the moisture content of the soil and the relative humidity (R.H.) of air of that district. The ecological effect of this on the erstwhile local ecosystem though not yet fully known, but is very likely to be considerable. The fate

of other Indian rivers are scarcely better. Unbriddled rise in human population coupled with public and Govt. apathy towards maintaining the health or river ecosystems are slowly choking the Indian rivers. Indian rivers urgently need health care, but little actual works are being done. Most are ad hoc steps.

2.C. BIOLOGICAL POLLUTANTS

So far we had been discussing only about various chemical and physical agents which disturb the rhythm of Nature and the consequences that stem from such disturbances. There is however another type of pollution which essentially concerns with the characteristics of populations. So the effects are not so obvious in the initial stages. Generally a healthy natural ecosystem remains more or less self—supporting and stable for hundreds of years and the various populations that inhabit it remain unchanged. (In the long run however, nothing is unchanging otherwise evolution would not have taken place). In fact the stability of the sizes of component-populations is a basic feature of a healthy self-sustaining ecosystem. Now, if through human interventions the polulations of one species is suppressed or encouraged, the result will be the near elimination of one species or explosion of another or both.

2.C. Biological Pollutants

a. Here is a case where suppression of one has resulted in the explosion another. In the Virginia State of U.S.A. they have several reserve forests. In these hunting of deers is prohibited and also they have eliminated the natural enemy of deers i.e. cougars (*Felis concolor*) from these forests. Populationwise for deers the signal is green and for cougars red. Soon the deer population exploded. So to keep the forests from being overgrazed by deers and the road safe to motorists, every year the Forest Department of Virginia declares a few days as open season for deer shooting. Around 50,000 deers are shot down every year in Virginia State alone. This is a clear case of population explosion owing to the removal of predators. Thus predators help to keep the forests healthy. (Similar situations can be identified from the relative population changes of animals and plants of different countries). More have been written on this earlier (V. 3.7).

Explosion of deer Population in Virginia U.S.A.

b. Another case is human beings (*Homo sapiens*). Man owing to their superior intellect (thinking, remembering, communication capability and of using tools etc.), since their beginning, had been a negative influence on their environments. Wherever man settled in large numbers, the number of other organisms whether plants or animals, got severely depleted. Lions (*Felis leo*) who were endemic throughout north and east Afrika and western Asia including India, have been eliminated from most of these places. In fact these regal animals were so common in western India that emperor Asoke used their regal look to adorn the heads of the beautiful pillars he erected in many places of his empire. Now these regal

Lions and Whales

animals are confined only in a few states of Afrika and a small reserve forest in India (Gir forest). Whales, the beautiful and majestic animals of seas were almost going to be hunted out from the surface of mother Earth but for the timely, intervention of International Whaling Commission. Today their numbers are again rising.

***c*. The industrial Revolution** of 16th century, a product of modern science, gave Europeans knowledge as to how to obtain fossil fuels and use these as sources of heat and power. Armed these twin tools—modern science and power from fossil fuels, Europeans began to exploit ecosystems of the entire world solely for their own benefit. The vast continents of North and South America were discovered and, found thousands and thousands of square miles of land there just lying open to be occupied and exploited. Soon the populations of immigrants from Europe to these continents, particularly from Gr. Britain, Spain, Portugal, France, Italy, Germany, Denmark, Holland and Norway and others—mainly the sea-faring nations, exploded. They occupied and colonised entirely North Americal, South America, Australia and New Zealand and partially the coastal belt of Africa. The relatively unresisting and small populations indigenous people of these countries were mostly decimated. (pl. see Table I. 1).

***d*.** This was a population explosion of the Europeans in a grand scale at the cost of other populations, just as lions were eliminated from most of Africa by the burgeoning human populations in that area. At that time most of European colonies to North and South Americas had very large families averaging six to ten children in each. Soon after that pristine ecosystems of North and South Americas began to suffer. Passenger pegions are completely eleminated. Bisons came to the brink of decimation. Bald Eagle's populations dropped to dangerously low levels*. Today even the rain-forests of South America and Afrika are being cut down, rethlessly for wood, agriculture and animal husbandry, at such an alarmingly fast rate that environmentalists are very worried and crying themselves hoarse still, the floodgate of devastation is far from being shut.

Artificial Fish-breeding and Damage to endemic gene-pool

***e*.** Here is another aspect of biological pollution. This is fish culture and gene pool. Recently techniques for fish culture have been vastly improved. Fishery biologists have taught the fish farmers how to inject the extract from pituitary glands to female fishes in order to induce them to spawn in such waters where normally they would not spawn. Prof. Hiralal Chaudhuri of Kolkata (1959), has made a significant contribution towards this. This and other associated improvements in fish culture, have encouraged fishermen in countries like Japan, India and others to begin commercial fish culture in artificial impoundments in coastal-waters and inland shallow ponds in an ever increasing scale.

*Tasmanian wolf (*Canis dingo*), the only marsupial carnivores, of Australasian region are eliminated by the immigrant sheep ranchers of Tasmania in late 1930s!

f. While this is good news to housewives but this is also eliminating the local fishes. Consequently today in Kolkata fish markets while the cultured fishes are relatively cheap and abundant but the endemic (local) small fishes which were dirt-cheap before have become rare and expensive. Mostly their habitats have been taken over for artificial fish culture.

Through the above way an omnimous consequence may follow. Some of the exotic commercial fishes such as, Tilapia (*Orechromis niloticus*) which have been imported from Afrika (Lake Victoria) are being released in the ponds of West Bengal, India. Thus while Tilapia has added to the list of relatively cheap fishes for kitchen, it is also eliminating most of the local fishes. Unless India and particularly West Bengal takes corrective measures immediately we are afraid, many of the endemic, fishes may vanish for ever. This would be a positive loss to the local ecosystem and to the endemic gene pool of the country and in the long run for the world. Similar things are happening with the food grains. Special vareities of rice and wheat are being imported from South America and Manila. These require lot of fertiliser and water still farmers are growing these, to the exclusion of local varieties, for quick profit. Gradually indigenous varieties of rice and wheat are vanishing. These are some of the deleterious effects of biological pollution. There are more.

(Fortunately, owing to the efforts of Dr. M.S. Swaminathan, F.R.S., Govt. of India has set up a gene bank for indegenous plants but no such efforts have yet been initiated to protect the genes of endemic animals.)

If we think a bit we shall realise that **at the root of most of the biological pollution lies the explosive growth of human populations during the last thousand years (Fig. I. 1)** particularly since Industrial Revolution. Only in India human population has grown five times during the last century (Table IX. 1).

2.D. PSYCHOLOGICAL POLLUTANTS

2.D. Psychological Pollutants

As this is not the theme of this book, so we shall only touch upon this most briefly. At the beginning of this chapter it has been proposed that "any agent—chemical, physical, biological or cultural which interferes with the normal rhythm of Nature is pollution". By interference we generally mean detriment. From this angle, there are a few psychological situations a human being may be exposed to, which leads to the detriment of his mind. These situations are psychological pollutants. Here are some of the most obvious ones.

a. Intense Competition for Best Grades In School

Today in many countries particularly poorer countries like India, (author is an Indian) a child is put to school as early as possible even before he or she is three. At once the happy childhood vanishes. Every

Table IX.1.
POPULATIONS AND GROWTH RATES IN INDIAN SUB-CONTINENT DURING THE LAST CENTURY (INDIAN POPULATION HOWEVER EXCLUDES THE INDIAN TERRITORIES OCCUPIED BY PAKISTAN AND CHINA). FROM CENSUS DATA FROM INTERNATIONAL DATA BASE AND OTHER SOURCES

Years	*INDIA*				*PAKISTAN*		*BENGLADESH*		
	Population (in millions)	*Birth (per 1000)*	*Death (per 1000)*	*Growth (%)*	*Population (in millions)*	*Growth (%)*	*Population (in millions)*	*Growth (%)*	*Comments*
1911	252	49	43	0.6	–	–	–	–	A considerable
1921	252	48	48	0.0	–	–	–	–	portion increase
1931	279	46	36	1.0	–	–	–	–	in population is
1941	319	45	31	1.4	–	–	–	–	due to reduction
1951	361	40	27	1.3	34	–	–	–	in child
1961	439	42	23	1.9	43	–	51	–	mortality and
1971	548	41	19	2.2	65	–	–	–	lack of desire
1981	683	37	15	2.2	89	–	90	–	for family
1991	844	32	11	2.1	132	–	–	–	planning
2001	–	–	–	–	–	–	129	–	

day the child faces grilling both at school and in home for more and more marks in class tests. Nothing less than 90% will do. The child's position must be within the top 10% of the class. His happy childhood is shattered. Both in school as well at home the child is in front of either books memorising or, note-books writing. Even the child's holidays are booked for tuitions, endless tuitions—mathematics, painting, music, swimming, dancing (and even cricket). On top of all these the child's parents are forever chiding him/her for not doing better, for getting less mark than the best boy/girl of class and so on. Hearing such uncomplimentary comments all the time, that he/she is dull, that he/she has no 'grey matter' in brain, in life he/she is sure to be a failure etc., the child is very likely to develop a warped personality. What a nightmarish childhood they go through. Later at the age of 5 or 6 the child will have to carry a huge school-bag which would weigh 3/4 kg. We are afraid their backbones may develop defects.*

Intense Competition in School

***b*. An unhappy and book-worm-like-childhood** is unnatural and any child who goes through this torture is very likely to suffer as an adult. Many mothers instruct their their children not to share his/her tiffin with any body else. How can a child taught so by mother can over be selfless?

Children are encouraged to be selfish

***c*. Cultural Outlooks of Communities**

Achievements and attitudes of a man result primarily from three factors—genes, family environment and schooling, the latter two we shall concern ourselves with.

***d*. Role of Family**

In many families children hear their parents belittling people of other communities such as, fair-skinned people against dark-skinned people, Moslems against Jews, so called Brahmin Hindus against non-Brahmin Hindus and so on. Rarely children hear of basic human values and dignity of man. How can such a child ever grow into a fair minded person?

Role of Family

***e*. Role of Teachers and Curricula**

Again in schools students are too busy in learning merely a few skills which would enable them to earn lots of money only. They neither have time nor allotted any time to learn to distinguish morals from immorals, ethical from unethical, loyalties from disloyalties or meaning of responsibility. Simply they do not know that **"Man does not live by Bread Alone"**.

Role of Teacher

Many teachers neither teach properly nor show through personal example that taking money without discharging obligation tantamounts to stealing. A man's duty to nation and himself extends far beyond his

*Recently the British Medical Journal LENCET has reported that school bags of children are too heavy for healthy growth of their backbones.

immediate needs and comforts, that he is a moral guardian of his environment—animals, plants, forests, and all. It is time we realise that the long time interest—of a country lies in the interest of other countries as well.

It seems to us, lack of these awarenesses is the root cause of most of the unhappinesses of human beings over the world today.

Chapter X

Problems and Solutions

(Challenges and Rising to Them)

Topics

X. 1. Philosophy of Ecology

X. 2. An Overview of Ecology

X. 3. Problems that we have generated

X. 4. Solutions

X. 5. Reorganise Town-Planning

X. 6. Agriculture and Ecology

X. 7. Better Water-Management

X. 8. Eco-Politics

X. 9. World Bank and Population of Under-Developed Countries

X.10. Ecology, Education and Values

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CHAPTER X

PROBLEMS AND SOLUTIONS

(*Challenges and Rising to Them*)

1. PHILOSOPHY OF ECOLOGY

Before delving into the enviromental problems and their ecological solutions, it is time we briefly state the philosophy of ecology.

*All living beings of the entire earth and their non-living environments are inter-connected and inter-dependant. Damage in any corner of earth affects every other corners of earth.

*Organic evolution over the ages, have resulted in occupation of all the varieties of niches of entire earth, be it a dark cave or a blazing desert, with plants and animals who are specifically adapted for each specific niche.

*Competition and elimination of the unfit are natural and necessary processes of life and evolution hence should not be interfered with by human beings unless unavoidable.

*Recycling of all bio materials is vital for continuity of life.

*The bounty of Mother Earth is not for men alone but for all living beings. All living beings—from men, to decomposers, have a claim on the space and resources of Earth as each play a vital role in maintaining harmony in ecosystem.

*Human beings being endowed with the unique capacity of learning, thinking, communicating and writing have a special duty to ensure that justice is done to all other living beings, be it a humble insect or a mighty whale, be it a blade of grass or a mighty sequoia tree.

*Finally, happiness of Individuals lies in the happiness of All.

2. AN OVERVIEW OF ECOLOGY

This small book contains the basic ecological concepts and information in very simple language, for people whose knowledge of science may be just minimal. It is like an attempt to present Zoology to someone through a tour of a zoological garden. I am not sure if I have succeeded in explaining to the readers, or lost them midway owing to the poverty of my english which is not my mother tongue, the complexities of the ecological

principles and the importance of leading our lives in an eco-friendly way. I hope the better. So here is in brief the principal ecological concepts introducid in this small book.

