Problems of Control of the Biosphere

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In Scientific World, *No. 2, 1973, we published an article by P. Kapitza, of the U S S R, on aspects of environmental pollution: we publish here a second article from the U S S R on problems of control of the Biosphere. The authors express a guarded optimism on human influences on nature, and stress the role of science in neutralizing untoward effects—given the right social environment.*

THE EARTH'S BIOSPHERE, which came into being at the same time as living matter, simultaneously expanded and became more and more complex. The world of living things with its increasingly progressive forms of organization invaded the depths of seas and oceans, populated the atmosphere, converting the upper layer of the lithosphere to soil. But even today, when life exists on Earth in 1.5 million species and the weight of the biomass is in excess of 300 000 million tons on a dry matter basis, the biosphere remains a delicate film covering the Earth's surface and therefore having a spherical form.

Mankind is the product of historical development and a component part of the biosphere, as well as an entity differing from, interacting with and opposed to it. In the course of Mankind's historical progress, the dialectical *interaction* of society and the biosphere gradually transforms into *control* — at first of individual elements of the biosphere, then of its larger parts and, finally, of the entire biosphere on a planetary scale. Mankind has still a long way to go to the practical solution of the latter problem, but on a theoretical plane it is already urgent. We shall discuss only briefly some philosophical aspects of this problem.

Mankind's entry into the epoch of the scientific-technological revolution in the second half of the 20th century has resulted not only in a wider scale but also in a fundamental qualitative change of the actual character of the impact produced by society on nature. In earlier epochs this impact was relatively limited in respect both of its scale and consequences. In the 19th century the key problem of interaction between society and nature, in the opinion of bourgeois champions and of opponents of Malthusianism, was one of populating the Earth's territory by the human race and of supplying the growing population with food. Today, however, this interchange of matter between society and the biosphere is clearly receding to the background despite the "population explosion" due to the reduction in the mortality rate and the continuing high birth rate in the developing countries. According to ecological estimates, the 3 500 million people living today are producing as great an impact on nature as would have taken roughly 30-40 thousand million people to produce in the Stone Age, although per capita food consumption is about the same as it was thousands of years ago. The key factor today is the *impact produced on nature by human technology,* resulting, in, particular, in pollution of the environment with production and household wastes.

The basic factors of influence on the biosphere are conditioned today not so much by the increase in population and in agricultural production, development of new territories, etc., as by industrial, technological production activities, which result in pollution of the atmosphere and the waters of rivers, lakes, and oceans with dust, gases, chemicals and radioactive substances dangerous to health.

The report of the CPSU Central Committee to the 24th Congress referred to nature conservation as an internal problem and as an international problem. Taking steps to accelerate scientific and technological progress in the U S S R, "it is necesary to do everything to combine it with a frugal attitude to natural resources so that it will not be a source of dangerous pollution of the air and water, of exhaustion of the soil". The report emphasized the willingness of the Soviet State "to participate also in collective international measures for conservation of nature and national utilization of its resources", "in solving such problems as protection of the environment".*

Control of the biosphere

Control of the biosphere is, in perspective, one of the most breathtaking tasks facing mankind. The complete incompatibility of capitalism with the requirements of historical progress manifests itself with striking clarity in this question. F. Engels spoke of this as far back as a century ago. Noting the discrepancy between the goals set and the results of human activity, Engels saw the root cause of this discrepancy in the domination of private interest.

Transition from man's spontaneous influence on the biosphere to its conscious control is unthinkable without a knowledge of the laws governing the functioning and development of the biosphere. Of all the sciences of the biological cycle ecology is undoubtedly the one to tackle this problem.

Every biogeocenosis as an element of the biosphere is in turn a most complex system whose elements are populations of definite species of animals, plants and micro-organisms, entering into its composition. According to V. N. Sukachev's conception, biogeocenoses are biological macrosystems which must be considered as peculiar natural laboratories whose law of life is the unity of living and indirect components. The principal "division of labour" within them is as follows: plants produce primary organic products, animals feed on plants, and micro-organisms decompose organic matter produced by both, thereby providing conditions for the circulation of matter and energy. Biogeocenoses possess simultaneously a measure of stability in given environmental conditions, and variability. The stability of biogeocenoses (and not infrequently their productivity as well) increases with the growing complexity of their structures. In complex systems, energy is consumed more economically, the food chains are longer and many of them run in parallel. This creates an opportunity for mutual substitution in case of emergency; plants, these

*"*Proceedings of the 24th CPSU Congress", Moscow,* 1971, *pp.* 57-58, 30.

