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DIVERSITY AND ECOLOGY OF TERRESTRIAL GASTROPODS OF THE KABYLIA REGION (NORTHERN ALGERIA)

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Abstract

Sadouk G., Ramdini R., Medjdoub-Bensaad F., Bouaziz-Yahiatene H.: Diversity and ecology of terrestrial gastropods of the Kabylia region (northern Algeria). Ekológia (Bratislava), Vol. 42, No. 3, p. 248–256, 2023.

The snail and slug fauna of the Kabylia region (Bouira and Tizi-Ouzou) was studied during the years 2018/2019 and 2020/2021, focusing on seven stations belonging to three altitudinal levels (low, middle, and high altitude). A total of 5111 individuals were collected and 29 species were identified, with confirmation of the existence of *Leiostyla anglica* in the Kabylia region. Our results showed that altitude has a significant effect on the distribution and abundance of terrestrial gastropods in the study area – the low-altitude sites had the highest number of species (S = 21), while the high-altitude sites had the lowest species richness (S = 10).

Key words: snails, slugs, altitudinal distribution, Bouira, Tizi-Ouzou.

Introduction

The mollusks are the most diverse phylum after the arthropods (Zhang, 2013). They are divided to 118,061 living species, including the gastropods, which occupy a large part of this diversity, where they represent three-quarters of these animals (Audibert, Bertrand, 2015). During their evolution, gastropods were able to colonize most natural environments (Ponder et al., 2020). Several species are considered suitable indicators of habitat health and stability, including global warming, because of their strict dependence on habitat conditions and their low dispersal (Beltramino et al., 2015; Torre et al., 2014)but studies about the impacts of climate change on molluscan biodiversity are virtually nonexistent. Bioclimatic models provide an important tool to assess how habitat suitability may change in a warming planet. In this study, we examine potential impacts of climate change on a giant land snail (Megalobulimus sanctipauli. The gastropods are one of the fastest declining taxa in the world. Therefore, it is required to acknowledge the diversity and ecology of this group of animals (Cuttelod et al., 2011; Lydeard et al., 2004).

In Algeria, the diversity of gastropods is far from exhaustive and remains unknown. The first investigations began with the work of Michaud (1833) and Terver (1839), which was later followed and completed by Bourguignat (1864, 1877).

Recently, malacological studies have focused on the diversity and ecology of terrestrial gastropods. Larbaa, Soltani (2013) studied the diversity and spatiotemporal distribution of gastropods in the northeastern region of Algeria, wherein they were able to identify 14 different species, including *Cornu aspersum* as a bioindicator of heavy metals in the soil. Hamdi-Ourfella, Soltani (2016) investigated the diversity of terrestrial gastropods in different regions of eastern Algeria (12 species were identified) and tested the effect of an insecticide on *Cantareus apertus*. Ameur et al. (2019)in the North eastern part of Algeria. The species sampling was performed weekly throughout the spring period of the year 2013, using Barber pots and sight hunting in parcels of spontaneous vegetation. The study area was represented by four sites, selected following the gradient of aridity; from the less arid to the most arid. The sites are named, station 1 is Batna proximities, station 2 is Lambiridi, station 3 is El Ghadjatti and station 4 is Ain Touta These stations are a mosaic of landscapes including woody mountain lands and in the vast majority, plains characterized by a variety of cultivated areas. The systematical study of 604 collected individuals revealed the presence of 11 species of terrestrial pulmonates belonging to four families: Helicidae, Zonitidae, Subulinidae and Sphincterochilidae. The occurrence frequency shows that the most constant species are: Helicigona lapicida (C = 71.43% sampled in the arid region of Batna (northeast of the country), where they identified 11 different species. Belhiouani et al. (2019)El-Hadef El-Okki M, Afri-Mehennaoui FZ, Sahli L. 2019. Terrestrial gastropod diversity, distribution and abundance in areas with and without anthropogenic disturbances. Biodiversitas 20: 243-249. The objective of this study was to establish an inventory of terrestrial gastropods from different sites in the northeast of Algeria. Several points were sampled from five various areas relatively affected by hu-

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Table 1. Sampling sites.