2.a.*i.* Men of ancient civilisations were aware of the need of maintaining Nature so, the sages and priests of those days introduced certain social customs and taboos to protect animals and plants. "Ecology" as a defined branch of science with a name of its own appeared only in 1869 through Ernst Haeckel (German) and the word "Ecosystem" in 1935 through A.G. Tansley, (English). Thus began the march of Ecology as a separate discipline of knowledge.

ii. Three most remarkable and charming early books of ecological nature that could be recommended to all are:

(1) Darwin And The Beagle—Alan Moorehead, Penguin, 1971.
(2) Silent Spring—Rachel Carson, Houghton Mifflin, 1962.
(3) My Family and other Animals—Gerald Durrell,

Reading these will arouse curiosity of readers to our living environment.

iii. Simply speaking, Ecology is that branch of knowledge which deals with the relationships that the living beings have with their non-living environments and vice-versa. Being basically an applied science, Ecology draws upon various relatively pure branches of science such as, Zoology, Botany, Genetics, Physiology, Behaviour Science, Geography, Chemistry etc. (Chapter I).

2.b.*i.* The smallest **self-sustainign unit of Earth's biosphere** is called **Ecosystem**. For example, a forest, a lake or a coral reef etc. All these are self-sustaining and hence ecosystems; with only sunlight from outside these can sustain themselves. The main components of an ecosystem are two—the living beings or **biotic components** and the non-living or **abiotic components.**

ii. Plants, animals, fungi, bacteria etc. form the bulk of the biotic components and, soil, water, air and sunlight form the bulk of the abiotic components of an ecosystem. Besides sunlight, which comes daily from sun, all the other components are integral parts of the ecosystem. The biotic component again are devided into three main categories—the green plants—who manufacture food materials from simple inorganic ingredients by using energy from sunlight, the animals who live on food manufactured by green plants and the fungi, bacteria etc. who, after the death of plants and animals break-down the biomaterials locked up into their bodies into simple inorganic materials and return these to earth to be picked up and recycled once again by plants and thus repeat the cycle of life over and over again (Fig. X. 1) (Chapter II).

2.c.i. The ecological fact of recycling of nutrients from abiotic to the biotic components of the ecosystem, and then again from biotic to the abiotic and so on and on—one cycle succeedig another till the ecosystem

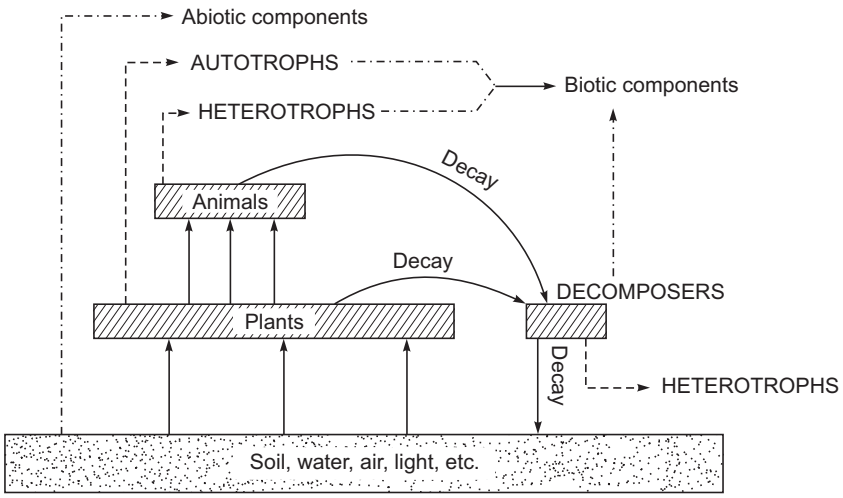


Figure X.1 An ecosystem showing cycles of life death and life again (schematic).

lasts, is somewhat analogous to the religious beliefs of reincarnation (rebirth after death) which we find in many religious teachings. While the ecological fact of recycling is discovered through painstaking research and observations which can always be verified through experiments, the religious beliefs however, seem to us, owe their origin to the dictates of the religious leaders or powerful coteries who used these beliefs to control the minds of their followers. The earlier one is fact-based while the latter is faith-based.

ii. All the food that we eat, all the wood that we use, all the rubber that goes into the production of tyres etc., all the coal and petroleum that we burn to obtain power, heat and all the clothings that we wear etc. etc. are either produced by plants or obtained from power stored in plants. As a matter of fact all human activities of the entire world are mostly directly or indirectly powered by plants and plant products. Successive eras of human civilisation have been possible only through more and more efficient use of plants and their produce. Only recently men are obtaining power directly from sunlight through such devices as solar cells, windmills, etc.

iii. Production of bio-materials by green plants is called primary productivity, by herbivores as secondary productivity and by carnivores as tertiary productivity and so on. A portion of the total primary production of plants is used up by the plants themselves to keep them alive and provide energy for their metabolic processes. The remaining portion is available to all animals and human beings for their food and other uses.

iv. The total biomaterial produced by plants is called gross primary productivity or G.P.P. and the surplus portion of G.P.P. which is available to the consumers is called net primary productivity or N.P.P. Similarly

there are terms for secondary producers such as G.S.P. and N.S.P. and so on. Also, not more than 2% of sunlight is used by plants to produce all the biomaterials of the world.

v. The health of an ecosystem is directly correlated with the amount or its G.P.P. (This however is an anthropocentric point of view; there are ecosystems which by virtue of their locations are bound to be of low productivity such as, open ocean desert, but these are not necessarily unhealthy from the point of view of Nature).

vi. G.P.P. in time, through N.P.P. influences G.S.P. and so on. For these reasons measurement of productivities is a very important yardstick to an ecologist. From the point of view of G.P.P. biomes like rain-forest, agricultural fields and coral reefs are highly productive ecosystems. An estimate of the annual N.P.Ps and Standing Biomasses, per unit areas per year of all ecosystems (i.e. all biomes-both natural and manmade), are also given (Chapter III Table 1).

2*.d.* Sunlight is the source of energy for green plants. Powered by solar energy, green plants manufacture food utilising simple inorganic nutrients. As the world depends of biomaterials manufactured by green plants or G.P.P., the wheel of life of the entire world rotates on green Plants and sunlight. This passage of solar energy by stages, with gradual dissipation, from plants through various animals i.e. herbivores to carnivores and so on till it gets totally dissipated into the environment, is known as energy circuit (Fig. X. 2.). The aim of all agriculturists is to increase the primary productivity of their lands. The success of a civilisation begins here (Chapter IV).

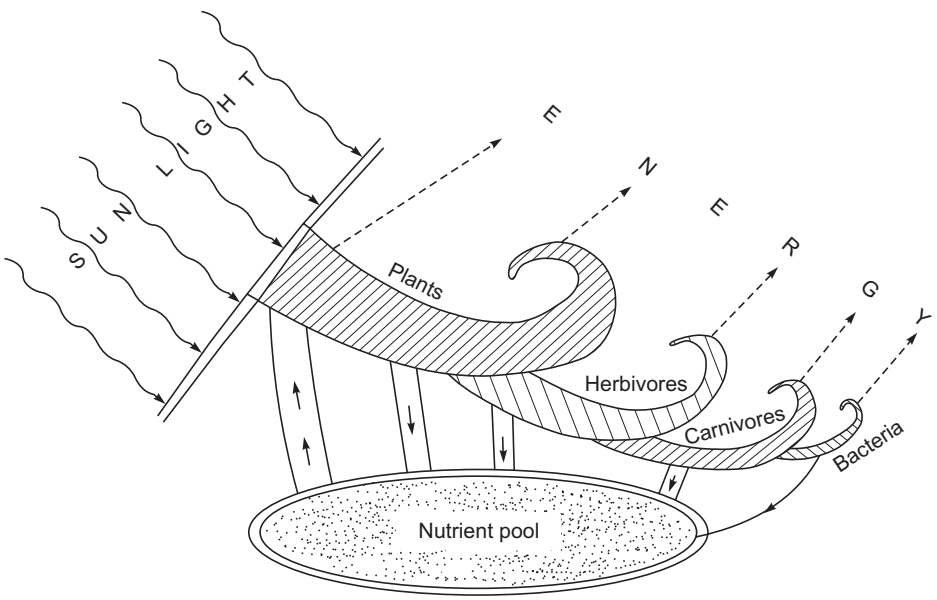


Figure X.2 The energy circuit of an ecosystem (schematic).

2.e.*i*. The energy from sunlight, after being trapped by the plants, gradually gets dissipated away as it passes from one stage to another i.e. from plants to animals etc. and gets lost for ever into the environment, The inorganic constituents of living bodies however do not share the same fate. The materials which are picked up by plants during photosynthesis, after passing through various stages instead of gettig dissipated into the environment like energy from sunlight, are returned to their reservoir pools i.e. abiotic environments to be picked up once again by plants to initiate a new cycle of life. This means that while the energy picked up by plants from sunlight is lost to the environment irrevocably, the inorganic molecules however are recycled again and again. This repetitive back and forth movements of inorganic materials from the bodies of living beings through the door of decomposition into the world of non-living and then reentry into the world of living through the door of photosynthesis is bio-gee-chemical cycle (Fig. X. 3).

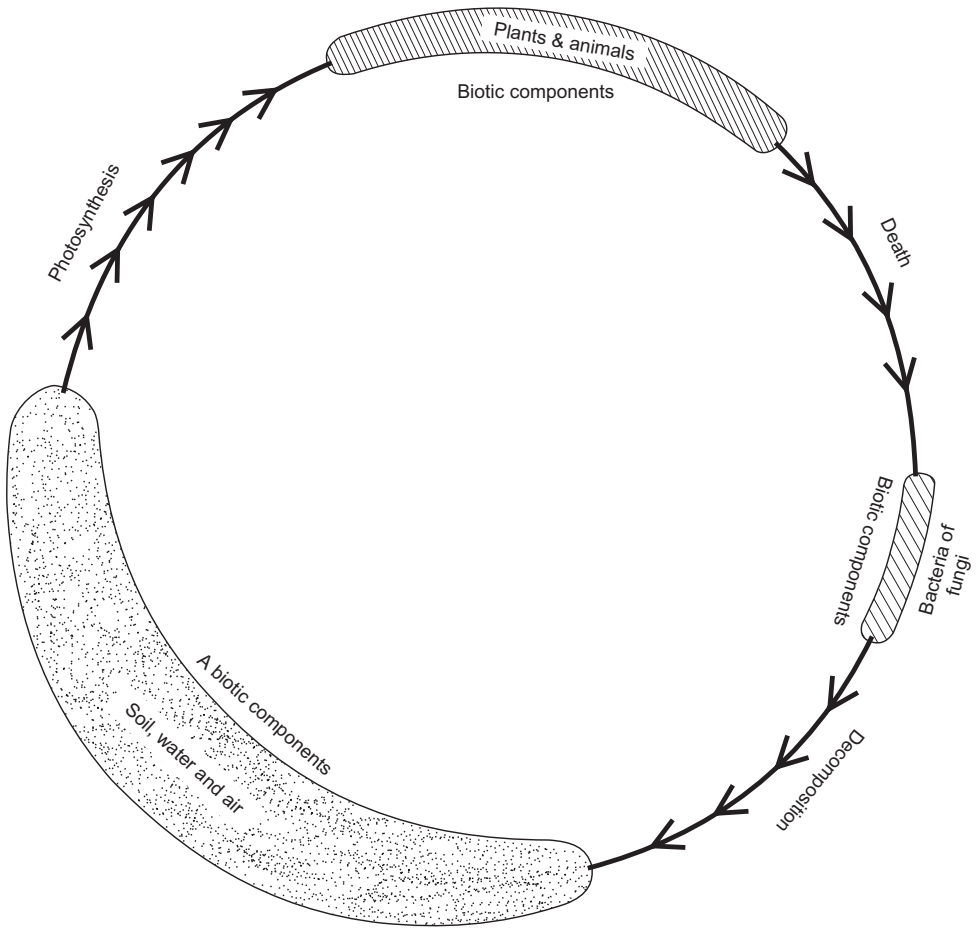


Figure X.3 A geo-bio-chemical cycle (schematic).

***ii*.** Each chemical has a specific pattern of pathway. The study of these pathways and the rates at which these chemicals move from one compartment into another and while doing so, how these pathways are now-a-days being frequently disturbed through interferences by men fueled by population explosion, froms an extremely challenging as well as exciting area of modern ecological studies. (Chapter X.V).

