ACADEMIA ROMÂNĂ

SCOSAAR

Anexa nr. 6

REZUMATUL TEZEI DE ABILITARE*

TITLU: SOIL BIODIVERSITY ACROSS SCALES: FROM INTEGRATIVE TAXONOMY OF COLLEMBOLA TO EUROPEAN ASSESSMENT AND MONITORING

Domeniul de abilitare: BIOLOGIE

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*în cazul în care teza va fi redactată într-o limbă străină, textul în limba română va fi adaptat

SUMMARY

Scientific rationale and overall research framework

Soil biodiversity is a fundamental component of terrestrial ecosystems and supports essential processes such as organic matter decomposition, nutrient cycling, carbon storage, regulation of microbial communities, soil-structure maintenance, and climate regulation. Nevertheless, belowground biodiversity remains insufficiently documented compared with above-ground biodiversity, particularly in regions where taxonomic expertise, long-term ecological studies, and standardized monitoring have historically been limited. These knowledge gaps are especially relevant in Eastern and Southeastern Europe, including Romania and the Carpathian region, where incomplete taxonomic inventories and uneven distributional data still constrain the integration of regional information into continental biodiversity assessments.

My habilitation thesis synthesizes more than two decades of scientific activity carried out primarily at the Institute of Biology Bucharest of the Romanian Academy, with particular emphasis on the research developed after completion of my PhD in 2012. Collembola (springtails) constitute the principal biological model of this research. They are abundant and diverse soil microarthropods involved in decomposition, nutrient cycling, and interactions with microbial communities, while their ecological sensitivity makes them valuable model organisms for investigating environmental change. The thesis is organized around a central idea: soil biodiversity must be investigated across interconnected biological and spatial scales. Reliable taxonomy defines the biological units to be studied; community ecology explains how these units respond to environmental drivers and assemble locally; biogeography reveals how historical and spatial processes shape their distributions; and large-scale monitoring translates this knowledge into comparable assessments relevant to soil biodiversity and soil health.

The thesis is structured into four main chapters: an Introduction defining the scientific rationale and overall research framework; a central chapter presenting the Scientific, Professional and Academic Achievements through three interconnected research directions—Collembola taxonomy, environmental drivers and community assembly, and European-scale biogeographical and phylogenetic patterns; a chapter devoted to Career Trajectory, Academic Leadership and Future Research Development; and a final chapter presenting the General Conclusions.

Accordingly, my scientific programme has developed along four interconnected directions:

taxonomy and systematics of Collembola; community ecology and responses to environmental and anthropogenic drivers; Carpathian and European-scale biogeography, macroecology, and phylogeography; and, more recently, the integration of national biodiversity data and research into European biodiversity databases, monitoring networks, and soil-health initiatives. This progression also reflects the evolution of my scientific profile from classical taxonomy and faunistics towards increasingly integrative approaches combining morphology, molecular methods, ecological statistics, spatial analysis, and international collaborative research.

Taxonomy and systematics of Collembola

Taxonomic research represents the species-level foundation of the thesis. Accurate species identification is indispensable for biodiversity inventories, ecological interpretation, distribution databases, and monitoring programmes, particularly in Collembola, where closely related species may differ in subtle morphological and chaetotaxic characters. My work has focused on species discovery and description, comparative evaluation of diagnostic characters, reassessment of insufficiently characterized taxa, and the development or updating of identification tools.

The studies selected in the thesis focus on four taxonomically challenging genera—*Pseudosinella, Hymenaphorura, Deuteraphorura*, and *Friesea,* belonging to Entomobryidae, Onychiuridae, and Neanuridae. Research on *Pseudosinella* combined detailed morphological and chaetotaxic comparisons with the description of *Pseudosinella hartnerae* from Hungary and Romania and the reassessment of related taxa. Work on *Hymenaphorura* resulted in the description of two Romanian species, *H. kalindera* and *H. urbana*, comparative diagnoses, and an updated identification key for the genus. Studies on *Deuteraphorura* contributed to the recognition and characterization of previously undescribed species from Romanian forest soils and to improved identification of species lacking pseudocelli on the first thoracic tergum. The revision of *Friesea* in Romania combined the description of three new species—*F. posada*, *F. mirceai*, and *F. stampa*—with new faunistic records and a broader assessment of the diversity and distribution of the genus.

These contributions extend beyond the addition of new taxa. They improve the interpretation of morphological variation, clarify characters of diagnostic value, and strengthen identification frameworks for Romanian Collembola. The resulting taxonomic information provides the foundation for the ecological and biogeographical analyses developed in subsequent sections of the thesis and facilitates the incorporation of Romanian records into wider biodiversity databases and research

infrastructures.

Environmental drivers and community assembly

The second major research direction extends the analysis from individual species to the ecological processes structuring Collembola communities. I investigated how environmental conditions, habitat characteristics, anthropogenic disturbance, dispersal, and isolation affect species richness, community composition, and spatial turnover. Managed vineyards and naturally isolated caves provided contrasting model systems for examining these mechanisms across different ecological contexts.