Altitudinal level	Sites	Geographic coordinates (degrees, minutes, seconds)	Altitude (m)
Low altitude	Ouacif	36°52‘424“N 4°20‘4923“E	300
	Erriche forest	36°23‘51“N 3°53‘10“E	540
Middle altitude	Haizer	36°24‘02“N 4°00‘23“E	600
	Assi-Youcef	36°30‘21“ N 4°02‘28“E	700
	Tikjda 01	36°24‘09“N 4°06‘06“E	850
High altitude	Tizi-Helouane	36°45‘26“35N 3°94‘79“87E	1000
	Tikjda 02	36°27‘45“N 4°09‘19“E	1722

man activity. Areas prospected were an industrial area (El-Hadjar, Annaba have identified 11 species of land snails in eastern Algeria. Cheriti et al. (2021), in their study in the Kebir Rhumel basin, have identified a record of 25 snail species in the eastern region of Algeria.

In north-central Algeria, we cite the work of Bouaziz-Yahiatene, Medjdoub-Bensaad (2016), who studied the biology and ecology of terrestrial gastropods in the Tizi-Ouzou region, where they identified 26 species. In the same region (Tizi-Ouzou), Ramdini et al. (2021b) increased the malacofauna of this region to 33 different species. In another study, Ramdini et al. (2021a) focused on the diversity of terrestrial gastropods in the regions of Algiers and Boumerdes and identified 27 species of snails and slugs.

In the west of the country, Damerdji (2008), in her study on the ecology of the malacofauna of the southern zone of the Tlemcen region, revealed a specific richness of eight species. Damerdji (2009) studied the composition and structure of malacofauna in the extreme west of the Algerian coast, and the species richness of gastropods showed that there were about 14 species. In addition, Damerdji (2010) studied the composition and structure of gastropod community in the stations of *Thymus ciliatus* Desf. (Labiatae) around Tlemcen (northwest Algeria) and identified 11 different species. After that, Damerdji (2018) was able to identify 25 species of snails and slugs in the northwest region of the country.

To improve the knowledge of the diversity and ecology of terrestrial gastropods in Algeria, an inventory was carried out in the regions of Bouira, southern side of the Djurdjura massif, and Tizi-Ouzou, northern side of the Djurdjura, following an altitudinal gradient, during the years 2018/2019 and 2020/2021.

Material and methods

Study area

The present study has been carried out at seven stations in two provinces in north-central Algeria: four in Bouira (Erriche forest, Haizer, Tikjda 01, Tikjda 02) and three in Tizi-Ouzou (Tizi-Helouane, Assi-Youcef, and Ath-Ouacif). The sampling sites are located in the Djurdjura massif. The seven sampling stations are classified into three altitudinal levels: low, middle, and high altitude (Table 1).

The study areas, Tizi-Ouzou and Bouira, experience a Mediterranean climate, characterized by dry, hot summers and wet, mild winters (Seltzer, 1946).

Sampling method

Sampling was carried out over a period from November 2018 to October 2019 in the stations of the Bouira region and from November 2020 to October 2021 in the stations of the Tizi-Ouzou region, at a rate of one sample per month on a surface of 100 m^2 for each station. The specimens present in this area were collected, identified, counted, and released. In case of doubt, the individuals were preserved in ethanol and brought back to the laboratory for identification using the anatomy of their reproductive system.

The methods used were direct sampling, which consists of hand-collecting species seen with the naked eye in their natural habitats, and litter sieving, where the fine fraction of the first soil horizons is observed under a binocular magnifying glass (this method aims to collect small species living in the litter as well) (Cucherat, Demuynck, 2008).

The specimens preserved in 75% ethanol are stored in the personal collections of Sadouk and Ramdini. (R-GH Col.) at the Laboratory of Production, Safeguarding of Endangered Species and Crops, Influence of climatic variations, Biology Department, University of Tizi-Ouzou, Algeria.

Species identification

Identification of the specimens was carried out according to the morphological criteria of the shell, followed by the study of the anatomy of the reproductive system using the available literature (Bourguignat, 1864; Kerney, Cameron, 2015; Welter-Schultes, 2012; Wiktor, 1983, 1987). The nomenclature of families and species was done following the work of Bouchet et al. (2017) and MolluscaBase ed. (2022).

Data analyses

To explain the different results obtained on the species of terrestrial gastropods encountered, several complementary ecological descriptors were studied to develop a comprehensive assessment on the species diversity of land snail community (Magurran, 2004).

Accordingly, snails and slugs were evaluated by calculating species richness (S), which represents the total number of species identified, relative abundance (RA), which represents the ratio of the number of individuals to the total number of individuals (N), Shannon diversity index (H’): $H' = -\Sigma (Pi \times \log_2 Pi)$, where

Table 2. Systematic list of species identified.

