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EVOLUTION OF MALACOLOGICAL DIVERSITY VERSUS GEOGRAPHY IN HIGH ALTITUDES OF SOME SW ANATOLIAN HEIGHTS

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Synopsis

In the study conducted in 2007, gastropod taxa of high (alpine) attitudes of 8 SW Anatolian mountains or mountain systems have been surveyed. It is also the first malacological study concerning these heights (Mts Honaz, Denizli Akdağ, Sandras, Bozdağ, Tahtalı, Kızlar Sivrisi, Sandıklı Akdağ, and Antalya Akdağ). Taxa determined belong to 43 nominal taxa of which 21 being endemics some being undescribed. The specimens generally belonged to rocky terrain, with a small portion of open land species. Among faunal findings, 2nd Turkish record of *Gittenbergia sororcula* is of particular interest.

According to our results, alpine fauna is characterized by a poor but relict fauna with different attributes (both paleo and neoendemics). Moderate and lower altitudes were richer in diversity and species numbers. Although total numbers were similar the rate of endemics showed considerable variation due to isolation and geological history. Although the lower altitudes, part of the top national diversity area for mollusks, is seriously under threat of tourism and habitat destruction. Although two of the studied mountains (Sandıklı Akdağ and Honaz) got protective statues, generally severely degraded higher zones are quite vulnerable to pressure from local herders, deforestation, fires is effective throughout

INTRODUCTION

Mountains, being important sources of water, energy, and biological diversity, show different vertical stratifications of precipitation, temperature, and insolation. Thus a variety of microhabitats may occur in mountains in natural conditions (KARADENIZ AND GÜNEŞ, 2002).

Especially in the last few decades, an important progress in malacofauna research of Turkey has been seen (BANK and MENKHORST, 1994; HAUSDORF, 1996-2000; YILDIRIM and SCHÜTT, 1997). Mediterranean region is the most extensively studies areas, due to its rich biodiversity. Taurus Mountains, situated in Mediterranean region of Turkey, show rich floral and faunal diversity. This is partly demonstrated for the malacofauna of lower altitudes. However, present knowledge about the alpine malacofauna in contrast is very scarce, an understandable consequence of short-term excursions. Thus the study was aimed to reveal the understudied malacofauna of some SW Anatolian heights.

Concerning the studied mountains and mountain systems, only malacological finding was from Akdağ (Fethiye) (SUBAI, 1994) in current literature.

General malacological literature concerning the study area can be summarized as follows:

STURANY (1905) studied different mountain systems between Konya and Niğde, and described *Chondrula lycaonica* (Enidae).

GERMAIN (1936) determined mollusk faunas from various regions in Turkey

FORCART (1940) published a monograph of Enidae of Turkey.

LIKHAREV & RAMMELMEIER (1962), in their book about land snails of former Russia and environs, described taxa from 3 orders and 24 families in detail.

STOJASPAL (1986) listed the malacological taxa collected during the biological excursion in İstanbul, İzmit, Çanakkale, Trabzon, Bursa, Konya, Eskişehir, Çorum, Isparta, Antalya, Adana, and Van provinces.

BANK & MENKHORST (1994), in their catalog study of the family Clausiliidae distributed in Turkey, listed 23 genera, 50 species and 22 subspecies, their synonyms and distributions.

NORDSIECK (1993, 1994, 2004), revised Clausiliidae of Turkey and described numerous new species of Sprattia Nordsieck 1994, Phyrgica NORDSIECK 1994, and *Albinaria* VEST 1867.

SUBAI (1994), in his revision of the genera *Levantina* KOBELT 1871 and *Isaurica* KOBELT 1901 (Helicidae), gave taxonomic and distribution information about *I. callirhoe* (ROLLE, 1894).

WIKTOR (1994) determined slugs collected from various areas of Turkey.

HAUSDORF (1996) revised Orculidae species of Turkey and Near East.

