*Russian Journal of Ecology, Vol. 36, No. 3, 2005, pp. 143–149. Translated from Ekologiya, No. 3, 2005, pp. 163–170.*


# Superorganismal Systems in Human Ecology

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Received December 17, 2004

**Abstract**—Comparison of the current approaches to human ecology shows a contradiction between certain views on the subject and the methodology of its analysis. The notion of human ecology as the ecology of the species *Homo sapiens* is being developed in terms of modern general ecology and should be considered at all organizational levels, from individual to global. Material and spiritual cultures, which are the main adaptations of human beings represent a continuation of the general trend of living matter towards progressive evolution and are accompanied by an increase in orderliness related to the intensification of energy consumption. This superindividual adaptation determines the human capacity for occupying new ecological niches without changing the hereditary background. Therefore, consideration of *Homo sapiens* at the superorganismal level is of special importance in human ecology. Analysis of this issue shows that the functional patterns of systems belonging to this level have certain characteristics in common with those of the population systems of other species.

*Key words*: ecological systems, humans, adaptation, superorganismal systems, regulation.

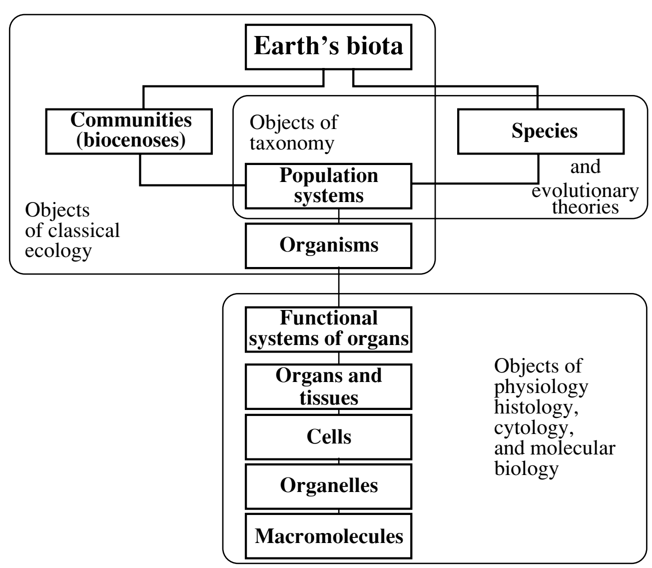
## INTRODUCTION

Ecological systems belonging to different organizational levels constitute the subject of modern general ecology. These systems are dynamic and open (i.e., they exchange substances, energy, and information with their environment); all of them include living subsystems that interact with one another and with inanimate, i.e., inorganic subsystems (the abiotic environment). Living components play the leading active role in ecological systems, performing the work that keeps the entire system in a state far removed from "thermal chaos." This is why modern ecology distinguishes the structural hierarchical levels of ecological systems according to the organizational levels of their biological subsystems, beginning from the individual level (Shilov, 1981).

This systemic hierarchy underlies the classification of the main branches of modern ecology (figure): ecological physiology (factorial ecology, or outecology), population ecology (demecology), ecology of communities (biocenology, or synecology), which is a subdivision of biogeocenology, and, finally, global ecology (Bolshakov and Kryazhimskii, 2001).

In addition to this functional (or ecological) subdivision of living systems, there is an older, evolutionary taxonomic principle of the classification of animate matter on the earth. The two "dimensions" of life on earth correspond to the scales of its change with time: the ecological scale (rapid, "momentary" changes) and the evolutionary scale (comparatively slow, irreversible changes). The subdivision of life on earth according to the main attribute of animate matter on which the classification is based corresponds to the two main branches of life science: ecological and evolutionary taxonomic. There is no need to explain that neither branch can exist without the other: they are combined in evolutionary ecology.

The evolutionary taxonomic subdivision of animate matter allows us to consider "the ecology of plants" and "the ecology of fungi" or, e.g., "the ecology of the wolf" and "the ecology of the frog *Rana ridibunda*." If we consider the ecology of an individual taxon (e.g., a




A simplified scheme of the structural organization levels of biological systems and the sciences by which they are studied.

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biological species, the main unit of the evolutionary taxonomic subdivision of animate nature) as a separate division of ecology, then, according to the structure of modern general ecology, it should be studied at different hierarchical levels. The ecology of a species should be subdivided into its ecological physiology, population ecology, studies on the biogeocenotic role of the species, and, finally, its global (biospheric) functions.