Families	Genus	Species
Achatinidae	*Rumina*	*R. decollata* (Linnaeus, 1785)
Chondrinidae	*Granopupa*	*G. granum* (Draparnaud, 1801)
Ellobiida	*Carychium*	*C. minimum* (O.F. Müller, 1774)
Enidae	*Mastus*	*M. pupa* (Linnaeus, 1758)
Ferussaciidae	*Ferussacia*	*F. folliculum* (Shoter,1778)
Geomitridae	*Cernuella*	*Ce. virgata* (Da Costa, 1778)
	Cochlicella	*C. acuta* (O.F.Müller, 1774)
	Trochoidea	*T. pyramidata* (Draparnaud, 1805)
	Xerosecta	*X. cespitum* (Draparnaud, 1801)
		Xerosecta sp.
	Xerotricha	*X. conspurcata* (Draparnaud, 1801)
Helicidae	*Cornu*	*Co. aspersum* (O.F. Müller,1778)
	Cantareus	*Ca. koraegaelius* (Bourguignat in Locard, 1882)
		Ca. subapertus (Ancey, 1893)
	Eobania	*E. vermiculata* (O.F. Müller, 1778)
	Theba	*T. pisana* (O.F. Müller, 1778)
Hydrobiidae	*Pseudamnicola*	*P. thawintea* (Sadouk et al., 2022)
Hygromiidae	*Ganula*	*G. flava* (Terver, 1839)
		Ganula sp.
Lauriidae	*Leiostyla*	*L. anglica* (Bourguignat, 1864)
Limacidae	*Ambigolimax*	*A. nyctelia* (Bourguignat, 1861)
Milacidae	*Milax*	*M. gagates* (Draparnaud, 1801)
		M. nigricans (Phillipi, 1839)
Oxychilidae	*Oxychilus*	*O. draparnaudi* (H. Beck, 1837)
Pristilomatidae	*Vitrea*	*V. diaphana* (S. Studer,1820)
Punctidae	*Paralaoma*	*P. servilis* (Shuttleworth, 1852)
Spiraxidae	*Poiretia*	*P. algira* (Bruguière, 1792)
Testacellidae	*Testacella*	*T. fescheriana* (Bourguignat, 1801)
Truncatellinidae	*Truncatellina*	*T. callicratis* (Scacchi, 1833)

(Pi) represents the proportion of the number of individuals of the species of rank (i) on the total number of individuals (N), maximum of Shannon index (Hmax): Hmax = $\log_2$ S, and equitability (E): E = H´/Hmax (Magurran, 2004; Colwell, 2013). Using the data collected in the sampling areas, we examined the similarity in species composition of the three altitudinal levels with the Jaccard index, an index based on the presence and absence of species (Rooney et al., 2004). It is calculated by the following formula: J (A, B) = (|A∩B|)/(|A|+|B| - |A∩B|), where A and B are any two sets to be compared (Costa, 2021).

The principal component analysis (PCA) was used to show the correlation between altitude and the number of species. The distribution of species to the three altitudinal gradients enabled us to divide the gastropod species sampled into groups. A Hierarchical ascendant classification or cluster analysis (HAC) was performed to confirm dissimilarities between taxonomic groups in the different ecosystems sampled.

In addition, sampling effort was assessed using the nonparametric species richness estimators of Chao, jackknife1, jackknife2, and bootstrap, which calculate the number of cumulative observed and expected species in the study sites. Statistical tests were performed using R software (Version 4.1.0).

Results

Diversity and systematics of terrestrial gastropods

Totally, 5111 snails and slugs belonging to 19 families, 25 genera, and 29 species were counted. The Geomitridae are the most diverse with six species, followed by Helicidae with five species. Milacidae and Hygromiidae are represented by two species each. The other 14 families are represented by only one species each (Table 2).

Distribution and community structure of terrestrial gastropods

The distribution and abundance of mollusk species differed from one station to another and form one altitudinal gradient to another (Fig. 1).

From a quantitative aspect, RA of terrestrial gastropod species varied from one altitudinal level to another. At the low-altitude stations, *Rumina decollata* was the most abundant with a rate of 18.94%, while *Cochlicella acuta* and *Milax nigricans* were

