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ECOLOGY AS A SCIENCE, ITS SUBJECTS AND SUBDIVISION

Abstract. The meaning of the word *ecology* has become obscure and polysemantic. In the biological and geographical context ecology could be described as a science concerned with dynamic systems in which stochastic relations and transmission of matter, energy and information between organisms or their assemblages on the one hand, and environmental factors or their complexes on the other, exist.

The research field of ecology can be subdivided on different grounds: (1) by organisms and their assemblages (autecology, population ecology or demecology, synecology or biocoenology, systems ecology, geoecology or landscape ecology, global ecology); (2) by environmental characteristics (terrestrial ecology, ecology of water organisms, factoral ecology, experimental ecology, etc.); (3) by interrelationships (biochemical ecology, systems ecology, indication ecology, etc.).

Key words: ecology, classification of sciences.

The word *ecology* has various meanings nowadays, it has entered many fields of human activities and its meaning has become obscure and polysemantic. In the present article an attempt is made to deal with ecology as a natural science and draw distinctions between its important branches.

Sciences are distinguished first and foremost on the basis of their subjects of research. Differentiation of sciences takes place due to the fact that the knowledge about investigated things and phenomena is all the time deepening and it becomes possible to see new aspects in them, which enables to depict them more precisely. Therefore it seems to be necessary to make a closer investigation of the subjects of ecological research.

In contrast to other biological sciences which study well-defined corpuscular biosystems — cells, tissues, organisms, etc. — ecology studies mostly systems of stochastic relations which are difficult to delimit and whose system-specific ties are hidden. In the case of relations at least two material subjects and ties between them varying in time and space are always involved — there exists transmission of matter, energy or information between them. Hence, in general ecology could be described as a science about dynamic systems in which there are relations between *O* — organisms or their assemblages, and *E* — environmental factors or their complexes:

$$O \leftrightarrows E.$$

Hence we get three principally different grounds for the subdivision of ecology as a science: the division of *O*, the division of *E*, and the division of their interrelations.

By "division" we refer to the differentation of a certain variety (set) which can be made with various levels of detailedness and can therefore yield an unlimited number of research branches (fields), each of which may develop into an accepted branch of science under certain conditions. Those divisions will be discussed below.

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Division of Ecology on the Ground of Organisms and Their Assemblages

Present-day biology can be divided roughly into levels of organization (structure perfectness) of biological subjects. Every level has its own main subject of research (which can be subdivided) and one or more branches which study that subject from different aspects (statements of problems). The table below gives a list of biological sciences, among them the main branches of ecology; of course, it is impossible to list all the branches here.

This table can cause arguments. The levels could be subdivided; e.g. the organ level could be inserted between the cellular and organismic levels, between the organism and the population there might be the colony. After the coenotic level we have placed the ecosystemic level. The latter differs from the former by the fact that abiotic environment as an element of the system is added here, guaranteeing completeness of cycling and regulation through the environment. The next levels — regional and global — are formed by geosystems where the role of biosystems diminishes and most of the research work is carried out in geographical sciences, geo-sciences.

Position of ecology among biological sciences

Organization level	Subjects of research: bio- and geosystems	Branches of sciences: in biology	Branches of sciences: in ecology
molecular	macromolecule *	molecular biology	
cellular	cell	cell biology (cytology)	
organismic	organism:	biology (s. str.)	autecology
	microbe	microbiology	microbial ecology
	fungus	mycology	myco-ecology
	plant	botany	phyto-ecology (plant ecology)
	animal	zoology	animal ecology
	human being	anthropology	human ecology
populational	population (subdivisions as above)	population biology (subdivisions as above)	demecology or population ecology
coenotic	community (biocoenosis):	symbiology (biocoenology)	synecology
	plant community (phytocoenosis)	geobotany ***	phytocoenology (or phytosociology)
	parasitocoenosis	parasitology	
ecosystemic	ecosystem		systems ecology (biogeocoenology)
	landscape **		landscape ecology or geo-ecology
	vegetation ***	geobotany	vegetation ecology
regional	region	regional biogeography	regional ecology
		floristics	regional geobotany
		faunistics	
global	biome (zonal macro-ecosystem)		global ecology
	ocean (as a mega-ecosystem)	oceanology (oceanography)	
	biosphere	biospherology	

* macromolecules are usually not regarded as biosystems;
** landscape as a typological geographical subject;
*** the field of geobotany covers vegetation studies from the populational level to global ones.

On the basis of the general table of biological sciences the branches of ecology can be characterized as follows:

AUTECOLOGY studies the simplest system — it is also called monocoen — which consists of an organism (an individual or group of individuals of certain species) and its environment:

$$O \rightleftarrows E_o$$

where E_o can be divided into environmental factors.