RIEDEL (1996) studied distributions of gastropods from family Zonitidae.

HAUSDORF (2000), in his revision of genus *Monacha* FITZINGER 1833 (Hygromiidae), described several new taxa from the area of study.

WIKTOR (2000), in his revision of the family Agriolimacidae, described species from Turkey as well as their distributions and ecology.

SCHÜTT (2005), in his book “Turkish Land Snails” (4th anlarged edition, first in 1993) put together present knowledge about 583 land snail species, their distributions, ecology and taxonomy.

STUDY AREA

For the study 8 important heights, of which the malacofauna were unknown or little know, in SW Anatolia were selected (See Figure 1)

1. Honaz Mountain

Located in province Denizli, Honaz is the highest mountain (2571 m) in Ageean region of Turkey and has the national park status. It is a part of the Büyük Menderes depression and situated to the south of Aksu basin.

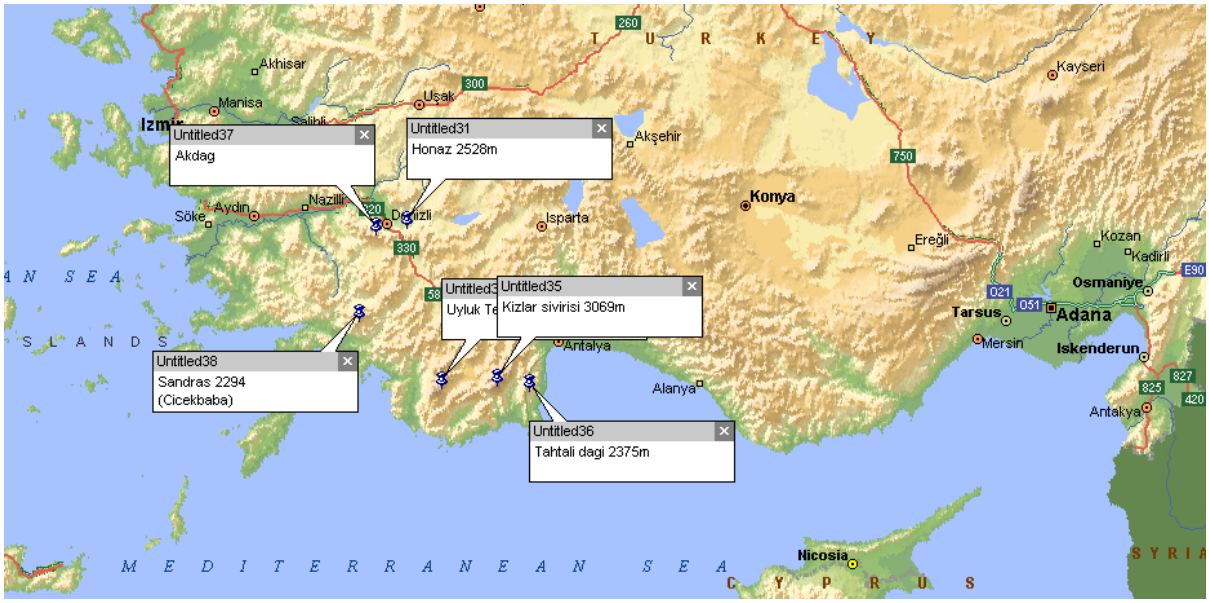


Figure 1. Map of study area

Honaz Mountain is among few places in W Turkey, where Pleistocene periglacial conditions were effective. Litologically it was formed by gneiss and mica schist, with seldom inclusions of crystalized limestone. Due to vertical faults, northern side of the mountain is very steep in contrast to southern sides. The mountain is situated at the transition belt of mediterranean and continental climates. Accordingly, mediterranean and irano-turanian elements are dominant in the flora (ÇELİK et al., 2002). The mountain show remarkable endemism of alpine and herbaceous plants.