The functional ecological classification of living systems does not replace or deny the evolutionary taxonomic one; ecological objects always act in accordance with their history and position within the evolutionary series.

Certainly, this basic scheme can be further detailed, revised, and infinitely extended, which is confirmed by various examples. For one, Reimers (1999) subdivides ecology into 62 (!) branches. Although we agree that this subdivision oriented to specific objects and/or goals of studies is possible and, to a certain degree, justified, we note that the theoretical importance ("fundamentality") of different branches varies considerably.

## HUMAN ECOLOGY AND GENERAL ECOLOGY

In our opinion, human ecology should be regarded as a synthetic science that originated from modern general ecology and underlies its development (Bolshakov *et al.*, 1997; Kryazhimskii *et al.*, 2001). On this point, we agree with V.P. Alekseev (1993), a famous Russian anthropologist who defined human ecology as a special ecology, i.e., the ecology of the biological species *H. sapiens* occupying a definite position in the evolutionary taxonomic classification. If so, human ecology should be focused on *ecological systems of different organizational levels* in which the species *H. sapiens* occupies positions of central (leading) subsystems.

Studies in human ecology should mainly be aimed at analyzing the interactions of these systems with both organic and inorganic systems.

As we noted earlier (Kryazhimskii *et al.*, 2001), reducing the subject of human ecology solely to environmental effects on the human body has become a distinct trend in Russia and other countries. The majority of institutes, laboratories, and departments of human ecology that were founded recently follow the same trend: they restrict their research in human ecology to the analysis of hygienic problems, i.e., of organism–environment interactions. At best, individual variation is taken into account when dealing with statistical samples. This is demonstrated by the contents of the journal *Ekologiya cheloveka* (Human Ecology) published under the aegis of the Northern State Medical University, and by studies performed at the Sysin Research Institute of Human Ecology and Environmental Hygiene of the Russian Academy of Medical Sciences. Undoubtedly, all these problems are important and necessary to study; nor is there any doubt that they pertain to human ecology. Nevertheless, if human ecology were to be confined to medical hygienic issues, its scope would be strictly outecological and, hence, rather archaic from a modern point of view. The restriction of human ecology to the organism–environment problem, which was first noted by E. Haeckel (1866), takes into account only the biological characteristics of the human body.

On the other hand, humans are often declared to be an element of higher-order systems, e.g., "anthropoecosystems" (Prokhorov, 2003). In this case, however, the outecological viewpoint remains dominant. Although studies on aspects of the life of *H. sapiens* that are considered the prerogative of humanitarian activities, such as demographic problems and family issues, are increasingly widely included in the scope of human ecology, they are regarded as exclusively "human," so that researchers never use the experience accumulated in general ecology when studying other biological species. In addition, familial and demographic problems are usually considered without account for the interaction of the systems into which the species *H. sapiens* is organized with other natural systems. Only the factors created by humans themselves, mainly technogenic factors, receive attention.

The "anthropoecosystemic" approach is essentially eclectic. For example, B.B. Prokhorov wrote in a recently published handbook that the methodological basis of human ecology is composed of demographic, biological, geographical, hygienic, epidemiological, and other methods "combined in an original set with the use of a systemic approach" (Prokhorov, 2003, p. 3). This "broad" view on human ecology is very close to that widespread in Western Europe and, to a certain degree, in North America. According to this view, human ecology is a loose conglomerate in which methodology and philosophy, positive scientific knowledge and attitudes towards life, worldview and social activity, and many other components are intermixed (Khens, 1996). This approach mechanistically includes the medical hygienic aspects of interactions with the environment into the scope of human ecology. However, as noted above, only the biological characteristics of the human body are taken into account, and the approach is in fact strictly anthropocentric. For example, although the term anthropoecology, which is often introduced as a synonym for human ecology (Prokhorov, 2003), is linguistically correct (it combines three Greek roots), it implies that humans should be considered as standing outside of animate nature. We cannot propose analogous terms for other species, many of which simply have no Greek names.

