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Endemism of slugs within the Balkan Peninsula and adjacent islands (*Gastropoda*: *Pulmonata*: *Arionidae*, *Milacidae*, *Limacidae*, *Agriolimacidae*)

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I dedicate this paper to my late Professor and Friend, Jan RAFALSKI,
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ABSTRACT. The region of the Balkan Peninsula along with the adjacent islands belong to the most abundant in terrestrial slugs parts of the world. In this small area as many as 101 species of *Arionidae*, *Milacidae*, *Limacidae* and *Agriolimacidae* occur. An overwhelming majority, i.e. 66%, is composed of endemics, usually having very small ranges. The families *Agriolimacidae* and *Milacidae* are represented by especially large numbers of species, 46 and 30 respectively. 80% of the *Agriolimacidae* of Greece are endemics occurring exclusively in this country. In *Milacidae* endemism is also a common phenomenon, but the concentration of these particular slugs concerns the territories of the former Yugoslavia and Albania, where 74% of the family's representatives are recorded. In spite of the fact that the mentioned countries are neighbours, not separated by any clear ecological barriers, they have different species representations of the two families. In the author's opinion, this is a result of the geological past of the region. In the Miocene the areas of the former Yugoslavia, Albania and Bulgaria constituted a whole with Central Europe, called the North Aegeide, while southern Greece and its islands were parts of another continent, the South Aegeide, the two being separated by a sea. Different centres of speciation characteristic of the families *Agriolimacidae* and *Milacidae* existed on those two continents. Their biocenoses were shaped independently of each other, and even though later the area of Greece was connected with the northern continent, i.e. the present Europe, the two faunae have not merged.

Key words: endemism, terrestrial slugs, Balkan Peninsula, *Arionidae*, *Milacidae*, *Limacidae*, *Agriolimacidae*.

Slugs are an artificial group comprising forms of gastropods similar with regard to external appearance, adaptations and ecological requirements but often of completely different phylogenetic origin and usually of different geographical distribution. Phylogenetically, nudeness is a phenomenon of secondary nature, consisting in embedding of the shell in a soft mantle and the former's partial - in extreme cases entire - reduction. This process of becoming sluggish occurred independently in phylogenetically different groups of terrestrial gastopods. It is a fine example of parallelism in phylogenetic development, and the characters typical of slugs must be advantageous since they are preserved in the process of evolution. Under certain defined conditions the slugs must win the competition with the less agile snails which have a big, heavy and rigid shell (SOLEM 1974; LIKHAREV and WIKTOR 1979, 1980; WIKTOR 1984).

Nudeness in *Gastropoda* is not an exceptional phenomenon. Among ca 60 families of land gastropods distinguished (authors of the particular systems discriminate varying numbers of families) there are as many as 15 that comprise species with a hidden or entirely reduced shell. Most often all the species that belong to those families are slugs, but there are also families composed of slugs as well as species with a more or less preserved external shell.

Although the geographical distribution of slugs in the world is uneven, most of them occur in the northern hemisphere, particularly in the Palearctic. The reduced shells of slugs have no characters useful for identification of the species, at most they exhibit some typical ones of the family, exceptionally of the genus. As calcareous structures, shells are often preserved as fossils. However, we are unable to identify them, nor to establish whether they are remnants of species like those currently existing or belong to some other ones. Thus, we cannot unequivocally interpret fossil record.

Based on the contemporary malacofauna, we can distinguish areas of especially marked concentration of the extant species of slugs. These are presumably secondary centres of speciation, not the original distribution range. Hence, it cannot be authoritatively stated that a particular family originated in the particular area and has survived until today or that it has migrated from some other region. As far as Europe is concerned, the areas of particular abundance of slug species are the Balkans, Iberian Peninsula and Caucasian-Transcaucasian region neighbouring with the European continent. In this respect they are incomparable, and the small Balkan Peninsula with the adjacent islands are undoubtedly the leaders.

The Balkan Peninsula, often referred to as the Balkans, comprises the following countries (in their political boundaries): Bulgaria, Greece, Albania and the former Yugoslavia, i.e. at present Slovenia, Croatia, New Yugoslavia, Bosnia and Herzegovina, and Macedonia (I use the term "former Yugoslavia" because after its disintegration the borders of the presently independent countries are still at issue).

According to the present state of research, 101 slug species occur in the region of the Balkan Peninsula (I do not take into account those of unclear taxonomic status) (see tables I-IV). Some of them have been described quite recently, which testifies to

the fact that our knowledge is not complete yet and we can still expect this list to be expanded. The total number of representatives of the four above mentioned families recorded in the world is estimated at ca 300 species. It should be recognized, however, that the knowledge of particular families is different, the family *Milacidae* being the only one which has its comprehensive review (WIKTOR 1987). In the Balkans and on the neighbouring islands more or less 1/3 of all species representatives of the four families occur. None of the families is endemic here. Their distribution ranges cover vast areas, even nearly the whole Palearctic. Only for *Arionidae* the peninsula constitutes the south-eastern range limit. The other families have their distribution borders limits far beyond the region concerned.

