THE SPECIES CONCEPT, THEMATIC SUBJECT IN NATURAL SCIENCES – THE SCIENTIFIC APPROACHES OF EMIL G. RACOVITZA AND NICOLAE BOTNARIUC

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Abstract. Species concepts represent one of the "hot" topics of the current evolutionary biology. The Romanian natural scientists EMIL G. RACOVITZA and NICOLAE BOTNARIUC defined animal species in different ways:

EMIL G. RACOVITZA supported a Genealogic species concept, expressed as "a colony of isolated consanguines". The RACOVITZA's concept considers species as homogenous lineages of organisms which evolve during their history. Description of such entities requires the recognition of primitive and derived states of the morphologic traits. Hence EMIL G. RACOVITZA's ideas preceded the principles of phylogenetic systematics of WILLY HENNIG and his followers. Geographic isolation is viewed by RACOVITZA as one of the main drivers of the speciation process.

NICOLAE BOTNARIUC developed an innovative Systems-species concept where quasi-independent organisms through their relationships within populations build a supraindividual system. The integrative properties of the population offer the necessary traits allowing the identification of species. Evolution is the emergent property of species (represented by populations) within the context of ecosystems and within the interpopulation relationships of a biocoenosis (the next level of the organizational hierarchy of the living matter). NICOLAE BOTNARIUC applied his concept to interbreeding and agamous populations. In this latter case the exchange of genetic information is realised through the self-reproducing individuals changing, under selection pressure, the clonal genetic structure of the population. The systems-species concept of BOTNARIUC applies to populations living within a wide spectrum of ecological conditions and existing during various time-frames; it offers a different perspective as compared to the narrow ecological species-concept of VAN VALEN.

Recent research offers additional confirmation of the views of the two Romanian biologists. It is argued that the species-concepts discussed should be used within a pluralistic cultural framework of the evolutionary systems biology. Finally, it is emphasized that the ideas of EMIL G. RACOVITZA and NICOLAE BOTNARIUC should represent stimulating arguments for new innovative research projects.

Key words: species concept, genealogic approach, systems approach, evolutionary biology, thematic subjects, natural sciences.

1. INTRODUCTION

One of the most durable thematic topics of the General Biology is the species problem, namely what it is and how natural scientists can identify them (WILKINS,

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2009). The thematic topic is a concept introduced by GERALD HOLTON (*e.g.* "Science and its burdens", 1986) in order to underlay the importance of ideas which persisted for generations within the cultural preoccupations of scientists. HOLTON (1986, p. 174) compared metaphorically this concept with "the old melodies to which each generation writes its new words". Moreover, there is a human predilection for identifying natural kinds and ordering them. Within natural sciences identifying, ordering and naming living beings is the domain of the taxonomy. Apparently, defining and identifying species are easy activities given enough expertise. The history of science shows exactly the opposite, plenty of debates arising around the ontological and epistemological aspects of the species concepts (WILKINS, 2009). The perception of the importance as cultural value of the species identification was repeatedly underlined by both scientists and laymen. Two examples, one offered by the historian of art ANDREI PLEȘU (2003), the other by the palaeontologist STEVEN JAY GOULD (2000) are presented in an annex to our text (*cf.* S1 – S2). For the present contribution we want to document how two leading Romanian natural scientists, EMIL G. RACOVITZA (1868 – 1947) and NICOLAE BOTNARIUC (1915 – 2011) at two different historical moments, using different scientific traditions, proposed alternative views on what species are and how they change. EMIL G. RACOVITZA offers us a view on the generation and existence of species that we will categorize as Genealogical Concept. It was developed at the beginning of the 20^{th} century under the impact of neo-Lamarckian ideas that he and his colleague RENÉ JEANNEL adopted during their research activities, especially those dealing with biospeological studies (CODREANU, 1970).

NICOLAE BOTNARIUC, a convinced adept of neo-Darwinian ideas, developed his concept of species during the second part of 20^{th} century within the impact of the general system theory of LUDVIG VON BERTALANFY (BOTNARIUC, 1992b, 2003a, 2003b). We will term his approach a Systems-species Concept.

The initial motivation of this essay was the invitation to deliver a talk to the symposium organized in memoriam Academician NICOLAE BOTNARIUC, at the centennial of his birthday, by the Romanian Academy, in Bucharest, March 12^{th} 2015 (*cf.* reports in the March 2015 issue of the 'Academica' journal for this event). We chose this topic because both "heroes" of our talk, EMIL G. RACOVITZA and NICOLAE BOTNARIUC, were not only leading personalities of Romanian biology, but also they taught university level courses of general biology for extended periods of time. RACOVITZA, helped by his assistants at the Institute of Speology, RENÉ JEANNEL and RADU CODREANU, offered the first course on this topic in Romania, at the University of Cluj. Starting at the beginning of 1924 this course existed until 1945 with short interruptions. NICOLAE BOTNARIUC offered the same course-subject to generations of students at the University of Bucharest, from 1948, until his official retirement in 1983.

Interesting enough both naturalists considered the species concept a key element within the evolutionary theory and the process of speciation as a property of organismic populations. Moreover those naturalists perceived an intellectual crisis related to the theory of evolution, in the case of RACOVITZA the crisis appeared at the beginning of 20th century (RACOVITZA, 1912) and for BOTNARIUC at the end of the 20th century (BOTNARIUC, 1992a, 1992b).

Coming back to the conceptual way to approach the species problem one could follow LEWIN (1981) who distinguish three major domains of inquiry: (1) the ontological, (2) the epistemological, and (3) the taxonomical one. From an ontological point of view, species are evolvable supraindividual entities; they are natural kinds. In this latter case, following LEWIN (1981), individual organisms which build this entity should express their capacity to perceive the membership to the group (population) to whom they belong. The way we delineate species belongs to the epistemology domain. Finally, a species is a taxon, namely a group of organisms with a given name; we are touching here the domain of taxonomy.

