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Leslie Nascimento Altomari

Contribution for the knowledge on microgastropods of the clades Heterobranchia and Mesoneura: Taxonomic and macroevolutionary aspects

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Leslie Nascimento Altomari

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Dissertação apresentada ao Programa de Pós-Graduação em Biodiversidade e Conservação da Natureza, da Universidade Federal de Juiz de Fora como requisito parcial para obtenção do título de Mestre em Biodiversidade e Conservação da Natureza. Área de concentração: Comportamento, Ecologia e Sistemática.

Orientador: Dra. Sthefane D'àvila

Coorientador: Dra. Mariana Fonseca Rossi

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ABSTRACT

This study aims to contribute to the understanding of micromollusks of the Heterobranchia clade, addressing their biodiversity, taxonomy, and the macroevolutionary aspects of miniaturization. The dissertation is organized into three chapters, each addressing different aspects of the subject. In the first chapter, we conducted an assessment of the time and mode of miniaturization evolution in marine heterobranch molusks, using molecular methods and genetic databases. The reconstruction analysis of the ancestral state reveals that miniaturization originated as a characteristic of the Heterobranchia ancestor during the Middle Devonian, followed by a dynamic evolution of size at the genus and species levels. In the second chapter, we aimed to provide a critical review of the species concepts adopted for basal heterobranch microgastropods, along with the methodologies associated with each concept (phylogenetic and morphological). It was found that predominantly morphological species concepts were adopted (98.06%), with varied operational criteria. Shell morphology was the main factor for 84.55% of species delimitation, while soft part anatomy and external morphology were also employed, individually or in combination. The exclusive association of the phylogenetic species concept with the criterion of monophyly reveals potential impacts on the current state of knowledge regarding the phylogeny and evolution of this group. The third chapter consists of a list of terrestrial and freshwater microgastropod species deposited in the Prof. Maury Pinto de Oliveira collection, donated by the Romanian malacologist Alexandru Grossu. This list results from a collection review, involving data compilation, specimen reconditioning, image acquisition through Scanning Electron Microscopy, and taxonomic updating through cross-verification of species taxonomic assignments. Additionally, an analysis of the representativity of the analyzed species in larger collections worldwide was conducted by researching records of these species in Romania through biological collections databases. This study not only expands our knowledge of micromollusks in the Heterobranchia clade but also emphasizes the importance of multidisciplinary approaches to advance the understanding of the evolution and diversity of these organisms.

Keywords: Macroevolutionary analyses; Microgastropod; Miniaturization; Species Concept; Biological collections

RESUMO

Este estudo visa contribuir para o entendimento dos micromoluscos do clado Heterobranchia, abordando sua biodiversidade, taxonomia e os aspectos macroevolutivos da miniaturização. A dissertação está organizada em três capítulos, cada capítulo abordando diferentes aspectos do tema. No primeiro capítulo, realizamos uma avaliação do tempo e modo de evolução da miniaturização em moluscos heterobrânquios marinhos, utilizando métodos moleculares e bases de dados genéticos. A análise de reconstrução do estado ancestral revela que a miniaturização teve sua origem como uma característica do ancestral de Heterobranchia durante o Devoniano Médio, seguida por uma evolução dinâmica do tamanho a nível de gênero e espécie. No segundo capítulo, buscamos fornecer uma revisão crítica sobre os conceitos de espécie adotados para microgastrópodes heterobrânquios basais, juntamente com as metodologias associadas a cada conceito (conceito filogenético e morfológico). Verificou-se que os conceitos de espécies adotados foram principalmente morfológicos (98,06%), com critérios operacionais variados. A morfologia da concha foi o principal fator para 84,55% da delimitação de espécies, enquanto a anatomia das partes moles e a morfologia externa também foram empregadas, individualmente ou em combinação. A associação do conceito filogenético de espécies unicamente ao critério de monofilia revela potenciais impactos no estado atual do conhecimento sobre filogenia e evolução desse grupo. O terceiro capítulo consiste em uma lista de espécies de microgastrópodes terrestres e de água doce depositados na coleção Prof. Maury Pinto de Oliveira, doados pelo malacologo romeno Alexandru Grossu. Essa lista resulta de uma revisão do acervo da coleção, incluindo a compilação de dados, o recondicionamento dos espécimes, a aquisição de imagens por meio de Microscopia Eletrônica de Varredura e a atualização taxonômica por meio da verificação cruzada das atribuições taxonômicas das espécies. Além disso, foi realizada uma análise da representatividade das espécies analisadas em coleções maiores em todo o mundo, por meio da pesquisa de registros dessas espécies na Romênia em bases de dados de coleções biológicas. Este estudo não apenas amplia nosso conhecimento sobre os micromoluscos do clado Heterobranchia, mas também destaca a importância de abordagens multidisciplinares para avançar na compreensão da evolução e diversidade desses organismos.

Palavras-chave: Análises macroevolutivas; Microgastrópodes; Miniaturização; Conceito de Espécie; Coleções Biológicas.

RESUMO PARA DIVULGAÇÃO CIENTÍFICA

A miniaturização é um processo evolutivo que quando presente, resulta em organismos extremamente pequenos. Esse fenômeno ocorre em diversos grupos de animais, sendo amplamente observado nas classes de moluscos. Devido à escala temporal de milhões de anos em que ocorrem processos evolutivos como a miniaturização, é necessário integrar o estudo das espécies viventes com o registro fóssil para desvendar esses fenômenos. O estudo dos micromoluscos apresenta vários desafios, desde a necessidade de especialistas aptos a dissecar e estudar esse material até a obtenção de recursos financeiros para viabilizar coleta, processamento e formação profissional. Neste estudo, contribuímos para o conhecimento da biodiversidade de microgastrópodes da subclasse Heterobranchia, abordando aspectos evolutivos e taxonômicos através de estudo da biodiversidade. No primeiro capítulo, avaliamos o tempo de divergência e o modo de evolução da miniaturização em todo o clado de gastrópodes marinhos heterobrânquios, utilizando uma ampla base de dados genéticos, informações sobre o tamanho corporal e registros fósseis. Nossa análise revelou que a miniaturização é um estado ancestral comum ao clado Heterobranchia e que, ao longo da história evolutiva do grupo, ocorreram pelo menos 20 reversões para o tamanho miniaturizado a partir de um aumento de tamanho. No segundo capítulo, avaliamos o estado do conhecimento na descrição de espécies de dois clados de microgastrópodes por meio de uma abordagem integrativa, utilizando bases de dados literárias, moleculares e a disponibilidade de via úmida em museus. O termo "espécie" foi atribuído aos microgastrópodes, predominantemente, com base em características morfológicas, especialmente da concha. No terceiro capítulo, elaboramos uma lista com imagens de microscopia de varredura das conchas, abordando a biodiversidade de microgastrópodes terrestres e de água doce provenientes da Romênia, depositados no Museu de Malacologia Prof. Maury Pinto de Oliveira, localizado em Juiz de Fora, Minas Gerais. Essa compilação resultou de uma revisão do acervo da coleção, envolvendo a compilação de dados dos lotes tombados, o recondicionamento dos espécimes e a atualização da classificação taxonômica.

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LIST OF ABREVIATURES

AMU – Adam Mickiewicz University in Poznań.

ANSP – Academy of Natural Sciences of Philadelphia.

BMSM – Bailey-Matthews National Shell Museum.

CM – Carnegie Museum of Natural History.

CMMPO – Coleção Malacológica Maury Pinto de Oliveira.

DMNH – Delaware Museum of Natural History.

FMNH – Field Museum of Natural History.

GRM – Muséum d'Histoire naturelle de Grenoble.

HNS – Haus der Natur Salzburg, Museum für Natur und Technik.

LI – Biologiezentrum Linz.

LMD –Löbbecke Museum Düsseldorf.

MCNB – Museu de Ciències Naturals de Barcelona.

MCZ – Museum of Comparative Zoology, Harvard University.

MHNL – Museum d'Histoire Naturelle de Lyon / Musée des Confluences.

MMPMPO – Museu de Malacologia Prof. Maury Pinto de Oliveira.

MZH – Finnish Museum of Natural History.

MZL – Musée Cantonal de Zoologie, Lausanne.

MZLU – Lund Museum of Zoology.

NHMA – Natural History Museum Aarhus.

NHMD – Natural History Museum of Denmark.

NHMUK – Natural History Museum (London).

NMBE – Naturhistorisches Museum Bern.

NMR – Natural History Museum Rotterdam.

NTNU University – Norwegian University of Science and Technology.

NRM – Swedish Museum of Natural History.

PRI – Paleontological Research Institution.

RBINS – Royal Belgian Institute of Natural Sciences.

SBMNH – Santa Barbara Museum of Natural History.

SDNHM – San Diego Natural History Museum.

SMF – Forschungsinstitut und Natur-Museum Senckenberg.

SNSD – Collection Malakologie Senckenberg Naturmuseum.

USNM – United States National Museum / National Museum of Natural History, Smithsonian Institution.

UT – University of Texas.

ZMB/Moll – Museum für Naturkunde, Berlin.

UF – Florida Museum of Natural History.

UMMZ – University of Michigan Museum of Zoology.

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1. GENERAL INTRODUCTION

The Phylum Mollusca constitutes a highly diverse group, representing approximately 7% of all animal species globally, estimated to range between 100,000 and 200,000 species, with over 52,000 species identified and described (BENKENDORFF, 2010). Traditionally, this group is divided into eight classes (Bivalvia, Caudofoveata, Cephalopoda, Gastropoda, Monoplacophora, Polyplacophora, Scaphopoda, and Solenogastres) (WORMS, 2024), which have been recovered as monophyletic groups in molecular phylogeny studies (KOCOT *et al.*, 2020).

The emergence of new proposals for molecular phylogenies, corroborated by paleobiological discoveries, has allowed for a better understanding of the relationships between classes and suggested substantial changes in the understanding of the internal evolutionary relationships among mollusks (KOCOT *et al.*, 2020). Regarding the class Gastropoda, the recovered internal relationships have shown that various commonly accepted taxonomic groups, especially those classified as families and orders, represented artificial groups (GRANDE *et al.*, 2004; AYYAGARI; SREERAMA, 2019). These results prompted the execution of molecular phylogenetic studies with broader taxonomic representation, aiming to understand the evolutionary processes related to the diversification of major monophyletic clades within Gastropoda (BRENZINGER; SCHRÖDL; KANO, 2021; GOEBBELER; KLUSSMANN KOLB, 2011; JÖRGER *et al.*, 2010).

The Heterobranchia comprises subgroups such as Euthyneura (containing Panpulmonata, Euopisthobranchia and Ringipleura), Mesouneura, and Lower Heterobranchia (BOUCHET *et al.*, 2017; BREZINGER *et al.*, 2021). Among the extensive variety of morphological plans observed in heterobranchs, there are species classified as microgastropods, named for their maximum adult size of 5mm (GEIGER *et al.*, 2007). Gastropods with these dimensions do not constitute a monophyletic clade, with representatives of microgastropods found in various taxa within Gastropoda, and such classification is pragmatic. Despite the continued interest of experts and amateur shell collectors, the information quality on the richness patterns of marine mollusk species is notably high, rivaling only the information available for fish. However, much of the literature focuses on macromollusks, which can be collected in the field and studied more effectively without specific techniques for visualizing their morphology (ALBANO; SABELLI; BOUCHET, 2011). This is likely because microgastropods require specific attention in collection/separation and are reputed to pose formidable taxonomic difficulties due

to the absence of apparent characteristics in their morphology (ALBANO; SABELLI; BOUCHET, 2011; GEIGER *et al.,* 2007).

Heterobranch microgastropods inhabit a variety of habitats in marine, terrestrial, and freshwater environments (JÖRGER *et al.,* 2010; DINAPOLI *et al.,* 2011; PÁLL-GERGELLY *et al.,* 2015). In marine and freshwater environments, they are commonly found associated with sediment and can have developed or reduced shells, with free-living or parasitic lifestyles. Morphological changes resulting from the process of miniaturization have been attributed to an adaptation to an interstitial lifestyle (JÖRGER *et al.,* 2010). In terrestrial environments, microgastropods include a significant number of endemic species found associated with litter, soil, and caves (WEIGAND *et al.,* 2013; PÁLL-GERGELLY *et al.,* 2015).

These tiny gastropod species have undergone an evolutionary process known as miniaturization, characterized by morphological transformations throughout their evolutionary history, culminating in an extremely small body, associated with significant changes in their lifestyle, ecology, behavior, and reproduction (HANKEN; WAKE, 1993). Miniaturization occurs in various eukaryotes, resulting in extremely small bodies, leading organisms to reach the so-called critical size, the maximum allowed to maintain the functioning of their physiological functions (HANKEN; WAKE, 1993). This phenomenon may involve the retention of larval characteristics (pedomorphy), allometric growth, and significant changes in the organism's ecology. However, studying these miniaturized animals is challenging due to the lack of knowledge about the internal morphology, cell biology, ontogeny, and reproduction of these extremely small organisms (HANKEN; WAKE, 1993; RUNDELL; LEANDER, 2010). Taxonomic groups that harbor a large number of miniaturized species are often neglected, resulting in a scarcity of information about their evolutionary relationships, diversity, and difficulties in establishing consistent classification systems.

Several theories have been proposed to explain the emergence and evolutionary success of miniaturization. One suggests that the exploration of new ecological niches drives the reduction of body size. In aquatic species, miniaturization may be related to the occupation of new microhabitats, such as adopting interstitial lifestyles and ectoparasitism, resulting not only in reduced body size but also in the acquisition of ciliated structures and a vermiform body (HANKEN; WAKE, 1993; RUNDELL; LEANDER, 2010). Although there is little knowledge about the drivers of miniaturization in terrestrial organisms, it is possible that they are equally associated with the occupation of new ecological niches, such as life in litter, parasitoidism, and troglobitic habits. Morphological adaptations related to the extreme reduction of body size in terrestrial animals include bone fusion and digit loss in vertebrates, reduced nervous system

in insects, and the presence of ciliated wings in wasps (HANKEN; WAKE, 1993; POLILOV, 2015; RUNDELL; LEANDER, 2010).

The evolutionary processes that led to the diversification of various life history traits of heterobranch gastropods are still uncertain (BRENZINGER; SCHRÖDL; KANO, 2021; DINAPOLI; KLUSSMANN-KOLB, 2010; GOEBBELER; KLUSSMANN KOLB, 2011; WILSON *et al.*, 2017). One challenge for understanding the evolutionary processes within a taxon is to encompass a satisfactory number of representatives for molecular analysis, as well as fossil representatives to accompany the molecular dating of lineages. The evolution of miniaturization in Gastropoda and, more particularly, in Heterobranchia, has not yet been satisfactorily addressed in comprehensive studies aiming to reconstruct the ancestral state of this characteristic and analyze ecological and morphological traits that can help clarify the evolutionary scenarios associated with this process.

The overall goal of this proposal is to provide a comprehensive view of the presence of lineages in the Heterobranchia clade, exploring the evolution of miniaturization through a macroevolutionary study. The intention is to reconstruct the evolutionary history of this process, identifying ancestral and derived traits such as body size, structural simplification, morphological variability, morphological novelties, and ecological characteristics. Regarding specific objectives, we aim to (1) conduct a systematic review of the adopted species concepts in different groups of basal and mesoneurous microgastropods. This approach aims to understand the possible biases of diminutive body size on taxonomic methodologies, the adopted species concept, and its limitations for advancing knowledge of the group's phylogeny and evolution. Additionally, we propose (2) to conduct a macroevolutionary study to estimate the evolutionary processes related to miniaturization in various heterobranch lineages. The intention is to formulate hypotheses about the origin and evolutionary pathways of this process. Another specific objective is (3) to provide an updated list of terrestrial and freshwater microgastropod species deposited at the Prof. Maury Pinto de Oliveira Malacology Museum donated by the Romanian malacologist Alexandru Grossu.

2. TIME AND MODE OF EVOLUTION IN THE MINIATURIZATION OF EXTANT MARINE HETEROBRANCH GASTROPODS

2.1. INTRODUCTION

The reduction in body size is an evolutionary process that occurs in eukaryotes and results in an extremely small body (HANKEN; WAKE, 1993). When subjected to miniaturization, the organism reaches a critical size, the maximum it can reduce without compromising the functioning of its physiological functions. In this context, the organism may retain larval characteristics (paedomorphosis), exhibit allometric growth, and undergo significant changes in its ecology. Investigating miniaturized animals poses a challenge because much of the internal morphology, cellular biology, ontogeny, and reproduction of these extremely small organisms are still unknown (HANKEN; WAKE, 1993; RUNDELL; LEANDER, 2010). Consequently, taxonomic groups with many miniaturized species are often overlooked, leading to a scarcity of information about these species and hindering the understanding of their evolutionary relationships, diversity, and the establishment of consistent classification systems.

Several hypotheses have been proposed to explain the emergence and success of miniaturization. One of them includes the exploration of new ecological niches as a driving force for the reduction of body size (HANKEN; WAKE, 1993). In aquatic organisms, miniaturization may be related to the occupation of new microhabitats, the adoption of an interstitial lifestyle, and ectoparasitism, resulting, in addition to the reduction in body size, in the acquisition of ciliated structures and a vermiform body (RUNDELL; LEANDER, 2010). Although little is known about the drivers of miniaturization in terrestrial organisms, this reduction may also be associated with the occupation of new ecological niches, such as life in leaf litter, parasitoidism, and troglobitic habits (POLILOV, 2015). Morphological adaptations associated with extreme reduction in body size in terrestrial animals include bone fusion and digit loss in vertebrates, reduction of the nervous system in insects, and the presence of ciliated wings in wasps (HANKEN; WAKE, 1993; POLILOV, 2015; RUNDELL; LEANDER, 2010). Hanken and Wake (1993) proposed the hypothesis that a miniaturized organism may arise independently in non-miniaturized taxa, while an increase in body size occurs gradually in evolutionary history. However, this hypothesis could not be proven, as analyzing the evolution of lineage sizes requires a robust dataset with diverse morphological and ecological

characteristics. This poses a particular challenge for mollusks, as many species have been described based on shell characteristics.

In this scenario, macroevolutionary analyses based on molecular data substantially contribute to the understanding of evolutionary processes associated with phenotypic traits, such as miniaturization, allowing the reconstruction of ancestral states, divergence times, and species diversification rates. However, macroevolutionary analyses remain scarce for the eight classes that make up the phylum Mollusca (Bivalvia, Caudofoveata, Cephalopoda, Gastropoda, Monoplacophora, Polyplacophora, Scaphopoda, and Solenogastres) (KOCOT *et al.,* 2020).

Among the lineages recovered in the Gastropoda clade through molecular phylogenetic analyses, the Heterobranchia group stands out for the morphological and ecological diversity of its species (GÖBBELER; KLUSSMANN-KOLB, 2011). The extensive variety of morphological plans observed in heterobranchs includes the miniaturized body plans of species classified as microgastropods, which are so named because they have a maximum adult size of 5 mm (GEIGER *et al.,* 2007). Microgastropods do not constitute a monophyletic clade, with representatives from various taxa in Gastropoda.

The evolutionary processes that led to the diversification of life history traits in heterobranch gastropods remain uncertain (BRENZINGER; SCHRÖDL; KANO, 2021; DINAPOLI; KLUSSMANN-KOLB, 2010; GOEBBELER; KLUSSMANN-KOLB, 2011). One challenge in understanding evolutionary processes within a taxon is encompassing a satisfactory number of representatives for molecular analysis, as well as fossil representatives to track lineage dating. The evolution of miniaturization in Gastropoda, and more particularly in Heterobranchia, has not been satisfactorily addressed in comprehensive studies aimed at reconstructing the ancestral state of this characteristic and analyzing ecological and morphological traits that may help clarify the evolutionary scenarios associated with this process. Herein, we provide the first ancestral reconstruction and phylogenetic analyses of miniaturization in Gastropoda, using a broad set of molecular and ecological data, with inferences about the diversification dynamics within these animals.

2.2. MATERIAL AND METHODS

2.2.1 Phylogenetics Analyses and molecular data

We conducted a comprehensive search on the GenBank (https://www.ncbi.nlm.nih.gov/genbank/) database, selecting the two most representative genes, cytochrome oxidase subunit 1 and 16S rRNA, to ensure optimal taxonomic coverage.

The dataset included three outgroups in Caenogastropoda: *Littorina littorea*, *Abyssochrysos melanioides*, and *Aperostoma palmeri*. Alignment was performed using MAFFT v.7.0 software with standard parameters and subsequently edited in Gblocks software to eliminate poorly aligned sites (KATOH; TOH, 2008; TALAVERA; CASTRESANA, 2007). Matrices were aligned and edited separately, and the data was concatenated in SEAVIEW (GOUY *et al.*, 2021) after editing. The nucleotide substitution model GTR + G + I was determined as the best fit using JModel-Test v. 2.1.4 on the MEGA 11 platform (DARRIBA; POSADA, 2014; KUMAR *et al.*, 2018). Phylogenetic reconstruction was carried out through Maximum Likelihood (ML) using IQTree software (NGUYEN *et al.*, 2015). Divergence time inference in RelTime software (TAMURA *et al.*, 2012) in the MEGA X program was utilized for estimating divergence times in Heterobranchia. Primary fossil species were employed for calibrating nodes, with respective minimum and maximum age information listed in Table 1.

Table 1. Fossil records used for node calibration in the Maximum Likelihood (ML) Heterobranchia phylogeny. The fossils were recorded in amber and the ages represent the minimum and maximum limits of paleontological dating.

Species	Minimum age (My)	Maximum age	References
Paleocarboninia jankeii	385.3	397.5	Bandel & Heidelberguer (2002)
Diacria sp.	20.4	-	Scarsella (1934)
Cuvierina sp.	7.2	-	Marshall (1918)
Berthelinia elegans	33.9	-	Tracey et al. (1993)
Mesauriculastra accelerata	152	-	Tracey *et al.*, (1993)
Bullidae	167	-	Tracey *et al.*, (1993)
Acteonidae	200	-	Bandel (1994); Bandel *et al.*, (2002)

Source: Prepared by the author (2023)

2.2.2 Reconstruction of ancestral character state

The ancestral size was inferred in order to obtain a complete macroevolutionary scenario for size traits in Heterobranchia. The ML tree was employed for reconstructing ancestral

character states using MBASR (HERITAGE, 2021), a package that employs an ML-based methodology. For each terminal, the size character states were categorized as either miniaturized (size < 5mm) or larger (size > 5mm). Size data were sourced from specialized literature, Malacolog 4.1.1 databases (www.malacolog.org/), and the Sea Slug Forum for opisthobranchs (www.seaslugforum.net). Supplementary material 1 contains detailed information on species, size, and references. Supplementary Table 1 and 2 contain detailed information on GenBank accession numbers, size data and references.

2.3 RESULTS

2.3.1 Phylogenetics Analyses and Divergence Times

The phylogenetic analysis using the maximum likelihood approach revealed a remarkable concordance with the phylogenies previously proposed. The inferred tree highlighted a similar topology recovery, especially concerning the superorders and orders of heterobranch gastropods.

In the context of the relationships between clades that recover orders and superorders, some aspects deserve attention. Lower Heterobranchia and Mesoneura persist as the earliest clades to diverge in the tree, grouping with robust 100% support. The subclass Euthyneura was recovered by maximum likelihood with 99% support. However, some divergences emerged in the relationships between superorders and orders. The relationship between Cephalaspidea and Aplysiida, as well as between Umbraculida, was recovered with 100% bootstrap? support. Additionally, for the first time to our knowledge, Gymsommata and Rissoeloidea were recovered with 81% support, forming a clade that grouped with Thecosomata, the latter with 99% support. Ringiculidae was recovered with 95% support; however, its relationship with Pleurobranchida and *Cima* generated only 51% support in the inferred tree. Finally, Nudibranchia was identified as the sister group of Actenoidea, with 62% support, adding intriguing nuances to the understanding of phylogenetic relationships within this complex system of heterobranch gastropods.

Figure 1. Dated Maximum Likelihood Phylogeny for the subclass Heterobranchia. Black branches represent non-miniaturized species, and red branches represent miniaturized species. The geological bar indicates the eras, periods, and millions of years (My).



Source: Prepared by the author (2023)

The temporal analysis of divergence events provides a new perspective on the evolution of Heterobranchia. The results indicate that the radiation of this group occurred approximately 393 million years ago, during the Devonian period. This evolutionary milestone harks back to environmental conditions that likely shaped the evolutionary trajectory of Heterobranchia. In contrast, the infraclasse Euthyneura emerged more recently, around 236 million years ago, during the Triassic period. The history of miniaturization in marine mollusks is fascinating and spans various geological periods. Initially, around 314 million years ago, during the Carboniferous period, the taxa Valvatidae and Mesoneura underwent miniaturization. In the Jurassic, the gastropods Ringiculidae witnessed a radiation of miniaturized species, including the genera *Microglyphis* and *Ringiculoides*. During the same period, miniaturized species of Acoclidiimorpha and Pyramidellidae emerged. Transitions to reduced size persisted over time, involving the Rissoeloidea in the Cretaceous and miniaturized species in Sacoglossa, specifically in Juliidae, where the genera *Julia* and *Ascobulla* diverged, along with the genera *Costasiella* and *Limapontia*. Within the order Cephalaspidea, a series of transitions to miniaturized size were observed, spanning different periods. In the Jurassic, the genera *Acteocina* and *Retusa* exhibited this characteristic, while in the Cretaceous, it occurred in *Velicolla*, *Weinkaufla*, *Colpodapsis*, *Colobocephallus*, *Hamineobulla*. In the Paleogene, the genera *Bakawan*, *Phanerophthalmus*, and *Siphopteron* followed the trend. The radiation dates of these clades, detailed in Table 2, offer a chronological insight into understanding the evolution of these organisms and their adaptation throughout geological eras.

Table 2. Posterior mean for divergence time in different clades of Heterobranchia.

Clades	Posterior average (My)
Acoclidiimorpha	166
Actenoidea	201
Aplysiida	137
Cephalaspidea	193
Gymnosomata	93
Hygrophila	140
Lower Heterobranchia	372
Mesoneura	314
Nudibranchia	204
Pleurobranchida	199

Pyramidellidae	164
Raiz	393
Ringiculidae	192
Rissoeloidea	117
Runcinida	191
Sacoglossa	185
Siphonariida	172
Styllomatophora	144
Systellomatophora	153
Thecosomata	109
Umbraculida	193
Valvatidae	207

Source: Prepared by the author (2023)

2.3.2 Reconstruction analysis of the ancestral state

The ancestral state reconstruction analysis revealed that the last common ancestor of these organisms, dating back to the Devonian period, exhibited a miniaturized state, suggesting that this characteristic was a fundamental part of their biology in this early stage. A significant change occurred at the ancestral node of Euthyneura during the Triassic period, approximately 236 million years ago, marking the transition from miniaturized to non-miniaturized size. This event may have played a crucial role in the adaptation and exploration of new ecological niches by Heterobranchia.

A reversion to miniaturized size was observed in Panpulmonata during the Jurassic period, around 198 million years ago. It is interesting to note that there were multiple reversions to miniaturized size in various orders, such as Acoclidiimorpha, Actenoidea, Cephalaspidea, Eupulmonata, Hygrophila, Nudibranchia, Pyramidellidae, Ringiculidae, Rissoeloidea, Runcinida, Sacoglossa, and Umbraculida, occurring after the size increase in the ancestral Euthyneura. These transitions suggest considerable evolutionary complexity, with repeated changes in body size strategy. The table 3 details the specific transitions from miniaturized to non-miniaturized and vice versa along the phylogenetic tree. Surprisingly, transitions from miniaturized to non-miniaturized are more prevalent in higher taxa, at the level of orders and families. This observation underscores the importance of these size changes on broader evolutionary scales and in higher taxonomic groups. In Panpulmonata, there was a radiation of

miniaturized lineages such as Rissoeloidea, Thecosomata, Pylopulmonata, following the radiation of non-miniaturized groups like Sacoglossa and Siphonariida.

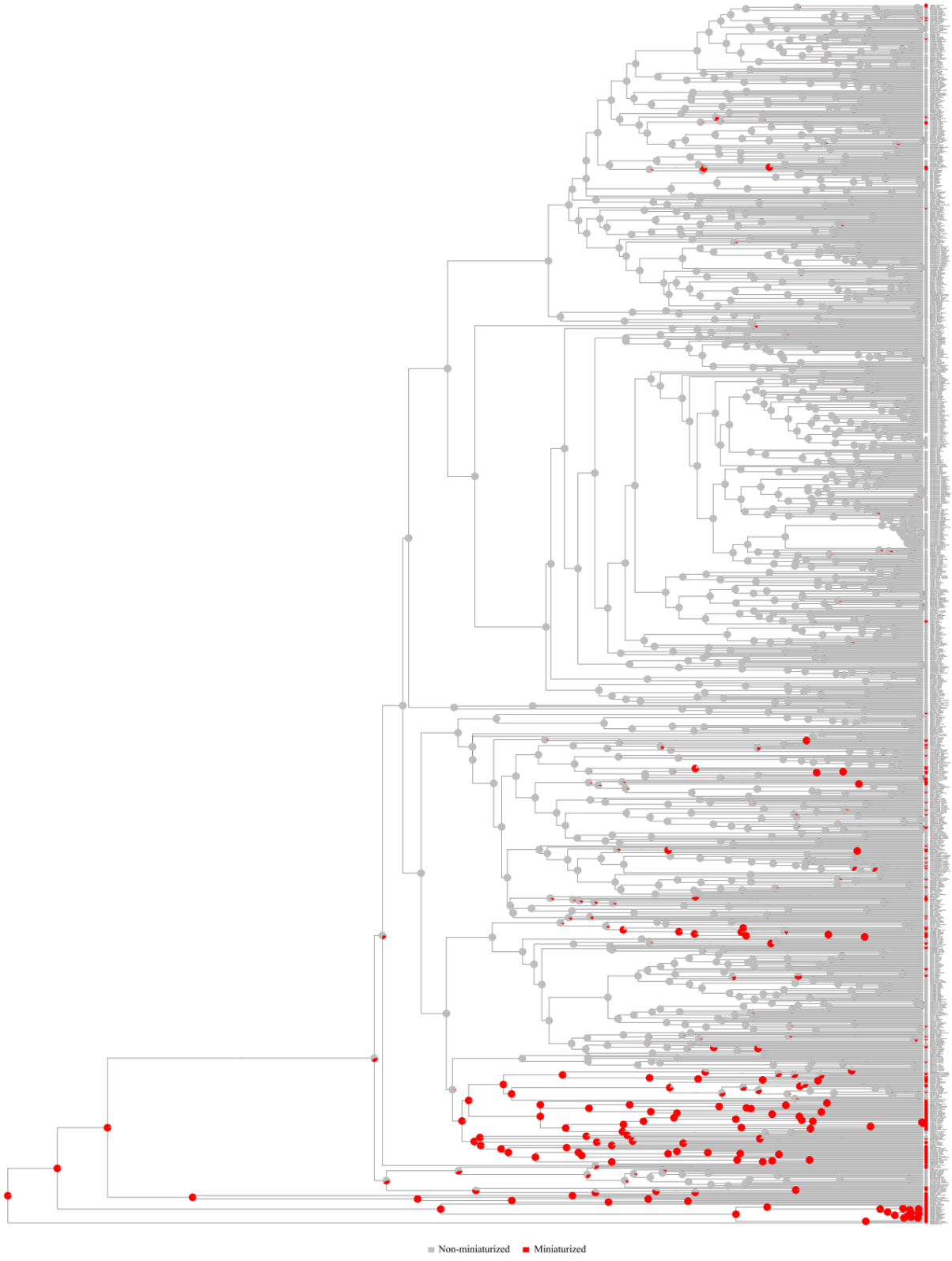
Table 3. Average time and 95% credibility interval (CI) estimated for the different evolutionary routes characterized for orders for Heterobranchia.

Body Size Transition	Clade	Period	Posterior average (Mya)
Miniaturized – Non-miniaturized	Euthyneura	Triassic	236
Non-miniaturized - Miniaturized	Ringiculidae	Jurassic	192
Non-miniaturized - Miniaturized	Ringiculidae	Cretaceous	114
Non-miniaturized - Miniaturized	Pleurobranchida	Cretaceous	144
Non-miniaturized - Miniaturized	Nudibranchia	Cretaceous	94
Non-miniaturized - Miniaturized	Nudibranchia	Cretaceous	89
Non-miniaturized - Miniaturized	Nudibranchia	Palaeogene	41
Non-miniaturized - Miniaturized	Nudibranchia	Cretaceous	95
Non-miniaturized - Miniaturized	Cephalaspidea	Jurassic	160
Non-miniaturized - Miniaturized	Cephalaspidea	Jurassic	152
Non-miniaturized - Miniaturized	Cephalaspidea	Palaeogene	63
Non-miniaturized - Miniaturized	Cephalaspidea	Palaeogene	30
Non-miniaturized - Miniaturized	Cephalaspidea	Neogene	21
Non-miniaturized - Miniaturized	Cephalaspidea	Cretaceous	83
Non-miniaturized - Miniaturized	Cephalaspidea	Cretaceous	109
Non-miniaturized - Miniaturized	Cephalaspidea	Cretaceous	97
Non-miniaturized - Miniaturized	Cephalaspidea	Palaeogene	45
Non-miniaturized - Miniaturized	Cephalaspidea	Cretaceous	131
Non-miniaturized - Miniaturized	Sacoglossa	Cretaceous	129
Miniaturized - Non miniaturized	Sacoglossa	Cretaceous	78
Non-miniaturized - Miniaturized	Sacoglossa	Cretaceous	90
Non-miniaturized - Miniaturized	Sacoglossa	Palaeogene	58
Non-miniaturized - Miniaturized	Sacoglossa	Neogene	3
Non-miniaturized - Miniaturized	Pulmonata	Jurassic	198
Miniaturized - Non miniaturized	Gymsomata	Cretaceous	93

Source: Prepared by the author (2023)

Figure 2. Reconstruction of ancestral body size for the subclass Heterobranchia, with transitions in size changes. The pie charts at the nodes display the probability of occurrence of miniaturized and

non-miniaturized ancestral states. The red color corresponds to the current miniaturized state, and the gray color represents the current non-miniaturized state.



Source: Prepared by the author (2023)

2.4 DISCUSSION

This work represents the first comprehensive effort to conduct a phylogeny of Heterobranchia, identifying the position of miniaturized species and reconstructing the ancestral state of size in heterobranch gastropods using molecular tools. Additionally, our study represents the first attempt, to the best of our knowledge, to infer a dated phylogeny of Heterobranchia, covering a sample size of over 1000 species.

The phylogenetic analysis using the maximum likelihood approach revealed a remarkable concordance with the phylogenies previously proposed by Dinapoli e Klussmann-Kolb (2010), Jorger et al. (2011), Medina et al. (2011), Brezinger et al. (2021), and Varney et al. (2021). The inferred tree highlighted a similar topology recovery, especially concerning the superorders and orders of heterobranch gastropods (BOUCHET *et al.,* 2017).

The maximum likelihood inference robustly recovered the 17 suborders and orders of the Heterobranchia subclass, with high support (>90%), as seen in previous studies and the radiation of Euthyneura was also strongly supported (BRENZINGER; SCHRÖDL; KANO, 2021; DINAPOLI; KLUSSMANN-KOLB, 2010; JÖRGER *et al.,* 2010; KANO *et al.,* 2016; VARNEY *et al.,* 2021).

However, some divergences were found in the relationships between orders and suborders. Analyzing the Euopistobranchia clade, we observed the recovery of Cephalaspidea as the sister group of Aplysiida and Umbraculida, consistent with previous studies (KANO *et al.,* 2016; MEDINA *et al.,* 2011; VARNEY *et al.,* 2021). However, there is variation in their position in studies that include the Pteropoda, a group often underrepresented in phylogenies, emphasizing the need for additional investigations to better understand the relationships between clades (MEDINA *et al.,* 2011). In our phylogeny, Pteropoda is polyphyletic, with Gymnosomata grouping with Rissoeloidea with 81% support, while Thecosomata grouped with an acoclid, Hedylopsis spiculifera, with only 65% support. This observation highlights the need for further investigations using concatenated marker phylogenies and a broader sample range (BURRIDGE *et al.*, 2017).

The consistent recovery of Panpulmonata in all recent phylogenies was also confirmed in our maximum likelihood analysis, as well as the position of Sacoglossa diverging before Siphonariida, aligning with previous studies (BRENZINGER; SCHRÖDL; KANO, 2021; DINAPOLI; KLUSSMANN-KOLB, 2010; KANO *et al.*, 2016; MEDINA *et al.*, 2011; VARNEY *et al.,* 2021). However, our analysis revealed a differentiation in Gymsomata and

Thecosomata, both Pteropods, which did not form a single monophyletic clade, contrary to the group's phylogeny (BURRIDGE *et al.*, 2017).

