Russian Journal of Ecology, Vol. 32, No. 6, 2001, pp. 369–374. Translated from Ekologiya, No. 6, 2001, pp. 403–408.
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Man in the Light of Current Ecological Problems

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Received May 22, 2001

Abstract—The interaction of man and nature is considered in terms of classical ecology, which is becoming a synthetic systemic science based on a set of other sciences. The divisions of modern human ecology that deal with different organizational levels of ecological systems have been developed to different degrees. Attention is given to the necessity of discrediting the mechanistic concept of opposition between man and nature and taking into account the specific ecological functions of man related to group adaptation (culture), as well as the global role of all living organisms in the maintenance of environmental conditions on Earth.

Key words: human ecology, the global role of man in the biosphere, population ecology.

The new synthetic branch of science that is called human ecology has been rapidly developing in recent years. Three approaches to human ecology (as well as general ecology) may be distinguished: narrow (medical and physiological), broad (interdisciplinary), and traditionally ecological (Bol'shakov *et al.*, 1996, 1997; Kryazhimskii, 1999; Rozenberg, 1999). The first approach is focused on the effect of the ecological (environmental) situation on human health and adaptation to changes in this situation (Kaznacheev, 1988). The second approach, which is now widely used abroad, regards human ecology as a vast conglomeration of humanities and sciences.

An example of this vague understanding of human ecology is the definition proposed by the International Center for Human Ecology, which unites universities in France, Belgium, Switzerland, Italy, and Denmark: "Human ecology might be seen either as the beginning of a new scientific discipline, a reflection on science and its values, or an approach to societies in their environment. More precisely, human ecology initiates, starting from different disciplinary approaches, a methodological step forward, taking into account the dynamics of the biocultural interactions in ecosystems" (Hens, 1996).

In this study, we uphold the third viewpoint, according to which human ecology is defined as special ecology, i.e., the ecology of the species *Homo sapiens* (Alekseev, 1993; Bol'shakov *et al.*, 1997; Kryazhimskii, 1999). Human ecology has formed on the basis of classical ecology and should primarily use the set of tools and approaches developed within the framework of this science, which is now considered to represent a new generation of sciences.

MODERN ECOLOGY AS A SCIENCE OF A NEW GENERATION

Until a relatively recent time (about the mid-20th century), "classical" natural sciences, whose standards were set by theoretical physics, mainly dealt with the linear cause-and-effect series (one cause and one consequence). For example, theoretical mechanics provides a precise solution to the problem of attraction between two bodies (the sun and a planet) and, hence, makes it possible to precisely predict the future positions of terrestrial bodies and even the existence of the planets that are as yet unknown to astronomers. Due to the prevalence of mechanistic philosophy, the universe was viewed as something like a giant clockwork that can be disassembled and reassembled again.

The mechanistic approach was founded by great people such as G. Galileo, F. Bacon, R. Descartes, and I. Newton, who brought to perfection the mechanistic picture of the world. At that time, nature appeared to be a comprehensible, harmonic, and fairly simple construction; and science, which had understood the essence of this harmony, was the power that could allow the people to really put the universe under control. Mathematics became the language of theoretical physics.

Nevertheless, the signs of inconsistency of the mechanistic approach became obvious in science, primarily physics, on the verge of the 20th century. The scientific community encountered the problems that could not be solved in terms of mechanistic theories. For example, from the mathematical viewpoint, the problem of interaction between three bodies has no analytical solution and can only be solved by the method of approximation. Scientists did not address most of these problems until recently; attempts to depart from the mechanistic dogma "divide into parts and study them separately" were labeled "metaphys-

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ics" and resented by official science (Bertalanffy, 1969). It will suffice to remember that a "strange attractor" in the set of equations that describe three interacting objects and have a quasi-stochastic dynamics (although the equations are deterministic) was only discovered in the second half of the 20th century (Lorenz, 1963).

