Ecology and Earth History Richard N. T-W-Fiennes

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RICHARD N. T-W-FIENNES

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INTRODUCTION

This volume outlines in simple terms the basic concepts of ecology. It is not a textbook of ecology, but an introduction to the subject and to the more advanced presentations of special aspects that will appear in succeeding volumes. There are many excellent textbooks of ecology, to some of which the reader is referred and to which the present volume should also serve as a useful primer.

I have linked this presentation of ecological theory to a survey of present theories of Earth History. All of earth history is, in a sense, ecology. Earth's environments have evolved throughout the ages from the time when no life existed, just as life forms have evolved from primitive to complex. It seems to me, therefore, that one should understand how these environments have come into being. I have also presented a simple account of the energy systems that are used by living things. These too need to be understood, if we are to appreciate energy problems. Man, like all other living things, requires the energy provided by his food, but unlike other creatures his way of life demands additional ('auxiliary') energy, and this has introduced a new factor to man's ecology. Hitherto, most of this auxiliary energy has been obtained from fossil fuels, coal, oil and uranium. But these are not inexhaustible; they represent capital, not income, and it is still not clear what the sources of the auxiliary energy will be.

The sun's energy is responsible also for the movements of the clouds, the winds and the ocean currents, and for circulating fresh water from the oceans to land surfaces. Otherwise, there could be no life on land. Here again, man's ecology demands more than that of other animals. Not only must man have water for drinking, but also for removal of his industrial and urban wastes. There are signs too that, lacking further energy input, this resource may be inadequate.

Man's future is beset with many doubts and complexities. To overcome them, mankind must understand his nature and move forward to find solutions that will be of benefit to all.

NOTES

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2 H. Godwin and A.G. Tansley, *The Natural History of Wicken Fen,* Bowes & Bowes, Cambridge, 1929

3 R.N.T -W - Fiennes, *The Ecology of the Grasses of the Lango District of Uganda, East Africa,* Government Printer, Entebbe, 1939

4 H.W. Mulligan (ed.), *The African Trypanosomiases,* Allen & Unwin, London, 1970
5 R.N.T -W - Fiennes, *Man, Nature and Disease,* Weidenfeld & Nicolson, London, 1964

Further Reading

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1 GENERAL PRINCIPLES OF ECOLOGY

The Evolution of Habitat

In its simplest meaning, ecology is the study of habitat (Greek *oikos*, house or habitation). Ecology has, however, become a complex science with a terminology of its own and journals devoted to it. Only recently has the word appeared in the popular press in connection with environmental problems. In spite of this, as a science it has a respectable ancestry. Early naturalists, including Wallace and Darwin, recognised the relationships of living things with their habitat and with each other. Definitive studies on ecology appear to have been initiated by a German scientist, Möbius, in the 1880s. Subsequently and until the present day, the importance of such studies has been widely recognised and they have been pursued in Britain and North America, as well as in Germany. A critical review of the subject is given by Macfadyen,[1] and a short, but useful account by Healey.[2]

It is obvious that certain kinds of animals or plants can only live in certain types of habitat. Fishes cannot live out of water and a monkey thrown into water will drown if it cannot escape. It is generally accepted, too, that since life appeared on earth there has been a progression of life forms of increasing complexity. This progression is attributed to evolution, a process which increasingly adapts living things to be successful in the areas where they are evolved.

It may be less obvious that not only life forms undergo a process of evolution, but habitats as well. You have only to observe the local duck-pond to see that, left unhampered, water weeds grow in it and in time it gets filled and becomes earth with grass and trees and shrubs growing where there was once water. Similarly, look at any disused road or air strip and you will see that the surface is gradually weathered away, plants appear, in time soil is formed and it will eventually appear not unlike the surrounding area. Even on hard concrete, you can see that lichens quickly appear on the surface, followed by mosses and other plants.