Table I
Number of slug species in different parts of the Balkan Peninsula.

Area	former Yugoslavia + Albania	Greece	Bulgaria	Balkan Peninsula with adjacent islands
Total number of species	46	56	37	101

In order to show how species-rich the slug fauna of the Balkan Peninsula is, it can be compared, for example, with that of the former USRR with its neighbouring countries, thus a huge area stretching from Central Europe to the Sakhalin and Himalayas. According to LIKHAREV and WIKTOR (1980), ca 100 slug species inhabit this region, and, what is more, they represent as many as 8 families, including the four mentioned above. The peculiarity of the Balkans does not rest solely on the great variety of species, but also on an unusual development of endemism, pertaining, however, only to particular species. This phenomenon does not concern slugs alone but also other animal as well as plant species. Of the mentioned 101 species belonging to the group discussed, as many as 78, i.e. ca 78% of the whole slug fauna, are endemics, living only on the Balkan Peninsula, at the very most slightly penetrating the neighbouring regions, e.g. the coasts of Turkey, border-close Alps or adjacent areas of Roumania. Most of these endemic species have their distribution ranges considerably narrowed, covering merely a fragment of the peninsula or single islands. Therefore, I will be calling them "narrow endemics". The remaining 22% of slugs recorded in this area are more widely distributed (non-endemic) species: those inhabiting also Central Europe (8 species), south-European ones (4 species), slugs widely distributed in the Palearctic (4 species) and the Panmediterranean ones (2 species). The list is closed with foreign species, accidentally introduced by man (4 species).

In spite of the fact that the Balkan Peninsula is a relatively small area, it is markedly diverse and not homogeneous in respect of representation of particular families (tables II-V).

Table II
Index of *Arionidae* occurring on the Balkan Peninsula and adjacent islands.

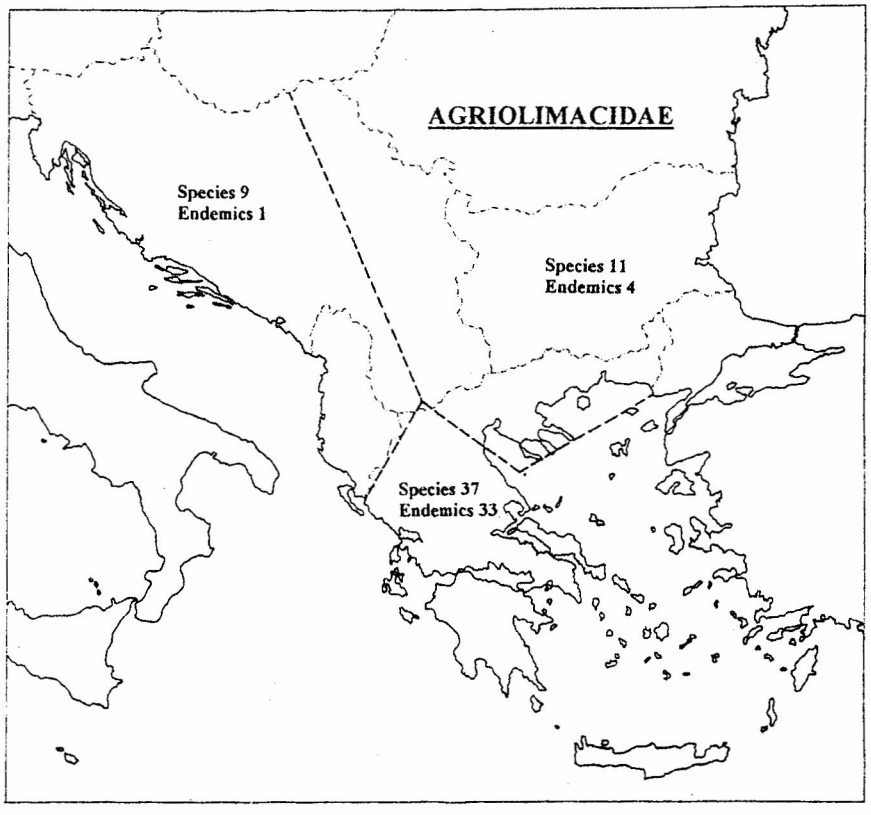
Species	former Yugoslavia + Albania	Greece	Bulgaria	Distribution
Arionidae				
Arion				
alpinus	*	-	-	EA
circumscriptus	*	-	-	WE
distinctus	*	-	*	F
fasciatus	*	-	-	F
lusitanicus	*	-	*	F
silvaticus	*	-	*	WE
subfuscus	*	*	*	WP
Total number of species	7	1	4	
%	100	14	57	

The division the indexes provide, based on the presently known distribution ranges, or single localities, allows to define the species in terms of their zoogeographical character. Such a division does not cover all zoogeographic issues. Nevertheless, at our still poor knowledge of slugs, it helps to outline the problem of endemism, a phenomenon so typical of the area concerned. For the sake of better understanding, I use both names of the geographical regions and of the countries as defined by their political borders.