## THE SPECIAL POSITION OF SUPERORGANISMAL SYSTEMS

As we noted earlier (Bolshakov *et al.*, 1997; Kryazhimskii *et al.*, 2001), most definitions of the subject and methods of ecology overlook an important level of the interaction between *H. sapiens* and the environment (i.e., nature). This is the level of superorganismal systems, which is, to a certain degree, analogous and even homologous to the population level in other biological species. However, the term human ecology was coined back in the early 1920s by sociologists (R. Park and E. Burgess) to mean the science of the organization and interactions of human individuals as related to selective, distributive, and accomodative forces of the environment (Lawrence, 2001).

It is known that population level occupies a special position in structuring life on earth. On the one hand, population-level systems belonging to different biological species are elements of biocenoses as superspecific (in the ecological sense) systems, ensuring their integrity during mutual interactions (Beklemishev, 1951; Shvarts, 1971). On the other hand, systems of this level are horologic units of species and elementary subjects of the main microevolutionary factors (Chetverikov, 1965; Shvarts, 1967; Timofeeff-Ressovsky *et al.*, 1973).

The superorganismal level is very important for humans, because it imparts an evolutionary ecological meaning to the assertion that humans are social beings, which is repeated so often that it has become a commonplace.

## HUMANS AS A PRODUCT OF PROGRESSIVE EVOLUTION

A.N. Severtsov noted the relationship between evolutionary progress and an increase in "the energy of life activity" when formulating, back in the first quarter of the 20th century, the concept of progressive evolution via aromorphoses (Severtsov, 1925). Later, this assumption was justified in terms of natural science (physics and chemistry), which was mainly related to the formation and further development of the thermodynamics of irreversible processes (e.g., Shnol', 1979). A small book by Schrödinger (1945) that interpreted biological processes in thermodynamic terms substantially influenced the development of modern biology. According to J. Watson (1969), this book inspired the physicist F. Crick, Watson's colleague and one of the discoverers of the structure of DNA, to take up molecular biology.

In terms of the modern thermodynamics of irreversible processes in open systems, the specific respiration rate of a living system may serve as a basis for estimating its orderliness (Odum, 1967). In the late 1950s, V.S. Ivlev (1959) found that specific respiration rates increased in the evolutionary succession of animals. Later, V.R. Dol'nik (1968) conclusively demonstrated that this relationship was especially distinct if the respiration rate was normalized to the so-called metabolic equivalent of body mass rather than body mass per se. The metabolic equivalent of body mass is coefficient $a$ in the allometric equation relating standard metabolic rate ($R$) and body mass ($M$): $R = aM^b$, where $b$ is an allometric exponent; it varies comparatively little in different systematic groups.

When later A.I. Zotin and coworkers developed a thermodynamic model theory of growth and development, they demonstrated that this coefficient may be considered a criterion of orderliness (Konoplev and Zotin, 1975; Zotin and Zotin, 1999). Respiration is underlain by a complex system of biochemical processes, i.e., enzymatic reactions the rates of which first exponentially increase with an increase in body temperature according to Arrhenius's law and then drastically decrease as the enzyme structure changes. This allowed A.I. Zotin and A.A. Zotin (1999) to assume that a temperature of approximately 40°C (close to the mean optimum for enzymatic reactions) is a "thermal threshold": temperatures higher than this are incompatible with normal biochemical reactions.

To overcome this barrier, qualitative changes in the functional characteristics of newly emerging species are necessary. The appearance of homeothermic animals, which was the first such transformation, occurred, according to the aforementioned researchers, at the organismal level, when $a$ values in the most "evolutionarily advanced" (i.e., the most highly organized) insects reached 4–8 mW. When chemical thermoregulation appeared, passerine birds reached the "thermal threshold" (with the $a$ parameter in the equation of standard metabolism being about 47–50 mW). For the family Hominidae, the $a$ value is lower (24–25 mW) (Zotin and Zotin, 1999).

However, humans, i.e., a species from precisely this taxon, have overcome the second "thermal threshold" via perfecting (increasing the degree of organization, or orderliness) superorganismal systems, rather than the body.

## CULTURE AS A SUPERORGANISMAL ADAPTATION

The emergence of *culture, a superorganismal adaptation* that became the main adaptation of *H. sapiens*, was related to a unique ecological function, namely, the ability to use energy (and matter) from sources that cannot be used by other biological species.

