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DIVERSITY OF TERRESTRIAL GASTROPODS IN KABYLIA REGION (TIZI-OUZOU, NORTHERN ALGERIA)

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ABSTRACT: The goal of this study was to record the malacofauna of the Kabylia region, Tizi-Ouzou, in Northern Algeria, at the edge of the Mediterranean Sea, and to report the distribution pattern of terrestrial gastropod diversity in five different types of habitat (dune, agricultural fields, rural sites, forests, and mountain locations). A total of 33 species of terrestrial snails and slugs were recorded, which represented 27 genera of 19 families, mainly Geomitridae and Helicidae. The rural habitat was the richest, with 23 species, while the mountain habitat yielded 20 species. The dune and forest habitats showed the smallest species richness.

KEY WORDS: diversity; habitat; land snail and slugs; Kabylia; Tizi-Ouzou; Algeria

INTRODUCTION

The Mediterranean Basin has one of the highest levels of biodiversity in the world. The geological landscape of the region is varied; a variety of habitats have developed there. The plant communities, and consequently several different types of ecosystems, are a result of the heterogeneous environment. These conditions have made the Mediterranean Basin one of the 36 global biodiversity hotspots (MÉDAIL & MYERS 2004, BLONDEL et al. 2010). The Basin holds a large diversity of flora: native tree species and subspecies, and cryptic woody trees of 245 taxa (MÉDAIL et al. 2019). Its reptile, amphibian, bird, and mammal faunas are also rich, including numerous Mediterranean species (VALAVANIDIS & VLACHOGIANNI 2011). The Mediterranean Basin hosts 50% of all known crab and crayfish species, 48% of reptile species, 25% of mammal species, 14% of dragonfly species, 6% of shark and ray species, and 3% of bird species. Besides, 18% of the world's macroscopic marine species live in the region, of which 25% to 30% are endemic (BIANCHI & MORRI 2000). Finally, the Mediterranean wetlands are considered important habitats for migratory birds as stopover or breeding sites (CUTTELOD et al. 2009).

The African continent is home to 25% of the world's 4,700 mammal species, as well as more than 2,000 species of birds (20% of the currently known species), at least 2,000 fish species, 950 amphibian species, 100,000 insect and arachnid species. In fact, the African continent alone holds eight biodiversity hotspots (JONSON & CHENJE 2008). One of these is located in Algeria, North Africa (MYERS et al. 2000). Due to its geographical location, Algeria is a crossroads between continents with a copious history and massive biodiversity, and whose fauna, particularly terrestrial molluscs, needs further study. Monitoring the malacofauna of Algeria began in the early years of French colonisation (MICHAUD 1833, TERVER 1839); later, BOURGUIGNAT (1864), LETOURNEUX (1870), and PALLARY (1901) expanded the original knowl-

edge of molluscs by documenting different species of terrestrial gastropods in Algeria (Audibert & Boyer 2007).

After that early period, research into the terrestrial gastropods of Algeria remained suspended, leaving a gap in the knowledge of the Algerian malacofauna. However, in the last decade, molluscs once more attracted attention of several researchers (Douafer & Soltani 2014, Bouaziz-Yahiatene et al. 2017, Damerdji 2018, Ameur et al. 2019, Belhiouani et al. 2019, Holyoak et al. 2020, Ramdini et al. 2020, 2021). In the Kabylia region of Algeria, few studies focused on terrestrial molluscs (Aucapitaine 1862, Bouaziz-Yahiatene & Medjdoub-Bensaad 2016). In this study we surveyed and recorded the diversity and different communities of terrestrial gastropods, including both snails and slugs, to establish an initial database of malacofauna in the Kabylia region (Tizi-Ouzou) in north-central Algeria.

MATERIAL AND METHODS

STUDY AREA

The survey was conducted in the Tizi-Ouzou region, which is located in north-central Algeria. The region is delimited by the Mediterranean Sea in the north, the city of Boumerdes in the west, the province of Bouira in the south and the city of Bejaia in the east, with coordinates of 36°43'N, 04°02'E (Fig. 1). Sampling was done at 12 sites located in the environs of the region's five main cities. The sampling sites were located at different altitudes and represented five habitats: dune, mountainous area, rural habitats, forest, and agricultural field (Table 1).

SAMPLING

Samples were collected from October to March of 2018, 2019, and 2020 at each site, with a frequency of one sampling session per month in each site. Terrestrial snails and slugs were collected during their active periods at low temperatures and high relative humidity or after rainfall. The gastropods were collected by hand; and litter was sieved to retrieve micro-snails buried in the soil and litter (Cucherat & Dumyunck 2008). Micro- and small snails stay in a wet and humid topsoil and leaf litter. In humid conditions, snails may also be observed on wet stones, leaves, or tree trunks (Mahlfeld et al. 2016). A coarse sieve was used to sieve the leaf litter, then the samples were spread