We obtained low resolution in the grouping of Nudibranchia, Pleurobranchida, and Ringiculidae. In our phylogeny, Nudibranchia grouped as the sister group of Actenoidea (65%), while Pleurobranchida grouped with Ringiculidae (51%), contradicting previous studies (KANO *et al.*, 2016). The relationship between these groups remains a subject of discussion, demanding further investigations.

It is crucial to highlight that discrepancies between our phylogenetic trees and previous ones in Heterobranchia can be attributed to the use of mitochondrial markers, the most abundant in our database, and the representativity of the studied groups. While we predominantly used mitochondrial markers, other Heterobranchia phylogeny studies employ a variety of concatenated molecular markers (18S, 28S, 16S, and COI), transcriptome, or genome, contributing to differences in tree topology (BRENZINGER; SCHRÖDL; KANO, 2021; DINAPOLI; KLUSSMANN-KOLB, 2010; KANO *et al.*, 2016; MEDINA *et al.*, 2011; VARNEY *et al.*, 2021). Here, we focused on obtaining a high taxonomic representativeness to compose the diversification scenario of miniaturization in Heterobranchia. Therefore, we should take, this variety of approaches highlights the complexity and importance of considering multiple aspects in phylogenetic investigations.

Addressing the temporal aspect of our research, it is important to note that we employed a broader set of fossils to date our phylogenetic tree. Our goal was to encompass a wider range of Heterobranchia lineages, both miniaturized and non-miniaturized. The resulting data align with the latest dating proposed by Brezinger et al. (2021) but differ from the results obtained by Medina et al. (2011), as in addition to a set of phylogenomic data, the authors employed a model of absolute rate dating, while here we used a relaxed clock dating model.

The ancestral state reconstruction analysis reveals that the oldest ancestor of Heterobranchia was a miniaturized organism that lived during the Middle Devonian. This organism gave rise to the radiation of mostly miniaturized taxa, including Lower Heterobranchia and Mesoneura. The radiation of Euthyneura, during the Triassic, marked the first significant size change. After this transition to non-miniaturized organisms, the reversion to miniaturization occurred multiple times independently along the phylogenetic tree.

Examples of miniaturization are abundant and span a wide taxonomic diversity, including both living and extinct invertebrates and vertebrates. The complexity in quantifying the frequency of miniaturization lies in the lack of a simple criterion for recognizing it in individual taxa, as pointed out by Hanken e Wake (1993). Defining an organism as miniaturized

is challenging, given that the boundaries between the reduction in body size to a critical size are not clear. This challenge becomes even more significant when analyzing groups like heterobranch gastropods, which, even in non-miniaturized sizes, exhibit a variety of strategies, body plans, and diets. The diversity of miniaturized organisms still lacks a complete description. In the context of the evolution of Heterobranchia, miniaturization preceded the development of large organisms, contradicting the proposition that before the miniaturization event, there is a gradual decrease (or a gradual increase) in size (HANKEN; WAKE, 1993).

The increase or decrease in size in heterobranch gastropods can be explained by abiotic and biotic factors. The abiotic conditions of the Paleozoic suggest that the ancestral miniaturized organism lived under constant extinction processes, possibly due to the rising sea levels and increased productivity causing anoxia in the seas. The adaptability of this organism, requiring less oxygen due to its size, likely herbivorous, led it to settle in shallow waters near the development of photosynthesizing algae (BARASH, 2006; GOEBBELER; KLUSSMANN-KOLB, 2011). These conditions suggest a dominance of benthic organisms tolerant to low oxygen concentrations in the water, contributing to lower gastropod diversity but with more abundant species in this period (BARASH, 2006).

The transition to a non-miniaturized Eutineuran organism occurred in the Triassic, marking a period of intense changes in the Mesozoic. Species experienced the so-called Mesozoic Marine Revolution, a process in which marine species in the Triassic underwent size increases and other ecological traits to resist predators that fed on shell-bearing organisms (VERMEIJ, 1977). The diversification of Euthyneura may have been driven by various factors, including the emergence of carnivore opisthobranchs (GOEBBELER; KOLB, 2011). Subsequently, various opisthobranch lineages at the family and genus levels radiated, returning to miniaturization during shorter anoxic periods in the Cenomanian, caused by intense volcanic activity due to tectonic plate movements (BARASH, 2008).

The reversion to miniaturized size occurred in Panpulmonata during the Jurassic, after an extinction event between the Triassic and Jurassic. In this period, there were several changes in the marine environment with high dynamics of CO2 and SO2, leading to a biotic crisis (BARASH, 2008). Miniaturization may represent an advantage in environments with lower oxygen concentrations, requiring less oxygen either through the loss of gills in some species or the adoption of an interstitial lifestyle. This complex interplay of geological and atmospheric events underscores the ongoing need for further in-depth investigations into the potential drivers of the diversification of miniaturized species.

2.5. FINAL CONSIDERATIONS

In conclusion, this study represents a significant advancement in understanding the phylogeny and evolution of Heterobranchia, specifically focusing on miniaturization. Through the application of molecular tools and a comprehensive dataset, we successfully identified the position of miniaturized species and reconstructed the ancestral state of size in heterobranch gastropods. Our analysis, covering over 1000 species, provided a dated phylogeny with robust support for the 17 suborders and orders of the Heterobranchia subclass, confirming the radiation of Euthyneura. Nevertheless, some divergences were observed in the relationships between orders and suborders, highlighting the complexity of heterobranch gastropod evolution. Notably, the polyphyletic nature of Pteropoda and challenges in resolving the relationships within Nudibranchia, Pleurobranchida, and Ringiculidae indicate the need for additional investigations and a broader sample range.

The discrepancies observed between our phylogenetic trees and previous studies can be attributed to the predominant use of mitochondrial markers and the representation of studied groups. The choice of molecular markers significantly influences tree topology, as highlighted by the differences with studies employing concatenated markers, transcriptome, or genome data. Recognizing these methodological variations underscores the complexity of phylogenetic investigations, emphasizing the importance of considering multiple aspects.

Addressing the temporal aspect of our research, the broader inclusion of fossils in dating our phylogenetic tree provided insights into the evolutionary timeline of Heterobranchia. The ancestral state reconstruction analysis revealed that the oldest ancestor of Heterobranchia was a miniaturized organism from the Middle Devonian, marking the beginning of a radiation of mostly miniaturized taxa. The subsequent transition to non-miniaturized organisms during the Triassic, followed by multiple independent reversions to miniaturization, illustrates the dynamic nature of size evolution in these organisms, related to events such as marine life extinction, low oxygen levels, and geological phenomena that occurred throughout their evolutionary history. Our study contributes valuable insights into the intricate evolutionary history of Heterobranchia, shedding light on the factors influencing size changes, adaptation strategies, and the complex interplay of geological and atmospheric events. This work sets the stage for future investigations, emphasizing the ongoing need for a multidisciplinary approach to unravel the mysteries of miniaturization in heterobranch gastropods.

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3. AN INTEGRATIVE REVIEW ON SPECIES CONCEPT AND OPERATIONAL CRITERIA FOR SPECIES DELIMITATION IN LOWER HETEROBRANCHIA AND MESONEURA MICROGASTROPODS

3.1 INTRODUCTION

The conceptual and methodological foundations that delineate the boundaries between species have been widely debated in the scientific community over the past decades (BUTLIN; STANKOWSKI, 2020; DE QUEIROZ, 2007; FREUDENSTEIN *et al.*, 2017; GALINDO-CRUZ; SAHAGÚN-SÁNCHEZ; ROJAS-SOTO, 2022). During this period, various species concepts have been proposed, and currently, there are approximately 24 cataloged species concepts (see ALDHEBIANI, 2018; DE QUEIROZ, 2007).

The description of biodiversity, undertaken by taxonomists, necessitates the adoption of a species concept. This concept is influenced not only by the researcher's perspective but also by the characteristics and limitations of the organism group under consideration (URRY *et al.*, 2016). Therefore, for example, in the case of asexual organisms, Mayr's biological species concept (1942) cannot be applied. Consequently, the investigation into the existence of reproductive barriers is not part of the set of relevant evidence for determining species boundaries. Similarly, other concepts have limitations in their use; the typological species concept, for instance, cannot be applied to organisms that cannot be preserved in biological collections. Meanwhile, the morphological concept (CRONQUIST, 1978) is challenging to adopt in the taxonomic practice of unicellular organisms with very similar cellular morphology among distinct lineages or variations in cellular morphology determined by the extracellular environment and life cycle phase (ALDHEBIANI, 2018). The molecular and phylogenetic species concept cannot be adopted in organisms where there have been no collection efforts to obtain available genetic material.

The definition of species is crucial for the study of biodiversity (DE QUEIROZ, 1998, 2005; MAYDEN, 1997) because any change in the concept of species directly impacts other research fields, including taxonomy, ecology, biogeography, conservation, and evolution (FIŠER; ROBINSON; MALARD, 2018). There is a distinction between species concepts and operational criteria for their delimitation, but this distinction is not always consistently applied. The species concept is the idea that assigns the term "species" to an entity, while operational criteria represent the attributes necessary to classify an entity as a species (DE QUEIROZ, 1998, 2005, 2007). Operational criteria vary depending on the type of organism and the species

concept employed (DE QUEIROZ, 1998). These criteria, chosen by taxonomists may be connected to one or more species concepts (ALDHEBIANI, 2018; DE QUEIROZ, 1998, 2005, 2007), though they may not always provide all the information to fully support the species concepts in all their aspects (FREUDENSTEIN *et al.*, 2017). In taxonomic practice, the application of operational criteria to delimit species, in most cases, seems not to be directly linked to the goal of testing hypotheses about different species concepts or corroborating a specific concept (DE QUEIROZ, 2007). Nonetheless, species concepts underlie the operational criteria used to delimit species (DE QUEIROZ, 1998; FREUDENSTEIN *et al.*, 2017).

The choice of operational criteria and, consequently, the underlying species concept, seems to be primarily determined by practical reasons. These include intrinsic characteristics of the organisms studied, which may limit viable approaches to species delimitation, the availability of samples suitable for analysis through different methodologies, the taxonomist's free choice and affinity for a particular approach, and the availability of resources required for analyses that involve higher financial demands (DE QUEIROZ, 2005, 2007; FREUDENSTEIN *et al.*, 2017). Such practical motivations play a crucial role in defining species concepts and operational criteria, influencing progress in the study of a taxonomic group in various aspects, including morphology, anatomy, biology, phylogeny, and evolution (MAYDEN, 1997). Scientific tradition also influences the choice of operational criteria for species delimitation, depending on the criteria historically valued and frequently adopted in the taxonomy of a specific group (DE QUEIROZ, 2005, 2007; MAYDEN, 1997).

Often, we observe disparities among the methodologies used in the taxonomic practice of taxa belonging to the same taxonomic group. Such disparities occur especially when certain groups exhibit peculiarities that justify the pursuit of greater efficiency in the species delimitation process, including highly distinct morphological characters, miniaturized bodies, economic or medical importance, or conservation concern (BRENZINGER; WILSON; SCHRÖDL, 2011; JÖRGER *et al.*, 2010; JÖRGER; SCHRÖDL, 2013). This demand drives the employment of new operational criteria, based on alternative species concepts, and sets of operational criteria linked to different species concepts. It also stimulates improvements in methodologies associated with traditionally employed concepts, such as the use of modern microscopy techniques, gametic ultrastructure, computed tomography, 3D histological reconstruction, and computational species delimitation (BRENZINGER; HASZPRUNAR; SCHRÖDL, 2013; HEALY, 1993; SANTO *et al.*, 2022). However, as emphasized, (PONDER; LINDBERG; PONDER, 2020), it is possible that species of economic, medical, and cultural interest remain extensively sampled, to the detriment of other taxa. This may be due to a lack

of specialists in other groups or insufficient investment in exploring knowledge about new species. The alternative to address this issue lies in better curation and selection of species, aiming to enhance initiatives for investing in biodiversity knowledge (PONDER; LINDBERG; PONDER, 2020).

The integration of different sources of data can provide a more comprehensive and accurate understanding of the systematics and evolution of organisms, contributing to biodiversity conservation, enhances our understanding of evolutionary processes, and aids in the identification of new species (DAYRAT, 2005; FUJITA *et al.*, 2012; PADIAL *et al.*, 2010).

Organisms with distinct body plans within the same taxon pose challenges in selecting operational criteria and, consequently, species concepts. Among these characteristics, organisms with simplified body structures and diminutive sizes, often referred to as miniaturized (<5mm), stand out (GEIGER *et al.*, 2007; HANKEN; WAKE, 1993; RUNDELL; LEANDER, 2010). They have a lower number of morphological characteristics available as operational criteria for species delimitation. Moreover, miniaturized organisms pose methodological challenges for their morphological and anatomical study, requiring the use of new technologies. These technologies may be more costly, require more time for specimen and sample preparation, or may not be globally available. This can lead to stagnation in the evolution of operational criteria/species concepts adopted for certain taxonomic groups (BOUCHET *et al.*, 2005; GEIGER *et al.*, 2007). As a result of this stagnation, there are groups that represent black boxes and are potentially hubs of substantial, yet unexplored biodiversity (ALBANO; SABELLI; BOUCHET, 2011).

Traditionally, the taxonomy of molluscs has been based on shell traits, such as coloration, ornamentation, patterns in the shell aperture, and sculpture of the apex. The resolution and understanding of mollusk systematics increased as more modern techniques emerged, allowing for the visualization of previously hidden characters. This was particularly crucial for taxa where reliance solely on the shell was insufficient for understanding taxonomic classification, such as Aplacophora (FALLER *et al.*, 2012), acoclidia (JÖRGER; SCHRÖDL, 2013) and rodopidea (BRENZINGER; SCHRÖDL; KANO, 2021).

A subclass of gastropods, Heterobranchia, comprises the greatest diversity of body plans among these organisms. It includes species with shells, varying in their presence, reduction, and absence. Additionally, this subclass exhibits vermiform shapes and encompasses a wide range of lifestyles, from free-living to small interstitial organisms. Within this group, the lineage of gastropods Lower Heterobranchia and Mesoneura is particularly noteworthy for featuring distinct representatives in terms of body plan, and habitat.

Given that a significant portion of Lower Heterobranchia and Mesoneura species are miniaturized, it is expected that this characteristic will impact the availability of morphological criteria for species identification and delimitation. In this context, the utilization of more modern species delimitation techniques represents a crucial alternative to unveil the diversity and evolutionary history of this group. Recently, (BRENZINGER; SCHRÖDL; KANO, 2021) assessed the morphological adaptations of these organisms in association with phylogenetic reconstructions. The use of such tools has facilitated a deeper understanding of the evolution of Lower Heterobranchia families and led to the creation of a new taxon called Mesoneura.

The study of micromolluscs is challenging, as it requires greater attention in collection and processing due to the fragility of their size. Moreover, there is often a lack of conchological characters, especially in marine species with smooth shells (BOUCHET *et al.*, 2002; GEIGER *et al.*, 2007). Advancements in the study of micromolluscs experienced an exponential increase in the 1990's. The understanding of these species has been deemed essential for the progress of malacology in the 21st century, given their significant but largely unexplored diversity (ALBANO; SABELLI; BOUCHET, 2011; BOUCHET *et al.*, 2002).

Published phylogenies of Heterobranchia have a low representation of the Lower Heterobranchia and Mesoneura clades, thereby increasing the challenge for a comprehensive understanding of the internal relationships within the group. This also extends to the relationship between this clade and other lineages within Heterobranchia (BRENZINGER; SCHRÖDL; KANO, 2021; DINAPOLI; KLUSSMANN-KOLB, 2010; KOCOT *et al.*, 2011). Several factors contribute to the low molecular representation of this group. Among them is the species concept employed and, consequently, the methodological approaches and operational criteria for characterizing and delimiting species. These factors likely influence the availability of molecular sequences for basal heterobranchs.

Examining the concepts of species and operational criteria used for species delimitation in a particular taxon can provide a diagnosis of the state of knowledge about that group. It helps identify knowledge gaps essential for other areas of science (evolution, phylogeny, ecology, conservation) that use species as the unit of analysis or depend on species information obtained through taxonomic practice (FIŠER; ROBINSON; MALARD, 2018; ROSSELLÓ-MORA; AMANN, 2001). Integration with the analysis of the availability of molecular sequences in genetic databases, as well as the availability of unsequenced specimens with wet tissues deposited in biological collections, can help paint a picture of the state of knowledge about basal heterobranchs. Consequently, this can aid in coordinating actions for new collections and expanding studies on this group.

Herein, we aimed at providing a comprehensive overview of the current state of species delimitation in Heterobranchia and Mesoneura microgastropods. We analyze the species concept, operational criteria employed, and the availability of molecular data and ethanol preserved specimens across various databases. We hope this review serves as a starting point for taxonomists to explore new operational criteria and enhance the resolution of internal relationships within heterobranch gastropods.

3.2. MATERIALS AND METHODS

3.2.1. Data Collection

The preliminary search for miniaturized species that compose the clades "Lower Heterobranchia" and "Mesoneura" was performed in the bibliographic databases *Science Direct, Scopus, and Web of Science*. We selected original and review scientific articles about taxonomy (description and species delimitation) in English, Spanish, German, and French which provided information allowing identification of species as microgastropods, as well as their habitat (marine, freshwater), species concept employed (conchological, anatomical or molecular), techniques used for species description at the time of description or later, and collections where they are deposited. The search code employed was: (gastropod AND (minute OR micro OR small) AND (“lower heterobranchia” OR ectobranchia OR valvatoidea OR omalogyroidea OR architectonicoidea)). The list of species was complemented by searching the Mollusca Base (https://www.molluscabase.org/) for their taxonomic status and checking species original description to confirm the miniaturized condition using a criterion of body size smaller than 5 mm (GEIGER *et al.*, 2007).

To verify if there was molecular information available for the species analyzed a search was performed with the term "Lower Heterobranchia" in the molecular database GenBank in December 2022. Nucleotide data relative to lower heterobranchs were downloaded in the complete GenBank format, and available molecular markers were parsed using Pearl scripts to extract information related to molecular markers and species representativeness. Then, species that were listed as basal heterobranchs but currently belong to other clades according to were removed from the analysis (BOUCHET *et al.*, 2017). Information regarding the availability of specimens in museums was obtained through a literature review and the Global Biodiversity Information Facility - GBIF (*https://gbif.org*). Records from museums were considered if they had species-level identification and information about the collection locality.

3.2.2. Graphical analyses

The data was organized into sheets and analyzed in the R environment v. 4.2.0 (TEAM, 2022). In order to obtain a better visualization and mapping of the collected information from all databases, the graphics were generated with the aid of the ggplot2 (WICKHAM; CHANG; WICKHAM, 2016), viridis (GARNIER *et al.,* 2018), and ggrepel (SLOWIKOWSKI *et al.,* 2018) packages.

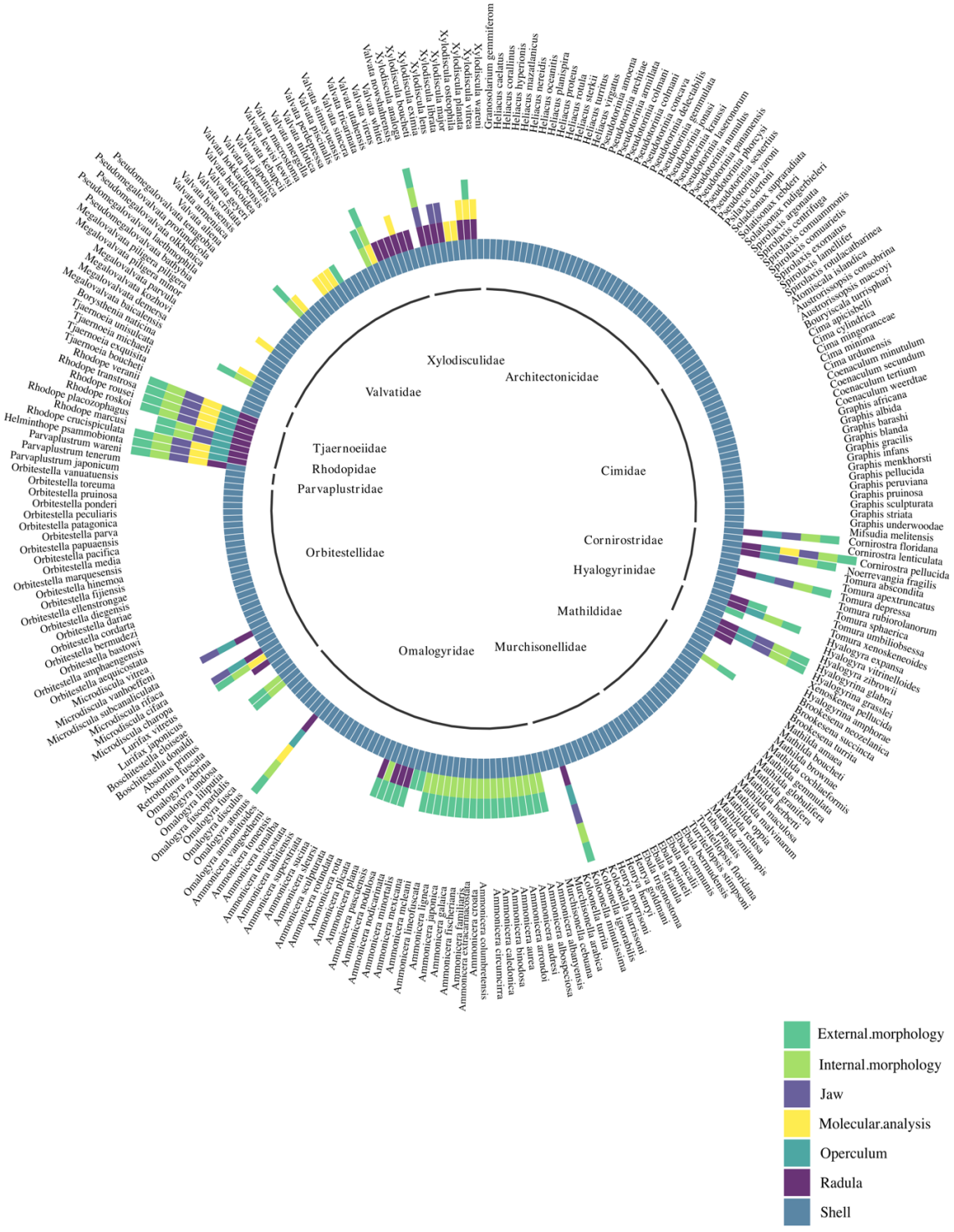
3.3 RESULTS

3.3.1 Species concept, operational criteria and tecniques

A total of 127 articles published between 1798 and 2022 were reviewed, addressing the concepts of species, operational criteria, and analytical methods to describe 258 species of Lower Heterobranchia and Mesoneura, distributed across 13 families. Only morphological (254 species; 98.06% of the species analyzed) and phylogenetic species concept (5; 1.94%) were adopted. The list of analyzed species and size information can be viewed in the supplementary material.

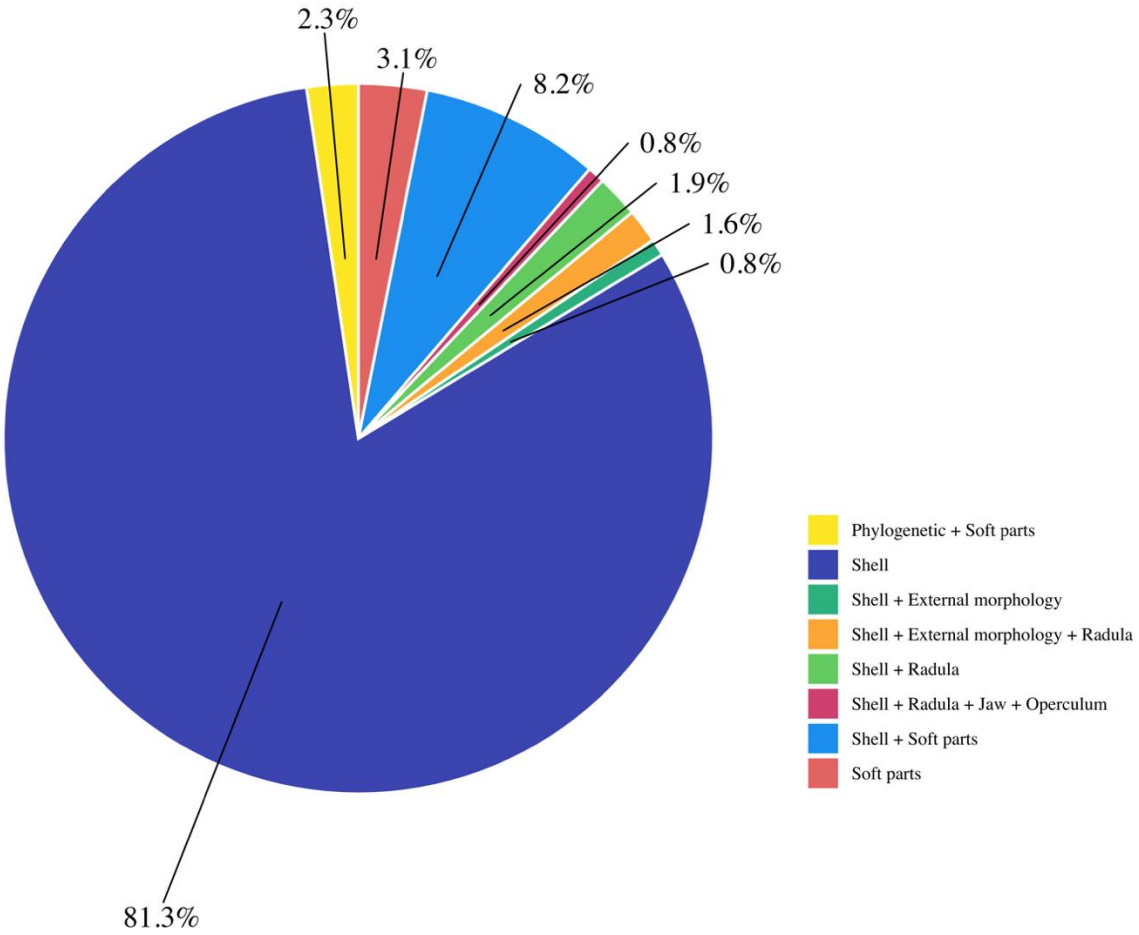
Shell morphology was used as operational criteria to delimit 211 species (84.55% of the species analyzed). Anatomy of the soft parts was employed to delimit 20 species (7.72%). External morphology was employed to delimit 2 species (0.77%). The operational criteria used for delimitation by species were organized as shown in figure 1.We also found combinations of operational criteria: (1) shell morphology + anatomy of the soft parts + external morphology (2 species; 0.77% of the species analyzed); (2) shell morphology + radula (9 species; 3.47%); (3) external morphology + radula (3 species; 1.15%); (4) shell morphology + radula + external morphology (1 specie; 0.38%); (5) shell morphology + anatomy of the soft parts + radula + operculum (1 species; 0.38%); (6) shell morphology + radula + operculum + jaw (2 species; 0.77%); (7) shell morphology + radula + external morphology + operculum + jaw (1 specie; 0.38%); and (8) shell morphology + anatomy of the soft parts (2; 0.77%). Monophyly was the sole operational criteria associated to the PSC (5 species; 1.93%) (Figure 2).

Figure 1 – Operational criteria used to delimit each of the 258 species evaluated



Source: Prepared by the author (2023)

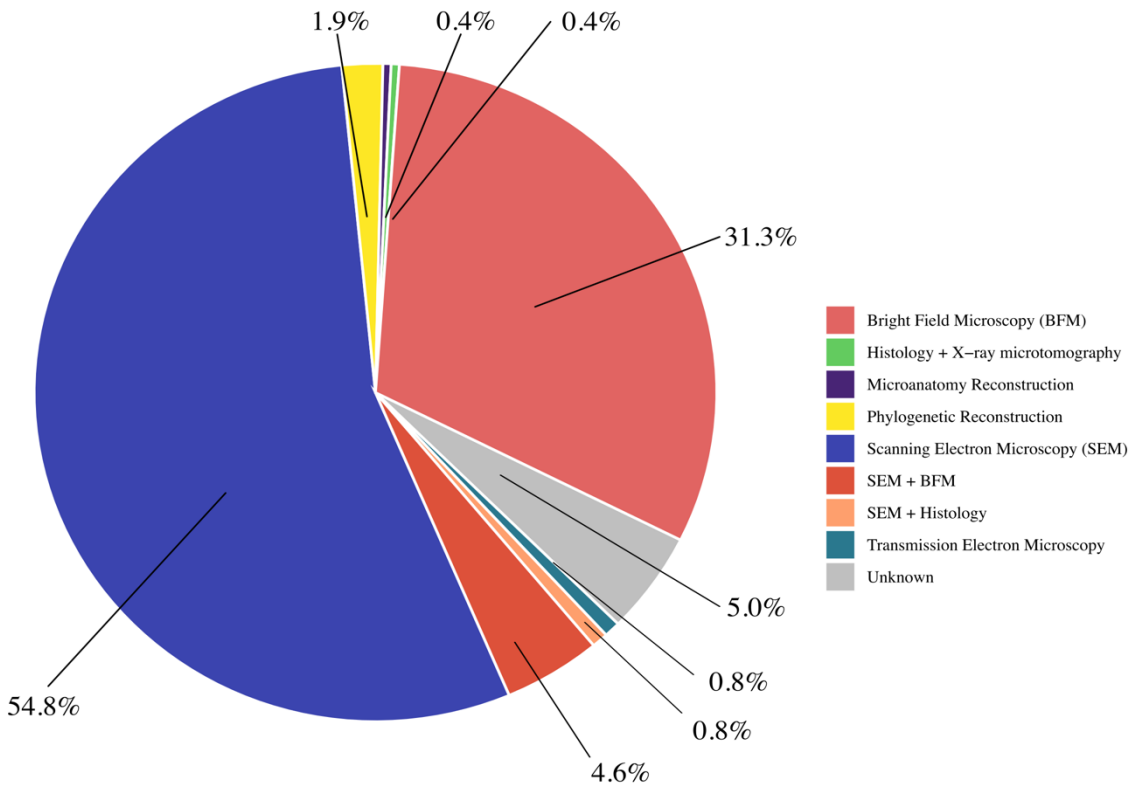
Figure 2 – Percentage of operational criteria, and their combination in the delimitation of the microgastropod species Lower Heterobranchia and Mesoneura



Source: Prepared by the author (2023)

The methodological approaches used to characterize these species were Scanning Electron Microscopy – SEM (142 species); Bright Field Microscopy – BFM (81); SEM + BFM (12); Phylogenetic Reconstruction (5); SEM + Histology (2); Transmission Electron Microscopy (2); 3D Microanatomy Reconstruction (1); Histology + Micro Computed Tomography (1). Information was missing for 13 species (Figure 3).

Figure 3 – Techniques, and their combination in delimiting the species of Lower Heterobranchia and Mesoneura.



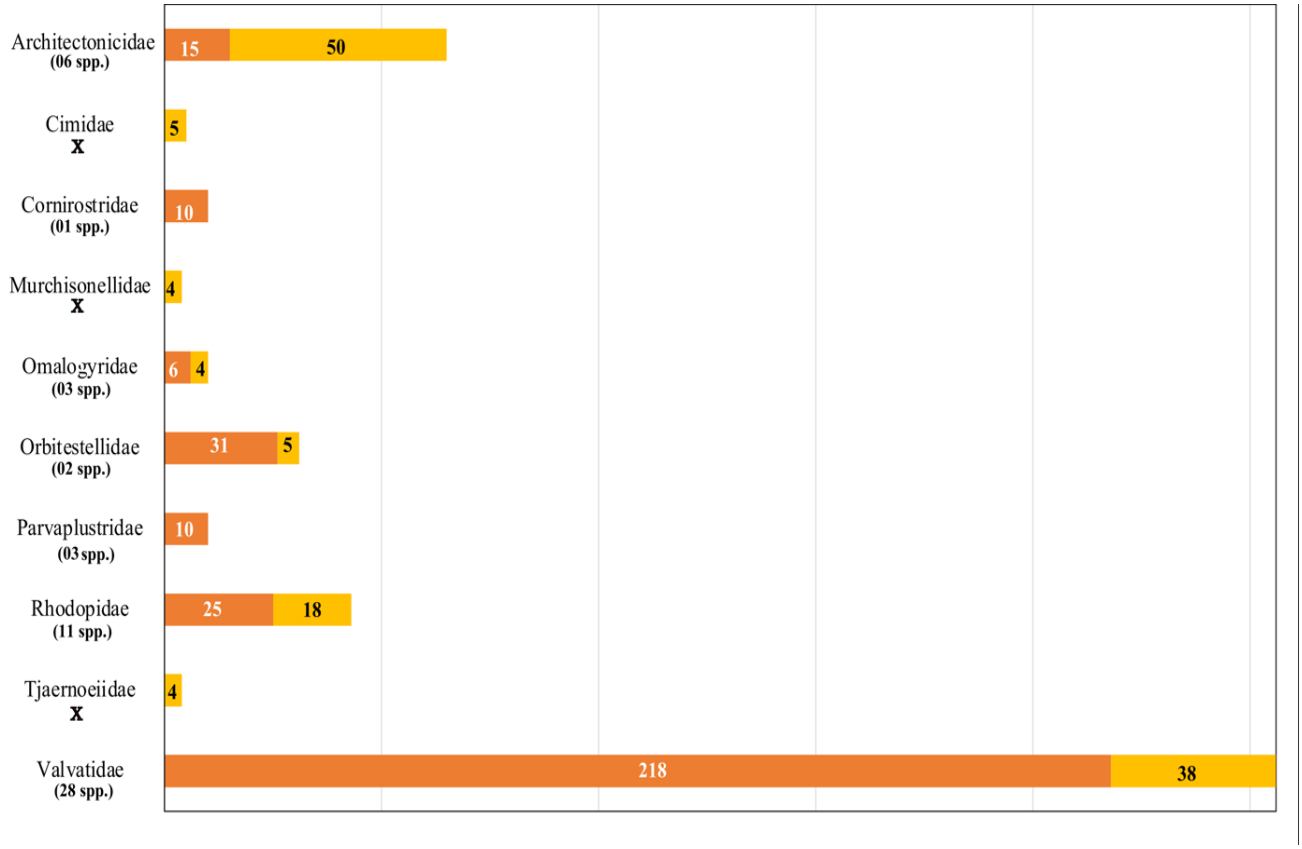
Source: Prepared by the author (2023)

3.3.2 Molecular data on GenBank

The search for nucleotide sequences in the GenBank database yielded 808 records, with 441 of these belonging to Lower Heterobranchia. Species that, according to current taxonomy, are classified under Euthyneura, Acteniomorpha, and Ringiculimorpha were excluded. (Bouchet, 2018).

Among the 13 families that constituted the diversity of microgastropods evaluated, only 6 families have species-level representatives: Architectonicidae, Cornirostridae, Omalogyridae, Orbitestellidae, Rhodopidae, and Valvatidae. This accounts for 73.02% (n= 322) of the total sequences, while 26.98% (n= 119) represented unidentified species-level sequences. The Valvatidae family corresponded to 48.07% (n= 212) of the identified species-level sequences (Figure 4).

