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Current knowledge on the habitat distribution of freshwater snails (Mollusca: Gastropoda) in Bulgaria

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Abstract. This review article proposes a systematic classification of freshwater snail habitats in Bulgaria and synthesizes current data on species distribution across these environments. Based on the Palaearctic Habitat Classification and refined by hydrological and environmental parameters, fourteen distinct habitat types were identified. Analysis reveals that cold-water springs harbor the highest species richness (53 species), followed by eutrophic standing waters (36 species), the Danube River (30 species), and subterranean systems (30 species). In contrast, anthropogenic and oligotrophic mountain habitats exhibit significantly lower diversity, ranging from 2 to 12 species. The findings underscore the critical role of springs and subterranean waters as biodiversity hotspots and provide a foundational ecological framework for the future monitoring and conservation of Bulgaria's unique malacofauna.

Key words: malacofauna, Balkans, ecology, species, diversity.

Introduction

Freshwater gastropods represent a vital component of aquatic ecosystems, serving as key primary consumers, essential links in nutrient cycling, and sensitive bioindicators of environmental health. In Bulgaria, the malacological diversity is remarkably high, characterized by a significant degree of endemism, particularly within spring-associated and subterranean habitats (Dillon, 2004). Despite several decades of faunistic research, the ecological preferences and specific habitat requirements of many species remain insufficiently synthesized (Georgiev, 2014).

The complexity of Bulgaria's hydrographic network - ranging from high-alpine glacial lakes and karst springs to the large-scale lotic system of the Danube River - necessitates a standardized ecological framework. Currently, data regarding species distribution are often fragmented across various taxonomical reports, making it difficult to assess the conservation status and ecological niches of these mollusks effectively.

The present review article aims to propose a systematic classification of habitats specifically tailored to freshwater snail species in Bulgaria. Furthermore, this study seeks to summarize and integrate the current knowledge regarding species distribution within the proposed habitat types. By establishing this classification, a foundational tool for future monitoring can be provided, and the development of targeted conservation strategies for the country's aquatic biodiversity.

Materials and methods

The classification of habitat types followed the criteria of the Palaearctic Habitat Classification, further refined by the size and origin of the water body (natural or artificial), as well as specific environmental conditions not explicitly defined within the Palaearctic system. For the charac-

terization of water bodies, the following fundamental literature sources were consulted: Zhadin (1952), Angelov (2000), Glöer (2002), Varbanov (2002), Dillon (2004), Hubenov (2005), Glöer & Diercking (2009), and Cheshmedjiev et al. (2010).

The present classification includes only habitats characterized by permanent water presence or those retaining water for the greater part of the year. Temporary habitats, which typically support only pseudopopulations of freshwater gastropods, were excluded from this analysis.

In analyzing the species composition across the different habitat types, the study relied exclusively on literature concerning the territory of Bulgaria, supplemented by the author's original data (Angelov, 2000; Hubenov, 2005; Georgiev, 2014). Information from more recent studies published after the aforementioned monographs was also integrated (Glöer & Georgiev, 2014; Georgiev & Glöer, 2015; Gashtarov & Georgiev, 2016; Osikowski et al., 2015, 2017; Georgiev, 2023).

Results and Discussion

1. Lentic Habitats (Standing Waters)

1.1. Natural Habitats

Oligotrophic Lakes. These consist of high-mountain and mountain lakes characterized by nutrient-poor waters. The water is typically clear and transparent, while the substrate is rocky with minimal sediment accumulation. This category primarily includes the glacial lakes of the Rila and Pirin Mountains. Only three species of freshwater gastropods have been recorded in these habitats: *Radix labiata*, *R. balthica*, and *Galba truncatula*.

Mesotrophic Lakes. This group includes semi-mountainous and certain lowland lakes exhibiting moderate levels of eutrophication and the growth of plankton and macrophytes. Examples include various karst or landslide lakes (e.g., the Smolyan Lakes, the lakes at the Glava Panega spring, the lake at Chirpan Bunar Cave, etc.). The fauna in these lakes is more diverse and primarily composed of limnophilous species. However, a significant number of limnoreophilic species are also present, and in cases where benthic springs occur, typical rheophilic species may be found. The recorded species include: *Theodoxus danubialis*, *Valvata piscinalis*, *Acroloxus lacustris*, *Stagnicola palustris*, *Radix labiata*, *R. auricularia*, *Galba truncatula*, *Physa fontinalis*, *Physella acuta*, *Planorbis planorbis*, *Gyraulus albus*, and *Ancylus fluviatilis*.