EMIL G. RACOVITZA and NICOLAE BOTNARIUC offer us two interesting perspectives related to the species problem that we will below review, *i.e.* the information pertaining RACOVITZA-views organized by IONEL G. TABACARU (I. G. T.) and DAN L. DANIELOPOL (D. L. D.), those of BOTNARIUC synthesised by D. L. D. We will discuss the actuality of the two species concepts with examples taken from recent scientific research on subterranean and/or surface water biota, others coming *inter alia* from research done within projects where in some way also students from the laboratory of one of us (D. L. D.) at the Limnological Institute of the Austrian Academy of Sciences, in Mondsee were involved. Finally we will mention also the contribution of young Romanian biologists working on closely related topics in Romania and/or abroad.

2. THE SPECIES CONCEPT OF EMIL G. RACOVITZA

The Romanian zoologist EMIL G. RACOVITZA exploring in 1904 an anchialine cave, Cueva del Drach, in the Mediterranean Island Mallorca, noted the scientific interest of subterranean fauna. RACOVITZA specialised in the terrestrial and aquatic isopods, crustaceans which occur frequently in caves. Some years later (1907) RACOVITZA published a remarkable review of the scientific information related to the subterranean domain, "Essai sur les problèmes biospéologiques". Here he proposed a whole research programme within which careful descriptions of the troglobites within "monographs of small groups doing systematic revisions, studying their affinities, their origins, their biology etc. in order to have solid basis for determining their speleological history" (RACOVITZA 1907, p. 381, in the 2006 edition, p. 133). The interest for a careful description of species and their phylogenetic and biogeographic affinities is mentioned again in his studies on crustacean isopods (*e.g.* RACOVITZA, 1912). In this latter study on the subterranean cirolanid isopods the problem of the species is discussed in more details. For RACOVITZA a species is "an isolated colony of consanguines" which evolves. It means that the members (individuals) of a species should have a relationship by descent from the same ancestor. From an epistemological point of view, RACOVITZA defines species as "animal lineage". Additionally, the species is the focal taxonomic unity, which receives also a name, within the systematics of the animal groups under study. The mission of taxonomists is to reconstruct the history of homogenous animal lineages, it means of closely related species (see similar argumentation also in RACOVITZA, 1923, 1926, and more recently, 1993 in the "Glose Biologice" (Biologic Glosses), an unpublished manuscript, written sometimes between 1935 and 1946. The manuscript was discovered and published by Dr. GHEORGHE RACOVIȚĂ. In the annex to our presentation we present excerpts of some of these statements (*cf.* S3 – S7).

In the conception of RACOVITZA (1912) animal species originate mainly by isolation of animal populations. This can be by spatial (*e.g.* geographic sites) or by physiological and/or behavieoral processes (*e.g.* sexual isolation). The idea of a geographic isolation was adopted by RACOVITZA and his colleague RENÉ JEANNEL from the publications of the German biogeographer MORITZ WAGNER (JEANNEL, 1930 p. 127).

From an epistemological point of view the species definition of RACOVITZA can be considered a Genealogical concept, with the meaning of "the smallest monophyletic lineage" (*cf.* BROTHERS, 1985 p. 38; LUCKOW, 1995, p. 589 for such a definition). The species has an origin and its individuals by reproduction help to perpetuate populations during generations, in other words the species has its own life until it becomes extinct. This succession in time of populations gives the temporal (historic) dimension, a characteristic that for RACOVITZA represents a fundamental property of species (RACOVITZA, 1926). Therefore, to the species as an entity with momentary morphologic traits and biogeographic distribution one has to add its historic dimension (RACOVITZA, 1926, p 49). From here it is proposed to consider genealogic species as "homogenous lineage" or to give up to the name of species and to adopt those of "lineage" as a biologic "unit". In order to better define such homogenous lineages RACOVITZA (1926, p 49) suggested the study of their characteristics by comparing step by step in time and space the morphological and biological changes of various populations (see excerpt S5b in the annex to our presentation).

The adoption of the "lineage" concept for current taxonomic research was considered by RACOVITZA especially useful for evolutionary research and for phylogenetic reconstructions (RACOVITZA, 1927 and 1928, in the Forewords to the 2nd and 3rd volumes of the "Lucrările Institutului de Speologie din Cluj").

We have to note that RACOVITZA used the term of "lineage" in two different ways. In his 1912 Cirolanidae monograph as well as in the 1926 report, where he presents the research programme of the "Biospeologica", the species with its time dimension is equivalent with the Simpson's Evolutionary Species concept "An evolutionary species is a lineage (an ancestral-descendent sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies." (SIMPSON, 1961, p. 153). This similarity was first noted by VANDEL (1952). In terms of ELDREDGE-views (1985) the RACOVITZA-lineage is the equivalent to monophyletic species. RACOVITZA (1926, p 49) speaks also from the necessary elaboration of phylogenies for animal groups using comparative morphology and this can be done only within "homogenous lineages". In this case ELDREDGE and GRENE (1992, p. 104) describe "monophyletic taxa" as "genealogic strings of species". The two authors defined such monophyletic taxa as "phylogenetically linked series of species sharing one or more organismic features that serve to mark a particular lineage." JEANNEL (1930, p. 40) call such monophyletic taxa "a bundle of elementary lineages" or "phyletic branches".

TABACARU & DANIELOPOL (2011) pointed out that RACOVITZA is the forerunner for the evolutionary and phylogenetic species concept, as developed by WILLY HENNIG (1950). This is due because RACOVITZA's concept considers species as homogenous lineages of organisms which evolve during their history. Description of such entities requests the recognition of primitive and derived states of the morphologic traits. The concept of "phyletic branches" (see JEANNEL op. cit.) is the equivalent of the "clade" as used by de QUEIROZ (1999, 2005).

VANDEL (1952) noted also that the species concept of RACOVITZA based on sexual and geographic isolation preceded the classic biological species definition of MAYR (1942), this latter definition being, following VANDEL (op. cit.), surprisingly similar to those of RACOVITZA. We have to point out also that RACOVITZA considered the species, from the ontological point of view, as a natural (real) entity, of fundamental importance for organismic evolution (RACOVITZA, 1923, 1926, 1993, here S6).

RACOVITZA criticised the specialists who admitted the importance of the individual organisms against the idea that species are real evolutionary units, represented by populations of organisms (*cf.* RACOVITZA, 1993, p. 307). There are various deniers of species as real entity (*cf.* WILKINS, 2009). As an example, J. B. S. HALDANE (1956, p. 95) expressed vividly his doubt to the existence of species as natural kinds: "I object to the term Species Concept which I think is misleading… A species in my opinion is a name given to a group of organisms for convenience, and indeed of necessity" (quoted from WILKINS, 2009, p. 222).