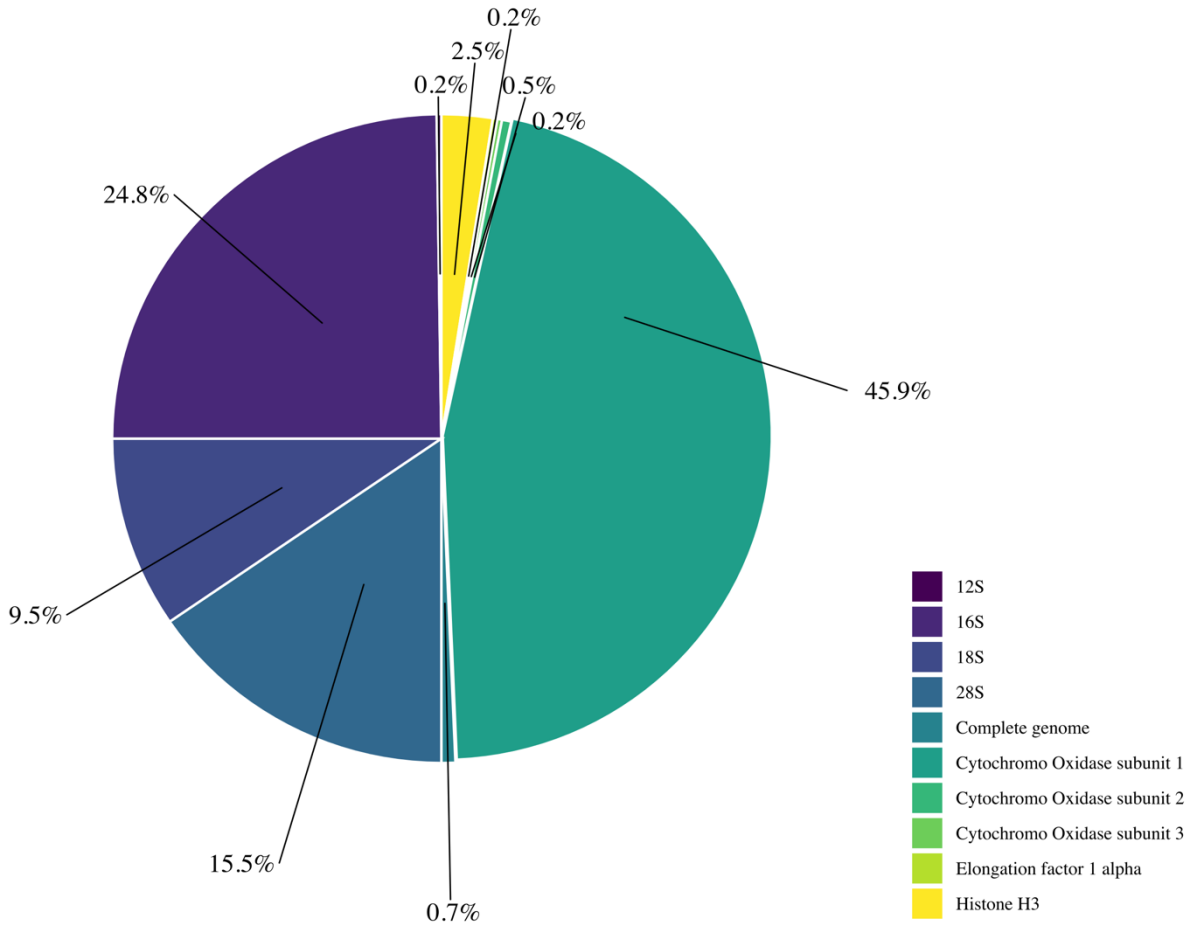
Figure 4 - Number of identified (orange) and unidentified (yellow) molecular sequences from the microgastropod families Lower Heterobranchia and Mesoneura is depicted. The number of identified species is in parentheses, with the X representing the absence of individuals identified at the species level.



Source: Prepared by the author (2023)

The molecular marker cytochrome oxidase 1 is the most abundant, accounting for 45.91% of the available sequences, followed by the genes: 16S (24.77%); 28S (15.45%); and 18S (9.55%). Data from histone H3 (2.5%), genomic data (0.68%), and other molecular markers such as cytochrome oxidase 2 (0.45%), and 12S (0.23%), cytochrome oxidase 3 (0.23%), elongation factor 1 alpha (0.23%) are available to a lesser extent (Figure 5).

Figure 5 – Percentage representation of molecular markers for the microgastropods LH and Mesoneura.



Source: Prepared by the author (2023)

3.3.3 Specimens deposited in Museums

A total of 3,749 records of the species listed in this study were retrieved, with GBIF (3268) being the primary contributor to the records, and literature providing a smaller quantity (481). These records are predominantly concentrated in dry deposits, with only 55 records in wet deposits. Regarding the databases, 26 wet deposits are from GBIF, and 29 are from the literature. As for specimens deposited in dry deposits, there are 3,241 (GBIF) and 452 (literature). The data also includes information on the representativity of records by family, as well as the specimens in wet deposits (Supplementary table).

3.4 DISCUSSION

3.4.1 The species concept is associated with the operational criteria used

Species delimitation in current taxonomy is a crucial topic, and relying solely on morphological or molecular criteria raises methodological concerns. We found only two articles employing computational methods or tridimensional reconstruction for this delimitation (BRENZINGER; WILSON; SCHRÖDL, 2011; SAITO *et al.*, 2018). Description based solely on shell characters may be insufficient, as our results indicate, emphasizing the need for revisions to incorporate anatomical features, genetic materials, and ecological information. The lack of rigorous reviews for specific groups makes the delimitation process even more challenging (FIŠER; ROBINSON; MALARD, 2018)

Malacology has benefited from modern tools in taxonomic studies, especially in understanding the evolutionary relationships of molluscs such as interstitial slugs, acoclydes, and rodepomorphs, and in discovering cryptic species of gastropods (JÖRGER *et al.*, 2010; JÖRGER; SCHRÖDL, 2013; SCHÄCHINGER *et al.*, 2022; WILSON *et al.*, 2017).However, the inability to quantify biodiversity hinders comprehensive group detection, especially considering the presence of cryptic species (SHIN; ALLMON, 2023).

The integration of genetic, morphological, geographical, paleontological, and ecological data as support for defining the species concept is seen as a solution in integrative taxonomy (DAYRAT, 2005; PADIAL *et al.*, 2010). However, this approach requires a significant amount of data, collection effort, and specialization by taxonomists. We observe that this integration does not always occur, and the definition of the term "species" is not always explicit in texts, as mentioned in other works (SHIN; ALLMON, 2023).

Species descriptions in Lower Heterobranchia often rely exclusively on shell characters, particularly in micro-gastropods like *Pseudotorinia*, *Heliacus*, *Granosolarium*, *Solatinosonax*, *Spirolaxis*, where taxonomy is predominantly based on shell or anatomical characters (BIELER, 1988; HASZPRUNAR, 1985), often utilizing scanning microscopy (BIELER *et al.*, 1998; CAVALLARI; SALVADOR; SIMONE, 2014; KONTADAKIS *et al.*, 2021). The same pattern is observed in Cimidae, a family described by (WARÉN, 2013) based on shell descriptions and the anatomy of *Cima inconspicua* and *Cima cuticulata*. However, other species in the group were primarily described based on the shell, using schematic representations with bright-field microscopy and scanning microscopy. Some species, like *Graphis albida*, described in 1798, have not been revisited since and lack additional studies (KANMACHER, 1798). These issues are concerning, as the significant temporal gap between collection and revisitation of a species described over 200 years ago may result in taxonomic gaps for lineages that may no longer exist amidst anthropogenic effects and climate changes.

Currently, the situation of species description based on shell characters is not much different, especially for many micro-gastropod species in Lower Heterobranchia. These species are often described solely based on unique shell characteristics using scanning microscopy, as seen in Cornirostridae and *Tomura* (ROLÁN; ROLÁN; RUBIO SALAZAR, 2008; ROMANI; SBRANA, 2016) and twelve species of Orbitestellidae (KETWETSURIYA; DUMRONGROJWATTANA, 2021; ORTEGA; GOFAS, 2019). So far, details of the internal anatomy of these species are sparsely represented in the literature, except for species like *Cornirostra pellucida*, *C. floridana*, and *Noerrevangia fragilis* (BIELER *et al.*, 1998; PONDER, 1990; WAREN; GOFAS; SCHANDER, 1993).

Other techniques, albeit on a smaller scale, have been employed in the classification of heterobranch gastropods, both non-miniaturized and miniaturized. For instance, the ultrastructure of gametogenesis has been studied in the genera *Psilaxis* (HEALY, 1982), *Heliacus* (HEALY; JAMIESON, 1991; ROBERTSON, R, 1989), and Mathildidae (HEALY, 1995), suggesting potential distinctions between the Architectonicoidea and Valvatoidea groups, considered ancestral lineages of heterobranchs compared to Euthyneura (HEALY, 1993). These approaches have strengthened cladistic studies, theoretically supporting the monophyly of Lower Heterobranchia.

Modern techniques have significantly contributed to understanding the internal relationships within Lower Heterobranchia groups, with the studies on the microanatomy and three-dimensional reconstruction of microgastropods (BRENZINGER; HASZPRUNAR; SCHRÖDL, 2013; HASZPRUNAR *et al.*, 2011; JÖRGER; SCHRÖDL, 2013). For the clade Rhodepomorpha, composed of interstitial slugs with a vermiform shape that externally resemble flatworms, reconstructions not they revealed new observable features but also corrected aspects of the original description (BRENZINGER; HASZPRUNAR; SCHRÖDL, 2013; BRENZINGER; WILSON; SCHRÖDL, 2011). The authors addressed potential apomorphies, convergences, and the characteristics of the “Meio Fauna Syndrome” (evolutionary convergences in various organisms, especially euthyneurous gastropods like acoclydians, nudibranchs and sacoglossans) (ROBINSON; MORSE, 1979; RÜCKERT; ALTNÖDER; SCHRÖDL, 2008). These studies were crucial in supporting phylogenetic configurations proposed by molecular analyses (DINAPOLI; KLUSSMANN-KOLB, 2010), such as the sister group relationship between Rhodepomorpha and Murchisonellidae. Brenzinger *et al.*, (2014) describing the anatomy of *Koloonella minutissima*, identified a series of shared characters, such as a modified digestive tract with a reduced radula and pharynx, a

large esophagus, and a euthyneurous nervous system with fused pleural ganglia of the brain with parts of the visceral loop.

Revisiting previously described species of new morphological and molecular characters creates a cascading effect that benefits all surrounding taxa. Chaban et al. (2022), in describing new species of microgastropods *Parvaplustrum* from hydrothermal sources, relied on molecular information sequenced by Brenzinger et al. (2021) in mesoneura molluscs. This not they allowed delineating the species *P. wareni* but also suggested a revision of the they collected by the authors at the same locality. Valvatidae, the small freshwater snails, are likely one of the best-documented taxa of basal heterobranchs, with a broad distribution in the Northern Hemisphere (HASZPRUNAR, 2014, 2022). Despite Haszprunar's efforts to quantify and compile information on fossil and living species, there is an abundance of molecular data available in GenBank compared to the basal and mesoneurous heterobranchs.

However, there are few studies on species delimitation, phylogeny, and biogeography, although they indicate the existence of species complexes that have persisted since the last glacial period (HAUSWALD; ALBRECHT; WILKE, 2008; SAITO *et al.*, 2018). Testing the boundaries of a species directly, employing any chosen concept, such as identifying reproductive incompatibility with species from adjacent or overlapping natural populations, is challenging and rarely carried out (FIŠER; ROBINSON; MALARD, 2018). Instead, morphological characteristics are often used in species identification, assuming that morphological differentiation reflects genetic divergence, acting as a proxy for reproductive isolation (FIŠER; ROBINSON; MALARD, 2018).

3.4.2 A "gap" in the evolutionary history of Heterobranchia.

Supporting the monophyly of a clade whose representatives exhibit morphological and ecological characteristics so distinct is no easy task. Although significant efforts have been made to understand the relationships within Heterobranchia as a monophyletic clade in Gastropoda, the challenge lies in understanding the internal relationships. Phylogenetic studies of heterobranchs have been inadequately represented in basal and mesoneurous heterobranch species, especially in miniaturized species (CUNHA; GIRIBET, 2019; KOCOT *et al.*, 2011; KOCOT; HALANYCH; KRUG, 2013; LEE *et al.*, 2019).

Morphologically, support for the monophyly of Heterobranchia is based on a set of characteristics, including a pigmented mantle organ, even if reduced in some groups, a simple esophagus, a distinct ultrastructure of gametogenesis, and a larval shell with a left-handed spiral

in a planktotrophic veliger (HASZPRUNAR, 1985, 1988; HEALY, 1993).These studies of Haszprunar and Healy were strongly supported by the sister-group relationship between Omalogyroidea and Architectonicoidea. However, it is important to note that analyses of these characteristics still leave entire genera underrepresented, such as the small snail group *Ammonicera*, and the intriguing position of *Larochella*.

Valvatidae has been identified as the first branch of heterobranchs to diverge, based on conchological, anatomical, and ontogenetic features when compared to the families Cornirostridae, Xylodisculidae, and Orbitestellidae (HASZPRUNAR, 1988; HEALY, 1993; PONDER, 1990; WAREN; GOFAS; SCHANDER, 1993). However, in subsequent molecular analyses of more extensive taxa, basal heterobranchs were underrepresented, except for species like *Valvata*, *Cornirostra*, and *Philippea*. Due to the fact that many species were described only based on shell characteristics, understanding relationships between groups was also limited (COLGAN; PONDER; EGGLER, 2000; GRANDE *et al.*, 2004).

Dinapoli and Klussmann-Kolb (2010) constructed a phylogeny with a substantial number of basal and mesoneurous heterobranch species, including the genera *Valvata*, *Cornirostra*, *Architectonica*, *Omalogyra fusca*, *Ebala*, *Murchisonella*, *Cima*, *Orbistestella*, *Larochella*, and *Graphis*. However, some representatives were identified only at the genus level and were later identified by Waren (2013). This phylogeny supported the monophyly of Heterobranchia and some hypotheses, such as the sister-group relationship between Omalogyroidea and Architectonicoidea, already suggested by studies of gametogenesis ultrastructure.

Two genera, *Graphis* and *Larochella*, which had an unstable taxonomic position in the past, are microgastropods belonging to Caenogastropoda, Aclididae. The hypothesis that these genera were not caenogastropods was initially proposed (FRETTER; GRAHAM, 1982). Subsequently, Ponder (1984; 1991) confirmed this hypothesis based on shell and mantle characteristics, placing Larochella and Graphis in Heterobranchia. This information was later corroborated by molecular studies conducted by Dinapoli and Klussmann-Kolb (2010). This clarification was only possible through the use of various sources and tools, contributing to a more comprehensive understanding of evolution in Heterobranchia.

Advancements in molecular approaches have significantly contributed to unraveling the evolutionary path of Heterobranchia, especially by focusing on the sampling of basal heterobranchs. Integrative and molecular taxonomy work on Rhodopidae (WILSON *et al.*, 2017) elucidated the relationships of this taxon, standing out for its distinct morphological features, such as the absence of a shell, vermiform shape, and lack of a sole. Rhodopidae was

identified as the sister group to Murchisonellidae, and later, Brenzinger (2021) recognized it as the intermediate clade between basal heterobranchs and euthyneurs, called Mesouneura. Including miniaturized groups such as Murchisonellidae, Tjaernoeiidae, and Rhodopidae was crucial for an enhanced understanding of relationships between these groups.

The introduction of species with distinct and miniaturized morphological characteristics has also impacted the understanding of Euthyneura. Jorger (2010) provided new insights by examining acyclid species in molecular phylogeny, proposing significant changes to the traditional understanding of Euthyneura and the close relationship between the former Pulmonata and Opisthobranchia.

However, it is evident that a significant portion of the species in the Lower Heterobranchia clade faces a taxonomic gap. Many of the microgastropod families addressed in this study have limited records of internal anatomy, gametic ultrastructure, and ecology. Other groups, such as miniaturized genera of Architectonicidae, Cimidae, Omalogyridae, among others, are predominantly described based on shell characters. Despite efforts to describe these species, the limited approach to conchological characters creates challenges for researchers, resulting in an extensive list of species with limited information about their evolutionary history. This becomes even more problematic when considering phenotypic plasticity, species crypticity, and evolutionary convergence, which are particularly persistent in interstitial miniaturized species, exhibiting distinct features from common heterobranchs, such as acyclids and rhodopidae (JÖRGER *et al.*, 2010; WILSON *et al.*, 2017).

Furthermore, the evolutionary convergence of morphological characteristics, such as a vermiform body plan, miniaturization, and specific ecological features (interstitial lifestyle), reflects little of the evolutionary history of gastropods and other invertebrate animals. This highlights the so-called "meiofauna syndrome," where ecological pressures are not sufficient to explain phylogenetic relationships, making it necessary to find more conserved characteristics justifying phylogenetic groupings (JÖRGER *et al.*, 2010; LAUMER *et al.*, 2015).

3.5 FINAL CONSIDERATIONS:

It's noteworthy that, despite specific advancements in understanding the evolutionary history of some gastropod groups, new tools such as CT-Scans, tridimensional reconstruction methods, and computational species delimitation address very little when it comes to basal heterobranch microgastropods. This disparity stems from intense research efforts dedicated to certain groups, while others have only been described and, as far as we know, have not been

revisited. This highlights the urgency of training taxonomists capable of revisiting groups that haven't received much attention in recent years.

In this study, we compiled information from the literature on the species concept used in describing basal heterobranch microgastropods and mesoneurous, utilizing data sources from literature, genetic databases, and museums. Additionally, we reflected on the importance of directing focus towards revisiting and expanding knowledge about already described species, aiming to address taxonomic and evolutionary challenges. It's crucial for malacology to move towards comprehensive studies, incorporating information from various sources, and investing in the training of taxonomists for less-studied groups.

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4. A SAMPLE OF ROMANIAN DIVERSITY AT THE MALACOLOGICAL MUSEUM PROF. MAURY PINTO DE OLIVEIRA: TERRESTRIAL AND FRESHWATER MICROGASTROPODS DONATED BY ALEXANDRU GROSSU

(Chapter submited in the Anais da Academia Brasileira de Ciências)

4.1. INTRODUCTION

Natural history collections (NHCs) represent true treasures of biological data, harboring a wide diversity of taxa in centralized locations (Beauvais *et al.,* 2017; Meineke *et al.,* 2018). In addition to preserving specimens, NHCs also play broader roles as these repositories have been used as true sources of ecological and evolutionary information (Holmes, 2016). The physical specimens and associated data contained within NHCs present utmost relevance for understanding the biology of global changes (Beauvais *et al.,* 2017; Meineke *et al.*, 2018), as they bear information like ecological signatures, and evidence of physiological processes in response to various factors that impact species conservation (Miller-Struttmann *et al.,* 2015; Schilthuizen *et al.,* 2016; Beauvais *et al.,* 2017; Malmstrom *et al.,* 2007; Miller-Rushing *et al.*, 2009). The data stored in these collections offer valuable insights into how environmental changes have impacted populations over time, enabling us to understand its effects on species traits such as their life history patterns, ecological roles, and evolutionary potential (Wolkovich *et al.,* 2013).

Over decades and even centuries, specimens from a wide variety of taxa from all around the globe have been collected, curated, and housed in NHCs from esteemed institutions such as major museums, universities, and research centers, but also in small collections (SC) (Suarez & Tsutsui, 2004; Pyke & Ehrlich, 2010; Casas-Marce, 2012). The significance of the SCs should not be underestimated as they harbor a surprising diversity of species, many of which are endangered or rare (Casas-Marce, 2012). The data associated to the specimens housed in SCs can fill gaps in the knowledge on the life history, ecology, and diversity of species across different temporal and geographical scales, even for those taxa abundantly represented in renowned museums (Sierwald *et al.,* 2018).

The malacological collection Maury Pinto de Oliveira (Coleção Malacológica Maury Pinto de Oliveira – CMMPO) was first assembled by Professor Oliveira in the 1950s, gaining institutional recognition in the 1960s, when it was donated to the Federal University of Juiz de Fora, Brazil. During the following decades, the taxonomic and geographical significance of the CMMPO was increased as the result of collection efforts in Brazil and extensive scientific

exchange with researchers, and collectors from all around the world. The CMMPO incorporates specimens donated by renowned malacologists, as those belonged to the collection hold by Addison Gulick and donated by Morris Karl Jacobson (American Museum of Natural History), specimens donated by George Thomas Floyd (Cleveland Museum), William Erwood Old Jr. (American Museum of Natural History), Eliezer de Carvalho Rios (Museu Oceanográfico), J.-J van Mol (Musee Royal de l'Afrique Centrale, Tervuren, Belgium), Richard van Belle (Royal Atheneum), among many others. In the 1990s, Professor Maury Pinto de Oliveira acquired a batch of shells from Romania, collected and curated by Professor Alexandru Grossu. The lot contained several micro-gastropod species, from both terrestrial and freshwater environments, along with five volumes of the series titled “Gastropoda Romeniae”. Professor Alexandru Grossu was born in Ciorăni (Vrancea). He graduated from the University of Bucharest in 1934 with a degree in Natural History and earned his doctoral degree in 1939, under the guidance of Professor Popovici-Bâznoşeanu. From 1939 to 1951, he held various roles in Timisoara, including educator, school inspector, teacher, and director of Loga College. He also taught at the Institute of Medicine during this period. In 1951, he moved to Bucharest, becoming a professor and later the rector of the Pedagogical Institute. For over 20 years, starting in 1955, he served as a Professor in the Faculty of Biology (Antipa Museum, 2023). Between 1955 and 1957, he was the Director of the "Grigore Antipa" Museum of Natural History, restructuring the museum, establishing a diverse expert team, and founding the Travaux du Muséum journal. From 1957 to 1964, he served as the Dean of the Faculty of Biology in Bucharest. From 1975 to 1990, he held the role of Professor Consultant. Internationally recognized as a leading malacologist of the 20th century, Professor Grossu balanced teaching and research activities, contributing significantly to the scientific community. His collection, a substantial part of which was donated to the Antipa Museum, formed the basis for scientific exchanges with other countries (Antipa Museum, 2023). Professor Alexandru Grossu passed away in 2004, leaving behind a legacy of over 160 works, including the volumes “Fauna Mollusca” and “Gastropoda Romaniae” (Antipa Museum, 2023).

Herein, we revisited the specimens of terrestrial and freshwater microgastropods donated by Professor Alexandru Grossu to the CMMPO, providing the data associated to the specimens. The study involved data compilation, reconditioning of the specimens, image acquisition through Scanning Electron Microscopy, and taxonomic updating by cross-checking species taxonomic attributions. We also verified the representativity of the species herein analyzed in larger collections worldwide, by searching for records of these species in Romania at the Global Biodiversity Heritage Library.

4.2. MATERIAL AND METHODS

The search for microgastropods donated by Alexandru Grossu was made by examining all the lots ascribed to each family of freshwater and terrestrial snails represented in malacological collection Maury Pinto de Oliveira (CMMPO). The data associated to each lot was compiled, including accession number, species name, locality, collector, mode of preservation and additional information. The specimens were originally kept in glass tubes partially filled with cotton, and they were never removed from these original containers. We reconditioned all the specimens into new glass vials without cotton coats. The species taxonomic status and higher classification was updated by consulting MolluscaBase (http./www.molluscabase.org) and Bouchet *et al*. (2017), respectively.

The specimens were examined under a stereoscopic magnifying glass, and the best-preserved ones were selected and cleaned in a 10% hydrogen peroxide solution (Geiger *et al.,* 2007), positioned in small pieces of carbon tape, and analyzed under a scanning electron microscope (SEM) FEI Quanta 250 without any additional preparation. The species represented by only one specimen were not subjected to SEM procedure to ensure they wouldn't be damaged during sample handling.

To provide spatial information on the collecting locations of the specimens, a map was generated by the free software Q-GIS 3.16.10 Hannover (http://www.qgis.org). Species distributions were plotted and overlaid with Romania geopolitical boundary area layers obtained from DIVA (http://www.diva-gis.org/gdata) and Natural Earth (naturalearthdata.com/downloads/) resources. The data was georeferenced in GeoLocate (https://www.geo-locate.org/) based on the collection locations present on the labels of the microgastropod specimens.

To verify the representativity of the species herein analyzed in larger collections worldwide, we searched for records of these species in Romania at the Global Biodiversity Heritage Library – GBIF. We used the species names as search criteria and selected the filters “preserved specimens” as basis of record, “Europe” as geographical area, and “Romania” as country. We also searched for the type specimens of each species by using the filter “type status”. The datasets accessed corresponded to collections at the Field Museum of Natural History – Invertebrate Zoology Collection (Grant *et al.,* 2023); Natural History Museum of Denmark – Invertebrate Zoology Collection (Eibye-Jacobsen *et al.,* 2023); Musée des Confluences – Bourguignat's Land and Freshwater Molluscs Collection (Audibert & Grange,

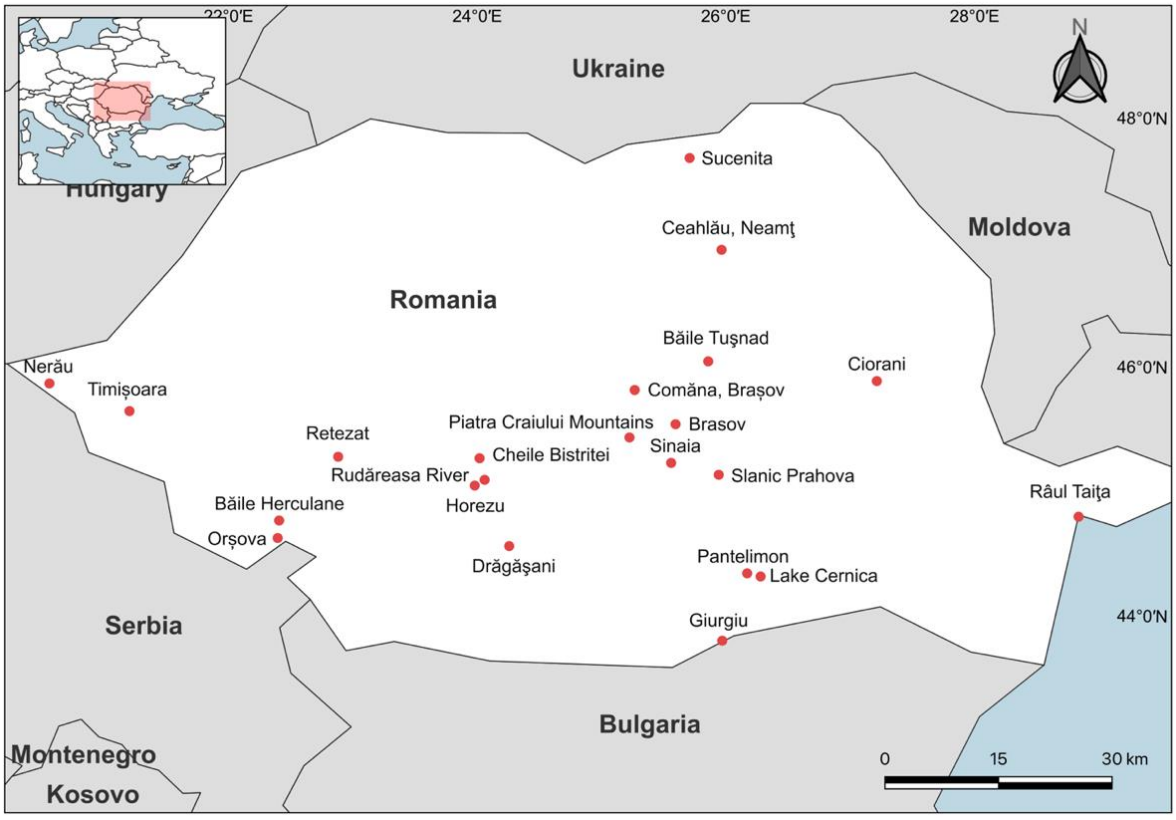
2023); Natural History Museum (London) – Mollusca Collection (Natural History Museum, 2023); Academy of Natural Sciences of Philadelphia – Malacological Collection (Academy of Natural Sciences, 2023); Museum für Naturkunde, Berlin – Collection Malakologie (Systax, 2023); National Museum of Natural History, Smithsonian Institution – Invertebrate Zoology Collection (Orrell, 2023); Santa Barbara Museum of Natural History – Invertebrate Zoology Collection (Chaney *et al.,* 2023); University of Michigan Museum of Zoology – Mollusk Collection (UMMZ Mollusk Data Group, 2023); Museum of Comparative Zoology, Harvard University – Malacology Collection (Morris, 2023); Royal Belgian Institute of Natural Sciences – Mollusca Collection (Pauwels *et al.,* 2021); Natural History Museum Aarhus –Malacology Collection (Natural History Museum Aarhus, 2023); Naturalis Biodiversity Center – Mollusca Collection (Goud *et al.,* 2023); San Diego Natural History Museum – Marine Invertebrate Collection (San Diego Natural History Museum, 2023); Senckenberg – Collection Malakologie (Senckenberg, 2023); Florida Museum of Natural History – Invertebrate Zoology Collection (Florida Museum of Natural History, 2023). Finnish Museum of Natural History – Mollusca (Luomus) Collection (Finnish Biodiversity Information Facility, 2023); Museu de Ciències Naturals de Barcelona – Malacological Collection (Garcia & Agulló Villaronga, 2023); Carnegie Museum of Natural History – Mollusks (Carnegie Museums, 2023); Adam Mickiewicz University in Poznań – Natural History Collections of the Faculty of Biology AMU (Adam Mickiewicz University in Poznań, 2023); Lund Museum of Zoology – Zoological Collections (Ekström, 2023); Delaware Museum of Natural History – Mollusks Collection (Delaware Museum of Natural History, 2023); Muséum d'Histoire naturelle de Grenoble – Collections Zoologiques (Candegabe, 2018); Norwegian University of Science and Technology Museum – Terrestrial and limnic invertebrates systematic collection (Hårsaker *et al.,* 2024); Naturhistorisches Museum Bern – Invertebrate collection (Naturhistorisches Museum Bern, 2024); Musée Cantonal de Zoologie, Lausanne – MZL Invertebrate Collections (Freitag, 2019); Löbbecke Museum Düsseldorf – SysTax Zoological Collections (SysTax, 2024); Natural History Museum Rotterdam – Specimens Collection of the Natural History Museum Rotterdam (Slieker *et al.,* 2023). Haus der Natur Salzburg, Museum für Natur und Technik – Biodiversitätsdatenbank Salzburg (Haus der Natur Salzburg, 2024); Jackson School Museum of Earth History, University of Texas at Austin – Non-vertebrate Paleontology (Boucher & Appleton, 2024). Biologiezentrum Linz – ZOBODAT (Biologiezentrum Linz Oberoesterreich, 2023); Bailey-Matthews National Shell Museum – Mollusks Collection (Bailey-Matthews National Shell Museum, 2024); Swedish Museum of Natural History – Invertebrates (Type Specimens) (Stöhr, 2023); Paleontological Research Institution – Paleontological Research

Institution Collections (Skibinski, 2023). The associated data to the specimens from the collections mentioned above were cited in accordance with the format proposed by Chester et al. (2019) in the topic “Other material from Romania”. Some information was sometimes not available, such as the number or the kind of available specimens (dry shell or ethanol preserved shell and soft parts). All the species were listed according to their current taxonomic status.

4.3. RESULTS

We recorded a total of 41 lots of terrestrial and freshwater microgastropods including 35 species belonging to 20 families, collected between 1934–1972 in Romania; i.e.: Acroloxidae (1 species), Aghardiellidae (1), Argnidae (1), Chondrinidae (2), Clausiliidae (2), Cochlicopidae (3), Discidae (2), Ellobidae (2), Euconulidae (1), Orculidae (1), Oxychillidae (1), Planorbidae (2), Pristilomatidae (3), Punctidae (1), Pupillidae (4), Pyramidullidae (1), Spelaeodiscidae (1), Succineidae (1), Vallonidae (3), and Vitrinidae (2). The locations where the specimens were collected is represented in Figure 1.

Figure 1. Occurrence localities in Romania of the species of microgastropods donated by Alexandru Grossu, housed in the Malacological Collection Maury Pinto de Oliveira.



Source: Prepared by the author (2023)

4.3.1 Systematic Part

Class Gastropoda Cuvier, 1798

Subclass Heterobranchia Haszprunar, 1985

Order Hygrophila Férussac, 1822

Superfamily Lymnaeoidea Rafinesque, 1815

Family Acroloxidae Thiele, 1931

Genus *Acroloxus* Beck, 1838

Acroloxus lacustris (Linnaeus, 1758)

(Fig. 5G)

Patella lacustris Linnaeus, 1758: 778

Ancylus lacustris – Bourguignat, 1853: 197. – Reeve, 1863: 172. – Clessin, 1882: 57.

Acroloxus lacustris – Babor & Novak, 1909: 156. – Walker, 1914: 114; – Walther *et al.,* 2006: 271; – Shirokaya *et al.,* 2012; – Soldatenko & Petrov, 2019: 510; – Soldatenko *et al.,* 2022: 192.

Type Material: not found.

Material examined: ROMANIA • 1 shell; Lake Cernica; 09 May 1938; A. Grossu leg.; CMMPO 7862.

Other material from Romania: not found.

Family Planorbidae Ralfinesque, 1815

Genus *Ancylus* O. F. Müller, 1773

Ancylus fluviatilis O. F. Müller, 1774

(Fig. 2A–B; Fig. 5A–D)

Ancylus fluviatilis O.F. Müller, 1774: 201. – Weiss *et al.,* 2018: 1063.

Pseudancylus simplex Buc'hoz, 1771: 1692.

Ancilus sinuosus Brard, 1815: 201 (pl. 7, fig. 4).

Ancylastrum riparium Desmarest, 1814: 19.

Ancylus orbicularis Held, 1837: 901-919.

Ancylus strictus Morelet, 1845: 88 (pl. 8 fig. 4).

Ancylus obtusus Morelet, 1845: 88 (pl. 8 fig. 5).

Ancylus vitraceus Morelet, 1845: 87 (pl. 8 fig. 3).

Ancylus fabrei Dupuy, 1849: (1-3).

Ancylus cyclostoma Bourguignat, 1853: 193.

Ancylus abyssinicus Jickeli, 1874: 223 (pl. 5, figs 5-6, pl. 7, figs 27-28).
Ancylus compressus Jickeli, 1874: 223 (pl. 7, fig. 26).
Ancylus libanicus Nägele, 1897: 13.
Pseudancylus argenteus Connolly, 1941: 37 (pl. 3, figs 11, 12).

Type material: SYNTYPE of *Ancylus fluviatilis* O.F. Müller, 1774**.** GERMANY • 1 preserved specimen; Weimar; NHMD90989. SYNTYPE of *Ancylus abyssinicus* Jickeli, 1874. ETHIOPIA • 3 preserved specimens; Hamaszen, Mekerka (Toquor river); FMNH Invertebrate Zoology 34402. SYNTYPE of *Ancylus simplex* (Buc'hoz, 1771). FRANCE • 7 preserved specimens; île-de-France, Hauts-de-Seine, Clichy; MHNL.45049099. FRANCE • 10 preserved specimens; Île-de-France, Val-de-Marne, Vincennes; MHNL.45049203. SYNTYPE of *Ancylus strictus* Morelet, 1845. PORTUGAL • 3 preserved specimens; NHMUK ZOO 1893.2.4.525-527. SYNTYPE of *Ancylus obtusus* Morelet, 1845. PORTUGAL • 2 preserved specimens; NHMUK ZOO 1893.2.4.529-530. LECTOTYPE of *Ancylus libanicus* Nägele, 1897. LEBANON • 1 preserved specimen; Hesse, P. don.; ANSP MAL 289762. PARALECTOTYPES of *Ancylus libanicus* Nägele, 1897. LEBANON • 14 preserved specimens; Hesse, P. don.; ANSP MAL 466149. SYNTYPE of *Ancylus vitraceus* Morelet, 1845. PORTUGAL • 2 preserved specimens; Alentejo; MNHN IM 200-33265. SYNTYPE of *Ancylus compressus* Jickeli, 1874. ERITREA • preserved specimen; ZMB / Moll 95370. SYNTYPE of *Ancylus abyssinicus* Jickeli, 1874. ERITREA • preserved specimen; ZMB / Moll 95371. ERITREA • preserved specimen; ZMB / Moll 95372. ERITREA • preserved specimen; ZMB / Moll 95373. PARATYPE of *Pseudancylus argenteus* Connolly, 1941. No location information; ZMB / Moll 75594. TYPE of *Pseudancylus argenteus* Connolly, 1941. YEMEN • 13 preserved specimens; Shab'a, Hureidha; NHMUK ZOO 1939.4.19.244-256.
Material examined: ROMANIA • 22 shells; Nera Barrat; 08 Sep 1942; A. Grossu leg.; CMMPO 7748.
Other material from Romania: ROMANIA • 2 preserved specimens; Sasca Montana; 1942; G. Poppe leg. RBINS INV_MOL POP. 4217. ROMANIA • 9 preserved specimens; Botosani; ANSP MAL 22058. ROMANIA • 7 preserved specimens; Hermannstadt, Transylvania; ANSP MAL 22066.

