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VALUATION OF ENVIRONMENTAL PROCESSES BY INVERTEBRATE GROUPS AS BIOINDICATORS

Key words: environment, ecological systems, bioindication, invertebrates.

Introduction

The description of an ecological system is double, in particular when it takes place in the environmental aspect. The environment may be understood as a time and space (with the emphasis on the time element) multisystem organized hierarchically (Tab. 1), or space and time (with the emphasis on the space element) monosystem. The two ways of describing the environment entail two distinct methods of its structure which are subject to various modifying processes. This duality of the description results, however, is from a wide-scale subjection of anthropogenic transformations of ecological systems (COLLIER et al. 1973, KREBS 1994, ODUM 1971). Each of the methods of describing the environment is related to its different functions and processes.

The most frequently applied form of bioindicating ecological changes and the quality of the environment is biotesting its physical and chemical state on the basis of individuals of a particular species in most cases in the local or regional aspect. The range and types of environmental changes indicate, however, the need to widen the bioindication to larger measures of time and space (KLIJN 1991) as well as the necessity to introduce monitoring methods (CHUDZICKA & SKIBIŃSKA 1998). Moreover, the application of space and time scale facilitates not only the supervision

Tab. 1. Hierarchical match of terms describing ecological system and its subsystems within the environment

Ecolological system	Biotical subsystem	Abiotical subsystem
Biosphere	Producers + Consumers + Reducers	Atmosphere + Hydrosphere + Lithosphere
Biome	Physiocenosis*	Physiotope***
Landscape (Estuary)		
Ecosystem	Biocenosis**	Biotope***
	Cummunity	Physical and chemical factors
	Population (Specimen)	

* habitat of very active consumers
** habitat of less active consumers
*** habitat of producers

of physical and chemical properties of the environment but also many of its other states, processes, and functions.

Another necessary deviation from the bioindication form in the environment applied so far at the level of a population and level of an individual (for example LD50 – VETULANI 2001, WŁODKOWIC 1997) is the use of bioindicators at the level of an interaction group. Invertebrates are animal bioindicators deserving particular attention in this respect. Common occurrence of this group of animals as well as the wide spectrum of influencing within the environment results in them being used to control changes occurring in varied ecological systems. This paper is an attempt to ascribe the defined environmentall systems to bioindicate the environmental changes by invertebrates.

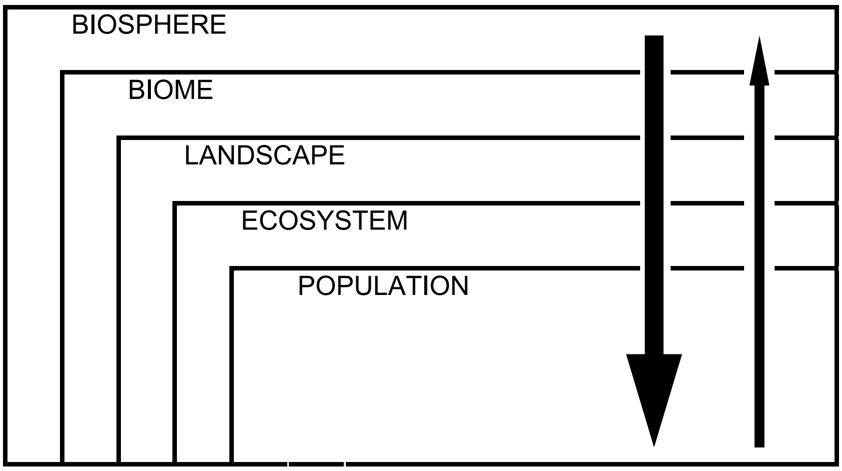
Definition of the environment

Environment is defined as an ecological system diversifying in time and space on the surface of the earth. The process of this diversification may be presented in a multi- or mono-system approach with different area scopes. Each of these methods of presenting the environment may be described on a closed time-space block differentiated, in the first instance, by the prevalence of natural processes and, in the second instance, by the prevalence of anthropogenic processes.

Such description of environment refers mainly to land areas of continental plates which are defined as land environments with a differentiated share of surface waters and estuarial environments. Sea and ocean environments are rather in large spaces than land environments. As a result, obviously, they do not function in land with respect to the landscape level. Their certain equivalents at the landscape level (for example biome) may be sea and ocean areas whose temperature of surface layers is related to the temperature of particular climatic zones or areas with characteristic geomorphology of bottom. In theory, however, these ocean landscapes have been inadequately researched.