Eutrophic Lakes. These are characterized by nutrient-rich waters and a high proliferation of plankton and macrophytes. This category includes the Danubian lakes, abandoned riverbeds (oxbow lakes) of the Maritsa and Tundzha rivers, the Rabisha and Dragoman marshes, and the floodplains of the Maritsa River near the city of Plovdiv. These water bodies exhibit the highest species richness (35 species), with the greatest diversity recorded in Lake Srebarna (29 species) and the Maritsa floodplains near Plovdiv (21 species). The recorded freshwater gastropod composition in this habitat type is as follows: *Viviparus contectus*, *V. acerosus*, *V. viviparus*, *Valvata cristata*, *V. piscinalis*, *Bithynia tentaculata*, *Acroloxus lacustris*, *Radix auricularia*, *R. labiata*, *R. balthica*, *R. lagotis*, *Stagnicola palustris*, *S. corvus*, *S. montenegrinus*, *Galba truncatula*, *Lymnaea stagnalis*, *Planorbarius corneus*, *Planorbis planorbis*, *P. carinatus*, *Anisus vortex*, *A. vorticulus*, *A. septemgyratus*, *A. leucostoma*, *A. spirorbis*, *Bathyomphalus contortus*, *Gyraulus albus*, *G. piscinarum*, *G. laevis*, *G. crista*, *Hippeutis complanatus*, *Segmentina nitida*, *Physa fontinalis*, *Physella acuta*, *Aplexa hypnorum*, *Ferrissia fragilis*.

Coastal Lakes and Brackish Lagoons. Along the Black Sea coast, lakes of the liman type (blocked river mouths) and lagoon type (isolated marine areas) predominate. These include Lake Varna (before its salinization), Lake Shabla, Lake Burgas, Lake Mandra, and others. This habitat supports a specific fauna of salt-tolerant freshwater mollusks coexisting with marine species that are tolerant to some degree of freshening (desalination). The following species have been recorded: *Theodoxus fluviatilis*, *Th. pallasi*, *Viviparus acerosus*, *Lithoglyphus naticoides*, *Bithynia tentaculata*, *Turricaspia lincta*, *Radix auricularia*, *R. balthica*, *Planorbarius corneus*, *Planorbis planorbis*, *Anisus vortex*, *Segmentina nitida*, *Bathyomphalus contortus*, *Gyraulus albus*, *Ferrissia fragilis*.

Wet Mountain Meadows with Permanent Water. This habitat is characterized by a limited amount of available water, near-complete freezing during the winter, and low freshwater snail species richness. Only two species have been recorded: *Radix labiata* and *Galba truncatula*. These species exhibit a partially amphibious lifestyle and are highly resilient to cold temperatures.

1.2. Anthropogenic Habitats

Micro-reservoirs. Micro-reservoirs (micro-dams) are small water bodies located in the country's in-

terior, primarily used for agricultural irrigation, with many also serving for fish farming. They are predominantly situated in the lowlands and low-lying hilly regions. These habitats are characterized by meso- to eutrophic waters and vary from weak to extensive macrophyte development. The freshwater gastropod species composition is relatively poor, with the following recorded species: *Viviparus acerosus*, *Acroloxus lacustris*, *Radix auricularia*, *Lymnaea stagnalis*, *Planorbarius corneus*, *Planorbis planorbis*, *Physa fontinalis*, and *Physella acuta*.

Large Reservoirs. These are large-scale artificial water bodies constructed primarily for hydroelectric power generation, drinking water supply, and irrigation. They are mainly situated in the lowlands and low-lying hilly regions of the country, and more rarely at altitudes exceeding 1000 m a.s.l. (above sea level). They are characterized by oligo- to mesotrophic waters. The freshwater gastropod species composition is very poor, with only the following recorded: *Viviparus acerosus*, *Galba truncatula*, *Radix auricularia*, and *Physella acuta*.

Quarry Lakes. These are lentic water bodies formed by the filling of sand quarry excavations with water. They are characterized by slow water turnover and rapid eutrophication. The following species have been recorded: *Radix auricularia*, *Stagnicola montenegrinus*, *Lymnaea stagnalis*, *Planorbarius corneus*, *Planorbis planorbis*, and *Physella acuta*.

