Chapter 7: Class Malacostraca (SubClass Eumalacostraca)

Piscart C., Camacho A., Christodoulou M, Wittmann K.J., Messana B., Coisneau N.

Section 1. Introduction to Malacostraca

Christophe Piscart
French National Centre for Scientific Research (CNRS), University of Rennes 1, France

Section 2. Amphipoda

Christophe Piscart
French National Centre for Scientific Research (CNRS), University of Rennes 1, France

Section 3. Bathynellacea

Ana I. Camacho
Museo Nacional de Ciencias Naturales (CSIC), Dpto. Biodiversidad y Biología Evolutiva, C/ José Gutiérrez Abascal 2, 28006- Madrid, Spain
Phone: +34 914111328 ext. 1215

Nicole Coineau
67 Avenue du Puig del Mas, 66650 Banyuls-sur-Mer, France

Section 4. Decapoda

Magdalini Christodoulou

German Centre for Marine Biodiversity Research (DZMB), Senckenberg am Meer, Südstrand 44, 26382 Wilhelmshaven, Germany

Section 5. Ingolfiellida

Christophe Piscart

French National Centre for Scientific Research (CNRS), University of Rennes 1, France

Section 6. Isopoda

Giuseppe Messana
Istituto di Ricerca sugli Ecosistemi Terrestri (CNR-IRET), Sesto Fiorentino, Firenze, Italy.

Christophe Piscart
French National Centre for Scientific Research (CNRS), University of Rennes 1, France

Section 7. Mysida and Stygiomysida

Karl J. Wittmann
Department of Environmental Health, Medical University of Vienna, Austria

Section 8. Thermosbaenacea

Christophe Piscart
French National Centre for Scientific Research (CNRS), University of Rennes 1, France

Abstract

This chapter present an updated taxonomic review of Freshwater Malacostraca. It is organized into an introduction to Malacostraca followed by 7 other sections corresponding to the main orders of freshwater Eumalacostraca (Amphipoda, Bathynellacea, Decapoda, Ingolfiellida, Mysida and Stygomysida, Isopoda, and Thermosbaenacea) present in Mediterranean Basin. Each section contains the ecology and distribution of orders, the necessary material preparation methods, the relevant morphological terms, and current limitations in our knowledge of the group. Dichotomous identification keys to family, genus and even species are provided for most of groups (only genera with more than 15 species were not include in keys to species).

Keywords: Crustacea, Mediterranean Basin, taxonomy, biogeography

1. Introduction to Malacostraca

Christophe Piscart
French National Centre for Scientific Research (CNRS), University of Rennes 1, France
christophe.piscart@univ-rennes1.fr

INTRODUCTION

Malacostraca are the most diversified class of Crustacea and represent more than half of total crustacean diversity. They are characterized by the development of ambulatory legs and specializations for benthic life, the absence of free-living larval development (brooding eggs), and the colonization of every kind of fresh and salted aquatic environments. Their body size range is very wide, from a few millimetres up to 3 m, even if the largest freshwater specimens (i.e. the Tasmanian giant freshwater crayfish) do not exceed 80 cm.

Malacostraca are composed of three subclasses (Eumalacostraca, Hoplocarida, Phyllocarida); two of them exclusively include marine species, and all the freshwater species of the class belong to the subclass Eumalacostraca. They constitute a very diversified group that includes around 75% of all freshwater crustacean species (Balian et al., 2008), and are represented by eight orders and at least 1,086 species in the Mediterranean basin (Table 1). The Mediterranean basin can be considered as a hotspot for Malacostraca: it harbors 18% of the world freshwater species, up to one third of the world known species of almost all orders, and up to more than 50% of Thermosbaenacea (Table 1). Only Decapoda are less diversified in this area, with only 2% of the world diversity of this order.

ECOLOGY AND DISTRIBUTION

Among freshwater Malacostraca of the Mediterranean basin, most species (≈73%) inhabit groundwaters, and the remaining species colonize running waters (≈18%), lakes or ponds (≈5%), and only 3.5% survive in brackish waters. The Mediterranean basin is therefore characterized by a very high proportion of groundwater species, which represent around 24% of freshwater crustaceans in the world (Gibert & Culver, 2009). The proportion of obligate groundwater species in the Mediterranean basin is likely related to two major historical events: i) a strong vicariance related to the paleological instability of the Mediterranean Sea and the sea level fluctuations (e.g. Messinian crisis) (Ayati et al., 2019), and ii) the relative long-term climatic stability observed throughout the Pleistocene period, when speciation events accumulated over time (Zagmajster et al., 2014).