Culture can be subdivided into two main interrelated components, material and spiritual. For simplicity, material culture may be regarded as the potential of human intraspecific systems (the structural level of which is homologous to the population level of other species) to obtain the substance and energy that are necessary for the development of these systems by exploiting the earth's resources that are not used by other species: humans have no competitors in the entire animate world. With the same degree of simplification, spiritual culture may be regarded as the ability of humans to exchange information and transmit it to successive generations in a "nonhereditary," i.e., nonbiochemical way. These characteristics of culture as a superorganismal adaptation allowed humans to change their ecological function (niche) very rapidly (almost simultaneously on an evolutionary scale), because humans were able to avoid the long trial-and-error period that is inevitable in the case of biological mechanisms of selection. The physiological and biochemical mechanisms based on the characteristics of organic molecules are still functioning because each individual is a biological system; however, they are not the cause of the high fitness of humans, which is expressed in extremely rapid population growth.

The comparison of different mathematical approximations of the curve of human population growth throughout the historical period (beginning with the Neolithic or agricultural revolution) demonstrated that the hyperbolic equation (theoretically assuming that the numbers will be infinite at a certain finite moment of time) described global human population dynamics better than Malthus's exponential equation. In other words, the specific rate of population growth increased at an acceleration as the population grew. In terms of population ecology, this means that the mechanisms of "intraspecific cooperation" prevailed over the mechanisms of "intraspecific competition."

In terms of energetics, the development of culture was accompanied by a steady increase in the mean specific (i.e., per capita) energy consumption. This is so obvious that it has been included in some textbooks on human ecology (e.g., Prokhorov, 2003). Note that this increase in energy consumption (and expenditure) meant, in terms of thermodynamic considerations, an increase in the degrees of organization, order, and, hence, complexity, of the systems in which humans are the central element (Zotin and Zotin, 1999). For example, according to Zotin and Lamprecht's (1996) estimation, the use of fire by prehistoric humans (the appearance of the "extraorganismal" energetics) made it possible to increase the $a$ value (the criterion of orderliness) to 50 mW or higher. After the industrial revolution of the 7th to 19th centuries, which gave rise to industrial society, and the functions of human superorganismal systems began to be ensured mainly by the "reserve funds" of the biosphere (i.e., nonrenewable resources), this value became higher than 800 mW (in Western countries where industrial society had been developed). Later, the increase in per capita energy consumption snowballed hyperbolically, i.e., in a manner similar to the pattern of human population growth.

The drastic growth in energy consumption (and expenditure) was ensured by the appearance of new pathways of the global biogeochemical cycle. For example, from the biogeochemical point of view (i.e., in terms of general ecology), the mass combustion of hydrocarbons essentially represents the pumping of carbon from the biospheric reserve funds (deposits of coal and hydrocarbon minerals) into the "current capital" (the atmosphere and ocean) that was practically absent until humans and human culture appeared. Global warming is one possible consequence of this phenomenon; in ecological terms, however, this is merely a side effect of the intense use of the resources accumulated during the long period of activity of living systems on earth that constitute the biospheric reserve funds, which is the very essence of technological processes in human superorganismal systems. The rapid development of new resources (occupying new ecological niches, in classic ecological terms) did not involve substantial changes in hereditary background—humans remained the same biological species as before. Bold as this statement may seem, we believe that the progressive evolution of the biota stopped when humans and human culture (as their main superorganismal adaptation) appeared: new biological species more advanced than humans are will never appear on the earth.

It cannot be denied that the intense development of the central nervous system (encephalization) in the ancestors of humans was the prerequisite for the appearance of culture, an adaptation related to the ecological function of the species *H. sapiens* that was new for biological species. However, socialization, i.e., the formation of stable groups (mainly those based on family relations) characterized by mutual help (cooperation) rather than competition, which is inseparable from encephalization, was equally important.

The existence of culture as a superorganismal adaptation is determined by interaction between individuals organized into intrasystemic groups. These interactions ensure that human superorganismal systems function as an integrated whole. Population systems of other biological species are also integrated wholes due to the interactions between the constituent individuals and groups. In many other biological species, especially those with a high degree of socialization, some adaptations are also expressed at the population level. Most often (especially in higher animals), they are mediated by behavioral interactions between individuals.