Especially the northern side is covered with forest vegetation, of *Pinus nigra* between 950-1700 and *Juniperus excelsa* (and *J. foetidissima*) between 1700-2250 meters, replacing cushion forming alpine flora in higher altitudes. The southern side differing in plant cover is rocky, poor in vegetation due to pressure from herders allowed to enter non protected parts of the mountain.

2. Akdağ (Denizli)

Also in Denizli, it is among the highest mountains (2308 m) in the area.

3. Sandıras Mountain

Sandıras Mountain (2295 m), located at the SW corner of Gölgeli Mountains (Doğu,1993), and at the eastern border of Outer Menteşe region (DARKOT & TUNCEL, 1988), is surrounded by Namnam stream, Köyceğiz lake, and Dalaman stream. The mountain is affected by tectonic movements in Miocene onwards (DOĞU,1986), and the mounting of serpantines on Mesozoic limestone is observed (PAMIR, 1974). On higher altitudes (over 200 m), glacial formations from Würm period was developed (DOĞU, 1993). Among on of the glacial valleys, Kartal lake was formed.

Pure stands of black pine (*Pinus nigra*) around the lake, oldest black pine forest in Turkey, display a rare forest ecosystem. Around Kartal lake floral diversity is very rich. Due to unique biological and geological features 1309 Ha. around the lake was declared as a Nature Protection Area.

4. Bozdağ

Bozdağ (2441 m), is located between Acıpayam-Gireniz valley and Tavas - Barza plain. Along with Sandıras, it forms Gölgeli Mountains. Most parts are covered by ophiolites and limestone. Karstic formations (dolines) are common on the limestone areas (ARINÇ, 2004; ATALAY & MORTAN, 2003:). The dolines are used for livestock husbandry in summer, accordingly the vegetation is greatly degraded. Recent attempt to open the area for winter sports is currently suspended.

5. Akdağ (Muğla)

Western Taurus Mountains show great elevation difference as compared to surrounding areas. Akdağ (Uyluk Tepe: 3024 m) is the second highest mountain of these ranges, after Bey Mountains (Kızlar Sivrisi-3069 m). It is located on the SW of Elmalı plain and NW of Eşen valley. Generally exposed rocks are Mesozoic, with inclusions of Miocene shale, limestone, and marn (DOĞU et al., 1999). The foothills of the mountains are covered with forests.

Due to close distance to favorite tourism centers, recently visitors to the area have increased. Especially on the eastern side, effects of the destruction of the vegetation for husbandry and firewood are prominent.

6. Tahtalı Mountain

Tahtalı Mountain, arising like a tent above Antalya bay, to the southwest of Kemer, reaches 2366 m at the highest point. The main rock type is limestone (KALAFATÇIOĞLU, 1973). On the mountain, deep valleys are encountered. To 1000 asl *Pinus brutia* forests are dominant, replaced by cypress and cedar stands up to ca 2000 m.

7. Kızlar Sivrisi

Kızlar Sivrisi (Elmalı, Antalya) is the highest mountain of the western Taurus Mountains (3079 m) and calcareous in rock type (COLIN,1954).

8. Akdağ (Afyon)

At the borderline of Denizli and Afyon provinces, it is among the highest the mountains in the area (two peaks with 2449 and 2345 m alt). The mountain is steep in N-S directions. Kocayayla is located on the northern side. Due to its protected black pine forest cover and isolated red deer population, 14781 ha area of the mountain has been declared as Akdağ Nature Park. Due to presence of rare mountain birds (like lammergeyer), the mountain has also IBA (important bird area) status. On the mountain 1058 plant taxa (124 being endemics) are determined so far, a species named *Polygonum afyonicum* LEBLEBİCİ & GEMİCİ being endemic only to the mountain (GEMICI, 1988).