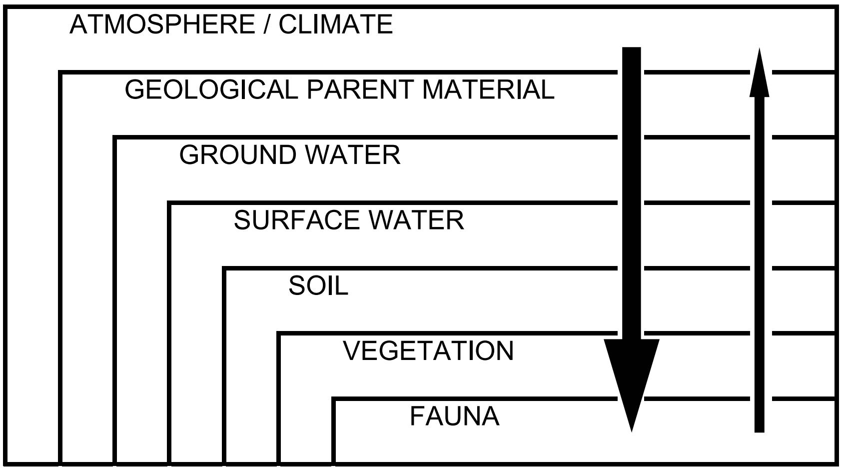
In a multisystem approach to the environment, its biotic components, in a presumably abiotic background, influence one another and remain under the immense influence of natural processes (COLLIER et al. 1973, WEINER 1999). These influences are directed according to the scale of space and time functions starting from the biosphere to the population. At the same time, between these components, oppositely directed weaker functions take place from the level of the population and individual to the level of the biosphere (Fig. 1).

Fig. 1. Hierarchical complex of different ecological systems as the environment with relations considering their diversified functions. Arrows indicate the intensity of influencing relations between systems of diversified size.



In a monosystem approach to the environment, its abiotic and biotic components remain in functional interlinkages with one another (VAN DER MAAREL & DAUVELLIER 1978, BAKKER et al. 1979, 1981, PIKET et al. 1987). These interlinkages refer to mutual influences which are directed according to the space and time scale of subjection, starting from the atmosphere to fauna and man. At the same time, between these components, there are oppositely directed influences from fauna elements to atmosphere, with weaker connections, however (Fig. 2).

Fig. 2. Hierarchical complex of the structural components of the environment as ecological system (according to VAN DER MAAREL & DAUVELLIER 1978, BAKER et al. 1979, 1981, PIKET et al. 1987). Arrows indicate the intensity of relations between structural components of the ecological system.



Bioindication of the environment

In the description of spatial component relations of a multisystemic environment, there is the hierarchy of size of ecological systems (as in Tab. 1). At the same time, particular ecological systems may be connected with differentiated spatial levels of the environment (Tab. 3). Depending on the size of the ecological system, the number of spatial levels subjected to the system changes. So, the population (of plants and animals) covers its space and time influence on the area from the ecoelement to the ecosection, while the biocenosis - from the ecoelement to the ecodistrict.

Natural processes prevail among the components of the multisystemic environment; these are biogeochemical cycles, transformation, succession (including also sustainable development), evolution, dynamics of the density (including dispersion, invasion, gradation of individuals, mortality) and physiological processes such as toxicological reaction, growth, maturation, reproduction, ontogenesis as well as biochemical and genetic adaptations (Tab. 4).

In the description of spatial relations of the components of the monosystemic environment, there is the hierarchy of the size of environments (as in Tab. 2). Differentiated spatial levels may be connected with abiotic and biotic components of the environment (Tab. 5). Depending on area of the described environment, the share of particular components of the environment changes. Hence, for example ecoelement and ecotope covers mostly relations between surface waters, soil, vegetation, and fauna.

Tab 2. Hierarchical classification of various environment spatial mapping scales (according to KLIJN 1991)

Environment		Mapping scales	Mapping units
Ecozone	[EZO]	1:>50000000	>62500 km²
Ecoprovince	[EPR]	1:10000000-50000000	2500-62500 km²
Ecoregion	[ERE]	1:2000000-10000000	100-2500 km²
Ecodistrict	[EDI]	1:500000-2000000	625-10000 ha
Ecosection	[ESC]	1:100000-500000	25-625 ha
Ecoserie	[ESR]	1:25000-100000	1.5-25 ha
Ecotope	[ETO]	1:5000-25000	0.25-1.5 ha
Ecoelement	[EEL]	1:<5000	<0.25 ha

Tab 3. Relation between ecological systems as in the hierarchical complex (Fig. 1) and various environment scale levels (as in Tab.2)

Ecological system	Levels of environment							
	EZO	EPR	ERE	EDI	ESC	ESR	ETO	EEL
Biosphere	+	+						
Biome	+	+	+	+	+			
Landscape (Estuary)			+	+	+	+	+	+
Ecosystem				+	+	+	+	+
Population (Specimen)					+	+	+	+