By the mid-20th century, it became obvious that the predominant philosophy should be at least supplemented, if not completely replaced, with some alternative views. It is nothing new in the world, as the saying goes, and the development of science is not an exception (which reflects the cyclic pattern of its development). Note that the philosophical credo "the whole is the sum of its parts" has coexisted with "the whole is more than the sum of its parts" (ascribed to Plato) throughout the history of science.

The cornerstone of this philosophy is the so-called emergence principle, which postulates that new properties emerge in a whole (something more complex) relative to a part (something more elementary). These speculations, which initially were purely philosophical, laid the basis for the methodology of the general systems theory. This methodology is now the main characteristic of modern science and has become a multidisciplinary approach that transverses barriers between different fields of knowledge.

The division of science into separate fields, with their specific subjects and methods, is to a certain degree a matter of convention, because the knowledge of nature is essentially unified. This became especially obvious in the second half of the 20th century, when synthetic, consistently systemic branches of science such as cybernetics, thermodynamics of irreversible processes, and synergetics appeared. They are constantly developing and interweave, forming a new generation of sciences whose subjects are characterized by organized complexity. Modern ecology is one of these sciences.

Although classical ecology formed within the framework of traditional zoology, its appearance revolutionized not only this science, but also many other life sciences. Haeckel (1866), who coined the term "ecology," was the first to assign zoologists and botanists a new strategic task. Before Haeckel's work, the main goal of biology was to create a classification based on distinguishing the substantial characters that would allow the scientists to estimate similarity between objects. Haeckel demonstrated that it is necessary to study the interactions and relationships between objects. Since then, classical ecology has passed the narrow limits of the traditional biology, because its subject now includes inorganic (abiotic) components of environment as well.

It is well known now that the chemistry of the atmosphere and the strongly buffered physicochemical medium on our planet considerably differ from those on Venus and Mars, our closest neighbors in the solar system. In addition, the fluctuations of the chemical composition and physical conditions on Earth are negligible, compared to those on other planets. The main factors determining conditions on those planets are the distance from the Sun and the mass of the planet (i.e., Newtonian mechanical factors) and chemical processes. Calculations demonstrate that, had these been the governing factors for our planet, Earth's atmosphere would have contained 98% carbon dioxide and less than 2% nitrogen, whereas the oxygen content would have been negligible (Lovelock, 1979). The average temperature of Earth's surface would have been about 290°C. In fact, the atmosphere of Earth mostly consists of nitrogen and oxygen, and the mean surface temperature is about 15°C.

Why does our planet differ so drastically from the others? On Earth, in contrast to any other known planet, there is the special substance that Vernadsky (1978) named living matter. This term refers to all living organisms as a whole. It is now considered an established fact that living organisms not only adapt to one another and the physical (abiotic) environment, but also change this environment by their combined action and adapt the geochemical medium to their biological needs. Organisms constantly change the physical and chemical properties of inert substances, letting out new compounds and sources of energy. Vernadsky was, in the early 20th century, the first to point out the global role of living matter (see Vernadsky, 1978). Thus, living organisms and their geochemical environment on Earth function as a whole and form a giant integrated system that is capable of self-organization and self-regulation (Lovelock, 1979; Gorshkov, 1988, 1995; Gorshkov and Kondrat'ev, 1990).

Obviously, it is important for us to understand the mechanisms and functional patterns of this sophisticated system which is the common home of humankind. This is the ultimate goal of the new synthetic line of research based on the advances in the integrated system of sciences, into which the science of ecology is now being transformed. The objects of ecology are distinctly systemic: ecology is destined to be a branch of science whose main methodology is the systemic approach. The subject of modern ecology as a systemic science are ecological systems whose central elements are biological objects belonging to different organization levels. Interacting with one another and with abiotic components, they form integrated complexes.

Form the standpoint of systemic analysts, the main characteristics of ecological systems are as follows (*Ekologicheskie sistemy…*, 1981).

(1) Ecological systems are not static. Instead, their characteristics, including the structural and functional organization, productivity, biotic diversity, and stability, are permanently changing.