Ecology basically looks at habitats in an evolutionary sense. It regards them initially as sterile areas, devoid of vegetation or other forms of life. 'Pioneer' forms of plant life then appear and begin to erode the surface or alter it in some other way which makes it more suitable for colonisation. The process continues and more demanding plants appear, which continue the process. At the same time, weathering assists the development: wind and rainfall break up and fissure the surface; frozen water in winter widens the fissures; roots of shrubs or small trees will enter the fissures and break them wide open; and soil begins to be formed. The evolution of a habitat proceeds by a series of steps or 'successions' until the 'climax' is reached. The 'climax' is the point at which both habitat and life forms on it are in full unison, so that development will not proceed further provided there is no change of climate. Examples of 'climax' habitats are primary forest, such as the big equatorial forests in Central Africa and South America, and prairie grasslands like those developed on chernozem soils across central North America and the steppes of Siberia and southern Russia into Europe. In such areas, a characteristic animal fauna is developed also, adapted to the conditions of the habitat: there are forest animals and birds in the forests, and plains animals and birds on the plains, differing in their ways of acquiring food, in colour and other protective measures, and in their general reactions and physiology.

The general process of 'succession' is known as a 'sere'. The process arising in water is known as a 'hydrosere' and that on land or rock surfaces as a 'xerosere'. The direct succession to the climax is known as the 'primary succession'. If, however, there is interference with the climax, as by cutting timber or clearing for agriculture, a 'secondary succession' develops, which may be a reversion to an earlier stage of the 'primary succession', or something different. When there is interference with a pre-climax stage of a succession, as, say, by dry season burning, the 'primary succession' may be deflected, and we speak of a 'deflected succession', which may reach a kind of climax of its own persisting until the cause of the deflection is removed.

An understanding of these seres and their stages is fundamental to an understanding of environmental problems and pollution by human activities. Most of these create a new form of pioneer surface, on which the object of reclamation is to recreate an advantageous succession leading to recovery in the shortest possible time. Soil erosion leads to loss of topsoil and in tropical areas to laterisation – that is chemical change and rock-like concretion – of the subsoil. The reverse process under natural conditions may take centuries, but the ecologist may find ways to hasten the process. Large sections of the Sahara carried human and animal populations within human memory and have been converted to desert largely by human activities.[3,4] If the process of desiccation can be reversed, this can only be done with a knowledge of the ways in which suitable ecological successions can be encouraged. A polluted river or estuary is another instance of a pioneer type of substrate, which can be remedied if the right kind of microbes are introduced to devour the pollutants or in the case of chemical pollutants to alter them by their metabolic activities. Even oil slicks can be attacked by the right kind of organisms and quickly degraded into harmless substances or even into nutrients for higher forms of life.

The spate of journalism in recent years on ecology and the environment appears to ignore the absolute necessity of studying the ways in which natural processes may be stimulated and accelerated. Governments appear mesmerised by the necessity of appearing to do something, even the wrong thing, rather than to invest the public's money in fundamental research on these problems. One might suppose, from what one reads, that human activities are universally detrimental to earth's environment, certainly from his own point of view. The natural successions have been either deliberately or unwittingly 'deflected'. The problem is to understand the nature of these deflections and to remove their undesirable features; this means study.

The Ecological Community

Hitherto, we have considered the successions which occur in an ecological sere. Let us now look at the concept of the 'community' or 'ecosystem', to use the term introduced by A. G. Tansley[5] in 1935. First, what are the factors which determine the type of community to be developed in a given habitat? There are only two of major importance, the climate and the soil. It might be objected that this ignores the importance of the atmosphere. The composition of the earth's atmosphere has, however, been so constant over millions of years that we can for the present ignore it.