MATERIAL AND METHODS

All collections were made in summer of 2007. Stations were selected from different heights as possible to monitor altitudinal changes from base to summit. Only the alpine zone of Afyon Akdağ (AF) could be surveyed due to official restrictions. Collected material is currently deposited in private collection of Dr M. Z. YILDIRIM. Stations and mountains were coded with initials for convenience: Afyon Akdağ (AF), Antalya Akdağ (AK), Bozdağ (BO), Denizli Akdağ (DAK), Honaz Mountain (HO), Kızlar Sivrisi (KIZ), Sandıras Mountain (SA), Tahtalı Mountain (TA). For comparison of stations Jaccard and Euclidean distance methods were used for cluster analysis (with software PAST).

	HO	DAK	SA	BO	AK	TAH	KIZ	AF
1	37º 37/29º 17 Summit	37º 38/28º 49 1050 m	37º 25/28º 53 1283 m	37º 16/29º 011 055 m	36º 15/29º 26 336 m	36º 32/30º 30	36º 36/30º 04 1789 m	38º 22/30º 01 1387 m
2	37º 37/29º 16 2376 m	37º 39/28º 54 1361 m	37º 22/28º 52 1231 m	37º 23,15/29º 10 1250 m	36º 20/29º 28 1095 m	" " 2365 m	36º 36/30º 05 2078 m	38º 26/0º 00 1115 m
3	2280 m	37º 40/29º 00 1360 m	37º 17/28º 50 901 m	37º 22/29º 11 1737 m	36º 33/29º 37 1579 m	36º 32/30º 29 1712 m	" " 2605 m	
4	1940 m	" " 1509 m	37º 09/28º 53 1342 m	37º 20/29º 10 1865 m	36º 33/29º 36 1780 m	36º 30/30º 26 994 m	36º 36/30º 04 1749 m	
5		37º 41/29º 02 1709 m	37º 07/28º 49 1473 m	" " 2010 m	36º 33/29º 37 1820 m		36º 36/30º 04 1820 m	
6	1780 m		37º 05/28º 50 1910 m	37º 18/29º 11 2060 m	36º 33/29º 36 1868 m		36º 36/30º 04 1713 m	

7	37º 39/29º 15 1498 m		" " 1895 m	" " 2330 m	36º 32/29º 36 2075 m		36º 35/30º 00 1650 m	
8	" " 1437 m		37º 01/28º 45 990 m	37º 18/29º 12 2420 m	36º 33/29º 36 1940 m			
9	37º 39/29º 14 1137 m				36º 32/30º 03 2245 m			
10	" " 1192 m			37º 19/29º 11 1919 m	36º 32/29º 36 2100 m			
11					36º 26/29º 32 1311 m			
12					36º 28/29º 27 924 m			

Table 1. Mountains and stations surveyed in the study (N (Lat) / E (Lon) Altitude). Light grey areas show lower species numbers (<3), dark grey areas show higher species numbers (3 or more)

RESULTS

1. General Evaluation

The determined species and subspecies (n=43) are distributed to 19 families and 29 genera. With the exception of few aquatic taxa (n=3), most taxa belongs to rocky terrain (Table 2). *Gittenbergia sororcula,* showing a relict alpine distribution in the Mediterranean area, could only recorded once (Schütt, 2005) and therefore in Table 2 it was marked with D (=narrow range)

Neotaeniogloassa			
Sadleriana byzanthina (KÜSTER, 1852)	SA	E, D	springs
Pulmonata-Basommatophora			
Galba truncatula (MÜLLER, 1774)	AF		stagnant waters
Planorbis planorbis (LINNAEUS, 1758)	SA		stagnant waters
Pulmonata-Stylommatophora			
Lauria cylindracea (DA COSTA, 1778)	DAK		rocks-forest
Orculella ignorata HAUSDORF, 1996	HO, BO, TAH, AF		rocks
Schileykula scyphus (PFEIFFER, 1848)	HO	E, D	rocks
Gittenbergia sororcula (BENOIT 1857)	HO	D	alpine, rocks
Pyramidula rupestris (DRAPARNAUD, 1801)	SA		rocks
Chondrina arcadica bulgarica NORDSIECK, 1970	HO		rocks
Jaminia loewii (PHILIPPI, 1844)	All exc. SA and BO	D	openland, rubble
Chondrula lycaonica (STURANY, 1904)	HO, BO, DAK, KIZ	E, D	rocks
Multidentula squalina eudoxina (NAEGELE, 1894)	AF	D	rocks