Tab 4. Processes, its range (↓) and point of action (+), on ecological systems in the hierarchical complex as in Fig. 1

Ecological system	Processes					
	BGC	TRA	SUC	EVO	NUM	PHY
Biosphere	↓+	↓	↓	↓	↓	
Biome	↓+	↓+	↓	↓	↓	
Landscape (Estuary)	↓+	↓+	↓	↓	↓	
Ecosystem	↓	↓	↓+	↓	↓	
Population (Specimen)				↓+	↓+	↓+

BGC = biogeochemical cycles
TRA = transformation
SUC = succession (also sustainable development)
EVO = evolution
NUM = numerosity (also dispersion, invasion, gradation, mortality)
PHY = physiology (also biochemical and genetic adaptations)

Tab 5. Relation between environment components as in the hierarchical complex (Fig. 2) for various environment scale levels (as in Tab.2)

Components	Levels of environment							
	EZO	EPR	ERE	EDI	ESC	ESR	ETO	EEL
Atmosphere	+	+						
Geology	+	+	+	+	+			
Ground water			+	+	+	+		
Surface water			+	+	+	+	+	+
Soil				+	+	+	+	+
Vegetation					+	+	+	+
Fauna					+	+	+	+

Anthropogenic processes prevail among the components of the monosystemic environment. In general, they may be defined as processes disturbing the components of the environment. These are acidification, eutrophication, pollution (including poisoning), desiccation, destruction of the functional subjection of components, plants dissecting or other methods of modifying vegetation (also cutting and destroying), disturbing fauna (scarring off, hunting, holding in captivity, limiting the living-space, etc), and contributing to the escalation of the greenhouse effect. These disturbances include and directly influence various components of the environment (Tab. 6).

Tab 6. Perturbations, their range (↓) and point of attack (+), on dependent components of environment as in the hierarchical complex (Fig. 2)

Components	Perturbations							
	ACI	EUT	POL	DES	DET	DIS	DIT	GHE
Atmosphere	↓+		↓+					↓+
Geology	↓		↓+		↓+			↓
Ground water	↓	↓+	↓+	↓+	↓			↓
Surface water	↓	↓+	↓+	↓+	↓+			↓
Soil	↓+	↓+	↓+	↓	↓+			↓
Vegetation	↓	↓	↓	↓	↓+	↓+		↓+
Fauna	↓	↓	↓	↓	↓+	↓	↓+	↓

ACI = acidification
EUT = eutrophication
POL = pollution and intoxication
DES = desiccation
DET = destruction
DIS = dissection
DIT = disturbance
GHE = green house effect

The above-listed disturbances remain within the scope of bioindication (biotesting or biomonitoring) through various bioindicators at the levels of: population (including level of an organism), community (including an ecocen, for example soil fauna, herbivore fauna, pollinating insects, predatory macro-invertebrates, benthic macroinvertebrates), biocenosis and physiocenosis (Tab. 7). It indicates that the levels of bioindicators are, at the same time, components of the multisystem model of environment. Here the two environmental describtions overlap. In this complex the environment represented mainly in the spatial aspect is controlled by its natural components. These natural components (individual, population, set, biocenosis, physiocoenosis) reflect the course of various processes in the environment through changes in their structure. So, at the level of an individual, morphological changes occur, at the level of population – changes of density and the quantity share of age groups, and at the levels of community (any cenosis) – changes in the number of species in space and time, in the dominating structure, and in the diversity of species.

Tab 7. Bioindicator levels for environment in hierarchical classification

Environment	Bioindicators			
	Population[1]	Community[2]	Biocenosis[3]	Physiocenosis
Ecozone	S	S	S	S+
Ecoprovince	S	S	S	S+
Ecoregion	S	S	S	S+
Ecodistrict	S	S	S	S+
Ecosection	S+	S+	S+	S+
Ecoserie	S+	S+	S+	S
Ecotope	S+	S+	S+	S
Ecoelement	S+	S+	S+	S

[1] also **group of specimens** (= organism level)
[2] first of all **competition community** for environmental resources, **ecocen** (e.g. soil fauna, herbivore fauna, pollination insects, predatory macroinvertebrates, benthic macroinvertebrates)
[3] also **phytocenosis**, **zoocenosis** or **taxocen** (genus, family, order)

S – structure: morphology for specimens, age groups and numerosity for populations, number of Species and diversity for biocenosis
+ – direct impact on elements of system (processes as in tab. 4 and 6)

Moreover, the reaction of the structure of bioindicators to environmental processes may be observed only in selected spatial ranges of the environment. Hence, a direct reaction of the structure of a bioindicator at the level of population is observed only within the ecoelement to ecosection mainly for such natural processes of an ecological system as evolution, dynamics of density or physiological