Rice Fields. These are shallow, extensive basins designed for rice cultivation in the lowland regions of Bulgaria. They are submerged during the spring, summer, and autumn. A key characteristic is the periodic treatment of crops and water with various chemical substances. Rice fields are typically connected to the main regional river via a system of irrigation canals. The recorded species include: *Radix auricularia*, *Stagnicola montenegrinus*, *S. palustris*, *S. corvus*, *Lymnaea stagnalis*, *Planorbarius corneus*, *Planorbis planorbis*, *P. carinatus*, *Gyraulus albus*, *Hippeutis complanatus*, and *Physella acuta*.

Fish Ponds. These are shallow, extensive basins designed for fish farming, with a large portion of their banks consisting of natural soil. Water and stocking material are frequently transported to these ponds from various parts of the country, and occasionally from water bodies abroad. Consequently, a wide variety of freshwater gastropod species may be expected to occur. To date, however, only *Radix labiata* and *Planorbarius corneus* have been reported.

Fountain Troughs. These are small, typically concrete, isolated basins filled by the flowing spring water of outdoor fountains. Their trophic status varies from oligo- to eutrophic, particularly when filled with decaying plant matter, algae, and mosses. They represent a specific habitat occupied by two groups of species: rheophiles, including endemic spring-dwelling Truncatelloidea (two species: *Grossuana codreanui* and *G. angeltsekovi*) and widely distributed species (*Ancylus fluviatilis*), and eurybiont species (*Radix auricularia*, *R. labiata*, *Galba truncatula*, *Planorbis planorbis*, and *Physella acuta*).

Decorative Artificial Basins. These are basins of various sizes constructed in urban parks for aesthetic purposes. Although *Radix labiata*, *Anisus spirorbis*, and *Planorbis planorbis* have been recorded in them, practically any species could potentially be introduced into these environments.

2. Lotic Habitats (Running Waters)

2.1. Natural Habitats

Thermal Springs. Only a few species have been recorded in thermal springs: *Bithynia rumelica*, *Melanopsis parreyssi* (both extinct), *Radomaniola bulgarica*, *Galba truncatula*, *Radix labiata*, *Planorbis planorbis*, and *Physella acuta*. The species *Melanoides tuberculata*, which is frequently kept in aquariums, has also been established in such warm springs. Theoretically, these locations are susceptible to the introduction of various snail species kept by aquarists, such as members of the families Ampullariidae (apple snails) and Planorbidae (e.g., *Helisoma* spp.).

Cold-water Springs. This habitat type is significantly richer in species compared to thermal springs, particularly regarding local and regional endemics. All species from the Truncatelloidea have been recorded here, including the invasive *Potamopyrgus antipodarum* and various stygobiont species. Additionally, several widely distributed species occur in these habitats: *Theodoxus fluviatilis*, *Th. danubialis*, *Valvata piscinalis*, *Physa fontinalis*, *Physella acuta*, *Aplexa hypnorum*, *Galba truncatula*, *Radix auricularia*, *R. labiata*, *R. balthica*, *Lymnaea stagnalis*, *Planorbarius corneus*, *Planorbis planorbis*, *Anisus vortex*, *Hippeutis complanatus*, *Ancylus fluviatilis*, and *Ancylus recurvus*.

Lowland Rivers and Streams. These are characterized by relatively slow currents and predominantly silty substrates, often supporting dense aquatic vegetation. The following species have

been recorded in this habitat type: *Theodoxus fluviatilis*, *Th. transversalis*, *Th. danubialis*, *Potamopyrgus antipodarum*, *Valvata piscinalis*, *Galba truncatula*, *Radix auricularia*, *R. labiata*, *R. balthica*, *Myxas glutinosa*, *Lymnaea stagnalis*, *Stagnicola palustris*, *S. corvus*, *Physella acuta*, *Planorbarius corneus*, *Planorbis planorbis*, *P. carinatus*, *Anisus spirorbis*, *A. leucostoma*, *A. septemgyratus*, *A. vortex*, *Bathyomphalus contortus*, *Gyraulus albus*, *G. piscinarum*, *G. laevis*, *G. crista*, *Hippeutis complanatus*, *Segmentina nitida*, and *Ancylus fluviatilis*.

Mountain and Semi-mountain Rivers and Streams. These are characterized by relatively fast currents and sandy-gravel substrates with minimal or no silt accumulation. Fewer species have been recorded here compared to lowland rivers: *Potamopyrgus antipodarum*, *Hydrobia acuta*, *Galba truncatula*, *Radix labiata*, *Physella acuta*, *Planorbis planorbis*, *Gyraulus albus*, *G. crista*, and *Ancylus fluviatilis*.