The indexes of species are quoted from previously published papers (WIKTOR 1983, with slight corrections; WIKTOR, VARDINOYANNIS, MYLONAS 1994; WIKTOR 1996; WIKTOR in print), where more detailed information on the nomenclature, distribution, morphology, etc is available.

Explanations to tables II-V
EA - Alpine endemic
B - Balkan endemic - localities situted also in several neighbouring countries
EB - Bulgarian endemic

EC - endemic of south-Greek islands, i.e. the Cyclade Archipelago, Crete and islands in its neighbourhood
EE - east-Greek endemic - occurring on islands close to Asia Minor, mainly the Dodekanese Archipelago; some having their localities also in adjacent Turkey
EJ - Yugoslavian endemic - not exceeding the former Yugoslavia's borders, inhabiting mainly Dalmatia
EN - north-Greek endemic - living in the border-close areas of Macedonia, Albania, Greece and Bulgaria
ES - south-Greek endemic - inhabiting southern part of continental Greece and the Peloponnesus
F - foreign species introduced by man
WE - widely distributed west-European species
WM - widely distributed Mediterranean species
WP - widely distributed Palearctic species
WS - widely distributed south-European species



Map 1. Total number of *Agriolimacidae* species, including narrow endemics

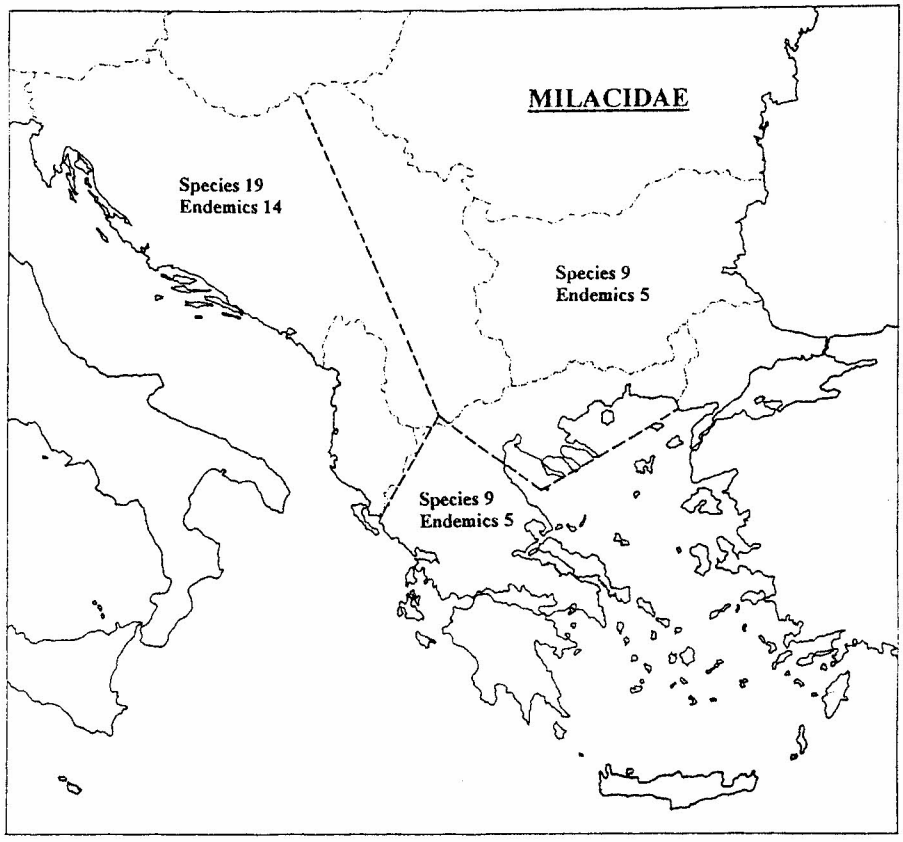
Table III
Index of *Milacidae* occurring on the Balkan Peninsula and adjacent islands.

Species	former Yugoslavia + Albania	Greece	Bulgaria	Distribution
Milacidae				
Milax				
aegaeicus	-	*	-	EC
altenai	-	*	-	EE
nigricans	*	-	-	WM
parvulus	-	-	*	EB
verrucosus	-	-	*	EB
Tandonia				
albanica	*	-	-	EN
bosnensis	*	-	-	EJ
budapestensis	*	-	*	WSE
cavicola	*	-	-	EJ
cretica	-	*	-	ES
cristata	-	*	*	B
croatica	*	-	-	EJ
dalmatina	*	-	-	EJ
fejervaryi	*	-	-	EJ
jablanacensis	*	-	-	EJ
kusceri	*	*	*	B
lagostoma	*	-	-	EJ
macedonica	*	-	-	EN
melanica	-	*	-	EN
pageti	-	*	-	EE
piriniana	-	-	*	EB
pinteri	-	-	*	EB
rara	*	-	-	EJ
reuleauxi	*	-	-	EJ
robici	*	-	-	EA
rustica	*	-	-	WSE
serbica	*	-	*	EB
simrothi	*	-	-	EA
sowerbyi	*	*	-	WM
totevi	-	*	*	?EC
Total number of species	19	9	9	
%	63	30	30	