2.*f*. Dfferent environments or ecosystems affect different species in different ways. For instance, frogs and toads will prosper in humid places while reptiles will find dry places better. Also, growth of a population (say deers) will depend on availability of food and presence of competitors such as, other herbivores and predators. Therefore factors which regulate the growth of the the population of a species, the nature of the growth pattern of a population (i.e. if 'J' shaped or 'S' shaped), the size of a population that can be supportedly a particular habitat, and the carrying capacity of an ecosystem for a species, etc., all require careful study and clear understanding if, we want to nurture a balanced ecosystem (Chapter VI.).

2.*g*. No ecosystem can be made of single species population. Several interacting and interdependant species populations go into making of a stable self-sustaining ecosystem. (This is true for human societies as well). How from a no-life situation, through gradual stages, a stable, self-sustaining ecosystem is developed is a matter of great interest. These and also how populations of different species, through their life activities support each other and create a holstic* process are discussed in Chapter VIII.

X.2.*h*. The beauty of the living world lies in its infinite variety of colours, activities, sizes and behaviour of its inhabitants. Every single individual is an unique creation of God. An insect is, from its own background is no less pretty and useful than a resplendent tiger in a semi-dry forest. This reminds us of two poets who wrote:

"To see a World in a Grain of Sand
And a Heaven in a wild Flower
Hold Infinity in the palm of your hand
and Eternity in an hour".

—*William Blake*
(Auguries of Innocence)

বহু দিন ধ'রে বহু ক্রোশ দূরে
বহু ব্যয় করি বহু দেশ ঘুরে
দেখিতে গিয়েছি পর্বতমালা
দেখিতে গিয়েছি সিন্ধু।
দেখা হয় নাই চক্ষু মেলিয়া
ঘর হতে শুধু দুই পা ফেলিয়া
একটি ধানের শিষের উপরে
একটি শিশিরবিন্দু॥

— রবীন্দ্রনাথ ঠাকুর

স্ফুলিঙ্গ

*Holistic : An approach to the study of things or a situation taking into account all the possible variables; a totalistic approach. This is opposite of meristic approach which considers only one situation or one aspect at a time.

Such uniquenesses of each ecosystem and the roles these play in the overall life-processes of Earth are discussed in brief in Chapter VII.

X.2.*i.* Finally we have devoted a full chapter to discuss as to how by introducing receklessly anthropocentric features into ecosystems (i.e. features which are useful to men only) such as, dumping of harmful chemicals into rivers or lakes etc. or pulling down large tracts of virlin forest to make way for ranches or plantations, we are gradually strangling the normal functioning of many of them. Unless such interferences are halted immediately or, regulated stringently so as to let the ecosystem function once again normally, the future of our human race is dark indeed. All these are presented in this chapter—chapter X.

3. PROBLEMS THAT WE HAVE CREATED

After this brief recapitulation of the basic principles of ecology, we shall now make a survey of the major injuries we have already caused to our Earth.

3.*a.* The first major injury that comes to our minds is the **wanton cutting down of trees** and converting good forest lands into agricultural fields or cattle ranches. To-day most countries of the world which includes India and China do not have even 30% of their original forest covers. India has only 23% of its lands covered with forests while U.S.A. has 30%, Canada 54% and Brazil 58%. (Some countries have even less). This is a terrible tragedy. The Thar desert of Western India is man made. 2000 years ago the Thar was a jungle—abode of lions Unless we are cautious now there may be more tragedies ahead of us. Here is a small table summarisig the benefits that we draw from a single good true in 50 years (Table X. 1).

(Data first given by Forest Research Institute, Dehra Dun, India in early 20th Century)

Table X.1

BENEFITS WHICH ACCRUE FROM A TREE IN 50 YEARS (ESTIMATED LIFE)

Item		*Monetary benefit (in rupees)*
1. Oxygen production	–	2,50,000
2. Fodder Production	–	20,000
3. Premention of soil Erosion and Moisture Retention	–	2,50,000
4. Control of Humidity and Temperature of Environment	–	2,50,000
5. Accommodation to other Living Beings	–	2,50,000
6. Green House Effect (Cooling effect through absorption sunlight)	–	5,00,000
TOTAL	–	15,20,000

X.3.b.*i.* The second is **hunting down of wild animals,** some for trophies and some for food. In British India, shooting tigers for trophies and deers

for meat—mostly for barbecue, was a status symbol to the British officers and rich Indians who loved to copy them. Christian Zuber in his thought provoking book 'Animals in Danger' (Barrons, New York, 1978) has reported that the tiger population of India has crashed from 40,000 in 1920 to a mere 1,800 in 1972 (Fig. II.3, & Fig. V.7). This alarming decline is not only due to deforestation but mostly for sports hunting and for furriers—who make a lucrative trade in selling furs, flesh and bones of tigers. Indian princes have also played no mean role in decimating tiger population. "There have been 'Maharajas' who have boasted of holding the world's record for number of tigers they killed. Three of them claimed to have killed 1,000 tigers apiece." The British Officers were not far behind. "There was hardly a British Officer in India who did take back home a number of tiger and panthar pelts to brighten his home in England." After independence Government of India has established the 'Corbett National Park' in the Himalayan Foothills of Western India to protect tigers and other animals. Jim Corbett was a renowned British hunter who had a genuine love and respect for tigers and shot them only to protect the distressed villagers of never for sport.

***ii*. Indian Forest Research Institute** at Dehra Dun, set up in early 20th century, has done valuable works about forest trees and insects but has not paid much attention towards conservation of forest animals. After independence of India, when animal fur as a trophy became very valuable, —poaching multiplied. At times this is done with the connivance of the guardians of forest. Indian lions are gone, tigers are going and if Indians do not wake up now may be even their splendid bird peacock will go the same way.

3.c.*i*. The third is the **unplanned growth of cities**. A city is like a big boil on the skin and the skin is the ecosystem. Just as blood from surrounding areas rushes to a boil and the spot feels warmer similarly, people rushes from surrounding areas to a city for a living. Eventually so many congregate there that they literally make a city climate warmer than the surrounding areas. Also, to make way for houses and roads hundreds of thousands of trees are felled—adding to the heat load of towns.

***ii*.** And just as poison from a boil gradually spreads into the whole body, the **environmental poisons generated by a city populace** such as, wastes, deforestations etc. gradually spread over the entire surrounding areas ravaging the ecosystem. Kolkata the first amongst the four British Indian cities and administrative centre of British India for nearly one hundred and fifty years, is positively an ecological disaster. Kolkata has polluted and silted the river Ganga, largely destroyed a jewel of Mangrove forests - the Sundarbans, swallowed and still swallowing the invaluable swamps in east of Kolkata and its roads, pavements and buildings all are preventing the recharging the groundwater during monsoon and causing a host of other ecological damages.

***iii*. Job Charnock, a British Officer founded Kolkata** in the Eastern side of Ganga, —a predominantly alluvial region, more than three centuries ago, as a trading post safe from the Maratha raiders from west and attacks from Nabab Sirajabdulla from north. Mostly attackers would come from west and so have to cross the river Ganga before attacking Kolkata. Hence Charnock chose East side of Ganga for Kolkata and placed his guns on the ramparts of fort William facing Ganga in west. British even dug a ditch within Kolkata—the 'Maratha Ditch'—to halt the Marathas.

***iv*. This city of Kolkata on the delta of Ganga stands upon millions of years' deposit of clay and peat**. One can still find soft peat soil under about 10' of clayey soil in Accra (Batanagar), near Kolkata. This soft black peat burns like coal. But now-a-days due to inadequate recharging during monsoons (explained earlier), the clayey soil of Kolkata is gradually drying up and buildings are sinking. This is more in Salt Lake area of Kolkata which is built up on swamps recently filled up with silt from Ganga. Roadside trees are not getting enough water as the footpaths are paved up upto the bases of the trees leaving no exposed soil for rainwater to enter into soil. Trees are gradually dying. Planting and maintainence of Kolkata's trees are both unplanned and ecologically unsound. A glance at table X. 1 will remind anybody about the harms of cutting down a tree.

***v*. Disposal of wastes from cities** is another ecological threat. The current tendency of land fils is a hasty cure for shortage of city dwellings. Long term consequences of such unrestricted use of garbage are generally overlooked. Such attitude is hazardous. Garbage needs to be sorted out before reuse. The poisonous chemicals with persistent texicity need to be sorted out before garbage is used. Otherwise such texicants will contaminate the groundwater and then many ills would follow. Only the ecologically harmless portions of garbage may be used for landfill. Part of garbage can be easily used for producing biogase and manures. In fact disposal of to day's garbage needs proper techniques based on knowledge. With use of scientific knowledge and modern managerial techniques the disposal of city-garbage can easily become industries creating jobs as well as giving revenue.

3.d**. Arsenic in Well-Water.** This is a man-made damage. How it is caused is discussed earlier (II. 3.c). Only on 12.01.99 the WNVC, TV in Virginia, U.S.A. reported in 'Asian News' that the wells set up in the hilly regions of Bangladesh for drinking water, with WHO money, are showing dangerously high levels of arsenic. Earlier when there was forest canopy in the hills, this arsenic problem was not there. Now when the forests have mostly been cut down and hence canopy gone, the rainwater without getting a chance to enter the soil rushes off into the nearest river. soil remains relatively dry. Hence Arsenic from lower layers come up and

poisons the well-waters. Similar cases of arsenic in well-waters are recently being reported from several places of West Bengal, India. (For details pl. see earlier II). Arsenic in drinking water is causing serious health problems.

3.e. Burning of Fossil Fuels (coal, oil etc.). Burning of fossil fuels such as coal for thermal plants or cooking or room-heating and petroleum products for automobiles, aircrafts, motor vessels, thermal plants and factories etc. are pouring in a lot of CO_2 into the atmosphere. Green plants are not able to tackle this huge additional load of CO_2 into atmosphere, through photosynthesis. This is resuting in gradual rise of CO_2 content of atmosphere. Consequently there is rise in atmospheric temperature. All these have already been discusses earlier (V. 3.15).

3.f. Explosive Rise in Human Population. Today this is the single biggest challenge facing humanity. Presence of Man is extremely destructive to any ecosystem. Also, higher the standard of living a man has the more costly is he to the ecosystem. Generally vegetarians are relatively cheaper to the ecosystem than the non-vegetarians and rich people who are not only mostly non-vegetarians but also demand many special items to maintian their high profile living. An acre of land may produce 25 quintals of wheat per year but it is unlikely to produce more than 2 quintals of beef per year as beef is a produce of secondary trophic level. A modern educated person would require not only wheat but also, beef, chicken, vegetables, tea, coffee, sugar, cheese, milk, wines, various fruits, etc. all to eat plus car, T.V. friege, washing machine, computer, books, air-conditioners and a host of other things such as variety of clothings, furniture, carpets, quilts and a four or five roomed house. On top of all these to ensure 'quality of life' a modern man must furnish his house with some 'cultural items' such a paintings, sculptures, some animal trophies etc. to remain 'modern' and socially acceptable. Compared to such a 'modern' man as we commonly find in Europe or North America a school teacher in an Indian village, who is by no means uneducated, would need very little to meet his needs. Three simple vegetarian meals a day and milk, a few pieces of simple furniture, three of four sets of cotton dresses, a few books, a bycle and a two roomed cottage, would perhaps satisfy most of his present day needs. But this simple hardworking school teacher of India would soon demand more when he knows that people of his profession in Europe and North America are enjoying such lavish life-style. But will the Indian ecosystem ever be able to provide all these to her one billion children? Not this ecosystem; not this India. At least the present author can't comprehend how. According to the Stanford Biochemist H.R. Hulett the carrying capacity of Earth for human beings living in U.S. standards is about 1 billion people (Ehrlich and Ehrlich, 1970, W.H. Freeman and Co., San Francisco). Our numbers is already far above this. Except a few how many countries of the world will ever be able to provide such facilities to

their all citizens? Here are a few facts gleaned from Table (VI. 2) showing the **land available in suqare metres per capita in some selected countries.** India has only 3400, Bangladesh 1150, and Gaza strip only 364 square metres of land per person. India has only 4% or world's land while 17% of population. This is terrible state indeed. The luckier countries have much more such as U.S.A. has 35,700, Brazil 52,600 and australia has 333,000 square metres of land per person. In fact population rise puts pressure on ecosystem in a two pronged way. One is the simple need of food and clothings and the other is rise in expectations of people. Earlier few thought of owning a car or friege or computer. To-day everybody want these. So we repeat : **POPULATION RISE IS THE SINGLE BIGGEST CHALLENGE FACING TO-DAYS WORLD** whatever else 'pundits' may opine. No country can avoid misery unless his population rise is halted immediately. China is the only country who has understood this ecological lesson and has put it into use. China has halted their population rise and China progressing fast. Whereas Indians only talk but do little. So they are lagging far behind.

