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ECOLOGICALLY ACTIVE SURFACES, METHODOLOGICAL APPROACH TO THE STUDY OF ECOLOGICAL FUNCTIONS

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Abstract

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In studies of individual organisation levels of organisms, the requirement of hollistic expression of structure and function is traditional despite the fact that structural direction prevails in studies. Less attention is paid to the place where function activity occurs in connection with the structure. This place is the surface – the medium where physical, chemical, biological and synergic processes interact. These surfaces are called ecologically active surfaces (EAS). From this standpoint, the surface is a place for energy exchange, which appears as mean studies of function and structural properties of the biological object**.**

The quantification of these areas taking into account the functional activities – (developed surface, the functional characteristics) to the desktop, or to the volume is the methodological starting point in the assessment of the country, or of its componens after the assessment of the energy potential of the environment. This ratio can be considered as the degree of heterogeneity of the conditions after taking into account the gradient of the environment.

We have achieved partial results related to EAS during the solution of tasks connected with the environmental evaluation of biotic components of a landscape, mainly during the investigation of aquatic biotopes, which are demonstrated on some examples.

Key words: ecologically active surfaces (EAS), aquatic biotopes, Eastern Slovakia.

Introduction

Application of ecological features and characteristics and their use in aquatic water facilities, either breeding or hydraulic infrastructure, is rather a long-term process and has not been fully exploited yet. During the last two decades, we have accumulated a large amount of data supporting the relationship between morphological and biological characteristics, which can be effectively used in numerous sections of water management. These opportunities arise from the existence of eco-active surfaces – EAS reflecting increased activity in different directions.

In the study of the basic ecological problem 'structure and function', considerable attention was given to phenomena and processes of water anthropogenic landscape elements, especially hydromelioration channels, flooded mining pits and dams. In terms of the agricultural landscape of Eastern Slovakia lowland, they form a significant landscape element with rather unknown and not very much used biotic functions. The primary objective of this study was to develop proposals that would increase biotic functions and their evaluation for a landscape-ecological plan (Ružička, 1990).

When studying different levels of the organisation of a biological system, the requirement for a holistic expression of the structure and function is traditionally claimed. The reality is that the structural focus of the research at various hierarchical levels still prevails and almost no attention is paid to the place where the functional activity occurs in relation with the structure.

The place where the functional activity is demonstrated in connection with the structure is the surface, a medium where the physical, chemical, biological and synergic processes take place, which we call ecologically active surfaces (EAS). From this perspective, the surface is a place of energy exchange – it is a means in the study of functional and structural properties of a biological object. The quantification of such surfaces, taking into account the functional activity per area or volume, is the methodological basis in the evaluation of the landscape or of its components after the assessment of the energy potential of the environment. This ratio may be regarded as the degree of the heterogeneity of conditions after taking into account the environmental gradient (Terek, 1991, 1994, 1999).

In the scientific literature, works studying phenomena such as an offshore, marginal, edge, boundary, outline or contour effect (Khailov, 1982), as well as biofilms, biological membranes, marginal layers and also active areas of biological surfaces, ecotones, wetted perimeter, impact zone and so on can be found. (Terek, 1991). We worked on the problem of absolute isolation. Numerous authors claim that this layer is manifested by enlarged biological activity, respectively abundance, biomass and species abundance.

Nowadays there are many direct and indirect proof and evidence from the fields of physics, chemistry and biology in particular, about the existence of this layer. Results show that increased activity is a result of complex photo-chemo-hydrodynamic interactions and other factors. Recently, we can find a number of of works studying 'boundary zones' from elementary particles to macrospace.

When solving tasks related to ecological evaluation, in particular, aquatic ecosystems, we have achieved partial results with the presence of EAS and their use, which we will demonstrate. The results concern long-term monitoring of hydromelioration channels and studies of zooplankton in the river Latorica, a tributary of the river Tisza in Eastern Slovakia (Terek, 1993, 1995). Results on the study of zooplankton in the river Rhine were evaluated in a similar way (Terek, Obrdlík, 1992).

