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On the ecological status of the concept "Boundary Conditions" A few methodological remarks

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Abstract. Plant and animal populations are frequently found in habitats where the environmental conditions are considered extreme or challenging for life form to exist. These conditions may be classified as either: (1) Supreme: a situation characteristic of degradation conditions where only a few species live under stress, and (2) Extra-ordinary: habitats that provide high biodiversity that are under stress conditions. Due to the differences in what we consider extreme conditions, it is necessary to distinguish between these two categories, because they are not comparable. Our presentation will include examples of these two extreme environmental categories.

Key words: etymology, definition of boundary conditions, extreme environmental conditions, explanation.

1. Etymological notes

In recent years, concepts such as: "extreme species" and "extreme habitat" have been popularized (especially in the English literature) to the extent that now they are used in many different contexts in ecological studies. However, it is necessary to more clearly define these terms and their application to habitat and population relationships. Let us begin with their etymology.

In English, "extreme" means "something that goes beyond normal limits and is very unusual or severe", while "extremely" means "to a very great degree" or "extraordinary". According to the "Dictionary of Foreign languages Phrases" (Kopaliński 1994) „ekstremum" in the mathematical sense means local maximum or minimum in the course of a function at a certain point. In Latin, *extremum* denotes "end"; *extremus* means the farthest and is derived from *exter(us)* – external. In the ecological language, each of the meanings mentioned above is related to: habitat, species, and population. Each of these etymological descriptions is associated with the concept of "**boundary conditions**" in which a given species or a population occurs.

2. Semantical concepts of "boundary conditions"

The concept of "boundary conditions" is frequently used interchangeably with the notion of "**limiting factor**" which is closely related to the concept of the minimum and is an important component of Liebig's law (Liebig 1840).

The law states that the growth rate, reproduction, photosynthesis, primary production or the size of a population are regulated by one or two limiting factors **which are in deficiency,** whereas other factors, **being in excess,** are often not used in the description of a particular biological (ecological) process (Pianka 1981; Łastowski 2002). Among numerous factors limiting the occurrence of a certain species are: nutrients, temperature, and access to light (Program and Abstracts 2000). Limiting factors which regulate the size of a population are: access to food, presence and activity of a predator, and climate changes. The habitat limiting factors are: changes in biogenic concentrations and the negative influence of accompanying species (negative allelopathy) (South, Whittick 1987).

As stated above, the semantic scope of the concept of boundary conditions includes degrees of: **excess and deficiency** (Reichholf 1996; Łastowski 2002). Their usage is connected with the **law of tolerance** (Shelford 1913). Since the energy budget of each organism has a finite value, identifying the "boundary conditions" which would specify an excess or deficiency seems possible in many cases (the Shallow Lakes 2002). Precisely for this reason the organism possesses highly limited regulative skills in a specific situation, and what is most important; its homeostatic skills may also be impaired. In other words, the category of "boundary conditions" is interpreted rather freely by many scholars, and which can be observed when they, for instance, characterize the environmental stress of a given plant, whose presence usually entails further limitations of its tolerance to stress (Kocjan, Łastowski 1995).

In the situations described above, geneticists use another concept, i.e., "**population narrowing**". The fundamental basis of this approach depends upon the characteristics that influence the success and size of a population. Some scholars refer also to **natural selection**, chiefly in situations where it exerts its influence after the intensification of genetic drift, which may initiate great changes in the features and variety of a population (Ziętkiewicz 2002).

Nevertheless, if we investigate a population or species in the geological (evolutional) time scale, as well as in present (including ecological) time, then the definition of "boundary conditions" may be expanded. These definitions are determined, with reference to the time scale, by understanding one of the most fundamental tenets in biology: the consequences of natural selection (Fisher 1930). Most often, the concept of "boundary conditions" is used to indicate the effectiveness of natural selection, i.e., when we assess: (1) which genes are dominant or recessive; (2) which organisms live longer; (3) which organisms reproduce successfully; (4) which organisms are common or rare; (5) which organisms are more adaptable to change; (6) which organisms are monogamous or polygamous; and (7) which organisms change sexual partners (Palmer 1980).

Nonetheless, quite frequently the specification of "boundary conditions" in the characterization of a species, or a population, is connected to their successful survival in a habitat under extreme environmental conditions. In other words, the issue is their ability as organisms to exhibit a natural propensity to significant tolerance of disturbances to the state of equilibrium in which they live. A good example of surviving under extreme environmental conditions is the survival of certain species of diatoms and water fungi in nuclear reactors and water-cooled power plants.