3.g. Our Obligations to Animals and Plants. Don't animals have right to live in peace? Are they not as much children of God as as we are? Have we forgotten the Biblical teachings through Noah's arc? Don't animals and plants have as much claim to the milk of mother Earth as we have? Who granted us the *Homo sapiens* the exclusive right to kill and use each and every species of living beings be it a gignatic blue whale (*Balaenoptera* sp.) or a royal Bengal Tiger (*Panthera tigris*) or a beautiful monach butterfly (*Danaus flexippus*) or a shy earthworm (*Pheretima posthuma*) or shady huge banyan tree (*Ficus bengalensis*) or just even the blade of a grass (there are many many species of grasses). Just to suit our convenience? Plants are mute and most animals voice we can't interpret. But they feel and they weep just as we do. Sir Jagadish Chandra Bose a plant biologist from Kolkata proved long ago that (Comparative Electro-Physiology—1907, Longmans, Green) that plants, if hurt plants do feel pain just as we do. My dog Jimmy was such a jolly fellow that we could almost see him laughing while playing with us; In U.S.A. they have animal courts and special laws to prevent cruelty to them. But what about the rest? We firmly believe that every animal has as much right to a chunk of space in Earth as we have. On the other hand the fact that we human beings are endowed with superior mental faculties than plants and animals, this enjoins us to act as the guardians of plants and animals and not their killers. We must protect them from wanton destruction. Every species of living being be it a plant or an animal must have some space to live free from human intervention.

3.h. Our Obligations to our Children. Having enjoyed so much of the generous bounties of mother Earth, we are beholden with the duty of leaving mother Earth, as a better and more rich and more gorgeous place to our children than in what state we found her. With vision and courage

to act now and make suitable sacrifices which are not too much, it is still possible to salvage mother Earth from further impoverishment and set her on road to recovery. Eventually such actions will yield rich dividends for all.

Now let us examine how our knowledge of Ecology can help us to discharge such vital obligations.

4. SOLUTIONS

Just as we have attempted to crystallise the major ecological problems we have created for our mother Earth, here we are proposing such curative measures which, we firmly believe, if adopted now will solve these serious problems to a great extent although may not entirely.

4.a. HALT POPULATION RISE

First halt population rise and than diminish population size

This is the single most urgent task. First thing to do is to halt population growth. Nobody to have more than two children irrespective of sex of the child and second thing to do is to see that in future families become mostly much smaller in size than now. The achievement of these would need a multiproged approach. Both incentives and disincentives are crucial. A incentive such as, cash award amounting to say, 3 to 6 months average pay of a person who goes for family planning after two children would very much induce most people to do so. As disincentives, withdrawal of some facilities such as, pay increments or promotions or trade licences or house loan, bank loans for crop, seeds, fertilisers etc. would put adequate pressure to most people to restrict their family size to two. As an additional incentive rewards may be doubled if one goes for Family Planning after one child. Any Govt. who thinks such expensive rewards as too costly for his exchequer is simply myopic. With a simple personal computer any Govt. Officer can work out how much a Govt. has to spend on education, health, housing, travel, job, old age pension etc.; on a single person during his lifetime. If he does so he will surely find that giving a one time reward to a person for not having more than two children is much more profitable to the Govt. than the latter options. Simply, in most countries there is not enough land for more human beings. Family size is going to be crucial for prosperity of any country. With world's highest female fertility (7.68) and shortest doubling time (10 years). citizens of Gaza strip are most likely to remain poverty-ridden. (Table X. 2).

Table X.2.
SOME SELECTED COUNTRIES OF THE WORLD WITH THEIR FEMALE FERTILITIES, POPULATION GROWTH RATE AND EXPECTED DOUBLING TIME OF POPULATION; ARRANGED IN A DESCENDING ORDER OF DOUBLING TIME* WITH THE SHORTEST TIME AT THE TOP

Country	*Female Fertility*	*Population Growth Rate*	*Double Time (Yrs)*
Gaza Strip	7.68	6.59	10
Afganistan	6.01	4.21	16
Iraq	6.26	3.62	19
Saudi Arabia	6.41	3.42	20
Syria	5.73	3.30	21
Nigeria	6.17	3.05	22
Nicaragua	4.28	2.92	23
Laos	5.76	2.78	25
Cambodia	5.81	2.72	25
Jordon	4.94	2.60	26
Nepal	4.96	2.53	27
Papua New Guinea	4.26	2.27	30
Pakistan	5.02	2.22	31
Malaysia	3.40	2.15	32
Rep. Of Congo	5.06	2.15	32
Tanzania	5.49	2.14	32
Kenya	4.26	2.13	32
Iran	4.52	2.12	33
Egypt	3.50	1.89	37
Mexico	2.97	1.84	38
Bangladesh	3.45	1.82	38
India	3.29	1.72	40
South Africa	3.22	1.51	46
Taiwan	1.77	0.95	73
China	1.81	0.93	75
U.S.A.	2.06	0.89	78
U.K.	1.70	0.25	280
Japan	1.44	0.23	304
Poland	1.36	0.04	1750
Germany	1.24	0.00	–

***Note:** *Doubling Time:* For getting doubling time a thumb rule is used. Seventy divided by percent growth rate per year gives an approximate doubling time of a populations.

4.b. ROLE OF WORLD BANK, INTERNATIONAL MONETORY FUND AND SUCH AID BODIES

World Bank, I.M.F., countries such as G-8 and other such aid organisations and can play a very pivotal role in halting population growths. All aids should be linked with family planning. Except short-terms humanitarian loans for catastrophes such as, cyclones, etc. all long-term loans must be linked with family planning. Any country which seeks

Link all Aids with Family Planning and Basic Education

aids or loans from others must first introduce compulsory family planning and basic education for all its citizens before the country becomes eligible for loans. Population rise must be halted. There is no escape from family planning unless we are happy to live in perpetual misery. Number of children per couple must be restricted to two. (also see 4.a). Bigger families than this must be effectively discouraged. Countries with high female fertilities such as 7.68 (Gaza Strip); 6.41 (Saudi Arabia); 6.26 (Iraq); 6.17 (Nigeria); 5.81 (Cambodia); 5.49 (Tanzania); 4.52 (Iran); 5.02 (Pakistan); 4.96 (Nepal); 3.45 (Bangladesh); 3.29 (India); and similar other countries are a type of population "atom bombs" ticking to explode (Table X. 2.). The whole world is interconnected. Misery and terrorism are sure to reach, sooner or later, other corners of earth which are free from these now. The recent World Trade Towers destruction should be an eye opener to all. Unless immediate as well as long term measures are taken now, more such tragedies are likely to follow. Just as the effect of a boil if left unattended will, effect the whole body, so is with human populations. Poet Tagore very aptly said.....

Limit Female-Fertility to 2 only

হে মোর দুর্ভাগা দেশ, যাদের করেছ অপমান
অপমানে হতে হবে তাহাদের সবার সমান।
মানুষের অধিকারে বঞ্চিত করেছ যারে,
সম্মুখে দাঁড়ায়ে রেখে তবু কোলে দাও নাই স্থান
অপমানে হতে হবে তাহাদের সবার সমান॥

* * * * * *

যারে তুমি নিচে ফেল সে তোমারে বাঁধিবে যে নিচে,
পশ্চাতে রেখেছ যারে সে তোমারে পশ্চাতে টানিছে।

– রবীন্দ্র নাথ ঠাকুর
(গীতাঞ্জলি, অপমানিত)

A glance at the earlier Table (X. 2.) would, we hope convince most our readers that countries with high female fertilities are rushing to the brink of misery and also pulling the rest of the world down with them. Aid without family planning is a sure recipe for breeding terrorism. Besides, owing to corruption most of the International aids gets evaporated in the pipe line leaving very little to reach the destinations. Some of the aid money get siphoned off for arms-purchase from developed countries, many of whom seem to willy nilly connive with these unethical practice. Selling F16 fighter planes to such countries is sure bring more trouble and not peace.

4.c. PROTECTION OF WATER SHED

Prevent Soil Erosion and Desertification

c.*i.* Water from snow-melts and rains all run through mountains, hills and valleys till these reach the rivers and finally the sea. From sea water rises as evaporation to form clouds from which water comes down once again on earth as snows and rains. This goes on year in and year out and the process is called hydrologic cycle. When rain water flows through

wooded water-sheds, a good deal of it gets absorbed in soil (by sponge effect action) and recharges ground water and the aquifers. If, on the other hand, the watershed is made bare owing to human activities such as, deforestation, agriculture etc., the rain water quickly rushes away, carrying away with it huge amount of valuable top soil, before enough of rain water can penetrate the soil to recharge ground water and aquifers, Thus monsoon washes off top-soil and causes extensive land slides, creates gullies, silts up river beds and increase frequency and severity of floods. In fact soil erosion puts the entire river valley system in jeopardy.

***ii*.** Thus Soil Erosion is a very serious problem. It takes more than thousand years to build up one inch topsil. But many places of earth are loosing several inches of top soil owing to erosion. Soil loss through erosion in Asia is highest in the whole World. Asia's Forest cover is also smallest. In India the vast valley of Chambal river is completely ruined by soil erosion. Now the valley is full of ravines and scrub jungles and hideout for outlaws. So the following steps are being proposed to protect the watersheds and river valley systems not only of Asia but also for the rest of the world.

Cover all bare grounds with vegatation

II. RESTRICT DESERTIFICATION

Over the years, man's activities have greatly increased deserts and westlands. Desert covers of Earth surface have increased from 9.4 to 23.3 percent and prime deep forests have decreased from 43.9 to 21.1 percent. The Southern region of Sahara desert and most of Thar desert of India is man made. During the time of emperor Ashok the centre of Thar was forest and abode of lions. Even to day Thar is increasing in size and Sahara is advancing southward on a broad front at a rate of several miles per year.

4.c.iv. PROTECT AND NURTURE THE FORESTS

Cutting down of trees must be halted immediately. This is to be taken on war footing. In forests old trees which are long past their primes may be cut down by timber merchants but only after permission from forest officer and under strict supervision of him. Logging to be strictly controlled and immediately followed with afforestation. Also the same timber merchant must be made to plant four saplings of the same tree and protect this till these grow to suitable height. He should also undertake to repair the damage to the road environment that might be caused by tree-felling and use of heavy vehicles to transport the logs. To ensure all these the merchant must be made to deposit guarantee—money with the Government.

Logging only on Ecologically sound basis

4.c.v. REWARD AFFORESTATION

Each person to plant some trees

Individuals who afforest on their own inclination, ought to be rewarded. This will help greening countryside, reduce soil erosion, provide shelter and food to birds and animals as well as provide an wonderful opportunity of earning for elderly and retired villagers. The reward should be handsome and quick to motivate people and also to be given only after these plants have reached a certain height. Thus villagers on their own would become guardians of forests. *Penalty and reward both are complimentary components of good administration.*

4.c.vi. GRAZING AND TWIG PICKING IN PUBLIC LANDS

vi(*a*). Grazing of all domestic animals in public properties has to be altogether stopped if necessary, by suitable enactments. Grazing loosens the soil surface and thus facilitates washing away of the top soil during monsoons. So grazing does considerable damage to the ecosystem as well as afforestation endeavours. Further of the local domestic animals (with some exceptions) most are of very poor quality and consumes a lot but gives very little. So it seems prevention of grazing in public lands will do three goods. (1) Reduce damage to ecosystem, (2) reduce soil erosion and (3) encourage people to keep only high yielding domestic animals and buy fodder for these. Financially keeping only high quality domestic animals will be more profitable and at the same time keep the ecosystems healthy. Holland is an example.

vi(*b*) Letting villagers to bring their cattle into the forests during day time, must also be stoped forthwith, for the same reason. These cattle not only denudes the forests of their nutrients but also creates too much disturbance to forest animals who need privacy and silence for breeding. We have seen in Mudumalai forests of South India, cattle are let into the forests in the morning and taken out in the evening at about 4 p.m. Also the villagers who accompany the cattle pick up twigs and leaves from the forest floor to be used as fual. The combined activities of the cattle and the villagers not only denude the forest of their vital nutrients but also disturb the forest animals too much. Consequently the soil is impoverished. Besides, the carpet of dead and decaying leaves on the soil surface acts as a sponge and help the rain water to enter the soil and recharge the aquifers. Without this protective carpet rain water will quickly run down the forest floor to the nearest river carrying with it the valuable top soil of forest as silt. Then more ills will follow.

vi.(*c*) Anybody who wants to see himself the harmful effect of grazing on land will only have to do a simple experiment. Fence up a 10' × 10' price of land which forms parts of the land which is grazed, with chicken mesh so that no grazing, twig—picking leaf licking etc. take place. Let it remain so just for one year. The adjacent land will remain semi-barren and

the fenced up piece of land will look like forest in begining [Photo—X.1.(a) & (b)].

vi.(*d*) Summing up. If grazing, twig picking, leaf picking etc. are stopped, the problems of soil erosion will be 50% less if not 75% within just couple of years. Soil erosion in many tropical and sub-tropical countries such as India is man-made which is due to lack of knowledge and indifference of the natives to the long term good of the ecosystem and thus the country. The best way to help villagers or tribals who live in the fringe of the forests or in pockets within forests is to employ them in the service of the forests so that they have some income through forests and at the same time their knowledge of forests can be tapped to protect forests.