Genus *Ferrisia* B. Walker, 1903
Ferrissia californica (Rowell, 1863)
(Fig 5E–F)

Gundlachia californica Rowell 1863: 21 (fig. 5). – Vecchioni *et al.*, 2018: 150.
Ancylus caurinus W. Cooper, 1860: 378.
Ancylus fragilis Tryon, 1863: 149 (fig. 15).
Gundlachia meekiana W. Stimpson, 1863: 250 (fig. 2).
Ferrissia fragilis Tryon, 1863: 149 (pl. 1, fig. 15).
Ferrissia caurina Cooper, 1870: 100.
Gundlachia stimpsoniana Smith, 1870: 399 (fig. 6).
Ancylus shimeki Pilsbry, 1890: 48.
Ancylus obliquus Shimek, 1890: 214 (pl. 3, fig. 5).
Ancylus pumilus Sterki, 1900: 36.
Ancylus sharpi Sykes, 1900: 394 (fig. 14). – Christensen, 2016: 5.
Ancylus (Ferrissia) hendersoni Walker, 1908: 138 (pl. 9, fig. 8–10).
Ancylus (*Ferrissia*) *novangliae* Walker, 1908: 138 (pl. 9, figs. 5–7).
Ferrissia bartschi Walker, 1920: 525 (fig. 1).
Watsonula wautieri Mirolli, 1960: 61.
Gundlachia (*Kincaidilla*) *japonica* J. B. Burch, 1964: 2 (figs 1–10).
Ferrissia japonica – Habe & Burch, 1965: 2 (figs 1–8).

Type material: PARATYPES of *Gundlachia californica* Rowell 1863. UNITED STATES OF AMERICA • 2 shells; Marysville, Yuba County, California; UMMZ 102011. LECTOTYPE of *Gundlachia californica* Rowell 1863. UNITED STATES OF AMERICA • 1 shell; Feather River, Marysville; Yuba County, California; SBMNH IZ 35010. PARALECTOTYPE of *Gundlachia californica* Rowell 1863. UNITED STATES OF AMERICA • 1 shell; Feather River, Marysville; Yuba County, California; SBMNH IZ 35011. HOLOTYPE of *Ancylus caurinus* W. Cooper, 1860. UNITED STATES OF AMERICA • 1 shell; San Diego, California; USNM 9098. HOLOTYPE of *Ferrisia bartschi* Walker, 1920. UNITED STATES OF AMERICA • 1 shell; Lake Maxinkuckee, South end of marsh, Indiana; USNM 334709. PARATYPES of *Watsonula wautieri* Mirolli, 1960. ITALY • 5 preserved specimens; Lago di Mergozzo; NHMUK ZOO 19601541. PARATYPES of *Gundlachia* (*Kincaidilla*) *japonica* J. B. Burch, 1964. JAPAN • 20 shells; Fuchinobe, Sagamihara City, Kanagawa, Kanto; UMMZ 216832. SYNTYPES of *Ancylus* (*Ferrissia*) *novangliae* B. Walker, 1908. UNITED STATES OF AMERICA • 10 shells; Cambridge, nr Fresh Pong, Clay pit, Massachusetts; MCZ 164776. UNITED STATES OF AMERICA • 6 shells; Cambridge, Massachusetts; ANSP MAL 94670. SYNTYPE of *Gundlachia stimpsoniana* S. Smith, 1870. UNITED STATES OF AMERICA • 5 preserved specimens; Greenport, Long Island, New York; ANSP MAL 134988.
Material examined: ROMANIA • 6 shells; Slanic Prahova; May 1961; A. Grossu leg.; CMMPO 7587.

Other material from Romania: not found.

Eupulmonata Haszprunar & Huber, 1990

Order Stylommatophora A. Schmidt, 1855

Family Agardhiellidae Harl & Páll-Gergely, 2017

Genus *Agardhiella* P. Hesse, 1923

Agardhiella parreyssii (L. Pfeiffer, 1848)

Clausilia parreyssii Pfeiffer, 1848: 400. – Subai *et al.,* 2011: 82.

Argna (Agardhiella) moldavica Grossu & Negrea, 1968: 726.

Argna parreyssii – Damjanov & Likharev, 1975: 108. – Dedov, 1998: 748.

Agardhiella licherdopoli Grossu, 1986: 9.

Argna truncatella Irikov, 2002.– Georgiev, 2005: 434.

Type material: not found.

Material examined: ROMANIA • 1 shell; Giurgiu; A. Grossu leg.; 14 July 72; CMMPO 7863.

Other material from Romania: ROMANIA • 2 preserved specimens; Corani-Vrancea, aluviuni r. Siret; A. Grossu col.; 12 May 1955; I. Wistar Moris III don.; ANSP MAL 443190. ROMANIA • 1 preserved specimen; Piatra, Sipotului, Transylvania; 1914; ANSP MAL 218624. ROMANIA • 5 preserved specimens; Transylvania; ANSP MAL 4842. ROMANIA • 2 preserved specimens; Transylvania; ANSP MAL 4842. ROMANIA • 4 preserved specimens; Banat; ANSP MAL 71491. ROMANIA • 3 preserved specimens; Siebenbürgen, Transylvania; RBINS Hist.17.

Family Argnidae Hudec, 1965

Genus *Argna* Cossmann, 1889

Argna bielzi (Rossmässler, 1859)

(Fig. 2D)

Pupa bielzi Rossmässler, 1859: 1–3 (fig. 942).

Pupa biplicata Bielz, 1867: 96.

Aghardia bielzi – Grossu, 1955:103 (fig. 88).

Aghardiella bielzi – Schileyko, 1984: 153 (figs 81, 82).

Type material: not found.

Material examined: ROMANIA • 2 shells; Cheile Bistritei - Valcea (Horezu); 18 Oct 59; A. Grossu leg.; CMMPO 7730.

Other material from Romania: ROMANIA • 1 shell; Borszek, Transylvania; P. Hesse don.; 1912; ANSP MAL 218631. ROMANIA • 9 preserved specimens; Botosani; ANSP MAL 22690. ROMANIA • 4 preserved specimens; Rodna; ANSP MAL 114993. ROMANIA • 2 preserved specimens; Bodna Guara at Herosu, Transylvania; ANSP MAL 218630. ROMANIA • 2 preserved specimens; Csik-Gyimas Mountains, Transylvania; ANSP MAL 218632. ROMANIA • 2 preserved specimens; Sinaia, Val. Peles; ANSP MAL 443286. ROMANIA • 8 preserved specimens; Bistra 5, Forest; NHMUK ZOO 20200036. ROMANIA • 2 shells; Rodna, Transylvania; UMMZ 110402.

Family Chondrinidae Steeberg, 1925

Genus *Chondrina* Reichenbach, 1828

Chondrina arcadica clienta (Westerlund, 1883)

(Fig. 2C; Fig. 6A)

Pupa avenacea var. clienta Westerlund, 1883: 60.

Chondrina clienta Westerlund, 1883: 60. – Grossu, 1955: 207; – Schileyko, 1984: 229.

Glischrus (Torquilla) hordeum Studer, 1820: 19.

Type material: not found.

Material examined: ROMANIA • 107 shells; Cheile Bistritei - Valcea (Horezu); 10 July 1966; A. Grossu leg.; CMMPO 7724.

Other material from Romania: ROMANIA • 30 preserved specimens; Mehadia, Băile Herculane, Hotel Romania; ANSP MAL 443325. ROMANIA • 6 preserved specimens; Piatra Craiului Riu-Tal, Transylvania; L. Nemeth leg.; ANSP MAL 443326. ROMANIA • 5 preserved specimens; Cheile Sohodol, near Runcu, South Carpathias Gorj County, Transylvania; L. Nemeth leg.; ANSP MAL 443327. ROMANIA • 20 preserved specimens; Cheile Turzii (Torder Schlucht), Transylvania; ANSP MAL 443327. ROMANIA • 31 preserved specimens; B. Herculane, Val. Cernei, Transylvania; A. Grossu rec.; ANSP MAL 443329. ROMANIA • 6 preserved specimens; Karan-Pass (Barnat); FMNH 129630. ROMANIA • 4 preserved specimens; Banat; J. Gerber leg.; FMNH 103516. ROMANIA • 17 preserved specimens; Herkulesfürdö; FMNH 123339. ROMANIA • 2 preserved specimens; Karan-Pass (Barnat); FMNH 129345. ROMANIA • 1 preserved specimen; Herkulesfürdö; FMNH 295822. ROMANIA • 7 preserved specimens; Seitental des Garcinbachtales unterhalb Pojan-Kö, am

Nordfusse des Piatra-Gebir; FMNH 48887. ROMANIA • 3 shells; Belias´s Pass, Transylvania; MCZ Mala 197340. ROMANIA • 11 shells; Bacofalu; NHMA M 13859. ROMANIA • 10 shells; Zagan; NHMA M 13860. ROMANIA • 8 shells; Zinne; NHMA M 13864. ROMANIA • 6 shells; Cheia; NHMA M 13862. ROMANIA • 8 shells; Zinne; NHMA M 13864. ROMANIA • 3 shells; Törzburg; NHMA M 13863. ROMANIA • 6 shells; Comana; NHMA M 13861. ROMANIA • 4 shells; Bacofalu b. (South) Kronstadt; NHMA M 13865. ROMANIA • 3 shells; Tesla; NHMA M 13858. ROMANIA • 6 preserved specimens; Banat 10, Forest; NHMUK ZOO 202000158. ROMANIA • 1 shell; Scæaerisoara; RBINS HIST.11. ROMANIA • 4 shells; Scæaerisoara; RBINS HIST.12. ROMANIA • shell; RMNH.MOL.247372. ROMANIA • shell; RMNH.MOL.247373. ROMANIA • shell; RMNH.MOL.247374. ROMANIA • shell; RMNH.MOL.247375. ROMANIA • shell; RMNH.MOL.247376. ROMANIA • shell; RMNH.MOL.247377. ROMANIA • shell; RMNH.MOL.247378. ROMANIA • shell; RMNH.MOL.247379.

Genus *Granaria* Held, 1838

Granaria frumentum (Draparnaud, 1801)

(Fig. 2E; FIG. 6B)

Pupa frumentum Draparnaud, 1801: 59.

Pupa frumentum – Rossmässler, 1835: 81–82 (fig 34).

Abida frumentum Draparnaud, 1801: 59. – Grossu, 1955: 203.

Granaria frumentum – Gittenberger, 1973: 45 (fig. 12). – Schileyko, 1984: 225 (fig. 144).

Type material: not found.

Material examined: ROMANIA • 5 shells; Ciorani-Vrance; 08 May 1957; A. Grossu leg.; CMMPO 7641. ROMANIA • 5 shells; Băile Herculane; 08 May 1957; A. Grossu leg.; CMMPO 7778.

Other material from Romania: ROMANIA • 7 preserved specimens; B. Herculane, Banat; J. Feete don.; SDNHM 87794. ROMANIA • 10 preserved specimens; Banat 14, forest; NHMUK ZOO 202000156. ROMANIA • 6 preserved specimens; Banat 10, forest; NHMUK ZOO 202000157. ROMANIA • preserved specimen; SNSD 420-S. ROMANIA • 20 preserved specimens; Turda Gorge, Transylvania; ANSP MAL 442914. ROMANIA • 10 preserved specimens; near Hotel Romania, Mehadia, Băile Herculane, Severin County; ANSP MAL 442918. ROMANIA • 4 preserved specimens; Gorj, Mts Tismana; A. Grossu leg.; ANSP MAL 442923. ROMANIA • 3 preserved specimens; Pestera Panoare, Baia de Asama; A. Grossu leg.;

ANSP 442921. ROMANIA • 5 shells; Banat; Naile Herculane; UF 462535 – Mollusca. ROMANIA • 7 preserved specimens; B. Herculane, Banat; J. Feete don.; SDNHM 87794. ROMANIA • 4 preserved specimens; B. Herculane, Bant; A. Grossu leg.; ANSP MAL 442922. ROMANIA • 27 preserved specimens; Saca Montana Val. Susara; A. Grossu leg; ANSP MAL 442920. ROMANIA • 21 preserved specimens; Piatra Arsa, Bucegi Mountains; A. Grossu leg.; Piatra Arsa, Bucegi Mountains; ANSP MAL 442939. ROMANIA • 3 preserved specimens; Transylvania; C.A. Westerlund leg.; HLA.11.4281. ROMANIA • 5 preserved specimens; Transylvania; NHMUK ZOO 1898.5.20.2373-2377. ROMANIA • 6 preserved specimens; Govasdia prés Vajda-Hunyad; FMNH 48601. ROMANIA • shell; Transylvania; UF 239951-Mollusca. ROMANIA • 1 shell; Siebenbürgen; NHMA M 12232. ROMANIA • 4 preserved specimens; Transylvania; ANSP MAL 22816. ROMANIA • 6 preserved specimens; Hermannstadt, Transylania; ANSP MAL 22817. ROMANIA • 40 preserved specimens; Nandor, Transylvania; ANSP MAL 66041. ROMANIA • 14 preserved specimens; Cseklya; FMNH 69394. ROMANIA • shell; Transylvania; UF 113040-Mollusca. ROMANIA • shell; RMNH.MOL.246553. ROMANIA • shell; RMNH.MOL.247800. ROMANIA • shell; RMNH.MOL.246554.

Family Clausiliidae J. E. Gray, 1855

Genus *Alinda* H. Adams & A. Adams, 1855

Alinda stabilis (L. Pfeiffer, 1847)

(Fig. 2F)

Clausilia stabilis L. Pfeiffer, 1847: 701.

Balea stabilis L. Pfeiffer, 1847: 701.

Lacinaria stabilis Grossu, 1955: 269 (fig. 141).

Type material: not found.

Material examined: ROMANIA • 3 shells; Sucenita; 13 August 1984; A. Grossu leg.; CMMPO 7750.

Other material from Romania: ROMANIA • 4 preserved specimens; Transylvania; ANSP MAL 4788. ROMANIA • 6 preserved specimens; Transylvania; ANSP MAL 24605. ROMANIA • 1 preserved specimen; Transylvania; ANSP MAL 238963. ROMANIA • 4 preserved specimens; Beliora near Salcida de Jos; ANSP MAL 443155. ROMANIA • 4 preserved specimens; Retezat Gebirge, Gura, Zlata; ANSP MAL 443156. ROMANIA • 2 preserved specimens; Bucegi Mtns, Sinaia-Peles; A. Grossu leg.; ANSP MAL 443159.

ROMANIA • 2 preserved specimens; Mt Succvita, Suceava; A. Grossu leg.; ANSP MAL 443162. ROMANIA • 1 shell; Rauberbrunnen, Transylvania, Brasov; CM – Mollusks 175929. ROMANIA • 5 preserved specimens; Mt Detonata, Transylvania; FMNH Invertebrate Zoology 70411. ROMANIA • shell; valea Comorilor, Bucegi; MCNB-Malac MZB 2003-1361. ROMANIA • 4 shells; Transylvania; MCZ Mala 391214. ROMANIA • 5 shells; Transylvania; MCZ Mala 391215. ROMANIA • 3 shells; Transylvania; MCZ Mala 391218. ROMANIA • 3 shells; Transylvania; MCZ Mala 391219. ROMANIA • 2 shells; Transylvania; MCZ Mala 391220. ROMANIA • 2 shells; Sibiu, Transylvania; MCZ Mala 391221. ROMANIA • 5 shells; Sibiu, Transylvania; MCZ Mala 391222. ROMANIA • 10 preserved specimens; Bistra 5, Forest; NHMUK ZOO 202000117. ROMANIA • 10 preserved specimens; Bicaz 4, Forest; NHMUK ZOO 202000118. ROMANIA • 10 preserved specimens; Retezat 1, Forest; NHMUK ZOO 202000119. ROMANIA • 1 shell; Hermannstadt, Sibiu; RBINS HIST 2264. ROMANIA • preserved specimen; SMF Collection Mollusca 320707. ROMANIA • preserved specimen; SMF Collection Mollusca 324485. ROMANIA • preserved specimen; SMF Collection Mollusca 327364. ROMANIA • preserved specimen; SMF Collection Mollusca 330760. ROMANIA • preserved specimen; SMF Collection Mollusca 330765. ROMANIA • preserved specimen; SMF Collection Mollusca 345767. ROMANIA • preserved specimen; SMF Collection Mollusca 345770. ROMANIA • preserved specimen; SMF Collection Mollusca 345777. ROMANIA • 2 shells; Transylvania; UMMZ-Molluscs 155610.

Genus *Ruthenica* Lindholm, 1924

Ruthenica filograna (Rossmässler, 1836)

(Fig. 3G; Fig. 6C)

Clausilia filograna Rossmässler, 1836: 17 (Fig. 264).

Clausilia filograna var. transsylvanica A. Schmidt 1857: 57.

Clausilia filograna – Bielz, 1867: 151.

Clausilia filograna var. sancta Clessin, 1872: 53.

Gracilaria filograna – Grossu, 1955: 243 (fig. 127).

Ruthenica filograna – Szybiak & Leśniewska, 2008: 186. – Szybiak & Gabala, 2013: 280.

Type material: not found.

Material examined: ROMANIA • 6 shells; Rudoreasa; 28 May 1972; A. Grossu leg.; CMMPO 7851. ROMANIA • 6 shells; Cheile Bistritei - Valcea (Horezu) 28 May 1972; A. Grossu leg.; CMMPO 7852.

Other material from Romania: ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005417. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005418. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005419. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005420. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005421. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005422. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005423. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005424. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005425. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005426. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005427. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005428. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005429. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005430. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005431. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005432. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0005433. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008187. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008188. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008189. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008190. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008191. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008192. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008193. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008194. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008195. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008196. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008197. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008198. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008199. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008200. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008201. ROMANIA • preserved specimen; G. Jankowski leg.; AMU NHC-ZOO MOLCL-JU-0008202. ROMANIA • preserved specimen; G. Jankowski leg.; AMU

NHC-ZOO MOLCL-JU-0008203. ROMANIA • 4 preserved specimens; Cserna Valley, near Mehadia, Transylvania; ANSP MAL 238974. ROMANIA • 5 preserved specimens; Transylvania; ANSP MAL 4771. ROMANIA • 11 preserved specimens; Transylvania; ANSP MAL 4792. ROMANIA • 12 preserved specimens; Botosani; ANSP MAL 24948. ROMANIA • 6 preserved specimens; Hermannstadt, Transylvania; ANSP MAL 24949. ROMANIA • 2 preserved specimens; Banat, Transylvania; ANSP MAL 238971. ROMANIA • 38 preserved specimens; Near Ariesul, Stream Valea Turdas (Mountain-Gorge of Turda) Cuj County, Transylvania; ANSP MAL 372205. ROMANIA • 1 preserved specimen; Vadu Crisului; ANSP MAL 443071. ROMANIA • 20 preserved specimens; Cheile Turzii (Tordaer Schlucht), Transylvanya; L. Nemeth leg.; ANSP MAL 443072. ROMANIA • 27 preserved specimens; Turda-Schlucht near Turda, Transylvanya; ANSP MAL 443073. ROMANIA • 6 preserved specimens; Valea Jiu, Cheile, Transylvanya; L. Nemeth leg.; ANSP MAL 443074. ROMANIA • 8 preserved specimens; Persani Mtns, Codlea, Magura-Berg, Transylvanya; L. Nemeth leg.; ANSP MAL 443075. ROMANIA • 28 preserved specimens; Turda, near Mikael Vitezul, Transylvanya; ANSP MAL 443076. ROMANIA • 10 preserved specimens; Vrancea Greb., Muntele Tisaru; A. Grossu leg.; ANSP MAL 443088. ROMANIA • 7 preserved specimens; Rudareasa, Val. Lotu; A. Grossu leg.; ANSP MAL 443095. ROMANIA • 2 preserved specimens; Jaroslave, Anges; A. Grossu leg.; ANSP MAL 443096. ROMANIA • 3 shells; CM Mollusks 104199. ROMANIA • 2 shells; Zenegova, Transylvania / Siebenbürguen; CM Mollusks 62.26844. ROMANIA • 2 shells; Transylvania; DMNH – Mollusk 75702. ROMANIA • 15 preserved specimens; Cerna – Tal, b. Herkules?rdo, {Banatus}; FMNH Invertebrate Zoology; 47746. ROMANIA • 2 preserved specimens; Banatus; FMNH Invertebrate Zoology 102148. ROMANIA • 1 preserved specimen; Schuler Mountain (=Cristian=Postavarul=Keresztenyhav), on the road between Paj; FMNH Invertebrate Zoology 170794. ROMANIA • 3 shells; Transylvania; MCZ Mala 288195. ROMANIA • 4 shells; Transylvania; MCZ Mala 390704. ROMANIA • 4 shells; Trecsin, Transylvania; MCZ Mala 390707. ROMANIA • 4 shells; Brasov, Tampa; MCZ Mala 390711. ROMANIA • 12 shells; Brasov, Kronstadt; MCZ Mala 390712. ROMANIA • 10 shells; Herkulesfurdo, Cerna Valley; MCZ Mala 390715. ROMANIA • 1 shell; Brasov, Mongura, Transylvania; MCZ Mala 390717. ROMANIA • 2 shells; Mongura, Transylvania; MCZ Mala 390718. ROMANIA • 3 shells; Transylvania; MCZ Mala 390725. ROMANIA • 2 preserved specimens; Hunedoara; MHNGr.CO.1616. ROMANIA • preserved specimen; Transylvania; MZH HLA 114149. ROMANIA • 2 shells; Siebenbürgen, Transylvania; MZLU EVERTEBRATA L874/3407. ROMANIA • 2 preserved specimens; Transylvania; NHMUK ZOO 1898.5.20.7312-7313.

ROMANIA • 2 preserved specimens; Transylvania; NHMUK ZOO 1898.5.20.7314-7315. ROMANIA • 10 preserved specimens; Fenes 1, Forest; NHMUK ZOO 20200095. ROMANIA • 10 preserved specimens; Gilau 2. NHMUK ZOO 20200096. ROMANIA • 10 preserved specimens; Predeal 2. NHMUK ZOO 20200097. ROMANIA • 10 preserved specimens; Bistra 4, Forest; NHMUK ZOO 20200098. ROMANIA • 10 preserved specimens; Banat 8, Forest. NHMUK ZOO 202000149. ROMANIA • 10 preserved specimens; Banat 12. NHMUK ZOO 202000150. ROMANIA • 1 shell; Banat; NTNU-VM DRY-84737. ROMANIA • 1 shell; Siebenbürgen, Transylvania; F. de Malzinne leg. RBINS INV-MOL Hist 426. ROMANIA • 16 shells; Siebenbürgen, Transylvania; A.E. Craven leg.; RBINS INV-MOL Hist 469. ROMANIA • 1 shell; Siebenbürgen, Transylvania; RBINS INV-MOL Hist 1689. ROMANIA • shell; Transylvania; RMNH.MOL.263908. ROMANIA • shell; RMNH.MOL.263909. ROMANIA • shell; RMNH.MOL.263910. ROMANIA • shell; RMNH.MOL.263911. ROMANIA • shell; RMNH.MOL.263912. ROMANIA • preserved specimens; SMF Collection Mollusca 330766. ROMANIA • preserved specimens; SMF Collection Mollusca 323464. ROMANIA • preserved specimens; SMF Collection Mollusca 323472. ROMANIA • preserved specimens; SMF Collection Mollusca 323477. ROMANIA • preserved specimens; SMF Collection Mollusca 320681. ROMANIA • preserved specimens; SMF Collection Mollusca 320687. ROMANIA • preserved specimens; SMF Collection Mollusca 320701. ROMANIA • preserved specimens; SMF Collection Mollusca 320720. ROMANIA • preserved specimens; SMF Collection Mollusca 320733. ROMANIA • preserved specimens; SMF Collection Mollusca 320739. ROMANIA • preserved specimens; SMF Collection Mollusca 320743. ROMANIA • shell; Transylvania; UF Invertebrate Zoology 195667-Mollusca. ROMANIA • 1 shell; Transylvania; UMMZ – Mollusks 232905. ROMANIA • 2 shells; Transylvania; UMMZ – Mollusks 001252. ROMANIA • 4 shells; Transylvania; UMMZ – Mollusks 015001. ROMANIA • 1 shell; Transylvania; UMMZ – Mollusks 232905.

Family Cochlicopidae Pilsbry, 1900

Genus *Cochlicopa* A. Férussac, 1821

Cochlicopa lubrica (O. F. Müller, 1774)

(Fig. 2G; Fig. 6G)

Helix lubrica O. F. Müller, 1774: 104.

Turbo glaber da Costa, 1778: 87 (pl. V, fig. 18).

Bulimus nitidissimus Krynicki, 1833: 420.

Bulimus lumbricoides W. Stimpson, 1851: 54.

Bulimus maderensis R.T. Lowe, 1852: 119.

Bulimus subcylindricus Moquin-Tandon, 1856: 38.

Bulimus subcylindricus var. *fuscus* Moquin-Tandon, 1856: 304.

Bulimus subcylindricus var. *albinos* Moquin-Tandon, 1856: 304.

Cochlicopa lubrica var *hyalina* Jeffreys, 1862: 293.

Cionella pfeifferi Weinland, 1874: 36.

Cionella columna Clessin, 1875: 41 (pl.2, fig. 4a,b.).

Physa aenigma Westerlund, 1877: 104.

Ferussacia subcylindrica var *grisea* Locard, 1880: 220.

Ferussacia subcylindrica var *opaca* Locard, 1880: 220.

Zua locardi Pollonera, 1885: 535.

Zua lubrica – Clessin, 1885: 226.

Cionella (*Zua*) *lubrica* var *sinistrosa* Goldfuss, 1900: 182.

Cochlicopa lubrica – Grossu, 1955: 164 (fig. 64).

Cochlicopa repentina Hudec, 1960: 277.

Type material: PARATYPE of *Cochlicopa repentina* Hudec, 1960. CZECHIA • preserved specimen; Mocidla im Badeort Msené-Dolní Pochrí; SMF Collection Mollusca 163935. SYNTYPE of *Helix lubrica* O. F. Müller, 1774. JAPAN • 6 preserved specimens; Hachijojima, Izu; CM Mollusks 62.15450-CM. SYNTYPE of *Bulimus maderensis* R.T. Lowe, 1852. PORTUGAL • 3 shells; Madeira; RMNH.MOL.335018.

Material examined: ROMANIA • 19 shells; Timișoara; 12 April 49; A. Grossu leg.; CMMPO 7637.

Other material from Romania: ROMANIA • 14 preserved specimens; Hermannstadt, Transylvania; ANSP MAL 23343. ROMANIA • 38 preserved specimens; Botosani; ANSP MAL 23345. ROMANIA • 33 preserved specimens; Val Marului, Mt Vrancea; A. Grossu leg.; ANSP MAL 442872. ROMANIA • 15 preserved specimens; Val. Marului, Mt Vrancea; ANSP MAL 442873. ROMANIA • 8 preserved specimens; Brosteni 2 Forest; NHMUK ZOO 202000127. ROMANIA • 10 preserved specimens; Predeal 4; J. Feet don.; NHMUK ZOO 202000128. ROMANIA • 15 shells; Hermannstadt, Sibiu; B.M. Pokiysilio leg.; RBINS HIST 48; ROMANIA • 7 preserved specimens; Ciorani-Adjud; SDNHM MarineInvertebrates 87764.

Cochlicopa lubricella (Porro, 1838)

(Fig. 2H; Fig. 6H)

Bulimus lubricus var. lubricella Porro, 1838: 53.

Cionella lubrica var. lubricella Porro, 1838: 53. – Westerlund, 1887: 148.

Achatina collina Drouët, 1855: 152. – Menke, 1830: 29. – Picard, 1840: 149.

Achatina lubrica var. exigua Menke, 1830: 29.

Achatina minima Siemaschko, 1847: 111 (pl.1, fig. 3).

Glandina azorica Albers, 1852: 125.

Cochlicopa (Cochlicopa) collina Drouët, 1855: 152.

Cochlicopa lubrica exigua – Grossu, 1955: 165

Cionella (Ferussacia) pulchella Mousson, 1873: (217–218).

Cochlicopa lubricella Armbruster 1997: 386. – Armbruster & Bernard, 2000: 13.

Type material: not found.

Material examined: ROMANIA • 5 shells; Rudoreasa; 23 June 65; A. Grossu leg.; CMMPO 7775.

Other material from Romania: ROMANIA • 8 preserved specimens; Ciorani-Vrancea, banks of Siret River; ANSP MAL 443110. ROMANIA • 4 preserved specimens; Banks of Mures, Targu, Mures; A. Grossu leg.; ANSP MAL 443111.

Cochlicopa nitens (M. von Gallenstein, 1848)

(Fig. 2I ; Fig. 6I)

Bulimus nitens M. von Gallenstein, 1848: 10.

Bulimus subcylindricus var. *grandis* Moquin-Tandon, 1856: (2) 304. – Stabile, 1864: 72.

Bulimus subcylindricus var. *pachygastra* Stabile, 1864: 72.

Cochlicopa (*Zua*) *lubrica* var. *maxima* Clessin, 1908: 8.

Cochlicopa nitens – Grossu, 1955: 165. – Hudec, 1960: 278. – Ložek, 1958. – Ormio *et al.*, 2016.

Type material: TOPOTYPE of *Cochlicopa lubrica nitens* (M.von Gallenstein, 1848). AUSTRIA • 3 shells; Carinthia; MCZ Mala 155617.

Material examined: ROMANIA • 22 shells; Ciorani-Vrance; 07 May 1956; A. Grossu leg.; CMMPO 7685.

Other material from Romania: ROMANIA • 2 preserved specimens; Sinaia, Lunca r. Prahova; A. Grossu leg.; ANSP MAL 443189.

Family Discidae Thiele, 1931

Genus *Discus* Fitzinger, 1833

Discus ruderatus (W. Hartmann, 1821)

Helix ruderata W. Hartmann, 1821: 231.

Glischrus (Helix) ruderata Studer, 1820: 12.

Discus ruderatus – Kuznik-Kowalska, 2006. – Schileyko & Rymzhanov, 2013: 150 (pl.12; fig. 66); – Čejka, 2022: 743.

Type material: not found.

Material examined: ROMANIA • 1 shell; Jaruspavele; 25 June 1967; A. Grossu leg.; CMMPO 7832.

Other material from Romania: ROMANIA • 3 preserved specimens; Bezirk Hargitha, Heilligen-Anna-See; L. Nemeth leg; ANSP MAL 442973. ROMANIA • 8 preserved specimens; Retezat, Gura Rau; A. Grossu leg; ANSP MAL 442981. ROMANIA • 15 preserved specimens; Cruce, Carpathian Mountains; ANSP MAL 47666. ROMANIA • 10 preserved specimens; Klansenburg, Transylvania; ANSP MAL 65911. ROMANIA • 1 preserved specimen; Transylvania; ANSP MAL 152760. ROMANIA • 8 shells; Cluj-Napoca, Cluj Co, Nord-Vest; CM 629595. ROMANIA • 4 preserved specimens; Carpaths Mts; FMNH 46350. ROMANIA • 2 preserved specimens; Retezat; NHMUK ZOO 202000043. ROMANIA • 1 shell; Særisoara; O.M. Boettger leg.; RBINS INV.92947.

Gonyodiscus perspectivus (Megerle von Mühlfeld, 1816)

(Fig. 6F)

Helix perspectiva Megerle von Mühlfeld, 1816.

Helix (*Patula*) *solaria* Menke, 1830

Discus perspectivus – Kennard & Woodward, 1925: 85–86. – Fukoh, 1997: 70. – Kuznik-Kowalska, 2005: 159 (fig.3). – Kuznik-Kowalska, 2008: (3–4).

Gonyodiscus perspectivus – Salvador *et al.*, 2023: 163.

Type material: not found.

Material examined: ROMANIA • 1 shell; Ciorani-Vrance; 07 May 1956; A. Grossu leg.; CMMPO 7878.

Other material from Romania: ROMANIA • 2 preserved specimens; Bucegi Geb., Val. Peles; A. Grossu leg.; ANSP MAL 442970. ROMANIA • 10 preserved shells; Predeal 4; NHMUK

ZOO 20200044. ROMANIA • 10 preserved specimens; Hermannstadt, Transylvania; C.A. Lund leg.; MZH 113789.

Family Ellobiidae L. Pfeiffer, 1854

Genus *Carychium* O. F. Müller, 1773

Carychium minimum O. F. Müller, 1774

(Fig. 3A; Fig. 6D)

Carychium minimum O. F. Müller, 1774: 125. – Clapp, 1912: 24. – Strauch, 1977: 150. – Weigand *et al.,* 2011: 256. – Weigand *et al.,* 2012: 378. – Weigand *et al.*, 2013: 2–23.

Carychium ovatum F. Sandberger, 1880 †

Type material: Type of *Carychium minimum* O. F. Müller, 1774. [no associated information on country nor specific locality, and number of specimens]; NHMD90782.

Material examined: ROMANIA • 78 shells; Ciorani-Vrance; 23 April 1957; A. Grossu leg.; CMMPO 7858.

Other material from Romania: ROMANIA • 35 preserved specimens; Ciorani-Vrancea, Mare Balta; A. Grossu leg.; ANSP MAL 442874. ROMANIA • 11 preserved specimens; Botosani; ANSP MAL 22517.

Carychium tridentatum (Risso, 1826)

(Fig. 3B; Fig. 6E)

Saraphia tridentata Risso, 1826: 84. – Kuiper, 1956: 2–11.

Carychium tridentatum – Schlesch, 1947: 112. – Weigand *et al.,* 2011: 256. – Weigand *et al.,* 2013: 2-23.

Type material: not found.

Material examined: ROMANIA • 97 shells; Sinaia; 26 July 1935; A. Grossu leg.; CMMPO 7859.

Other material from Romania: ROMANIA • 15 preserved specimens; Transylvania; ANSP MAL 22516. ROMANIA • 7 preserved specimens; Mehadia, Băile , Herculane, Tal des Cerna-Bachs; L. Nemeth leg.; ANSP MAL 442995. ROMANIA • 22 preserved specimens; Ciorani-Vrancea, Mare Balta; ANSP MAL 442996. ROMANIA • 28 preserved specimens; Sibiu, Rasinari; A. Grossu leg.; ANSP MAL 442997. ROMANIA • 10 preserved specimens; Predeal 3; NHMUK ZOO 20200010. ROMANIA • 10 preserved specimens; Predeal 4; NHMUK ZOO

20200011. ROMANIA • 10 preserved specimens; Fenes 3; NHMUK ZOO 20200012. ROMANIA • 10 preserved specimens; Fenes 3; NHMUK ZOO 3. ROMANIA • 10 preserved specimens; Bicaz 2; NHMUK ZOO 20200013. ROMANIA • 10 preserved specimens; Bistra 5 Forest; NHMUK ZOO 20200013. ROMANIA • 2 preserved specimens; Retezat 3; NHMUK ZOO 20200014. ROMANIA • 10 preserved specimens; Bistra 5 Forest; NHMUK ZOO 20200015. ROMANIA • 10 preserved specimens; Banat 28; NHMUK ZOO 202000176.

Family Euconulidae H. B. Baker, 1928

Genus *Euconulus* Reinhardt, 1883

Euconulus fulvus (O. F. Müller, 1774)

Helix fulva O. F. Müller, 1774: 56.

Zonitides fulvus O. F. Müller, 1774: 58. – Taylor, 1883: 28.

Conulus fulvus O. F. Müller, 1774: 56. – Jeffreys, 1830: 332.

Euconulus fulvus Pilsbry, 1908: 25-26. – Stanisic, 1981: 82. – Schileyko & Rymzhanov, 2013: 52. – Horsákova *et al.,* 2020: 149.

Type material: COTYPE of *Helix fulva* O. F. Müller, 1774. UNITED STATES OF AMERICA • 2 shells; Dyea Valley, Alaska; UMMZ-mollusks 033656. PARATYPE. UNITED STATES OF AMERICA • 28 preserved specimens; Dyea Valley, Alaska; CM Mollusks 46780. SYNTYPE of *Conulus fulvus alaskensis* Pilsbry, 1899. UNITED STATES OF AMERICA • 16 preserved specimens; Dyea Valley, Alaska; ANSP MAL 461186. SYNTYPE of *Conulus fulvus alaskensis* Pilsbry, 1899. UNITED STATES OF AMERICA • 1 preserved specimen; Dyea Valley, Alaska; ANSP MAL 59522.

Material examined: ROMANIA • 1 shell; Drăgăşani; 05 June 1972; A. Grossu leg.; CMMPO 7834.

Other material from Romania: ROMANIA • 4 preserved specimens; Corani-Vrancea, aluviani r. Siret; A. Grossu leg; ANSP MAL 442885. ROMANIA • 3 preserved species; Cruce, Carpathian Mountains; ANSP MAL 49144. ROMANIA • 8 preserved specimens; Bicaz 4; NHMUK ZOO 20200042.

Family Orculidae Pilsbry, 1918

Genus *Orcula* Held, 1838

Orcula dolium (Draparnaud, 1801)

(Fig. 3 C)

Pupa dolium Draparnaud, 1801: 58.
Orcula dolium – Schileyko, 1998: 70 (fig.74). – Harl *et al.*, 2014: 2. – Groenenberg *et al.*, 2017: 9.