Oxyloma elegans (RISSO, 1826)	SA		wetlands
Rumina decollata (LINNAEUS, 1758)	AK		coastal rubble
Zonites beydaglariensis RIEDEL, 1982	TAH	E, D	rocks
Zonites osmanicus RIEDEL, 1987	HO, BO, DAK	E, D	rocks
Zonites caricus (ROTH, 1839)	AK	E, D	coastal rubble
Limax flavus LINNAEUS, 1758	HO		rubble
Deroceras reticulatum (MÜLLER, 1774)	DAK		agricultural land
Gallandia annularis (STUDER 1820)	HO, SA, BO, KIZ		alpine rubble
Albinaria anatolica (ROTH, 1839)	AK	E, D	rocks
Albinaria kemerensis NORDSIECK, 1993	TAH	E, D	rocks
Albinaria lycica phaselis NORDSIECK, 1993	TAH	E, D	rocks
Phrygica riedeli NORDSIECK, 1994	DAK	E, D	rocks
Sprattia sowerbyana (PFEIFFER, 1850)	TAH	E, D	rocks
Lindholmiola gyria ((ROTH, 1839)	TAH	E, D	rocks
Monacha pamphylica HAUSDORF, 2000	TAH	E, D	rocks
Monacha solidior (MOUSSON, 1863)	AF	D	under stones
Xeropicta derbentina (KRYNICKI, 1836)	HO		openland
Metafruticicola proclivis (MARTENS, 1889)	HO, BO, DAK, SA, KIZ	D	rocks
Metafruticicola schuberti (ROTH, 1839)	AK, TAH	E, D	rocks
Isaurica callirhoe (ROLLE, 1894)	AK	E, D	alpin,e rocks
Isaurica lycia (MARTENS, 1889)	TAH	E, D	Coastal, rocks
Helix lucorum LINNAEUS, 1758	AK		openland -orchard
Helix asemnis BOURGUIGNAT, 1860	TAH	D	openland -rocks
Helix cincta MÜLLER 1774	HO, DAK, AF		openland -rocks
Helix dickhauti (KOBELT, 1903)	HO, AF	E, D	openland -rocks

Table 2. Determined taxa, their endemicity and habitats (E=endemic, D= narrow range) (*)

*** Species identified at genus level (eg juveniles) etc are not presented here.**

2. Comparison of mountains

The highest taxa were found in Honaz, Akdağ (AK) and Tahtalı mountains respectively, while the lowest number of taxa (n=3) were recorded from Kızlar Sivrisi (KIZ).

3. Comparison of stations

In general alpine localities are poor in species richness, but not with lesser endemism.

In Honaz Mountain (HO), clear difference between the malacofauna between the upper alpine zone and lower zones (HO1=highest station). In Akdağ (DAK), however, altitudinal difference was lower. In the latter, *J. loweii* was consistent in all heights. Sandıras Mountain (SA), located much southward and geologically different from the previous mountains, possesses faunal resemblances (Figure 3). The fauna at the base was shaped by Dalaman valley.

In Bozdağ (BO) the presence of *C. lycaonica* migrated from the southeast is interesting. Akdağ (AK), is a mountain showing one of the highest base-summit differences. *J. loewii*, present there in almost all altitudes, displays also here a prolific species character in open, treeless slopes with stones or rubbles.