Very often, an example of "boundary conditions" includes the occurrence of a species or a population in very unusual habitat conditions. They are then regarded as an indication of an entirely peculiar phenomenon of nature which shows the diversity of habitats supporting life on Earth, including those that are truly ephemeral, or short-lived. An appropriate example of this is the presence of many *Cyanoprokaryota* in the Antarctic (investigated by Dr Komárek) or the occurrence of diatoms in baptismal fonts (reported by Prof. Lange-Bertalot). The term "natural phenomenon" is also used to describe species which inhabit unusual altitudes or depths. Such situations deserve this designation, but they also require a precise indication and specific characterization of their

"boundary conditions". Thus, we strongly recommend that this is a special condition that requires additional attention and a critical approach in defining the survival boundaries and conceptual status of organisms.

An example of such specialization is present in the boundary conditions characterizing the water ecotone habitat that occurs at the border of water and land ecosystems. It has not been decided yet whether or not the inundated grounds occurring with high water levels should be treated as an extreme "boundary condition" in the changing water levels that occur in reservoirs and lakes. More definite "boundary conditions" characterize the border between the hydrosphere and atmosphere, as well as, the hydrosphere and lithosphere. An example of the former is the surface layer of water where neuston populations are present; and of the latter is a moist rock, cave or a layer of deep sand where psammon species are found (Shubert at al. 2001).

3. Methodological status of "boundary conditions": the methodological argument

The content-related characteristics of "boundary conditions" given above gain another argument in methodological practice. This is because the way in which "boundary conditions" are understood is particularly important for the explanation of biological and ecological phenomena.

The classical scheme of explanation proposed by Hempel (1964) comprises the explained component (explanandum) and the explaining one (explanans). The latter consists of two types of premises: (1) the major premise (set of laws indispensable for the explanation of the phenomenon investigated), and (2) the minor premise, whose content includes the description of concrete conditions (these being the specifying conditions) in which a given phenomenon occurred. It is this concrete description of "boundary conditions" which is included in the minor premise, for the minor premise (the specifying conditions) depicts more or less precisely a concrete situation in which the explained phenomenon occurs. This methodological assumption has its validity in ecological research as well, e.g. those studies which constitute the subject of our emphasis here in particular.

As we have shown earlier, the difficulties in specifying the boundary conditions which biologists face include problems with a reliable explanation and – which is of paramount importance in science – with an exact prognosis. It is precisely the appropriate understanding of "boundary conditions" that determines the efficacy of explaining ecological phenomena and the accuracy of prognosis. There is no need to develop this matter further here, but each meticulous researcher in ecology faces these difficulties. Giving the methodological argument, we sought to point out the crucial, albeit purely theoretical, significance of the problem presented in the paper.

It is unfortunate and often misleading, especially with the diverse interpretations of the concept of "boundary conditions" ("2. Semantical concepts- - - " above), that this condition lacks for proper explanation and is very often disregarded. Irrespective of other demands (e.g. adopting scientific ways of explanation, i.e. scientific laws), its definition associated with various habitats is necessary if we wish to discuss factual reasons for ecological changes.

4. Conclusion

Finally, the question "why did we deal with the issue" seems worth answering. In everyday practice of ecological research the issue of characterizing "boundary conditions" seems, on the surface, insignificant. However, we stress the importance of a more clearly defined and precise characterization of the extreme boundaries for the biotic components in various habitats. We have provided examples of the diversity of etymological approaches that have been applied to comprehending this theoretical category and usage in scientific papers. To establish a precise and coherent application of this concept is hardly an easy task. How difficult it is depends to what extent and how clearly we understand the theoretical premises that are indispensable for scientific descriptions and studies.

Therefore, ambiguous descriptions of species and populations or inaccurate characteristics of the habitat (e.g. a category defined in terms of extre-

mum, or extrema), require from the author not only the scope of tolerance or appropriate ascription of boundary conditions, but the essential objective of the research, which determines to what extent the explanation is feasible and applicable. Thus, in this sense and only when we know precisely how to use and describe these boundaries in our explanations is it justifiable to apply the notion of minimum-maximum values, deficiency, or excess of factors in ecological studies.

Needless to say, the opponents to this proposal will purport that in ecology it is not "boundary conditions" that are the most important, but optimal values in which a given ecological phenomenon occurs. Naturally, this is a valid assumption, however it also requires the proviso to identify the conditions a given ecological phenomenon not only does not occur, but when present it actually disappears. The view presented here asserts that the investigation into the subtleties of optimal ecological processes (however they are understood) presupposes somewhat unequivocal specification of divisions (extremities) of their process and evolution.

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