Like much in ecology, the influence of climate is superficially obvious. In the most extreme climates, waterless desert and polar ice, life cannot exist, although abundant unicellular protozoa live in the waters below the polar ice. At the other extreme, life is most abundant and prolific in the wet tropics, where rainfall is heaviest and the sun's rays are most powerful. In such areas, too, seasonal variations are at a minimum, whereas in other areas rainfall and temperatures are variable throughout the year and the vegetation varies also. Both plants and animals show adaptations to lean periods when water is scarce or the temperatures low. Trees shed their leaves; annual plants bury their seeds in the ground to grow again when conditions are favourable; some birds – mammals too – migrate, and some mammals, birds and reptiles hibernate or aestivate. These are commonplace facts and do not require elaboration. They are, however, facts of which ecology takes account, and which the ecologist must study if he is to understand his area.

The facts relating to soil conditions are somewhat more complex. As a basic principle, soil is formed from a parent rock, usually the rock underlying it. However, it may be impoverished by leaching or erosion, or enriched by wash or silt. Usually the chemicals present in a soil will only be those present in the parent rock. If this is deficient in any of the minerals important for plant growth, these will be deficient in the soil too. There are many minerals important for plant growth, such as calcium, phosphorus, magnesium, zinc, cobalt, molybdenum, manganese, iron and copper. In some cases, only trace quantities of the element are needed. In some areas, plant growth is limited by these deficiencies and is less luxuriant than climatic conditions would appear to warrant. As a result of the poor growth of herbage, the development of a rich soil is either retarded or inhibited. It also happens that soil minerals may be adequate for the development of a rich plant cover, but are inadequate for the nutritional requirements of animals that feed on them. In this case, the fauna is scanty, although the vegetation is rich and might be expected to support large numbers of animals. In all parts of the world, areas are known where domestic animals do not thrive on the pastures, suffering from deficiency diseases known by various names, such as pine, swayback, staggers, and so on. These diseases were for a long time a mystery to stock-breeders, until it was discovered that there existed underlying defects in the minerals present in the soil. The deficiencies are sometimes slight, and one Australian farmer remedied a deficiency of copper by drawing a short length of copper pipe across his pastures behind a tractor.

As soils develop, they become enriched by the addition of humus. This is derived from broken-down organic debris of dead plant and animal material. Thus, the more quickly rich vegetation becomes established in a habitat, the more quickly will the soil become improved and move towards climax conditions. Here again the ecologist, and indeed the town-house gardener, can accelerate the process by thorough cultivation and by addition of materials to the soil to remedy deficiencies and improve its structure and water-holding capacity. These activities, however, must be properly orientated and based on proper soil analysis and examination. With the more difficult types of habitat, such as sand dunes and salt marshes, much can be done also by introducing pioneer plants adapted to them; certain types of grass will grow on sand dunes and, when introduced, will initiate the soil formation process.

Quite apart from the plants we can see, the soil itself teems with life. Everybody knows of the beneficial effect of earthworms in aerating and improving the soil structure. The soil is also alive with bacteria, fungi, small helminths and other organisms, whose activities are advantageous; indeed, without this active life in the soil itself, many of the higher plants we can see could not exist. Not least amongst these are the small fungi and bacteria which form root nodules on coniferous trees and leguminous plants, such as clover, so fixing atmospheric nitrogen, and their allies in the soil.

Also amongst these organisms are the so-called saprophytes, responsible for breaking down dead organic material and making its products ready for re-use. Without this 'recycling' of organic materials, life will in time grind to a halt. Unfortunately, in the euphoria which followed the discovery of agricultural chemicals, their effect on soil communities was largely overlooked as with their effect on the insect life required for plant pollination. Today, in our large combine-harvested fields scant attention is still paid to the effects of these chemicals on the soil-living communities; pests are eradicated by chemicals and deficiencies made good by the use of artificial fertilisers. Aeration and structure of the soil are ignored and experts are asking how long such conditions can persist; belatedly land-owners are stipulating specified rest periods for their fields during which recovery can take place. But can it? Again, organised ecological studies of soil life are essential, if permanent deterioration of soils is not to take place as has happened over such vast areas of the American Middle West and elsewhere.