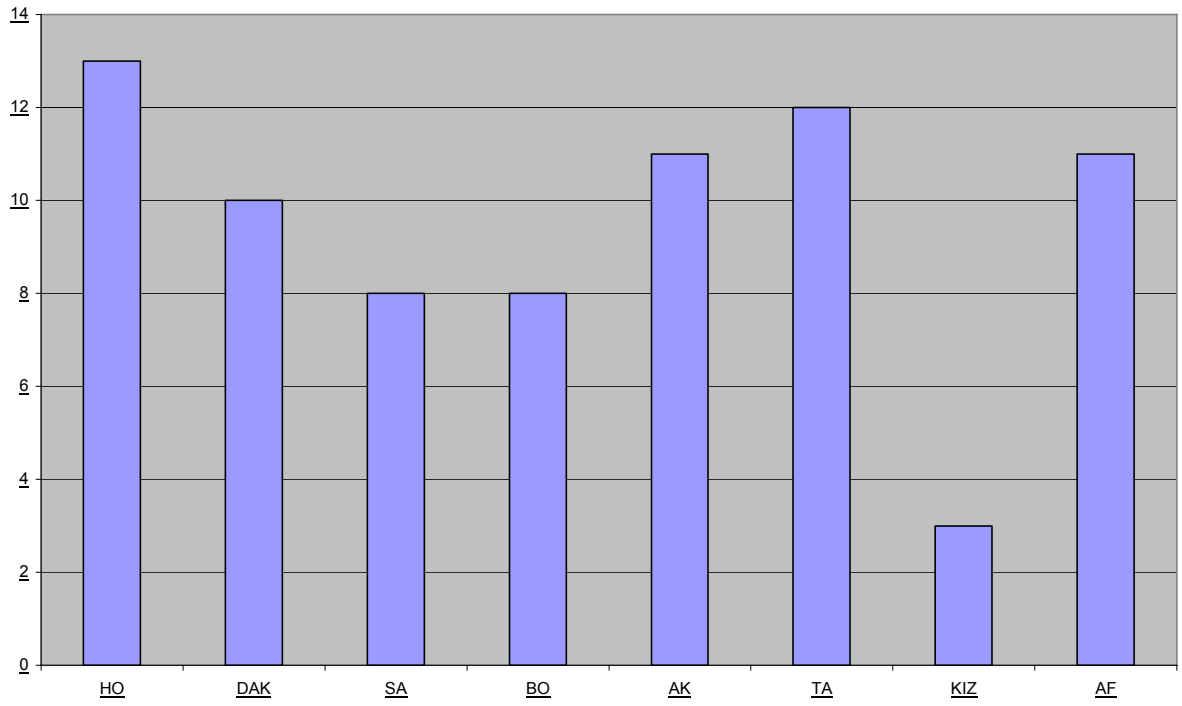


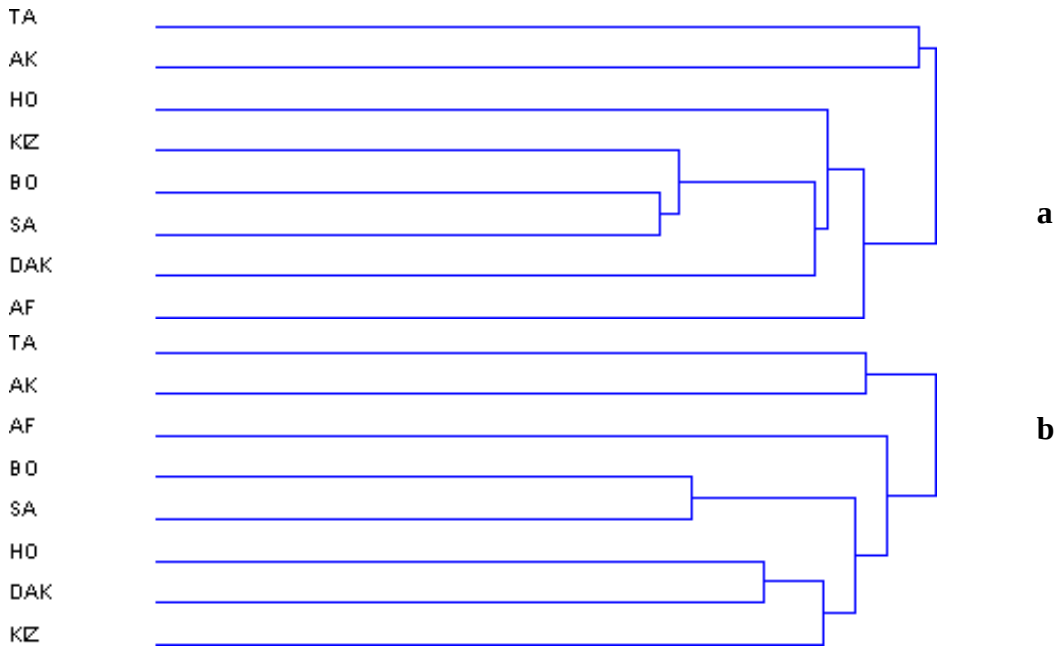
Figure 2. Comparison of the malacofauna of the mountains.

With a rich fauna at the base (TA1), Tahtalı Mountain does not show much difference in higher altitudes. One interesting aspect is the presence of lowland species (eg *Metafruticicola proclivis* and *Pyramidula rupestris*) in the alpine zone. Kızlar Sivrisi (KIZ), on the other hand, is characterized by a poor open land fauna.

Afyon Akdağ (AF), is one particularly rich area for snail diversity due to combination of different origins.

Cluster analysis of the mountains, except Afyon Akdağ, geographical distance, is decisive in distribution of mountain snails. The mountains fall in three different speciation areas: Aegean (SA, DAK, BO, HO), Taurus (TAH,KIZ, AK), and Lakes Region (AF only) (Figure 3).

Figure 3. Cluster analysis of mountains according to Euclidean distance (a) and Jaccard (b) methods.



DISCUSSION

Presence of *Sadleriana byzanthina*, a common endemic Hydrobiid in SW Anatolia, indicates that the area was in contact with freshwater systems in (interior) Aegean region. Pupilloidean land snails are represented in rocky areas, incl. high mountains. Of the 6 species determined, endemic *Schileykula scyphus* is a species of interior regions penetrating into the study area (HAUSDORF, 1996; SCHÜTT, 2001). *G. sororcula* has a relict distribution