Similarly, the knowledge of EAS was used in the monitoring of the process of biodegradation of petroleum substances in the rivers of Latorica and Uh (Terek, 1996; Lauková et al., 1997).

The EAS theory has been used in the development of the categorisation and optimisation of channels of the Eastern Slovak plain (Terek, Hronec, 2013) and in the evaluation of the improvement of water quality in the upper part of the Domaša water reservoir in Slovakia (Terek, 2014).

In the past decades, there were works that dealt with EAS in general terms, especially in the application practice (Perrow, Davy, 2002; Perkol-Fingel et al., 2012), which emerged from the general knowledge that '… each substrate is able to provide specific conditions for colonisation of organisms and therefore it needs to be counted as the active ingredient'.

The aim of this paper is provide information about the basic principles of a comprehensive study and evaluation of ecological functions. On the basis of the principles of the existence of EAS, the modelling of the relations between morphometric and fine structural characteristics of the biota, or between variables for the modelling of functional relationships in a holistic understanding of the structure and function, should follow.

The article was based on the results of laboratory and field monitoring, which was occasionally done for the last 25 years.

Methods

In order to conduct the study, physical and chemical experiments were carried out, in particular the transfer of energy through a surface: solid substance–solid substance; solid substance–liquid; liquid–air (gas) and so on. But such studies were carried out in order to study selected parameters.

We carried out a series of experiments to study integrating parameters, which merged the transfer of energy for inorganic and organic substances with biological matter.

From among a number of results, I will demonstrate a simple experiment with natural algae cultures in containers in which the sizes of surfaces, as well as the water trophy and cyanobacterial culture, change.

Monitoring in semi-laboratory conditions was conducted in order to measure the values that would express the dependence of the production of cyanobacteria and algae on the size of the contact surfaces, that is, EAS, at various trophic potentials. Four series in three repetitions with multiplying EAP sizes were prepared. In total, 36 glass bottles were exposed for 14 days.

At the end of the exposure, biomass was determined in individual bottles with chlorophyll *a*. The extraction was done with acetone and it was measured by a spectrophotometric method (by STN 757715). The obtained values were recalculated to 1 litre due to the fact that the installed surfaces (thin-walled glass tubes) displaced a certain volume of liquid when the surface area was multiplied.

N-0., F-0: The surface of the inside of bottles (volume 2 litres)
N-1., F-1: Surface inside bottles increased by 50%
N-2., F-2: Surface inner part increased by 100%
N-0, 1, 2, F-0, 1, 2, 1,2,3 (x) repeats.

The cyanobacteria and algae culture was composed of the following species. *Raphidocelis subcapitata* Skulberg, *Monoraphidium cf.contortum* Reháková, *Chlorella kessleri* Long, *Scenedesmus obliquus* O.Lhocky, *S. quadricauda* Greifswald and *S. subspicatus* Brinckman.

In the intra-embankment area of Latorica river (Eastern Slovakia lowland), we have analysed relationship between changes in water level regime and qualitative–quantitative changes in zooplankton network in flooded reservoirs.

Results

The laboratory experiments clearly demonstrated the relation between the EAS and the periphyton (biomass of the natural culture of cyanobacteria) biomass at different levels of trophic potential (Table 1).

The production increases with the surface area at low trophic potentials and large surface areas (N-0, N-1, N-2).

The production is reduced after the nutrients are depleted in the artificial cyanobacteria culture with large areas (N-2).

The biomass of the natural culture of cyanobacteria and algae in pond water enriched with nutrients is more than thrice higher than in the water in a natural environment (F-0, F-1, F-2).

The cyanobacteria culture in nutrient-enriched water does not show a significant increase in the biomass with a larger surface area (F-0, F-1, F-2).

The optimisation process includes the determination of optimal parameters, such as the surface area, trophic level, exposure time and temperature. The regression curves suggest that the increase in the production differs, expressed by an angle of 42–83° (Terek, Mamrilla, 1995).