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suppliers of primary products, can feed a larger number of animals, and the system's biological mass grows by increment of natural products of the greatest value to man. Such biogeocenoses are usually characterized by the greatest stability, the system spending a relatively smaller amount of energy to maintain this stability.

This can be demonstrated by comparison of the biogeocenoses of different agricultural lands. Forests planted in the midst of fields are remarkable for their rich fauna. There, up to 1 500 different animal species may often be encountered, many of which are potential pests. Their mass-scale multiplication, however, is observed rarely, lasts for a short period; a well-balanced system quickly disposes of "trouble-makers". On natural meadows, however, the number of animal species is usually less than in a forest but here, too, pests, as a rule do not cause serious damage, because this system is also well-balanced and every pest meets with a host of enemies, competitors and parasites. On sowed grass fields, the number of species declines to a few hundred, the stability of the system is reduced, and an increase in the number of individual species is observed more often, lasts longer and causes appreciable damage. Finally, on ploughed land the number of animal species is still smaller, and here the stability of the system must be maintained by man. Not infrequently, it is impossible in general to maintain crops in normal conditions without special measures to fight animal pests.

The above described law is manifested distinctly in the observation of forest cultures. Fruit orchards perish within years if they are not protected against insect pests. Insect control must be among obligatory measures for the protection of cultivated forest land. A natural forest, for example the taiga, however, is capable of disposing of pests on its own. Even massive explosions of the population of the most formidable pests cannot disturb the dynamic balance of a natural system. A biogeocenosis treats its diseases itself.

A problem of biology and agriculture

Control of biogeocenoses with a view to raising their productivity and stability is a problem biological science is called upon to solve jointly with agricultural practice. To this end we must use not only the most effective measures to increase crop yields, to compensate by our activity for the instability of a cultivated biogeocenosis, but we must also take account of its internal laws.

This is important above all because changes we make in one of the links of the casual chain may lead to unforeseeable consequences. Let us examine the following concrete example by way of illustration. Scientists produced a model population of a specialized species of moth developing on wheat (an inexhaustible food reserve) and established that, in the absence of enemies, moths produce overpopulated colonies, and the greater part of their larvae perish. This accounts for the paradoxical results of subsequent experiments: during bacterial episodes (which destroyed up to 90 per cent of larvae) the total pest population, far from declining, sharply increased. The effective regulator of moth populations was a predatory tick which reduced the density of individual populations to from one tenth to one twentieth. The combined action of parasites and ticks, however, not only fails to produce the extinction of their "prey" but may even cause a rise in its population. A sharp reduction in the density of the prey population leads to the death of predators while the prey population increases. These results may be explained biologically. The character of changes in population and the rate of moth propagation are "calculated" for predators. Absence of predators disturbs the type of reproduction natural for a species, so that overpopulation results with all its ensuring consequences.

Since even the most primitive artificial communities are extremely complex biological phenomena whose development is governed by strict laws, it is not difficult to visualize the wide variety of events taking place within systems composed of hundreds of species. Regulations of the internal links means that under the same conditions (with equal supply of energy) the productivity of biogeocenoses may differ widely. This gives grounds for optimism. Indeed, man is unable to regulate the supply of energy in different geogrphical regions. Science is so far helpless in this field. But we are already capable of regulating the composition of communities and consequently the productivity of living systems.

Another basic trend which gives a practical outlet to ecology is the neutralization of harmful influences produced on natural and cultivated biogeocenoses by industrial activity—the growth of cities, motor transport, pollution of seas and inland bodies of water, changes in the atmosphere, etc. Here it is particularly important to emphasize dangers involved in underestimation of the laws governing the life of a biogeocenosis. The point in question is usually those obvious dangers which lead to an essential change in the numbers of one or several of its dominating components, i.e when a disturbance of the structure of the biogeocenosis which ensures its stability is a direct sequel of anthropogenis influence (change in chemistry of water results in the death of fish, insecticides or herbicides kill representatives of useful flora and fauna, etc.). Such facts strike the eye, and this enables us to take measures relatively quickly to save a valuable species or community threatened with extinction.

Not less dangerous, however, are situations in which a change in the habitat of living organisms does not lead directly to the destruction of or a decline in the population of any of the species making up biocenoses but changes the energy of their life processes.

For example, the industrial development of a region leads to an insignificant rise in the climatic temperature which influence the developments of animals and plants. But different species react differently to a disturbance in the environment, which results in a disco-ordination of activities within a biocenosis. The degree of its stability is reduced, disturbing the dynamic balance which supports the potential immortality of the existing ecological systems. The consequences likely to result from it are exemplified by the unprecedented explosion in the starfish ("a wreath of thorns") population which must be regarded as a catastrophe, if not on a global then of a continental scale, since this threatens the coasts of Australia. The essence of this catastrophe consists in a disturbance of natural balance, the destruction of the biocenoses of coral reefs.