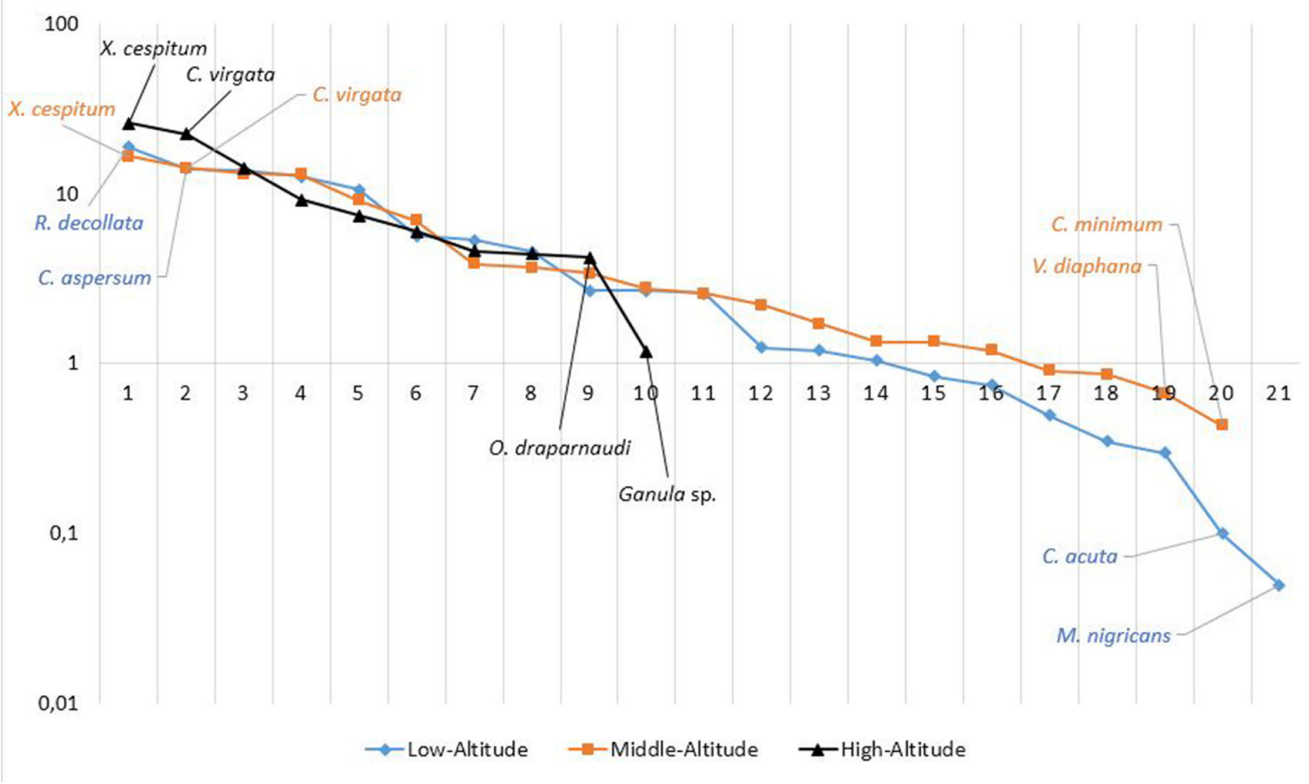


Fig. 1. Rank abundance of the different species recorded.