T a b l e 1. Cyanobacteria biomass production expressed in chlorophyll *a* ($\mu g \cdot l^{-1}$).

Natural water pond ($mg \cdot l^{-1}$). NH_4^+ – 0.6, NO_2^- – 0.04, NO_3^- – 0.7, PO_4^{3-} – 0.3			Natural water pond with fertiliser ($mg \cdot l^{-1}$). NH_4^+ – 10.2, NO_2^- – 0.06, NO_3^- – 7.2, PO_4^{3-} – 0.7		
N-0-1	7.72	8.23	F-0-1	25.12	20.30
N-0-2	8.65		F-0-2	19.61	
N-0-3	8.31		F-0-3	16.18	
N-1-1	9.21	9.05	F-1-1	33.21	32.86
N-1-2	9.19		F-1-2	31.09	
N-1-3	8.75		F-1-3	34.27	
N-2-1	9.65	9.70	F-2-1	36.65	36.82
N-2-2	10.59		F-2-2	37.21	
N-2-3	9.88		F-2-3	36.60	
Cyanophyte culture			Cyanophyte culture		
N-0-1	12.61	12.97	F-0-1	17.70	17.58
N-0-2	13.74		F-0-2	17.36	
N-0-3	12.56		F-0-3	17.69	
N-1-1	16.88	19.29	F-1-1	19.89	19.88
N-1-2	19.43		F-1-2	18.65	
N-1-3	21.56		F-1-3	21.10	
N-2-1	6.28	5.81	F-2-1	21.99	21.61
N-2-2	5.88		F-2-2	21.10	
N-2-3	5.26		F-2-3	21.85	

When solving problems related to the environmental assessment of landscape elements, particularly in the study of aquatic ecosystems we have achieved partial results with EAS, which we present in Fig. 1.

As an example, we can mention the structure of zooplankton in alluvial basins inside and outside of dam areas of the Latorica river; especially in dead branches and clay pits there is an abundant species diversity of zooplankton (Rotatoria, Copepoda, Cladocera). This condition is related to the great variability of environmental conditions manifested in time and space, as well as the possibility of supplying species of rafting and transport by birds. Ecologically diversed conditions in a small area are subject to constant water column changes, that is, changes in contact zones or EAS, where border effect is manifested by increased species diversity and its production (Terek, 1990, 1991, 1993): 64 taxa Rotatoria, 15 Copepoda and 26 Cladocera, as in the Rhine (Terek, Obrdlík, 1992) were determined. Seventy Rotatoria, 54 Cladocera, 25 Copepoda, 1 Brachiura, 76 Rotatoria, 10 Copepoda and 32 Cladocera were found again in the Latorica river area (Smoľak, 2009). In its natural sites, out of the embankment area where there is no significant fluctuations in water level, Zooplankton was a relatively poor species (37 Rotatoria, 7 Copepoda, 17 Cladocera).

When you change the conditions of the water column, significant changes happen in the zooplankton community structure, and the similarity index becomes low (Ja index). Applied to two sites with differing physiomorphological conditions, zooplankton in the inundated area appears to be an incomplete and unstable community, showing signs of ongoing restructuring.

The EAS principle was used to describe a situation in channel systems (Terek, 1998), especially in the optimisation of conditions associated with macrophyte overproduction. It has been prepared on the basis of categorisation channels, dominant submerged and emergent vegetation and the amount of oxygen (ibidem).

