

## GENERAL INTRODUCTION

L. BOTOSANEANU

(Editor)

As a result of the co-operation of an international team of 65 specialists this project, upon which I began effectively to work some 5 years ago, at last becomes a reality. Even if I consider the aims of this book as being relatively modest, viz., to give in as concise a manner as possible the maximum amount of sound information on the world fauna of subterranean waters, on its geographical distribution and on its habitats, all from a naturalist's perspective, the amount of work required has been tremendous indeed.

Such a synthesis became necessary because of the enormous amount of new information published especially during the last decades, information scattered in various periodical publications or books, and obtained more than ever by specialised teams working in hitherto unexplored areas and using improved and effective sampling methods. Some of these more recent discoveries are among the most sensational, the most rich in consequences, in the history of zoology. They include the discovery of many new types of biological organization, and of several new and unexpected habitats, world wide in occurrence, and with representative faunas.

An essential point for discussion concerns the meaning, or content, of the notion of "subterranean water" and what, from the biologist's viewpoint, are the component parts of this realm. Much has been written on this crucial topic, the general impression gained being one of great confusion and misunderstanding, some of it only semantic but some of it central in its importance. If it is true that "As for controversy, this is surely a sign of health in an active science" (B.F. Madore, *Nature* 294, 1981), then a "dialogue of the deaf" is a real danger in science. It is absolutely beyond my scope and means to here attempt even a summary of this discussion, but it would be a worthy task for one who had the courage to undertake it.

Some years ago I gave a sketch of such a discussion (Botosaneanu, L., 1971. *Observations sur la faune aquatique hypogée des Monts du Banat, Roumanie.* — *Trav. Inst. Spéol. E. Racovitza*, X: 123-166). I expressed there the firm belief that we are here concerned with a huge complex of distinct habitats, yet ones variously interdependent and intermingled, and that this is clearly reflected in the animal populations of these habitats. My work in later years, including that for the present book, has not in the least led to a modification of that opinion.

It is quite possible that the first biologist to have achieved a comprehensive conception of the "Realm of subterranean water" was A. Thienemann, who as early as 1925 (*Die Binnengewässer Bd. 1: Die Binnengewässer Mitteleuropas.* E. Schweizerbart, Stuttgart, 255 pp.) could write (p. 25): "Unter Grundwasser verstehen wir alles in der äußersten Erdrinde zirkulierende, unter der Erdoberfläche befindliche Wasser.... Es erfüllt Klüfte und Spalten der Gesteine, größere und kleinere Höhlungen der Felsen, aber auch alle lockeren und losen Ablagerungen und kann auch in ihnen gewaltige zusammenhängende Wassermassen... bilden". In doing this he was, of course, unable to profit by the discoveries of new habitats in the following decades, but he proved to possess that indispensable flair of the innate ecologist.

For S. Husmann (*Ecological studies on freshwater meio-benthon in layers of sand and gravel.* — *Smithsonian Contr. Zool.* 76 (1971): 161-169), who also quotes Thienemann, all this represents "the ecosystem "groundwater" (Stygocoen)", a conclusion with which I am in perfect agreement. In fact, it would be equally acceptable to consider the realm of subterranean water as a "bioregion" inhabited by a biome (being a "major life zone" sensu Odum, or a biochore (= Grosslebensraum): there are bibliographical indications pointing to this, but I must confess that I do not consider these aspects as really relevant for the present book.

Presently this viewpoint has gained more adherents and I shall quote here a passage which corresponds exactly with my ideas on the subject, from p. 112 of the book by Ginet and Decou (1977): "...on aboutit.... à considérer les eaux souterraines .... comme un vaste domaine continu dans l'espace, domaine qui se fragmente naturellement en un grand nombre de biotopes plus restreints, qui vont depuis le milieu hypotelminorhéique, situé juste sous le sol en montagne, jusqu'au milieu psammique des plages du littoral marin".

The most compelling initiative that I have had to take in this book was probably that of including the marine interstitial realm and its fauna. I must emphasize that this does not mean the marine meiofauna as a whole but only the interstitial fauna from marine sediments coarse enough to allow development of such a fauna in its typical aspect. I have no illusions concerning the general acceptance of this idea but I can say, nevertheless, that almost none of the contributors to the present book had difficulties in accepting it. In taking this initiative I relied on several criteria: (1) On the well

known physiographic continuity, having quite varied aspects, with other (= inland) subterranean aquatic habitats; (2) On the interpenetration of faunistic elements (often at the level of higher groups, but not infrequently at the generic level), this interpenetration being sometimes a quantitatively quite modest one, but also sometimes rather, or even quite, important; (3) On the generally accepted fact that the marine interstitial is one of the “gates” used by elements of marine origin in their colonisation of inland subterranean aquatic habitats (interestingly enough, the possibility of colonisation in the opposite direction was also stressed by, for example, J.-W. Wägele, for Microparasellidae); (4) On the existence of morphological and other adaptations of the typical marine interstitial fauna, which are in principle exactly the same as those shown by the typical animals inhabiting interstitial habitats of inland waters.

For all these reasons I am convinced that omitting this habitat from this book would have been a serious error.