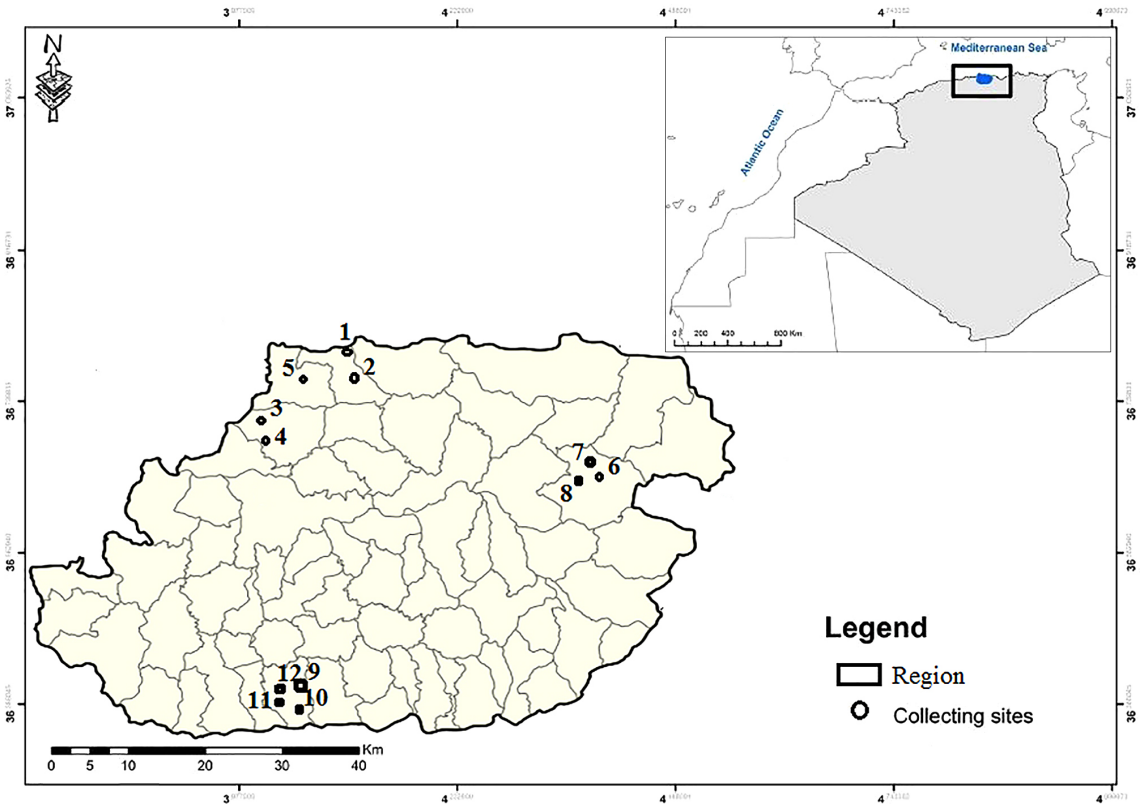


Fig. 1. Map showing the Tizi-Ouzou in Algeria and the collecting sites

Table 1. List of sampling sites with coordinates, altitudes and habitats

Town	(*) Station	Geographical coordinates	Altitude (m)	(**) Habitat type
Tigzirt	(1) Féraoun	36°53'54"N, 04°09'06"E	5	D
	(2) Tifra	36°50'40"N, 04°10'00"E	630	AF
Makouda	(3) Tigoulmamine	36°48'13"N, 04°01'46"E	350	RS
	(4) Hadouda	36°46'02"N, 04°02'00"E	70	AF
Mizrana	(5) Azroubar	36°50'37"N, 04°05'02"E	710	F
Yakouren	(6) Saccardy	36°43'41"N, 04°29'43"E	750	F
	(7) Sidi Brahim	36°44'45"N, 04°26'05"E	720	F
	(8) Tagma	36°43'48"N, 04°15'08"E	940	AF
Ait-Vouadou	(9) Ait Irane	36°30'11"N, 04°05'08"E	1,000	MA
	(10) Tigrathine	36°30'01"N, 04°04'32"E	700	RS
	(11) Achrir	36°29'53"N, 04°04'58"E	900	MA
	(12) Boughendja	36°29'52"N, 04°04'09"E	800	MA

(*) Site number on the map (Fig. 1).
(**) Dune (D), Mountainous area (MA), Rural sites (RS), Forest (F) and Agricultural field (AF).

out to dry in big trays lined with newspaper or paper towels (MAHLFELD et al. 2016), and passed through a smaller-mesh sieve. The samples were then transported to the laboratory, where the snails were picked out and identified based on shell characters. The genitalia were examined to confirm the identification of some of the species. The systematic arrangement used here follows BOUCHET et al. (2017).

DATA ANALYSIS

Species richness (S) was calculated for each habitat type. Relative abundance (RA%) was calculated for each species (percentage of the species (Ni) in the total number of all species combined (N); MAGURRAN 2004). Shannon index ($H' = -\sum P_i \times Log_2 \times P_i$), was calculated to assess the species diversity at each site (DAJOZ 1971). Pielou's equitability index (E) was also calculated (ratio of Shannon index to maximum diversity; RAMADE 2003). The sampling effort was evaluated using non-parametric diversity estimators (Chao, Jackknife1, Jackknife2, Bootstrap) with software R, version 4.1.0. These estimators were used to calculate the cumulative number of observed and expected species in the study region. Shell diameter (D) and height (H) are given for particular taxon as mean value of n measures with standard deviation (SD).