Type material: not found.
Material examined: ROMANIA • 2 shells; Băile Herculane; 26 May 1959; A. Grossu leg.; CMMPO 7868.
Other material from Romania: ROMANIA • 2 preserved specimens; Ciorani – Vrancea, Aluviuni r. Siret; A. Grossu leg.; ANSP MAL 442942. ROMANIA • 4 shells; Transylvania; UMMZ-Mollusks 014538.

Family Oxychilidae Hesse, 1927
Genus *Mediterranea* Clessin, 1880
Mediterranea inopinata (Uličný, 1887)

Hyalina inopinata Uličný, 1887: 89.
Mediterranea inopinata – Balashov *et al.*, 2018: 6.

Type material: not found.
Material examined: ROMANIA • 1 shell; Orșova; 19 May 1962; A. Grossu leg.; CMMPO 7759.
Other material from Romania: Romania • 1 preserved specimen; Corabia, Crusova; A. Grossu leg.; ANSP MAL 443361.

Family Pristilomatidae Cockerell, 1891
Genus *Vitrea* Fitzinger, 1833
Vitrea diaphana (S. Studer, 1820)
(Fig. 4G–H)

Glischrus (Helix) diaphana S. Studer, 1820: 304.
Helix contorta Held, 1837: 304.
Vitrea diaphana Damjanov & Likharev, 1975: 425.
Vitrea diaphana – Irikov, 2001: 37.

Type material: LECTOTYPE of *Glischrus (Helix) diaphana* S. Studer, 1820. NMBE-WL-15429.

Material examined: ROMANIA • 4 shells; Sinaia; 07 March 39; A. Grossu leg.; CMMPO 7871.

Other material from Romania: ROMANIA • preserved specimen; J. Ubański leg; AMU NHC-ZOO MOLCLAUS-URB-0019637. ROMANIA • preserved specimen; J. Ubański leg; AMU NHC-ZOO MOLCLAUS-URB-0019638. ROMANIA • 3 preserved specimens; Hetau, Transylvania; ANSP MAL 62700.ROMANIA • 3 preserved specimens; Kaltbrunn, Sibiu, Transylvania; ANSP MAL 236756. ROMANIA • 3 preserved specimens; Brasov, Transylvania; ANSP MAL 248095. ROMANIA • 9 preserved specimens; Botosani; ANSP MAL 333325. ROMANIA • 7 preserved specimens; A. Grossu leg.; ANSP MAL 443980. ROMANIA • 17 preserved specimens; Kronstadt, Transylvania; FMNH Invertebrate Zoology 45050. ROMANIA • 7 preserved specimens; Mt Bucses, Transylvania; FMNH Invertebrate Zoology 62388. ROMANIA • 2 shells; Belias's Pass; Transylvania; MCZ Mala 197341. ROMANIA • 10 preserved specimens; Bistra 5, Forest; NHMUK ZOO 20200016. ROMANIA • 10 preserved specimens; Bicaz 4; NHMUK ZOO 20200017. ROMANIA • 10 preserved specimens; Bicaz 1, Forest; NHMUK ZOO 20200018. ROMANIA • 5 shells; Kronstadt, Kapellenberg; MZLH L954/3849. ROMANIA • 5 shells; Sinaia; MCZ MALA 277954.

Vitrea transsylvanica (Clessin, 1877)

Hyalina transsylvanica Clessin, 1877: 133.

Vitrea transsylvanica Dvořák L & Horsak, 2001: 167. – Bank & Neubert, 2017.

Type material: LECTOTYPE of *Vitrea transsylvanica* Clessin, 1877. ROMANIA • Siebenbürgen [Hermannstadt]; SMF Collection Mollusca 45685.

Material examined: ROMANIA • 2 shells; Cheile Bistritei - Valcea (Horezu); 30 August 61; A. Grossu leg.; CMMPO 7874. ROMANIA • 1 shell; Horzen; 30 August 61; A. Grossu leg.; CMMPO 7879.

Other material from Romania: ROMANIA • preserved specimen; J. Urbanski leg. AMU NHC-ZOO MOLCLAUS-URB-0019889. ROMANIA • preserved specimen; J. Urbanski leg. AMU NHC-ZOO MOLCLAUS-URB-0019890. ROMANIA • preserved specimen; J. Urbanski leg. AMU NHC-ZOO MOLCLAUS-URB-0019891. ROMANIA • 3 preserved specimens; Bicaz-defile, w Piatra Neamt; G. Majoros leg; ANSP MAL 443312. ROMANIA • preserved specimen; Neamt, Tanau; A. Grossu leg; ANSP MAL 443312. ROMANIA • 13 preserved specimens; Hermannstadt, Tansylvania; FMNH Invertebrate Zoology 45126. ROMANIA • 2 preserved specimens; Hermannstadt, Tansylvania; FMNH Invertebrate Zoology 69383.

ROMANIA • 3 shells; Pestera Boli nr Petrosani; MCZ 277918. ROMANIA • 15 preserved specimens; Capraret 1; NHMUK ZOO 20200021. ROMANIA • 10 preserved specimens; Predeal 4; NHMUK ZOO 20200022. ROMANIA • 5 preserved specimens; Bicaz 4; NHMUK ZOO 20200023. ROMANIA • 2 preserved specimens; Transylvania; NHMUK ZOO 1898.5.20.13437-13438. ROMANIA • shell; Transylvania; UF Invertebrate Zoology 107466-Mollusca. ROMANIA • 2 shells; Sibiu, Transylvania; UMMZ-mollusks 136253. ROMANIA • 2 shells; Sibiu, Transylvania; UMMZ-mollusks 239106.

Vitrea erjaveci (Brusina, 1870)

Helicella erjaveci Brusina, 1870: 36.

Hyalinia densegyrata M. Kimakowicz, 1890: 37.

Vitrea densigirata – Grossu 1955: 369.

Type material: not found.

Material examined: ROMANIA • 7 shells; Sinaia; 20 March 54; A. Grossu leg.; CMMPO 7880.

Other material from Romania: ROMANIA • 1 preserved specimen; Sinaia, Mt Compatu; A. Grossu leg.; ANSP MAL 443378.

Family Punctidae E. S. Morse, 1864

Genus *Punctum* E. S. Morse, 1864

Punctum pygmaeum (Draparnaud, 1801)

Helix pygmaeum Draparnaud, 1801: 93.

Helix flocculus Morelet, 1858: 8.

Helix schwerzenbachii Calcara, 1841: 90.

Punctum pygmaeum – Baur & Baur, 1988: 375. – Baur, 1989:175. – Hendricks, 2012: 189.

Type material: not found.

Material examined: ROMANIA • 1 shell; Sinaia; 26 Sept 1965; A. Grossu leg.; CMMPO 7880.

Other material from Romania: ROMANIA • 6 preserved specimens; Vrancea, Mt Tisaru; A. Grossu leg.; ANSP MAL 442931. ROMANIA • 10 preserved specimens; Fenes 1, Forest; NHMUK ZOO 20200038. ROMANIA • 10 preserved specimens; Predeal 3; NHMUK ZOO 20200039. ROMANIA • 2 preserved specimens; Retezat 3; NHMUK ZOO 20200040.

ROMANIA • 10 preserved specimens; Bicaz 4; NHMUK ZOO 20200041. ROMANIA • 10 preserved specimens; Banat 28; NHMUK ZOO 2020000175. ROMANIA • 1 shell; Transylvania; ZMA.MOLL.389386.

Family Pupillidae W. Turton, 1831

Genus *Pupilla* J. Fleming, 1828

Pupilla alpicola (Charpentier, 1837)

(Fig. 3D; Fig. 6J)

Pupa (Sphyradium) alpicola Charpentier, 1837: 16 (pl. 2, fig. 5).

Pupa muscorum pratensis Clessin, 1871: 101.

Pupilla alpicola – Horsák *et al.*, 2010. – Bank & Neubert, 2017.

Type material: SYNTYPE of *Pupa (Sphyradium) alpicola* Charpentier, 1837. SWITZERLAND • 20 preserved specimens; Bagnes, Mauvoisin, Le Giétro; MZL-INVERT-68472.

Material examined: ROMANIA • 12 shells; Băile Herculane; 17 Oct 1958; A. Grossu leg.; CMMPO 7845.

Other material from Romania: ROMANIA • 17 preserved specimens; Bucegi-Geb., Babele; A. Grossu leg.; ANSP MAL 443107. ROMANIA • 5 preserved specimens; Bucegi-Geb., Bucura Dumbava; ANSP MAL 443108.

Pupilla muscorum (Linnaeus, 1758)

(Fig. 3E; Fig. 6K)

Turbo muscorum Linnaeus, 1758: 767.

Pupa badia Adams, 1840: 331 (pl. 3, fig. 18).

Pupa muscorum lundstroemi Westerlund, 1876: 98.

Pupa muscorum caucasia O. Boettger, 1880: 399.

Pupa muscorum asiatica Möllendorff, 1902: 381.

Pupilla muscorum – Schileyko, 1998: 111. – von Proschwitz, 2009: 316 (fig. 1).

Type material: COTYPE of *Pupa muscorum var caucasica*. RUSSIA • Michailowo, on the Kura River, Caucasia; UF Invertebrate Biology 113136 – Mollusca. SYNTYPE of *Pupa badia* C.B. Adams, 1840. UNITED STATES OF AMERICA • 1 preserved specimen; New York,

Essex, Crown Point; MCZ Mala 247405. UNITED STATES OF AMERICA • 45 shells; New York, Essex, Crown Point; MCZ Mala 247406.

Material examined: ROMANIA • 62 shells; Ciorani-Vrance; 08 June 1958; A. Grossu leg.; CMMPO 7848.

Other material from Romania: ROMANIA • 25 preserved specimens; Hermannstadt, Transylvania; ANSP MAL 22708. ROMANIA • 26 preserved specimens; Fogarasek; Transylvania; ANSP MAL ROMANIA • 10 preserved specimens; Cheile Turzii, Transylvania; ANSP MAL 442863. ROMANIA • 5 preserved specimens; Mehadia, Băile Herculane, Hotel Romania; ANSP MAL 442864. ROMANIA • 29 preserved species; B. Herculane, Val Cernei; ANSP MAL 442865. ROMANIA • 3 shells; Sinaia, SE Prahova Co., Mt Bucegi Prahova; DMNH Mollusk 82587. ROMANIA • 2 preserved specimens; Hermannstadt, Transylvania; FMNH Invertebrate Zoology 48432. ROMANIA • 8 preserved specimens; Fogarasch [=Fagaras]; FMNH Invertebrate Zoology 48581. ROMANIA • 18 preserved specimens; Fogarasch, Transylvania; FMNH Invertebrate Zoology 103601. ROMANIA • 8 preserved specimens; Fogarasch; FMNH Invertebrate Zoology 160798. ROMANIA • preserved specimen; LMD 257881. ROMANIA • 2 preserved shells; Transylvania; NHMUK ZOO 1898.5.20.2826-2827.

Pupilla sterri (von Voith, 1838)

(Fig. 6L)

Pupa sterri Voith, 1840: 459.

Pupilla wolfae Tzvetkov, 1940: 384.

Pupilla sterri – Pokryszko *et al.*, 2009: 439. – Schileyko, 1998: 111 (fig. 127).

Type material: not found.

Material examined: ROMANIA • 1 shell; Retezat; 26 Oct 1967; A. Grossu leg.; CMMPO 7883.

Other material from Romania: ROMANIA • 15 preserved specimens; Bucegi Geb, Curmatura Jepi; A. Grossu leg.; ANSP MALA 443118. ROMANIA • 2 preserved specimens; Thorda-Schlucht, near Klausenburg, Transylvania; FMNH Invertebrate Zoology 48541. ROMANIA • 1 preserved specimen; Thorda-Schlucht, near Klausenburg, Transylvania; J. Gerber leg.; FMNH Invertebrate Zoology 296645.

Genus *Gibbulinopsis* Germain, 1919

Gibbulinopsis pupula (Deshayes, 1863)

(Fig. 3F)

Pupa pupula Deshayes, 1863: 92 (pl. 11, figs 2–4).

Costigo borbonica H. Adams, 1868: 290 (pl. 28, fig. 8).

Vertigo (Alaea) borbonica H. Adams, 1868: 290 (pl. 28, fig. 8).

Gibbulinopsis pupula – Schileyko, 1998: 107, fig. 121. – Griffiths & Florens, 2006: 83.

Type material: not found.

Material examined: ROMANIA • 5 shells; Piatra Craiului Mountains (Munții Piatra Craiului) 18 Oct 1959; A. Grossu leg.; CMMPO 7864.

Other material from Romania: not found.

Family Pyramidulidae Kennard & B. B. Woodward, 1914

Genus *Pyramidula* Fitzinger, 1833

Pyramidula rupestris (Draparnaud, 1801)

(Fig. 4I–J ; Fig. 6M)

Helix rupestris Draparnaud, 1801 : 71 (pl. 8, fig. 7-9).

Helix rupestris – Rossmassler, 1838: 2 (fig. 534). – Bielz, 1867: 51.

Helix umbilicata Montagu, 1803: 434 (pl. 13, fig. 2).

Delomphalus saxatilis Hartmann, 1842: 122 (pl. 37, fig. 4-6).

Patula rupestris – Clessin, 1885: 123 (fig. 60).

Pyramidula rupestris – Grossu, 1955: 169 (fig. 66). – Gittenberger & Bank, 1996: 76. – Sysoev & Schileyko, 2009: 56. – Horsákova *et al.*, 2022: 233–260.

Type material: not found.

Material examined: ROMANIA • 118 shells; Băile Herculane; 12 July 1973; A. Grossu leg.; CMMPO 7860.

Other material from Romania: ROMANIA • 31 preserved specimens; Cheile Turzii (Tordaer Tal), Transylvania; L. Nemeth leg.; ANSP MAL 442943. ROMANIA • 11 preserved specimens; Bihar-Gergibe, Girda, Valea Ordineusa, Transylvania; L. Nemeth leg.; ANSP MAL 442944. ROMANIA • 6 preserved specimens; Brassov-Poina, Postvarul; L. Nemeth leg.; ANSP MAL 442945. ROMANIA • 21 preserved specimens; Mehadia, Băile Herculane, near Hotel Romania; L. Nemeth leg.; ANSP MAL 442946. ROMANIA • 3 preserved specimens; Cerna-Tal, Băile Herculane; L. Nemeth leg.; ANSP MAL 442947. ROMANIA • 38 preserved

specimens; Bucegi-Geb., Piatra Arsa; A. Grossu leg.; ANSP MAL 442948. ROMANIA • 28 preserved specimens; Sinaia, Val. Peles; L. Nemeth leg.; ANSP MAL 442949. ROMANIA • 5 preserved specimens; Transylvania; ANSP MAL 47682. ROMANIA • 2 preserved specimens; Chiele-Bicazului, Transylvania; ANSP MAL 244237. ROMANIA • 13 preserved specimens; Petroszeny, Transylvania; FMNH 69369. ROMANIA • 6 shells; Transylvania; MCZ MALA 17467. ROMANIA • 8 shells; Bukowina, Rarcu; MCZ Mala 64801.

Family Spelaeodiscidae Steenberg, 1925

Genus *Aspasita* Westerlund, 1889

Aspasita triaria (Rossmässler, 1839)

(Fig. 4K–L)

Helix triaria Rossmässler, 1839: 9-10 (fig. 611).

Aspasita triaria – Schileyko, 1998: 92 (fig. 101). – Sunai & Dedov, 2008: 115 (fig. 1-6). – Domokos & Páll-Gergely, 2021: 127.

Type material: LECTOTYPE of *Helix triaria* Rossmässler, 1839. ROMANIA • Banat, Berg Domokled bei Mehadia; SMF – Collection Mollusca 5065.

Material examined: ROMANIA • 41 shells; Ceahlău, Neamț; 20 May 1967; A. Grossu leg.; CMMPO 7861.

Other material from Romania:

ROMANIA • 19 preserved specimens; Transylvania; ANSP MAL 4840. ROMANIA • 2 preserved specimens; Transylvania; ANSP MAL 8226. ROMANIA • 5 preserved specimens; 65930. ROMANIA • 2 preserved specimens; Petroseny, Transylvania; ANSP MAL 65931. ROMANIA • 2 preserved specimens; Schielthal, Transylvania; ANSP MAL 65932. ROMANIA • 2 preserved specimens; Transylvania; ANSP MAL 30828. ROMANIA • 1 preserved specimen; Transylvania; ANSP MAL 238617. ROMANIA • 3 preserved specimens; Ravine of Torda, Transylvania; ANSP MAL 238619. ROMANIA • 2 preserved specimens; Lotriora Valley, Vorostornyi Pass, Transylvania; ANSP MAL 248153. ROMANIA • 10 preserved specimens; Băile Herculane, Banat; ANSP MAL 295161. ROMANIA • 7 preserved specimens; Băile Herculane, Banat; ANSP MAL 338074. ROMANIA • 4 preserved specimens; Erdely, Girda de Sus (Alsogirda), Ordincus-Voelgy; ANSP MAL 442852. ROMANIA • 4 preserved specimens; Judetul Bihor, Transylvania; L. Nemeth leg.; ANSP MAL 443130. ROMANIA • 3 preserved specimens; South Karpaten, Runcu, Cheile, Sohodol; L. Nemeth leg.; ANSP MAL 443131. ROMANIA • 4 preserved specimens; Mehadia, Băile Herculane, Cerna-

Tal; ANSP MAL 443132. ROMANIA • 10 preserved specimens; Mehadia, Băile Herculane, near Hotel Romania; L. Nemeth leg.; ANSP MAL 443133. ROMANIA • 21 preserved specimens; Cerna-Valley, Băile Herculane; A. Grossu leg.; ANSP MAL 443134. ROMANIA • 19 preserved specimens; Closani-Mehed, Val. Motru; A. Grossu leg.; ANSP MAL 443136. ROMANIA • 5 preserved specimens; Banatus; FMNH invertebrate zoology 48689. ROMANIA • 12 preserved specimens MT. Domoglet (Aufstieg) B. Herkules, Banatus; FMNH invertebrate zoology 48690. ROMANIA • 1 preserved specimen; Cerna-Valley, Transylvania; FMNH invertebrate zoology 48691. ROMANIA • 1 preserved specimen; Unter Vidra, Transylvania; FMNH invertebrate zoology 48755. ROMANIA • 8 preserved specimens; Mehadia, Banatus; FMNH invertebrate zoology 69363. ROMANIA • 9 preserved specimens; Banatus; FMNH invertebrate zoology 93741. ROMANIA • 9 preserved specimens; Domoglet, Banatus; FMNH invertebrate zoology 93690. ROMANIA • 2 preserved specimens; Herkulesbad, Siebenbürgen; W. Blume leg.; FMNH invertebrate zoology 216302. ROMANIA • 2 preserved specimens; Hercules-Bad, Renat; J. Gerber leg.; FMNH invertebrate zoology 217499. ROMANIA • preserved specimen; HNS 1883382. ROMANIA • preserved specimen; Băile Herculane; HNS 2475621. ROMANIA • shell; Govajdia Ghelari Vest Hunedoara; MCNB-Malac MZB 80-8440. ROMANIA • shell; Băile Herculane, Caras-Severin, Vest; MCNB-Malac MZB 80-8441. ROMANIA • shell; Băile Herculane, Caras-Severin, Vest; MCNB-Malac MZB 80-8442. ROMANIA • 2 preserved specimens; Mehadia; C.A. Westerlund leg.; MZH HLA.113865. ROMANIA • 2 preserved specimens; Siebenbürgen, Transylvania; MZLU Evertebrata L874/3038. ROMANIA • 7 preserved specimens; Transylvania; NHMUK ZOO 1898.5.20.14870-14876. ROMANIA • 2 preserved specimens; Siebenburgen, Transylvania; NHMUK ZOO 1924.5.28.7-8. ROMANIA • 10 preserved specimens; Fenes 3; NHMUK ZOO 202000129. ROMANIA • 10 preserved specimens; Banat 8 Forest; NHMUK ZOO 202000166. ROMANIA • 10 preserved specimens; Banat 20; NHMUK ZOO 202000167. ROMANIA • 1 shell; Scærisoara; O. Boettger leg.; RBINS INV-MOL Hist.59. ROMANIA • 16 preserved specimens; Băile Herculane, Banat; SDNHM MarineInvertebrates 87770.

ROMANIA • preserved specimen; Banat, Băile Herculane; SNSD Collection Malakologie 33891-MTD. ROMANIA • preserved specimen; Gyalui Mountains, Cheile Runcu; SNSD Collection Malakologie 36883-MTD. ROMANIA • shell; Ciresu, Tolponita Cave, Mehedinti Dist.; UF invertebrate zoology 76997-Mollusca. ROMANIA • 17 shells; Banat, Băile Herculane; UF invertebrate zoology 462551-Mollusca. ROMANIA • 3 shells; Transylvania; UF 489807-Mollusca. ROMANIA • 1 shell; Transylvania; UMMZ-mollusks 015558. ROMANIA • 1 shell; Transylvania; UMMZ-mollusks 015559. ROMANIA • 2 shells;

Transylvania; UMMZ-mollusks 151921. ROMANIA • 4 shells; Transylvania; UMMZ-mollusks 151922. ROMANIA • 3 shells; UMMZ-mollusks 242284. ROMANIA • 8 shells; Mehadia, Banatus, Caras-Severin; fossil specimen; UT 2228.

Family Succineidae Beck, 1837

Succinella Mabille, 187

Succinella oblonga (Draparnaud, 1801)

(Fig. 3H)

Succinea oblonga Draparnaud, 1801: 56–59 (pl. 3, fig. 24).

Succinea oblonga – Bielz, 1867: 38. – Rossmässler, 1835: 1 (fig. 47).

Succinea paludinaeformis F. Sandberger, 1873: 1–2 (pl. 35, fig. 16).

Succinea oblonga schumacheri Andreae, 1884: 67–68 (pl. 2, fig. 96–100).

Lucena oblonga – Clessin, 1885: 349 (fig. 206).

Succinella oblonga – Kiauta & Butot, 1968: 9. – Sysoev & Schileyko, 2009: 20. – Schileyko & Rymzhanov, 2013: 315.

Type material: not found.

Material examined: ROMANIA • 11 shells; Ceahlău, Neamţ; 13 April 1967; A. Grossu leg.; CMMPO 7761.

Other material from Romania: ROMANIA • 4 preserved specimens; Hermanstadt, Transylvania; ANSP MAL 23573. ROMANIA • 4 preserved specimens; Girda, Valea Ordincusa, Transylvania; L. Nemeth leg.; ANSP MAL 442950. ROMANIA • 9 preserved specimens; Ceahlau (in Loess); ANSP MAL 442951. ROMANIA • 4 preserved specimens; Rasarea – Ilfou, Mt Pustnicul; ANSP MAL 442952. ROMANIA • 1 shell; Transylvania; UMMZ-mollusks 123065.

Family Valloniidae E. S. Morse, 1864

Genus *Vallonia* Risso, 1826

Vallonia costata (O. F. Müller, 1774)

(Fig. 4C–D)

Helix costata O. F. Müller, 1774: 31.

Helix arenella Montagu, 1803: 441 (pl. 8, fig. 3).

Helix pulchella costata – Moquin-Tandon, 1855: 140 (pl. 11, fig. 32-33).

Vallonia jurassica Geyer, 1908: 34 (pl.13, fig. 13-14).

Vallonia costata – Clessin, 1885: 130 (fig. 64). – Kimakowicz, 1890: 44. – Grossu, 1955: 210 (fig. 102). – Sysoev & Schileyko, 2009: 39. – Nicolai & Forsyth, 2021: 290 (fig. 1).

Type material: SYNTYPE of *Vallonia jurassica* Geyer, 1908. GERMANY • 3 preserved specimens; Urach, Wurttemberg; ANSP MAL 248156. SYNTYPE of *Vallonia jurassica* Geyer, 1908. GERMANY • 1 shell; Bad Urach; CM 62.16728. PARALECTOTYPE of *Vallonia jurassica* Geyer, 1908. GERMANY • 3 shells; RMNH.MOL.335021.

Material examined: ROMANIA • 23 shells; Sinaia; 7 August 1939; A. Grossu leg.; CMMPO 7646.

Other material from Romania: ROMANIA • preserved specimen; Constanta, nahe dem Hafen; LI ZOBODAT 102130738. ROMANIA • 9 preserved specimens; Mehadia, Băile Herculane, Hotel Romania; L. Nemeth leg.; ANSP MAL 442898. ROMANIA • 44 preserved specimens; Valea Cerna, Băile Herculane; A. Grossu leg.; ANSP MAL 442900. ROMANIA • 18 preserved specimens; Cheile Dambovicoare, Rucar; A. Grossu; ANSP MAL 442903. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016182. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016230. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016209. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016210. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016212. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016213. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016214. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016215. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016216. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016217. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016218. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016219. ROMANIA • 1 preserved specimen; Petroszeny, Transylvania; FMNH Invertebrate Zoology 295802. ROMANIA • 10 preserved specimens; Hermannstadt, Transylvania; C.A. Westerlund leg.; MZH HLA.113299. ROMANIA • 10 shells; Transylvania; NMNH IZ USNM 510995.

Vallonia pulchella (O. F. Müller, 1774)

(Fig. 4E–F; Fig. 6N)

Helix pulchella O. F. Müller, 1774: 30.

Helix adela Westerlund, 1874: 57, (pl.2 figs 1–4).

Vallonia pulchella – Whitney, 1937: 209 – Biggs, 1962: 68. – Sysoev & Schileyko, 2009: 41. – Kunakh *et al.,* 2018.

Type material: SYNTYPE of *Helix pulchella* O.F. Müller, 1774. PORTUGAL • 1 shell; RMNH.MOL.295444. LECTOTYPE of *Vallonia pulchella* (O.F. Müller, 1774). UNITED STATES OF AMERICA • preserved specimen; Staten Insland, New York; ANSP MAL 10080. PARALECTOTYPE of *Helix adela* Westerlund, 1874. SWEDEN • 5 preserved specimens; Ystad; NRM EVType Type-5229.

Material examined: ROMANIA • 3 shells; Pantelimon, Bucharest; 12 Nov 1934; A. Grossu leg.; CMMPO 7696.

Other material from Romania: ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016183. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016184. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016185. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016222. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016223. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016224. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016225. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016226. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016227. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016228. ROMANIA • preserved specimen; J. Urbański leg.; AMU NHC-ZOO MOLCLAUS-URB-0016229. ROMANIA • 1 preserved specimen; Botosani; ANSP MAL 22618. ROMANIA • 8 preserved specimens; Hermanstadt, Transylvania; ANSP MAL 22619. ROMANIA • 3 preserved specimens; Hermanstadt, Transylvania; ANSP MAL 22633. ROMANIA • 2 preserved specimens; Brosteni; ANSP MAL 22633. ROMANIA • 1 preserved specimen; Botosani; ANSP MAL 22643. ROMANIA • 14 preserved specimens; Botosani; ANSP MAL 22644. ROMANIA • preserved specimen; Fogaoasek, Transylvania; ANSP MAL 65935. ROMANIA • 43 preserved specimens; Ciorani – Vrancea, Siret River; A. Grossu leg.; ANSP MAL 443901. ROMANIA • 42 preserved specimens; Bucurest, Pantelimoz; A. Grossu leg.; ANSP MAL 443904. ROMANIA • 1 shell; Transylvania Alps; BMSM 122703. ROMANIA • 10 preserved specimens; Fogaras, Transylvania; FMNH 75717. ROMANIA •

preserved specimen; Crisan-See; LI ZOBODAT 102131432. ROMANIA • preserved specimen; Constanta, nahe dem Hafen; LI ZOBODAT 102131490. ROMANIA • 6 preserved specimens; Siebenbürgen, Transylvania; MZH HLA.118286. ROMANIA • 9 shells; Siebenbürgen, Transylvania; RBINS INV-MOL Hist.10. ROMANIA • 20 shells; Girelsau, Transylvania; RBINS INV-MOL Hist.15.

Vallonia tenuilabris (A. Braun, 1843)

(Fig. 4M–N)

Helix pulchella tenuilabris A. Braun, 1843: 143.

Vallonia tenuilabris – Yen, 1939: 77; – Sysoev & Schileyko, 2009: 41.

Type material: PARALECTOTYPE of *Vallonia tenuilabris* (A. Braun, 1843). GERMANY • 2 preserved specimens; CM Mollusks 62.28323.

Material examined: ROMANIA • 18 shells; Ceahlău, Neamţ; 7 August 1968; A. Grossu leg.; CMMPO 7872.

Other material from Romania: ROMANIA • 33 preserved specimens; Ceahlau, Neamt; ANSP MAL 443152.

Family Vitrinidae Fitzinger, 1833

Genus *Oligomax* P. Fischer, 1878

Oligolimax annularis (Studer, 1820)

Glischrus (Hyalina) annularis Studer, 1820: 11.

Vitrina plicosa Bielz, 1867: 35.

Helicolimax annularis – Grossu, 1955: 388 (fig. 219).

Phenocolimax conoidea Daminanov & Likharev, 1975: 251.

Phenocolimax annularis – Daminanov & Likharev, 1975: 252 (fig. 176-177).

Oligolimax annularis – Sysoev & Schileyko, 2009: 137 (fig. 71E). – Bank & Neubert, 2017.

Type material: LECTOTYPE of *Glischrus* (*Hyalina*) *annularis* S. Studer, 1820. [There is no location information published for this record]; NMBE-WL-15396.

Material examined: ROMANIA • 1 shell; Piatra Craiului Mountains (Munții Piatra Craiului); 15 August 39; A. Grossu leg.; CMMPO 7745.

Other material from Romania: not found.

Genus *Vitrina* Draparnaud, 1801

Vitrina pellucida (O. F. Müller, 1774)

(Fig. 4A–B; Fig. 6O)

Helix pellucida O. F. Müller, 1774: 15.

Helix limacoides von Alten, 1812: 85 (Fig. 20).

Helix elliptica T. Brown, 1818: 525 (pl. 24, Fig. 8).

Vitrina alpina Gredler, 1856: 38.

Vitrina servainiana Saint-Simon, 1870: 20.

Vitrina hiemalis C. Koch, 1876: 218.

Vitrina globosa O. Boettger, 1880: 115.

Vitrina pellucida var. *brunnensis* Uličný, 1883: 202.

Vitrina bielzi Kimakowicz, 1890: 25.

Vitrina alaskana Dall, 1905: 37.

Vitrina pellucida – Sysoev & Schileyko, 2009: 137.

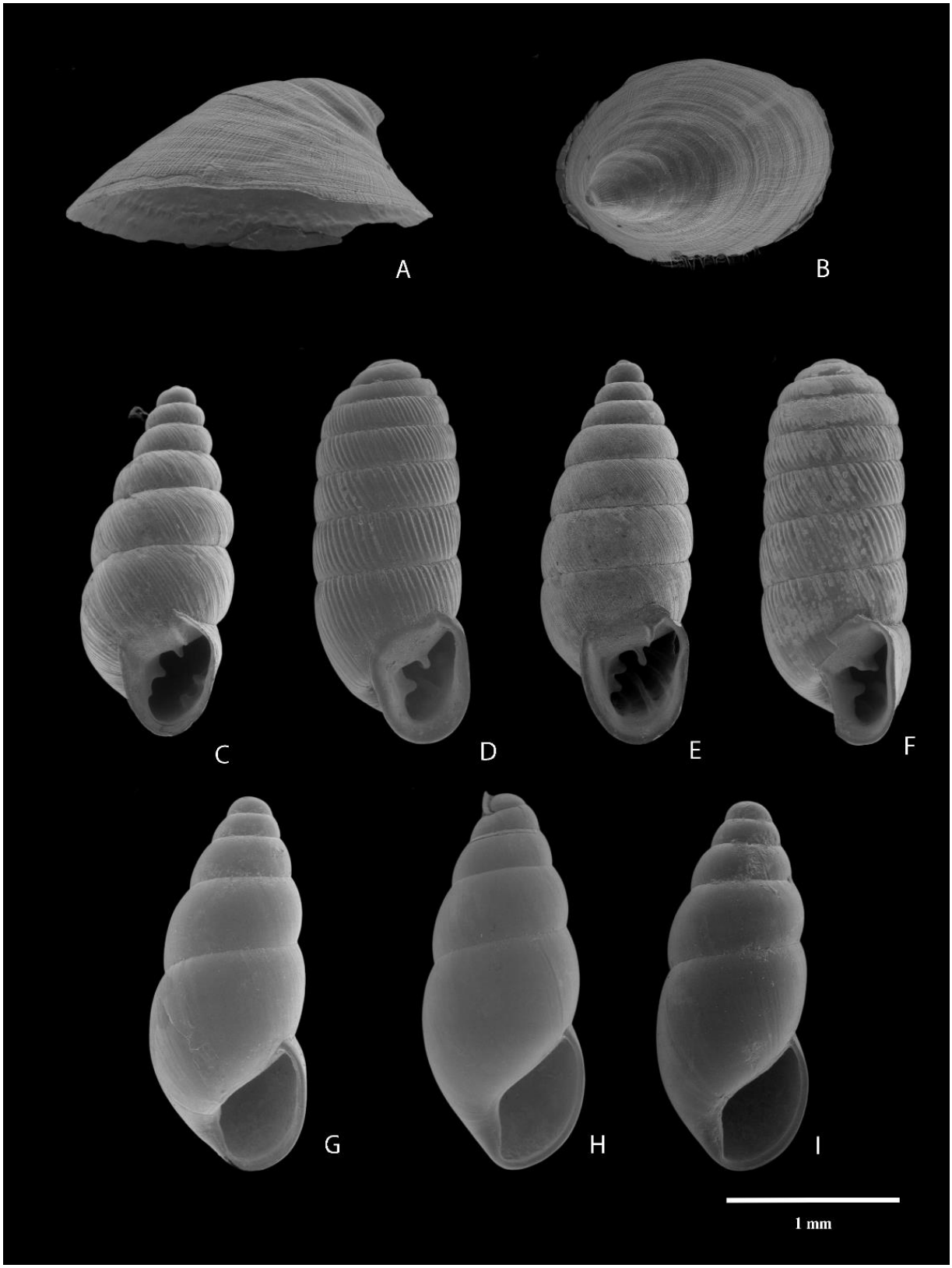
Type material: HOLOTYPE of *Helix pellucida* O. F. Müller, 1774. DENMARK • WoRMS Editorial Board dr_id_1490834. NEOTYPE of *Vitrina pellucida* (O. F. Müller, 1774). DENMARK • 1 shell; Frederiksdae, Nordsjeelland; NHMD 90680. SYNTYPE of *Vitrina pellucida* (O. F. Müller, 1774). UNITED STATES OF AMERICA • 6 preserved specimens; Nevada; PRI 10318. COTYPE of *Vitrina pellucida* (O. F. Müller, 1774). FINLAND • 1 shell; RBINSMT.2070. SYNTYPE of *Vitrina globosa* O. Boettger, 1880. GEORGIA • 1 preserved specimen; Tbatani, Transcaucasia; ANSP MAL 248067. LECTOTYPE of *Vitrina globosa* O. Boettger, 1880. GEORGIA • Trankaukasien, Tbatani; SMF Collection Mollusca 107222. PARALECTOTYPE of *Vitrina globosa* O. Boettger, 1880. SYNTYPE of *Vitrina pellucida* var. *brunnensis* Uličný, 1883. CZECHIA • Brünn; SMF Collection Mollusca 106610. GEORGIA • Trankaukasien, Tbatani; SMF Collection Mollusca 107223. SYNTYPE of *Vitrina pellucida* var. *brunnensis* Uličný, 1883. CZECHIA • Brünn; SMF Collection Mollusca 169772. SYNTYPE of *Vitrina pellucida* var. *brunnensis* Uličný, 1883. CZECHIA • Brünn; SMF Collection Mollusca 169773. LECTOTYPE of *Vitrina hiemais* C. Koch, 1876. AUSTRIA • Rothmoosferner bei Obergurgl; SMF Collection Mollusca 150655.

Material examined: ROMANIA • 1 Shell; Retezat; 9 May 1964; A. Grossu leg.; CMMPO 7865.

Other material from Romania: ROMANIA • 6 preserved specimens; Transylvania; ANSP MAL 4800. ROMANIA • 1 preserved specimen; Cheile Turzii; ANSP MAL 443906.