I am forced here to make something of a digression. In a paper by P. Ax & R. Ax (Das Verteilungsprinzip des subterranean Psammon am Übergang Meer-Süßwasser. — Mikrofauna Meeresbodens 1 (1970): 5-51) the interesting and surprising conclusion was reached that (p. 47): “Von den marinen Küsten mit und ohne Gezeiten bis in den Grenzbereich zwischen Thalassopsammal und Limnop-sammal ist die Feuchtsandzone durchgehend der spezifische Lebensraum des subterranean Mesopsammon. Zum Grundwasserhorizont erfolgt generell ein rapider Abfall der Individuendichte. Das Grundwasser ist gewöhnlich schon in geringer Tiefe ganz unbesiedelt”. It would have been impossible not to take into account such an important idea, one which in my opinion, casts doubt on the very existence of a truly aquatic marine-interstitial fauna, and I took it into account (see P, P1, P2 in my “List of habitats of subterranean water ...”). But I should add that many chapters of the present book (Mystacocarida, for one example) provide evidence seemingly contradicting this idea. Moreover, if *true aquatic animals* are living exclusively in the *upper* sand layers of a marine beach (“Feuchtsandzone”) is not the water moistening this sand at least partly “Küstengrundwasser” raised here by capillarity? Finally, it is my opinion that the recent discovery of an important typical interstitial fauna in permanently immersed sands of the sublittoral, even at relatively considerable depths, is clear evidence of the lack of general applicability of the above-mentioned theory.

In this context two minor parenthetical remarks should be made. First, the “lowest limit” in the distribution of the marine-interstitial fauna is, in principle, the lowest limit where sediments coarse enough are present; it seems that this limit more or less corresponds with the inferior limit of the sublittoral. Second, Ax & Ax (1970:47) also make the following statement: “Der Vergleich mit dem ufernahen Endogaeolimnon von Seen und Fließgewässer führt zu allgemeinen Schlussfolgerungen für die Subterranoökologie.

Wie an der Meeresküste existiert auch am Seeufer kein stygobiontes Mesopsammon unterhalb des Grundwasserlinie. Es ist nach dem heutigen Stand der quantitativen Untersuchungen ebensowenig im ufernahen Grundwasser von Fließgewässern vorhanden”. This is refuted on the whole by the results obtained by sampling and by the study of the extremely characteristic truly aquatic fauna of the running water underflows especially from studies using pumps (as described by Bou & Rouch or by Husmann) which enable one to sample the underflow fauna directly under the stream or river, and in permanently immersed sediments.

Reference will now be made to my list of “Habitats (biotopes) of subterranean water (sensu lato = Stygal)” (see the annexes of this book, and column 4 of the tabular parts of the chapters). In formulating this I believe that I have made use of all the achievements in this field of these last decades (numerous publications on stygobiology, groundwater hydrology, or hydrogeology, etc., impossible to mention here). I am satisfied with the result, for after all the point is that of knowing exactly what is involved and to express it as clearly as possible.

In a MS to be published by Stock, Iliffe & Williams in *Stygologia*, 2, 1986, the “marginal marine caves” (marine Randhöhlen) are considered as part of the anchialine habitat; I am not sure that this is actually so, being for a more restricted acceptance of the concept “anchialine”.

I regret not having in due time introduced a special category for “submarine + marine littoral caves”: most of the fauna of such caves is beyond the scope of this book, as being purely marine, but some elements were discovered in them which are relevant for stygobiology.

I refer especially to “ $\beta$ ”, which is intended for all the situations not clearly corresponding to one of those mentioned in the list. Use of a  $\beta$  in column 4 of the tables would make a “note” at the end of the relevant chapter almost a necessity (frequently, but not always, this was done).

I must also comment on the fact that in a few publications the idea has been expressed that a deep sea fauna lives in some caves: there is clearly a misunderstanding here. Examples of relationships, and of common adaptations of stygobiont elements and of elements of the abyssal fauna are well known. The explanation mostly certainly involves common ancestry (mainly from shallow marine waters) of deep sea taxa on the one side, and of taxa inhabiting the waters of karstic hollows, mainly near marine shores, on the other side, the adaptive potentialities of these ancestors having found propitious circumstances for their development in both these situations. Bearing all this in mind any mention of deep sea faunal elements has been excluded from the book. A quite different point is the recently expressed idea that in some particular circumstances elements of the deep sea fauna could have migrated to the surface through cracks in rocks, some stygobiont — even freshwater — elements be-

ing consequently of deep sea origin. I am moderately sceptical about this theory, but cannot ignore it.

The “List of habitats” is not a glossary; it cannot mention the authors of the terms nor consider questions of priority. Nonetheless, such a glossary would be most welcome. The only one known to me, and one necessarily fragmentary, is that of W. H. Monroe, 1970 (A glossary of karst terminology. — Geological Survey Water-Supply, paper 1899-K: K1-K26. Washington).

It was never my intention to give here a description of the Stygal biotope, even a very concise one. But in answer to the question as to what factors could be considered as being common for the Stygal in all its habitats, the following features could be mentioned: (a) obscurity; (b) variations of temperature, water flow, and other factors of a lower amplitude and occurring later than in neighbouring surface habitats; (c) impoverished trophic resources, the energy input being mainly or exclusively allochthonous. On the other hand, there is a tremendous variation in such other essential factors as granulometry and water salinity.