4.c.vii. STOP "SLASH AND BURN" CULTIVATION

The 'slash and burn' cultivation which is locally known as "Jhum cultivation" in Eastern Indian hills is still practiced by some local tribals. This is no longer ecologically viable. Population have increased and so have "slash and burns". On the other hand, such scars on valleys increase soil, erosion, river silting and finally floods. The increasing ferocity of the annual monsoon flood of river Brahmaputra is partly due to 'Jhum' cultivations. Government must stop this ill practice if necessary, by compensating the tribals. This will be far cheaper than flood control.

4.c.viii. AGRICULTURE AND SOIL EROSION

Single biggest source of soil erosion, silting and flooding is agriculture. Birth and death of many civilisations are caused by agriculture and grazing by domestic animals. Civilizations of Persia, Mohenjodaro and Harappa all were splendid agricultural civilization. Their demise, we believe, were primarily caused by soil erosion and silting owing to extensive tilling of soil for agriculture. The entire "fertile crescent"* is no longer fertile. To prevent this malady every agriculturist must ensure that the run-off water from his fields do not carry away top soil or silt. He should also stop grazing or at least regulate it carefully so that no soil erosion takes place. Soil erosion must be stopped or at least reduced considerably at all costs otherwise more misery are sure to follow.

4.c.ix. DISCOURAGE SETTLEMENTS NEAR RIVER BANKS

ix.*a*. Human settlements near river banks are ecologically wrong for two reasons. First such settlements mostly get washed away during monsoon

*"Fertile Crescent": Crescent shaped agricultural region of the ancient Near East beginning at the Mediterranean Sea and extending between the Tigris and Euphrates rivers to the Persian Gulf.

floods causing loss of life and property and headache for the governments. Secondly, run off from such settlements carry away additional top soil silting up the river beds further and generating more severe floods in succeeding years. To reduce the extent of such calamities we propose two corrective measures. First all human settlements should allow a 50 to 100 mtrs. margin beyond the high water level of monson. Depending upon the gradient of the water shed, a 50–100^{m} margin should give enough safety margin for monsoon floods. Secondly, all river banks should be meticulously covered with greenery—trees or grasses. And no grazing whatsoever should be permitted in river banks. Cutting or pruning of trees can only be permitted under supervision of forest rangers or similar competent authorities.

Human settlements beyond 100 meters of banks

ix.*b*. River banks near cities are gifts of God. City fathers should convert them into beautiful strands to be enjoyed by all and ruined by none. Unfortunately in many U.D.C.s people look upon the river fronts as free-for-all and hence soon convert these into cess pools of dirt, squalor and crime. The banks of river Ganga on Kolkata and Varanasi and the banks of Jamuna of Delhi are good examples of such misuse. With good will and determination river fronts or waterfronts (by the side of lakes) can be assets. For example, Chicago is a big city of U.S.A. by the side of the Lake Michigan. About 70 years ago the Chicago water front was nearly in as bad shape as the Ganga water front of Kolkata to-day. But the then city-fathers of Chicago resolved to change the situation. Result—to-day the Chicago water front is a pride to Americans and the Kolkata water-front is, we suspect, a shame to Kolkata. This poor state of affair of Kolkata water front is man made and man must undo it. Recently however one Park has been set up in by the side of Ganga at Kolkata. But it is too little.

Develope river-banks as tree-lined strands

4.c.x. RECTIFY AGRICULTURAL PRACTICES

Agricultural practices of many countries need radical changes. Briefly the followings are proposed.

(*a*) First: The modern large farms are ecological disasters. Tilling facilitates soil loss. Loose soil is either carried away with water or blown away by wind. Large farms with their continuous tilled grounds causes considerable soil loss which must be reduced. To achieve this all such farms should maintain a ring of undisturbed forest land like a girdle around them. Such a girdle of forest land would reduce considerably the soil loss and harbour many insects, birds and other animals who would help to check the agricultural pests and thus serve a dual purpose.

Punctuate agricultural fields with strips of forests

(*b*) Secondly, we believe large and continuous tracts of agricultural lands have caused demise of many splendid animals. Lions of India, passenger pegions and bisons of North America and Tasmaniam wolf (*Canis dingo*) of Tasmania all are such victims of agriculture or animal husbandry. It is

time to pause and think. Large tracts of monoculture are very eco-costly.

(*c*) Thirdly, Chemical fertilisers are causing havoc with ecosystems. Eutrophication of rivers and lakes is bringing change in the profiles of flora and fauna of soil, rivers and lakes (explained earlier V. 3.7). All these result mostly from agricultural fertilisers. Developed countries are learning fast and changing their agricultural practices but U.D.C.s like India seem to be reluctant to learn. Generally it seems to us more use of nitrogen fixing bacteria, compost, and such natural fertilising organisms such as earthwarms would reduce the need of chemical fertilisers to a great extent. Also alternate sowing of cereal crops with leguminous crops (pulses) will help in maintaining soil fertility.

Replace chemical fertilisers with bio-fertilisers

4.c.xi. NO MORE INCURSION ON FORESTS

(*a*) Within last seventy to eighty years most of the U.D.C.s have lost between 30-50% of what their forest cover was in the beginning of 20th Century. This loss is mostly due to rise in population of these countries.

(*b*) This population rise however is not due faster breeding as is popularly believed but due to better medical care and use of insecticides —both of which are contributions of Western science and partly due to logging for richer countries who preferred to import cheap and good wood from poor countries to save money as well as their forests. This is still going on. For example, export of the beautiful Salwood (*Shorea robusta*) of from Malayasia and Indonesia is still going on. Another example is the plight of Sunderban in the Gangetic delta of India the abode of India's pride—Royal Bengal Tigers (*Panthera tigirs*). About 100 years ago Sundarbans was nearly double of its present size. To-day Sunderbans is only 2585 sq. km. One single tiger, being the largest carnivore positioned at the top of ecological pyramid, require about 50 sq. km. of forests to provide it with food. So Sunderban of today can't support more than 50 or so tigers. 50 tigers is not enough for a healthy population. *Present day Sunderban is not big enough for tigers.* Some vigorous corrective measures are urgently needed if Indians want to save their tigers and their pride.

Halt in Population Rise will reduce pressure on Forests

Enlarge Sunderbans

(*c*) On top of this precarious situation it is being proposed by the state of West Bengal of India to erect an atomic power station in Sunderban. If tigers of Sunderban can not be saved we think it will be a day of shame for not only Indians but entire humanity. The long term ecological problems that result from atomic power plants are very well documented in N.G.S. of July 2002. We have also discussed about the harms of this projects earlier (IX. 2.B.1g.h.).

(*d*) Summing up, any further shrinkage of any forest land must be halted at all costs. Fallow lands adjacent to the forests should be taken into the forests. Small villages at the fringe of forests should be gradually added to the forests by paying the villagers adequate compensation so that they can

Enlarge Forests wherever possible

settle elsewhere and or, by employing the villagers in forest service. Through vigorous ecotourism money can easily be raised for such compensations. In fact forests and rivers are the life support system of all countries. These must be protected and nurtured at all costs if we want leave a better Mother Earth for our children.

4.c.xii. NURTURING NATURE IS PROFITABLE

Eco tourism will save Forests

(*a*) Moneywise Forests, Lakes, Rivers and Coral reefs alll are revenue yielding resources. Properly managed, all these will attract tourists. Visits to forests, collections of specimens from forests, hunting when culling is necessary, (as they do for deers in U.S.A. and elephants in Zambia, Africa), fishing and boating in lakes, collection of plant specimens for medicine, all can yield revenues. If nature is managed wisely by well trained and well meaning persons, using modern management techniques, we have no doubt whatsoever that protection of the ecosystems will generate assets for a country.

Let Forest Guardians be Co-owners of Forests

(*b*) As an incentive the guardians of forests should be allowed to share a part of the revenue from forests. If this is done immediately the forests, will become assets. Well managed "Safaries" are very profitable. Example —African reserve forests. Much of a reserve depends upon the planners and executors. Here are two examples.

Man Nature wisely and sell forests' produce

Once myself with family spent a day in Jaldapara Reserve Forest in North Bengal, India. I felt the forest is poor and animals are too shy for a reserve forest. Here animals should fear no harm from humans. Their rarity and shyness was certainly not healthy. The second are the reserve forests in Tamilnadu and Karnataka states of South India. There are herds of elephants and stands of sandal wood trees (costliest wood and used only for religious purposes). A person—Birappan—a fugitive from law with his gang has made these forests his abode for the last 20 years or so. He is killing elephants for tasks and cutting down trees of sandal wood for the last 20 years or so without caring for law. He defied the Govt., killed several forest guards and some police efficers including a few senior ones. It is believed that he has made at least 1000 million rupees, if not more, through these illegal operations. Recently he has abducted a very popular film star and asked a ransom for his freedom making absurd demands from the State Govts. of Tamilnadu and Karnataka. It defies common sense to concieve how such a brigand can successfully defy law for a such a long time.

Profitability or liability of Nature depends exclusively upon the wisdom and will of people and Government.

4.d. INTERCONNECT RESERVES : CORRIDORS

(*a*) Unlike plants animals move. In fact they need to move. Passports and Visas are not for them. Some animals produce offstrings in one part of

the globe while they forage and grow to maturity in another part of the globe. The two areas may be thousands of miles apart. Birds from Siberia fly to India during winter to bred [Fig. 4. d.(a)] Eels spawn in the sargaso sea while, the elvers, (eel larvae) grow in Atlantic and English rivers (Fig. VI.22) near Florida, Marine turtles, whales, salmons and many other species regularly travel thousands of miles between breeding grounds and growing arenas. African wildebests and Alaskan moose both travel hundreds of miles in search of food and favourable climate.

Need of Corridors between Reserves

(*b*) Similarly animals in reserve forests need to migrate in search of food or good weather or breeding grounds. To facilitate such migrations all forest reserves, as far as possible, should have corridors connecting each other. Inconnecting corridors would not only help in survival but also help in the admixture of genes and thus ensure the health of a population. Predators are great travellers. Tigers and lions easily travel 20 to 40 miles in a single night. Elephants have to travel even more. Many Afrikan highways are laid along the elephant tracks, as these have best gradients. Most Indian reserves for elephants are too small for their seasonal migration. So frequently these stray into human habitations. Corridors between reserves will help the seasonal migrations of animals and flow of genes. Also as far as possible these corridors should be from north to south to facilitate summer—winter movements.

Corridors would facilitate Gene-Admixture, so species vigour

4.e. RECYCLE GARBAGE

Many of the items we use in our daily lives are recyclable. For example, paper, plastic, wood, metals, glass, and ceremics all are reusable (after due processing). The food wastes can be used to generate biogas and fertilizers. Much of our own resources can be saved by recycling and the environment will remain cleaner. Except North America, European countries and Japan, it seems to us most countries are still not practicing good recycling methods. In many countries of Indian sub-continent, recycling is done genreally by ragpickers. The ragpickers only pick up plastic items, papers and scrap metals. The rest of the garbage is used by estate developers for filling up swamps to build houses on them. This is a very dangerous practice. Many poisonous chemicals thus get released into soil. Bioproducts are not available for power generation. Recyclable items, glass and ceremic are denied recycling. Also indiscriminate feeling up of swamps prevents recharging of water bearing strata of soil and thus increase severity of summer drots.

Many merits of Recycling

4.f. DISPOSAL OF HAZARDOUS CHEMICALS

(*a*) Presently hazardous chemicals in usage are of six broad catagories. **First** the fertilizers, **second** the insecticides, **third** the detergents, **fourth** the industrial effluents, **fifth** burning of fossil fuels and lastly or **sixth** the radio-isotopes. To render each one harmless needs more research to find

out how long each of such items remain toxic in nature, what happens when their breakdown-products interact with other chemicals in nature and the effect of these chemicals and their breakdown product on other non-target living beings. A few examples would elucidate some of these points.