Research conducted in 16 commercial vineyards in the Târnave wine-growing region of Transylvania evaluated the effects of agricultural management on surface-active Collembola communities. A total of 4,692 individuals belonging to 24 species were recorded. Management practices, particularly tillage frequency, fertilization, herbicide application, and vegetation-cover management, influenced community composition and abundance. Increasing management intensity did not produce a simple linear decline in species richness; rather, the responses reflected the combined effects of individual practices and the capacity of springtails to persist in or recolonize disturbed habitats. Low-intensity management, including alternating tillage and permanent vegetation cover, supported comparatively stable and abundant populations. These results demonstrate that agricultural production and biodiversity conservation are not necessarily incompatible and support the development of management practices that reduce pressure on non-target soil arthropods.

Subterranean ecosystems provided a complementary setting characterized by environmental stability, strong habitat isolation, and restricted dispersal. Analyses of Collembola communities from 187 Romanian karst caves, comprising 141 species, showed low local richness but exceptionally high turnover among caves. Many species displayed restricted distributions, including taxa confined to individual cave systems. Species richness was associated mainly with local cave characteristics, including cave depth and soil conditions, whereas surface climate and vegetation had more limited explanatory power. Further analyses indicated that dispersal limitation, historical isolation, neutral colonization processes, and long-term speciation–extinction dynamics can be more influential than recent environmental filtering in structuring cavernicole assemblages.

The very high beta diversity of Romanian cave Collembola emphasizes the importance of caves as long-term refugia and evolutionary laboratories. At the same time, it demonstrates that regional diversity may be generated by the accumulation of highly distinct local communities rather than by

high species richness within individual sites. Together, the vineyard and cave studies show that Collembola communities are shaped by different combinations of disturbance, environmental conditions, isolation, dispersal, and historical processes depending on ecosystem context and spatial scale. This community-level research therefore forms the conceptual bridge between species-level taxonomy and continental biogeographical analysis.

Biogeographical and phylogenetic patterns at the European scale

The third research direction places local and regional patterns within a broader historical and geographical framework. Contemporary Collembola distributions across Europe reflect not only present-day environmental conditions but also long-term processes of isolation, dispersal, extinction, speciation, and postglacial recolonization. A continental analysis of **2,078 species distributed across 55 European countries** and major islands investigated geographical variation in phylogenetic relatedness and species range size in relation to Pleistocene history.

The analysis revealed marked geographical structure. Range-restricted species were concentrated particularly in southern European regions associated with glacial refugia, including the Iberian Peninsula, southern France, Greece, and other topographically complex areas. Long-term climatic stability and geographical heterogeneity in these regions favored persistence, isolation, and evolutionary differentiation. By contrast, assemblages in formerly glaciated parts of northern and central Europe retained signatures consistent with postglacial recolonization. The analyses also indicated major recolonization pathways converging in Central Europe and the Pannonian Basin. These findings demonstrate that present-day European springtail assemblages cannot be interpreted solely from contemporary environmental conditions and that historical climatic processes have left persistent signatures in their geographical and phylogenetic structure.

A complementary synthesis focused on European troglobitic Collembola, for which habitat isolation and restricted dispersal are especially pronounced. The compiled dataset documented **338 obligate cave-dwelling** species belonging to 50 genera and 12 families. Approximately 90% of these species were known from a single country, while many had much smaller distributions restricted to individual caves or karst systems. Major mountain and karst regions, including the Alps, Carpathians, Pyrenees, Dinarides, and Caucasus, emerged as important centres of subterranean diversity, endemism, and long-term persistence. The synthesis also examined convergent morphological adaptations to subterranean life, including reduction or loss of pigmentation and eyes and modifications of

appendages and claws. Together, these patterns illustrate how geographical isolation, restricted dispersal, and environmental specialization have shaped the evolution of European cave Collembola.

Across these studies, range size, dispersal capacity, geographical isolation, and Pleistocene history emerge as interacting determinants of contemporary diversity. The results reinforce the central framework of the thesis: taxonomic, ecological, and biogeographical scales are not separate research domains but mutually dependent components of an integrated approach to biodiversity.

Scientific trajectory, leadership, and European integration

My scientific career has developed for more than two decades at the Institute of Biology Bucharest, where I progressed from Research Assistant to Senior Researcher I. My doctoral work established a multidisciplinary foundation integrating taxonomy, ecology, trophic studies, and biogeography. After 2012, I consolidated an increasingly independent research programme in Collembola systematics and progressively expanded it towards community ecology, macroecology, phylogeography, molecular approaches, and European-scale soil-biodiversity research. International research stays and long-term collaborations with specialists from several European countries contributed to this methodological and conceptual development.