The wide-scale endemism observed in the region under discussion can be best illustrated by the example of slugs whose distribution ranges are restricted to very small areas, namely narrow endemics (maps 1-2). Among the 37 *Agriolimacidae* species of Greece there are as many as 33 narrow endemics (map 1): most (29 species) recorded only from this country, and very few of similar type that inhabit the border

region (3 species). The narrow endemics occurring only in Greece include 17 species that inhabit the islands of the Aegean Sea (EC), 7 of the islands close to Asia Minor (EE) and 5 recorded in the southern, continental, part of the country (ES) (map 1). The number of narrowly endemic *Agriolimacidae* species confined to the territory of Bulgaria is merely 4 whereas in the whole former Yugoslavia there is only one narrow endemic of this family and, what is more, described as recenty as 1996.

The situation is substantially different in the case of the *Milacidae* narrow endemics (map 2). In the former Yugoslavia there are 14 such species, including 9 that occur exclusively in this area (EJ) and 1 recorded also from Albania. Continental Greece has only 2 endemics of narrow ranges (EN, ES), and further 4 endemic slugs live on islands (EE, EC). Considering the total number of narrow endemics of *Milacidae*, also Bulgaria yields precedence to Yugoslavia. Yet, the former country has 9 endemics, including as many as 5 with very small distribution ranges (EB).



Map 2. Total number of *Milacidae* species, including narrow endemics

In the case of the other families of slugs no such wide differences are observed within the Balkans.

Among the *Limacidae* species there are very few narrow endemics, i.e. 4 slugs (EJ, EN, EE). Further 4 endemics are Balkan species (B), and the remaining 10 have wider ranges.

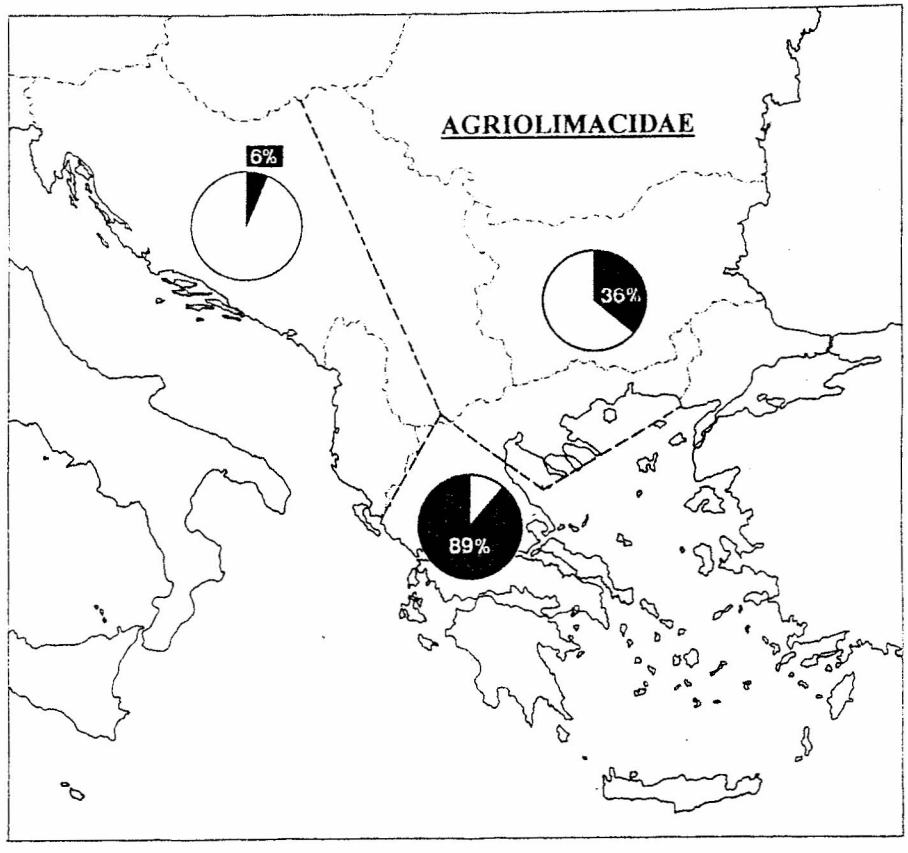
The last family, namely *Arionidae*, is represented by a mere single south-Alpine endemic (EA), inhabiting a small part of the discussed region, i.e. the Slovenian Julian Alps.