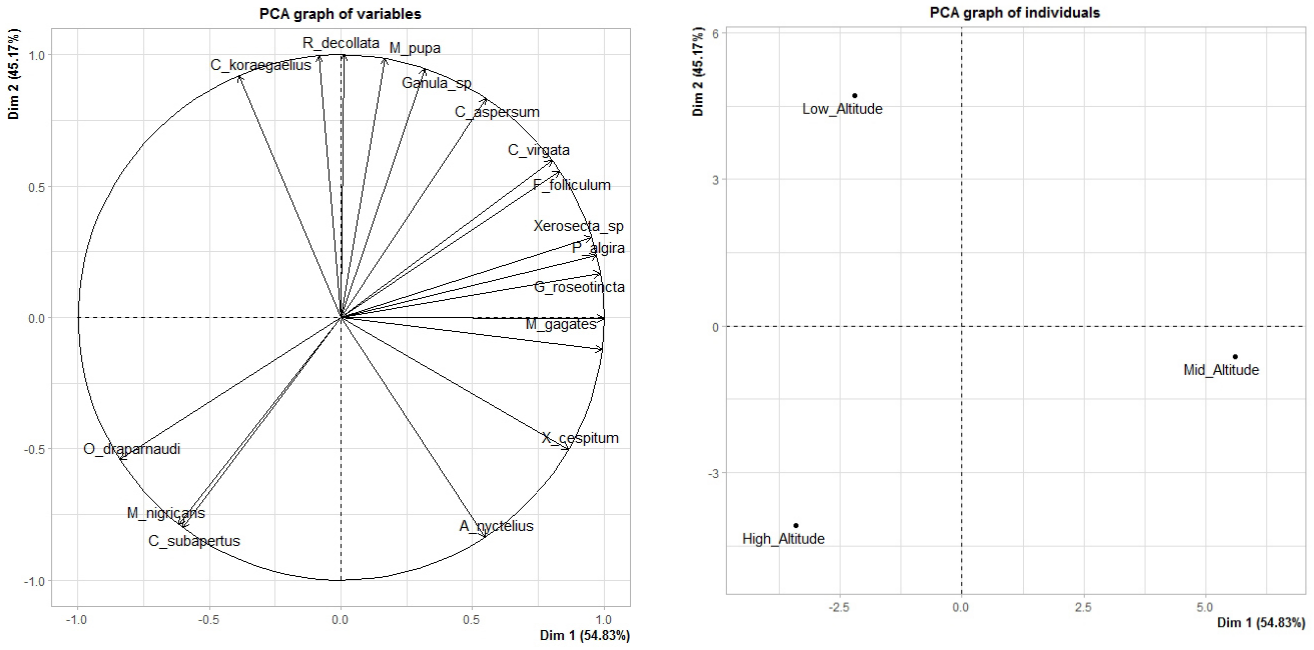


Fig. 2. Factor scores of the different altitudes surveyed (individuals) and species collected (variables) on the first two axes of a principal component analysis (PCA).

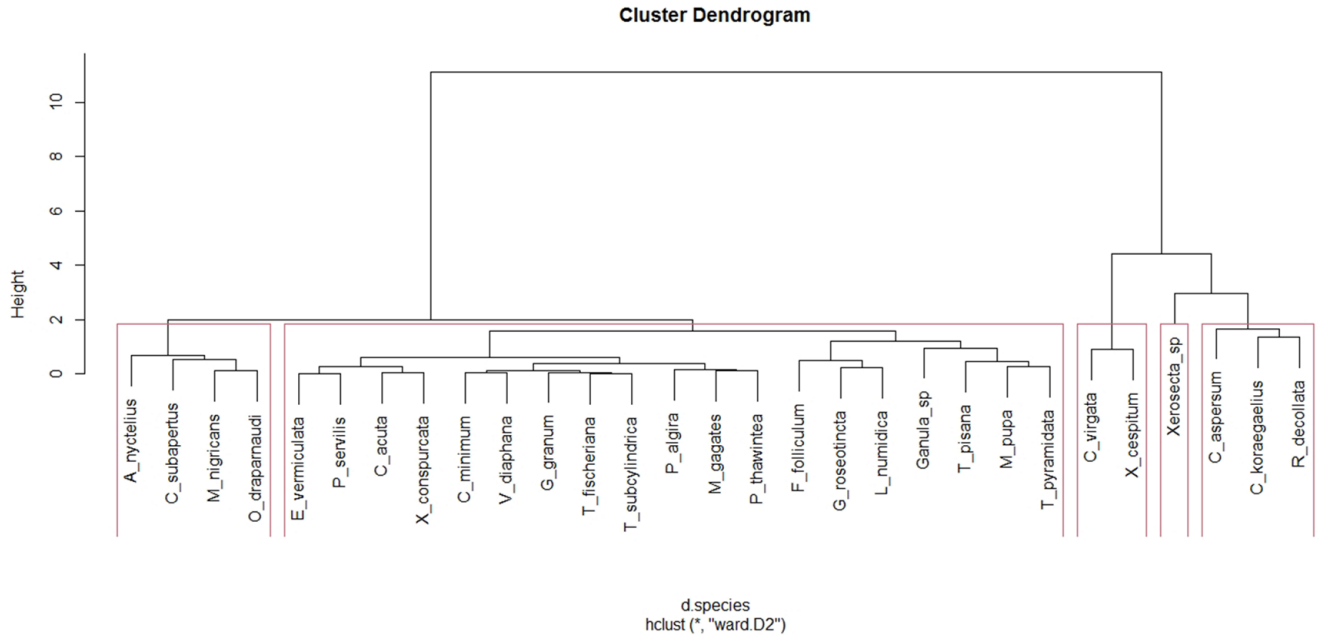


Fig. 3. Result of hierarchical clustering (HAC) according to relative abundance of species at different altitudes (Ward.2 method and Euclidian distance).

the least abundant with an RA of 0.09 and 0.04%, respectively.