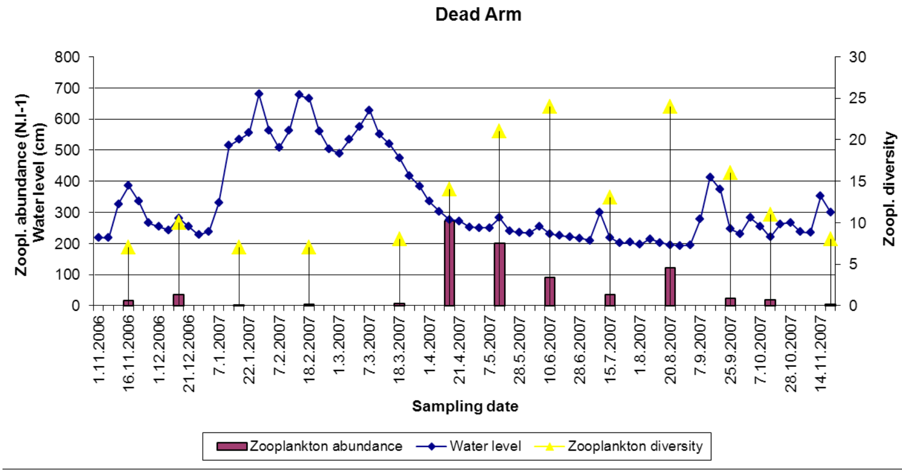

Fig. 1. Changes in the water column (cm) and subsequent changes in abundance (n.l^{-1}) and species diversity of net zooplankton.

The results of monitoring being done in the upper parts of the multipurpose reservior Domasa has showed the elimination of woody vegetation to a large extent through its active surface. One square metre of floor contact area reached 60 m^2 of woody vegetation; periphyton was represented by 62 species. In these areas, there is a significant elimination of agricultural nutrients, and water quality has been improving from the alpha to beta mesosabsorobic level (Terek, 2014).

When studying the biodegradation of petroleum substances in rivers Latorica and Uh, there was a rapid biodegradation process; so within one year the biodegradation was reduced up to 96.1%. This condition was related to the presence of suspended soil particles and particles of pollution in municipal water, which provides a large area for microorganism development (Terek et al., 1996; Lauková et al., 1997).

Discussion

In practical hydrobiology, there have been studies explaining, for example, the relationship between catches of fish and morphometric characters of tanks (Khailov, 1982). Rousnsefell has found indirect dependence proportional between productivity and the tank size (Rounsefell, 1946), Rawson argues that a good indicator of productivity is depth (Rawson, 1952), Ryder et al. (1973) coins the term morpho-edafic index, which is a relationship between the quantity of substances in water and the water depth. Similarly, Zelinka (1979) evaluates artificial reservoirs based on morphometric characters. The existence of a 'border effect' is also related to the theory of island biocenosis (Diamond, May, 1979). Those references attest to, directly or indirectly, the existence of EAS explained in many ways.

Although interpretations can be made in the context of the dilution effect as regards the abundance expression to 1 litre, species diversity clearly shows a significant increase in coupling: S.V = K (Fig. 1).

The observed increase in cyanobacteria and algae presented in the first example shows a tendency for the actual values to possess evident methodological error (Table 1).

The presented relationship (Fig. 2) expresses the ratio of all contact surfaces to the volume K, and in flowing ecosystems, also the turnaround time and water change. The value A is an interpretation of environmental activity (species diversity, biomass, self-cleaning ability etc.).

The authors come to the conclusion that biological production and intensification are possible to an extent; the greater the replenishment from outside the ecosystem, the greater the improvement in material flow. Closed energy flows donot offer an opportunity to show the biopotential of ecosystems.

The relation S (surface) . V (water volume) has already been used by Khailov (1982). For flowing water ecosystems, it is necessary to introduce 'water exchange time' T. More morphometric characteristics, such as the size of the bottom surface, vegetation, microparticles and water exchange are gradually added (Eqs 1, 2).

This relationship has wide validity and application (landscape ecology, soil science, hydrobiology, biogeography), in several disciplines.

The principle of this relationship was used in the optimisation process.