Maps 3-4 still better illustrate the problem of endemism, showing clusters of narrow endemics belonging to the families *Milacidae* and *Agiolimacidae*. It turns out

Table IV
Index of *Limacidae* occurring on the Balkan Peninsula and adjacent islands.

Species	former Yugoslavia + Albania	Greece	Bulgaria	Distribution
Limacidae				
Limax (Limax)				
cephalonicus	*	*	-	EN
cinereoniger	*	-	*	WE
conemenosi	*	*	*	B
graecus	*	*	*	B
hemmeni	-	*	-	EE
maximus	*	*	*	WE
punctulatus	-	-	*	?WSE
subalpinus	-	-	*	?WSE
wohlberedti	*	-	-	EJ
Limax (Limacus)				
ecarinatus	-	*	*	F
flavus	*	*	*	WSE
Malacolimax				
mrazeki	*	-	-	EJ
Lehmannia				
brunneri	*	*	*	B
horezia	-	-	*	?B
marginata	*	-	-	WE
nyctelia	*	-	*	WS
sarmizegetuzae	-	-	*	?B
szigethyae	*	*	-	EN
Total number of species	12	9	12	
%	67	50	67	

that this phenomenon mostly concerns very limited areas, clearly different from one another. The Dalmatian and Albanian mountain ranges are characterized by numerous narrow endemics of *Milacidae* but lack of *Agriolimacidae* endemic species. In contrast, nearly the whole of southern Greece with its islands abound in narrow endemics of *Agriolimacidae*. The latter area can be divided into four different regions. These are: an overwhelming part of continental Greece with the Peloponnesus and neighbouring islands, the Cyclade Archipelago, Crete with the adjacent smaller islands, and the Dodekanese Archipelago with most islands close to Asia Minor, i.e. Turkey. The area of the northern Balkans, stretching from north-eastern Greece through Bulgaria to the part of the former Yugoslavia north of Dalmatia and Albania, has considerably fewer narrow endemics, the two above mentioned families having comparable representations.



Map 3. Percentage of *Agriolimacidae* narrow endemics in the slug fauna of the region

Table V
Index of *Agriolimacidae* occurring on the Balkan Peninsula and adjacent islands.

Species	former Yugoslavia + Albania	Greece	Bulgaria	Distribution
Agriolimacidae				
Deroceras (Deroceras)				
agreste	*	-	*	WP
astypalaeensis	-	*	-	EC
attemsi	-	*	-	EN
n. sp.	-	*	-	EN
boeoticum	-	*	-	EN
boettgeri	-	*	-	EC
bulgaricum	-	-	*	EB
cycladicum	-	*	-	EC
gavdosensis	-	*	-	EC
gorgonium	-	*	-	EC
haelieos	-	*	-	?EB
ikaria	-	*	-	EE
johanae	-	*	-	EC
karnaniensis	-	*	-	ES
kasium	-	*	-	EE
keaensis	-	*	-	EC
korthionensis	-	*	-	EC
kythirensis	-	*	-	EC
laeve	*	*	*	WP
lasithionensis	-	*	-	EC
lothari	*	-	-	WS
maasseni	*	-	-	EJ
malkini	-	*	-	EE
melinum	-	*	-	EC
minoicum	-	*	-	EC
neuteboomi	-	*	-	EE
nyphoni	-	*	-	EC
oertzeni	-	*	-	EC
pageti	-	*	*	ES
panormitanum	-	*	*	ES
parium	-	*	-	ES
parnasium	-	*	-	ES
pseudopanormitanum	-	*	-	WSE
rethimnonensis	-	*	-	EC
reticulatum	*	-	*	WE
rhodensis	-	*	-	EE
rodnae	*	-	-	WE
samium	-	*	-	EE
seriphium	-	*	-	EC
sturanyi	*	*	*	WE

continued on p. 215

Table V (continuation)

Species	former Yugoslavia + Albania	Greece	Bulgaria	Distribution
thersites	-	*	*	?EC
turcicum	*	*	*	B
zilchi	-	-	*	?EB
Deroceras (Liolytopelte) *bureschi*	-	-	*	EB
Krynickillus *urbanskii*	-	-	*	EB
Mesolimax *brauni*	-	*	-	EE
Total number of species	8	37	12	
%	17	80	26	