POPULATION ECOLOGY or DEMECOLOGY studies the system of interrelations within a species located in a habitat (biotope, site, ecotope, E_H) or in some part of the area of the species:

$$O_1 \rightleftarrows O_2 \ldots (\rightleftarrows E_H),$$

where O_1, $O_2 \ldots$ are individuals of a certain species.

SYNECOLOGY or BIOCOENOLOGY studies relationships between different species (O_A, $O_B \ldots$) in a corresponding habitat E_H, in the case of parasites in host organism's body or on its surface. The main emphasis is laid on the interrelations between species:

$$O_A \rightleftarrows O_B \ldots (\rightleftarrows E_H).$$

SYSTEMS ECOLOGY studies ecosystems, i. e. producers (P), consumers (C) and decomposers (D), and the system of the respective interrelations of the environment (E) with the main emphasis on the cycling of matter and energy:

$$(P \rightleftarrows C \rightleftarrows D) \rightleftarrows E.$$

Though the term 'systems ecology' is rarely used, it forms the core of ecology. Systems ecology deals with ecosystems of various size and complexity.

GEOECOLOGY or LANDSCAPE ECOLOGY studies interrelations between (meso-) ecosystems (M_1, $M_2 \ldots$) in the geographical environment of landscapes (E_L):

$$M_1 \rightleftarrows M_2 \ldots \rightleftarrows E_L.$$

GLOBAL ECOLOGY studies interrelations between biomes (i. e. zonal (macro-) ecosystems (B)) under global environmental conditions (E_G):

$$B_1 \rightleftarrows B_2 \ldots \rightleftarrows E_G,$$

as well as the interrelations between the biosphere (G_1) and other geospheres (G_2, $G_3 \ldots$) — atmosphere, hydrosphere and lithosphere on the whole globe:

$$G_1 \rightleftarrows G_2 \ldots \rightleftarrows E_G.$$

A number of problems arise when we try to distinguish structural units (especially basic units) of ecology on the coenotic and ecosystem levels. Therefore, it would be interesting to go into this field of ecology in some detail.

When talking about community as a subject, we generalize the matter considerably, because community is "a very complicated system" both from the theoretical (cybernetic) viewpoint and in practical investigation.

Delimitation of community in nature is conventional and no matter how it is done, the number of species (and individuals) belonging to it is very large, being practically impossible to define. There exists no team of experts in the world that would be able to determine them all. Therefore, it is absolutely necessary to find ways to simplify the investigation and description of communities; some such approaches are discussed below. Naturally, simplification results in information losses and the investigator must combine different approaches to obtain a realistic picture about the research subject. The simplification can be realized in the following ways.

1. Only **macroscopic** organisms are studied, all microbes (bacteria, cyanophycea, microfungi and -algae) are excluded. In this case the peculiarities of biochemical characteristics of the microbal community (microbocoenosis) will be missed.

2. Species which occur rarely and exist in a community by chance, are excluded; to apply this approach, the investigator must have knowledge about the occurrence and frequency of species.

3. Only these species are studied which are more abundant, have a greater biomass and productivity in a community, assuming that they have a more important role in matter cycling; they are **predominant** or prevalent species, edificators of phytocoenoses ("builders" of structure).

4. If we regard community as a network of interrelations — a biocoenotic connex — it could be analyzed ("disentangled") inductively, beginning with elementary functional parts; here the following approaches are used:

4.1. Determination of an individual's **sphere of influence** and its competitors (other species and individuals of the same species belonging to the same trophical level), such an elementary unit is called coenocell, but it is very difficult to delimit it in practice.

4.2. Determination of the **ecological niche** of individuals (or age groups) belonging to a certain species. The generally accepted opinion is that an econiche represents the state of a species in a multidimensional space and to find it, it is necessary to determine the ecological amplitude of the species at least according to the most important environmental factors.

4.3. Determination of the **consumers** — species connected trophically (in food chain) with a certain species and its food subjects.

4.4. Determination of the set of food chains initiating from a certain species — **consortium** (catenarium).

If we expand this approach also species related in other ways (topoconsorts such as epiphytes, pollinators, distributors of diaspores, etc.) can be added to trophically related species (trophoconsorts).

5. The system of interrelations of a community can also be studied deductively, starting from more general trophical groups and other units of functional structure:

5.1. Differentiating **life forms** (biomorphs, ecobiomorphs) as groups of species that have similarly adapted at several levels and by several criteria.