(*b*) DDT in human bodies: DDT (Dichloro-diphenyl-trichloroethane) a chlorinated hydrocarbon is a powerful insecticide. This has been used very extensively all over the world for mosquito control since World War II. DDT is very powerful and at the same time a very durable insecticide. Fifty percent of DDT sprayed in a field may be found in it 10 years later. The other half may not be detoxified—it may only have gone elsewhere. There is another problem. DDE biologically active breakdown product of DDT is virtually immortal. As DDT is so durable, its concentration rises as it moves up through the food chain—from grass to herbivores and finally to carnivores (a process known as biological magnification which has been explained earlier). The permissible level of DDT in cows milk set by Federal Department of Agriculture (F.D.A.), U.S.A. is only 0.05 ppm. But around mid-sixties the level of DDT found in human body fat in different countries was much higher (Table V. 3).

DDT reduces bird-population in nature. In the next example the negative effect of DDT on ecosystem is more vividly demonstrated. DDT interferes with the birds' ability to metabolise calcium. So the birds lay very thin shelled eggs. Such thin shelled eggs are easily crushed by the weight of the nesting parents. So the bird population drops. Populations of fish eating birds such as, peregrine falcon, brown pelican, Bermuda petrol all dropped due to their thin egg cells. Nesting failures amongst the bald egales almost anihilated this species. Bald eagle (*Haliacetus leucocephalus*) is the National Bird of U.S.A. (for more pl. see V). Fortunately timely reduction and complete stoppage of use DDT saved these birds from extinction.

(*c*) In this context Carson's crusade in already mentioned (IX. 2.A.c). Here we shall add a bit more. Rachael Carson (1907-64), editor for U.S. Fish and wildlife Service published a striking book in 1962 "Silent Spring" where she clearly stated that "The chemical barrage, as cruel a weapon as a caveman's club, has been hurled against the fabric of life". Immediately the manufacturers of chemical pesticides challenged her opinion; but gradually she was proved correct till in 1976 the XV Int. Cong. of Entomology firmly rejected the widespread use of broad spectrum and persistant pesticides in favour of an integrated post management approach. Carson's first book, 'The Sea Around Us' was a best seller. In 1952 she resigned her job to write full time. Then came in 1962 'The Silent Spring'. In 1964 she succumbed to cancer.

(*d*) In 1980, India began manufacture of a very powerful toxin methyl isocyanate (MIC) at Bhopal in a factory owned by Union Carbide of

U.S.A. Methyl isocyanate is used to make 'Sevin'* (Carbaryl) a very powerful pesticide effective against more than 100 insect pests. In 1984, on December 3, for reasons not yet clear, MIC from one of the three storage tanks (of 40 tonnes capacity each), leaked out. Safety devices failed. "Within days and with no known treatment or antidote, MIC mained more than 1,00,000 people and killed 2500 making Bhopal accident the worst industrial accident ever" (Brewer, p. 468). The victims are still suffering.

Bhopal accident

(*e*) Letting industrial effluents go into the water systems (rivers and lakes) or air is another source of danger. There are many examples. Here are only two. Only a few months ago fishes of a river Churni, a small river—about 50 miles North East of Kolkata, India, died. On enquiry it was found that effluents from a paper mill entered Churni and caused the death of fishes. The other is C F C and Ozone. C F C or Chloro-fluro-carbon is extensively used in refrigeration. When this leaks out it goes into the upper atmosphere, interacts with Ozone and destroys it. Now, presence of Ozone in upper atmosphere is very important for living beings. Ultra violet rays, a component of solar radiation, is lethal to living beings. Ozone layer of upper atmosphere cuts it off and thus greatly benefits living beings. If Ozone layer is destroyed due to C F C, "Ozone—holes" are created in places of upper atmosphere. Already some Ozone holes are created in the polar regions and harmful effects on living beings of those areas are being noticed.

Industrial Affluents

(*f*) Another extremely problematic area of disposal is radio-active substances. We already know of the horrendous effects of atom bombs through Hiroshima. and Nagasaki. Also the serious consequences of failure of an atomic reactor at Chernobyl, as yet remain unknown to us. A few months ago 'Kursk' a Russian nuclear submarine sunk off North of Norway—in Barents sea with 118 men and officers on board. All these are very worrying indeed.

Radio-isotopes

(*g*) All these, from DDT to nuclear submarines—all are very ominous warnings for humanity. We think all nations ought to do the followings. Review carefully the process of manufacturing, storage, use and detoxification and decomposition of all items manufactured in factories. Medidincs, fertilisers, pesticides, plastics and radio-isotopes—none should escape srcutiny. Stop manufacture, storage and use of atom bombs and similar mass destructive weapons. Halt erection of any atomic power plant till we can ensure complete safety for the ecosystem. United Nations should take this up as one of their priorities. Otherwise cleanup operations would be very expensive (Nat. Geog. Soc. July, 2002), if not painful and hazardous.

*Trade name given by Union Carbide.

X.5. REORGANISE TOWN—PLANNING

5.*a*. Towns are generally children of powerful economic interests. Rarely a town is planned keeping in mind the needs and health of its future growing citizenry. For example, Kolkata was founded by Mr. Job Charnock—an officer of East India Company as a trading centre protected from the periodic forages of Marathas and Nawab Sirajadoulla's soldiers. Thus initial aim was to pick up the merchandise from Eastern India at cheap rates and without trouble and sell those at high rates in England. East India Company saw to it that their English officers and staff can live in decent surroundings. The local people were allowed to stay in the fringe of this English people's Colony and manage as best as they could.

5.*b*. This is the overall history of most of the Indian modern towns which grew up with the English. Thus grew Chennai, thus grew Mumbai. Amongst the modern big town of India only Jamshedpur and Chandigarh are planned from the beginning. As as result of all these life in most of Indian cities and, I believe, in other U.D.C.s as well is very trying. Houses are very conjested, car parking very difficult and road traffic very slow. During office days one takes one hour to travel only 10 km. Roads are very narrow and footpaths are mostly occupied by hawkers. Schools, hospitals, and educational facilities mostly are both inadequate and or poor. Few parks which are left are mostly bereft of lawn and trees and are now being constantly used for Trade Fair or nibbled at by Government. Children have no place to play and olds have no place to stroll or sit upon. Now in order to widen the roads they are pulling down even the shady trees which the earlier city-planers planted. (Trees absorb about 40-45% of incumbent sun's rays). So soon in summer Kolkata will become hotter.

Kolkata's owes

5.*c*. Stagnant house-rent is another bottleneck. In Kolkata house owners can't raise the rents nor can evict the tenants—both of which required lengthy and costly legal procedures, which few can afford. With the result the tenants are paying rents which are 1/10th to 1/50th of the current rents. This has resulted in corruption in various facets.

Stagnant House Rent and Corruption

5.*d*. So vigorous town planning is urgently needed. Towns must be planned for future—remembering the mistakes of the past and sufferings of the present. Followings are some suggestions. These however are based on Kolkata which is the present authors home town. No city should become a megacity. From an ecological point of view 10 million seems to be the upper limit to which a city can grow. Just as a little bit of increase in radius leads to manifold increase in circumference and in a similar way, a little a bit of increase in population of a city beyond healthy level results in various managerial as well as ecological and technological problems. Human beings are not robots; they need a proper psychological environment to grow in a healthy way. In houses adequate space should

be available per person as well as parking facilities for cars etc. Too many people living in small spaces should be discouraged, by law if necessary. High rise buildings are not always ecologically sound. It seems for residential houses a maximum of five and for office upto ten stories should be the upper limits. Roads should be wider (minimum three lanes), with wide footpaths all of which should be laced with turf for rain water to enter into soil, and trees at least on one side. Most of the rain water of Towns/cities should be allowed to percolate into the city soil so that aquifers become recharged during monsoon. No stalls should be permitted on foothpaths. There must be adequate car parks in all public places such as markets, offices, sports ground, parks, strands etc.. Target space should be one car for every fourth person. If necessary under- ground car-parks and wherever unavoidable, multistory above ground car parks ahould be constructed. Very soon every family will own one car if not two. City planners should brace themselves up for these urgent tasks.

Eco-Friendly Town Planning: A few Suggestions

5.*e*. Parking car in New Market area of Kolkata is a nightmare. This should have never been allowed. If all the existing municipal markets of Kolkata can be converted into 10 storey shopping malls with 2-4 storey undergrounds car parks and if under all large tanks 2-4 storey car parks are constructed, present car parking problems will largely vanish.

10 storey shopping malls and car parks under markets and tanks

5.*f*. Sewerage and garbage disposal is most primitive in most of the U.D.C, cities and towns. In cities in tropical and subtropical regions where heavy monsoon rains are not uncommon, sewerage should be adequate for such exigencies. Kolkata's chronic water logging in monsoon is a glaring example of inadequacy in planning and execution. Such things should end. Garbage should be presorted at the point of its generation and then put to reuse. This does not need any import of technology only needs will and consciousness of the citizenry.

Sewarage and Garbage

5.*g*. Rent laws of many cities particularly Kolkata, are very primitive. While a landlord is not permitted to increase the rent (which might be his livelihood) of his house except going through long-drawn and expensive legal proceedings which may take years and a fortune to settle but a vendor of tea in footpath can raise with immunity the price of his cup of tea every three or four months. Hotel owners including those owned by Govt. can raise their tariff almost every year. As a matter of fact everybody can raise the price of his /her merchandise but not the landlord. This is as if to be a landlord is a crime. One fails to understand the logic behind this system. If I.T.D.C. (Indian Tourism Development Corporation) can raise room rents of his hotels why can't the landlord for the rooms of his house? It seems the grand intention of such laws is to protect the interest of the middle class (a very hazy concept anyway). But the result do not seem to be so. All these should end. New rent laws should be enacted with justice for all and progress of the country in mind.

Rent Laws vs. Hotel Tariffs

5.*h*. There should be **plenty of open space in a city.** Parks, lakes, canals, gardens and sports fields all should be in plenty. Every child should have access to a park within at least half a kilometre of his/her residence. Cities like Kolkata, Varanasi, Allahabad and Delhi are blessed. They are situated on river banks which are such natural assets. If the strands are developed properly these could be beauty spots of a city. In no circumstances a park should be viewed by politicians as a no man's land ready for grabbing. Calcutta maiddan has already been nibbled at in many places in this way. These should never happen again. Parks are like sacred social temples—meeting ground for all. Nobody should fracture them. Like the body a Cheetah a city need to have plenty of green spots i.e. parks. These parks should have tanks, play grounds and trees. Parks with trees and tree-lined boulvards will not only provide shades to people and roosts for birds, trees also produce oxygen—a vital requirement for all living beings. Trees also keep a place cool by absorbing 40% of sunlight. Similarly large tanks with some land around these as watersheds will act as injection points to recharge aquifers with rainwater.

Parks with trees and tanks

Tree line Boulevards

5.*i*. A city should never have any factory which produces harmful affluents. These should be located far from the cities with adequate protection for environment. Modernisation of rent-control law is revelent even from this angle as well. Sometimes it is found that the grandfather who was the original tenant used the house for residence but the grandson has converted the house into a factory—perhaps a tannery. The present landlord stands as an helpless onlooker.

Factories in Cities

5.*j*. Cities in U.D.C.s tend to collect a considerable size of floating population. These people stay in city virtually free of cost. They sleep free of cost on pavements, use parks and river-banks for answering calls of nature, use roadside water taps for taking baths and washing clothes and for running footpath restaurants. Virtually except buying food they spend no money for living in a city like Kolkata. All of them earn—husband, wife, children all—and send thousands of rupees every month to their homes. Many own lucrative businesses right on the footpaths of busy commercial centres and earn much better than many tax paying job holders. Some of them owns cows and goats etc. which roam and feed free in the "maidan" of Kolkata and give milk or meat to their owners to make money. Besides food these people perhaps spend nothing more to stay and earn in Kolkata. But the tax payers are bearing their burden. This reminds us of Charles Dickens' portrayal of London night during his time. Are we still living at that age?

Floating Population of a City

5.*k*. All these must be put an end to. Footpaths should not be used for sleeping in night. Night bunks should be provided for by Government on a fee. Roadside taps should only be used for drinking water and not for bathing, washing and running tea stalls or food stalls. For such purposes special paytaps should be arranged. For answering calls of nature

Pay and Use Facilities

frequent pay and use public toilets should be installed. **All citizens i.e. people who live and earn in a city should pay for the city facilities they enjoy.** Getting things free spoils people's character and in the long term even the nation is affected.

Canals as Roads

5.*l.* Many of the city features of to-day can easily give dividends. Fishing and boating in lakes can be charged for. Canals can serve as roadways and also provide for fishing. These will be economically profitable and reduce conjestion on roads and traffic fumes.

Lecture Arenas

5.*m*. Need for public places for meetings: It seems all good cities and towns should have several large open spaces—such as large fields, for lectures by anybody. Police permission or intervention is undesirable as long as the speaker does not encourage violence. Such places for airing one's views openly lets the steam out of a person and thus in the long run helps all.