This book consists of chapters, of varied length and scope, each being devoted to a single “group”. This may be a phylum or a species. Almost all the groups presently known as comprising stygobionts could be included, one exception being, unfortunately, the marine-interstitial Turbellaria, for which no contribution could be obtained. Not all the chapters could be brought to a common plan; some because of the imperfect state of knowledge concerning the respective groups, lack a tabular part. But in general a “complete” chapter is structured as follows:

1. An introduction giving a general overview of the group and its relationships with the Stygal. The essential aims of such an introduction are (a) to tackle the problem of the boundary between what is and what is not stygobiont in the group, frequently an extremely complex problem, and (b) to discuss those taxa known or assumed to be stygophiles and which are in consequence excluded from the tabular part. I emphasise the point that many and varied instances of stygophiles could be highly significant from the point of view of evolutionary biology.

2. A “key” bibliography.

3. An illustration, usually comprising habitus figures of stygobionts, and selected in such a way as to afford the reader an impression of what most of the “morphological types” within the group look like. This illustration is complementary to the rather sparse introductions to the morphology and systematics of the different groups.

4. A tabular part forming the “core” of the chapter, and essentially confined to the stygobionts (a term introduced by Thienemann, 1925). For the purposes of this book stygobionts are “free-living taxa which (a) are exclusively found, or

almost so, in all their developmental stages in one or more subterranean aquatic habitats, and (b) which display adaptations generally to be seen as characteristic of subterranean aquatic animals”. Taxa belonging to either (a) or (b) were also taken into account but with an explanation for every such occurrence being provided as a “note”. Authors and editor have tried hard to adhere to this concept but it was not always an easy task!

With reference to “free-living taxa.....” one exception was made for the commensal Entocytherid ostracods.

An aside is necessary to explain “adaptations generally to be seen as characteristic of subterranean aquatic animals”. These are, firstly, the more or less complete anophthalmy and tegumental depigmentation and, secondly, a possible lower metabolism, longer period of development, and reduced progeny in comparison with related epigeal forms. Somewhat oversimplifying, there are other classes of adaptations which are characteristic either for the stygobionts living in karstic hollows, or in porous habitats.

The tabular part has four columns.

Column 1 provides a numbering of the species and subspecies, which is independent for each chapter.

Column 2 is reserved for the taxa. Suprageneric taxa are systematically arranged but at the generic level authors could choose between a systematic or an alphabetical arrangement. For the species of a single genus, subgenus or species group, the order is always alphabetical. For subspecies within a species the nominate ssp. occurs first and the remainder alphabetically. Names of genera and subgenera are in boldface, which renders an index superfluous. For the most part taxa as yet undescribed but known to the authors are also included here (or in the final “notes”).

Column 3 gives the geographical distribution of species and subspecies (incl. varieties). One of the most difficult decisions to be made was that of dividing the globe into a simple, reasonable and more or less generally acceptable system of zones-provinces-districts reflecting the present level of our knowledge. I took a pragmatic viewpoint and relied upon, among other things, the published evidence on the distribution of aquatic subterranean faunas, large or small geographic (geomorphological) units, and occasionally political-administrative units. Several colleagues, with experience for specific areas helped me in this task, and I am especially indebted to the following: Prof. Dr. R. Ginot (France), Dr. J. P. Henry and Dr. G. Magniez (France and the Iberian peninsula), Prof. Dr. J. R. Holsinger (North America), Prof. Dr. W. Noodt (South America), Prof. Dr. S. Ruffo (the Italic peninsula), Prof. Dr. H. K. Schminke (Africa and Australia). But responsibility for any errors or inconsistencies in the final arrangement of these divisions rests with me.

I cannot claim to be completely satisfied with this first attempt at a stygogeographic division of the globe, but I hope

that this tool can be improved. Some of its imperfections of which I have become aware are: (a) The proposed lower limits of some mountainous zones of Europe (Alps, Mittelgebirge, Carpathians) proved to be too rigid. In fact in many cases they were used in a more flexible sense, i.e. they were considerably lowered for taxa present in an environment exhibiting a true mountainous contour also below the proposed limits. (b) There are several situations where it is practically impossible to choose between two provinces or districts (e.g. Skopje, in the Yugoslav Macedonia, is situated on the River Vardar, exactly between I8b and I9b). For such cases the solution was the use of both symbols separated by/or -. (c) There are some inconsistencies in the treatment of some islands such as those of the North and South Atlantic, Madagascar and other Indian Ocean islands, islands of the Red Sea, and the Galápagos, in that the marine shores were not given a separate symbol, contrary to the normal convention.

Column 4 gives the habitats. The list of "Habitats of subterranean water..." has already been discussed. In principle, the succession of two or several letters used for a taxon has some meaning, reflecting the decreasing importance of the various habitats in the ecological spectrum. A glance at this column throughout the book will also show how important the gaps still are in the ecological characterisation of numerous stygobionts. Surprisingly it is only in recent years that there has grown interest in a more exact and detailed description of the habitats!

5. Notes placed at the end of the chapter. Their essential aim was to permit the authors to provide some information considered to be important, but which did not belong in the introduction nor in the tabular part. The order is that of the taxa in the tabular part; numbered taxa are mentioned only by their numbers and unnumbered ones are named in full.

The "additional notes" to various chapters, were prepared by the authors during the first half of 1985.