RACOVITZA has the merit to have argued for treating species descriptions within an integrative way, an idea that finds today amply interest (*cf.* RACOVITZA, 1920, p. 63 and here S7; DAYRAT, 2005).

Finally, we have to point out that RACOVITZA's idea to use the "Lineage" as taxon-name (in Romanian "Spița") instead of the classic term Species (*cf.* RACOVITZA, 1926, report on "Biospeologica"; see also excerpt S5b in the annex to our presentation) should be integrated within the modern debates on species concepts (*cf.* WILKINS, 2009).

3. THE SPECIES CONCEPT OF NICOLAE BOTNARIUC

As a zoologist NICOLAE BOTNARIUC is well known for his studies on crustacean Phyllopoda. His doctorate thesis published 1947 focused on Diplostraca, clam shrimps. Later BOTNARIUC and his colleague TRAIAN ORGHIDAN published the monographic volume "Phyllopoda" in the series "Fauna Republicii Populare Romîne" (1953). Moreover, BOTNARIUC became also an expert on chironomids (Insecta). In his study on the astatic ponds in the Romanian Plain, near Bucharest, BOTNARIUC (1953) described the seasonal dynamic changes of the crustacean populations, where species belonging to Phyllopoda, Cladocera, Copepoda and Ostracoda, displayed alternative peaks of population abundances. BOTNARIUC explained this dynamics as a result of complex reactions of species within temporary ecosystems, namely as result to chemical excreta released by some of these crustacean species as well as to the hydrological dynamics of the water bodies. Due to the interest for ecological relationships leading to the structuring of an ecological system BOTNARIUC came in contact with the ideas of LUDWIG VON BERTALANFY related to systems theory.

As a biologist, specialised in animal physiology, BERTALANFY (1932) offered a very compelling definition for what an organism is, and we quote it here, because it was very inspiring for BOTNARIUC's ideas.

"A living organism is a system consisting of a large number of different parts, organized in hierarchic order, in which a large number of processes are ordered in such a way that, through their continuous interactions within wide borders, with a continuous change of substances and energies, the system stays, even when disturbed from outside, in its own state, or it builds up that state, or these processes lead to the generation of similar systems." (BERTALANFY 1932, p. 83, translation quoted from DRACK, 2015, p. 79). BERTALANFY (1950) noted that the biosphere is organised in a myriad of systems, each system being formed by a multitude of interconnected parts. Systems are whole units with emergent properties which differ from those of the component sub-units. In the conception of BERTALANFY (1950) systems are governed by laws of functioning which are largely isomorphic between the different sectors of activities. Moreover, series of systems form hierarchies following their degree of complexities. BERTALANFY (1960) synthesized his ideas in a general theory of systems for which he traced also the practical way to study them. For instance, hierarchies can be studied either bottom-up or top-down.

Additionally to the ideas of BERTALANFY, here briefly presented, BOTNARIUC took up ideas published by K. M. ZAVADSKI in the book "Theory of species" (1961, translated in Romanian 1963). ZAVADSKI enumerated the general traits of species and mentioned also that this taxon represents a system (ZAVADSKI, 1963, p. 136). However ZAVADSKI never developed thoroughly this idea. It is BOTNARIUC who took over the project and we find the subject fully treated in his book "Principles of general biology" (BOTNARIUC, 1967, pp. 93–143). BOTNARIUC shows that species are natural biological systems, represented by populations of interacting living organisms. This idea was expressed also by MAYR (1942, p. 119–120): "the most important aspect of the biological species definition is that it uses no artificial criterion, but decides each case on the basis of whether certain organisms behave as if they were conspecific or not" (quoted after YODER *et al.,* 2005, p. 6587). However, the definition used by BOTNARIUC (1967, p. 226–227) for the species as systems entity, expressed by a population of individual organisms, integrates also elements of BERTALANFY's theory, e.g. the population is formed by autonomous individuals representing subsystem elements. Additionally, the species (population) is a wholeness entity with cybernetic properties and emergent organismic traits due to the action of external and internal selection pressures. These characteristics which are known in the case of populations with sexual reproduction and which form the basis for the Darwinian concept of "variational model of change" (*cf.* LEWONTIN, 2000) are visible also in populations with asexual reproduction. BOTNARIUC notes: "in agamous species the wholeness of populations is a result of the clonal polymorphism". Selection, "acts in the sense of elaboration and maintenance of the most advantageous clonal composition of the population" (BOTNARIUC, 1967, p. 227). This treatment of species as systems entity is interesting because it allows applying the definition for organisms with sexual and asexual reproduction.

One of the most important aspects of the species (population) is the way individuals within their relationships build an integrated system at the level of the whole population. BOTNARIUC (1967, p. 95) calls this aspect the integrality (meaning the wholeness) of the species as system (*cf.* S9). He offers *inter alia* an example that he previously studied, the case history of *Chironomus thummi*, where each of the four developmental stages displays different ways of life and support high mortalities due to fish predation. However the species completes its life cycle reaching the adult stage (*i.e.* it keeps its integrity) and the population remains at densities which allow to perpetuate its existence and to start a new cycle of development, hence avoiding extinction.

A system by definition has, as constituents, subsystem units. In the case of species, the population keeps its organisation through the cohesive activity of quasi-independent individual organisms. Therefore, BOTNARIUC repeatedly speaks of the species as a supraindividual system. This aspect is included in his crown book "The evolution of supraindividual biological systems" published, in its last version, in 2003 (BOTNARIUC, 2003a).

Populations have the capacity of self-regulating the density of individuals and BOTNARIUC (1967) offers compelling examples, like in the case of the green algae *Chlorella,* that regulate their upper cell densities through the emission of chemical inhibitors released in water. The integrality, or wholeness, of the species is realised through a process of natural selection acting on the population. This process has an adaptive role under natural conditions, namely keeping in dynamic state the population, integrated within its ecosystem.