(2) Ecological systems are open; they cannot exist without exchanging the flows of matter and energy with the environment. The importance of this feature was

understood only recently due to the development of nonequilibrium thermodynamics, which is one of the most significant branches of modern theoretical physics.

(3) Ecological systems are complex, and their internal structures (partitions) overlap with one another; hence, the hyperstructures of ecosystems are multidimensional.

(4) The complexity of ecological systems is related to their nonlinear organization. This makes the analytical solution of the equations simulating the ecosystem dynamics extremely difficult, whereas a numerical simulation requires precise quantitative data on the governing parameters and variables. Although it may be impossible to obtain the necessary data, and this creates considerable obstacles for practical work, the main problem is to discriminate between the governing parameters proper and the variables, which is always difficult and sometimes impossible in principle. Strict fixation of causes and consequences reflects the mechanistic approach. A consistently systemic analysis implies that multiple (nonlinear) cause–effect series exist. Considerable variation of behavioral parameters, which is determined by the structure of the system itself, rather than stochastic fluctuations, is another characteristic feature of complex systems which results from their nonlinear nature.

(5) Complex dynamic systems are characterized by a partially irreversible development (memory): their behavior depends on the previous development (history), so that a mere description of the system's state at a given moment is not enough for predicting its behavior (Nicolis and Prigogine, 1989).

The main methodological problem of ecology as a synthetic science based on a system of sciences is the search for the ways to analyze the systems that possess the aforementioned properties. The well-being of humankind now and in the future largely depends on a successful solution to this problem. Theoretically, the current ecological crisis caused by depletion of natural resources and disturbances in biospheric regulation may be overcome in two ways: (a) to reach harmony between man and nature (one of the aspects of the so-called sustainable development) and (b) to create, instead of living nature, a self-regulating supersystem with desirable characteristics.

Both ideas are unrealistic (the latter is more so than the former); however, we will inevitably travel along one of these ways (or some combination of them). Therefore, it is necessary to study the mechanisms of operation of natural systems (in the former case, in order to understand how we can reach harmony; in the latter case, in order to construct an artificial "sociosphere").

MAN AS A COMPONENT OF ECOLOGICAL SYSTEMS

Undoubtedly, man is a biological species (*Homo sapiens*) and occupies a definite position in the zoological classification; and the systems in which people are the central component must possess all of the aforementioned characteristics of ecosystems. Therefore, it seems logical that human ecology should use the data accumulated when studying the ecosystems whose active components are other species.

If we regard human ecology as the ecology of a species, we should first have a look at the "vertical" structure of this science and try to estimate the development of its divisions that correspond to different structural levels of ecosystems. According to the hierarchy of the biological systems, we may distinguish three main levels that serve as the central links of the ecosystems.

At the first hierarchical level, a single organism serves as this central link. Physiology (or factorial ecology) deals with this level. Human physiology and related (including medical) sciences are well developed: human physiology has been studied better than the physiology of any other species. On this basis, numerous studies have been performed on the effect of environment on the organism as a whole; this field of research may be called ecological human physiology. This division of human ecology mainly deals with the biological characteristics of man. Human physiology, except for some divisions concerning higher nervous activity, is closest to traditional animal physiology with respect to its methods and approaches. Therefore, it is natural that results obtained on animals are widely used in human physiology. Animals (mostly mammals, which are taxonomically closer to man) actually serve as natural models of man in risky experiments that cannot be performed on people. General human physiology and medicine are well developed; hence, ecological human physiology is a large complex of sciences, which includes environmental hygiene and ecotoxicology.

At the next level, groups of individuals of the same species (population groups) serve as biological subsystems. This level is the subject of population ecology, which focuses on the dynamics of these groups as determined by their exposure to internal and environmental factors. The latter include populations of other species and the abiotic environment.