RESULTS

DIVERSITY AND DISTRIBUTION PATTERNS OF TERRESTRIAL GASTROPODS

Among the total of 7,539 specimens, 33 species were identified of 27 genera and 19 families. The number of species inventoried varied among the habitats, from 23 (rural habitat) to 14 (dune and forest habitats). The Geomitridae were represented by six species, followed by the Helicidae with five species. The Enidae, Chondrinidae, Hygromiidae, Sphincterochilidae, and Milacidae were represented by two species each, while each of the remaining families contained only one species (Table 2).

Cernuella virgata, *Cornu aspersum*, *Ganula flava*, *Rumina decollata*, and *Xerosecta* sp. were present in all habitat types, which corresponds to their adaptability. In the mountainous area, *Xerosecta cespitum* was the most dominant species with a relative frequency of 24.73%, followed by *Xerosecta* sp. with 18.73%. The dune ecosystem was dominated by *T. pisana*, which is a xerophile better adapted to this type of habitat, with a relative frequency of 17%. *C. virgata* was the most abundant species in the rural and agricultural habitats with relative frequencies of 22.24% and 36.38%, respectively. *Milax nigricans* was the most abundant species in the forest ecosystem, which is a humid habitat and suitable breeding environment for this species, with a relative frequency of 18.19%.

The Shannon index was high in all habitats, with its highest value in the rural habitat (H' = 3.72), and the lowest value in the agricultural habitat (H' = 2.96). The equitability index (E) was close to one in all habitat types; it ranged from 0.72 to 0.95 (Table 3).

SPECIES RICHNESS

In Kabylia region, the estimated total species richness was higher than the observed value (S. obs = 33). According to the different used estimators, the number of new species to be found in these sites is 8 with the Chao and Jackknife1 indices, 12 with the Jackknife2

index and 4 with the Bootstrap index. The completeness rate of the inventory was calculated under the assumption that the average of these four estimators was 80%, suggesting that 75% of the species were detected (Table 4).

The inadequacy of the sampling effort in the region was confirmed by the growth of the species accumulation curve (S. obs) and its divergence from those of the selected estimators (Fig. 2).

Table 2. Relative abundance and frequency of occurrence of each gastropod species in different habitats

Family	Species	RA % (*) Habitat type				
		D	MA	RS	F	AF
Geomitridae	*Cernuella virgata* (Da Costa, 1778)	4.69	11.19	22.24	9.76	36.38
	Cochlicella acuta (Müller, 1774)	0	0	0	0	4.39
	Cochlicella barbara (Linnaeus, 1758)	0	0	0	0	9.56
	Xerosecta cespitum (Draparnaud, 1801)	3.76	24.73	2.87	0.56	0
	Xerosecta sp.	4.23	18.73	2.51	6.48	7.12
	Xerotricha conspurcata (Draparnaud, 1801)	0	1.58	2.44	0	0.14
Helicidae	*Cantareus koraegaelius* (Bourguignat, 1882)	9.62	0	6.74	8.64	1.22
	Cantareus subapertus (Ancey, 1893)	0	9.32	9.25	0	0
	Cornu aspersum (Müller, 1774)	10.09	9.32	17.43	9.69	18.62
	Eobania vermiculata (Müller, 1774)	11.15	0	0	0	1.65
	Theba pisana (Müller, 1774)	17.02	0	0	5.09	0
Enidae	*Mastus pupa* (Linnaeus, 1758)	3	1.50	1.79	0	0.36
	Mauronapaeus terverii (Forbes, 1838)	0	0,04	0	0	0
Chondrinidae	*Granopupa granum* (Draparnaud, 1801)	0	0.08	0.65	0	0
	Rupestrella michaudi (Bourguignat, 1862)	0	0.04	0	0	0
Hygromiidae	*Ganula flava* (Terver, 1839)	6.46	1.99	6.03	16.93	6.69
	Ganula sp.	0	0	1.36	1.60	0.22
Sphincterochilidae	*Sphincterochila (Zonites) otthianus* (Bourguignat, 1864)	0	5.03	0	0	0
	Sphincterochila (Zonites) piestius (Bourguignat, 1864)	0	6.20	0	0	0
Milacidae	*Milax gagates* (Draparnaud, 1801)	0	2.43	4.52	0	0
	Milax nigricans (Philippi, 1836)	6.92	0	3.66	18.19	2.80
Limacidae	*Ambigolimax nyctelius* (Bourguignat, 1861)	0	1.05	2.80	16.45	4.39
Testacellidae	*Testacella riedeli* Giusti, Manganelli et Schembri, 1995	0	0	0.79	0	0
Agriolimacidae	*Deroceras* cfr. *riedelianum* Wiktor, 1983	0	0	0.22	3.97	3.02
Achatinidae	*Rumina decollata* (Linnaeus, 1758)	9.98	2.47	6.67	1.67	3.09
Discidae	*Discus rotundatus* (Müller, 1774)	0	0	0	0.7	0
Ferussaciidae	*Ferussacia folliculum* (Schröter, 1784)	4.81	0	2.44	0	0
Megalostomatidae	*Cochlostoma atlanticum* (Bourguignat, 1868)	0	0.04	0	0	0
Oxychilidae	*Oxychilus* sp.	0	2.39	0.07	0	0
Spiraxidae	*Poiretia algira* (Bruguière, 1792)	0	1.22	0.57	0.28	0
Punctidae	*Paralaoma servilis* (Shuttleworth, 1852)	0	0	1.72	0	0
Trissexodontidae	*Caracollina lenticula* (Michaud, 1831)	3.05	0	1.87	0	0.22
Pomatiidae	*Tudorella sulcata* (Draparnaud, 1805)	5.16	0.28	1.36	0	0.14
** Total (S)		14	20	23	14	17

(*) Dune (D), Mountainous area (MA), Rural sites (RS), Forest (F) and Agricultural field (AF); (**) Species richness (S).