Therefore, notwithstanding the substantial, even fundamental differences between humans and other biological species with respect to their ecological role and according to the principle of systemic polymorphism, human superorganismal systems must exhibit characteristics similar to those of the population systems of other biological species.

## PREREQUISITES FOR THE ANALYSIS OF SUPERORGANISMAL SYSTEMS IN HUMAN ECOLOGY

S.S. Shvarts, one of the founders of population and evolutionary animal ecology in Russia, was among the first Russian ecologists to emphasize, back in the 1970s (Shvarts, 1974, 1976), the importance of the estimation of general ecological relationships for understanding problems of human ecology. Shvarts noted that the "group effect," the "population dominant" psychology, and other population ecological or, more precisely, population ethological phenomena, are more often encountered in human society than they are generally believed to be. V.R. Dol'nik's popular-science book (1994), which is also interesting for ecologists, provides excellent examples of the "zoopsychological" or "ethological" basis of many social phenomena.

Alekseev (1993), when developing the concept of anthropogeocenosis (using so-called traditional societies as an example), assumed that human–environment relationships were modified by the relationships between individuals (and their groups) in the superorganismal systems of the species *H. sapiens.* Environment (which Alekseev referred to as "exploited territory") served as a source of resources, and the relationships of the aforementioned superorganismal human systems with this source, as "productive activity." Alekseev defined superorganismal groups of humans as "production teams," with special emphasis on their functional (i.e., ecological) role as consisting of resource use. In these superorganismal systems, relationships between individuals ensure, first, integrity and, second, the distribution of functions among structural subdivisions. In classic ecological terms, "production teams" belong to the population rank, which V.P. Alekseev also noted.

When addressing the main level of the organization of ecological systems, whose cores are formed by the systems into which *H. sapiens* is organized, human ecologists should probably take into account L.N. Gumilev's (1989) theory of ethnogenesis (certainly, after considerable modification). The ethnic group as a unit of systemic organization of the species *H. sapiens* is one of the few concepts (together with the aforementioned developments of Alekseev) that regard processes occurring at the superorganismal level of this species as a necessary condition of its interaction with the environment, i.e., the "accommodating [*the ethnic group*] landscape." There is no need to tell professional ecologists that the "biological component" of Gumilev's considerations (e.g., the notion of "passionarity" as a result of a large-scale momentary mutation), which was probably inspired by the popularity of genetics and the synthetic theory of evolution in the 1950s and 1960s, does not stand up to scrutiny. What is much more important, however, is that Gumilev understood and demonstrated that the origin and formation of superorganismal systems of *H. sapiens* always involve interaction with the environment, i.e., are determined by ecological processes.

Note that at around the same time that Gumilev is likely to have formulated the theory of ethnogenesis in a more or less complete form (in the late 1950s), D. Chitty (1957) put forward a well-known hypothesis to explain the mechanisms of the population cycles of small mammals. Chitty's behavioral polymorphism hypothesis, which played an important role in the development of population ecological studies (see Krebs, 1978 for review), is largely concordant with Gumilev's theory: both assume that the cyclic behavior of superorganismal systems is determined by the prevalence of carriers of different hereditary behavioral characteristics in them. In the theory of ethnogenesis, these are "passionaries" (persons with an increased social activity), "hormonaries" (persons with a balanced attitude towards the society), and "subpassionaries" (persons with a decreased social function); in Chitty's theory, these are "aggressive" individuals (wasting energy on intrapopulation contacts) and "tolerant" ones (fertile, spending energy on reproduction).

If we assume that the terms "exploited territory" and "accommodating landscape" are partly equivalent, and that "microethnos" and "production team" are also partly equivalent, then the theories developed by Gumilev and Alekseev seem to agree with each other. Alekseev's scheme of the development of anthropogeocenoses turns into a cross section of the initial stages of the civilization cycle (changes in the "color of time") according to Gumilev.

## SIMILAR BEHAVIORS OF SUPERORGANISMAL SYSTEMS OF HUMANS AND OTHER SPECIES

V.I. Vernadsky raised the problem of the role of life on earth as early as before World War II; however, other researchers only addressed it near the end of the 20th century (Vernadsky, 1978). Since Lovelock's (1979) sensational book was published, much theoretical and empirical evidence has been obtained in favor of Vernadsky's notion that life is the key component of the system maintaining global homeostasis (e.g., Gorshkov, 1995).