Overall, the solution to this problem in aquatic ecosystems is divided into phases:

- empirical (Ravson, 1952; Rounsefell, 1946; Ryder et al., 1973),
- proof-existence EAP (Ajzatullin et al., 1984; Khailov, 1982; Glushkov, Nikolaeva, 1980; Terek, 1991; Terek, Mamrilla, 1995; Terek, 2014),
- modelling functional relationships (awaits us).

$$K = \frac{Sa + Sb + Sv + Sm}{V} \qquad \text{(Eq. 1),}$$

$$A(N, B, P, Sc) = K \cdot T \qquad \text{(Eq. 2),}$$

where *Sa* – surface area of the water body; *Sb* – bottom surface area; *Sv* – vegetation surface area; *Sm* – number of microparticles; *V* – volume of water; *T* – water exchange time.

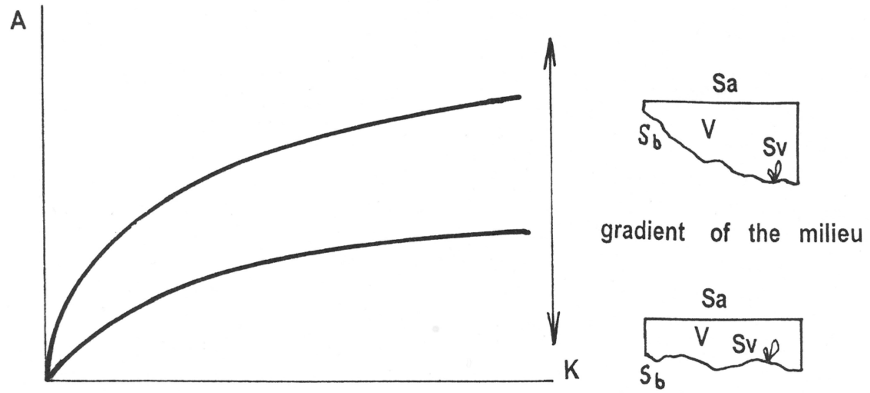

Fig. 2. Relation *A*-activity (species diversity *N* as well as biomass *B*, production *P* and self-cleaning capacity *Sc* against the proposed characteristic *K*).

The evaluation depends on the depth of the study of the relation water volume (*V*) . unfolded surface area (*S*) . bottom surface area (*Sb*) + air surface area (*Si*) + vegetation surface area (*Sv*) + microparticle surface area (*Sm*), while considering the water exchange time (*T*) and taking into account the environmental gradient. When evaluating that formula, we start from the premise that 'the higher the ratio (*K*), the greater the possibility of different environmental conditions', that is, the higher the number of different species, the quantity of the biomass (*B*), the production (*P*) and the self-cleaning capacity (*Sc*). With the enlargement of the boundary areas *K*, the efficiency increases as the result of an increased biological activity of the A boundary zone, which manifests itself in an increased diversity of species, productivity, biomass, self-cleaning capacity and so on.

EAS parameters should have been considered when designing water structures and the volume of water exchange, trophy, temperature, biota, and number of microparticles should be taken into account.

Conclusion

The results obtained from our own measurements and numerous literary sources confirm that the EAS ratios to the volume are the summarising indicators and constitute one of the methodological issues not only in assessing the capacity of selected landscape elements and their components, but also for the study of the production, stabilisation, endurance and self-cleaning function at the different hierarchical levels of organism structure.

The proposed EAS values reflect a number of factors and may act as summary indicators, which significantly influence the direction and processes in the ecosystem. They allow to develop the methods of landscape element evaluation and their components at different levels of anthropic load. Optimisation of the country from this perspective is the regulation of bioenergy potentials of different types of landscape elements. In addressing the tasks, the following still need to be clarified:

- Relations between morphometric and fine structural characteristics of biota in aquatic ecosystems and terrestrial ecosystems, respectively, and their parts
- Morphometric analysis of the studied objects and biological activity of the boundary zone EAS
- Analyse and categorise the relationship between the areal size of the bottom, water mirror, biomass, species diversity and production activity.

Attention must be given to the following:

- Modelling of the relationships between morphometric and fine structural characteristics of biota
- Successional processes and EAS
- Quantified research of ecotone environment.

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