The Danube River and the Lower Reaches of Its Tributaries. The following species have been established: *Viviparus acerosus*, *V. sphaeridius*, *V. viviparus*, *Theodoxus transversalis*, *Th. fluviatilis*, *Th. danubialis*, *Esperiana daudebartii*, *E. esperi*, *Holandriana holandrii*, *Turricaspia lincta*, *T. variabilis*, *Bithynia tentaculata*, *B. danubialis*, *Lithoglyphus naticoides*, *L. pyramidatus*, *Valvata macrostoma*, *V. piscinalis*, *Borysthenia naticina*, *Acroloxus lacustris*, *Stagnicola corvus*, *S. turricula*, *Radix auricularia*, *R. balthica*, *Physa fontinalis*, *Physella acuta*, *Planorbarius corneus*, *Planorbis planorbis*, *P. carinatus*, *Anisus spirorbis*, *A. vortex*, and *Gyraulus laevis*.

Estuaries. These habitats are characterized by brackish water, slow currents, and sandy-silt substrates. The following species have been recorded: *Theodoxus fluviatilis*, *Potamopyrgus antipodarum*, *Galba truncatula*, *Physella acuta*, *Planorbis planorbis*, and *Ancylus fluviatilis*.

Subterranean Rivers and Streams. Cave-dwelling running waters are characterized by specific environmental conditions: constant temperature, absence of light, high dissolved oxygen levels, and sandy-stony or rocky substrates. Two major ecological groups of Truncatelloidea are found here: stygobionts and troglophiles, such as *Belgrandiella dobrostanica*, *B. pandurskii*, *Grossuana derventica*, and *Pontobelgrandiella tanevi*. In the subterranean waters of Northern Bulgaria, representatives of numerous endemic genera have been established: *Saxurinator* Schütt, 1960; *Insignia* Angelov, 1972; *Devetakia* Georgiev & Glöer, 2011; *Balkanica* Georgiev, 2011; *Balkanospeum* Georgiev, 2012; *Microstygia* Georgiev & Glöer, 2015; *Kolevia* Georgiev & Glöer, 2015; *Stoyanovia* Georgiev, 2017; *Devetakiola* Georgiev, 2017; and *Polatenia* Georgiev, 2023. This high degree of endemism is the result of speciation following the retreat of the Sarmatian Sea and the subsequent Messinian Salinity Crisis. Approximately 7.5 million years ago, these events forced microgastropods to adapt to subterranean environments.

2.2. Anthropogenic Habitats

Canals (with concrete or soil banks). These habitats are characterized by fluctuating water levels and vary significantly in terms of current velocity, substrate structure, function, size, and the degree of macrophyte coverage. They are inhabited by widely distributed limnophilous and limnoreophilic species: *Viviparus acerosus*, *Bithynia tentaculata*, *Radix auricularia*, *Stagnicola montenegrinus*, *S. palustris*, *S. corvus*, *Lymnaea stagnalis*, *Planorbarius corneus*, *Planorbis planorbis*, *Gyraulus albus*, *Hippeutis complanatus*, and *Physella acuta*.

Conclusions

In summary, the present review highlights the distinct variation in species richness across the diverse aquatic habitats of Bulgaria. Cold-water springs emerge as the most biologically significant habitats, supporting the highest diversity with 53 recorded species, including a high proportion of narrow-range endemics. Eutrophic lentic water bodies follow as the second most diverse habitat type, harboring 36 species, followed closely by the Danube River and subterranean rivers and streams, each with 30 species. Lowland rivers and streams exhibit a similar level of diversity with 29 species, while mesotrophic standing waters support a more modest assemblage of 12 species.

Conversely, anthropogenic habitats and high-mountain oligotrophic lakes are characterized by significantly lower species richness, ranging from 2 to 12 species. Among man-made environments, rice fields and irrigation canals show the highest diversity within this category (10 and 12 species, respectively), likely due to their connectivity with natural river systems.

These findings underscore the critical importance of spring and subterranean ecosystems for the conservation of Bulgaria's malacological heri-

tage. Further targeted research is essential to elucidate the underlying ecological drivers of these distributional patterns and to define the precise habitat requirements of rare species. Such data are fundamental for implementing effective monitoring programs and developing robust conservation strategies to protect threatened taxa in the face of increasing anthropogenic pressure and climate change.

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