Scientific independence has been strengthened through the securing and managing **13 competitive research grants and project budgets**, as well as through increasing leadership responsibilities in national and European projects. A major current responsibility is the coordination of the Romanian partnership within the **Horizon Europe SOB4ES project**, with a budget of €400,000 allocated to the Institute of Biology Bucharest. Participation **in EUdaphobase, BOTTOMS-UP, GINTONIC, SoilBON, SOB4ES**, and related initiatives has enabled the integration of Romanian soil-biodiversity data into European research infrastructures and monitoring frameworks. My responsibilities have evolved from scientific participation to coordination, including representation of Romania in COST Management Committee, coordinating a work package within EUdaphobase, coordinating national research teams, and leading the Romanian contribution to international projects.

Mentoring and research-group development have become increasingly important components of my academic profile. I have supervised and trained research assistants, postdoctoral researchers, and visiting early-career researchers in field sampling, classical taxonomy, molecular identification, DNA barcoding and metabarcoding, biogeographical analysis, bioinformatics, statistics, and scientific writing. These activities, together with peer review, international collaboration, and participation in

scientific networks, provide a strong foundation for doctoral supervision and for developing an interdisciplinary research group in soil biodiversity.

Future research and academic development

Following habilitation, my principal objective is to consolidate an internationally visible research programme and research group in soil biodiversity at the Institute of Biology Bucharest. Future development will build directly on the scientific continuity demonstrated throughout the thesis and will integrate fundamental taxonomy with quantitative ecology, European monitoring, open biodiversity data, and doctoral training.

The first priority is to advance integrative taxonomy and molecular systematics by combining morphological expertise with high-throughput DNA barcoding, metabarcoding, and, where appropriate, phylogenetic approaches. Particular attention will be given to cryptic diversity and difficult species complexes, the development of high-quality molecular reference libraries linked to reliably identified voucher specimens, and the digitization of the IBB Collembola collection. Connecting curated collections and datasets with infrastructures such as GBIF and EUdaphobase will increase their accessibility and value for research and monitoring.

The second priority is to expand ecological, macroecological, and biogeographical research across European mountain systems and vulnerable habitats, particularly the Carpathians, Balkans, Alps, caves, peatlands, and old-growth forests. These studies will integrate taxonomic, functional, phylogenetic, molecular, and environmental information and will increasingly focus on predictive analyses of biodiversity responses to land-use and climate change. A related objective is to strengthen long-term ecological monitoring and to identify the mechanisms that determine persistence, endemism, and community reorganization under environmental change.

The third priority concerns European soil-biodiversity monitoring and soil-health assessment. Building on experience from international networks, I intend to contribute to harmonized sampling approaches, interoperable datasets, and biologically meaningful, cost-effective indicators. Particular attention will be given to linking high-quality taxonomic information with molecular methods, community metrics, functional traits, and environmental data. This work can strengthen the contribution of soil biodiversity to sustainable agriculture, forest management, ecosystem restoration, and climate resilience while improving the scientific basis of national and European soil-health initiatives.

The fourth priority is academic mentoring and capacity building. Habilitation will support the development of a structured doctoral and postdoctoral training pathway in which classical taxonomic competence is combined with molecular, computational, ecological, and quantitative skills. Future researchers will be encouraged to develop independent scientific profiles through international mobility, joint supervision, interdisciplinary collaboration, and participation in competitive European projects. Open science and FAIR data principles will be promoted throughout this programme, together with the integration of Romanian biodiversity datasets into European and global infrastructures.

Conclusions

The research synthesized in this habilitation thesis demonstrates a coherent and independent scientific trajectory connecting species-level taxonomy, community ecology, subterranean biology, continental biogeography, molecular approaches, and European-scale soil-biodiversity monitoring. Taxonomic studies have expanded knowledge of Romanian and European Collembola through new species descriptions, revisions, and improved identification tools. Ecological research has clarified the effects of agricultural management, habitat characteristics, isolation, and dispersal on community structure, while biogeographical studies have demonstrated the persistent influence of glacial refugia, postglacial recolonization, restricted ranges, and historical isolation on present-day European diversity.

The defining feature of this trajectory is continuity across scales. Rigorous taxonomy provides reliable biodiversity units; ecological studies explain community responses and assembly; biogeography identifies the historical and spatial processes shaping distributions; and monitoring frameworks translate this knowledge into comparable assessments relevant to soil health and ecosystem functioning. The progressive integration of morphological, ecological, molecular, and quantitative approaches marks a transition from predominantly descriptive studies towards increasingly integrative, predictive, and scalable biodiversity research.

At the same time, international collaboration, competitive project leadership, mentoring, and participation in European research networks have created the institutional and academic framework for the next stage of development. Through doctoral supervision, the consolidation of an interdisciplinary research group, continued international cooperation, and stronger connections between fundamental biodiversity science and applied environmental assessment, I aim to strengthen Romania's scientific capacity in soil biodiversity and to increase its contribution and visibility within European research and monitoring initiatives.