X.6. AGRICULTURE AND ECOLOGY

6.*a*. One of the aims of Ecology is to find out how we can encourage one species and discourage another. So aim the agriculturists. The agriculturists however depend more upon artificial inputs such as, fertilisers, pesticides, and power tilling. The ecologists on the other hand tend to exploit more of biological principles such as competition, symbiosis etc. While the first are environment costly the latter are environment friendly. Here are some suggestions based on the latter approach.

India an U.D.C. is already producing enough food for its own citizens. Based on current information, Indians have 97.5 kg of cereals available per person per year (Table—X.3.) 97.5 kg. of cereals per year for a person is certainly more than adequate as, besides cereals there are other items which go into the dinner plate of people. The following points/view presented here based on the above table and information from earlier chapters.

Table X.3
ANNUAL PRODUCTION OF CEREALS IN INDIA AND CEREALS AVAILABLE PER CAPITA PER YEAR. (BASED ON DATA OF 1999)

Annual Production (Ton)	*Population (Millions)*	*Available per capita (gross)*	*Less 25% as wastage from insects, rats etc.*	*Available per capita (Net)*
130 million	1000 million	130 Kg.	97.5 million	97.5 Kg.

Halt Deforestation

6.*b*. Based on the above data on India, it can be safely suggested that no more forests need be felled in India to make way for agriculture, or pastures or plantations.

Fourth Phase: Phase of Genetic Engineering

6.*c*. As per the history of human civilisation **world is now at the doorstep of fourth cultural phase.** The earliest was the phase of hunters and food gatherers; next came the phase of herdsmen and the third is the current phase—the phase of agriculturists. Now mankind is poised at the threshold of the next phase—the **phase of genetic engineering** i.e. agriculturists of genetically engineered plants. At each phase food production per acre rose broadly ten fold. So did the human population (Fig. I.1). Now if both U.D.C. and D.C.s use genetically engineered seeds or clones only, the production of food will rise so much that the world will literally float on "milk and honey". At the same time we must put an end to any further rise of human population sparing no costs. Soon after stabilising population growth we should aim at a gradual reduction of population all over the world (save perhaps a few countries such as Australia). Then we shall easily be able to return some lands to forests. More forests will result in less soil erosion and more space for flora and fauna to occupy and all to enjoy.

Bio-garden

6.*d*. Need of bio-gardens. As more and more genetically engineered seeds and clones will go into agriculture and animal husbandary, more and more native plants and animals will tend to vanish. That will be hazardous. Each species has evolved over hundreds of thousands of years to fit a particular niche. To eradicate any of them just to make way for our immediate needs will be ecologically costly and will also cause irreperable damage to Nature. We are custodians of Nature and not a band of usurpers. In order to prevent this risk all countries should join hands and create extensive bio-gardens all over the world—both on land and sea, spread over thousands of square kilometres apiece. In these bio-gardens all endemic varieties and species of plants and animals will be left in peace to breed and survive as per the laws of Nature. As far as possible these should be interconnected three corridors.

Vegetarianism is ecofriendly and more healthy

6.*e*. Need for vegetarianism: From our knowledge of ecology we now know that weight for weight, meat production requires approximately ten times more land than food grains. Therefore the more men adopt vegetarian food habits the less will be our need for land for agriculture and pasture. The preponderence of vegetarians amongst the Indians is an eco-friendly habit. We now know that as a result of 'biological magnification' (please refer V), the various chemicals we use to-day in agriculture are becoming increasingly concentrated in our bodies as these move from plants to herbivores and from them to carnivores, (ex. DDT in human body, Table V. 3.). Very likely some of these unwanted guests into our bodies are the causes of some of our present-day ailments. For example, it has been proved that the virility of human males is going down as the use of chemicals in our daily lives are going up. It seems therefore both on the count of demand for land and on the count of concentration of poisonous chemicals into our bodies, vegetarianism is a better option.

6.*f*. Should we eliminate competition amongst humans?

Should human beings who are born with congenital defects be allowed to reproduce uncontrolled and perpetuate those defects? Or, let the natural process of competition and elimination of the unfit be allowed to prevail? Most of the attitudes which are prevalent now seem to stem from hearts than from heads. With more and more technology at our disposal, human societies are becoming increasingly insulated from forces of Nature. Nature tends to eliminate the weak and favour the fittest and thus maintains species vigour. Are we not interfering too much with the forces of nature?

Competition and elimination of the unfit

6.*g*. It seems it is time politicians, scientists, social scientists, doctors and such people should take a hard look on this important issue of reproduction by persons having congenital drawbacks. Now-a-days owning to urge of family planning and availability of better medical care, infants even with congenital defects mostly survive and can pass on their defective genes to the society and thus perpetuate it. It is time the aforesaid peer group should ponder on this grave issue and then give a humane as well as logical advice to parents regarding the suitability of their having children with serious genetical drawbacks, without infringing however upon their basic human rights, on a case-by-case-basis. It is a very contentious issue but still a beginning should be made.

Congenital draw back and defects

X.7. BETTER WATER MANAGEMENT

7.*a*. Most of the underdeveoped countries receive a good deal of rain water. However due to lack of knowledge and enterprise these countries are not able to make much profit from this bounty of Nature. Mostly rainfall is allowed to rush down the ground-surface to the nearest river or lake after, a wet monsoon and giving only one seasonal crop and leaving rest of the year more or less dry and unproductive. Using ecological principles as guidelines and energy to act, much of the surplus water of monsoon can be used much more effectively. First, some rainwater can be stored into small above-ground tanks to be used as drinking water throughout the year. This will solve arsenic problem. Secondly, part of rainwater can be stored in suitable small earth impoundments or dug-out ponds for irrigation during dry seasons. Thirdly, some rainwater need to be allowed to seep into the soil to replenish the depletion of ground water owing to irrigation wells and tube wells etc.

Monsoon water and its proper use

7.*b*. All the three above suggestions are neither economically costly nor need hitech. UDCs can easily construct small earth/stone impoundments in hilly areas or dig suitable ponds in flat lands. Local people can donate some free labour and also sell the surplus earth thus dug out from the pond. The seeping of rainwater into the soil can also be encouraged easily. The roads and the footpaths can be thus paved that, rainwater falling on these instead of rushing headlong to the nearest river or lake

Revenue from Water

through the sewers, will slowly seep into the soil through a turfed strip of land by the side of roads and the rest would flow into a nearby lake which will form part of park for the neighbourhood. Every town and city should be dotted with such parks and lakes. From fishing, boating, swimming and their orchards, a park can give good revenue. Further, rewarding of individuals for afforestation in public lands and compulsory afforestation for loggers will help increase the ground cover with trees and recharging the aquifers. Grazing of domestic animals in public properties should also be strictly regulated and charged for so that saplings and ground cover of soil with vegetation is not disturbed.

All the three above suggesions if put into action will greatly ameliorate the chronic water shortage problems of many UDCs without much cost. These would neitheir need foreign aid nor hitech. Only will to act and use of a little bit of ecological knowledge, are adequate.

X.8. ECO-POLITICS

8.*a.* Political decisions are most conducive when these are enmeshed and strengthened with scientific discoveries and inventions. During 15th to 18 centuries a number of very important discoveries were made in West European countries. Prince Henry the Navigator of Portugal (1394-1460) established a School of Navigaton which made vast improvements in techniques of navigation in sea. Sir Isac Newton in England (1642-1727) and Wilhelm Leibniz of Germany (1646-1716) developed Calculus which helped in astronomical calculations and navigation in sea. All branches of Sciences underwent a spurt of growth. At that time the King of Portugal commissioned several expeditions through sea to find an alternate sea route to India—the fabled land of wealth. (The other known route was through land which was dominated by Arabs). Bartolomeu Dias was sent South. He arrived at Indies in 1447. Christopher Columbus sailed west and arrived at a island of Bahama group, near America in 1942. Dom Vasco da Gama arrived at Calicut of India in 1498. Later, Captain James Cooke sailed on his now-famous circum-navigational voyage sailing, "Endeavour", and arrived at Australia, New Zealand and Tasmania during 1768-71 and hoisted flags of Gt. Britain on these vast areas. During that period Sir Joseph Banks (1743-1820), a young, rich and Oxford trained naturalist provided the outfit of Cook's expedition and accompanied him. On return to England Banks threw himself into a flurry of activities, initiating steps to collect economic plants from all over the world and introduce them in suitable countries. The then reigning monarch of England patronised Banks. The famous Kew Botanic Gardens in London is primarily a result of Banks' endeavours. Similarly at that time Warren Hastings—the first Governor General of India (1774-85) sent an expedition to Tibet primarily collect and bring all plants/animals from there, which are likely to be economically beneficial. Thus from 1500 till 1800 European civilisations spread out rapidly to the entire world and

Scientific Discoveries and Expansion of Western Culture and Torpor in Orient

through them a new global order emerged. Thus began exploitation of Nature and spread of European culture in a global scale. During that golden age of Europe, Orient was languishing in the glories of her past.

8.*b*. Ecology is a growing branch of science. Its main aim is to find out the relationships of living beings including humans with their environment and vice versa. Knowledge of ecology ought to be very relevant for national planning. Unfortunately however, men in power particularly in U.D.C.s mostly run after quick profit sometimes even by comprising long-term interests of their nations. To compound the problem further the so called intellectuals of U.D.C.s tend to confine themselves with narrow academics without trying honestly enough to make their knowledge and skill useful to their countries. National decision-makers too rarely demand their service and result oriented works. Gradually with time, such intellectuals get distanced from society and her needs. Many Universities in the Orient tend to remain—serene and aloof without much concern about the needs of the society which supports them. Consequently, many political decisions in the U.D.C.s are of ad hoc nature without using much of science and consideration for long term interests of the countries and ecological consequenses of such actions. Many of these motional interests however can be easily identified if ecological principles are considered. Here are some examples:

Ecology and National Planning

8.*c*. Selling out national resources most of which are of non-renewable nature. It is an well established fact of ecology that when watershed gets exposed owing to logging or agriculture etc. severe soil erosion follows leading to many ills. Old regal sal trees (*Shorea robusta*) of Malayasia are being cut down and exported. Most of these must be more than hundred years old but are still healthy and having a diameter of 4 feet or so. These are being sold to rich countries for dollars apparently without cosidering the severe ecological damages that is being caused to the land. Malayasia's beautiful forests along animal fauna all are going. One has only to read a few pages of **Alfred Russell Wallace's** travel memories of Malaysia's jungles to get a glimpse of its past beauties of that region. It is a natiolnal tragedy for Malaysia whose ripple would soon reach rest of the world. When the public will at last wake up it will be too late. India is exporting her best iron ores from Balaidilla mines of Orissa, with 80% iron, which is world's best, for money. Mineral resources are irreplacable, and one should be very very cautious about using up these. In Congo valley of Africa they are cutting down lots of prime forests for wood to make figurines for export or for decorated coffins. These are ecologically very unsound practices. Many U.D.C.s are replete with such mistakes. U.S.A. is carefully protecting per prime forests. Ecological consciousness amongst the guardians of these UDCs could have ameliorated many of such ills. The paws of Dollars are on the throats of most UDCs.

U.D.C.s are selling out their wealth

8.*d*. Governing without considering effects of population interaction/ (i.e. ignoring Gause's principle). Gause's principle states clearly when two populatios compete for the same resource, one who have slight edge over the other will ultimately eliminate the later. For instance, when an ethnic group of financially very smart people migrates amongst another ethnic group of people, whose financial sense is not so keen, as the immigrants; the native group will soon find themselves outwitted and outmanouvored by the immigrants. The recent success of immigrants from Gujarat. India, to U.S.A. is an example. Such immigrants have captured a large share of the chain food shops and other businesses. Similarly, the money market of Kolkata is by and large, gone into the hands of people from other corners of India. The locals are outwitted. Histories of human migration is replete with stories of such tragedies for the locals and comedies for the immigrants. Again this is also an ecological truth that the population intermix and gene interflow are necessary to improve populations. Therefore powers that rule the countries should ensure some amount of competition but not allow complete elimination of one group by another so that, ultimately by slow intermingling of populations all will benefit. Success of U.S.A. as a nation seems to us, owes much to this slow admixture of various populations. Afro-Amricans to day are as much an American as Euro-Americans are. So to ensure survival of all communities in an area/state, government has to allow provisions so that a relative weak comunity does not have to face very stiff competition but at the same time is not entirely free of competition. Such policy will ensure slow admixture and improvement of all communities. Theocratic societies or countries who tend to discourage presence of other communities amongst them usually with time degenerate.