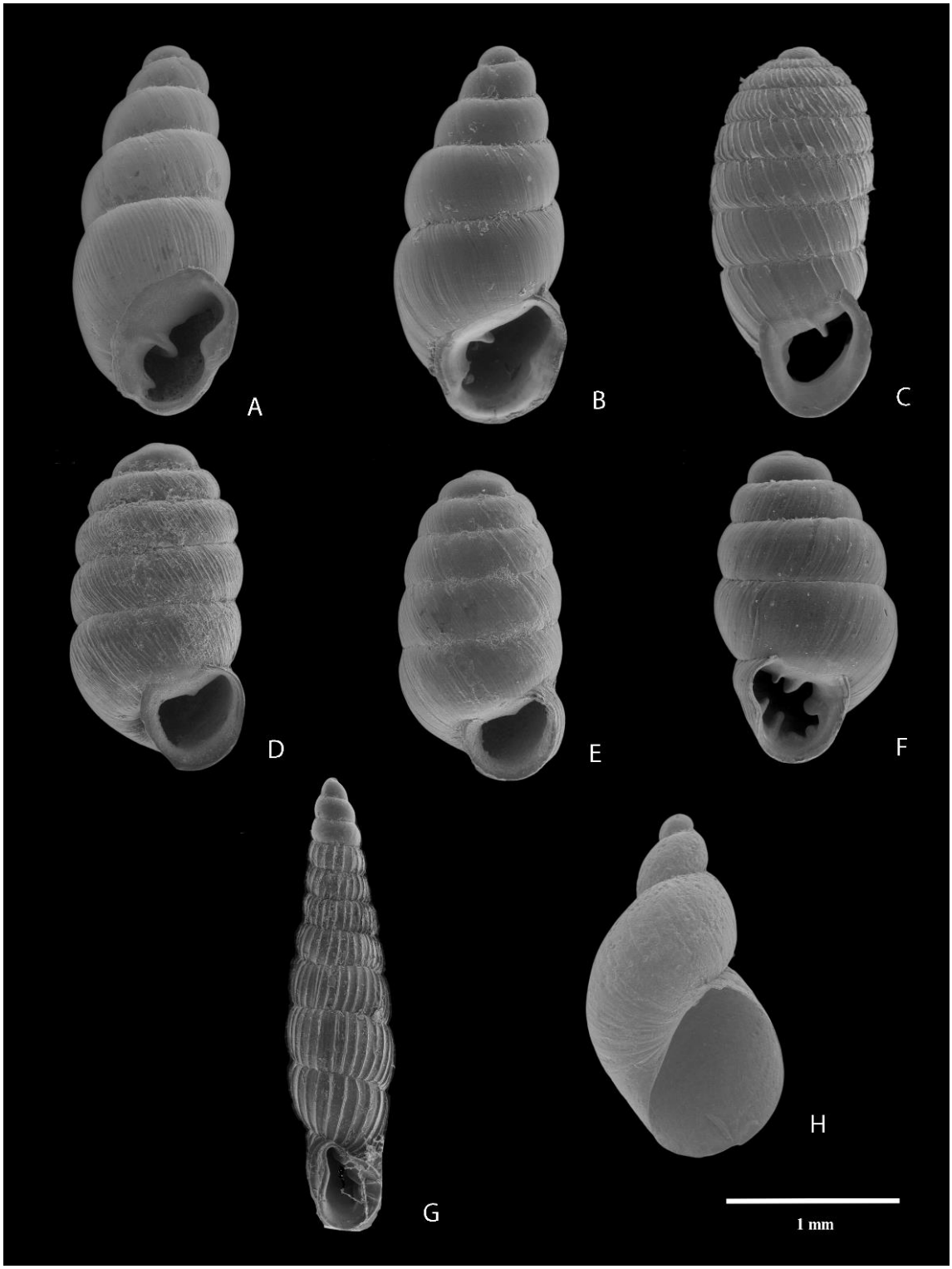
ROMANIA • 10 preserved specimens; Hermannstadt, Transylvania; ANSP MAL 48775. ROMANIA • 5 preserved specimens; Klanenburg, Siebenbingen; ANSP MAL 66022. ROMANIA • 5 preserved specimens; Hermannstadt, Transylvania; FMNH Invertebrate Zoology 44523. ROMANIA • 10 preserved specimens; Retezat 4; NHMUK ZOO 20200054. ROMANIA • 10 preserved specimens; Fenes1, Forest; NHMUK ZOO 20200055. ROMANIA • 3 shells; Siebenbürgen, Transylvania; RBINS INV.109039.

Figure 2. Scanning electron micrographies of the shells of microgastropods from Romania housed in the Malacological Collection Maury Pinto de Oliveira. **A** and **B**. *Ancylus fluviatilis* O. F. Müller, 1774 (Planorbidae). **C.** *Chondrina arcadica clienta* (Westerlund, 1883) (Chondrinidae); **D.** *Argna bielzi* (Rossmässler, 1859) (Argnidae); **E.** *Granaria frumentum* (Draparnaud, 1801) (Chondrinidae); **F.** *Alinda stabilis* (L. Pfeiffer, 1847) (Clausillidae); **G.** *Cochlicopa lubrica* (O. F. Müller, 1774) (Cochlicopidae); **H.** *Cochlicopa lubricella* (Porro, 1838) (Cochlicopidae); **I.** *Cochlicopa nitens* (M. von Gallenstein, 1848) (Cochlicopidae). Scale bar: 1mm.



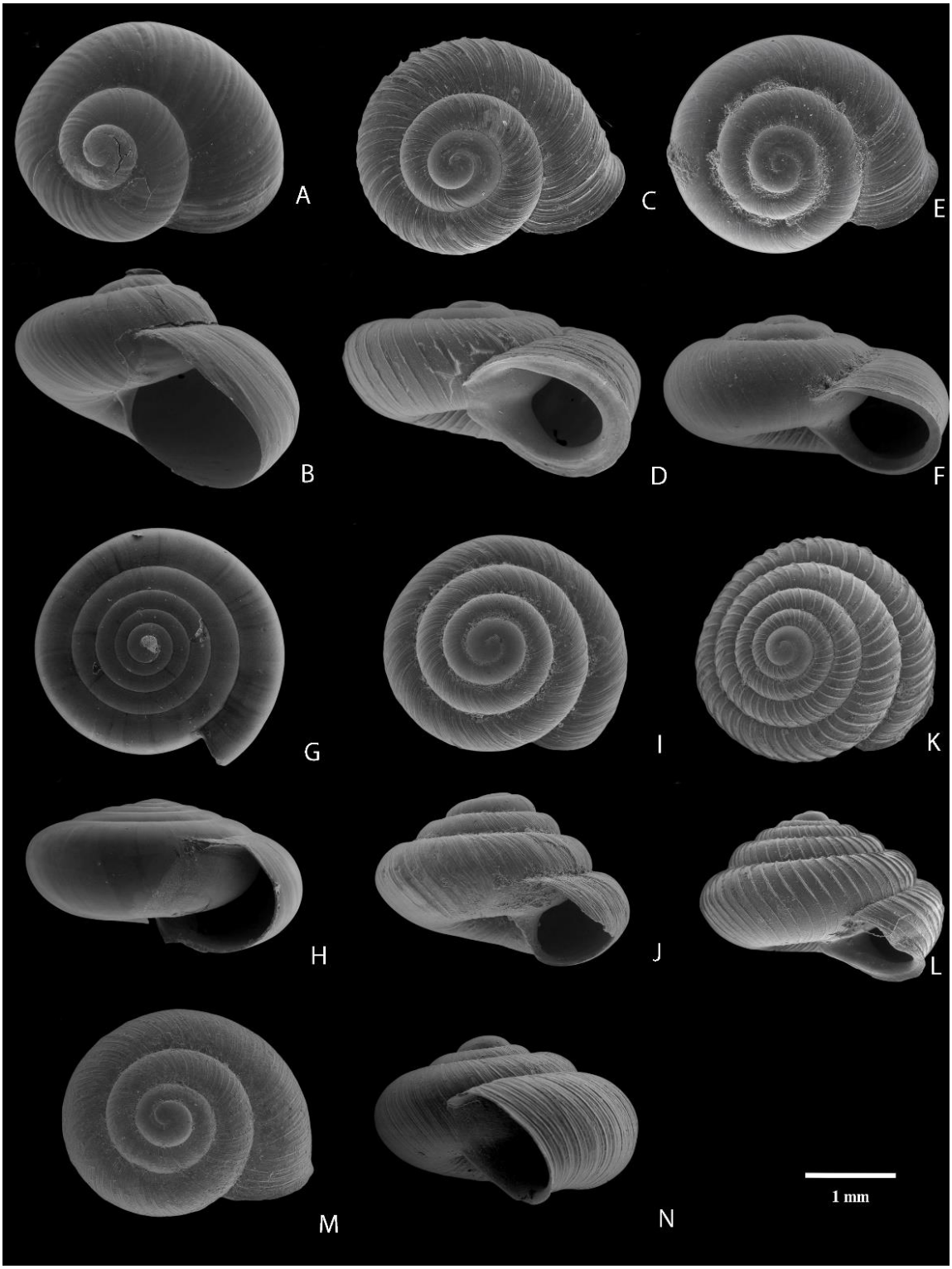
Source: Prepared by the author (2023)

Figure 3. Scanning electron micrographies of the shells of microgastropods from Romania housed in the Malacological Collection Maury Pinto de Oliveira. **A.** *Carychium minimum* O. F. Müller, 1774 (Ellobiidae); **B.** *Carychium tridentatum* (Risso, 1826) (Ellobiidae); **C.** *Orcula dolium* (Draparnaud, 1801) (Orculidae); **D.** *Pupilla alpicola* (Charpentier, 1837) (Pupillidae); **E.** *Pupilla muscorum* (Linnaeus, 1758) (Pupillidae); **F.** *Gibbulinopsis pupula* (Deshayes, 1863) (Pupillidae); **G**. *Ruthenica filograna* (Rossmässler, 1836) (Clausillidae); **H**. *Succinella oblonga* (Draparnaud, 1801) (Succineidae). Scale bar:1mm.



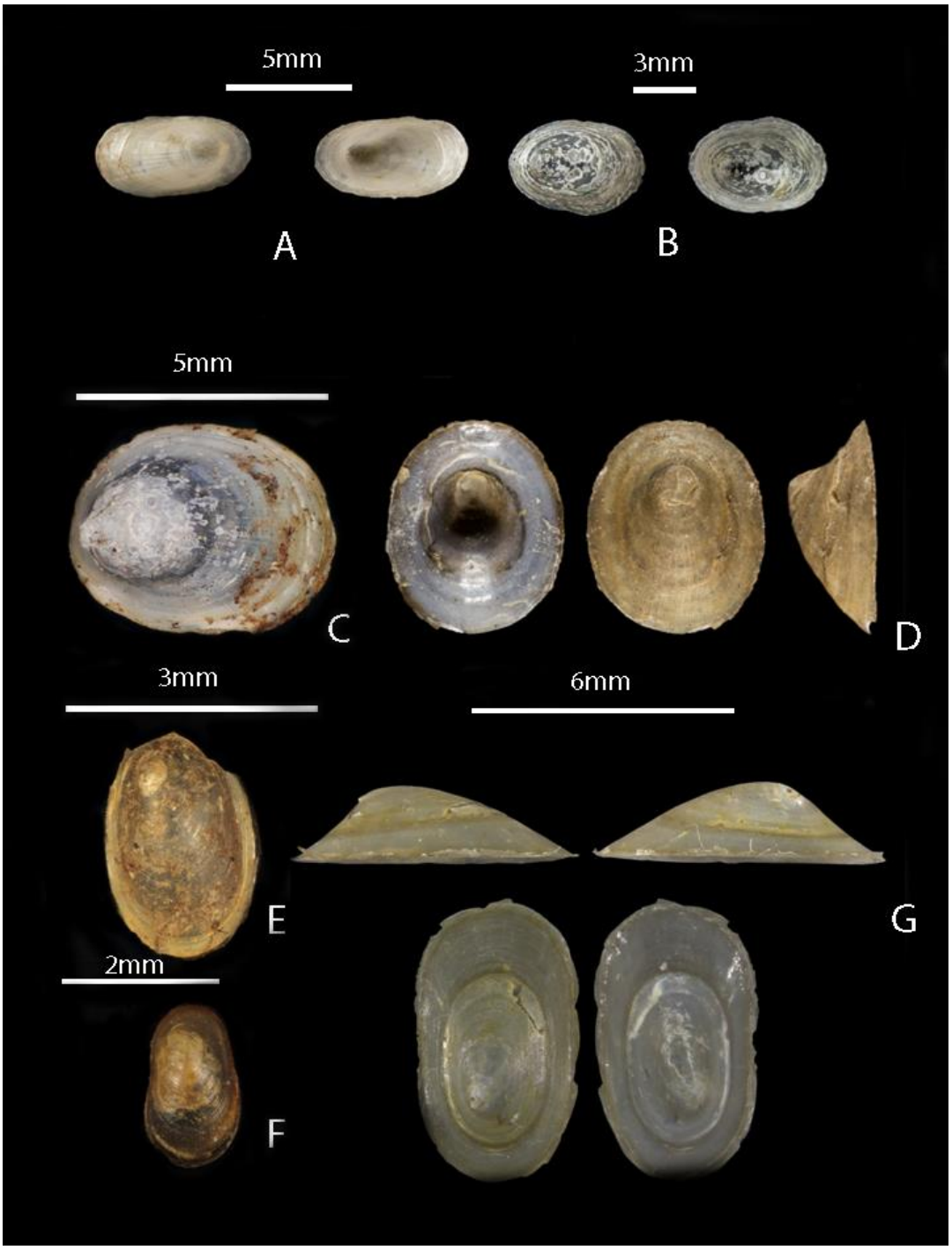
Source: Prepared by the author (2023)

Figure 4. Scanning electron micrographies of the shells of microgastropods from Romania housed in the Malacological Collection Maury Pinto de Oliveira. **A** and **B**. *Vitrina pellucida* (O. F. Müller, 1774) (Vitrinidae); **C** and **D**. *Vallonia costata* (O. F. Müller, 1774) (Valloniidae); **E** and **F**. *Vallonia pulchella* (O. F. Müller, 1774) (Valloniidae); **G** and **H**. *Vitrea diaphana* (S. Studer, 1820) (Pristilomatidae); **I** and **J**. *Pyramidula rupestris* (Draparnaud, 1801) (Pyramidulidae); **K** and **L**. *Aspasita triaria* (Rossmässler, 1839) (Spelaeodiscidae); **M** and **N**. *Vallonia tenuilabris* (A. Braun, 1843) (Valloniidae). Scale bar:1mm.



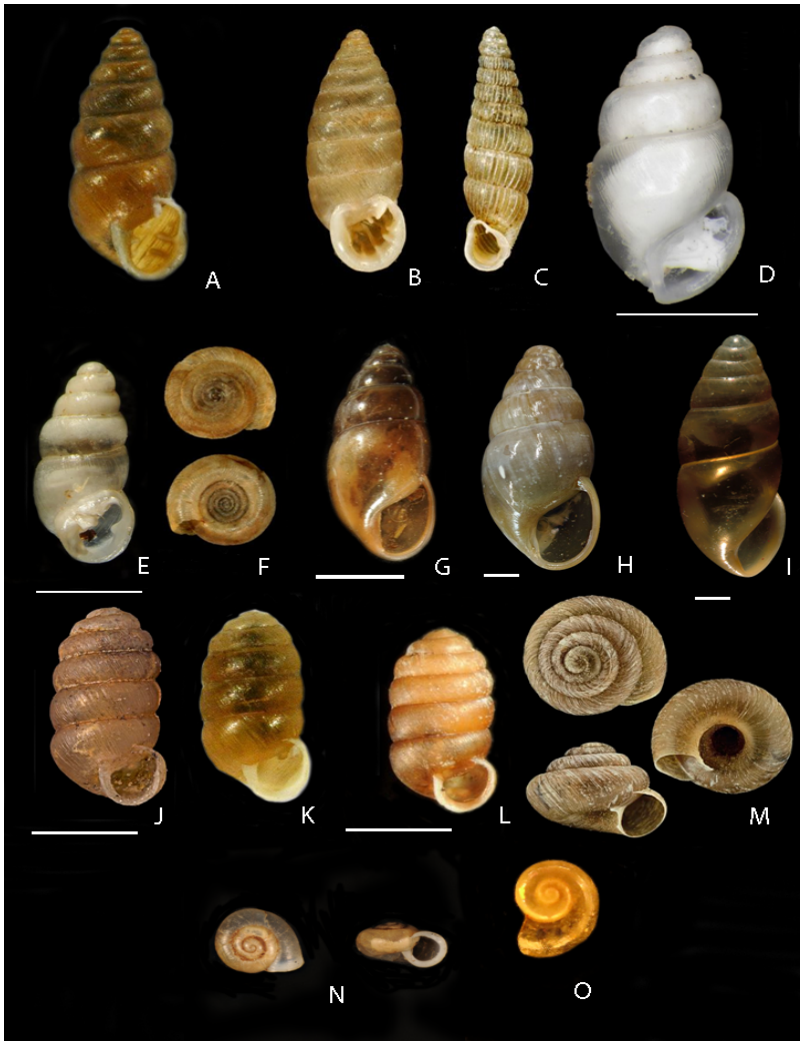
Source: Prepared by the author (2023)

Figure 5. Type and other museum specimens of freshwater microgastropods occurring in Romania (Planorbidae and Acroloxidae). **A.** NHMUK ZOO1893.2.4.525-527, syntype of *Ancylus strictus* Morelet, 1845, collected in Portugal by The Trustees of the Natural History Museum, London **B.** NHMUK ZOO 1893.2.4.529-530, syntypes of *Ancylus obtusus* Morelet, 1845, collected in Portugal by the Trustees of the Natural History Museum **C.** ANSP MAL 280762, Lectotype of *Ancylus libanicus* Nägele, 1897 **D.** MNHN IM 2000-33265, Syntype of *Ancylus vitraceus* Morelet, 1845, collected in Portugal Shell dimension not given. **E**. ANSP MAL 94670, Syntype of *Ancylus* (*Ferrissia*) *novangliae* B. Walker, 1908 **F.** ANSP MAL 134988 Syntype, of *Gundlachia stimpsoniana* S. Smith, 1870. **G.** NMBE 2318, *Acroloxus lacustris* (Linnaeus, 1758) collected in Switzerland (MolluscaBase image https://www.molluscabase.org/aphia.php?p=image&pic=153401&tid=181590). All images are licensed under creative commons (http://creativecommons.org/licenses/by/4.0/).



Source: Prepared by the D`ávila, S. (2023)

Figure 6. Type and other museum specimens of terrestrial microgastropods occurring in Romania. **A.**, *Chondrina arcadica clienta* (Westerlund, 1883), collected in Austria. Actual size 6.5 mm **B**. NMR 61083, *Granaria frumentum* (Draparnaud, 1801) collected in Italy. Actual size 9mm. **C**. *Ruthenica filograna* (Rossmässler, 1836) collected in Poland. Actual size 8mm. **D.** MCNB-Malac 2017-0765, *Carychium minimum* O. F. Müller, 1774 collected in Spain by MCNB/Miguel Prieto. **E**. MNHN IM 2009-21464, *Carychium tridentatum* (Risso, 1826) collected in France. **F**. NMR 993000059467, *Gonyodiscus perspectivus* (Megerle von Mühlfeld, 1816) collected in Austria G. MNHN IM 2009-21377, *Cochlicopa lubrica* (O.F.Müller, 1774) collected in France **H**. MCNB-Malac MZB 2017-0812, *Cochlicopa lubricella* (Porro, 1838) collected in Andorra by MCNB/Miguel Prieto **I**. DMNS: Inv:29838, *Cochlicopa nitens* (M. von Gallenstein, 1848) collected in Czech Republic **J.** MZL-INVERT-68472, Syntype of *Pupa* (*Sphyradium*) *alpicola* Charpentier, 1837 collected in Switzerland **K**. NMR 993000048018, *Pupilla muscorum* (Linnaeus, 1758) collected in Netherlands **L**. MNHN IM 2009-21441, *Pupilla sterrii* (Voith, 1840) collected in France **M**. MCNB-Malac 2009-0749, *Pyramidula rupestris* (Draparnaud, 1801) collected in Spain by MCNB Shell dimension not given. **N.** ANSP MAL 10080, Lectotype of *Vallonia pulchella* (O. F. Müller, 1774) collected in United States of America by Academy of Natural of Sciences of Philadelphia. Actual size 2.2 mm. **O.** NHMD90680, neotype of *Vitrina pellucida* (O.F. Müller, 1774), collected in Denmark by Natural History Museum of Denmark. All images are licensed under creative commons (http://creativecommons.org/licenses/by/4.0/).



Source: Prepared by the D`ávila, S. (2023)

4.3.2. Representativity of the species in malacological collections

The analysis of the records of the 35 species of microgastropods recovered from 34 malacological collections represented in GBIF evidenced a low representativity of specimens collected in Romania (Table 1). For most of the species, despites the high number of records recovered, only few lots of specimens collected in Romania are available in malacological collections worldwide. For three species, in particular, no record of specimens collected in Romania was obtained, i.e.: the search in GBIF resulted in 1,899 records of *Acroloxus lacustris* in malacological collections, 833 records of *Ferrissia californica*, and 27 records for *Gibbulinopsis pupula*, with no record for Romania. For 13 species the number of records in malacological collections was very low (1 to 5 records), i.e. *Ancylus fluviatilis*, *Cochlicopa lubricella*, *Cochlicopa nitens*, *Gonyodiscus perspectivus*, *Carychium minimum*, *Euconulus fulvus*, *Mediterranea inopinata*, *Vitrea erjaveci*, *Pupilla alpicola*, *Pupilla sterri*, *Succinella oblonga*, *Vallonia tenuilabris*, and *Oligomax annularis*. Low number of records was also recovered for 11 species (7 to 19 records), i.e.: *Agardhiella parreyssii*, *Argna bielzi*, *Cochlicopa lubrica*, *Discus ruderatus*, *Carychium tridentatum*, *Vitrea diaphana*, *Vitrea transylvanica*, *Punctum pygmaeum*, *Pupilla muscorum*; *Pyramidula pupula*, *Vitrina pellucida*. Only 8 species were represented by more than 20 records (21 to 118 records), i.e.: *Chondrina arcadica clienta*, *Granaria frumentum*, *Alinda stabilis*, *Ruthenica filograna*, *Orcula dolium*, *Aspasita triaria*, *Vallonia costata*, *Valonia pulchella*. Each species was represented in 1 to 16 malacological collections in Europe and United States of America. The malacological collection of the Academy of Natural Sciences of Philadelphia was the most representative as it included lots of 32 from the 35 species analyzed (Table 1). For several lots from ANSP collection, ascribed to 23 species, the species identification was performed by A. Grossu (i.e.: *A. parreysii*, ANSP MAL 443190; *C. arcadica clienta*, ANSP MAL 443329; *G. frumentum*, ANSP MAL 442923, ANSP MAL 442921, ANSP MAL 442922, ANSP MAL 443920, ANSP MAL 442939; *A. stabilis*, ANSP MAL 443159, ANSP MAL 443162; *R. filograna*, ANSP MAL 443088, ANSP MAL 443095, ANSP MAL 443096; *C. lubrica*, ANSP MAL 442872; *C. nitens*, ANSP MAL 443189; *G. perspectivus*, ANSP MAL 443970; *C. minimum*, ANSP MAL 442874; *C. tridentatum*, ANSP MAL 442997; *E. fulvus*, ANSP MAL 442885; *O. dolium*, ANSP MAL 442942; *M. inopinata*, ANSP MAL443361; *V. diaphana* ANSP MAL 443312; *V. transylvanica*, ANSP MAL 443312; *V. erjaveci*, ANSP MAL 443378; *P. pygmaeum*, ANSP MAL 442931; *P. alpicola*, ANSP MAL 443107; *P. sterri* , ANSP MAL 443118; *G. pupula*, ANSP MAL 442948; *A. triaria*, ANSP MAL 443134, ANSP MAL 443136; *V. costata*, ANSP

MAL 442900, ANSP MAL 442903; and *V. pulchella*, ANSP MAL 443901, ANSP MAL 443904). The search in GBIF recovered information on type specimens for 17 out of the 35 species herein analyzed (Table 2). Most of the records recovered did not explicit the type of preparation of the specimens (dry specimens, or ethanol preserved specimens).

Table 1. Representativity of the micro-gastropod species herein analyzed in malacological collections worldwide. Data accessed by using the search tools of the Global Biodiversity Information Facility – GBIF.

		Total number of records recovered	**Number of records for Romania**	**Number of institutions where the specimens are housed and their acronyms**
Acroloxus lacustris	Acroloxidae	1,899	No record	-
Ancylus fluviatilis	Planorbidae	4,802	4	(1) ANSP
Ferrissia californica	Planorbidae	833	No record	-
Agardhiella parreyssii	Agardhiellidae	30	7	(2) ANSP; RBINS.
Argna bielzi	Argnidae	40	10	(3) ANSP; NHMUK; UMMZ.
Chondrina arcadica clienta	Chondrinidae	1,880	33	(7) ANSP; FMNH; MCZ; NHMA; NHMUK; RBINS; RMNH.
Granaria frumentum	Chondrinidae	3,346	36	(9) ANSP; FMNH; HLA; NHMA; NHMUK; RMNH; SDNHM; SNSD; UF.
Alinda stabilis	Clausillidae	1,213	32	(9) ANSP; CM; FMNH; MCNB; MCZ; NHMUK; RBINS; SMF; UMMZ.
Ruthenica filograna	Clausillidae	1,964	118	(16) AMU; ANSP; CM; DMNH; FMNH; MCZ; MHNGr; MZH; MZLU; NHMUK; NTNU; RBINS; RMNH; SMF; UF; UMMZ.
Cochlicopa lubrica	Cochlicopidae	19,706	9	(4) ANSP; NHMUK; RBINS; SDNHM.

Cochlicopa lubricella	Cochlicopidae	953	2	(1) ANSP
Cochlicopa nitens	Cochlicopidae	179	1	(1) ANSP
Discus ruderatus	Discidae	6,418	10	(5) ANSP; CM; FMNH; NHMUK; RBINS.
Gonyodiscus perspectivus	Discidae	2,125	3	(3) ANSP; NHMUK; MZH.
Carychium minimum	Ellobidae	5,148	2	ANSP
Carychium tridentatum	Ellobidae	8,236	13	(9) ANSP; CM; FMNH; MCNB; MCZ; NHMUK; RBINS; SMF; UMMZ.
Euconulus fulvus	Euconulidae	18,687	3	(2) ANSP; NHMUK.
Orcula dolium	Orculidae	4,287	24	(2) ANSP; UMMZ.
Mediterranea inopinata	Oxychilidae	139	1	(1) ANSP
Vitrea diaphana	Pristilomatidae	1,703	17	(6) AMU; ANSP; FMNH; MCZ; NHMUK; MZLH.
Vitrea transylvanica	Pristilomatidae	1,165	18	(7) AMU; ANSP; FMNH; MCZ; NHMUK; UF; UMMZ.
Vitrea erjaveci	Pristilomatidae	17	1	(1) ANSP
Punctum pygmaeum	Punctidae	13,054	7	(4) ANSP; NHMUK; ZMA.MOLL.
Pupilla alpicola	Pupillidae	291	2	ANSP
Pupilla muscorum	Pupillidae	13,347	12	(5) ANSP; DMNH; FMNH; LMD; NHMUK.
Pupilla sterri	Pupillidae	949	3	(2) ANSP; FMNH.
Gibbulinopsis pupula	Pupillidae	27	No record	-
Pyramidula rupestris	Pyramidulidae	3,034	12	(3) ANSP; FMNH; MCZ.
Aspasita triaria	Spelaeodiscidae	109	51	(13) ANSP; FMNH; HNS; MCNB; MZH; MZLU; NHMUK; RBINS; SDNHM; SNSD; UF; UMMZ; UT.
Succinella oblonga	Succineidae	5,931	5	(2) ANSP; UMMZ.
Vallonia costata	Valloniidae	21,683	21	(6) AMU; ANSP; FMNH; LI; MZH; NMNH.

Vallonia pulchella	Valloniidae	13,888	29	(7) AMU; ANSP; BMSM; FMNH; LI; MZH; RBINS.
Vallonia tenuilabris	Valloniidae	78	1	(1) ANSP
Oligomax annularis	Vitrinidae	815	4	
Vitrina pellucida	Vitrinidae	27,067	19	

Source: Prepared by the author (2023)

Table 2. Type material of the micro-gastropod species herein analyzed, including their synonyms. Data accessed by using the search tools of the Global Biodiversity Information Facility – GBIF.

Acroloxus lacustris	Acroloxidae	Type material not found
Ancylus fluviatilis	Planorbidae	Syntypes (10); Lectotype (1); Paralectotype (1); Paratype (1) type (1)
Ferrissia californica	Planorbidae	Paratypes (3); Lectotype (1); Paralectotypes (2); Holotypes (2); Syntypes (2)
Agardhiella parreyssii	Agardhiellidae	Type material not found
Argna bielzi	Argnidae	Type material not found
Chondrina arcadica clienta	Chondrinidae	Type material not found
Granaria frumentum	Chondrinidae	Type material not found
Alinda stabilis	Clausillidae	Type material not found
Ruthenica filograna	Clausillidae	Type material not found
Cochlicopa lubrica	Cochlicopidae	Paratype (1); Syntypes (2).
Cochlicopa lubricella	Cochlicopidae	Type material not found
Cochlicopa nitens	Cochlicopidae	Topotype (1).
Discus ruderatus	Discidae	Type material not found
Gonyodiscus perspectivus	Discidae	Type material not found
Carychium minimum	Ellobidae	Type (1)
Carychium tridentatum	Ellobidae	Type material not found
Euconulus fulvus	Euconulidae	Cotype (1); Paratype (1); syntypes (2).
Orcula dolium	Orculidae	Type material not found

Mediterranea inopinata	Oxychilidae	Type material not found
Vitrea diaphana	Pristilomatidae	Lectotype (1)
Vitrea transylvanica	Pristilomatidae	Lectotype (1)
Vitrea erjaveci	Pristilomatidae	Lectotype (1)
Punctum pygmaeum	Punctidae	Type material not found
Pupilla alpicola	Pupillidae	Syntype (1)
Pupilla muscorum	Pupillidae	Cotype (1); Syntype (1).
Pupilla sterri	Pupillidae	Type material not found
Gibbulinopsis pupula	Pupillidae	Type material not found
Pyramidula rupestris	Pyramidulidae	Type material not found
Aspasita triaria	Spelaeodiscidae	Lectotype (1)
Succinella oblonga	Succineidae	Type material not found
Vallonia costata	Valloniidae	Syntypes (2); Paralectotype (1).
Vallonia pulchella	Valloniidae	Syntype (1); Lectotype (1); Paralectotype (1).
Vallonia tenuilabris	Valloniidae	Paralectotype (1)
Oligomax annularis	Vitrinidae	Lectotype (1)
Vitrina pellucida	Vitrinidae	Holotype (1); Neotype (1); Syntypes (6); Cotype (1); Lectotypes (2) ; Paralectotype (1).

Source: Prepared by the author (2023)

4.4 DISCUSSION

The gastropod fauna of Romania was extensively studied by Alexandru Grossu (Grossu, 1981; 1983; 1984a,b; 1986a,b; 1987), and new species records continue to be documented to this day (Gloer, 2013; Păpureanu *et al.*, 2014; Páll-Gérgely, 2012; Domokos & Pall-Gérgely, 2021). Within the scope of this study, we directed our attention to the micro-gastropods donated by Alexandru Grossu. These specimens not only enriched the Malacological Collection Maury Pinto de Oliveira (CMMPO) but also shed light on the richness of Romanian biodiversity (Grossu, 1986; Domokos & Lennert, 2007; Hórsak *et al.*, 2010; Balashov & Gural-Sverlova, 2012; Dmitrovic *et al.*, 2023).

Herein, the species analyzed present wide or more restricted distributions in Europe. It is interesting to note that the records in Romania for some widely distributed species seems to be not so common in prominent malacological collections worldwide. As an example, the search in GBIF resulted in 1,899 records of *Acroloxus lacustris* in malacological collections, but no record in Romania; 4,802 records for *Ancylus fluviatilis*, with only four records in Romania; 19,706 records for *Cochlicopa lubrica*, with only 9 records in Romania; 953 records for *Cochlicopa lubricella*, with only 2 records in Romania; 179 records for *Cochlicopa nitens*, with only one record in Romania. Thus, our results evidence that some species may be subsampled in some parts of its geographical range, despite the high number of records in malacological collections in general. Overall, our results showed a low representativity of specimens collected in Romania, considering the 34 malacological collections represented in GBIF. These results evidence the importance of the collection of micro-gastropods donated by Alexandru Grossu, housed in the CMMPO. It is worth of note that the search in GBIF didn't evidence malacological collections from South America including representatives of the Romanian malacofauna, showing that the scientific interchanges with malacologists from all around the world promoted by Prof. Maury Pinto de Oliveira have made the CMMPO very peculiar, as this small collection houses specimens from all continents and several countries (D'ávila, 2016). This fact evidences a recent perception that small, regional collections can significantly contribute to the knowledge on biodiversity, as they often house unique specimens, with the potential to filling gaps in our understanding of species distribution, morphology, taxonomy, among other traits (Sierwald *et al.,* 2018; Monfils *et al.,* 2020). Several species of micro-gastropods inhabit limestone, as calcium availability play a crucial role in their life history (Gittenberger, 2007). Indeed, for many species, great abundance of calcium sources is not merely favorable, but practically indispensable. Calciferous areas, such as rocky outcrops, function as diversity hubs for terrestrial gastropods, resembling geographical islands (Gittenberger, 2007; Szybiak & Lesniewska, 2008; Kokshoorn *et al.,* 2010). This peculiar geographical distribution, with limestone soils acting as natural boundaries, with relatively high levels of endemism, isolates communities and promotes local diversification (Fehér *et al.,* 2010). This fact, allied to the recent view that the traditional operational criteria for species delimitation in land and freshwater snails may not be so effective, highlights the importance of addressing species limits based on new operational criteria and methodological approaches, and using comprehensive datasets that include samples covering the species distribution ranges. In this context, specimens deposited in malacological collections may be useful as source of occurrence data useful for new sampling efforts as well as direct source of morphological and

molecular data. Herein, most of the records recovered did not explicit the type of preparation of the specimens (dry specimens, or ethanol preserved specimens). However, it is possible that most of these records correspond to dry shells only, as observed for Mollusca in general, due to the traditional use of the shell as the sole or most important operational criterial for species identification and delimitation. Nonetheless, although the widespread presence of dry specimens in malacological collections impairs their utility for anatomical and genetic studies, occurrence records associated to museum specimens may be useful in studies on species distributions allowing to trace species distribution shifts, besides niche modeling, and environmental monitoring (MacLean *et al.,* 2019; Kling *et al.,* 2019).

Among the species herein analyzed, only *Ferrissia californica* is invasive in Romania. This species has been introduced in new areas in Europe and other continents (Vecchioni *et al.,* 2018; Mabrouki *et al.,* 2023). Its presence in Romania as an introduced species is reported in the distribution map of *F. californica* available in MolluscaBase. However, we could not find any record of this species for Romania in the malacological collections represented in GBIF. The collection date attributed to the specimens housed in CMMPO is 1961. These specimens were sampled in just one locality in Romania. Considering the time interval of 63 years and the high invasive potential of this species, it is probably that now this freshwater snail presents a wider distribution in Romania; the collection efforts to clarify its occurrence range and potential negative effects on native species being greatly necessary (Vinarski & Palatov, 2018).

Small collections, whether private or associated with academic institutions and research centers, play a crucial role in cataloging and preserving biological diversity (Monfils *et al.,* 2020; Sierwald *et al.,* 2018). Many of them, however, rely entirely on funding provided by government agencies to ensure proper curation and infrastructure improvements. Currently, one of the main challenges facing collections is the need for trained human resources in curation, management, and specimen processing. Sierwald et al. (2018) argued that positions for researchers and curators are often tied to careers as professors and research biologists, and these professionals frequently engage in other activities such as teaching and mentoring undergraduate and graduate students. In small collections, the curator's role is often performed on a voluntary basis without institutional affiliation, or additional remuneration for this function (Oliveira & Costa, 2016, Sierwald, 2018). Furthermore, the human resources often consist of emeritus professors, volunteers, undergraduate, and graduate students. This illustrates the dedication of these professionals to the maintenance of the collections but also highlights a shortage of specialized personnel and investment in hiring staff (Oliveira & Costa, 2016; Rocha-Barreira, 2016; D'ávila, 2016; Sierwald *et al.*, 2018).