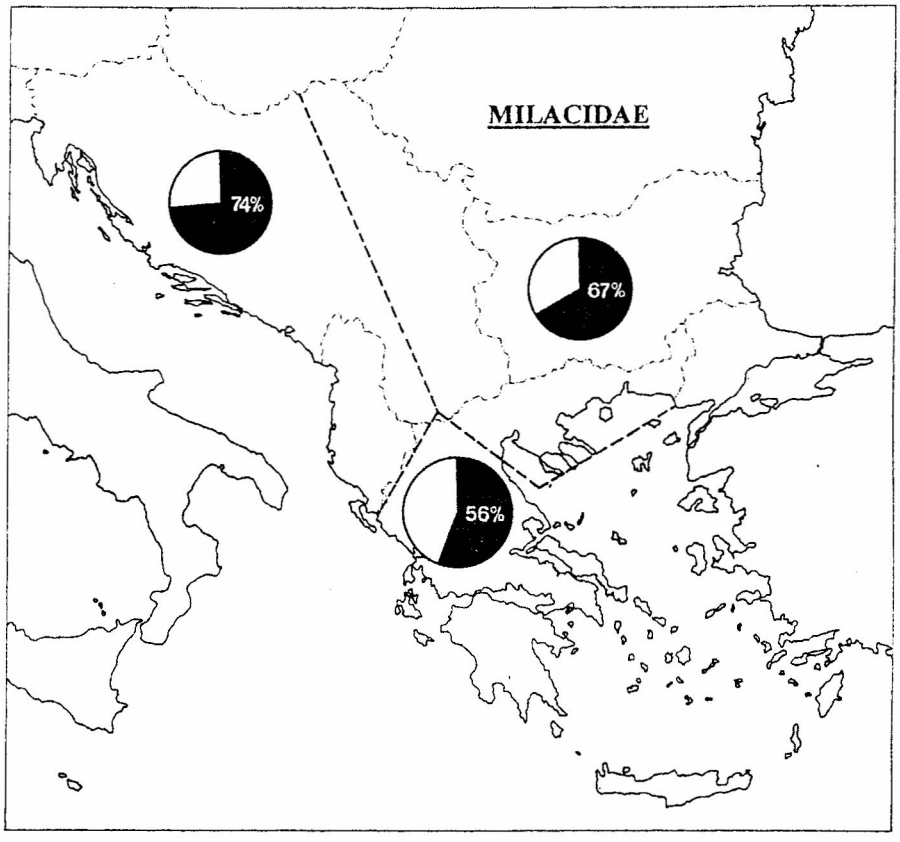
It is also worthwhile to compare the percentages of narrow endemics in the particular areas (map 5). As seen from tables VI-VII and maps 4-5, the percentages definitely confirm the marked dominance of the endemism of *Milacidae* in the southern part of the former Yugoslavia, and that of *Agriolimacidae* in southern areas of Greece.

What accounts for this distinctness of the Balkans as compared with the rest of Europe and, at the same time, for such a rich variety of slugs in such a relatively small area? The explanation should be sought both in the remote, Tertiary, past of this region and, undoubtedly, in a somewhat more recent history, i.e. the Glacial Epoch. The configuration of continents looked substantially different as recently as the Tertiary Period (map 6). The whole area covering southern, continental, Greece together with the Peloponnesus and all Greek islands, now 170 in number, was permanently or periodically joined with the present continental part of Asia Minor whereas the whole of the former Yugoslavia, Albania and Bulgaria had a permanent connection with the rest of Europe. The old fauna was shaped independently on the two neighbouring continents, i.e. vast areas of present Europe and none the less extensive areas of what is now Asia Minor. The continents, called the North and the South Aegeide, were separated by a sea. The sea constituted a natural migratory barrier difficult to get through by slugs. It was relatively recently that a fragment of land got disconnected from the South Aegeide and joined to the then North Aegeide and the present northern Balkans. The present area of numerous islands situated

between continental Greece and Turkey was periodically and fragmentarily sinking in the sea and emerging to the surface again. Nowadays land habitats are discountinuant in character: they are islands making up different archipelagos.

Before the two continents merged, two distinct local faunae (biocenoses), undoubtedly adapated to the existing conditions, must have already been shaped on those two lands. Despite the junction, they have preserved their distinctness not entering reciprocally the newly connected areas. Although the former barrier of the separating sea disappeared, it has left its lasting trace in a marked zoogeographical barrier, which separates the area of the intense speciation of *Agriolimacidae* in Greece and a similar speciation zone of *Milacidae* in the region of the former Yugoslavia and Bulgaria.

Concluding, the widespread endemism within *Agriolimacidae* can be accounted for by sinking in the sea and emergence of particular islands, coming into existence and disappearance of different geographical barriers and temporary land-bridges. The



Map 4. Percentage of *Milacidae* narrow endemics in the slug fauna of the region

bionomical properties of this group of slugs must have been of some importance as well. Some of these species could reproduce uniparentally and most of them had a comparatively short life cycle (several months). The slugs' geographic isolation on islands and features mentioned must have been conducive to intense speciation.