Table 3. Diversity index of gastropod species communities in the five habitats under study of the Tizi-Ouzou region

Habitat (*)	D	MA	RS	F	AF
Shannon Index (H')	3.62	3.29	3.72	3.24	2.96
Pielou's equitability index (E)	0.95	0.76	0.82	0.85	0.72

(*) Dune (D), Mountainous area (MA), Rural sites (RS), Forest (F) and Agricultural field (AF).

Table 4. Estimated total richness of terrestrial gastropods

Estimator	Value	Completeness	Completeness mean
S observed	33		80%
Chao	41.06	80%	
Jackknife1	41.8	79%	
Jackknife2	45.7	72%	
Bootstrap	37.12	89%	

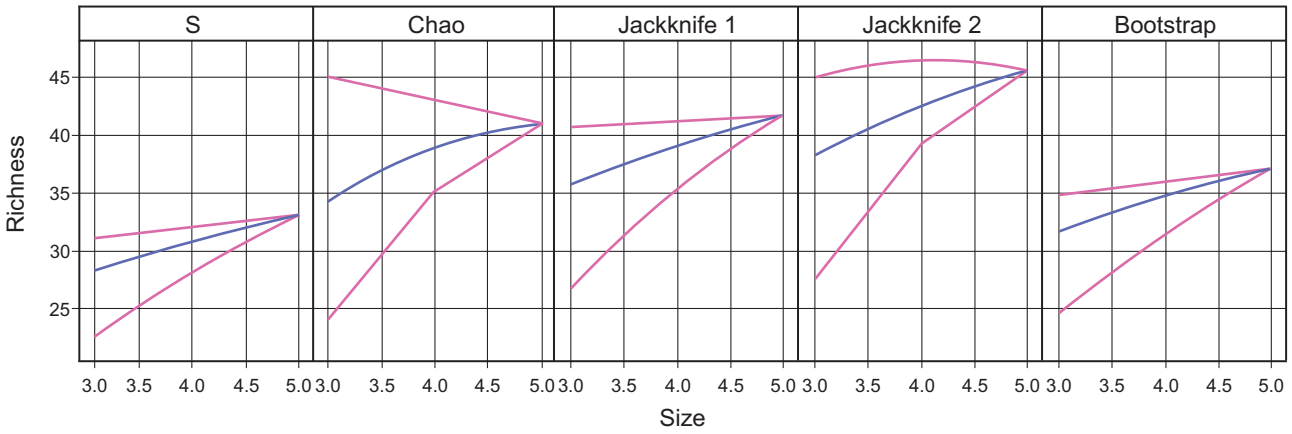
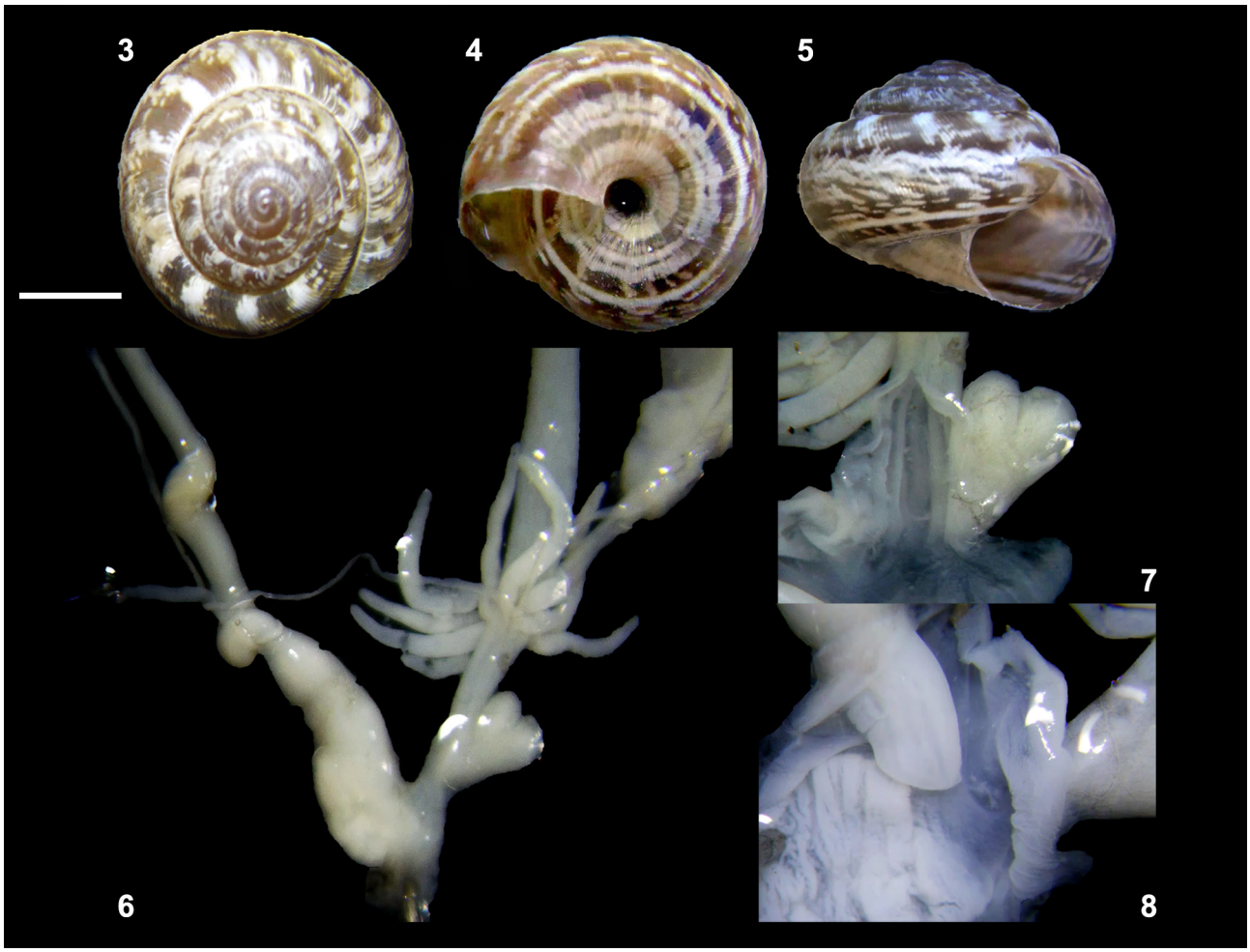