The systems aspects of the species were discussed repeatedly by BOTNARIUC. In the lecture on the occasion of his election as member of the Romanian Academy (BOTNARIUC, 1992b), he emphasised that species, as populations, represent an elementary system able to exist autonomously. Through turnover of its individual organisms populations are able to perpetuate during undefined periods of time. The intrapopulation relationships determine the biologic profile of the species as an emergent trait. Populations are in a dynamic state; their changes depend on selection pressures occurring inside the system and among populations within the biocoenosis, this latter integrated in an ecosystem. The main functional role of species (as populations) within ecosystems is realised through their contribution to the transfer of matter and energy and to the exchange of information within the biocoenosis.

In his 1976 book "The systemic conception and method in general biology" BOTNARIUC offers an interesting view on the species as autonomous systems. Species within ecosystems are not only the object of natural selection but they can be also subjects which through their capacity to explore and/or to exploit their environment are able to transform their surroundings (BOTNARIUC, 1976, pp. 164–166). In other words organisms, in populations, through their collective behaviour select and construct their niche.

An original idea proposed by BOTNARIUC (1976) is the way genetic information can be transmitted in agamospecies. DOBZHANSKY (1951) considered that only biological species (*i.e.* displaying sexual reproduction) are able to exchange genes and therefore build Mendelian populations. This is not the case with the uniparental (agamous) populations. This determined DOBZHANSKY (1951, p. 274) to refuse them the status of species equivalent to those existing for the bisexual populations. However, BOTNARIUC (1976, p. 209) suggested in the case of agamospecies that "the exchange of genetic information *among populations* may take place… through an exchange of-self-reproducing individuals, which would be able to alter the clonal genetic structure of the population, thereby opening the way for selection. The ensuring phenomenon could be termed *populational genetic recombination*".

Within his conceptual system of the organisation of the living matter BOTNARIUC (1985) proposed a triplet of hierarchic systems (*cf.* also BOTNARIUC, 1992a, 2003a, 2003b). The organismal subindividual structures build in the individual living system; they form a somatic hierarchy. From the individual level ongoing, supraindividual systems are arranged in a growing organizational hierarchy, with successive levels: population, biocoenosis, biome, and culminating with the whole biosphere. Moreover BOTNARIUC recognises a third hierarchic system, named taxonomic hierarchy. This latter, like in the Linnean taxonomic system, covers successive ranked taxa, the species, the genus, the family, etc. For BOTNARIUC only the species represented by populations have the quality to evolve and hence they are part of the organizational hierarchy too. In other words, the species plays a dual role, it is taxon (a group of organisms receiving a given name, being a unit of classification) and as population (a unit of biological organization which evolves) belongs to the supraindividual organizational hierarchy. The other supraspecific taxa within the taxonomic hierarchy are additive categories which do not evolve but are important for keeping order with the richness of the supraindividual biological diversity. This idea is well expressed also by DUPRÉ (2001 p. 217) who notes: "it is important to impose order on the biological world…with a methodology that is pragmatic, pluralistic and sometimes frankly nominalist."

The whole diversity of living matter can be included within a general hierarchy (with three subhierarchies). The species (population) as system unit therefore has its place within the framework of the general hierarchic structure and can be studied either top-down or bottom-up within the hierarchy. DANIELOPOL & CRISTESCU (2015) discussed recently the interest of this approach for modern research in systems biology. Species defined as living systems can be recognised as snap-shots within various time-frames of ecological arenas. The historicity of population within homogenous lineages is not a prerequisite factor for defining systems-species, as requested by the genealogic or phylogenetic species-concept discussed in the previous section.

Finally, we should note that the systems-species concept developed by BOTNARIUC, briefly presented here, passed practically unobserved. Much of the literature pertaining to species concepts deal with other categories of species like the biological species, the genealogical one, including evolutionary and phylogenetic approaches and/or with the ecological one (*cf. inter alia* de QUEIROZ, 2005; WILKINS, 2009). Below we will document the actuality of the systems-species concept, especially related to uniparental species. This latter aspect represents one of the original ideas of BOTNARIUC.

4. THE ACTUALITY OF THE TWO SPECIES CONCEPTS

One of the pillars of the scientific method which applies to both empirical and theoretical research is the principle of corroboration of empirical data with statements made by theories. The Webster's New World Dictionary (edition 1976, p. 1475) defines the theory concept in several ways: "a speculative idea or plan as to something might be done; systematic statements of principles involved; a formulation of apparent relationships or underlying principles of certain observed phenomena which have been verified to some degree".

The genealogic (lineage) concept of RACOVITZA and the species as systems-unit of BOTNARIUC (especially for the uniparental populations) appear to us as theoretical models were a part was developed from empirical observation and another part represents what it is sometimes called "rational intuition" (FLONTA, 1994, p. 94). Both species concepts are clearly defined but to allow them to become "Evidence" they need careful confirmation through additional corroborative data. In the case of a lack of corroboration there is the possibility to account for theory modification or replacement over time (*cf.* FLONTA, op. cit., and also MALATERRE discussion in O'MALLEY & KOONIN, 2011, p. 17).

Both, EMIL G. RACOVITZA and NICOLAE BOTNARIUC, argue that the species as population is the unit of evolution. However we know that the distribution in time and space of populations cannot be exactly evaluated and the population-level phenomena appear to investigators as a matter of degree (*cf.* GANNETT, 2003). This latter author considers that "population boundaries are not fixed but vary from one context of inquiry to another". Therefore, the subjective role of the observer describing aspects of populations has to be considered when we evaluate the theoretical models they present. It is important to see if we need additional confirmation and/or if necessary improvements to these evolutionary scenarios are requested. This epistemic approach was already recognised by RACOVITZA (1930) when he analysed JEANNEL's monographic study of the Trechini (Coleoptera). RACOVITZA (1930) considered that the interpretation of data presented by JEANNEL (1926 - 1930) corroborated only in part the species concept as "lineage". Therefore RACOVITZA suggested a rethinking of the scenario proposed by JEANNEL for the special case of the above mentioned insect group (see the exact quotation of RACOVITZA's opinion in the annex to our presentation, the S8 excerpt).

Below we present several studies which actualise and/or consolidate the ideas of both, EMIL G. RACOVITZA and NICOLAE BOTNARIUC.