The stability of living systems

The stability of many biogeocenoses is so great that their age is incommensurate with the age of objects of inanimate nature, and this is perceived as the "eternity" of steppes, forests and prairies. The stability of a living system, however, is based on the great sensitivity of its elements to changes in the environment. The more sensitive a living component of a biogeocenosis to a change is the conditions of its existence, the more perfect is the reaction of the population homeostasis and the less probable is the irreversible change of the biogeocenoses as a whole, and the greater is its stability. The mechanisms of maintaining the stability of a living system, however, operate faultlessly only within a historically conditioned range of environmental factors. If these factors are changed, the destruction of a biocenosis is only a matter of time.

Modern biology considers biogeocenoses to be functional units of the biosphere. Consequently, it may be asserted that an anthropogenic change in the environment causing disco-ordination of the functions of biogeocenoses poses a more formidable danger than direct destruction of individual species of animals and plants. The key to understanding and consequently to averting this danger is to regard biogeocenoses as systems whose dynamic balance can be maintained within a very broad but not limitless range of environmental factors.

The links of biogeocenoses in the biosphere are links between elements of a single system; therefore, cenoses must be regarded as open systems. The interconnections between biogeocenoses manifest themselves in different aspects: two of them—spatial and functional—are particularly important. Periodical and non-periodical migrations of animals connect biogeocenoses separated by great distances into a single ecological system. For example, a change in the "wintering" conditions of birds in the tropics determines the number of the major components of Arctic cenoses; a change in the conditions existing in reed thickets of southern rivers determines the populations of migrating locust forms and may cause a catastrophe in far away northern cenoses; the outbreak of epizooties of rabies among bats of South America may produce an essential influence on the biocenoses of the Far North; radioactive fallout from an atomic explosion at the equator carried by the air masses on the border of the troposphere and the stratosphere produces a heightened radioactive background in the Arctic with all the biological consequences involved. These and similar examples clearly demonstrate that the independence of biogeocenoses is conventional, and that the biosphere is a single entity. It follows from this that hopes for localizing existing disturbances in the biosphere are naive, to say the least, and that therefore control of the biosphere requires joint efforts by all the nations.

Another aspect of the same problem is the interconnection of biogeocenoses developing in different media—aquatic and terrestrial. Despite the fact that the conditions of existence in water and on land are widely different, fresh-water and land cenoses form a single whole. Many species of insects, for example, those whose larval stages live in water, on completion of the metamorphosis, bring from the body of water a tremendous quantity of live protoplasm running into millions of tons in a given landscape zone. It is natural, therefore, that any change in the environmental conditions on land is to be followed by a corresponding change in the structure of fresh-water cenoses. Usually this does not lead to an essential cenotic imbalance, since the population mechanisms regulate the "entrance" and "exit" of the biological mass from a body of water. When, however, environmental changes go beyond the historically formed limits, a disturbance in cenotic balance becomes inevitable. To assess the scope of such a "disco-ordination" of functions of the biological system, suffice it to mention that the weight of a swarm of certain insects runs into thousands of tons.

Thus, in assessing human influence on nature, optimism must be based on clear awareness of all the dangers, both direct and indirect, with which this influence is fraught, and on consideration of all the remedies science has at its disposal for neutralizing untoward effects.

The biological proper, or rather ecological, levers of control of living nature have been described above in brief. Knowing the laws governing the relationships of populations within a biogeocenosis we can settle new species in it which will contribute to an increase in the productivity and stability of cenoses, regulate its composition, affecting the size of individual populations, using some factors to oppose others made inevitable by industrial growth, etc.

The role of ecology

Ecology may be described as the science of the structure of living nature on earth, the structure of the biosphere. This is precisely why it is potentially the science of control of the development of the biosphere. Of course, ecology cannot neutralize predatory, reckless actions causing damage to the biosphere which are intrinsically connected with capitalism. Nevertheless, it can warn of many of such consequences of these actions that escape public notice and are underestimated, contributing thereby to efforts to secure nature conservation. Its genuine positive role, however, will be brought into full play under social conditions ensuring purposive and consistent struggle for providing the optimum conditions for man's welfare on a global scale. The socialist transformation of society gives us a key to the solution of this problem and a basis for real optimism, making possible a correct assessment of the gravity and scope of the hazards involved in the scientific-technological revolution, in the initial stages of its historical development.

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