Malacostraca are widely distributed throughout the Mediterranean basin (Fig. 7.1A), but 80% of species are endemic (i.e. restricted to one country or one archipelago) (Fig. 7.1B). There also exists a clear positive correlation ($R^2 = 0.91$) between the total number of species in each country and the number of endemic ones. Groundwater species are generally restricted to less than two countries, whereas epigean species can be widely distributed, especially species able to survive in brackish waters. However, it is difficult to draw robust conclusions on the species distribution because information is lacking in many countries such as the Middle-East countries and about some groups (e.g. groundwater species). For example, countries in the north of the Mediterranean basin harbor a higher diversity than southern countries do, but this difference might be related to poor knowledge about the southern part of the basin (Kayo et al., 2012; Zagmajster et al., 2018).

General diversity patterns can be drawn despite this limitation. If we analyze diversity in the north and in the south separately, total diversity tends to decrease from west to east (Fig. 7.1A). In the Mediterranean islands, the Balearic Islands and Sardinia are the richest as regards total species richness as well as the proportion of endemic species (48% and 37.5%, respectively).

The analysis of presence/absence data for all Malacostraca clearly highlights four main groups of faunal assemblages (Fig. 7.2). One group includes countries from the northern part of the Mediterranean basin, and is divided into 4 sub-groups: Iberian countries (sub-group N1); France, Italy and Slovenia (sub-group N2); Balkanian countries from Croatia to Greece (sub-group N3); and Turkey (sub-group N4). The second group includes eastern countries and Egypt (group S1), the third one includes Maghreb (group S2), and finally the fourth one includes the Mediterranean islands and Lybia (group S3).

KEY TO ORDER OF EUMALACOSTRACA

(Cumcea and Tanaidacea not include in the key)

1 Carapace reduced or absent ……...…… 2

1’ Carapace well developed (Fig. 7.3B,F) ….……..…… 5

2(1) Thoracopods uniramous, body vermiform or not …..……... 3

2’ Thorocapods biramous, body vermiform, less than 2 mm (Fig. 7.3E) ….....……..…. Bathynellacea

3(2) Body laterally compressed (Fig. 7.3A), telson and abdominal segments free ……...…. 4

3’ Body dorsoventrally compressed (Fig. 7.3C), telson and abdominal segments fused into a pleotelson …...……...……..……..…..….. Isopoda

4(3) Cephalothorax composed of head and first segment of the mesosome fused together (Fig. 7.10); presence or not of vestigial pedunculate eyes; eyes lacking; pleosome without epimera and with reduced pleopod/uropod appendages ……..……..……Ingolfiellida

4’ Head not fused with the first segment of the mesosome (Fig. 7.4); vestigial pedunculate not present; eyes present or lacking; pleosome with three epimera and normally developed appendages …...…….…...… Amphipoda

5(1’) Compounds eyes generally present, but absent in some groundwater genera, when present they are pedonculate; pleopods always developed ……..……...……...….6

5’ Eyes absent, Pleopods reduced and only on the two first abdominal segments, absent from remaining segments, eight pairs of thoracopods, first modified as a maxilliped ……Thermosbaenacea

6(5) Seven pairs of thoracopods (Fig. 7.3D) ..……....……...7

6’ Five pairs of walking legs, including chelae ……..……..…….……..… Decapoda

7(6) Eyes normally developed, endopod of uropods with very large statocyst; sympod without ventral lobe; cornea mostly well-developed, rarely reduced ……..……..……Mysida

7’ Eyes reduced to flat ocular plate, endopod of uropods without statocyst; sympod with spiny ventral lobe; cornea reduced …….Stygomysida