I am sure that this book could supply the "raw materials" for some interesting syntheses concerning the faunistics, the biogeography, and the ecology of subterranean aquatic animals; perhaps even it will be a stimulus towards these ends! I confine myself to pointing out the phenomenon which I would call "the flock syndrome", that is, the existence of smaller or larger "flocks" of nearly related taxa in-

habiting one type of habitat in a well-delimited geographic area. Of course, this phenomenon provides no surprises for the evolutionist; nevertheless it is extremely well exemplified throughout the present book and I hope to have the opportunity of referring to it in a special publication.

This book will give a correct idea of the impressive progress made in our knowledge, and of the no less impressive gaps that remain, and I hope that it will be a stimulus to further research. It has been put together in a way that makes possible a IIInd edition without too many difficulties.

The Editor has striven for a degree of uniformity throughout the book. At the same time he has accepted that obsessive concern with uniformity in both the general lines and the details would have been an error. For example many, and interesting, desiderata of the individual authors were accepted even if they meant important deviations from the original plan.

The various contributions are published in English, French, or German. This was not only because I wanted to give each contributor the possibility of expressing himself at ease, but also as a matter of personal principle — I do not believe in the absolute hegemony of one language in science.

I am grateful to Prof. Dr. Ian Ball who kindly improved the English of this general introduction. The excellent cooperation during these years with the Publisher is highly appreciated, and I am particularly grateful to Dr. W. Backhuys, Director, and to Mr. B. Dijksterhuis, head of the Production Department.

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**Zones — provinces — districts and code figures and letters  
used to indicate them in column 3 of the Tables.**

**I. Periponto-caspi-mediterranean (sensu lato) (see maps 1 & 2).**

1. Iberian Peninsula (Pyrenees and most of the Cantabrian Mts. excluded; northern limit: line Gijón-Barcelona).
  - a. Northern & Western District.
  - b. Southern & Eastern District.  
The limit between 1a and 1b starts at the mouth of Guadiana, follows the ridge of Sierra Morena, leaving south the whole hydrographic systems of the Guadalquivir, Segura, Júcar, Turia, and Mijares, and ends at the mouth of the Ebro.
2. Balearic Islands.
3. Pyrenean - Aquitanian Province (including the Pyrenees, most of the Cantabrian Mts., and the Aquitanian Bassin).  
Southern limit: line Gijón-Barcelona; northern limit: starting at the Gironde Estuary, following the northern limits of the hydrographic system of the Garonne, and ending westward from the mouth of the Hérault.
4. Rhodano-Lotharingian Province (lower bassin of the Rhône with the Saône, Lower Provence, "mountains" of Vivarrais, Lyonnais, Beaujolais, Charolais, Côte d'Or, and Southern Lorraine).  
Eastern limit: the 800 m. limit of the Alps (very roughly marked on map 1); western limit: starting at the mouth of the Hérault — this valley completely included —, following the western limit of the above mentioned "mountains", northwards reaching Metz, turning east to Sarreguemines, and slowing down along the western limit of the Vosges to Belfort, and then to Basel on the Rhine.
5. Italian Peninsula and Sicily.
  - a. Padano-alpine District (the Po Lowlands northward from the river, and the southern slopes of the Italian Alps, within the 800 m. limits).  
Northern limits very approximately marked on map 1.
  - b. Apulian District, including the whole of Apulia, from and with Monte Gargano, to and with the Salentine Peninsula.
  - c. Appennine District, including all parts of the Italian Peninsula not belonging to a) or b); but also Sicily, the Tyrrhenian Islands, Malta.
6. Corsica & Sardinia.
  - a. Corsica.
  - b. Sardinia.
7. West-Balkan Province.
  - a. Slovenia (excluding the Alps above the 800 m. line, and the north-eastern lowland).
  - b. Istra (until Trieste!).
  - c. Dinaro-Dalmatine District (including all the Dalmatine Islands).
  - d. Bosnia & Hercegovina.
  - e. Serbia — south from Sava and west from Morava.
  - f. Crna Gora (= Montenegro) & Kossovo.
8. South-Balkan Province.
  - a. Albania.
  - b. Yugoslav Macedonia, westward from the Vardar Valley.
  - c. Peninsular Greece.
  - d. Ionian Islands.
  - e. Aegean islands.
  - f. Crete.
9. East-Balkan Province.
  - a. Northern District, including: the Banat Mts. in Romania; the Transdanubian Carpathians between Morava & Timok; the Serbian Mts. eastward from Morava; Northern Bulgaria with Vitoša, the whole of the Balkan or Stara Planina Mts., the plateaus and lowlands between these mountains and the Danube; Dobrodsha.
  - b. Southern District, including: the Yugoslav Macedonia eastward from the Vardar Valley; Southern Bulgaria with Ryla, Pirin, the Rhodopes, the lowlands south from the Balkan

or Stara Planina Mts., the Strandja Mts.; european Turkey.

10. Crimea, Caucasus, Cis- & Transcaucasia, Northern Iran (north of the Tehran latitude).

11. Asia Minor & Cyprus.

12. Syria, Lebanon, Israel, the Sinai Peninsula.

13. North-Western Africa (until the northern limits of Sahara).

14. The marine shores of the Periponto-caspi-mediterranean (including of course, those of the Aegean & Adriatic).

**II. Western & Central Europe (only parts not belonging to zones I and III) (see map 1).**

1. The British Islands (excluding the marine shores).

2. European shores of the Atlantic Ocean, shores of North- and Baltic Seas, arctic shores of Europe.

3. Gallo-Rhenanian Province: middle-height mountains (= Mittelgebirge, moyennes montagnes) & lowlands of North-Western Europe, belonging to France, Belgium, Luxembourg, The Netherlands, and Western Germany. Eastern limit: the Rhine; other limits: see I 3 and I 4.