Note that the population level is of special significance in the system of organization of living matter. On the one hand, a population is an elementary unit of biocenotic interactions that functions as a subsystem of the ecological systems of higher rank, such as community and biogeocenosis (Shvarts, 1971); on the other hand, species populations are chorological units of the species (Shvarts, 1967) that play the role of elementary units in the evolutionary process (Timofeeff-Ressovsky *et al.*, 1973). Interacting individuals forming various intrapopulation structures (parcellar groups, demes, micropopulations, colonies, herds, etc.) are elements of population systems. Therefore, intrasystem relationships at the population level are the relationships between individuals and groups of individuals. Many of them account for self-regulation mediated by the effects on demographic processes (reproduction, mortality, and dispersal). For example, spatioethological structures play an important role in the population processes in higher animals (Shilov, 1977).

Man is an exceptionally social species. Cultural adaptations, which are the main adaptations determining the biological fitness of man, are only expressed at the levels of societies, i.e., associations of people. This means that interactions of people with the environment are mediated by relationships between individuals and groups of various ranks. These relationships are subjects of the humanities, such as economics, linguistics, ethnography, history, sociology, political science, etc. These humanities have potent scientific schools and well-developed methodologies. However, natural models and analogies with other species are almost never used when studying social relationships, in contrast to the situation in medicine and physiology. Conversely, contrasting the human society with all other natural systems is the prevailing attitude in this field. Qualitative differences of human groups from population structures of higher or other animals is considered, either explicitly or implicitly, as a fundamental dissimilarity.

When dealing with the laws of population biology, it is certainly very difficult to draw parallels between human social groups of various ranks and population groups in animals. The classical concept of population developed in the course of studying species is hardly applicable to the human society without substantial corrections (Shvarts, 1973). First of all, the specific ecological functions of man that ensure a high fitness of this species should be taken into account. These functions are maintained owing to culture, which may be regarded as adaptation at the group (instead of individual) level. To maintain fitness, man uses the substances and energy sources that are inaccessible to most other biological species. These resources are only used at the social level (in terms of classical ecology, at the population level) rather than at the individual level.

The number of people has rapidly grown over the last few centuries, with the growth being hyperbolic, i.e., even more rapid than exponential (Bazykin, 1985). This growth pattern is related to positive feedback between population size and its relative growth, which is interpreted in terms of classical ecology as the prevalence of intraspecific cooperation over competition. This illustrates the postulate that specific ecological functions of the species *Homo sapiens* are fulfilled at the group level. In an industrial society, the efficiency of resource use is related to the availability of manpower and the possibility of organizing complex functional groups (division of labor), which are determined, to a first approximation, by the total population size.

In general, we may postulate that the branch of human ecology that is analogous to population ecology is considerably less developed than ecological physiology and medicine. At the same time, general ecology deals with some important relationships that have not yet been applied to human beings. Attempts to use some analogies should certainly be made, if for no other reason than in order to understand how useful (or useless) knowledge is accumulated by general ecology for better understanding the place of man on Earth and prospects for the development of humankind.

The next organization level of ecological systems is the ecosystem level proper, at which biological subsystems are the communities of population groups of different species that interact with one another and with abiotic components. Looking through modern ecological literature, we found numerous works devoted to the anthropogenic impact on natural complexes of various ranks. Studying the influence of people on their environment has become popular among professional and semiprofessional ecologists. Most of these works are closely connected with practice, seeking to develop the approaches to “improving” the environment and reducing the adverse consequences of economic activities (primarily for people themselves, especially their health). The marked prevalence of such works is explained by the fact that it is impossible to avoid the anthropocentric attitude toward the existing problems: the consequences of human activities that concern human beings themselves are considered first.

However, the exclusively anthropocentric approach has limitations that will hamper a successful solution to the urgent problems facing the society. The main disadvantage of prevailing views is that the human society is considered separately from natural systems, as if its development were only governed by its own specific laws. Therefore, feedback between the natural environment and human society is practically never taken into account when addressing and solving ecological problems. Studies on the feedback effect of the environment on man are as yet limited to the medical and hygienic aspects. However, ecologists should know that man as a species is an integral part (component) of the biosphere and is certainly subject to the regulatory influence of this supersystem not only at the physiological level but also at higher organization levels.