REFERENCES

Ayati, K., R. Hadjab, H. Khammar, S. Dhaouadi, C. Piscart & E. Mahmoudi. 2019. Origin, diversity and distribution of freshwater epigean amphipods in Maghreb. Annales de Limnologie - International Journal of Limnology 55: 13. https://doi.org/10.1051/limn/2019012

Balian, E.V., H. Segers, K. Martens & C. Lévêque. 2008. An introduction to the Freshwater Animal Diversity Assessment (FADA) project. Pages 3–8 *in*: E.V. Balian, C. Lévêque, H. Segers, & K. Martens (eds), Freshwater Animal Diversity Assessment. Springer Netherlands, Dordrecht, Nehterland. https://doi.org/10.1007/978-1-4020-8259-7_1

Clarke, K.R., P.J. Somerfield & R.N. Gorley. 2008. Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. Journal of Experimental Marine Biology and Ecology 366: 56–69.

Gibert, J. & D.C. Culver. 2009. Assessing and conserving groundwater biodiversity: an introduction. Freshwater Biology 54: 639–648.

Horton, T., A. Kroh, S. Ahyong, N. …. & Z. Zhao. 2020. World Register of Marine Species (WoRMS). WoRMS Editorial Board, http://www.marinespecies.org. [Accessed 2020 December 31]

Tuekam Kayo, R.P., P. Marmonier, S.H.Z. Togouet, M. Nola & C. Piscart. 2012. An Annotated Checklist of Freshwater Stygobiotic Crustaceans of Africa and Madagascar. Crustaceana 85: 1613–1631.

Zagmajster, M., D. Eme, C. Fišer, D. Galassi, P. Marmonier, F. Stoch, J.-F. Cornu & F. Malard. 2014. Geographic variation in range size and beta diversity of groundwater crustaceans: insights from habitats with low thermal seasonality. Global Ecology and Biogeography 23: 1135–1145.

Zagmajster, M., F. Malard, D. Eme, & D. C. Culver, 2018. Subterranean Biodiversity Patterns from Global to Regional Scales. Pages 195–227 in: O.T. Moldovan, L. Kovac & S. Halse (eds), Cave Ecology. Springer, Cham.

2. Malacostraca: Amphipoda

Christophe Piscart
French National Centre for Scientific Research (CNRS), University of Rennes 1, France
christophe.piscart@univ-rennes1.fr

INTRODUCTION

Amphipoda Latreille 1816 are present in all types of continental waters (springs, rivers, lakes) and in groundwaters (subterranean interstitial and cave systems) on all continents. Apart from a few exceptions, they are easily recognizable in the field from their shrimp-like habitus. Biogeographic analysis indicates that amphipods were likely widespread in Pangea, Gondwana, and Laurentia (Väinölä et al., 2008). These studies were confirmed by the discovery of the oldest fossil *Rosagammarus minichiellus* in late Triassic limestone in Nevada (McMenamin et al., 2013). Marine ancestors subsequently colonized very early freshwaters during the Jurassic period before a probable massive diversification during the Cretaceous (Copilaș-Ciocianu et al., 2019) and Paleogene (Hou et al., 2014) periods.

The ancestors of Mediterranean amphipods may have an Atlantic origin around 40 Mya (Hou & Sket, 2016). They conquered its freshwater confluents, like *Iberogammarus* and *Echinogammarus sensu stricto* did. Finally, some crossed the proto-Mediterranean sea to the lands located at its eastern edges, (the *Typhlogammarus* group and part of the *Sarothrogammarus* group), or also spread along the future Mediterranean coasts (*Rhipidogammarus*). Other groundwater groups (e.g. hadzioid-thalassoid Metacrangonyctidae amphipods) result from ancient continental-level vicariance (Bauzà-Ribot et al., 2012), or from more recent vicariance and long-distance dispersal (Pseudoniphargidae; (Stokkan et al., 2018).

Among the 1,870 amphipod species and subspecies recorded from fresh or inland waters worldwide (Horton et al., 2020), more than 31% are present in the Mediterranean basin, where a total of 14 families, 50 genera and 581 species are recorded; most of them are endemic to the region.

GENERAL ECOLOGY AND DISTRIBUTION

Amphipoda are widely distributed and colonize all types of marine and continental waters on all continents. They represent one of the highest invertebrate biomass values and are prey for many other organisms. They also support many functional processes in these ecosystems like organic matter recycling and bioturbation.