4. The Alps within the  $\pm 800$  m. line.

5. The Central European middle-height mountains (Mittelgebirge, moyennes montagnes) within the limit of 500 m. Western limit: the Rhine; eastern limit: line connecting Vienna to the "Moravian Gates" (i.e. between the Oder- and Vistula springs); northern limit: the  $\pm 500$  m. limit of the mountains; southern limit: the  $\pm 800$  m. limit in the Alps.

6. The Transylvanian Plateau, with the Apuseni (or Bihar) Mts.

7. The Carpathian arch, within the  $\pm 800$  m. limits (without the Apuseni, or Bihar Mts., and without the Banat Mts.).

8. Middle- & Lower Danubian Lowlands, belonging to Austria (Wiener Becken, Burgenland), Czechoslovakia (lowlands of Slovakia), Hungary, Yugoslavia (north-eastern part of Slovenia; important parts of Croatia, mostly north from Sava; the Voivodina and a small part of Serbia with Belgrado), and to Romania (the Western Lowlands, as well as the Wallachian Lowlands — between the Danube, the Carpathians, and the Siret Valley).

**III. Palaeartic (or, at least, partly Palaeartic) areas not included in I or II.**

1. Lowlands & plateaus of Central, Eastern & Northern Europe (western limit: the lower Rhine; southern limits formed by the  $\pm 500$  m. northern line of the Central-European Mittelgebirge, followed by the  $\pm 800$  m. northern line of the Carpathians, and further south, by the Siret Valley until the Danube).

2. Central Asia.

3. Irak, Iran (northern parts until Tehran latitude excluded), Afghanistan.

4. Other continental areas.

5. Japan (marine shores of Japan: 5a).

6. Northern- and Southern Atlantic Islands (with the exception of Bermuda), including their shores.

**IV. Non-palaeartic Africa, and islands of the Indian Ocean and of the Red Sea.**

1. Sahara & Western Africa (essentially hydrographic systems of the Senegal, of the Niger, and of the tributaries of the Chad Lake).

2. Eastern Africa (essentially hydrographic system of the Nile, i.e. Egypt, Sudan, Ethiopia, Somalia, Kenya, Uganda, and parts of Tanzania).

3. Central Africa (essentially hydrographic systems of Congo (Zaire) and of Zambezi).

4. Southern Africa (essentially hydrographic systems of Limpopo and of the Orange).

5. Madagascar (including its marine shores).

6. Other islands of the Indian Ocean (including their shores).

7. Shores (and islands) of the Red Sea and African shores of the Indian Ocean.

8. Atlantic shores of Africa.

V. Non-palaeartic Asia, westward from the Wallace-line.

1. Arabian Peninsula.
2. Indian subcontinent (including Pakistan & Bangladesh) and Ceylon.
3. Indochina and Malaysia.
4. Philippines.
5. Indonesia westward from the Wallace-line.
6. Other areas, not above mentioned.
7. Asiatic shores of the Indian Ocean.
8. Other marine shores, belonging to 3, 4, 5, 6.

VI. Indonesia eastward from the Wallace-line, New Guinea, Australia, Tasmania, New Zealand, other islands of the Pacific Ocean.

1. Indonesia eastward from the Wallace-line.
2. New Guinea.
3. Australia.
  - a. Western Australia.
  - b. Other areas of Australia, and Tasmania.
4. New Zealand (including its subantarctic islands).
5. Other islands of the Pacific Ocean (including Hawaii; without Galapagos).
6. Marine shores of all the above mentioned.