Xerotricha cespitum was the most abundant at the middle-altitude and high-altitude stations with a frequency of 16.56 and 26.05%, respectively, followed by *Cernuella virgata* with a rate of 14.21% at the middle-altitude station and 22.61% at the high-altitude station. The least represented species in these two environments were *Vitrea diaphana* (0.67%) and *Carychium minimum* (0.43%) at the middle altitude and *Oxychilus draparnaudi* (4.22%) and *Ganula* sp. (1.17%) at the high altitude.

PCA (Fig. 2) was carried out on the data of terrestrial gastropod species at different altitudinal gradients (low, middle, and high). A matrix of 29 snails and slugs species and three altitudinal levels was expressed in the F1 × F2 factorial plane of PCA, which yielded 100% of the information, of which 54.83% was explained by the F1 axis and 45.17% by the F2 axis.

The F1 axis opposed low altitude and middle altitude to high altitude, and the F2 axis opposed high altitude and low altitude to middle altitude.

The PCA plot shows the variation of the species inventoried according to the different altitudinal levels. *Cantareus koraegaelius*, *Theba pisana*, *Ganula* sp., *Eobania vermiculata,* and *Trochoidea pyramidata* were the most abundant species at the low-altitude stations. At the middle-altitude sites, *Ganula flava*, *Xerosecta cespitum,* and *Xerosecta* sp. were the most abundant. Finally, at the high-altitude stations, *Milax nigricans*, *Cantareus subapertus,* and *Oxychilus draparnaudi* were the characteristic species (Fig. 2).

The HAC dendrogram showed that the species were assembled in five groups. **G1:** includes *Ambigolimax nyctelius*, *Cantareus subapertus, Milax nigricans, Oxychilus draparnaudi* found at the high-altitude stations with the highest abundances; **G2**: includes the majority of species; these species are the most common in the ecosystems studied; **G3:** with *Cernuella virgata* and *Xerosecta cespitum*, it represents the species collected at all stations with very high densities; these species seem to be unaffected by altitude and other environmental factors; **G4:** with *Xerosecta* sp., which is very frequent at low-altitude and middle-altitude stations and absent at higher altitudes; this species seems to be sensitive to altitudinal change; **G5:** includes *Cornu aspersum*, *Cantareus koraegaelius,* and *Rumina decollata*; these species are present in all stations, with a high density at low and medium altitudes, which confirms that these species belong to the lowlands (Fig. 3).

Ecological structure indexes

Specific richness (S), Shannon index (H'), and equitability (E)

The ecological indices characterizing the snail and slug communities in the different altitudinal levels are summarized in Table 3.

The species richness differed from one site to another. We recorded the maximum number of species at the low-altitude stations with 21 different species, followed by the middle-altitude sites with 20 species, while at the high-altitude level, only 10 species were collected.

The Shannon index calculated for the low-altitude and middle-altitude sites was of the order of 3.49 and 3.65 bits, respectively. At the high-altitude sites, this index was at its lowest value of about 2.9 bits. The equitability (E) was high at the different stations, ranging from 0.79 to 0.87, which reflects a balance in the distribution of species in the different ecosystems.

Jaccard similarity index (J)

The values of the Jaccard similarity index between the different sampled elevations are given in Table 4.

Table 3. Species richness (S), Shannon index (H'), and equitability (E).

Altitude levels	Species richness (S)	Shannon index (H')	Equitability (E)
Low altitude	21	3.49	0.79
Middle altitude	20	3.65	0.84
High altitude	10	2.9	0.87

Table 4. Jaccard index value (J).

	Low altitude	Middle altitude	High altitude
Low altitude	1	-	-
Middle altitude	0.48	1	-
Hight altitude	0.41	0.31	1

Table 5. Estimation of the total richness of the gastropods.

Estimators	Values	Completeness	Average completeness
S. observed	29		
Chao	40 ± 8.59	70%	71.2%
Jackknife1	40 ± 7.29	70%	
Jackknife2	45.83	61.09%	
Bootstrap	33.44 ± 4.33	83.73%	

The Jaccard similarity index (J) calculated between the different altitudinal levels showed a medium to low similarity between the stations. Maximum similarity was recorded between the low-altitude and middle-altitude stations with a similarity of 0.48; the lowest similarity was recorded between the mid-altitude and high-altitude stations with a value of 0.31.

Nonparametric estimation of biodiversity

To know the biodiversity of these organisms in our study regions, nonparametric biodiversity estimators (Chao, jackknife1, jackknife2, and bootstrap) were calculated (Table 5).