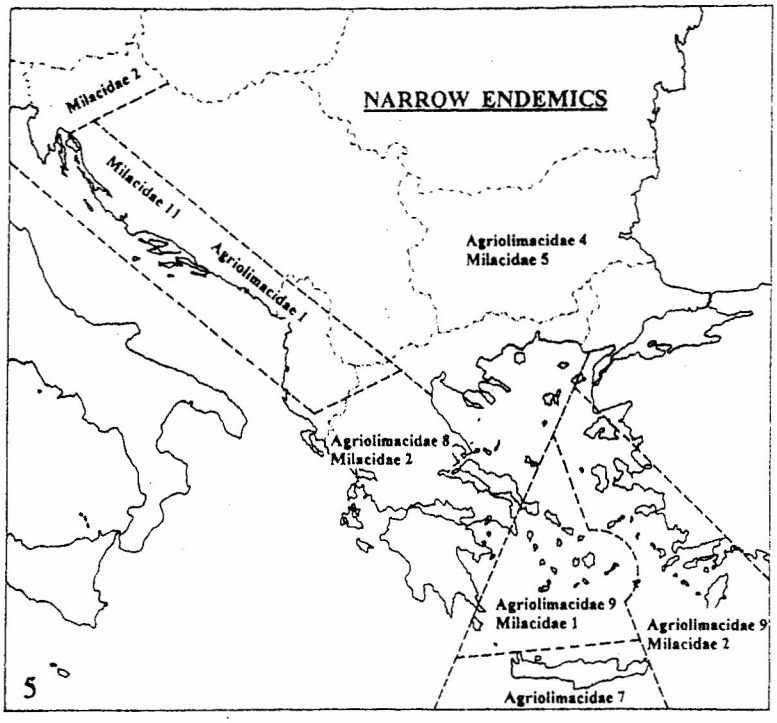
Table VI
Number of slug species in the country (in brackets - in the Balkans).

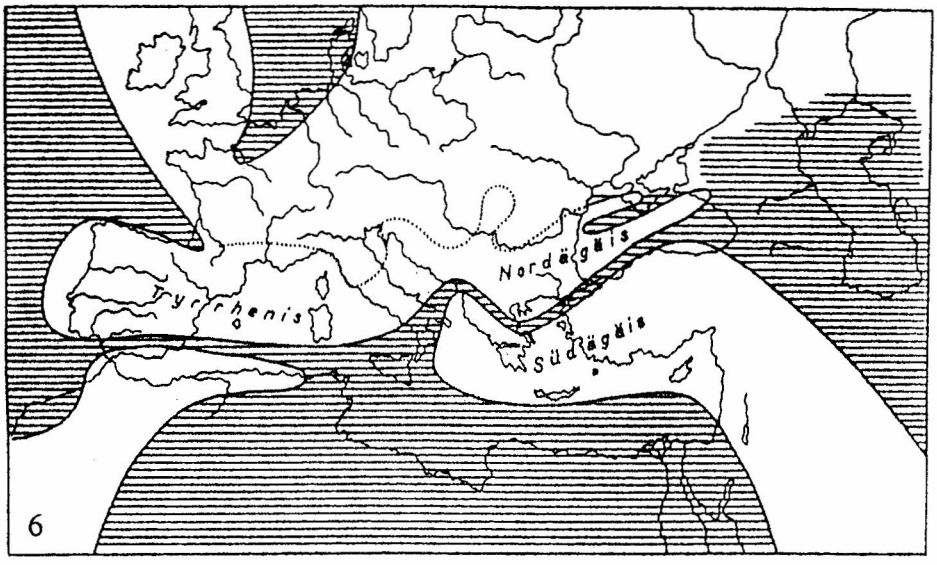
	Arionidae	*Milacidae*	*Limacidae*	*Agriolimacidae*	Total in the Balkans
Yugoslavia + Albania	7 (7)	**19 (30) = 63%**	12 (18)	8 (46)	101
Greece	1 (7)	9 (30)	9 (18)	**37 (46) = 80%**	
Bulgaria	4 (7)	9 (30)	12 (18)	12 (46)	

Table VII
Number of narrow endemics (in brackets - slug species in the country).

	Arionidae	*Milacidae*	*Limacidae*	*Agriolimacidae*	Total in the Balkans
Yugoslavia + Albania	1 (7)	**14 (19) = 74%**	?1 (14)	8 (46)	**65 (101) = 66%**
Greece	0 (1)	6 (9) = 67%	0 (9)	**37 (46) = 80%**	
Bulgaria	0 (7)	5 (9) = 56%	1 (13)	12 (46)	