5.2. Differentiating groups of species that consume the same kind of food and (in a wider sense) also other resources — **guilds.**

5.3. Differentiating groups of species with different **life strategies.**

6. **Communities of higher plants** rooting in soil form the most permanent (existing throughout the year) part of every ecosystem and thus indicate the pattern of environmental conditions for any communities in terrestrial habitats. So the study of plant communities (phytocoenoses) treated traditionally as main vegetation units provides a base for various ecological investigations. **Phytocoenology**, called also **phytosociology** can also be regarded as one of the subdivisions of the ecological **vegetation science** or **geobotany.**

The first task in the descriptive phase of vegetation studies is to analyse the **spatial structure.** The space (or surface) of the community is divided into vertical and horizontal parts which are more or less homogeneous internally, and it is assumed that plants and plant parts belonging to them have similar environmental requirements. In other words, by dividing vegetation into smaller and smaller parts, it is attempted to find such a minimal structural part which has a uniform species composition and environment. Those structural elements are as follows (the list is not complete):

6.1. **Horizons**, or more precisely, **biogeohorizons** — layers excluding each other, such as litter and soil horizons, tree and shrub canopies, surface horizon containing trunk bases and herbaceous plants, etc.

6.2. **Strata** or **layers** of aboveground plant community which in the case of division based on life forms coincide in the lower part: tree, shrub, grass (field), moss layers, etc. In the case of a division based on plant size stratum is also regarded as horizon.

6.3. **Synusiae** — parts of strata having the same microstructure and environmental regime, e. g. synusia of sphagnum mosses in moss layer, geophyte synusia in field layer, etc. The concept of synusia has various definitions; in recent years mostly functional subdivisions such as guilds (5.2.) have been preferred.

6.4. Microcoenoses, micro-groupings, and other elementary units of the plant community, differentiated by various characteristics in different schools are classified as **microassociations.**

Other members (animals, fungi) of terrestrial communities are usually described in the framework of the structural units mentioned above, in which they are related to each other (e. g. edaphon by soil horizons, arthropodes as members of merocoenoses or by strata) adding members independent of these structural units (lianas, macro-mammals).

7. The idea that all the characteristics of communities and environment are connected with continuous transitions in nature is followed — they form a **continuum** in which the initial delimitation of communities is improper and useless. The research method here is ordination — putting research subjects (species, points of investigation) in order by imaginary axes which characterize the existing variation at the given site and change when different sites are compared. As ordination axes environmental factors or their combinations may be used. In the course of data processing more distinct transitions like borders of conventional communities can be shown.

8. Assuming that sessile members of a community (higher plants, slow-moving animals, fungi) depend considerably on the environment in which they root or exist, it is possible to delimitate communities and their parts by easily distinguished **environmental characteristics** (land forms, lake bottom sediments, granulometric composition of soil, etc.). This phyto-topological method has been used in geobotany in forest typology, in landscape science for delimiting community complexes and ecosystems, in regional biogeography for delimiting larger ("higher") areas of territorial units.

Division of ecology on the basis of the most important **ecosystem types** is well motivated and widely accepted: e. g. forest ecology (which is already replacing a subject studied in schools — forest biology) studying forest ecosystems, agroecology studying agricultural ecosystems, urban ecology studying urban ecosystems, etc.

Division of Ecology on the Ground of Environment

In the widest sense of the word environment means everything that is surrounding, influencing, favouring or damaging an organism and may be influenced by an organism. However, such a simple and general definition is quite obscure and ambiguous.

First and foremost it is necessary to make clear what kind of material environment or medium an organism lives in. It could be air, water, tissue of another organism or a complex or contact surface of them.

As human beings belong to the organisms of atmospheric environment, we can easily understand the ecology of organisms breathing the air on land, i. e. **terrestrial ecology**, which has given the majority of information about ecology, therefore it is ecology in the most common sense of the term.

Ecology of water organisms is actually even not called ecology. This part of ecology is developed by oceanologists (studying marine biota), limnologists (studying lakes and other continental water bodies), or hydrobiologists (studying water organisms). Often they do not call themselves ecologists, although in principle they could do that. Further subdivision of the medium is usually based on any significant environmental factor, e. g. salinity or thermal regime in the case of water environment.

Delimitation of environment is hindered by the fact that differentiation of the subject and its environment on any organizational level is conventional. Even in a compact organism part of the environment exists inside the organism, e. g. the water, oxygen or food consumed. Environment is a natural part of a system on ecosystem level and on the higher levels of ecosystems hierarchy the functional role of environment even increases. Regional and zonal ecosystems are at the same time geosystems (geographical systems).

Secondly, environment is a set of surrounding and influencing phenomena and circumstances, i. e. **surroundings** (in the terrestrial sense), or a complex of factors — the whole sphere of influence or **milieu** (in the functional sense), or both of them together. Further subdivision of environment may be carried out according to the division or combination of ecological factors (milieu factors).