In this region, the estimated total species richness was higher than the observed value (S. Obs = 29). According to the different used estimators, the number of new species to be found on this site was 12 with the Chao 1 and jackknife1 indices, 17 with the jackknife2 index, and five with the bootstrap index.

In addition, the inventory completeness rate reached a value of 71.2% in this region. Moreover, the inadequacy of the sampling effort within the two sites was confirmed by the difference between the species accumulation curves (S. obs.) and those obtained using the adopted estimators (Fig. 4).

Discussion

The Mediterranean region is the habitat of a significant terrestrial mollusk richness as it receives a high rate of precipitation and is characterized by dense vegetation (Amr et al., 2018). The diversity and ecology of terrestrial gastropods in Algeria have been a subject of several recent studies (Ameur et al., 2019; Belhiouani et al., 2019; Cheriti et al., 2021; Damerdji, 2008, 2010, 2018; Hamdi-Ourfella, Soltani, 2014; Ramdini et al., 2021a, b; Seddon et al., 1993, Seddon, Holyoak, 1993)in the North eastern part of Algeria. The species sampling was performed weekly throughout the spring period of the year 2013, using Barber pots and sight hunting in parcels of spontaneous vegetation. The study area was represented by four sites, selected following the gradient of aridity; from the less arid to the most arid. The sites are named, station 1 is Batna proximities, station 2 is Lambiridi, station 3 is El Ghadjatti and station 4 is Ain Touta These stations are a mosaic of landscapes including woody mountain lands and in the vast majority, plains characterized by a variety of cultivated areas. The systematical study of 604 collected individuals revealed the presence of 11 species of terrestrial pulmonates belonging to four families: Helicidae, Zonitidae, Subulinidae and Sphincterochilidae. The occurrence frequency shows that the most constant species are: Helicigona lapicida (C = 71.43%. The taxonomic status of some species has been revised (Bouaziz-Yahiatene et al., 2017, 2019; Holyoak et al., 2020). Discoveries and rediscoveries of several species have been made (Glöer et al. 2010; Glöer, Ramdini, 2019; Ramdini et al. 2020; Sadouk et al. 2022).

The present study examines the species richness of seven different stations distributed over three altitudinal levels. The results of the malacological inventory revealed richness of 29 species belonging to 25 genera and 19 families.

Leiostyla anglica (Wood, 1828) was reported by Morelet (1853) as *Pupa anglica* and by Bourguignat (1864) as *Vertigo numidica* in a locality called Ain-Tlzid at the top of the Blida atlases. It has a restricted distribution in the Mediterranean basin,

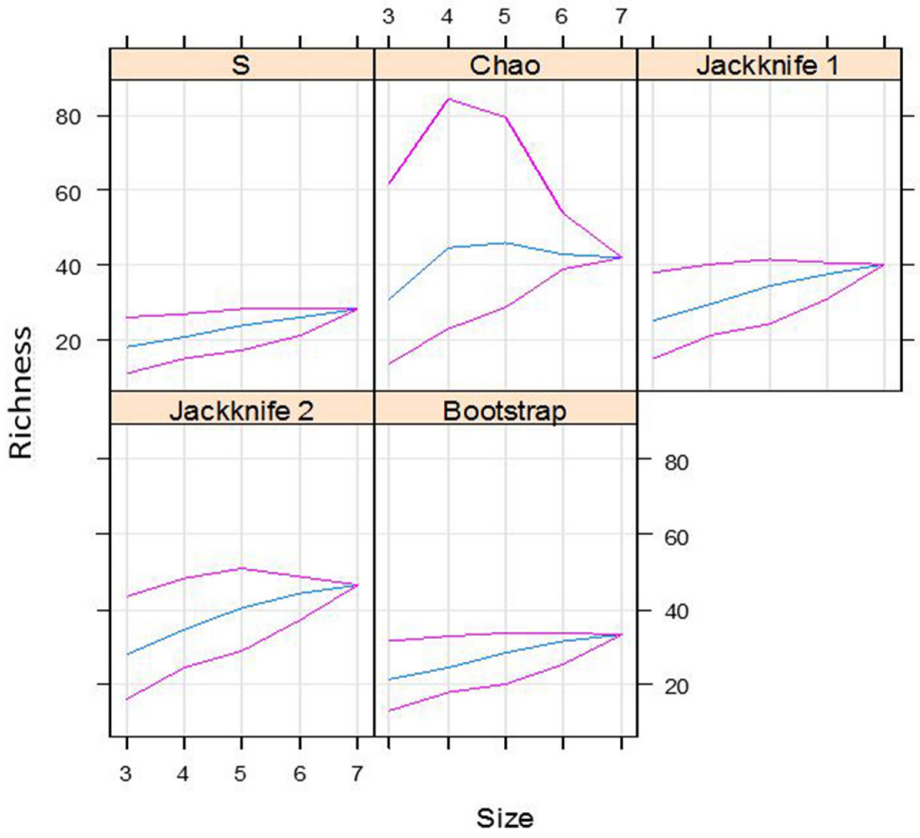


Fig. 4. Accumulative curves of the different biodiversity estimators.