4.1. THE SPECIATION OF THE HAWAIIAN CAVE PLANTHOPPERS (HEMIPTERA), ARGUMENTS FOR EMIL G. RACOVITZA'S IDEAS

Hawaiian lava tubes are formations that are recurrently generated. They are colonised by terrestrial arthropods which evolve toward troglobitic life. Their evolutionary process can be studied within this particular environment like a kind of replicate "natural experiment", where ecological conditions display low variability and can be assessed. It is the merit of FRANCIS G. HOWARTH and his collaborators to have developed evolutionary studies related to terrestrial arthropods living within this "special" subterranean environment (*cf.* HOWARTH, 1972; HOWARTH & HOCH, 2012; STONE *et al.* 2012).

Recently, WESSEL *et al.* (2013) reconstructed the species diversification of troglobitic insects belonging to *Oliarus polyphemus* species complex formed around the Kilauea Volcano. The insects studied belong to a monophyletic group of blind planthoppers which colonise lava tubes where the food web is sustained mainly by ephemeral decaying roots of plants. The authors show that the new tunnels can be colonised by a few founding individuals coming from the surrounding lava tubes which harbour older established populations. The spectacular aspect is that the age of the established founding population is about the same with those of the lava tube formation; this latter can be evaluated from the palaeomagnetic properties of the initial lava flow. The dispersal of the animals is about 10 m/yr and the whole process of speciation occurred during the last 1500 years.

Oliarus individuals have the capacity to produce low-frequency vibrations as signals for species-specific recognition. ANDREAS WESSEL and his collaborators (WESSEL *et al.* 2013) discovered that different populations of *Oliarus polyphemus* species complex display signals which were interpreted as population specific. They allow recognising between 12 populations significant differences which were interpreted as belonging to “cryptic acoustic species”. Additionally morphometric and genetic traits of 15 populations were treated using discriminant analysis. The *Oliarus polyphemus* species clade contains seven species. The speciation rate estimated for the Hawaiian planthoppers is very high as compared with those of classic endemic cichlid fishes of Lake Victoria.

The species specific differences were not correlated neither with the spatial distribution within the area investigated nor with the age of the lava tubes. Also none of the morphologic and/or ethologic traits of the various populations could be interpreted as adaptations to the habitat of their origin. Additionally, it was noticed that the dispersion of the insects in the new habitats was random, meaning that no clinal pattern exist. The phenotypic variability was highest in the younger lava tubes as compared to those populations existing in older habitats.

There are three significant aspects of these data which can be considered as consolidation of the RACOVITZA’s ideas:

(1) The founder population in the new habitats are represented by few specimens belonging to a monophyletic species group. This is equivalent to an isolated colony of consanguines or to the homogenous lineage of RACOVITZA, earlier discussed. (2) The spatial separation of populations in different lava tubes is an important factor for speciation process; this is similar to the argument of RACOVITZA that for speciation one needs spatial isolation. (3) Having the possibility to assess first the tempo of formation for lava-tubes and further to correlate this with variability of phenotypic traits in a precise way step by step allows to reconstruct the evolutionary changes of the various species within this clade. This is exact what RACOVITZA called the historical dimension of the species.

The Hawaiian study of WESSEL and his colleagues offer arguments for a revision of the RACOVITZA’s model in at least two points. The speciation process is not correlated with gradual adaptive changes and there is no clinal pattern in the geographic distribution of the populations which should play a role for the isolation process as mechanism of speciation. This latter is a neutral process resembling the Carson’s founder-flush model (WESSEL *et al.,* 2013).

4.2. THE RECENT TREATMENT OF CLONAL POPULATIONS AS SPECIES, ARGUMENTS FOR NICOLAE BOTNARIUC'S SYSTEMS-MODEL

The studies on uniparental populations became an active domain of research during last 20–30 years. Our discussion relies heavily on two synthesis, "Sex and Parthenogenesis" edited by KOEN MARTENS (1998) and "Lost Sex" edited by ISA SCHÖN, KOEN MARTENS and PETER VAN DIJK (2009).

In the modern literature uniparental (agamous) animal populations represented by individuals with identical (or quasi-identical) genetic-structure are referred as clones; they are generally identified by genetic techniques using different molecular markers with various power of resolution (MARTENS *et al.,* 2009). The treatment of such populations as species is a subject of debate. SIMPSON (1961, p. 161–163) considered that one should treat conceptually the uniparental populations as the bisexual ones, hence only one type of species exist. There were also opinions to consider the clonal populations as a separate type of species which deserves a special name, Agamospecies (CAIN, 1954), Paraspecies (MAYR, 1987). For WILKINS (2007) all organisms with asexual reproduction which cluster around genomes with a fitness "peak" should be assimilated to the concept of Quasispecies. Later on WILKINS (2009, p. 220) considered "that Agamospecies and Quasispecies should be treated as synonyms".

More recently MARTIN *et al.* (2010), discussing the way parthenogenetic population derives from bisexual species (the concrete case of *Cambarus fallax,* the so-called Marble crayfish), considered that for such uniparental populations the phylogenetic species concept should apply, because parthenogenesis is an apomorphic trait within a given phylogenetic lineage with bisexual ancestors. Finally, because clonal populations in some cases display precise ecological distributions one could apply to them the ecological species-concept of VAN VALEN (1976). For this latter author "a species is a lineage (or a closely related set of lineages) which occupies an adaptive zone minimally different from that of any other lineage in its range and which evolves separately from all lineages outside its range. A lineage is a clone or an ancestral-descendent sequence of populations." (VAN VALEN, 1976, p. 233).

We have to recall that one of BOTNARIUC's ideas (*cf.* his treatment of species as system in the 1967 monograph) was to use for both bisexual and uniparental populations the species as a unique taxon. Below we offer arguments which support BOTNARIUC's views on this systems-species concept:

(1) Many parthenogentic populations display seasonal differences in their numerical densities as well as in their clonal composition. ROSSI & MENOZZI (1990, 1993) reported their observations on the ostracod species *Heterocypris incongruens,* from a rice-field pond in the Po Plain (Northern Italy) combined with experimental data. The parthenogenetic females displayed in winter, as compared to the summer period, different frequencies for electrophoretic-allozyme clones.