Irrespective of personal attitudes towards Lovelock's "Gaea hypothesis" or Gorshkov's biotic regulation theory, every intelligent inhabitant of the earth wants to know "what a human being is." Are humans the destroyers of the global self-regulation mechanism adjusted during the long existence of the earth and, hence, the cause of the earth's forthcoming demise? Or does human history show a new way of this regulation? These questions are not so fantastic or far removed from science as they might seem.

It is known that global human population, whose growth is best described by the aforementioned hyperbolic curve, increased by more than two times from the 1960s to the beginning of the 20th century. However, more careful scrutiny shows a global "demographic transition" lasting for the past several decades, which is expressed in the simultaneous decrease in both birthrate and death rate on the global scale. This is accompanied by a distinct negative correlation between birthrate and societal well-being or "stability," the index of which may be per capita gross national product (Meadows *et al.*, 1994), i.e., an economic parameter. The decrease in birthrate has turned out to be a result of well-being rather than poverty; an increase in well-being causes the transition from a demographic strategy similar to that termed the *r*-strategy in evolutionary ecology to that close to the *K*-strategy. This transition sometimes occurs with striking rapidity. For example, Italy and Spain, where traditionally large families had remained common until the integration of these countries into the European Community, currently have the lowest birthrates in Europe.

The theory of optimal life histories, one of the theoretical divisions of evolutionary animal ecology, predicts that the *r*-strategy is selectively advantageous if the environment is unstable, intrapopulation interactions are relatively weak, and mortality rate has a considerable random component, especially at early ages. The *K*-strategy is advantageous if the environment is stable, the population density is high, and intrapopulation interactions are strong (Stearns, 1992).

Thus, comparison of the trends in human population dynamics with those observed in other biological species shows that, at the least, the former does not contradict the latter. Moreover, systems into which humans are organized exhibit signs of self-regulation: in general, human population growth has been decelerating for some years (Meadows *et al.*, 1994).

There is evidence that the expression of self-regulation may be related to the biotic regulation of environment (Kryazhimskii, 1999); therefore, there is still hope that humans play a role in the global function of life on earth. This is indirectly confirmed by two observations: first, the emergence of humans and the development (although by nonbiological mechanisms) of culture, which is their main adaptation, follows the general evolutionary trend of life on the earth; second, artificial systems resulting from activities of *H. sapiens* (or natural systems substantially altered by them) and combined with superorganismal systems of this species to form an indissoluble whole possess properties similar to the main properties of natural ecological systems. These systems are material, dynamic, open, and complex. They consist of at least two subsystems, one of which (a biological system in natural ecosystems and a "human" one in the systems formed around humans) plays an active role, keeping the other subsystem in an ordered state.

In this connection, it is not only useful, but is necessary for understanding the role, place, and future of humans, to use the knowledge and experience accumulated by classic ecology in the course of studying the interactions of living systems with one another and with the inorganic component of nature.

## ACKNOWLEDGMENTS

This study was supported by the Russian Humanitarian Science Foundation (project no. 03-06-00304a).

## REFERENCES

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

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

Beklemishev, V.N., Classification of Biocenological (Symphysiological) Connections, *Byul. Mosk. O–va Ispyt. Prir., Otd. Biol.*, 1951, vol. 56, no. 2, pp. 3–30.

Bolshakov, V.N. and Kryazhimskii, F.V., Ecology of Populations and Communities, in *Our Fragile World. Challenges and Opportunities for Sustainable Development*, Oxford: EOLSS Publishing Co., 2001, vol. 2, pp. 1313–1326.

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

Chetverikov, S.S., Some Moments of the Evolutionary Process from the Viewpoint of Modern Genetics, *Byul. Mosk. O–va Ispyt. Prir., Otd. Biol.*, 1965, vol. 70, nos. 4–6, pp. 171–176.

Chitty, D., Self-Regulation of Numbers through Changes in Viability, *Cold Spring Harbor Symp. Quant. Biol.*, 1957, vol. 22, pp. 57–70.

Dol'nik, V.R., Energy Metabolism and Animal Evolution, *Usp. Sovrem. Biol.*, 1968, vol. 66, no. 5, pp. 276–293.

Dol'nik, V.R., *Nerazumnoe ditya biosfery: Besedy o cheloveke v kompanii ptits i zverei* (A Thoughtless Child of the Biosphere. Discussion about Human in a Company of Birds and Animals), Moscow: Pedagogika-Press, 1994.