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APPENDIX A – Molecular data of the 16S and Cytochrome oxidase subunit 1 genes used in this study

Species	Acession Number COI	Acession number 16S
Abronica_abronia	KY128921	KY128716
Abronica_purpureoanulata	KY128970	KY128763
Abyssochrysos_melanioides	AJ622946	DQ093481
Acanthodoris_atrogriseata	KM219649	KJ653649
Acanthodoris_brunnea	GQ292045	KJ653651
Acanthodoris_hudsoni	KM219654	KM246808
Acanthodoris_lutea	KM219655	KJ653655
Acanthodoris_nanaimoensis	MK091882	KM246810
Acanthodoris_pilosa	KR084886	AF249236
Acanthodoris_pina	KM219669	KJ653668
Acanthodoris_planca	KM219672	KJ653670
Acanthodoris_rhodoceras	KM219675	KM246812
Acroloxus_lacustris		
Acteocina_lepta	KF992197	KJ022827
Acteon_tornatilis	DQ974649	AJ223405
Actinocyclus_verrucosus	MW278846	MF958311
Adalaria_loveni	KP340395	KP340300
Adalaria_proxima	KY996413	KJ653674
Adalaria_slavi	MN224050	MN224074
Aegires_albopunctatus	MF958439	MF958313
Aegires_flores	-	MF958316
Aeolidia_filomenae	KU160595	KU160563
Aeolidia_libitinaria	MH756137	MH756132
Aeolidia_papillosa	AY345028	KF317842
Aeolidiella_alderi	HQ616766	JQ996811
Aeolidiella_glauca	KX758255	KX758254
Aeolidiella_sanguinea	JX087537	JX087466
Aeolidiopsis_ransoni	JQ997043	JQ996838
Aglaja_ocelligera	JN825205	JN825080
Aglaja_tricolorata	AM421902	AM421854
Aiteng_ater	JF828031	JF828038
Akera_bullata	KF992164	KJ022795
Akiodoris_lutescens	-	MN224076
Alderia_modesta	DQ364309	DQ364418
Alderia_willowi	KM086348	DQ364426
Aldisa_albatrossae	KP871632	KP871679
Aldisa_cooperi	NC 063123	NC_063123
Aldisa_fragaria	MF288004	MF288006
Aldisa_sanguinea	MF958435	MF958309

Aldisa_smaragdina	KF992175	KJ022806
Aldisa_zavorensis	MF288005	MF288007
Aliculastrum_parallelum	KF992188	KJ022818
Amphorina_farrani	KR084393	KY128821
Ancylus_fluviatilis	AY282582	EF489312
Antarctophiline_alata	MN486296	MK024361
Antarctophiline_amundseni	MN486278	-
Antarctophiline_easmithi	MK015705	-
Antarctophiline_gibba	MN486282	-
Anteaeolidiella_cacaotica	JQ997030	JQ996825
Anteaeolidiella_chromosoma	-	JQ996813
Anteaeolidiella_oliviae	JQ997034	JQ996829
Anteaeolidiella_saldanhensis	-	JQ996827
Anteaeolidiella_takanosimensis	JX087529	JX087458
Antiopella_capensis		
Antiopella_longidentata		
Apata_pricei	MF523386	MF523413
Aperostoma_palmeri	AB930459	AB930403
Aplysia_argus	NC 063768	NC_063768
Aplysia_atromarginata	MK422837	MK422738
Aplysia_dactylomela	DQ991927	KJ022798
Aplysia_elongata	MW278786	MK422775
Aplysia_japonica	MK422873	MK422764
Aplysia_juliana	AF343425	MK422734
Aplysia_nigrocincta	MK422893	MK422787
Aplysia_parvula	KJ522466	MK422737
Aplysia_punctata	AY345019	MK422802
Aplysiopsis_enteromorphae	GU191059	GU191053
Aplysiopsis_minor	AB501314	AB501314
Aplysiopsis_toyamana	LC531989	LC532033
Ardeadoris_angustolutea	KT600677	KT595606
Ardeadoris_averni	KT600678	KT595607
Ardeadoris_cruenta	KJ001298	KT595609
Ardeadoris_egretta	EU982713	EU982762
Ardeadoris_poliahu	KT600681	KT595611
Ardeadoris_pullata	EF535137	EF534065
Ardeadoris_rubroannulata	JQ727873	JQ727755
Ardeadoris_scottjohnsoni	EU982714	EU982763
Ardeadoris_symmetrica	KT600682	KT595613
Ardeadoris_tomsmithi	JQ727881	JQ727762
Ardeadoris_undaura	JQ727882	JQ727763
Armina_lovenii	AF249781	AF249243
Armina_occulta	KX538791	KX018755

Armina_semperi	HM162696	HM162606
Armodoris_anudeorum	KP340387	KP340290
Arnemelassa_creedi	HG515080	HQ245442
Ascobulla_fischeri	-	KM204185
Ascobulla_fragilis	AY345022	-
Ascobulla_japonica	AB501301	AB501301
Ascobulla_ulla	KM086347	KM204187
Asteronotus_cespitosus	MW815565	MF958288
Asteronotus_hepaticus	MW559976	MW559976
Atagema_osseosa	MF958426	MF958296
Atalodoris_jannae		
Atys_naucum	KF992176	KJ022807
Atys_semistriatus	MW278347	KJ022822
Austraeolis_ornata	GQ403774	GQ403752
Austraeolis_stearnsi	KX889721	JQ699483
Babakina_anadoni	HQ616767	HQ616744
Babakina_indopacifica	HM162754	HM162678
Babella_caelatior		
Babella_mariellaeformis		
Baenopsis_baetica	HQ616755	HQ616718
Baeolidia_japonica	JQ997059	JQ996856
Baeolidia_moebii	HQ616771	JQ996858
Baeolidia_salaamica		
Bakawan_fusca	MK473530	-
Bakawan_puti	MZ831896	-
Bathyberthella_antartica	AY345027	FJ917429
Bathydoris_aioca	KP871635	KP871682
Bathyhedyle_boucheti	-	KX721048
Berghia_coerulescens	JQ997049	JQ996845
Berghia_columbina	JX087544	JX087474
Berghia_creutzbergi	JX087547	JX087478
Berghia_marcusi	KF273244	KF273243
Berghia_marinae	MK468733	MK468734
Berghia_rissodominguezi	JX087552	JX087484
Berghia_stephanieae	MW027646	MW027646
Berghia_verrucicornis	HQ616749	HQ616713
Berthelinia_caribbea	KM086349	KM204188
Berthelinia_limax	AB501305	AB501305
Berthella_andromeda	MK542746	MK542710
Berthella_californica	MK542773	FJ917432
Berthella_martensi	HM162683	FJ917431
Berthella_platei	FJ917492	FJ917434
Berthella_stellata	OK076914	FJ917430

Berthella_strongi	MK542762	MK542731
Berthellina_edwardsi	KF992165	-
Biuve_fulvipunctata	MF036520	MG323548
Boasia_chierchiae	KC774044	-
Bohuslania_matsmichaeli	MG323542	MG323548
Bonisa_nakaza	HM162746	HM162670
Boonea_seminuda	-	AF355163
Bornella_anguilla	KX889723	KP871683
Bornella_calcarata	HM162707	HM162627
Bornella_hermanni	MN690322	JN869404
Bornella_johnsonorum	HM162704	HM162624
Bornella_stellifera	MN690301	KF601556
Bornella_valdae	HM162706	JN869405
Bosellia_mimetica	MK764395	HQ616809
Brachystomia_angusta	-	AF355172
Bulbaeolidia_sulphurea	KY563101	KY563105
Bulla_ampulla	DQ986531	DQ986586
Bulla_arabica	KU557519	KU557522
Bulla_gouldiana	DQ986532	DQ986593
Bulla_mabillei	DQ986533	DQ986594
Bulla_occidentalis	DQ986541	DQ986605
Bulla_orientalis	DQ986535	DQ986597
Bulla_punctulata	DQ986556	DQ986617
Bulla_quoyii	DQ986558	DQ986619
Bulla_striata	DQ986564	DQ986632
Bulla_vernicosa	DQ974662	DQ986634
Bullacta_caurina		
Bullina_lineata	AY296847	GQ845196
Burnaia_helicochorda	KT200148	KT200147
Bursatella_hirsuta	MW080750	-
Cadlina_flavomaculata	EU982715	EF534041
Cadlina_japonica	NC 063124	NC_063124
Cadlina_kamchatica	MN224054	MN224080
Cadlina_koreana	NC 063125	NC_063125
Cadlina_laevis	AY345034	MN224087
Cadlina_luteomarginata	KM219678	KJ653679
Cadlina_modesta	MF958437	EU982773
Cadlina_pellucida	EU982724	EU982774
Cadlina_rumia	EU982725	EU982775
Cadlina_sparsa	EU982726	EU982776
Cadlina_umiushi	MT919641	MT919641
Cadlinella_ornatissima	KU496278	EU982779
Cadlinella_subornatissima	KP257095	MN224098

Caldukia_affinis	MH781054	-
Caliphylla_mediterranea	KM086352	GU191041
Caliphylla_viridis	KM086434	GU191052
Calma_glaucoides	KY128913	HG810888
Calma_gobioophaga	HG810898	HG810892
Calmella_cavolini		
Calmella_gaditana		
Caloria_elegans	HQ616751	HQ616738
Caloria_indica	MK514323	DQ417273
Calycidoris_guentheri	KP340397	KP340302
Camachoaglaja_africana	AY345017	MF036323
Camachoaglaja_berolina	MF036522	MF036324
Camachoaglaja_mariagordae		
Capellinia_doriae	MG934974	-
Cariopsilla_pharpa	MH087486	-
Carminodoris_armata	KF648917	-
Carronella_enne	MF523382	MF523439
Carychium_minimum	EF489386	EF489308
Catriona_aurantia	KY985467	MF523458
Catriona_columbiana	KF643448	KY128698
Catriona_gymnota	KY128908	KY128707
Cavolinia_gibbosa	FJ876856	-
Ceratophyllidia	MF958413	-
Ceratosoma_amoenum	EU982729	EU982780
Ceratosoma_brevicaudatum	EU512141	-
Ceratosoma_gracillimum	MN690295	JQ727691
Ceratosoma_ingozi	JQ727823	JQ727693
Ceratosoma_tenue	KJ001300	JQ727696
Ceratosoma_trilobatum	EU982730	EU982784
Cerberilla_affinis	MK091263	JQ996863
Cerberilla_annulata		
Cerberilla_bernadettae	JX087555	JX087489
Chelidonura_alisonae	MW277937	MF036329
Chelidonura_amoena	AM421901	MF036330
Chelidonura_electra	AM421899	JN825090
Chelidonura_hirundinina	MF036524	MF036335
Chelidonura_livida	MF036525	MF036336
Chelidonura_pallida	AM421876	MF036338
Chelidonura_tsurugensis		
Chelidonura_varians	MF036530	MF036351
Chlamylla_borealis	MF523321	MF523395
Chlamylla_intermedia	MF523330	MF523453
Chromodoris_africana	MG883099	MG882784

Chromodoris_alcalai	MG883199	MG882890
Chromodoris_annae	MF683074	NC_036426
Chromodoris_aspersa	MG883135	MG882823
Chromodoris_burni	MG883139	MG882827
Chromodoris_celinae	MK994116	MK994178
Chromodoris_colemani	MG883196	MG882886
Chromodoris_dianae	MG883149	MN104707
Chromodoris_elisabethina	MG883208	MG882900
Chromodoris_hamiltoni	MG883212	MG882904
Chromodoris_helium	MK994130	MK994169
Chromodoris_joshi	MG883220	MG882912
Chromodoris_kuiteri	MG883231	AF249240
Chromodoris_lochi	MG883263	JQ727727
Chromodoris_magnifica	DQ991931	MG882971
Chromodoris_mandapamensis	MG883316	MG883009
Chromodoris_michaeli	MG883317	MG883010
Chromodoris_orientalis	MH550543	NC_041196
Chromodoris_striatella	MG883330	JQ727737
Chromodoris_strigata	MG883344	MG883038
Chromodoris_westraliensis	MG883369	MG883063
Chromodoris_willani	MG883388	MG883066
Chromolaichma_dalli		
Chromolaichma_edmundsi		
Chromolaichma_sedna	JQ727879	JQ727760
Cima	FJ917279	FJ917260
Cingulina	GU331959	GU331950
Clio_convexa	MK749664	-
Cliopsis_krohnii	MF048962	-
Colga_pacifica	MZ782097	-
Colobocephalus_costellatus	KF992207	KJ022865
Colpodaspis_thompsoni	KF992158	KJ022774
Conualevia_alba	KC153021	KC153023
Corambe_obscura	KP340399	-
Cornirostra_pellucida	AY296842	
Coryphella_athadona	KT724949	MF523414
Coryphella_borealis		
Coryphella_browni		
Coryphella_chriskaugei	MF523357	MF523417
Coryphella_falklandica		
Coryphella_lineata		
Coryphella_monicae	MF523373	MF523441
Coryphella_nobilis	MF523347	MF523411
Coryphella_orjani	MF523368	MF523433

Coryphella_sanamyanae	MZ832430	MF523461
Coryphella_trilineata		
Coryphella_trophina	MZ580892	MF523460
Coryphella_verrucosa	MG422352	MF523421
Coryphellina_aurora	ON040934	-
Coryphellina_lotos	MF523387	KJ610026
Costasiella_arenaria	KJ610066	KJ610027
Costasiella_coronata	KJ610067	KJ610028
Costasiella_formicaria	KJ610068	DQ480215
Costasiella_kuroshimae	MN690318	GU191037
Costasiella_nonatoi	GU191065	DQ480216
Costasiella_ocellifera	KF411403	KJ610030
Costasiella_paweli	KJ610070	KJ610031
Costasiella_usagi	KJ610071	HQ616715
Cratena_peregrina	HQ616752	KY128709
Cratena_pilata	MK308327	EF142950
Creseis_virgula		
Crimora_lutea	EF142903	EF142950
Crosslandia_viridis	KP871637	-
Cumanotus_beaumonti	MN850076	-
Curnon_granulosa	GQ292060	KP871684
Cuthona_divae	JQ699569	JQ699479
Cuthona_nana	KY128966	KY128757
Cuthona_pallida		
Cuthonella_abyssicola	MW150847	-
Cuthonella_concinna	KY128936	KY128808
Cuthonella_denbei	MW150870	-
Cuthonella_georgstelleri	MW150862	-
Cuthonella_hiemalis	MG323545	KY128799
Cuthonella_osyoro	MW150856	-
Cuthonella_punicea	MW150858	-
Cuthonella_sandrae	MW150863	-
Cuthonella_soboli	KY129026	MG323552
Cuthonella_vasentsovichi	MW150865	-
Cuvierina_atlantica	MW125415	-
Cuvierina_cancapae	KP292727	-
Cuvierina_columnella	FJ876895	-
Cyerce_antillensis		
Cyerce_elegans	MW278831	KM204193
Cyerce_nigra	KF921378	KM204194
Cyerce_nigricans	GQ996658	EU140843
Cyerce_orteai	KM086355	KM204195
Cylichna_alba	MG421514	-

Cylichna_cylindracea	KR084947	KJ022779
Cylichna_gouldii	KF644235	-
Cylichnium_ancillarioides	MH933092	MH933215
Cylichnium_mucronatum	MH933090	MH933214
Cylichnoides_scalptus	MZ476252	-
Cylindrobulla_beauii	GQ996665	EF489321
Dendronotus_dalli	MN138385	KM397083
Dendronotus_elegans		
Dendronotus_europaeus	KY391837	KY391847
Dendronotus_frondosus	AY345041	KM397067
Dendronotus_iris	MG423495	HM162631
Dendronotus_jamsteci	MN808559	-
Dendronotus_kalikal	MK302458	KM397070
Dendronotus_robustus	KY996408	KY996404
Dermatobranchus_otome	MT527186	NC_062675
Diacavolinia_strangulata		
Diacria_major	FJ876908	-
Diacria_rampalae	FJ876900	-
Diacria_trispinosa	FJ876916	-
Diaphana_globosa	KF992162	KJ022791
Diaphana_minuta	KR084749	-
Diaphoreolis_flavovulta		
Diaphoreolis_lagunae	KY128960	KY128753
Diaphoreolis_viridis	KY129027	KY128899
Diaphorodoris_luteocincta	KP340405	KP340309
Diaphorodoris_papillata	KP340407	KP340311
Diaulula_greeleyi	KU950017	KU949947
Diaulula_nayarita	KU950018	KU949948
Diaulula_sandiegensis	MK037279	KU949982
Dicata_odhneri	HQ616773	HQ616739
Diniatys_dentifer	MZ560143	MH933163
Dirona_albolineata	MG422188	HM162668
Dirona_picta	KX889728	-
Diversidoris_aurantinodulosa	EF535141	EF534069
Dolabrifera_ascifera	MF669653	-
Dondice_occidentalis		
Dondice_parguerensis		
Doridoxa_walteri	MW139263	-
Doriopsilla_albopunctata	MK550636	KR002443
Doriopsilla_davebehrensi	KR002521	KR002478
Doriopsilla_gemela	KR002514	KR002451
Doriopsilla_spaldingi	KR002479	KR002427
Doriopsis_granulosa	MW815564	AF249223

Doriprismatica_atromarginata	MN171300	NC_057611
Doriprismatica_balut	KT600689	KT595618
Doriprismatica_kulonba	JQ727863	JQ727745
Doriprismatica_marinae	KT600691	KT595617
Doriprismatica_paladentata	KT600686	KT595616
Doriprismatica_rossi	KT600690	KT595620
Doriprismatica_sibogae	KJ522460	EF534063
Doriprismatica_stellata	KT600693	KT595621
Doris_kerguelenensis	GU227115	EU823255
Doris_montereyensis	KF644212	MF958294
Doris_ocelligera	MW522602	-
Doris_wellingtonensis	GQ292034	-
Doto_amyra	KJ486701	KJ486768
Doto_antarctica	KJ486705	KJ486765
Doto_columbiana	GQ292026	-
Doto_coronata	KX788145	KX788133
Doto_dunnei	KJ486725	-
Doto_eireana		
Doto_floridicola	AF249820	-
Doto_fragilis	KJ486735	KJ486755
Doto_greenamyeri	KJ486715	KJ486769
Doto_koenneckeri	HM162735	AF249249
Doto_kya	MH242737	-
Doto_lancei	KX889731	-
Doto_lemchei	KJ486727	KJ486749
Doto_maculata	MG934893	KJ486757
Doto_millbayana	KJ486726	KJ486759
Doto_paulinae	KX274281	-
Doto_pinnatifida	KJ486736	AF249250
Doto_tuberculata	KJ486734	KJ486756
Doto_ussi	HM162736	KJ486780
Duvaucelia_manicata	KY629602	KY629592
Duvaucelia_odhneri		
Duvaucelia_plebia	KX788134	KX788122
Duvaucelia_striata	LT596541	LT596543
Edmundsella_albomaculata	KJ721522	KJ721520
Edmundsella_pedata	HQ616758	AF249247
Elysia_annedupontae		
Elysia_asbecki	KM086360	KM204200
Elysia_atroviridis		
Elysia_buonoi	JQ914619	JQ914621
Elysia_leucolegnote	KM086381	KM204231
Elysia_lobata	KM086382	KM204232

Elysia_maoria	KM086383	-
Elysia_marcusi	KM086384	HQ616810
Elysia_marginata	MZ546942	JN819130
Elysia_orientalis	KP187842	KP187839
Elysia_ornata	NC 030537	NC_030537
Elysia_papillosa	HQ616860	HQ616831
Elysia_patina	HM187627	HQ616830
Elysia_pratensis	JN819112	HM187596
Elysia_pusilla	AB758959	EU140867
Elysia_rufescens	AB758961	DQ480171
Elysia_singaporensis	KM086398	KM204249
Elysia_stylifera	GU191057	GU191046
Elysia_subornata	JN819111	HQ616819
Elysia_sugashimae	KM086399	KM204251
Elysia_thompsoni	JN819088	KM204252
Elysia_timida	NC 035490	NC_035490
Elysia_tomentosa	MW278442	-
Elysia_velutinus	KM086402	JN819133
Elysia_yaeyamana	LC531991	LC532018
Ercolania_annelyleorum	HQ380197	-
Ercolania_boodleae	KM086388	GU191050
Ercolania_kencolesi	GU191062	GU191051
Ercolania_pica	KM086390	-
Ercolania_subviridis	KM086395	KM204244
Ercolania_tentaculata	KM086396	KM204245
Ercolania_viridis	KM086397	HQ380182
Eubranchus_mandapamensis	KY129036	KY128827
Eubranchus_odhneri	MF523318	MF523396
Eubranchus_olivaceus	MZ580894	KY128828
Eubranchus_rupium	KF644151	KY128863
Eubranchus_sanjuanensis	GQ292079	-
Eubranchus_tricolor	KR084872	KY128823
Euselenops_luniceps	MN690297	-
Facelina_annulicornis	JQ997076	JQ996881
Facelina_auriculata	MK320904	MK320915
Facelina_bostoniensis	AY345031	KY513633
Facelina_rubrovittata	MK091278	-
Facelina_vicina	KY513636	KY513630
Favorinus_tsuruganus	JX220454	JX220486
Felimare_fontandraui	LN912981	KT820530
Felimare_kempfi	KX279337	KT820522
Felimare_lajensis	KT833256	KT820517
Felimare_marci	-	JQ727787

Felimare_orsinii	AJ223265	AJ225189
Felimare_picta	KF992179	LN715185
Felimare_pinna	MK474117	KT820533
Felimare_porterae	MK474116	MF038094
Felimare_ruthae	EU982747	KT820521
Felimare_sechurana	MF038067	MF038100
Felimare_tema	MK474124	KT820515
Felimare_tricolor	MK474118	LN715198
Felimare_villafranca	LN715217	LN715201
Felimare_zebra		
Felimida_atlantica	KX279340	-
Felimida_baumanni	KJ812361	KJ804252
Felimida_binza	KX262417	KX262450
Felimida_clenchi	JQ727832	JQ727708
Felimida_elegantula	KJ812358	KJ804248
Felimida_krohni	AY345036	AF249239
Felimida_luteopunctata	KJ911282	MH594468
Felimida_luteorosea	KJ812355	KJ804244
Felimida_norrisi	EU982737	EU982788
Felimida_purpurea	KJ812354	KJ804243
Felimida_sphoni	MK474133	KJ804250
Fiona_pinnata	KU757572	JX087492
Flabellina_affinis	AY345055	HQ616716
Flabellinopsis_iodinea	KX889734	KY128849
Ganitus_evelinae	JF828034	JF828045
Gascoignella_aprica	KM086404	KM204255
Gascoignella_nukuli	KM086406	HQ168414
Gastropteron_bicornutum	KX552016	AM421822
Gastropteron_rubrum	AM421865	AM422902
Geitodoris_heathi	MH242764	-
Glaucus_atlanticus	KJ522459	JQ699517
Globophiline	MN326980	MN326896
Glossodoris_acosti	MZ823409	MZ823409
Glossodoris_andersonae	KT600694	KT595623
Glossodoris_bonwanga	KT600695	KT595647
Glossodoris_buko	KT600712	KT595638
Glossodoris_cincta	KT600702	MK322447
Glossodoris_hikuerensis	MK994107	MK994159
Glossodoris_pallida	KT600708	KT595624
Glossodoris_rufomarginata	KT600718	JQ727757
Glossodoris_vespa	EU512160	EU925586
Godiva_quadricolor	HM162756	HM162680
Goniobranchus_albonares	KJ001299	KJ018909

Goniobranchus_albopuntatus	JQ727827	JQ727700
Goniobranchus_albopustulosus	JQ727828	JQ727701
Goniobranchus_aureopurpureus	EU512128	EU512055
Goniobranchus_coi	EU982734	EU982785
Goniobranchus_collingwoodi	JQ727834	JQ727710
Goniobranchus_daphne	KJ001297	MH017991
Goniobranchus_decorus	MZ560015	EU982786
Goniobranchus_fidelis	MN690312	MK322448
Goniobranchus_geminus	JQ727840	JQ727716
Goniobranchus_geometricus	MK348906	MK322451
Goniobranchus_heatherae	JQ727844	JQ727720
Goniobranchus_hintuanensis	JQ727845	JQ727721
Goniobranchus_hunterae	MH018008	MH017993
Goniobranchus_kuniei	EF535112	JQ727725
Goniobranchus_leopardus	MZ747465	MZ747465
Goniobranchus_loringi	MH018013	MH018000
Goniobranchus_preciosus	OL685230	JQ727732
Goniobranchus_reticulatus	MZ560145	MN104719
Goniobranchus_rufomaculatus	EU512131	EU512057
Goniobranchus_sinensis	OL685246	JQ727735
Goniobranchus_splendidus	EU982738	MH017998
Goniobranchus_tasmaniensis	MH018007	MH017994
Goniobranchus_tinctorius	MH018010	MH017997
Goniobranchus_verrieri	JQ727858	JQ727740
Goniobranchus_vibratus	JQ727859	JQ727741
Goniobranchus_woodwardae	EU512127	EU512103
Goniodoris_nodosa	KR084683	AF249226
Gymnodoris_ceylonica	MZ382630	KY806790
Halgerda_aurantiomaculata	KJ001312	KJ018912
Halgerda_batangas	MK348904	MK322453
Halgerda_dalanghita	MW223042	MF958289
Halgerda_dichromis	MW223046	MH578118
Halgerda_leopardalis	MH578080	MH578114
Halgerda_meringuecitrea	MW223058	MH578113
Halgerda_nuarrensis	MH578102	MH578115
Halgerda_wasinensis	MZ558217	MH578126
Halgerda_willeyi	MW223083	KJ018913
Hallaxa_fuscescens	MZ539744	MG645394
Hallaxa_iju	EU982759	EU982813
Hallaxa_translucens	EU982760	EU982814
Haloa_japonica	MN911170	NC_053883
Haminella_solitaria		
Hamineobulla_kawamurai	MN433677	-

Haminoea_hydatis	DQ238004	KJ022796
Haminoea_natalensis		
Haminoea_navicula	EU314804	EU314806
Haminoea_orbignyana	KC404964	EU314807
Haminoea_orteai	KX383913	KC404960
Haminoea_vesicula	KF615843	MH933161
Haminoea_virescens	AF156142	AF156126
Hancockia_californica	HM162702	JN869408
Hancockia_uncinata	AY345047	-
Hedylopsis_ballantinei	HQ168454	HQ168416
Hedylopsis_spiculifera	KF709353	KF709246
Heliconoides_inflatus	FJ876927	-
Helminthope_psammobionta	KY806819	KY806791
Hermaea_bifida	KM086407	GU191043
Hermaea_cruciata	GU191058	GU191042
Hermaea_oliviae	KM086345	KM204184
Hermaea_wrangeliae	KM086409	KM204258
Hermania_indistincta	JX944798	KJ022832
Hermania_scabra	JX944792	KJ022833
Hermissenda_crassicornis	MG421500	KU950121
Hermissenda_opalescens	KX889736	KU950130
Hermosita_hakunamatata	KP143674	JQ699555
Hero_formosa	KR084953	-
Heterodoris_robusta	MW139261	-
Hexabranchus_sanguineus	MF958433	MN224102
Hinemoa	-	GU331946
Hocius_joani		
Hoplodoris_desmoparypha	MN720308	-
Hydatina_physis	DQ991932	DQ986637
Hypselodoris_alburtuqali	MG645554	MG645395
Hypselodoris_apolegma	MG645558	MG645398
Hypselodoris_bennetti	MH018005	MH017992
Hypselodoris_bertschi	MG645601	JQ727769
Hypselodoris_bollandi	MG645564	JQ727771
Hypselodoris_brycei	MG645567	MG645408
Hypselodoris_bullocki	MF785092	MF785092
Hypselodoris_capensis	MG645573	MG645414
Hypselodoris_carnea	MG645574	MG645415
Hypselodoris_confetti	MG645577	MG645419
Hypselodoris_decorata	MG645576	MG645418
Hypselodoris_emma	MN690292	JQ727774
Hypselodoris_infucata	JQ727891	FJ917426
Hypselodoris_jacksoni	JQ727893	JQ727778

Hypselodoris_kaname	MG645582	JQ727780
Hypselodoris_katherinae	MG645584	MG645425
Hypselodoris_krakatoa	MG645587	MG645426
Hypselodoris_lacuna	MG645588	MG645427
Hypselodoris_maculosa	MG645589	MG645428
Hypselodoris_maridadilus	MG645590	MG645429
Hypselodoris_maritima	MG645592	MG645431
Hypselodoris_melanesica	MG645594	MG645433
Hypselodoris_nigrolineata	MG645596	MG645436
Hypselodoris_nigrostriata	MG645597	MG645437
Hypselodoris_obscura	MG645598	MG645438
Hypselodoris_paradisa	MG645599	MG645439
Hypselodoris_paulinae	EU982746	EU982798
Hypselodoris_perii	MG645602	MG645442
Hypselodoris_pulchella	MG645603	MG645443
Hypselodoris_purpureomaculosa	JQ727900	JQ727791
Hypselodoris_regina	MG645604	MG645444
Hypselodoris_reidi	MG645605	JQ727792
Hypselodoris_roo	MG645609	MG645449
Hypselodoris_rositoi	MG645610	MG645450
Hypselodoris_rudmani	MG645611	MG645451
Hypselodoris_saintvincentius	EU512162	EU512081
Hypselodoris_skyleri	MG645580	MG645422
Hypselodoris_tryoni	MG645615	MK322455
Hypselodoris_variobranchia	MG645618	MG645458
Hypselodoris_violacea	MG645619	MG645459
Hypselodoris_whitei	MG645620	MG645461
Hypselodoris_zephyra	MG645560	MG645462
Idaliadoris_depressa		
Inuda_luarna	EU982718	EU982768
Janolus_anulatus	MH781058	MH781035
Janolus_comis	MH781066	MH781043
Janolus_flavoanulatus	MH781073	MH781048
Janolus_mirabilis	HM162750	HM162674
Janolus_tricellariodes	MH781075	MH814722
Japonacteon_nipponensis	KX863691	GQ845191
Jorunna_artsdatabankia	MW784173	-
Julia_exquisita	GQ996661	EU140895
Julia_zebra	KM086410	KM204259
Kabeiro_rubroreticulata	KJ486739	KJ486791
Kalinga_ornata	MN224072	MN224103
Kaloplocamus_ramosus	JX274105	JX274066
Lamprohaminoea_cymbalum	DQ974675	KJ022812

Lamprohaminoea_ovalis		
Laona_grandioculi		
Laona_pruinosa	JX944808	KJ022834
Laona_quadrata	JX944809	KJ022793
Lapinura_divae	KF992195	KJ022825
Latia_neritoides		
Learchis_poica	JQ699632	JQ699556
Lecithophorus_capensis	MZ382783	-
Leminda_millecra	HM162745	HM162669
Liloa_mongii	DQ974672	MH933206
Liloa_porcellana	KF992202	KJ022836
Limacia_antofagastensis	KX673497	KX673498
Limacia_clavigera	EF142906	EF142952
Limacia_cockerelli	KX673492	KX673502
Limacia_janssi	DQ231009	KX673503
Limacia_mcdonaldi	KX673495	KX673500
Limapontia_capitata	KM086411	KM204260
Limapontia_depressa	KM086412	KM204261
Limapontia_senestra	HQ380200	HQ380183
Limenandra_fusiformis	JQ997077	JQ996884
Limenandra_nodosa	KJ522456	JX087527
Lissachatina_fulica	MN708326	KX060743
Littorina_littorea	DQ093523	DQ093479
Lobiger_viridis	KM086415	EU140894
Lomanotus_vermiformis	KX889740	-
Longchaeus_inopinatus		
Luisella_babai	HQ616754	HQ616717
Lymnaea_stagnalis		
Madrella_ferruginosa	MH781053	MH781031
Mannesia_sabadiega	MF036531	MF036352
Mariaglaja_inornata	AM421898	MF036355
Mariaglaja_tsurugensis	JN825172	JN825113
Marianina_rosea	HM162733	HM162656
Marionia_abrahamorum	MH892390	MH892386
Marionia_arborescens	HM162722	KP226859
Marionia_blainvillea	MF440435	KY629594
Marionia_distincta	HM162725	KP226860
Marionia_gemmii	MF440436	MF440432
Marionia_levis	HM162723	KP153252
Martadoris_amakusana		
Martadoris_limaciformis	MW815563	EF142930
Megalovalvata_baicalensis	LC377798	LC377815
Megalovalvata_piligera	LC377786	KJ186052

Megastomia_winfriedi	MT920145	-
Melanochlamys_cylindrica	EU604706	EU604724
Melanochlamys_diomedea	MH242846	EU604732
Melanochlamys_ezoensis	KX683209	MF036364
Melanochlamys_fukudai	KJ704930	KJ704889
Melanochlamys_kohi	KJ704935	KJ704894
Melanochlamys_lorrainae	EU604710	EU604726
Melanochlamys_miqueli	KJ704896	KJ704851
Melibe_leonina	NC 026987	NC_026987
Mexichromis_antonii	EU982748	JQ727798
Mexichromis_festiva	MH018003	MH017990
Mexichromis_lemniscata	EU512134	EU982790
Mexichromis_macropus	EF535123	EF534050
Mexichromis_mariei	EU982749	EF534049
Mexichromis_multituberculata	JQ727907	JQ727802
Mexichromis_pusilla	AJ223269	EU982791
Mexichromis_similaris	EF535128	EF534055
Mexichromis_trilineata	EU982753	EU982806
Miamira_magnifica	EU982731	JQ727694
Microglyphis_furukawai	LC331796	-
Microglyphis_hasegawai	LC331800	-
Micromelo_barbarae	MZ048422	-
Micromelo_scriptus	MZ048445	-
Micromelo_undatus	DQ991933	DQ986638
Mnestia_villica	KF992161	KJ022789
Moridilla_brockii	JQ997083	JQ996888
Mourgona_murca	KM086416	KM204265
Mourgona_osumi	GQ996667	EU140847
Murchisonella_anabathron	FJ917278	FJ917259
Myja_karin	MK320901	MK320911
Myja_longicornis	MK320903	MK320914
Myrella_antarctica		
Nakamigawaia_felis		
Nakamigawaia_spiralis	MF036537	MF036370
Nanuca_sebastiani	JQ699633	JQ699557
Navanax_aenigmaticus	MF036538	MF036374
Navanax_gemmatus	MF036543	MF036387
Navanax_inermis	MF036546	MF036388
Navanax_polyalphos	JN825182	JN825079
Nembrotha_chamberlaini	DQ231006	EF142933
Nembrotha_livingstonei	EF142900	EF142947
Nembrotha_megalocera	EF142888	EF142939
Nembrotha_milleri	EF142896	KJ018920

Nembrotha_mullineri	DQ231004	EF142944
Nembrotha_purpureolineata	EF142884	EF142936
Nembrotha_yonowae		
Nemesignis_banyulensis	AF249782	HQ616740
Newnesia_abyssalis	MF929066	MF929068
Newnesia_antarctica	KX238909	KU939086
Niparaya_regiscorona	MF036548	MF036390
Nipponoscaphander_japonicus	MZ473268	-
Noemiamea_dolioliformis	-	AF355170
Notaeolidia_depressa	GQ292057	-
Notarchus_indicus	AF156151	-
Notobranchaea_macdonaldi	MF048963	-
Notobryon_thompsoni	JN869456	JN869413
Notobryon_wardi	HM162714	JN869411
Notodoris_citrina		
Notodoris_gardineri	DQ991934	HM162605
Notodoris_minor	KJ001314	KJ018906
Notodoris_serenae	MF958441	MF958315
Noumeaella_isa	JQ997084	JQ996889
Noumeaella_rehderi	MW278646	JQ996861
Odontoglaja_guamensis	DQ991935	MF036394
Odostomia_acuta	-	AF355165
Odostomia_hirotamurana	-	AF355171
Odostomia_plicata	MT920154	GU331948
Odostomia_sitkaensis		
Odostomia_tenuisculpta	MG421167	-
Odostomia_turrita	-	AF355168
Okenia_hiroi	MW408699	NC_056185
Okenia_vena	KY661381	KY661373
Olea_hansineensis	KM086420	KM204269
Onchidium_verrucosum		
Onchidoris_bilamellata	MH242876	AF249235
Onchidoris_evincta	KP340391	KP340294
Onchidoris_macropompa	MF958423	MF958292
Onchidoris_muricata	AY345033	KJ653677
Onchimira_cavifera	MN224073	MN224104
Orbitestella_vera	FJ917268	FJ917250
Oscilla_ligata	DQ093526	-
Otopleura_auriscati	MN389190	-
Otopleura_nodicincta	HQ659995	HQ650563
Oxynoe_antillarum	KM086419	FJ917425
Oxynoe_azuropunctata	KM086425	KF317063
Oxynoe_viridis	AB501304	AB501304