Also the size of the adult females and the length of time for reaching the adult stage differed. The winter individuals displayed a larger body size and developed slowly as compared to the summer cohort. The seasonal changes in the clone composition are in accordance with the BOTNARIUC's model, which explains that the dynamic of clone diversity in a population is important for its perennial preservation. It is also important to mention that the group reaction of populations of *H. incongruens* observed by ROSSI *et al.* (2011) building swarms for attacking prey is an intentional collective behaviour. This latter is an aspect of integrality of the population which generates order within a complex system (*cf.* for this theoretical approach STENGERS & BAILLY, 1987). The cannibalism reaction is interpreted as self-regulation of the population by ROSSI *et al.* (2011). Both aspects are systems-characteristics as described by BOTNARIUC (1967). Hence the idea to consider *Heterocypris incongruens* as a systems-species taxon is a viable solution.

(2) Uniparental populations of micro-crustaceans living in shallow water-bodies, like lakes or ephemeral (astatic) ponds are represented by polyphyletic lineages. The ostracod *Cypridopsis vidua* has a wide ecological and geographical distribution in Europe and North America (*e.g.* MEISCH, 2000). Agamo-populations display an exploratory behaviour and are able to colonise temporarily both epigean and subsurface habitats. ROCA & DANIELOPOL (1991) investigated experimentally this behaviour of *C. vidua* which appears as a characteristic of the population. The species is able to colonise repeatedly various habitats at different time periods. CYWINSKA & HEBERT (2002) show that *C. vidua* displays a high clonal diversity (*i. e.* 13 mitochondrial genotypes) in a Canadian pond, at Guelph. Following these authors this is due to repeated colonisation by different clones.

From the above information it is obvious that the systems-species concept is the better solution for populations which display the behaviour of active exploration and/or repeated colonisation of selected habitats (as compared to the other alternative, the phylogenetic-species concept). For this latter model, as we saw in the RACOVITZA's scenario, a unique colonisation event with a homogenous clonal structure is requested.

(3) *Limnocythere inopinata* is a polymorphic ostracod species with a world-wide geographic dispersion. A multi-disciplinary project studied aspects of the ecology, biogeography, life cycle traits, details of morphology and genetic structure of various populations at European scale, during 1994-1996. The rich data obtained by the different research groups of this project were published in a volume edited by KOEN MARTENS (1998). *L. inopinata* colonises various types of non-marine water systems, like ponds, shallow lakes, springs, interstitial habitats along streams, etc. (*cf.* MEISCH, 2000, p. 430–431). The species is mainly represented by parthenogenetic populations and few bisexual ones; these latter occur nowadays mainly in southern Europe (HORNE *et al.,* 1998; GRIPHITHS & HORNE, 1998). In Austria the electrophoretic survey of 11 populations from freshwater and saline water systems allowed the identification of 31 multilocus

genotypes (GEIGER *et al.* 1998). At a local regional level these authors found two types of populations, one with clones adapted to saline water, distributed in astatic ponds and the shallow lake Neusidlersee, in Eastern Austria, and another group of clones specialised for freshwater and occurring in western part of Austria (the littoral zone of lake Mondsee). MARTENS and his colleagues compared the effect of genotype and environment on the phenotype variability of populations from Europe with other ones from saline lakes in China (YIN *et al.,* 1999). At a worldwide level of the geographic distribution these authors could not find a clear discrimination of populations leading to a taxonomic re-evaluation of the nominal species; it was therefore decided to keep the taxonomic status with its Linnean connotation *Limnocythere inopinata*.

Genetic diversity of local populations of *L. inopinata* was either inherited from the original bisexual populations as historical contingency or maintained through the "distance effect" of colonisation via dispersal from surrounding similar aquatic systems within large metapopulations (ROSSI *et al.,* 1998; BALTANÁS, 1998).

The information on *Limnocythere inopinata,* mentioned above, offers support to the systems-species concept of BOTNARIUC. Neither the phylogenetic species-concept (*cf.* WILEY, 1981) nor the ecologic one of VAN VALEN (1976) can accommodate these data.

Additionally, BOTNARIUC's systems-species can be applied to the taxonomy of invasive species like the cladocerans *Cercopagis pengoi* and *Bythotrephes longimanus* (CRISTESCU *et al*., 2001; THERRIAULT *et al.,* 2002) and/or the amphipod *Echinogamarus ischnus* (CRISTESCU *et al*., 2004).

(4) During last years, research on uniparental species expanded into what is now called Integrative Taxonomy (*cf.* DAYRAT, 2005). This is a research direction which resembles to the approach described by O'MALLEY & DUPRÉ (2005) as the "pragmatic systems biology", it refers to interconnected biological aspects studied as "systems". For the taxonomy domain, this is achieved using data obtained from multiple and complementary investigations, *inter alia* from research on general morphology and geometric morphometrics, from molecular biology, from biochemistry, phylogenetics etc. These data are in most cases further treated with various mathematical algorithms. This way leads to a multidimensional image of species, as advocated *inter alia* by SBORDONI (1993) and YODER *et al.* (2005). It reflects the structural and/or functional complexity for species considered as a systems-unit. One should remember that E. G RACOVITZA is a forerunner of this idea (*cf.* RACOVITZA, 1920, and excerpt S7). Here we will mention as an example the project of HEETHOFF *et al.* (2011) who studied parthenogenetic populations of the terrestrial mites belonging to *Trhypochthonius tectorum* (Oribatida). For this study they used for the chaetotaxy description morphometric techniques, molecular analysis for mitochondrial and nuclear DNA-sequences and biochemical analysis for characterisation of the excreta produced by tegumentary glands. The complex study allowed the identification of several new taxa.

(5) An important progress in understanding how uniparental populations evolve is presented by BIRKY & BARRACLOUGH (2009). These authors show that the clonal structure of populations can change not only by the movement of individuals in and out the agamous populations but also by processes which exist at bisexual populations too, namely by mutation of individual organisms and multiplication of favourable lineages through divergent natural selection. The new aspects came from molecular biology data obtained from such uniparental groups, like the bdelloids (Rotatoria) and oribatids (Acari), and represents a major progress in comparison to the information that BOTNARIUC had at hand when he developed his systems-species concept applied to uniparental populations (*cf.* BOTNARIUC, 1967).