VII. Pericaribbean & Mexican Zone.

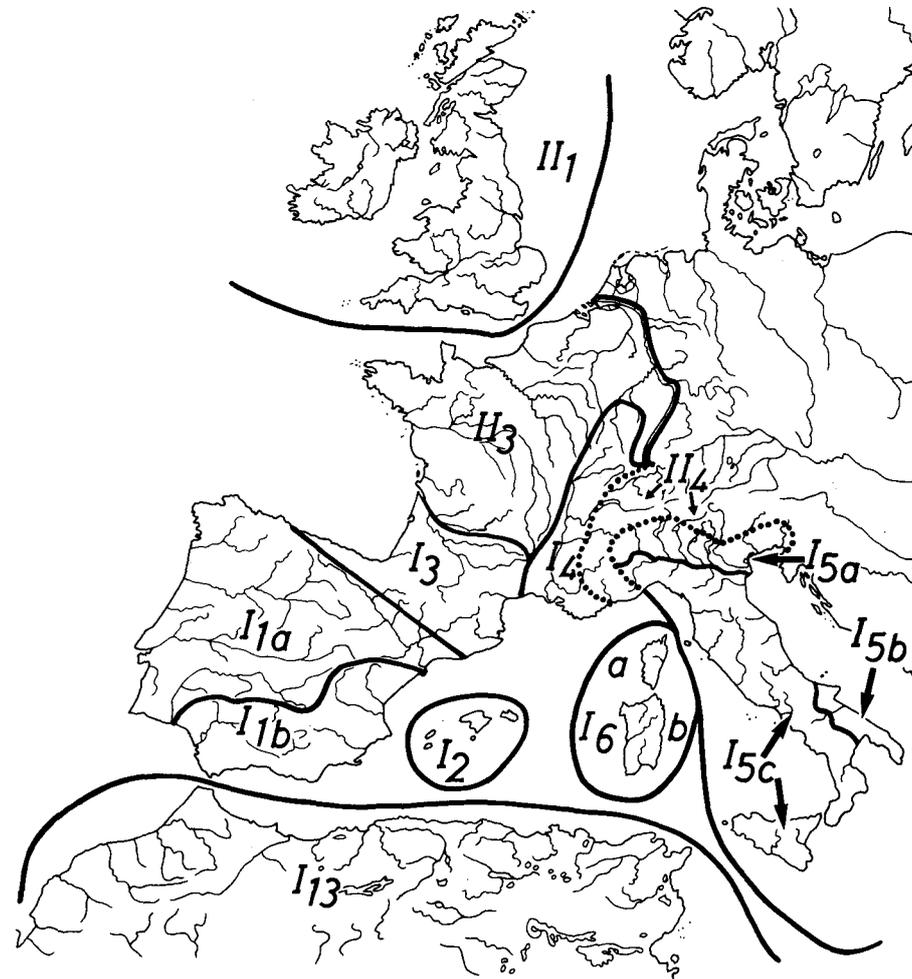
1. Mexico, without Yucatán.
2. Yucatán Peninsula.
3. Continental Central America, from the southern boundaries of Mexico to the boundary of Colombia.
4. Aruba, Curaçao, Bonaire, the Venezuelan Islands, Trinidad-Tobago.
5. The Windward and the Leeward Islands, from Grenada to Anguilla.
6. Virgin Islands.
7. Puerto Rico.
8. Hispaniola.
9. Jamaica.
10. Cuba.
11. Isla de Pinos + Cayman Islands.
12. Bahamas + Turks & Caicos.
13. Shores of the Mexico Bay (without those of Florida) and of the Caribbean Sea (including those of all the islands).
14. Pacific shores of Continental Central America (southward from mouth of Rio Colorado).

VIII. North America, north of Mexico (see map 3).

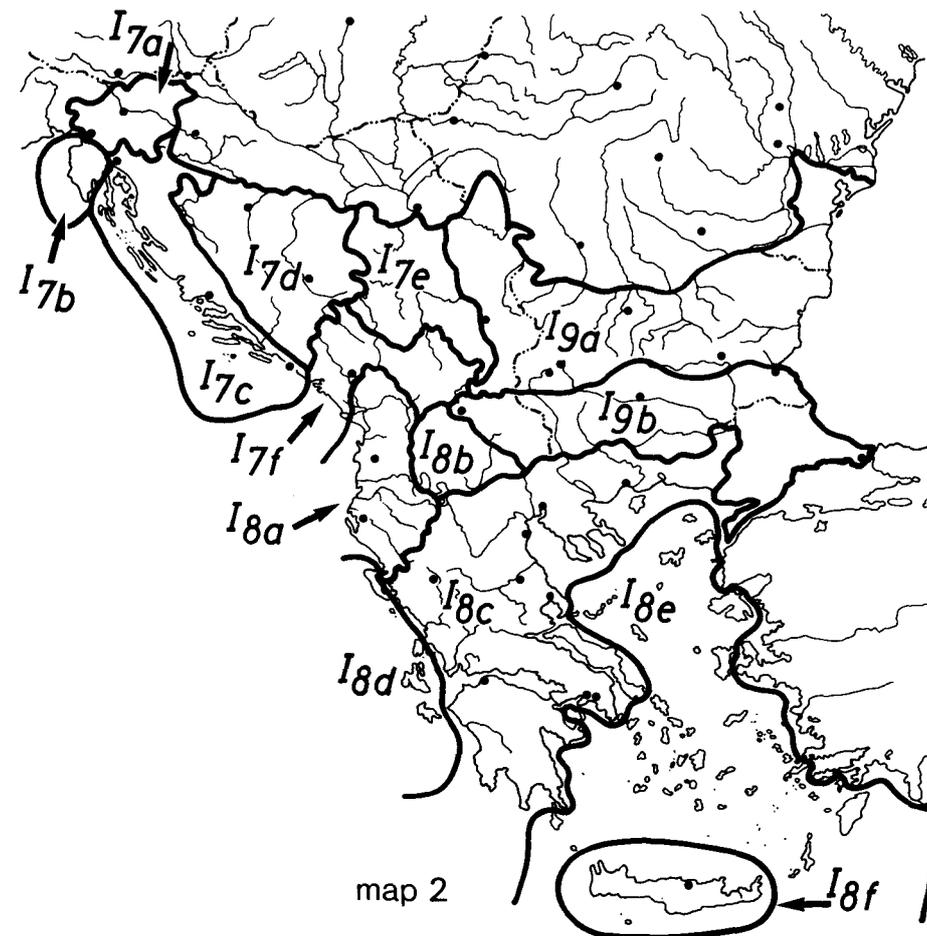
1. Appalachian Highlands.
2. Coastal Plain.
  - a. Floridian District.
3. Interior Low Plateaus.
4. Interior Highlands.
5. Central Lowland.
6. Superior Upland.
7. Great Plains.
  - a. Edwards Plateau.
8. Western Cordilleran.
  - a. Rocky Mountain System.
  - b. Intermontane Plateaus.
  - c. Pacific Mountain System.
9. Atlantic shores of North America (including those of Florida).
10. Bermuda (including the marine shores).
11. Pacific shores of North America (including those of California).
12. Arctic shores of North America (+ Greenland).