along the high mountains of Mediterranean Europe must have colonized the area possibly before Tortonian when the Anatolia was separated from Europe. In the region study area family Enidae is represented with 5 species (FORCART, 1940; YILDIRIM & SCHÜTT, 1997; SCHÜTT, 2001). From the family, endemic *J. l. loewii* was commonly seen in (especially) degraded, rocky slopes at various altitudes. *Zonites* MONTFORT, 1810 is restricted to S Greece, Aegean islands and SW Anatolia (RIEDEL, 1982, 1996). *Z. osmanicus* , characterized by flatter shell, is the most inland species (SCHÜTT, 2001). It may be and isolated species when the inner parts had a tropical/subtropical climate (*Zonites beckerplateni* SCHÜTT, 1985 from were found in Pliocene sediments of Ilgın, Konya)

Gallandia annularis is distributed from the Alps to Caucasia (HAUSDORF, 1995). This species, in contrast to Europe where it is basically alpine (KERNEY& CAMERON, 1979), it is common in Anatolia from 800 to 2500 (this paper) meters. However, it is relatively rare species in Aegean region. In the mountains from Taurus chain, all Clausiliidae taxa (n=5) were endemics (NORDSIECK, 1994), as the Helicid genus *Isaurica* (SUBAI, 1994) is. Accordingly it can be concluded that for long period the mountains although very close to others (eg Sandıras) remained isolated from the other mountains.

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