Gause's Principle and mixing of human populations

8.*e*. Demography and populations balance

Demography, a branch of population ecology, clearly shows that the nature of a population will be largly guided by size and nature of its pre-reproductive and reproductive populations, besides female fertility and infant mortality. Short sighted politicians tend to keep their eyes off these guidelines merely for the sake of winning elections. India is a good example. One of her Former Prime Minister amended the Constitution of India so as to let the Muslims have four wives at a time but not the non-Muslims. This discreminatory change in civil codes will ensure a faster growth of Muslim population in India than Hindus. Presumably Late Prime Minister did this unnatural thing to ensure Muslim votes so that he can retain his position in Parliament. Two ills may follow such an unsecular and ecologically unsound enactment. First: This will lead to demographic imbalance—with percentage of Muslims in Indian population perpetually rising against a perpetual drop in the percentage of non-Muslims. Secondly: The loyalty of Indian Muslim citizens will suffer from doubt. Now both of these appear to be happening.

Importance of secularity

8.*f.* This is however not fair to the Muslim community. We are sure some of them are as much loyal as any other Indian. Late Captain Hanifuddin of Indian Army is an example. During the Kargil conflict Captain Hanifuddin faught against Pakistan raiders, who were all Muslims, with examplary courage and fortitude. He laid down his life to recapture a strategic peak which the raiders sneaked up to during winter snow-storms. Befittingly India has renamed that peak as Hanifuddin peak. Nevertheless, if any Government woos a particular section of a cummunity for vote, at the cost of other sections, painful consequences are bound to follow. Already such symptoms are becoming increasingly conspicuous in India. Disregard to simple basic ecological principles by men in power causes a lot of harm to a country and its ecosystem. Considering all the above it seems to us that just as economists are required for National Planning so are ecologists. Both are vital.

Need of Ecologists in National Planning

X.9. WORLD BANK AND POPULATION OF UNDER—DEVELOPED COUNTRIES

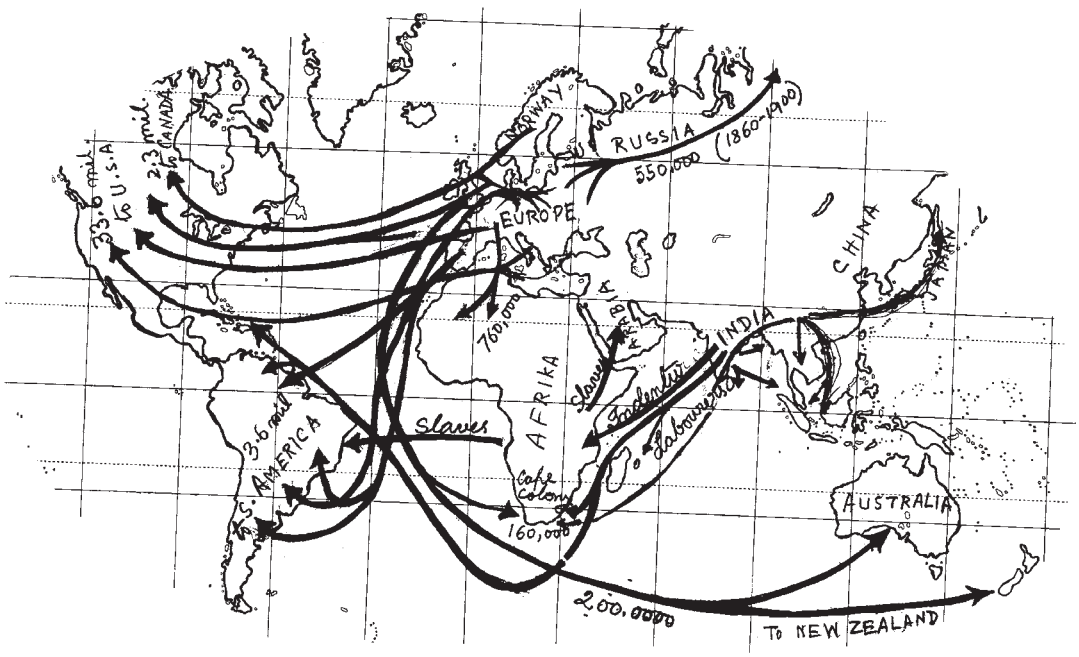
9.*a.* Most U.D.C.s are poor; their poverty however is largely man-made. Interestingly, most of them are rich in natural resources. When these countries achieved independence from their European rulers, they were left in relative peace and with a strong administrative fabric. Unfortunately however, when the ruled became rulers, most lost their sights. Instead of guiding their young countries to higher levels education, family planning and prosperity, most rulers, (with a few honourable exceptions), set their targets on personal interests and vote banks. The inevitables followed. Gradually these countries became riddled with corruption and burdened with bigger and bigger debts from developed countries. These, coupled with reduction in child mortalities and no serious effort for family planning, soon led to explosive growth of populations. With a little arithmatic and plain foresight the leaders could have easily guessed what lies ahead and so could take correative measures. But this they did not. Singapore is perhaps the only exception. Its leader had foresight and courage to act. In spite of poverty and ethnic diversity to start with, today Singapore stands with her head high in the comity of Nations.

9.*b.* India had 30 and Bangladesh (then East Pakistan) had $2^{1}/_{2}$ crore people when they became indepemdemt in 1947. Now they have 100 and 10 crores respectively. Inevitably they are always at the door of World Bank with beggars' bowl. World Bank which is primarily nourished with Developed Countries's (D.C.) money is giving loans but hardly the right advice. Instead of linking aids with population control, they are giving aids for power generation, agriculture etc. These are only short term solutions of some needs but the source of all problems—the rising populations remains unattended. Availability of more power and food-aids have, in a sense, become counterproductive to the U.D.C.s. Earlier infant

Over-population and Corruption

mortality of most U.D.C.s. were very high. Besides frequent famines, cholera, malaria, ptyphoid, small-pox etc. greatly checked the population rise (Darwinian effects). Today the influence of these natural population controls, owing to better medical facilities, are far less effective. Besides the surplus populations U.D.C.s have no place to go and colonise as D.C.s did earlier. Here we place some data from Harper Collins ATLAS OF WORLD HISTORY, 1998. (page 208 & 209).

9.*c.* It has been estimated that in the 19th century the population of the world expanded more rapidly than in any previous period, from about 900 million to 1600 million. (During the 20th century it was to grow four times faster.) The population of Europe increased from 190 million to 423 million; at the same time, European peoples—the emigrants and their descendants—settled in North and South America, South Africa, Australia, New Zealand and Siberia, and the population of these regions grew from 5,670,000 to 200,000,000 between 1810 and 1910 of the three countries which were the leading industrial states in 1914—the United Kingdom, Germany and the United States—the population had increased nearly five fold in the previous hundred years. The distribution of the world's population at the beginning of the 20th century was estimated to be as follows (again in millions): Europe 423, Asia 937, Africa 120, North and South America 144 and Australia 6. Here is a map of the world population movements from 1821 to 1910 (Map. X. 1.).



Map X.1 Migration of human populations from 1821-1910.

9.*d.* Amongst the earlier leaders of the U.D.C.s Chairman Mao Tse Tung of China was the only leader who had the right foresight. He insisted on family planning and self-dependence. India never learnt this lesson from China. To-day U.S.A. is flirting with China but frowning at India. China's atom bombs are O.K. with the D.C.s but India's and Pakistan's atom bombs are not. (The author does not support any atom bombs—whosoever may be the manufacturer or the owner. It is the partiality of the D.Cs' attitude that he is pointing out. This is not fair. Unfair actions breed unfair reactions). So the U.D.C.s of today are comming more and more under the economic domination of the D.C.s. and also the surplus population of U.D.C.s of today has no such opportunity for large scale migrations as the D.C.s had and still have. Unfortunately the U.D.C.s in general, seem to be indifferent of this menacing problem. Their too little land is shrinking further. Moreover some of their leaders even look upon population rise as an aid to their vote-bank. Some seem to encourage illegal immigration just for vote bank without caring for the horrendous future they are laying the seeds of. These myopic policies appear to us as a source of misery of most U.D.C.s. Only the Indian industrialist Late Mr. J. R. D. Tata foresaw this problem and tried his best to convince the rulers to pursue a more vigorous population control policy. But he failed. According to the latest census (2001) West Bengal of India, now has nearly 80 million people but only 88,752 sq. km. area. Can such a overpopulated state ever be affluent and develop a balanced economy? So is true of most of the other countries.

Oportunity of migrations D.C.s had and still have

9.*e.* Another game the D.C.s appear to be playing and which the U.D.C.s are not seeing through seem to be this. On flimsy excuses they are encouraging U.D.C.s to split up and become smaller states. The game is simple. A small state will remain permanently under the apron of D.C.s. For themselves D.C.s have different policy. They are uniting and becoming stronger. East and West Germany have become united and European Economic Community with single currency have been formed. Only recently EEC of 15 states have admitted 10 more states into their fold and thus has become a mega-state of 25 members—virtually an empire. Americans faught a civil was under the leadership of Late President Abraham Lincoln to remain united; whereas India faught a small civil war in 1946 to become devided. These two smaller countries, created by splitting one country, (by the then British rulers), are bleeding since then, whereas recently U.S.A and Canada has come under a single protective canopy for defence.

Altitude of the D.C.s

9.*f.* Late Prime Minister Winston Churchill once said that he would like to name the Second World War as the 'Unnecessary War' (Memories of Second World War. Winston Churchill, 1948-65. In the same way I would like to call the division of India into India and Pakistan in 1947 as 'The Unnecessary Division'. Also, Churchill once said that the uniting all the english speaking nations of the world under one banner, would be his

greatest service to his country. The U.D.C.s in general, dont seem to learn much lessons from history. The single biggest challenge to most of the U.D.C.s of today is to halt the galloping rise of their population. And another is to stop this fissiparous tendencies amongst their politicians and local leaders and make them realise where lies their real good.

X.10. ECOLOGY, EDUCATION AND VALUES

10.*a*. To a nation a properly educated person is an asset and a wrongly educated person is a liability. Violence is no way for fixing wrongs. The people or organisations who are orchastrating such senseless destructions and killings of the innocents as in World Trade Centre (11.09.2001), in Bali Night Club, in a train in Madrid, or valley of Kashimir, or Moscow and many other corners of the Earth , are doing more harm to their causes than good. While a person like Mahatma Gandhi with his message of universal love and non-violence, or Mother Teresa of Kolkata with her kind hands extended to sufferers to any corner of the earth or charitable organisation like Bharat Sevashram Sangha of Kolkata who always rush to any spot of natural calamity with food and clothings or for that matter International Red Cross, all are working as universal balm for humanity—always trying to save a life and not to take a life.

10.*b*. So for enduring peace and prosperity for future, all nations' first priority should be to educate their children in a proper way. Proper education is a self-regulating and self-correcting device. When into the young and impressionable minds of children the seeds of universal love, honesty and fairplay are implanted by family and teachers, these take root and stay put. Such children develop into useful and powerful adults. Unfortunately, many countries particularly U.D.C.s are not allotting enough money and thought for educating their future citizens. These countries are content if the people are literate. But mere literacy is not enough—not at all enough. The post-school education are mostly limited to teaching the students only a few skills by using which they will be able to earn a living. Most young people aim only at making money and more money. Few seem to look beyond money and seek higher goals. Fewer still seem to worry about moral values, loyalties, duties to nation and obligation to Nature. The state of affairs in some countries are deplorable. Some countries go even further. State fund is spend to teach students specific religious creeds to the exclusion of all others. Some of these creeds seem to teach their students about the superiority of one particular religion and stress on the inferiority of others' and so look down on them. Thus the seeds of dissention and hatred are sowed early in life.

Education and Ethics

10.*c*. Man does not live by bread alone. Therefore, besides teaching a student a skill for a livelihood, which he must earn, he must also be made conscious of the higher aims of human beings who are the supreme creations of God. We submit that besides teaching a student a skill to

earn a livelihood, a student needs to be taught the duties of a Man to Nature, to his Nation, to others who belong to Other Nations—as the world is really a whole and one—(only artificially partitioned by politicians for mean self-interests) and duties to his Family and Friends. The ultimate goal of Man is the search of self-realisation and see that he brings joy, happiness and prosperity to an ever widening circle of Humanity and Nature.

10.*d*. While we strive on and on the road to progress, we shall commit mistakes. But let not the mistakes be deterrents. As long as the intentions are fair and honourable, we should admit the mistakes, rectify the course and move on. We may be slow but still we shall progress. Philosophers said "Wounds of Reason can be Healed by Reason Alone". In the sanscrit scripture 'Vedas' this attitude is very optly put through a terse phrase.

Phitosophy and aim of Life

("Halt Not, Move on, Move on"—Translation by author)

The twin vice of igorance and greed have caused considerable damage to the health of our Mother Earth, still, all is not lost. If each one of us read a little, think a little, and do a little for Her. Her health will surely be restored. She will once again flower into Her many splendoured beauty and humanity will truely enter the Garden of Eden.

A little knowledge of Ecology and its practice in life would form the first step towards that goal.

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