In the same way as the research subjects of biology form an **encaptic row** beginning with the simplest and ending with the most complicated ones, in which every previous subject is an element of the following one (see the Table), we can regard the environment surrounding biosystems and connected with them as an encaptic row which starts with organism environment (influence sphere) and ends with global environment, having passed several stages of community environment:

$$E_O < E_H < E_L < \ldots E_G.$$

The approach to ecology by factors — **factoral ecology** — is mainly caused by methodological reasons. E. g. the investigation of radiation (actinometry, radio-ecology), chemical analysis of influencing chemicals (chemical and biogeochemical ecology), or the determination of the damaging effect of phytophagous animals are all very specific. **Experimental** ecology has numerous tasks in this field. On the other hand, factors have always a combined impact, it is the whole complex that exerts its influence, and the segregation of a single factor is questionable. Therefore, the division of ecology can also be carried out on the basis of such complex factors as climate and soil. The handling of ecological problems by zones is also justified and widely used.

New branches of ecology come into being in connection with the growing human impact which is a complex factor. In the first place ecotoxicology should be mentioned, i. e. the investigation of toxins in the environment. Anthropocentric treatment of ecology has led us to the stage at which ecology is becoming a science of human environment, leaving the existing frames of the biological science.

Division of Ecology on the Ground of the Character of Interrelationships

If we define ecology as a science concerned with interrelations of organisms and their communities, then the division should be based on the character of these interrelations. Biologists are not used to proceeding from such a starting-point, as they prefer dealing with tangible subjects of nature. The same can be said about geographers who study land areas. This kind of treatment is more common to geophysicists, geochemists, physiologists, and cyberneticists who are helping to transfer it to ecology as well. Below some sketchy subdivisions:

1. Interrelations of organisms with the abiotic environment and other organisms are differentiated. Among the latter, called **coenotic relations**, the most important are **trophical** or **nutrition relations.** In recent decades it has been observed that very small amounts of matter and moderate radiations in certain spectral parts can be important signals inducing certain behaviour or a physiological process. Applying methods of chemical microanalysis, the significance of secondary metabolic products in searching for food and mate and in regulating the relations between species has been discovered. This field of science is called **biochemical ecology.** The variety of interrelationships is even larger, including some phenomena which occur rather rarely, such as mechanical damage (e.g. fig-trees "strangle" trees on which they grow), use of another organism as a means of transport (beetles as tick carriers, ants as seed spreaders), use of material or constructions created by one animal by another, etc.

The most widely known division of biotic relations is based on whether (1) they are essential (useful and necessary — probiotic, or dangerous and harmful — antibiotic) only to one partner and indifferent to the other participant, or (2) essential to both participating organisms, being positive to one and negative to the other (predatoriness, parasitism), or (3) vitally essential to both partners (mutualism). In addition to direct (contact) relations there exist various indirect relations, mediated by the environment or an organism (transabiotic or transbiotic relations, respectively). All relations must be estimated from the aspects of their importance: are they vitally obligatory (living conditions), facultative, or even unusual and exceptional.

2. Ecologists ascertain environmental relations, but the mechanism of their impact on an organism is studied by physiologists or biochemists. This is why the border science between ecology and physiology — **ecophysiology** — has been developing rapidly. It makes wide-scale use of experiments and modelling to motivate regularities.

"Upwards" from the population level, especially when ecosystems are studied, the course of processes and regulation through the network feedback belong to the research sphere of ecologists. Modelling is very important in the case of such big and complex systems, as it is not possible and ethically allowed to carry out experiments on these levels. This developing branch of science belongs to **systems ecology.** In connection with rapidly growing environmental damage due to human impact it is vitally important for all mankind to study balance conditions of ecosystems and the whole biosphere and to forecast changes.

3. In addition to qualitative changes it is necessary to investigate quantitative features of the interrelations, i. e. their intensity, frequency, etc. Here mathematical methods play an important role, enabling to measure relations objectively, make distinctions between important and unimportant factors, and regular and occasional relations. The feasibility to distinguish a new branch of science on the basis of mathematical methods analoguously to biomathematics is disputable.

4. The dependence of organisms on environmental conditions has been the basis for using certain species as indicators of some environmental features for a long time. In the present situation it is essential to use indicator organisms as indicators of environmental decline and pollution level, therefore it could be said that **indication ecology** (or indication geobotany) is developing into a separate branch of science.

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Ecology, being a science concerned with topical problems, is expanding and altering rapidly. The scientific revolution which began in the middle of this century has considerably influenced ecology with the new data collecting and processing techniques and systems treatment. In connection with this many meanings change, terminology is renewed, but at the same time that part of the inheritance of "classical" ecology survives which has justified itself. The combination of the "old" and "new" reflects also the state of ecology at the present moment in Estonia.

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