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

Gumilev, L.N., *Etnogenez i biosfera Zemli* (Ethnogenesis and the Earth's Biosphere), Leningrad: Leningr. Gos. Univ., 1989.

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

Ivlev, V.S., Experience in Assessing the Evolutionary Significance of the Levels of Energy Exchange, *Zh. Obshch. Biol.*, 1959, vol. 20, no. 1, pp. 94–103.

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

Krebs, C.J., A Review of Chitty Hypothesis of Population Regulation, *Can. J. Zool.*, 1978, vol. 56, no. 12, pp. 2463–2480.

Konoplev, V.A. and Zotin, A.I., The Criterion of Orderliness and Its Application to Some Evolution Problems, in *Teoreticheskaya I Eksperimental'naya Biofizika* (Theoretical and Experimental Biophysics), Kaliningrad, 1975, no. 2, pp. 98–108.

Kryazhimskii, F.V., Fitness or Biotic Regulation? *Ekologiya*, 1999, no. 2, pp. 114–115.

Kryazhimskii, F.V., Bol'shakov, V.N., and Koryukin, V.I., Man in the Light of Current Ecological Problems, *Ekologiya*, 2001, no. 6, pp. 403–408.

Lawrence, R.J., Human Ecology, *Our Fragile World. Challenges and Opportunities for Sustainable Development*, Oxford: EOLSS Publishing Co., 2001, vol. 1, pp. 675–693.

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

Meadows, D.H., Meadows, D.L., Randers, J., and Behrens, W.W. III, *Beyond the Limits*, Kirkus Associates, L.P., 1992. Translated under the title *Za predelami rosta*, Moscow: Izd. gruppa Progress, Pangeya, 1994.

Odum, H.T., Biological Circuits and the Marine Ecosystems of Texas, in *Pollution and Marine Biology*, New York: Wiley, 1967.

Prokhorov, B.B., *Ekologiya cheloveka: Ucheb. dlya stud. vyssh. ucheb. zaved* (Human Ecology. A Textbook for the Students of Colleges and Universities), Moscow: Izd. Akademiya, 2003.

Reimers, N.F., *Ekologiya (teorii, zakony, pravila, printsipy, gipotezy)* (Ecology: Theories, Laws, Rules, Principles, and Hypotheses), Moscow: Zh. Rossiya Molodaya, 1994.

Schrödinger, E., *What Is Life? Physical Aspects of the Living Cell*, Cambridge: Cambridge Univ. Press, 1945, p. 91.

Severtsov, A.N., *Glavnye napravleniya evolyutsionnogo protsessa. Progress, regress i adaptatsii* (Main Directions of the Evolutionary Process: Progress, Regress, and Adaptations), Moscow: Izd. Dumnova, 1925.

Shilov, I.A., Biosphere, Levels of Life Organization, and Problems in Ecology, *Ekologiya*, 1981, no. 1, pp. 5–11.

Shnol', S.E., *Fiziko-khimicheskie faktory biologicheskoi evolutsii* (Physicochemical Factors of Biological Evolution), Moscow: Nauka, 1979.

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

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

Shvarts, S.S., Problems in Human Ecology, *Vopr. Filosofii*, 1974, no. 5, pp. 102–110.

Shvarts, S.S., Problems in Human Ecology, *Vestn. Akad. Nauk SSSR*, 1976, no. 12, pp. 80–89.

Stearns, S.C., *The Evolution of Life Histories*, Oxford: Oxford Univ. Press, 1992.

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

Watson, J. D., *The Double Helix*, New York: The New American Library, 1968. Translated under the title *Dvoinaya spiral'*, Moscow: Mir, 1969.

Zotin, A.I. and Lamprecht, I., Aspects of Bioenergetics and Civilization, *J. Theor. Biol.*, 1996, vol. 180, no. 2, pp. 207–214.

Zotin, A.I. and Zotin, A.A., *Napravlenie, skorost' i mekhanizmy progressivnoi evolyutsii. Termodinamicheskie i eksperimental'nye osnovy* (Direction, Rate, and Mechanisms of Progressive Evolution. Thermodynamic and Experimental Principles), Moscow: Nauka, 1999.