Regarding the current technology in human ecology at three main organization levels (organism, population, and ecosystem), we can see that most of the progress is now being made in human ecological physiology. At the biocenotic level, studies are mainly focused on the consequences of various human activities expressed in the so-called anthropogenic transformations of the environment, which, in turn, affect individual human health. The population (group) level, notwithstanding its special significance, remains almost completely unstudied in consistently ecological terms. This is explained by the aforementioned anthropocentric separation of man from nature (which is a relic of mechanistic philosophy typical of the passing industrial society) and by the natural difficulty of studying a system from within, as such studies require methodological approaches other than those used in classical science. For example, experiments, in the classical sense, with these systems are virtually impossible. Moreover, the main requirement for an experiment—its reproducibility—cannot be met in most cases.

ANTHROPOGENIC IMPACT ON NATURAL SYSTEMS AND ITS ASSESSMENT

The global role of humankind was not understood until the mid-20th century (Vernadsky, 1945; Teilhard de Chardin, 1955), and the problems of man's existence in the finite world became a matter of public concern as late as in the 1970s. Global computer models (Meadows *et al.*, 1994) have played an important role in attracting public attention to these problems. They clearly demonstrated that the resources of our planet are insufficient for maintaining economical and industrial development in the same form as before. The most widely known model is WORLD-III, which was intended for predicting changes in the state of Earth's resources and the environment that may result from different types (scenarios) of economic, political, nature-conservation, and social decisions affecting the development of human society on the global scale.

In this model, the global anthropogenic impact on the environment is described on the basis of the formula $I = PAT$, where I is the strength of an adverse effect, P is the population, A is the level of consumption, and T is the degree of technological development. The model takes into account many direct relationships and feedback loops at the global and regional levels. What it does not take into account is living matter and its global regulatory function. However, man is a product of biological evolution and can only exist within a narrow range of environmental conditions, which are created due to the functioning of the entire biospheric complex. Therefore, the future of humankind depends mainly on the maintenance of conditions adequate for life on Earth, rather than the availability of resources used by people. The model WORLD-III is yet another example of the prevalence of the purely anthropocentric approach to ecological problems.

Therefore, estimating the cost of the biological components of ecological systems (including commercially important renewable resources) in terms of their biospheric function is a topical problem. Most of the existing approaches to this problem are actually aimed at estimating damage that different types of economic activity cause to each other. In contrast, new approaches should be based on the *compensation principle.* In other words, these estimates should answer the question concerning the cost that the society will have to pay (if only hypothetically) to compensate for damage to the biosphere's regulatory function due to anthropogenic degradation of ecosystems (Bol'shakov *et al.*, 1998).

ACKNOWLEDGMENTS

This study was supported by the Russian Humanitarian Science Foundation, project no. 00-06-000564.

REFERENCES

Adaptive Environmental Assessment and Management, Holling, C.S., Ed., IIASA International Series, vol. 3, Chichester: Wiley, 1978. Translated under the title *Ekologicheskie sistemy. Adaptivnaya otsenka i upravlenie*, Moscow: Mir, 1981.

Alekseev, V.P., *Ocherki ekologii cheloveka* (Essays on Human Ecology), Moscow: Nauka, 1993.

Bazykin, A.D., *Matematicheskaya biofizika vzaimodeistvuyushchikh populyatsii* (The Mathematical Biophysics of Interacting Populations), Moscow: Nauka, 1985.

Bertalanffy, L., von., General Systems Theory: A Critical Review, in *Issledovaniya po obshchei teorii sistem* (Studies on the General Systems Theory), Moscow: Progress, 1969, pp. 23–84.

Bol'shakov, V.N., Krinitsyn, S.V., Kryazhimskii, F.V., and Martinez Rika, H.P., Problems of the Comprehension of the Basic Notions of Ecological Science by Contemporary Society, *Ekologiya*, 1996, vol. 27, no. 3, pp. 165–170.