Fig. 2. Species accumulation curves with richness estimators in all habitats combined

TAXONOMIC NOTES

Xerosecta sp.

This species of the Geomitridae has a globular shell (D = 16.3 mm, SD = 0.88; H = 11.9 mm, SD = 0.72; n = 6) which differs from *X. cespitum* in its more flattened shape; however, the conchological features and genitalia of our specimens (Figs 3–8) were similar to those of *Xerosecta dohrni* (Paulucci, 1882) as described by De Mattia & Mascia (2014). Thus, only a thorough anatomical and molecular study can determine the appurtenance of our specimens.



Figs 3–8. *Xerosecta* sp.: 3–5 – shell (3 – apical view, 4 – ventral view, 5 – frontal view); 6–8 – anatomy of genital organs of *Xerosecta* sp. (6 – situs, 7 – details of dart sac, 8 – penial papilla); scale bar 5 mm (3–5)

Ganula sp.

The shell (Figs 9–11) of this species is globular in shape and of medium size (D = 13.8 mm, SD = 1.27; H = 10.1 mm, SD = 1.15; n = 6). The basic background colour of the shell is yellowish-beige, whereas the peristome is bright pink. When the shell is fresh, the umbilicus is half-open. The genitalia (Figs 12–13) are characterised by a long, thick, cylindrical penis with a central bulge. The epiphallus is cylindrical, long, and thinner than the penis, with a very short flagellum. The female part is equipped with four dart sacs, which is a major difference from *Ganula lanuginosa* (Boissy, 1835) (MARTÍNEZ–ORTÍ 2021) and *G. gadirana* Muñoz, Almodovar et Arrébola, 1999 (MUÑOZ et al. 1999).

Oxychilus sp.

This species' shell is medium-sized (D = 12.9 mm, SD = 2.58; H = 5.1 mm, SD = 0.43; n = 6) and flattened. It is not very shiny, but is a light brownish-yellow, and translucent with a moderately wide and deep umbilicus. The shells that were collected in humid, shady places were empty. Only one subadult specimen was collected, but could not be dissected (Figs 14–16).

Sphincterochila (*Zonites*) *otthianus* (Bourguignat, 1864)