Methods for species identification using gene sequences data expressed within phylogenetic trees were recently developed by BIRKY & BARRACLOUGH (2009). They allow identification of clusters of genotypes which are separated on a phylogenetic tree by long-lasting gaps and document evolution *in situ* of agamospecies.

In conclusion, it is satisfying to see BOTNARIUC's approach confirmed, namely that for uniparental organisms taxonomic principles used to define bisexual populations can be safely applied and that the species as systems-model represents the solution of choice. Moreover, it is gratifying to see that ideas similar to those BOTNARIUC developed during many years, are now expanding and enrich the catalogue of topics dealing with systems biology.

5. FINAL CONSIDERATIONS

Looking retrospectively at the two conceptual models for the species, proposed by EMIL G. RACOVITZA and by NICOLAE BOTNARIUC, we mention that they reflect the different scientific interests of these naturalists for specific problems of general biology as well as their empirical experience with different ecological situations. RACOVITZA was an extraordinary zoologist with feeling for the exact description of his object of study. His main research interest was the biospeology, the subterranean life in the caves (ORGHIDAN, 1970). BOTNARIUC, also trained as zoologist, was predisposed for ecological studies which could lead to general patterns explaining the evolution. He was an expert for surface non-marine water environments like the astatic water bodies of the Romanian Plain and/or the shallow lakes along the lower Danube River, in Romania (NEGREA & NEGREA, 2008). Therefore, it is not surprising that the confirmation for the genealogic (lineage) species concept of RACOVITZA comes from a recent study on subterranean fauna and its environment and those on the systems-oriented species for uniparental animals is derived from case-studies on fauna living in surface astatic or permanent shallow-inland waters. Additionally, we should admit the evidence that the elaboration of the two different species concepts is related also to the subjective way EMIL G. RACOVITZA and NICOLAE BOTNARIUC perceived life.

In this case, the scientific knowledge offered by our two "Idols" is represented by a part of objectivity and a part by the subjective construction of reality related to the direct experience of the "Observers".

If we look back to the merits of the definitions of species offered by EMIL G. RACOVITZA and by NICOLAE BOTNARIUC we have to mention also that both are valuable contributions to evolutionary biology. We note that the two conceptual views, were largely confirmed by modern empirical research. Ontologically, species as evolvable populations are real natural entities. From the epistemological point of view, the two species concepts, the genealogical and the systems-oriented ones, diverge in many ways, but they are useful for different purposes. The BOTNARIUC's species-concept allows us to understand the world's organismic diversity within the frame-time of the present-day situation. The genealogic (lineage) concept of RACOVITZA is useful for understanding how related organisms, within their evolutionary transformation, generates diversity within phyletic lineages. Both species definitions should be accepted within a pluralistic evolutionary biology, keeping in mind also the cultural context within RACOVITZA and BOTNARIUC perceived the problem (see compelling arguments for similar ideas (DUPRÉ, 2001, 2007; DUPRÉ & O'MALLEY, 2009).

In this essay we acted as cultural historians (*cf.* for this concept GOMBRICH, 1979). We were interested to offer to readers something from the originality of two biologists who occupy a place in the "Idols Gallery" of the Romanian Natural Sciences (*cf.* IFTIMOVICI, 1977). This fact stimulates in us pleasure and pride and we try to communicate these feelings to others too. Possibly, the same feelings come out also when one reads MIRCEA ELIADE's essay on the scientific results of EMIL G. RACOVITZA and the Institute of Speology (ELIADE, 1939, reprinted 1994), where ELIADE stresses the value of the philosophy of the time and of the history in the reconstruction of the origins of living beings, an interest that exists also in other different cultural domains, like the ethnology.

In our opinion it is important to keep alive the cultural tradition of research based on a diversity of philosophical approaches. Only in this way a new generation of naturalists will become educationally prepared to assimilate fresh ideas which are now emerging within evolutionary biology (*cf. inter alia* PIGLIUCCI & MÜLLER, 2010; MCSHEA & BRANDON, 2010; JABLONKA & LAMB, 2014). Related to this cultural aspect we have to ponder the pessimistic opinion of BOTNARIUC (2003b, p. 527) who noted: "Evolutionism, as independent discipline, is no longer in the curriculum of many universities…" By this statement BOTNARIUC wanted to stress out his scepticism to the continuity of such tradition which in Romania existed during most of the 20th century. However we do not see the situation as pessimistic. A new generation of Romanian students, working in Romania or abroad, deal with evolutionary aspects like phylogenetic reconstructions of aquatic populations of amphibians and insects using molecular biology techniques (*e.g.* COGĂLNICEANU, in BABIK *et al.*, 2005; BÁLINT *et al.,* 2011); others use metagenomic techniques in order to better apprehend the biological diversity of organisms at large scales (CRISTESCU, 2014) or use geometric morphometry for the description of phylogenetic lineages of subterranean (stygobitic) crustaceans (IEPURE *et al.,* 2007). An analysis of modern problems of evolution was published by IORDACHE (2009). Statistic algorithms applied by NITZU (2001) to the eco-biogeography of the edaphic and subterranean coleopteran insects from Dobrogea karstic area, in Eastern Romania, contribute to the explanation of their evolutionary modes of distribution, during the Quaternary to Recent time.

Finally, we will repeat here the "Ideal" of GERALD HOLTON (2005, p. 134): "a culture is kept alive by the interaction of all its parts. Its development is an alchemical process, in which the culture's varied ingredients combine to form new jewels". Our two "Idols", EMIL G. RACOVITZA and NICOLAE BOTNARIUC, contributed to such an "alchemical process", namely their ideas help us to better perceive the multitude of aspects within which the concept of species is embodied. We should, therefore honour these two naturalists by developing projects of research where ideas here discussed will be expanded in a creative way.

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ANNEX –Excerpts from selected publications

S1 – A. PLEŞU (2003), p. 99: I would like to know their names (Our note: PLEŞU refers to names of trees in a wood) and there is not the first time when I regret my poor botanical knowledge. Not because without a name, I cannot identify and catalogue them. But in some way I cannot understand and I cannot enjoy what I am seeing. One cannot establish a dialogue with an unnamed object! (translation from Romanian, by D. L. D.).