Soils, therefore, to achieve optimum development must not only contain all the minerals necessary for the plants and animals they are to support, but must also be properly aerated and maintained by the small organisms that live in them. These organisms form the base of the ecological pyramid, their biomass (weight of living matter) far exceeding that of the visible plants and animals which depend on them at higher levels. Many of them use energy systems quite different from higher plants and animals; some do not require oxygen; some use as energy sources chemicals that are not available to higher plants and animals. Thus they perform activities that cannot be undertaken by other life forms and in situations not available to them; for instance they are found both in oil wells and in the upper layers of the atmosphere. They provide us with our antibiotics, our wine, bread, beer and soft cheeses, and are used in many industrial processes. To understand their activities is as important as not destroying them by artificial processes in agriculture.

An ecological community, then, is an association ('associes') of micro-organisms and higher plants and animals, which live together, are dependent on each other, and contribute to the improvement of the environment to a point dependent on conditions of climate and soil. We can now study the organisation of the community and the factors which lead to its stability. This is of special importance because man's activities in one way or another have so radically altered so many habitats and communities in ignorance of their structure and indifference to the effects. This is no new problem, because man has been doing it for 10,000 years or more; it is a pressing problem because of the increase in human numbers which has made the effects more widespread.

The Stability of the Ecosystem

Most plants and animals, of which the rat, man and the housefly are notable exceptions, are very 'habitat specific'; that is to say that they are confined to habitats which suit them within rather narrow limits. Quite slight alterations of a habitat result in a different species of bird, for example. When the habitats merge or intergrade, there may be a 'tension zone' where the two species are found but are in competition. Such gradations are seen in the case of a 'hydrosere', where at one end there is open water gradually rising through marsh from sloping land to upland. In such a situation, the vegetation – and the animals dependent on it – is 'zoned' from aquatic plants through marsh plants, to lowland wet-loving plants – grass and sedge – to dry-loving upland plants and trees.

A habitat comprises numerous 'niches', and there is a life form ideally suited to fill each niche. If a niche is empty, some form will quickly appear to fill it. Niches are extremely varied. We have already seen how many varied organisms live in and on the soil. Small insects and other creatures live in cracks in the bark of trees, under stones, and in every conceivable place where they can achieve their needs for food and breeding and reasonable security from predators. The term (niche) covers not only the places in which these creatures live, but also food requirements. For example, a niche is offered by animals living in the bark of trees for predators such as woodpeckers, or monkeys with long thin fingers that can get at them. Thus in each habitat, there exist food chains or food webs, which can be exceedingly complex in rich habitats such as tropical forest or rather simple in poor habitats such as desert. Basically, the energy which is the driving force of life is trapped by plant chlorophyll and used to convert carbon dioxide (CO_2) into higher carbohydrates such as starch, sugars, and fats. The stored energy is passed from mouth to mouth, through herbivores, carnivores, predators and scavengers, until it is dissipated by processes of decay and the residual organic materials are returned to the pool to be recycled.

In fertile areas, the communities developed are complex, well balanced and stable. Obviously they cannot be stable unless the numbers of plants and animals living in the community are kept within the limits that the habitat can support. To achieve this, the natural balances are maintained at optimum levels by a number of devices which serve to limit numbers when they tend to become excessive, and to build up numbers when conditions become favourable. Either way, the result is achieved in a remarkably short time. The underlying principle of this control is simple. More young are produced than can survive and the excess are eliminated in one way or another. Since the strongest – or at least the most fitted to the conditions – survive, the tendency is for constant improvement of the stock or a change of characteristics if this is advantageous because of changed circumstances. Once this principle is understood, it is easy to see the basic difficulties underlying human population problems at the present time. It is our endeavour to have as many of our babies survive as possible, irrespective of population pressures, and we thus preserve the weak and ill-adapted as well as the strong and well adapted. In this way, we could on the face of it be contributing to deterioration of the race. Authorities, such as the British geneticist Dr A.R. Penrose,[6] think that this is not necessarily the case, and that evolution in human communities is powerfully at work, but in a different way, as discussed in Chapter 4. J.B.S. Haldane also held this view.