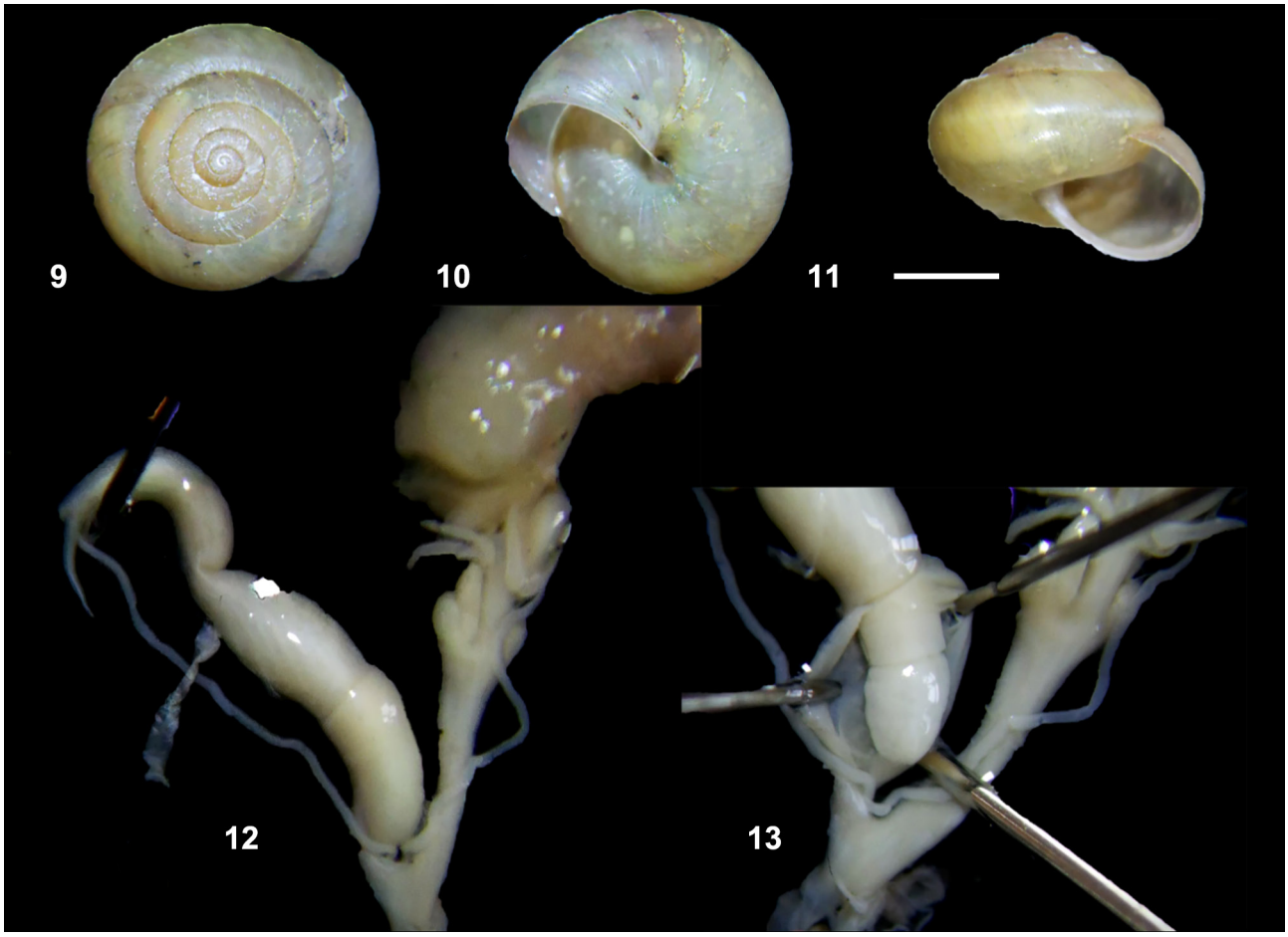
This shell is globular, large (D = 17.6 mm, SD = 1.94; H = 8.4 mm, SD = 1.72; n = 6), keeled, and solid, with a white background. The umbilicus is almost covered by the reflection of the columellar edge, which is white. The apex is smooth (Figs 17–19).

Sphincterochila (*Zonites*) *piestius* (Bourguignat, 1864)

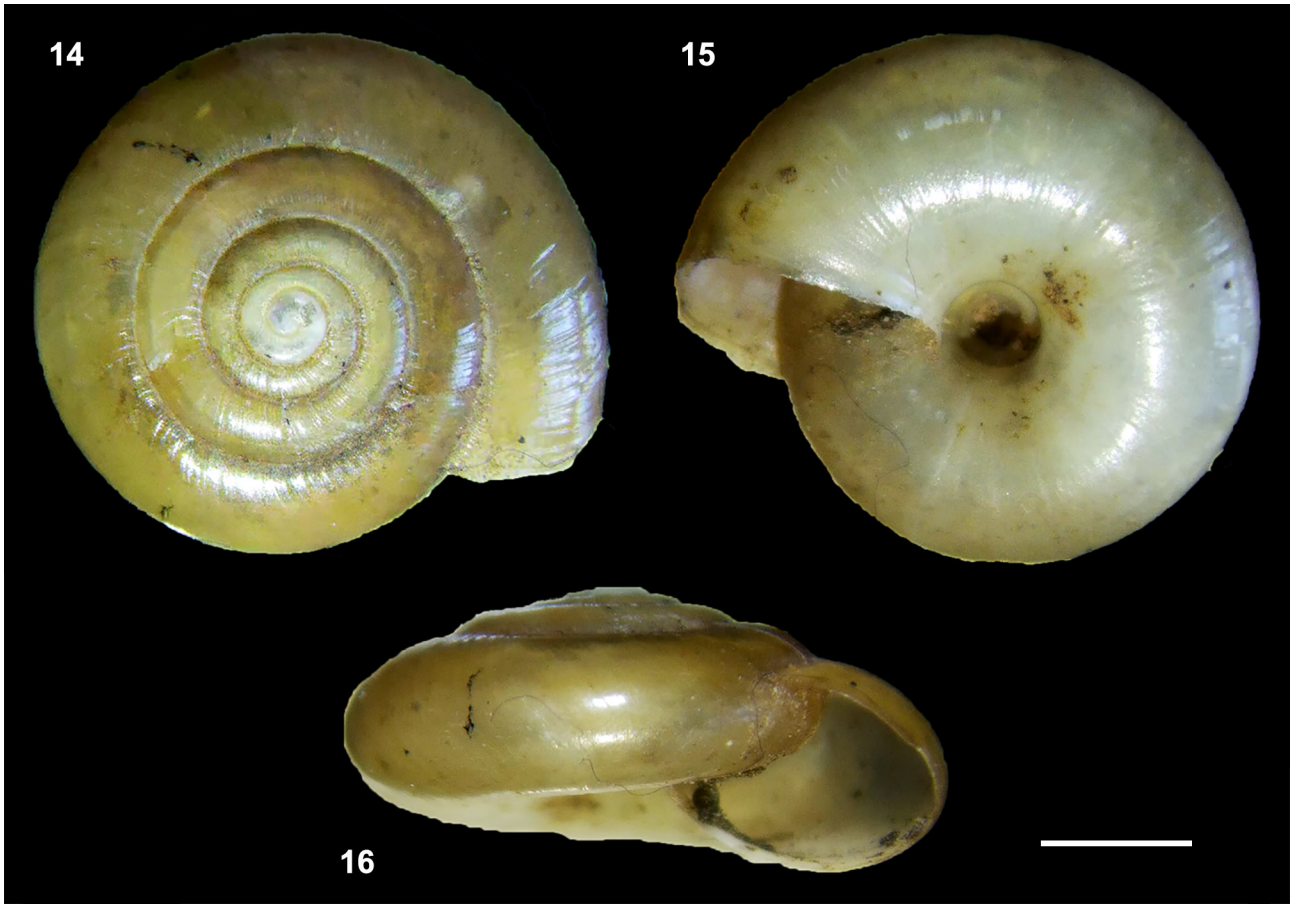
This shell is depressed and flattened (D = 18.1 mm, H = 9.2 mm). It is solid, and white in colour, with a smooth white apex, and has a wide and deep umbilicus (Figs 20–22).