S2 – S. J. Gould (2000), p. 105: …taxonomy should be viewed as one of the most fundamental, and most noble of scientific pursuits – for what can be more basic than parsing of nature's rich and confusing complexity? Our categories, moreover, record our mode of thought, and taxonomy therefore teaches us as much about our mental functioning as about nature's variety.

S3 – E.G. RACOVITZA (1912), S3a – p. 204: Le but principal des études taxonomiques, le seul qui m'intéresse d'ailleurs, c'est, d'après moi, la classification naturelle des animaux, c'est-à-dire une classification qui reflète aussi exactement que possible la parenté réelle des diverses lignées animales. Comprise de cette manière, la taxonomie devient une des branches de la biologie générale, car elle fournit le matériel pour l'étude des lois et modalités de l'évolution.

S3b – p. 206: Le devoir des taxonomistes est donc tout tracé s'ils veulent prendre part à ce renouveau, s'ils veulent signifier quelque chose dans l'œuvre immense qui se prépare. Ils doivent avant tout établir la filiation exacte des formes qu'ils étudient. Distinguer les espèces ne suffit plus; il faut retrouver les lignées homogènes et reconstituer leur histoire géologique.

S3c – p. 207–208: Fixer par des diagnoses les limites des espèces, grouper ensuite les espèces par lignées, et distribuer ces lignées en catégories hiérarchisées suivant la distances historique qui les sépare du tronc commun, c'est la tâche primordiale que doit se proposer le taxonomiste moderne. Le point de départ est donc l'espèce, l'unité taxonomique par excellence. Je tiens à exposer ici, très sommairement, ce qu'il me semble qu'on doit entendre par ce vocable.

S3d – p. 208: Pour qu'il y ait subdivision des lignées, donc spéciation, un isolement quelconque est indispensable mais suffisant. La différenciation morphologique est une suite fatale de l'isolement. Une colonie qui s'isole, qui évoluera derechef indépendamment des autres, c'est un facteur nouveau qui s'introduit dans l'histoire du globe. Ces prémisses une fois admises, la conclusion sera que la définition de l'espèce en tant qu'unité taxonomique ne pourra être autre que «Une colonie isolée de consanguins».

S4 – E. G. RACOVITZA (1923), p. 83: Dès le début de mes études j'ai conçu la zoologie comme une science historique, ce qui m'a singulièrement facilité la compréhension des morphologies animales. Il ne suffit pas de trouver l'origine et l'explication d'une structure; il faut, pour en tirer le maximum de bénéfice scientifique, l'étudier comparativement dans les diverses lignées homogènes et cela ne peut se faire avec les matériaux actuellement publiés.

S5 – E.G. RACOVITZA (1926), S5a – p. 48: Concevoir l'espèce comme un «phénomène purement actuel» est certainement une grave erreur. L'espèce doit être considérée comme une entité aussi bien morphologique, qu'historique et géographique. La taxonomie ne peut être autre chose que de la phylogénie appliquée. La définition d'une espèce doit contenir la synthèse de ses caractères morphologiques, de sa distribution géographique et de sa généalogie; il est impossible autrement de situer correctement cette entité biologique dans le système, et de s'en servir, sans inévitables erreurs pour les études spéciales ou les généralisations.

S5b – p. 49: Nous avons vu que, pour une définition complète de l'espèce, les données phylogéniques sont indispensables. Que l'on reconstitue l'histoire d'une espèce à l'aide de fossiles ou, en leur absence, à l'aide de la morphologie et de la morphogénie comparées, le résultat est le même: on dépasse la notion de discontinuité spécifique plus ou moins rigoureuse actuelle pour aboutir à la notion de continuité dans le temps; invinciblement, les délimitations spécifiques s'estompent et une entité plus compréhensive s'impose avec force: la lignée. Il me semble que la vulgarisation de la notion de «lignée comme «unité» biologique, et le fait d'en avoir précisé la signification et démontré la grande utilité par de nombreux exemples concrets, est un gain scientifique très appréciable. D'abord on serre incontestablement de plus près la vérité en substituant le concept: lignée, au concept: espèce, dans toutes les spéculations biologiques et surtout en phylogénie et en biogéographie.

Pour serer la vérité de plus près, pour reconnaître le sens et constater les modalités des transformations, pour trouver par conséquent l'origine certaine et la signification véritable des structures et des fonctions, il faut suivre les modifications pas à pas dans leur changement progressif ou régressif, en un mot: il faut faire des études comparées seulement à l'intérieur de "lignées homogénes".

S6 – E.G. RACOVITZA (1993), p. 307: Species is a fact, a concrete entity, which can be noticed with full certitude… The Racovitza's definition: the species is an isolated colony (population) of consanguines. The unique specific criterium which is always valid: it is an independent fact of evolution. (translation from Romanian, by D. L. D.).

S7 – E.G. RACOVITZA (1920), p. 63: Le taxonomiste qui se propose de faire œuvre scientifique doit utiliser tous les résultats des autres disciplines qui s'occupent des êtres vivants. Il doit tenir compte, pour arriver à ses fins, de tous les caractères des biotes, qu'ils soient morphologiques, anatomiques, histologiques, ontogéniques, physiologiques, œcologiques, éthologiques, en un mot, quels qu'ils soient, que leur découverte soit due à l'observation ou à l'expérimentation, car pour les caractères, seule vaut la distinction entre ceux qui sont utilisables et ceux qui ne le sont pas; il doit s'efforcer de situer, aussi exactement que possible, son espèce dans l'espace comme dans le temps, car l'espèce est une entité essentiellement historique.

S8 – E.G. RACOVITZA (1930), p. 12: Il est vrai qu'en somme il s'agit uniquement de théories, donc de concepts qui, même lorsqu'ils sont très bien établis et en concordance avec les faits connus à l'époque de leur conception, sont destinés à être remplacés par de nouvelles théories «plus à la page».

S9 – N. BOTNARIUC (1967), pp. 223–224: As a consequence of the structural and functional interaction and diferentiation of the component parts in the biological systems, their wholeness appears and is developed, consisting in the fact that the qualities of the whole cannot be reduced to the sum of the qualities of the parts taken isolatedly. At the same time, parts integrated into the whole exhibit new qualities, which do not appear when separated from the entire system. The development of the wholeness of the biological systems has, as a consequence the increase in the amount of information of the system, and the decrease in its entropy.