IX. Neotropical Zone (see map 4).

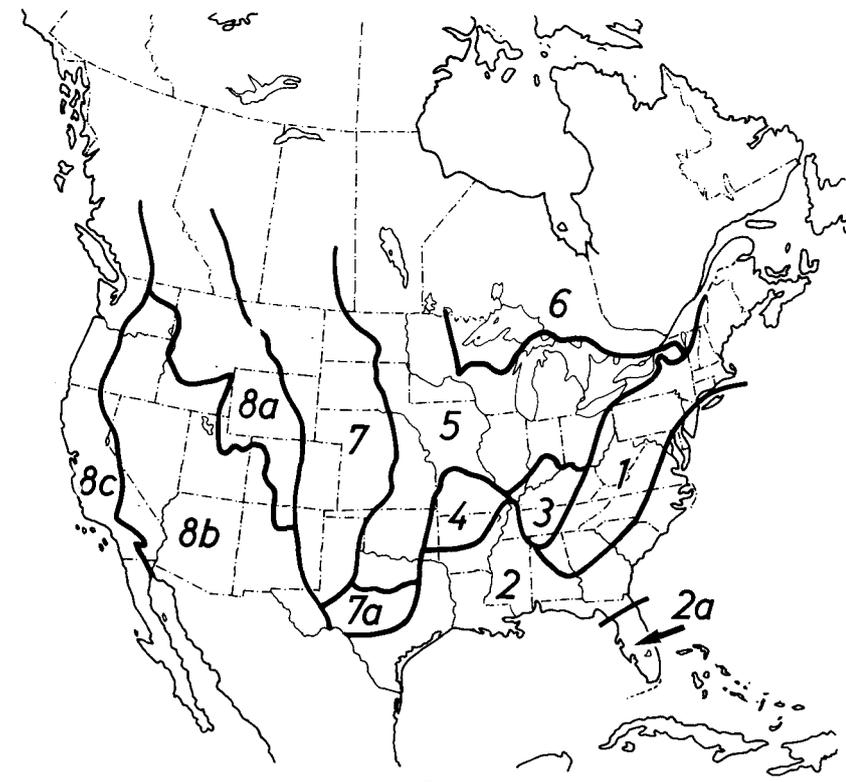
1. Archiplata Province (northern limit starting at the 30° parallel, then north of Salinas Grandes, slowing down westwards from Rio Salado del Norte, and then along the lower reach of Rio Paraná to its mouth).
2. Altiplano & Atacama Province (northward until the southernmost limit of the High-Colombian Mts.).
3. Central & Brazilian Province.
4. Northern Province (hydrographic systems of Rio Orinoco and of the Guyanese and Colombian rivers).
5. Galápagos (including their marine shores).
6. Atlantic shores of South America.
7. Pacific shores of South America.