Deroceras cfr. *riedelianum* Wiktor, 1983

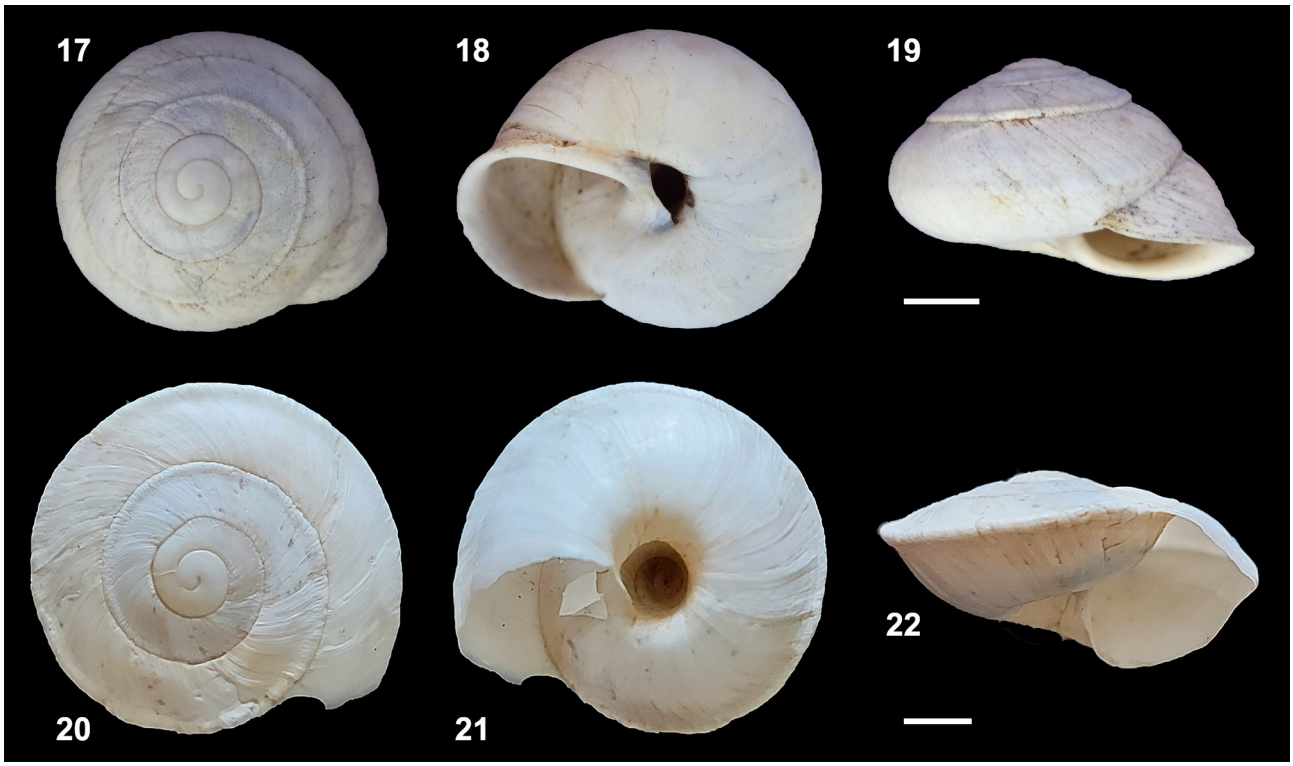
WIKTOR (1983) described *Deroceras riedelianum* for the first time from Skikda city (formerly Philippeville from 1838 to 1962) in the north-eastern region of Algeria, and port on the Mediterranean. The agrioli-