Tab 8. Range and processes of ecological systems bioindicated by invertebrates

Ecological process	Bioindicators (according to selected publications)
WE – trophy	C – zooplankton (Karabin 1981, 1985; Kowalczyk & Radwan 1982; Lityński 1925; Patalas 1954; Szlauer 1996); C – *Entomostraca* (Bowkiewicz 1938); C – *Chironomidae* (Giziński 1974); C – *Rotatoria* (Ejsmont & Hillbricht 1994)
WE – chemical pollutions	P – *Bivalvia* (Pempkowiak & Szefer 1992, Pawlikowski 2001, Skołowski et al. 2002); P,C – macrozoobenthos (Rosenberg & Resh 1993); P – *Daphnia magna* (Szlauer 1994, Szlauer at al.1994); P – selected species of *Ciliata, Cladocera, Copepoda* (Tarczyńska et al. 2000)
WE – physical pollutions	P,C – *Mollusca* (Hadderingh et al.1987)
TE – biocenotic type	C – *Apoidea* (Pawlikowski 1992a)
TE – hygrity	C – *Apoidea* (Pawlikowski 1989b)
TE – pollution and toxication	C – *Apidae* (Kosior & Nosek 1987)
TE – ecological changes (naturalization, destruction)	P – *Anoplodera sexguttata* (F.) (Zieliński 1998); Z – *Hymenoptera Aculeata* (Tscharntke et al.1998)
LE – natural fragmentation (by droughts, windfallens, fires, floods)	Z – *Hymenoptera Aculeata*
LE – anthropogenic fragmentation (forestry, agriculture, urbanisation, industry – area division, felling, chemization, cultures, arrange of vegetation, building etc.)	C – *Apoidea* (Pawlikowski 1989); C – *Apidae, Vespidae* (Pawlikowski 1992b, 1993)
LE – xerisation	C – *Apoidea* (Banaszak 1983, Pawlikowski 1989b, Pawlikowski & Hirsch 2002)
LE – retention of running waters	Z – *Hymenoptera Aculeata*
LE – climatic changes	P – *Lepidoptera* (Parmesan et al.1999); P,C – *Aphidinea* (Ruszkowska 1999)
LE – pollution and toxication	P – *Parnassius apollo* L. (Nuorteva et al.1993); P,C – *Aphidinea* (Wojciechowski et al.1991)
LE – ecological changes	C – *Acari* (Błoszczyk 1998, Czarnota & Błoszczyk 1998)

WE = water ecosystem, TE = terrestrial ecosystem, LE = landscape ecosystem, P = population, C = community, Z = zoocenosis adaptations. At the levels of a community or any cenosis, their reaction may be observed in the spatial range of a homogeneous system from the ecoelement to ecosection and it is mainly the reaction to succession changes, and in the spatial scope of a heterogeneous landscape, from the ecosection to the ecozone, mainly to various succession – transformation processes and biogeochemical cycles (as in Tab. 4).

Bioindicators of ecological systems

Both environmental descriptions presented the environment in various degrees of the heterogeneity of its structure. With the increase of the described area of the environment, in particular of the culture-modified environment, anthropogenic processes occur more intensively which means that applying elements of the monosystemic description is more appropriate to describe these. In a natural environment maintaining a relative structural and functional homogeneity, it is advised to describe its state on the basis of the elements of the multisystem description. Common occurrence of invertebrates in the environments of varied spatial scale in particular fosters the use of these as bioindicators of changes in homogeneous systems, that is in ecosystems, or in heterogeneous systems, that is in landscape systems (Tab. 8).

Competing communities of benthic species exhibit good bioindication properties in this respect for water ecosystems and active groups of herbivore insects (for example Hymenoptera Aculeata) for land ecological systems. The latter ones in particular change their structure under the influence of biocenosis changes (anthropogenic in particular) in the ecosystem or under the influence of changes in the hygric conditions or in the mosaic of habitats within the landscape.

Ocena procesów środowiskowych przez wskaźnikowe grupy bezkręgowców (streszczenie)

Przedstawiono dwa sposoby opisu środowiska do bioindykacyjnego monitorowania jego zmian przez bezkręgowce. Przyjęto, że środowisko to układ ekologiczny różnicujący się w czasie i przestrzeni na powierzchni ziemi. Każdy ze sposobów oceny oparto na zamkniętym bloku czasowo-przestrzennego zróżnicowania elementów i procesów naturalnych oraz elementów i procesów antropogenicznych. Stwierdzono dobre właściwości bioindykacyjne zespołów gatunków bentosowych dla ekosystemów wodnych oraz aktywnych naroślinnych grup owadów dla różnych ekologicznych systemów lądowych.

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