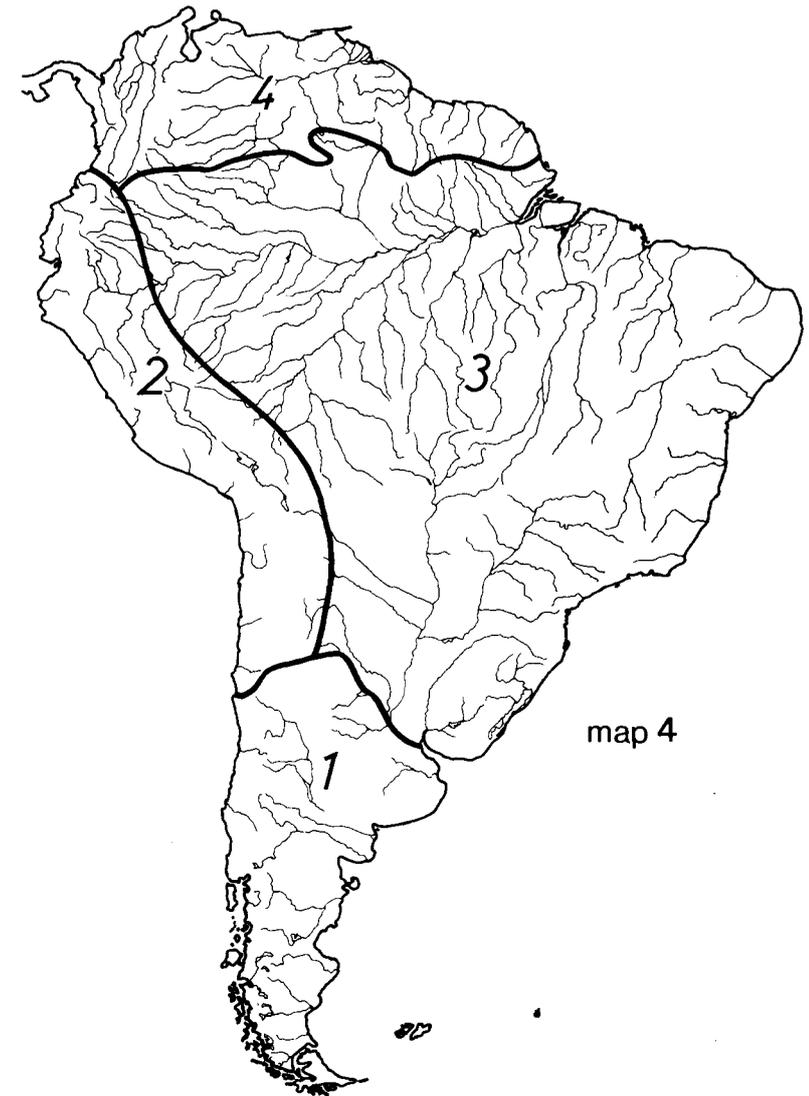
map 1



map 2



map 3



map 4

## Habitats (biotopes) of subterranean water (sensu lato = Stygal) and code letters and figures used to indicate them in column 4 of the Tables.

"Subterranean water" (no further specification possible), or "wells" (no further specification possible of the nature of the water reached):  $\alpha$

MILIEUX PERMÉABLES EN GRAND = EAU SOUTERRAINE DES CREUX, FENTES ET FISSURES. ESSENTIALLY: SUBTERRANEAN WATER IN KARST = KARSTOSTYGAL.

"Cave water" (no further specification possible): **A**.

Zone de percolation des grottes = vadose zone of caves (gours = rimstone pools, and any other hollows on cave floor, filled with percolating water): **B**. (gours, etc., with large amounts of bat guano on bottom: **B1**).

Zone de circulation = zone amphibie des grottes = epiphreatic zone in a cave system (permanent or temporary underground streams & rivers, as well as their remainders on cave floors, following drought periods): **C**. See also L3!

Zone noyée des grottes = phreatic or saturated zone in a cave system, cave "lakes", other component parts of a water table in a cave system: **D**.

Water of typical cenotes: **E**.

Cave water in direct contact with the sea (= marginal caves): **F**.

Anchihaline (or anchihaline) habitats (groundwater filling hollows & cracks in limestones, not very far from the sea-shore, water level influenced by tides and at least mesohaline: "casimbass", "grietas", "sinkhole ponds" etc.): **G**. See also E!

Water in subterranean hollows in rocks other than limestones (lava caves & tubes, mines etc.): **H**.

Other manners, not above mentioned, to reach the groundwater in karst (wells or artificial galleries hollowed in limestones, artesian water in karst...): **I**.

MILIEUX PERMÉABLES EN PETIT = GROUNDWATER IN POROUS HABITATS

True phreatic, alluvial, non-artesian water, usually reached — by different methods — through wells of different kinds, hollowed at some distance from water courses (thus not in their "lit majeur" or "lit mineur") = Eustygal = water saturating porous sediments below the water table, outside the karst: **K**.

Artesian and/or very deep-lying groundwater: **K1**.

Interstitial water in loose sediments accompanying running water courses in their "lit mineur" and "lit majeur", irrespective of the manner in which the interstitial water is reached (= Rhythrostygal + Potamostygal = hyporheic water = sous-écoulements = underflow): **L**.

Rhythrostygal: **L1**.

Potamostygal: **L2**.

Interstitial accompanying running water in a cave system (= Troglorhythrostygal): **L3**.

Interstitial water in loose sediments on border of freshwater stagnant water (= Limnostygal = "Hygropsammon + Eupsammon"): **M**.

The hypotelminorheic habitat (= Pedostygal = perched water tables = nappes éluviales ou colluviales de déversement = nappes pédologiques; including also the "nappes épikarstiques"): **N**.

Interstitial of artificial filters of sand or gravel: **O**.

Interstitial water of marine beaches, irrespective of the peculiarities of these beaches, and irrespective of the character of the sediment (only in sediments periodically or never immersed).

Species about which evidence is available that they inhabit exclusively or almost exclusively the nonsaturated zone (zone of vadose water = zone of aeration = Feuchtsandzone) in marine beaches: **P1**.

Species about which evidence is available that they inhabit exclusively or almost exclusively the zone of saturation (brackiges & marines Küstengrundwasser) in marine beaches: **P2**. Species either living as well in P1 and in P2, or about which no further specification is presently possible: **P**.

Interstitial of the marine sublittoral (only animals interstitially living in the permanently immersed sediments and showing some adaptations to the interstitial mode of life): **Q**.

Interstitial in loose sediments on borders or banks of brackish (**R1**) or hypersaline (**R2**) waters.

Springs (of course, all elements evidently or seemingly not belonging to the Stygofauna, are rigorously excluded).

Springs in general, no further specification possible: **S**.

Karst springs: **T**.

Springs fed by true phreatic water: **U**.

Springs fed by "nappes éluviales de déversement (see N!): **V**.

Thermal springs: **Z**.

All situations not clearly corresponding to one of the above mentioned, are marked with  $\beta$  (taxa showing adaptations generally considered as characterizing stygobiont animals, but inhabiting epigeal water courses, or the profundal zone of lakes — the marine abyssal fauna being completely excluded; stygobionts found in the drinkwater supply of towns; commensals of stygobionts; inhabitants of the pholeteros; etc. etc.). These situations are generally explained through notes for the respective taxa, at the end of the respective chapter.