Pacifia_amica	MG452633	-
Pacifia_goddardi		
Palio_dubia	MZ382786	-
Palisa_papillata	KX889743	-
Palliohedyle	JF828032	JF828040
Panderevela	-	KJ610035
Paraclione	MZ848608	-
Paracoryphella_islandica	MF523391	MF523398
Paradoris_liturata	MW223084	KP871696
Paraflabellina_ischitana	HQ616757	HQ616745
Parhedyle_cryptophthalma	JF828033	JF828042
Parthenina_affectuosa	-	AF355156
Parthenina_interstincta	-	AF355154
Parvaplustrum_cadieni	LC631487	LC631484
Peltodoris_atromaculata	AF120637	DQ280054
Peltodoris_lentiginosa		
Peltodoris_nobilis	HM162684	EU982816
Petalifera_petalifera	AY345020	-
Phanerophthalmus_albocollaris	MH294645	MH294555
Phanerophthalmus_albotriangulatum	MH294623	MH294562
Phanerophthalmus_anettae	MH294594	MH294537
Phanerophthalmus_batangas	MH294609	MH294588
Phanerophthalmus_cerverai	MH294622	MH294564
Phanerophthalmus_cylindricus	MH294652	MH294559
Phanerophthalmus_engeli	MH294612	MH294546
Phanerophthalmus_lentigines	MH294601	MH294542
Phanerophthalmus_luteus	MH294641	MH294574
Phanerophthalmus_minikoiensis	MH294650	MH294558
Phanerophthalmus_olivaceus	MH294625	MH294561
Phanerophthalmus_paulayi	MH294618	MH294551
Phanerophthalmus_perpallidus	MH294602	MH294545
Phanerophthalmus_purpura	MH294592	MH294530
Phanerophthalmus_rudmani	MH294610	MH294567
Phanerophthalmus_tibiricae	MH294607	MH294587
Phestilla_chaetopterana		
Phestilla_goniophaga	MW158916	-
Phestilla_lugubris	KJ522463	DQ417254
Phestilla_melanobrachia	MW403488	DQ417236
Phestilla_minor	DQ417313	DQ417264
Phestilla_sibogae	KY128975	GU550050
Phestilla_subodiosa	MN255481	MN255476
Phestilla_viei	MN239113	MN257606
Phidiana_hiltoni	MK333338	JQ699558

Phidiana_lascrucensis	KU950197	KU950131
Phidiana_lynceus	KX889745	JX087498
Philine_amabilis	KF892058	-
Philine_aperta	AY345016	DQ093482
Philine_argentata	MN326972	MN326885
Philine_babai	KF877703	KJ022854
Philine_dentiphallus	KJ411897	KJ411891
Philine_exigua	HQ168450	HQ168412
Philine_orientalis		
Philine_verdensis	KJ411900	-
Philinoglossa_praelongata	-	HQ168411
Philinopsis_depicta	AM421892	MF036396
Philinopsis_pusa	MF036552	JN825145
Philinopsis_speciosa	MF036558	MF036399
Philinorbis_teramachii		
Phyllaplysia_lafonti	DQ246445	-
Phyllidia_coelestis	MW815567	MF958279
Phyllidia_elegans	NC 063667	NC_063667
Phyllidia_ocellata	NC 030039	NC_030039
Phyllidia_picta	MN507477	KJ018916
Phyllidia_varicosa	OK482877	KP873169
Phyllidiella_lizae	KJ001309	AF430365
Phyllidiella_nigra	KX235952	MF958280
Phyllidiella_pustulosa	MK279705	MK279705
Phyllidiopsis_cardinalis	KJ001308	AF430367
Phyllidiopsis_krempfi	MT726194	NC_052698
Phyllidiopsis_sphingis	MN507483	AF430368
Phyllodesmium_briareum	HQ010491	GQ403753
Phyllodesmium_colemani	HQ010499	GQ403755
Phyllodesmium_crypticum	HQ010502	GQ403770
Phyllodesmium_horridum	HM162757	HM162681
Phyllodesmium_hyalinum	GQ403778	GQ403756
Phyllodesmium_jakobsenae	HQ010488	GQ403759
Phyllodesmium_karenae	HQ010483	HQ010517
Phyllodesmium_koehleri	HQ010494	GQ403760
Phyllodesmium_lembehensis	GQ403780	GQ403758
Phyllodesmium_lizardensis	HQ010496	GQ403772
Phyllodesmium_longicirrum	JQ699634	GQ403761
Phyllodesmium_macphersonae	HQ010482	HQ010522
Phyllodesmium_magnum	HQ010500	HQ010511
Phyllodesmium_opalescens	HQ010485	HQ010520
Phyllodesmium_tuberculatum	HQ010497	HQ010533
Physella_acuta	JQ390525	AY65124

Pinufius_rebus	HM162744	HM162667
Piseinotecus_soussi	LT718576	-
Placida_barackobamai	MF773473	MF773461
Placida_brookae	MF773470	MF773457
Placida_cremoniana	AB501312	AB501312
Placida_daguilarensis	LC531994	LC532036
Placida_dendritica	LC531993	LC532042
Placida_dendritica	KP254756	EU140871
Placida_kevinleei	KM086427	MF773464
Placida_verticillata	GU191064	GU191045
Plakobranchus_ocellatus	AP014544	AB501307
Plakobranchus_papua	KC573733	KM204281
Platydoris_sanguinea	MF958416	MF958285
Pleurehdera_haraldi	KM521726	-
Pleurobranchaea_meckeli	AY345026	FJ917439
Pleurobranchus_albiguttatus	KM521746	KM521602
Pleurobranchus_grandis	KM521697	KM521609
Pleurobranchus_hilli	FJ917497	FJ917438
Pleurobranchus_membranaceus	KM521752	FJ917437
Pleurobranchus_peroni		
Pleurobranchus_peronii	DQ237993	KM521595
Plocamopherus_ceylonicus	MZ382787	KP871698
Plocamopherus_imperialis	JX274103	JX274065
Plocamopherus_maderae	EF142905	EF142951
Pluscula_cuica	KF992203	KJ022837
Pneumoderma_violaceum		
Polybranchia_burni	MH087152	MH087123
Polybranchia_jannae	MH087157	MH087127
Polybranchia_jensenae	MW278443	MH087139
Polybranchia_mexicana	MH087173	MH087144
Polybranchia_orientalis	-	EU140846
Polybranchia_samanthae	MH087178	MH087146
Polybranchia_schmekelae	MH087181	MH087149
Polycera_atra	JX274085	KF425275
Polycera_capensis	MZ382789	JX274050
Polycera_faeroensis	MZ425340	JX274056
Polycera_hedgpethi	MZ713367	MZ713367
Polycera_quadrilineata	EF142907	AF249229
Polycerella_emertoni	JX274099	-
Pontohedyle_joni	JQ410902	-
Pontohedyle_milaschewitchii	JQ410898	JQ410929
Pontohedyle_neridae	JQ410922	-
Pontohedyle_verrucosa	JQ410919	JQ410977

Pontohedyle_wenzli	JQ410915	-
Pontohedyle_wiggi	JQ410911	-
Praephiline_finmarchica	JX944799	MN326887
Prodoris_clavigera	JX274106	AF249222
Protaeolidiella_atra	MN911169	NC_053882
Pruvotfolia_longicirrha	HQ616760	HQ616723
Pruvotfolia_pselliotes	HQ616762	HQ616725
Pseudobornella_orientalis	MT654637	HM162628
Pseudocingulina_terebra		
Pseudovermis_mortoni	MK059478	-
Pseudovermis_paradoxus	MN850077	-
Pseudovermis_salamandrops	MK059476	-
Pseudunela_cornuta	JF819774	JF819748
Pseudunela_espiritusanta	JF819776	JF819750
Pseudunela_marteli	JF819773	KF709248
Pseudunela_viatoris	JF819769	JF819743
Pteraeolidia_ianthina	MN690488	JN687513
Pteraeolidia_semperi	KJ200981	KJ201009
Pyramidella_dolabrata	AY345054	-
Pyrgiscus_crenatus	MG935213	AF355184
Pyrgiscus_jeffreysii		
Pyrgiscus_rufa		
Pyrunculus	DQ974678	-
Reticulidia_fungia	KX235990	AF430370
Reticulidia_halgerda	MF958414	MF958282
Retusa_nitidula		
Retusa_obtusa	MH012218	-
Retusa_operculata		
Retusophiline_lima	KF643758	-
Rhodope_marcusi	KY806821	KY806793
Rhodope_roskoi	-	KY806794
Rhodope_rousei	KY806822	KY806795
Rhodope_transtrosa	KY806824	KY806797
Rictaxis_punctocaelatus	EF489393	GQ845193
Ringicula_doliaris	LC150582	LC150582
Ringicula_pilula	LC150583	LC150583
Ringiculoides_kurilensis	LC150590	LC150593
Ringiculopsis_foveolata	LC150584	LC150584
Rissoella_elatior	MK210176	-
Rissoella_elongatospira	FJ917270	-
Rissoella_golikovi	MK210188	-
Rissoella_japonica	MK210185	-
Rissoella_rissoaformis	FJ917271	FJ917252

Roboastra_caboverdensis		
Roboastra_gracilis	EF142863	EF142912
Roboastra_tentaculata	EF142864	EF142914
Rostanga_pulchra	AY345044	-
Roxania_utriculus	MH933095	-
Roxaniella_multistriata	KX523204	MH933188
Rubramoena_amoena	KY128904	KY128696
Rubramoena_rubescens	KY128916	KY128710
Rumina_decollata		
Runcina_africana	DQ974680	KJ022780
Sabatia_bathymophila	MZ473275	-
Sacoproteus_smaragdinus	AB501310	AB501310
Sagaminopteron_multimaculatum	KX552034	KX551989
Sagaminopteron_nigropunctatum	DQ991937	KX551977
Sagaminopteron_ornatum	AM421857	KX551978
Sagaminopteron_pohnpei	AM421858	KX551993
Sagaminopteron_psychedelicum	AM421856	KJ022787
Sakuraeolis_arcana	MT997033	MT997029
Sakuraeolis_enosimensis	MT997034	HM162682
Sakuraeolis_japonica	NC 033968	NC_033968
Salinator	-	GU331952
Samla_bicolor	MW278850	KY128841
Samla_bilas		
Samla_macassarana		
Samla_takashigei	MF523384	MF523463
Scaphander_grandis	MZ473287	MK952768
Scaphander_lignarius	DQ974663	EF489324
Scaphander_mundus	MZ473292	KC351529
Scaphander_nobilis	MN433679	KC351530
Scaphander_punctostriatus	MZ473301	KC351534
Scaphander_subglobosus	MZ473309	KC351539
Scaphander_watsoni	MZ473313	KC351541
Schizobrachium_polycotylum	FJ876949	-
Sclerodoris_tuberculata	MF958417	MF958286
Scyllaea_pelagica	HM162711	JN869416
Siphonaria_alternata	HQ386679	EF489299
Siphonaria_brannani	KM086435	KM204294
Siphonaria_capensis	EF489379	EF489301
Siphonaria_concinna	EF489378	EF489300
Siphonaria_japonica	OL877063	HQ650567
Siphonaria_lateralis	MF652001	HQ650565
Siphonaria_lessonii	MF652021	HQ650566
Siphonaria_normalis	HQ659996	HQ650564

Siphonaria_pectinata	NC_012383	HQ650568
Siphonaria_serrata	EF489380	EF489302
Siphonaria_sirius	LC383971	MG242626
Siphopteron_brunneomarginatum	AM421864	AM421816
Siphopteron_michaeli	KX552033	KX551988
Siphopteron_tigrinum	KX552039	KJ022788
Smaragdinella_calyculata	DQ991938	KJ022815
Sohgenia_palauensis	KM086437	KM204296
Spiniphiline_persei	KR733277	KR733278
Spinoaglaja_orientalis	MF036559	MF036407
Spinoaglaja_petra	MF036561	MF036409
Spinophallus_coronatus	JN825188	JN825130
Spinophallus_falciphallus	MF036562	MF036410
Spiraphiline_bathyalis	MK015701	-
Spiraphiline_hadalis	MN326989	MN326902
Spiraphiline_kurilokamchatica	MN326991	MN326904
Spiraphiline_okhotensis	MN326979	MN326892
Spongiobranchaea_australis	MH482545	-
Spurilla_braziliana	MW277670	KF273261
Spurilla_dupontae	KF273271	KF273250
Spurilla_neapolitana	HQ616764	KF273264
Spurilla_sargassicola	JQ997098	JQ996901
Stiliger_aureomarginatus	KM086439	KM204298
Stiliger_berghi	LC531997	LC532034
Stiliger_fuscovittatus	KM086440	KM204299
Stiliger_ornatus	AB501311	AB501311
Styliola_subula	MW125360	-
Stylocheilus_longicauda	AF156156	-
Swennenia_jabae		
Tambja_abdere	DQ230995	EF142928
Tambja_affinis	EF142866	EF142916
Tambja_eliora	DQ230998	EF142923
Tambja_morosa	DQ230997	EF142918
Tambja_olivaria	EF142865	EF142915
Tambja_sagamiana	EF142870	EF142921
Tambja_simplex	EF142874	EF142925
Tambja_tentaculata	EF142864	EF142914
Tambja_verconis	EF142869	EF142920
Taringa_sublutea		
Taringa_telopia	MN720291	EU982817
Tayuva_lilacina	MW278701	-
Telodiacria_danae	KC774076	-
Telodiacria_quadridentata	FJ876902	-

Tenellia_adspersa	KY129085	KY128875
Tergipes_antarcticus	GU227106	GU227007
Tergiposacca_longicerata	KY129086	KY128877
Tethys_fimbria	AY345035	-
Thecacera_pennigera	JX274094	-
Thielea_helicoides	FJ876926	-
Thordisa_albomacula	MF958418	MF958287
Thorunna_arbuta		
Thorunna_australis	JQ727912	JQ727816
Thorunna_daniellae	EU982756	EU982809
Thorunna_florens	JQ727913	JQ727817
Thorunna_furtiva	EF535126	EU982810
Thorunna_punicea	JQ727914	JQ727820
Thuridilla_albopustulosa	KM086443	EU140889
Thuridilla_bayeri	MN525124	EU140886
Thuridilla_carlsoni	MN525065	EU140877
Thuridilla_gracilis	DQ991939	EU140885
Thuridilla_hoffae	MN525107	EU140880
Thuridilla_hopei	MN525110	KJ363917
Thuridilla_kathae	MN525137	EU140879
Thuridilla_lineolata	MN525115	EU140887
Thuridilla_livida	MN525117	HM187607
Thuridilla_malaquita	KU058141	KU058124
Thuridilla_mazda	MN525118	HQ616836
Thuridilla_neona	MW278545	DQ480209
Thuridilla_picta	KU058144	HQ616822
Thuridilla_splendens	MN525135	AB759042
Thuridilla_undula	MN525138	DQ480210
Thuridilla_vataae	MN525140	LC532028
Tjaernoeia	LC631486	LC631483
Tochuina_gigantea	MH243006	-
Tochuina_nigritigris	MH756138	MH756133
Toledonia_globosa	EF489395	EF489327
Tomthompsonia_antarctica	DQ237992	EF489330
Trapania_reticulata	MF958432	MF958303
Trinchesia_caerulea	MK587928	MK587932
Trinchesia_cuanensis	MK587922	MK587936
Trinchesia_diljuvia	MK587918	MK587934
Trinchesia_foliata	KY128912	KY128704
Trinchesia_morrowae	MK587927	MK587941
Trinchesia_ornata	KY128967	KY128758
Triopha_catalinae	HM162690	AF249227
Triopha_maculata	AY345045	HM162601

Tritonia_festiva	HM162719	KP153258
Tritonia_tetraquetra	NC 026988	NC_026988
Tritonia_vorax	MW444335	-
Tritonicula_hamnerorum	KP153293	KP153260
Tritoniella_belli	MW444341	GU227002
Tritoniopsis_elegans	KP153315	KP153282
Tritoniopsis_frydis	KX889749	KP153278
Trivettea_papalotla	KP153297	KP153264
Tubulophilinopsis_gardineri	MF036564	MF036413
Tubulophilinopsis_lineolata	MF036565	AM421839
Tubulophilinopsis_pilsbryi	MF036570	MF036411
Tubulophilinopsis_reticulata	MF036574	MF036420
Turbonilla_buteonis	MK308319	-
Turbonilla_fusca	JQ228468	JQ228491
Turbonilla_lactea	-	AF355176
Turbonilla_powhatani	MK308110	-
Turbonilla_subulina	-	AF355177
Turbonilla_toyatani	MH235901	-
Tylodina_perversa	KF992172	KJ022803
Tyrannodoris_caboverdensis	EF142859	EF142908
Tyrannodoris_luteolineata	DQ231001	EF142911
Tyrinna_delicata		
Tyrinna_evelinae	EU982757	EU982812
Unidentia_aliciae	MK204487	MK204484
Unidentia_nihonrossija	MF523385	MF523464
Unidentia_sandramillenae	MG452632	MG452683
Valvata_aliena	-	KJ186056
Valvata_amurensis	LC377788	LC377807
Valvata_biwaensis	LC377805	LC377822
Valvata_confusa	LC377796	LC377813
Valvata_hokkaidoensis	LC377799	AB028238
Valvata_japonica	LC377803	LC377820
Valvata_kizakikoensis	LC377801	LC377818
Valvata_middendorffi	LC377790	LC377809
Valvata_montenegrina	EU419014	KJ186047
Valvata_piscinalis	MT483647	FJ917248
Valvata_relicta	EU419015	KJ186051
Valvata_rhabdota	EU419006	KJ186050
Valvata_sibirica	KJ186033	KJ186057
Valvata_stenotrema	EU419012	KJ186048
Vayssierea	MZ382796	-
Vellicolla_amphorella	MH933116	MH933200
Vellicolla_muscaria	OQ206979	MH933190

Verconia_simplex	EU982752	EU982804
Verconia_varians	JQ727909	JQ727812
Verconia_verconis	EF535118	EF534046
Volvatella_angeliniana	AB501302	AB501302
Volvatella_maculata	KM086449	KM204314
Volvatella_ventricosa	KM086448	KF317060
Volvatella_viridis	HQ168451	EU140890
Volvulella	DQ974684	KJ022785
Waegelea_antarctica	MN486300	-
Weinkauffia_macandrewii	-	MH933210
Weinkauffia_ukulele	MH933102	MH933198
Williamia_peltoides	KM086451	KM204316
Xenocratena_suecica	MN850081	-
Yokoyamaia_ornatissima	MN327001	MN326916
Zelentia_fulgens	KY128952	KY128747
Zelentia_nepunicea	MH614985	MH614976
Zelentia_ninel	KY952181	MH614967
Zelentia_pustulata	KY952184	MH614972
Zelentia_roginskae	MH614983	MH614974
Zelentia_willowsi	MH614987	MH614978
Zeusia_hyperborea	KX758256	KX758251
Ziminella_abyssa	MF523342	MF523466
Ziminella_circapolaris	MF523354	MF523419
Ziminella_salmonacea	KF643407	KY128853
Ziminella_vrijenhoeki	MH756136	MH756130

APPENDIX B – List of species and size of the micro gastropods Lower Heterobranchia and Mesoneura evaluated in this study

Species	Family	Size
Pseudotorinia kraussi	Architectonicidae	0.9 mm
Pseudotorinia sestertius	Architectonicidae	0.9 mm
Spirolaxis rotulacatbarinea	Architectonicidae	0.9 mm
Spirolaxis exornatus	Architectonicidae	1.1 mm
Spirolaxis comuarietis	Architectonicidae	1.2 mm
Pseudotorinia amoena	Architectonicidae	1.3 mm
Pseudotorinia concava	Architectonicidae	1.5 mm
Pseudotorinia panamensis	Architectonicidae	1.6 mm
Pseudotorinia numulus	Architectonicidae	1.6 mm
Pseudotorinia gemmulata	Architectonicidae	1.7 mm
Spirolaxis argonauta	Architectonicidae	1.7 mm
Heliacus planispira	Architectonicidae	1.8 mm
Pseudotorinia laseronorum	Architectonicidae	1.8 mm
Pseudotorinia yaroni	Architectonicidae	1.8 mm
Pseudotorinia colmani	Architectonicidae	1.9 mm
Pseudotorinia colmani	Architectonicidae	1.9 mm
Pseudotorinia delectabilis	Architectonicidae	2 mm
Pseudotorinia armillata	Architectonicidae	2.1 mm
Spirolaxis comuammonis	Architectonicidae	2.1 mm
Heliacus sterkii	Architectonicidae	2.2 mm
Heliacus virgatus	Architectonicidae	2.3 mm
Pseudotorinia architae	Architectonicidae	2.3 mm
Heliacus rotula	Architectonicidae	2.7 mm
Heliacus corallinus	Architectonicidae	3 mm
Heliacus mazatlanicus	Architectonicidae	3.3 mm
Solatisonax rebderi	Architectonicidae	3.4 mm
Heliacus oceanitis	Architectonicidae	3.5 mm
Soladsonax supraradiata	Architectonicidae	3.5 mm
Granosolarium gemmiferom	Architectonicidae	3.0 mm
Heliacus hyperionis	Architectonicidae	3.6 mm
Heliacus caelatus	Architectonicidae	4 mm
Heliacus nereidis	Architectonicidae	4.3 mm
Heliacus proteus	Architectonicidae	4.4 mm
Heliacus turritus	Architectonicidae	4.6 mm
Pseudotorinia jonasi	Architectonicidae	2.7 mm
Spirolaxis centrifuga	Architectonicidae	0.43 mm
Spirolaxis lamellifer	Architectonicidae	1.58 mm
Psilaxis clertoni	Architectonicidae	2 mm
Solatisonax rudigerbieleri	Architectonicidae	2.3 mm

Pseudotorinia phorcysi	Architectonicidae	2.69 mm
Graphis albida	Cimidae	2.0 mm
Cima cylindrica	Cimidae	long. 1/30
Cima minima	Cimidae	2 mm
Graphis gracilis	Cimidae	2.4 mm
Austrorissopsis maccoyi	Cimidae	1.5 mm
Graphis striata	Cimidae	0.15 mm
Austrorissopsis consobrina	Cimidae	2 mm
Coenaculum minutulum	Cimidae	2 mm
Bouryiscala turrisphari	Cimidae	2.64 mm
Graphis africana	Cimidae	2.3 mm
Graphis sculpturata	Cimidae	2.1 mm
Graphis blanda	Cimidae	3 mm
Coenaculum secundum	Cimidae	1.5 mm
Graphis underwoodae	Cimidae	2.4 mm
Graphis infans	Cimidae	2.0 mm
Graphis pellucida	Cimidae	2.5 mm
Coenaculum tertium	Cimidae	1.5 mm
Graphis menkhorsti	Cimidae	0.75 mm
Atomiscala islandica	Cimidae	3.88 mm
Coenaculum weerdtae	Cimidae	2.1 mm
Mifsudia melitensis	Cimidae	1.1 mm
Graphis barashi	Cimidae	2.5 mm
Cima apicisbelli	Cimidae	0.93 mm
Cima urdunensis	Cimidae	1 mm
Cima mingoranceae	Cimidae	1.41 mm
Graphis pruinosa	Cimidae	2.1 mm
Graphis peruviana	Cimidae	1.19 mm
Tomura depressa	Cornirostridae	1.3 mm
Cornirostra pellucida	Cornirostridae	2.1 mm
Noerrevangia fragilis	Cornirostridae	1.7 mm
Cornirostra floridana	Cornirostridae	2.3 mm
Tomura xenoskeneoides	Cornirostridae	1.86 mm
Tomura abscondita	Cornirostridae	0.6 mm
Tomura umbiliobsessa	Cornirostridae	0.5 mm
Tomura sphaerica	Cornirostridae	0.94 mm
Cornirostra lenticulata	Cornirostridae	1.4 mm
Tomura apextruncatus	Cornirostridae	1.8 mm
Tomura rubiorolanorum	Cornirostridae	0.95 mm
Xenoskenea pellucida	Hyalogyrinidae	2.0 mm
Hyalogyrina glabra	Hyalogyrinidae	1.70 mm
Hyalogyra expansa	Hyalogyrinidae	2.65 mm
Hyalogyrina grasslei	Hyalogyrinidae	2.6 mm
Hyalogyra vitrinelloides	Hyalogyrinidae	2.25 mm

Hyalogyra zibrowii	Hyalogyrinidae	1.0 mm
Hyalogyrina amphorae	Hyalogyrinidae	1.48 mm
Mathilda gemmulata	Mathildidae	5 mm
Mathilda cochlaeformis	Mathildidae	4 mm
Mathilda retusa	Mathildidae	4 mm
Tuba pinguis	Mathildidae	0.3 mm
Mathilda zmitampis	Mathildidae	3.5 mm
Mathilda oppia	Mathildidae	3.35 mm
Mathilda malvinarum	Mathildidae	2.8 mm
Brookesena neozelanica	Mathildidae	2.5 mm
Brookesena succincta	Mathildidae	2.6 mm
Turritellopsis stimpsoni	Mathildidae	2.8 mm
Turritellopsis floridana	Mathildidae	2.6 mm
Mathilda granifera	Mathildidae	3 mm
Mathilda amaea	Mathildidae	4.5 mm
Mathilda globulifera	Mathildidae	5.2 mm
Mathilda maculosa	Mathildidae	4.4 mm
Mathilda boucheti	Mathildidae	5.0 mm
Brookesena turrita	Mathildidae	2.8 mm
Mathilda herberti	Mathildidae	4.8 mm
Mathilda brownae	Mathildidae	3.3 mm
Mathilda magellanica	Mathildidae	3 mm
Ebala striatula	Murchisonellidae	1 mm
Koloonella turrita	Murchisonellidae	3 mm
Koloonella harrissoni	Murchisonellidae	5 mm
Ebala bermudensis	Murchisonellidae	2 mm
Henrya morrisoni	Murchisonellidae	1.4 mm
Henrya goldmani	Murchisonellidae	2 mm
Henrya henryi	Murchisonellidae	2.1 mm
Koloonella minutissima	Murchisonellidae	1 mm
Koloonella ignorabilis	Murchisonellidae	5.2 mm
Ebala micalii	Murchisonellidae	1.6 mm
Ebala communis	Murchisonellidae	2 mm
Murchisonella arabica	Murchisonellidae	0.9mm
Murchisonella cebuana	Murchisonellidae	1.5 mm
Ebala trigonostoma	Murchisonellidae	1 mm
Ebala pointeli	Murchisonellidae	1.7 mm
Omalogyra fusca	Omalogyridae	3 mm
Omalogyra ammonitoides	Omalogyridae	0.4 mm
Omalogyra liliputia	Omalogyridae	0.61 mm
Ammonicera sucina	Omalogyridae	0.69 mm
Ammonicera extracarinacostata	Omalogyridae	0.45 mm
Ammonicera tenuicostata	Omalogyridae	0.51 mm
Ammonicera binodosa	Omalogyridae	0.64 mm

Ammonicera plicata	Omalogyridae	0.65 mm
Ammonicera nodicarinata	Omalogyridae	0.46 mm
Ammonicera vangoethemi	Omalogyridae	0.49 mm
Ammonicera rotundata	Omalogyridae	0.55 mm
Ammonicera lignea	Omalogyridae	0.85 mm
Omalogyra disculus	Omalogyridae	650 µm
Omalogyra undosa	Omalogyridae	650 µm
Ammonicera minortalis	Omalogyridae	0.35 mm
Ammonicera familiaris	Omalogyridae	0.37 mm
Ammonicera lineofuscata	Omalogyridae	0.45 mm
Ammonicera albospeciosa	Omalogyridae	0.47 mm
Ammonicera sculpturata	Omalogyridae	0.47 mm
Ammonicera circumcirra	Omalogyridae	0.58 mm
Omalogyra fuscopardalis	Omalogyridae	0.7 mm
Omalogyra zebrina	Omalogyridae	0.77 mm
Ammonicera plana	Omalogyridae	1. mm
Retrotortina fuscata	Omalogyridae	0.7 mm
Ammonicera mcleani	Omalogyridae	0.45 mm
Ammonicera mexicana	Omalogyridae	0.53 mm
Ammonicera sleursi	Omalogyridae	0.70 mm
Ammonicera galaica	Omalogyridae	0.46 mm
Ammonicera nodulosa	Omalogyridae	0.50 mm
Ammonicera arrondoi	Omalogyridae	0.6 mm
Ammonicera superstriata	Omalogyridae	0.62 mm
Ammonicera columbretensis	Omalogyridae	0.85 mm
Ammonicera rota	Omalogyridae	0.89 mm
Ammonicera andresi	Omalogyridae	0.9 mm
Ammonicera fischeriana	Omalogyridae	1 mm
Ammonicera aurea	Omalogyridae	0.43 mm
Ammonicera japonica	Omalogyridae	0.5 mm
Ammonicera tahitiensis	Omalogyridae	0.38 mm
Ammonicera tomalba	Omalogyridae	0.404 mm
Ammonicera tomensis	Omalogyridae	0.43 mm
Ammonicera pascuensis	Omalogyridae	0.436 mm
Ammonicera croata	Omalogyridae	0.45 mm
Ammonicera caledonica	Omalogyridae	0.5 mm
Ammonicera albanyensis	Omalogyridae	0.785 mm
Orbitestella bastowi	Orbitestellidae	0.35 mm
Orbitestella diegensis	Orbitestellidae	1.0 mm
Microdiscula cifara	Orbitestellidae	0.5 mm
Microdiscula rifaca	Orbitestellidae	0.5 mm
Orbitestella hinemoa	Orbitestellidae	1 mm
Orbitestella parva	Orbitestellidae	0.3 mm
Orbitestella toreuma	Orbitestellidae	0.27 mm

Microdiscula vitrea	Orbitestellidae	1.5 mm
Orbitestella dariae	Orbitestellidae	1.7 mm
Microdiscula vanhoeffeni	Orbitestellidae	0.76 mm
Microdiscula charopa	Orbitestellidae	1.4 mm
Microdiscula subcanaliculata	Orbitestellidae	1.4 mm
Orbitestella bermudezi	Orbitestellidae	0.74 mm
Boschitestella eloiseae	Orbitestellidae	0.2 mm
Boschitestella donaldi	Orbitestellidae	0.24 mm
Lurifax vitreus	Orbitestellidae	2.8 mm
Orbitestella ponderi	Orbitestellidae	0.7 mm
Orbitestella aequicostata	Orbitestellidae	0.67 mm
Orbitestella patagonica	Orbitestellidae	1.1 mm
Lurifax japonicus	Orbitestellidae	0.8 mm
Orbitestella pruinosa	Orbitestellidae	0.35 mm
Orbitestella amphaengensis	Orbitestellidae	0.88 mm
Orbitestella pacifica	Orbitestellidae	0.59 mm
Orbitestella peculiaris	Orbitestellidae	0.65 mm
Orbitestella ellenstrongae	Orbitestellidae	0.8 mm
Orbitestella vanuatuensis	Orbitestellidae	0.82 mm
Orbitestella fijiensis	Orbitestellidae	0.83 mm
Orbitestella cordarta	Orbitestellidae	0.85 mm
Orbitestella marquesensis	Orbitestellidae	0.89 mm
Orbitestella papuaensis	Orbitestellidae	1.03 mm
Orbitestella media	Orbitestellidae	1.17 mm
Absonus primus	Orbitestellidae	1.84 mm
Parvaplustrum tenerum	Parvaplustridae	2.8 mm
Parvaplustrum japonicum	Parvaplustridae	2.1 mm
Parvaplustrum cadieni	Parvaplustridae	2 mm
Helminthope psammobionta	Rhodopidae	1.5 mm
Rhodope transtrosa	Rhodopidae	1.65 mm
Rhodope marcusi	Rhodopidae	2 mm
Rhodope crucispiculata	Rhodopidae	400 µm (immature)
Rhodope roskoi	Rhodopidae	1.5 mm
Rhodope veranii	Rhodopidae	5 mm
Rhodope rousei	Rhodopidae	2 mm
Rhodope placozophagus	Rhodopidae	2.0 mm
Tjaernoeia unisulcata	Tjaernoeiidae	0.95 mm
Tjaernoeia exquisita	Tjaernoeiidae	0.6 mm
Tjaernoeia boucheti	Tjaernoeiidae	0.93 mm
Tjaernoeia michaeli	Tjaernoeiidae	0,62 mm
Valvata tricarinata	Valvatidae	4.1 mm
Valvata sincera	Valvatidae	5 mm
Valvata virens	Valvatidae	4 mm
Valvata macrostoma	Valvatidae	2.9 mm

Valvata nilotica	Valvatidae	3.3 mm
Valvata mergella	Valvatidae	
Valvata geyeri	Valvatidae	3 mm
Valvata helicoidea	Valvatidae	2.5 mm
Valvata perdepressa	Valvatidae	3.5 mm
Valvata whitei	Valvatidae	2.5 mm
Valvata simusyuensis	Valvatidae	4.2 mm
Valvata cristata	Valvatidae	1.0 mm
Valvata humeralis	Valvatidae	4 mm
Valvata nowshahrensis	Valvatidae	2.3 mm
Borysthenia naticina	Valvatidae	3.85 mm
Valvata kebapcii	Valvatidae	2.47 mm
Valvata aliena	Valvatidae	5.2 mm
Valvata hokkaidoensis	Valvatidae	3-3.5 mm
Valvata biwaensis	Valvatidae	3.75 mm
Valvata utahensis	Valvatidae	4-6 mm
Valvata piscinalis	Valvatidae	4.5 mm
Valvata japonica	Valvatidae	
Pseudomegalovalvata laethmophila	Valvatidae	3.0 mm
Pseudomegalovalvata bathybia	Valvatidae	1.8 mm
Pseudomegalovalvata olkhonica	Valvatidae	1.8 mm
Pseudomegalovalvata profundicola	Valvatidae	1.8 mm
Megalovalvata demersa	Valvatidae	2.8 mm
Pseudomegalovalvata tenagobia	Valvatidae	3.0 mm
Megalovalvata baicalensis	Valvatidae	3.20 mm
Megalovalvata piligera minor	Valvatidae	3.5 mm
Megalovalvata parvula	Valvatidae	4.0 mm
Megalovalvata piligera piligera	Valvatidae	4.7 mm
Megalovalvata kozhovi	Valvatidae	5.7 mm
Valvata armeniaca	Valvatidae	1.5 mm
Valvata lewisi lewisi	Valvatidae	3.5 mm
Xylodiscula librata	Xylodisculidae	1.2 mm
Xylodiscula vitrea	Xylodisculidae	1.75 mm
Xylodiscula eximia	Xylodisculidae	1.95 mm
Xylodiscula boucheti	Xylodisculidae	1.72 mm
Xylodiscula lens	Xylodisculidae	1.74 mm
Xylodiscula major	Xylodisculidae	3.88 mm
Xylodiscula osteophila	Xylodisculidae	1.07 mm
Xylodiscula planata	Xylodisculidae	1.7 mm
Xylodiscula analoga	Xylodisculidae	1.7 mm
Xylodiscula wareni	Xylodisculidae	1.1 mm

Source: Prepared by the author (2023)

APPENDIX C – Representation in the literature and GBIF, nominal species available in dry and ethanol, containing the names of the species that are preserved in ethanol

Family	Representativeness of records	Preparation	Preserved species
Architectonicidae	Literature- 189 GBIF - 280	Dry shell	-
Cimidae	Literature- 40 GBIF - 41	Dry shell	-
Cornirostridae	Literature- 16 GBIF - 15	Dry shell	-
Hyalogyrinidae	Literature- 16 GBIF - 10	Ethanol (3)	*Hyalogyrina grasslei*
Mathildidae	Literature- 26 GBIF - 50	Ethanol (1)	-
Murchisonellidae	Literature- 14 GBIF - 53	Dry shell	*Turritelopsis stimpsoni*
Omalogyridae	Literature- 83 GBIF - 54	Ethanol (17)	*Ammonicera lineofuscata, Ammnonicera nodicarinata, Ammonicera vangoethelmi*
Orbitestellidae	Literature- 40 GBIF - 69	Ethanol (13)	*Lurifax japonicus, Orbitestella bastowi, Orbitestella bermudezi Microdiscula vanhoeffeni*
Parvaplustridae	Literature- 4 GBIF - 7	Ethanol (5)	*Parvaplustrum cadiene*
Rhodopidae	Literature- 7 GBIF - 0	Ethanol (5)	*Rhodope rousei*
Tjaernoeiidae	Literature- 3 GBIF - 3	Dry shell	-
Valvatidae	Literature- 39 GBIF - 2683	Ethanol (11)	*Borysthenia naticina, P. bathybia, P, laethmophila, P. profundicola, Valvata armeniaca*
Xylodisculidae	Literature- 15 GBIF - 0	Dry shell	-

Source: Prepared by the author (2023)