Elimination of excessive young, which we shall examine below, is not the only way in which numbers are controlled. Both mammalian and avian populations are very sensitive to population pressures; when populations tend to become excessive, the community enters a 'stressed' state, especially if food is short. The condition of 'stress' is undergone by all members of the community and depends on alterations in the activity of glands of the endocrine system, especially the cortex of the adrenal gland. Through complicated feedback mechanisms, the animals become psychologically affected and more aggressive, the breeding urge becomes diminished and the females when they become pregnant are inclined to abort, and in any case bear fewer young. The young, when born, are inclined to be attacked and killed, and older and sick animals are also killed. In addition, the population becomes more susceptible to endemic diseases and parasites so that there is a higher natural death rate. In some animals, a migratory instinct develops and large numbers may leave the habitat to seek other suitable areas, or perish in the attempt. The suicidal migrations of the lemmings in Scandinavian countries are the best known example.[7]

The extent to which animals produce excessive young varies greatly. It is probably greatest amongst parasites, such as ticks and helminth worms, which must find a new host by rather hit and miss methods. Thus a female tick produces millions of eggs, dying herself in the process; these all hatch into larvae, of which probably only a few score find hosts; incapable of a free-living life, the rest perish. Small, vulnerable, short-lived animals such as rats and mice tend to produce large numbers of young, of which only a few survive unless conditions are especially suitable, when a plague of them may occur. The smaller birds too produce many more eggs than are likely to be needed for the next generation of breeding stock.

A number of these excess young may die at the hands of predators or from failure to find sufficient food. There is, however, a further controlling mechanism of the greatest importance, not only to the control of populations, but also to the structure and behaviour of a population within the community. This is the 'territorial' instinct. The instinct for territory is extremely ancient and universal, at any rate throughout the vertebrate kingdom. It is present among fish as well as mammals. It is surely not defunct in man, though not universally operative. The underlying principle, as with most principles of ecology, is again a simple one. Animals do not pair and breed until they have acquired a territory, and the territory they acquire must be adequate to provide them with food, a place to rear their young, and sufficient cover for their protection. A territory once acquired is respected by neighbouring animals of the same species, and trespassers, when attacked, do not defend themselves but retire. Territories are marked by various means. Birds proclaim their dominance over a territory in their song. Mammals mostly mark their territories by means of scent produced from scent glands or in the urine as with wolves and dogs. Animals with a social organisation, as say with monkeys and apes, carry the process a stage further in the 'social hierarchy' system. This is the system of the peck order; in which both males and females arrange themselves in a social order of dominants and subordinates. Amongst horses, the subordinate males are driven from the herd or killed. Amongst baboons and chimpanzees, they are tolerated but the dominant male is usually the one to cover the females. In any case, if numbers become too great, the subordinates are driven away and become easy prey for predators.

In the jungle code, indiscriminate killing of prey animals by predators does not *normally* occur, though overkills are sometimes reported. Predators take what they require and leave the main herd unmolested. The animals mostly taken are the young, which are produced in excessive numbers in any case, and the old and the sick which are more easily caught. The removal of the latter will lead to improvement of the herd generally and is not undesirable. Human beings too, such as the Red Indians and the Eskimos, obeyed these jungle laws, and although they lived by hunting the bison and caribou, never made harmful inroads on the stock, possibly because before the advent of the rifle they lacked the means to do so. They lived in harmony with nature for many generations before the appearance of Western man, the destroyer. The wanton killing of wildlife by Western man, a destruction which in some areas still continues, is an indelible blot on the human record. This is often done because of pure wantonness; at other times it is because of fancied harm done by the animals attacked, such as the usually amiable wolves or the seals which are supposed to deplete fish stocks. This is another instance in which ecological studies are required to lay old bogies.

Ecology, then, teaches us how to live together in well-balanced