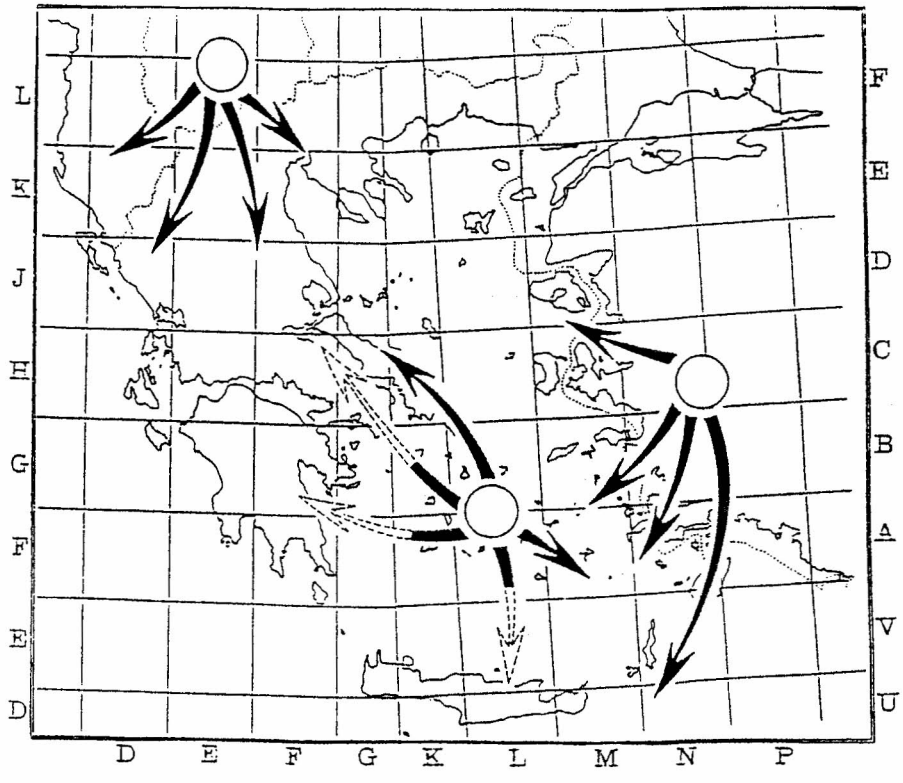
The later phase of the Glacial Epoch, which e.g. in Central Europe had exerted a strong influence on zoogeographic relations, here in the Balkans left a much less visible stamp. The climatic changes in the concerned region were not as drastic in character as those farther north. There were no factors forcing such great migrations





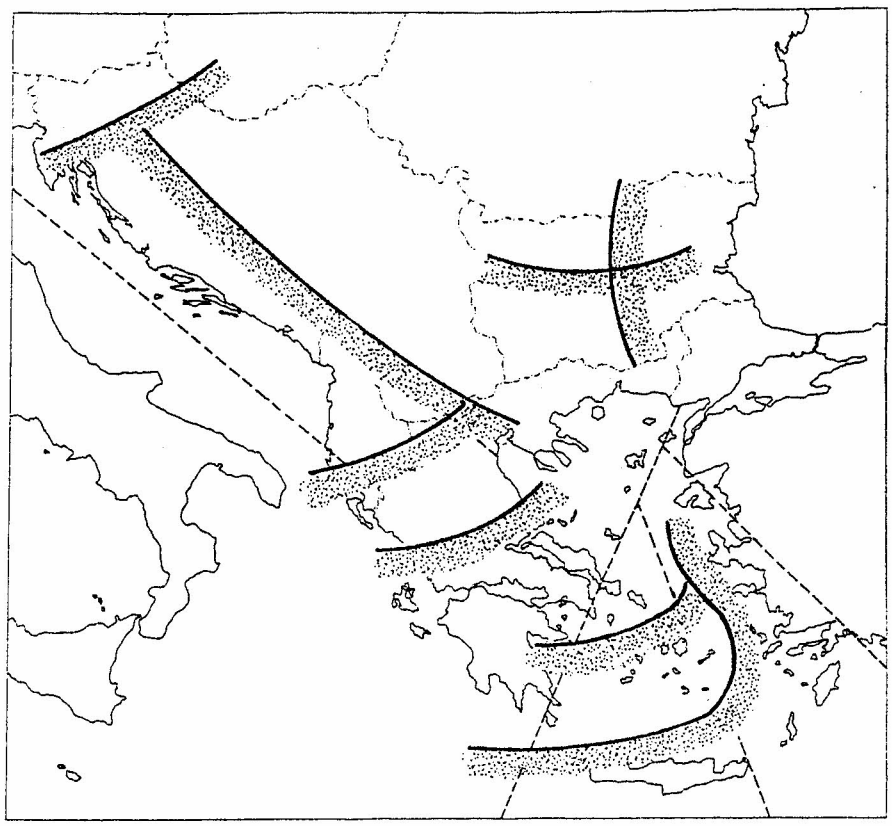
Map 5, 6: 5 - Division of the Balkan region into areas different with respect to narrow endemics of *Agriolimacidae* and *Milacidae*; 6 - Layout of continents in the Paleocene (Montien) (acc. to JEANNEL 1943 after RIEDEL 1969).

and profound changes in the fauna compositions. The only essential one operating during this period might be the impoverishment of the fauna, which must have also occurred later, i.e. in the prehistoric and historic times, when human activities were and have been changing the character of the environment. Destruction of forests and of many other natural habitats must have been of particular importance.



Map 7. Probable main centres of speciation.

The knowledge of the current distribution of slug fauna in this region allows a supposition that in the Balkans existed at least 3 different centres of speciation and spreading of slugs (map 7). It is evidenced by the clearly marked geographical boundaries (map 8).



Map 8. More important distribution range limits of slugs in the Balkan region.

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