Bol'shakov, V.N., Kryazhimskii, F.V., and Radchenko, T.A., Ecological Science and Ecological World Outlook, in *Ekologicheskie issledovaniya na Urale* (Ecological Investigations in the Urals), Yekaterinburg: Ural. Gos. Univ., 1997, pp. 5–9.

Bol'shakov, V.N., Korytin, N.S., Kryazhimskii, F.V., and Shishmarev, V.M., A New Approach to Estimating the Cost of Biotic Components of Ecosystems, *Ekologiya*, 1998, vol. 29, no. 5, pp. 339–348.

Gorshkov, V.G., The Range of Environmental Stability, *Dokl. Akad. Nauk SSSR*, 1988, vol. 301, no. 4, pp. 1015–1019.

Gorshkov, V.G., *Fizicheskie i biologicheskie osnovy ustoichivosti zhizni* (Physical and Biological Foundations of Life Stability), Moscow: VINITI, 1995.

Gorshkov, V.G. and Kondrat'ev, K.Ya., The Le Chatelier Principle as Applied to the Biosphere, *Ekologiya*, 1990, vol. 21, no. 1, pp. 7–16.

Haeckel, E., *Generelle Morphologie der Organismen*, Berlin, 1866, vol. 1.

Hens, L., Human Ecology in Western Europe, *Ekologiya*, 1996, vol. 27, no. 3, pp. 171–176.

Kaznacheev, V.P., *Ocherki teorii i praktiki ekologii cheloveka* (Essays on the Theory and Practice of Human Ecology), Moscow: Nauka, 1988.

Kryazhimskii, F.V., Human Ecology and Classic Ecology, *Ekologiya fundamental'naya i prikladnaya* (Basic and Applied Ecology), Yekaterinburg: Ural. Gos. Univ., 1999, pp. 48–54.

Lorenz, E.N., Deterministic Nonperiodic Flow, *J. Atmos. Sci.*, 1963, vol. 20, pp. 130–137.

Lovelock, J.E., *Gaia: A New Look at the Life on Earth*, New York: Oxford Univ. Press, 1979.

Meadows, D.H., Meadows, D. L., and Randers, J., *Beyond the Limits: Confronting Global Collapse, Envisioning a Sus-*

tainable Future, Chicago: Univ. of Chicago Press, 1982. Translated under the title *Za predelami rosta*, Moscow: Progress, 1994.

Nicolis, G. and Prigogine, I., *Exploring Complexity*, New York: Freeman, 1989.

Rozenberg, G.S., The Concept of Ecology: Analysis of Definitions, *Ekologiya*, 1999, vol. 30, no. 2, pp. 89–98.

Shilov, I.A., *Ekologo-fiziologicheskie osnovy populyatsionnykh otnoshenii u zhivotnykh* (Ecophysiological Principles of Population Relationships in Animals), Moscow: Mosk. Gos. Univ., 1977.

Shvarts, S.S., The Population Structure of Species, *Zool. Zh.*, 1967, vol. 46, no. 10, pp. 1456–1469.

Shvarts, S.S., The Population Structure of Biogeocenoses, *Izv. Akad. Nauk SSSR, Ser. Biol.*, 1971, vol. 28, no. 4, pp. 485–493.

Shvarts, S.S., Problems in Human Ecology, *Vopr. Filos.*, 1974, no. 9b, pp. 102–110.

Teilhard De Chardin, P., *Le phenomene humain*, Paris: Editiones de Seuls, 1955.

Timofeeff-Ressovsky, N.V., Yablokov, A.V., and Glotov, N.V., *Ocherk ucheniya o populyatsii* (An Essay on the Population Theory), Moscow: Nauka, 1973.

Vernadsky, W.I., The Biosphere and the Noosphere, *Am. Sci.*, 1945, vol. 33, no. 1, pp. 1–12.

Vernadsky, V.I., *Zhivoe veshchestvo* (Living Matter), Moscow: Nauka, 1978.