Figs 9–13. *Ganula* sp.: 9–11 – shell (9 – apical view, 10 – ventral view, 11 – frontal view); 12–13 – genital organs of *Ganula* sp. (12 – situs, 13 – penial papilla); scale bar 5 mm (9–11)



Figs 14–16. Shell of *Oxychilus* sp.: 14 – apical view, 15 – ventral view, 16 – frontal view; scale bar 3 mm



Figs 17–22. Shells of *Sphincterochila* spp.: 17–19 – *S. otthianus* (17 – apical view, 18 – ventral view, 19 – frontal view); 20–22 – *S. piestius* (20 – apical view, 21 – ventral view, 22 – frontal view); scale bars 5 mm (17–19), 3 mm (20–22)

macids are small-sized slugs (maximum of 25 mm when extended) with a translucent red-brown colour and black spots (Fig. 23). The genitalia are characterised by an elongated penis with a retractor muscle at its tip, and no appendages (Fig. 24). Compared to the results of WIKTOR's (2000) work on the Agriolimacidae, there was no resemblance to our specimens. Before proving the contrary, we interpret our specimen as a variation of *D. riedelianum*. A thorough anatomical and molecular study is necessary for further identification.

Figs 23–24. *Deroceras* cfr. *riedelianum*: 23 – body; 24 – genitalia

DISCUSSION

Our aim was to contribute to the knowledge of the malacofauna of the Kabylia region (Tizi-Ouzou, Algeria). We recorded 33 species of terrestrial gastropods of 27 genera and 19 families, with the dominance of the Helicidae and Geomitridae.

AUCAPITAINE (1862) recorded 26 species in the Haut-Kabylie region, 20 of which were terrestrial and six were freshwater. In the same region (Tizi-Ouzou, Algeria), BOUAZIZ-YAHIATENE & MEDJDOUB-BENSAAD (2016) presented a list of 26 terrestrial species. RAMDINI et al. (2021) recorded 27 terrestrial gastropods in the north-central region of Algeria (Algiers and Boumerdes). In eastern Algeria, 11 species of terrestrial snails and slugs were recorded (DOUAFER & SOLTANI 2014, BELHIOUANI et al. 2019). In the west, DAMERDJI (2009) recorded 14 species. In 2018, the same author listed 25 species in the region of Tlemcen (north-west Algeria). In the arid region of Batna (Algeria), AMEUR et al. (2019) identified 11 snail species. This study reports 33 species in important locations and habitats that have not yet been included in the new literature.

The species richness, distribution, and density depend on the characteristics of the sampled habitat. We recorded 23 species at the rural sites, 20 species in the mountainous area, 17 species in the agricultural field, and 14 species in the dune and forest habitats. LARBAA & SOLTANI (2013) and BELHIOUANI et al. (2019) suggested that species richness was higher in ecosystems that are farther away from human disturbance. DOUAFER & SOLTANI (2014) claimed that the distribution of species within ecosystems could be attributed to the influence of climatic factors and soil characteristics.

The ecological preferences of species are often very different. The existence of a high number of microhabitats significantly increases the species richness of ecosystems. KERNEY & CAMERON (2006) showed that the complexity of habitat structure played a very important role in the distribution of terrestrial gastropods. The habitat heterogeneity hypothesis is one of the fundamental bases of ecology (MACARTHUR & WILSON 1967).

In the dune ecosystem, *T. pisana* was the most abundant species at 17.02% of the total land snails;

in Ireland, this species is confined to coastal dunes in relatively frost-free localities, and tends to climb on dead vegetation (Byrne et al. 2009). In the mountainous area, *X. cespitum* was the most dominant (24.73%); *Xerosecta* is a genus of xerophilous Geomitridae with the distribution in the western Mediterranean; it occurs in a larger part of the Western Mediterranean (Puente 1995) as in Algeria (De Mattia & Mascia 2014). *C. virgata* was the most abundant species at the rural site (22.24%) and the agricultural field (36.38%). According to Welter-Schultes (2012), *C. virgata* is a Mediterranean and Western European species. In the forest habitat, *M. nigricans*, a milacid, was the most abundant (18.19%); it usually inhabits forests or synanthropic and cultivated areas. According to Wiktor (1987) the Milacidae are most abundant in forest habitats; they occur in Northern Africa from Morocco in the west to Tunisia in the east.

In conclusion, 33 species of snails and slugs were recorded in the region of Tizi-Ouzou, Algeria. The Geomitridae (6 species) and Helicidae (5 species) were the most species-rich. The species richness varied. The highest richness (S) was recorded in the rural habitat with 23 species, and the lowest in the dune and forest habitats with 14 species each. *C. virgata*, *C. aspersum*, *G. flava*, *R. decollata,* and *Xerosecta* sp. were all found in all habitat types and are generalist species. The equitability index tended towards one when all species had the same abundance. The index can measure an imbalance which the diversity index cannot. The closer its value tends to be to one the greater the equilibrium. The more diverse the community, the higher the index (Blondel 1979).

As shown by the diversity indices, further research is needed to identify the complete malacofauna of the Kabylia region. Molecular studies are necessary to confirm species identification. More extensive survey and monitoring are necessary to fill the gaps in the knowledge of the malacofauna of Algeria and to establish a comprehensive database of terrestrial gastropods for the study sites and habitats.

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