especially in Spain and Algeria (Seddon et al., 1993). Nevertheless, its presence is considered uncertain in Algeria due to the lack of recent molecular studies for this species (Seddon et al., 2020). Our morphological observations of specimens from the Tizi-Ouzou region corroborate the shells presented by Seddon et al. (1993), which confirm the presence of a population of this species in the Djurdjura Mountains.

A multitude of factors acting at different scales determine species diversity and density (Liew et al., 2010); it may be associated with habitat heterogeneity (Belhiouani et al., 2019)El-Hadef El-Okki M, Afri-Mehennaoui FZ, Sahli L. 2019. Terrestrial gastropod diversity, distribution and abundance in areas with and without anthropogenic disturbances. Biodiversitas 20: 243-249. The objective of this study was to establish an inventory of terrestrial gastropods from different sites in the northeast of Algeria. Several points were sampled from five various areas relatively affected by human activity. Areas prospected were an industrial area (El-Hadjar, Annaba, as well as being governed by soil properties and climatic parameters (Ondina et al., 2004). According to Lévêque, Mounolou (2008), the species richness of certain taxa decreases with altitude. Aubry et al. (2005) confirmed that the density of land snail species decreases considerably with increasing altitude.

Our results showed that altitude has a significant effect on species distribution. In fact, at low-altitude stations, we identified a total of 21 species, at mid-altitude stations 20 species, while at high-altitude stations, we recorded only 10 species. Indeed, in Kenya (Africa), Tattersfield et al. (2021) showed that the species richness and abundance of terrestrial mollusks decreases as the altitude of forest habitats increases. In this sense, temperature plays a very important role in the presence/absence and abundance of this taxon (Tattersfield et al., 2021), while altitude and rainfall have a more limited role (De Kock et al., 2003). Dreyfuss (2018) suggests that the relationship between distribution, terrestrial mollusk abundance, station elevation, and environmental factors varies between study regions. This can be justified by the results of Jokinen (1987), where he noted a positive relationship between the above parameters at one site, while it was negative at another site in the northeastern USA.

PCA indicated that the most abundant species at high-altitude stations are *Oxychilus draparnaudi*, which lives in habitats up to 2000 m, but rarely above 1000 m (Welter-Schultes, 2012), and *Cantareus subapertus*, which is restricted to the Djurdjura Mountains, where it occupies high habitats. It is also present in the northern promontory of this mountain ridge (Bouaziz-Yahiatene et al., 2019). It is also noted that three species are present at all sampling stations, namely, *Cornu aspersum* which is a species of Mediterranean origin (Welter-Schultes, 2012), colonizing various environments, particularly entropized environments as well as agricultural environments (Neubert, 2014; Ballard et al., 2021), and *Xerosecta cespitum* and *Cernuella virgata*, which have a Mediterranean distribution and are considered the most abundant, colonizing open, xeric, and sunny habitats (Arrébola, 1995; Welter-Schultes, 2012).

In conclusion, in the regions of Tizi-Ouzou and Bouira, 29 species of terrestrial mollusks belonging to 25 genera and 19 families were identified. The Geomitridae were the most diversified with six species, followed by the Helicidae with five different species. This richness seems to be affected by the altitudinal gradient, wherein we recorded the highest biodiversity at the low-altitude stations (21 species), while the high-altitude stations had very poor biodiversity (10 species). Thus, altitude is a factor that directly affects the diversity and distribution of terrestrial gastropods in the study area. The low-altitude (21 species) and medium-altitude (20 species) regions were richer in species, while the high mountains were less richer and had a particular malacological fauna, including *Cantareus subapertus*. *Cornu aspersum* is a cosmopolitan species, as it has low ecological requirements. *Xerosecta cespitum* and *Cernuella virgata* were the most abundant at all sampling stations.

The equitability (E) tends toward 1 at all sites, which shows that the mollusk communities are in equilibrium in their distribution. The Jaccard index showed that there is dissimilarity between the altitudinal levels, which highlights the role of altitude in the distribution of species.

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