In the Mediterranean basin, Amphipods are present in all countries and big islands. We recorded 559 species (96%) restricted to only one type of environment (running water, lake, groundwater, brackish water) and only 22 euryecous species (i.e. present in a least two types of aquatic ecosystems). Euryecous species are present mainly in running waters, lakes and brackish water, and only a few species (e.g. *Niphargus zagrebensis*) can live permanently either in groundwater or in surface waters.

The highest diversity is found in groundwaters, which represent 74% of the total amphipod richness with 429 species, followed by running waters (127 species) and lakes (31 species). Only 17 species live solely in lakes and originally came from Ohrid Lake (8 species) or from Turkey (9 species); the other lacustrine species are euryecous species that also live in running waters (14 species) or in brackish environments (4 species).

Among the 14 families recorded so far, most of them are widespread worldwide, with members living in both fresh and marine waters. Others (Crangonyctidae, Niphargidae, Pontogammaridae, and Typhlogammaridae) have a Eurasian distribution and are only present in the central and eastern parts of the Mediterranean basin, except *Crangonyx africanus* in Morocco. Metacrangonyctidae and Pseudoniphargidae are mainly distributed in the Mediterranean area but also have a few members in the Canary and Caribbean islands. Finally, only two families are endemic to the Mediterranean basin: Salentinellidae with 14 species widely distributed around the Mediterranean Sea between Greece and Algeria, and Sensonatoridae with only one known species in Spain (*Sensonator valentienensis* Notenboom, 1986).

TERMINOLOGY AND MORPHOLOGY

Amphipoda are medium/large-size Malacostraca (from 0.1 up to 35 mm in the Mediterranean basin). Their body is typically compressed laterally, though less so for Corophiidae. It is divided into 13 segments that can be grouped into the head, the mesosome, the metasome, and the urosome (Fig. 7.4).

The head is fused to the thorax and bears two pairs of antennae. The upper pair is antennae 1, with a basal peduncle composed of three articles and a distal flagellum composed of many articles. The third peduncular article also bears an accessory flagellum on its distal end, usually composed of a reduced number (less than 10) of tiny cylindrical articles. The second pair of antennae (antennae 2) has a flagellum composed of several small articles and a peduncle composed of five articles; articles 4 and 5 are much longer than the first 3 articles (the first one is hidden by the head). Most epigean species (with few exceptions like epigean *Niphargus zagrebensis* S. Karaman, 1950) have one pair of more or less developed sessile compound eyes. Eyes are absent in obligate groundwater species. However, we often found eyed species in groundwaters, especially in the Mediterranean basin, where epigean species can be present in a large proportion of groundwaters round the year. The mouthpart is on the ventral surface of the head and is composed of the labrum, labium, mandibles, maxillae I and II, and maxilliped.

The mesosome (or thorax or pereon) bears different kinds of legs, but no carapace. It has eight pairs of uniramous appendages, the first of which are used as accessory mouthparts. Two pairs of gnathopods (modified pereopods 1 and 2) are used for grasping, usually with a last subchelate article; the next five pairs (pereopods 3-7) are walking legs. Gnathopods and pereopods 3 and 4 have modified coxae transformed into large coxal plates. Coxal gills are present on mesosome segments in various numbers according to species, and sternal gills are known only in Crangonyctidae.

The metasome (or abdomen or pleion) is divided into two parts – the pleosome and urosome segments. Each segment bears one pair of legs. The pleosome bears three pairs of swimming legs named pleopods, with multi-articulated rami. The urosome bears three pairs of uropods. The length and the shape of uropod 3 can be highly variable among genera. The basal part of the uropod is the peduncle, that branches into an exopodite (with one or two articles, the second one can be short and hidden by the apical spines of article 1) and a medial branch named the endopodite (only one article or no article at all).

The telson – the final body segment – is attached above uropod 3.

COLLECTION, PREPARATION, AND IDENTIFICATION

Amphipoda are widely distributed in all aquatic environments, including groundwaters. Therefore, the sampling methods and devices are numerous and depend on the specific habitats where the fauna is found.

In surface waters, we can sample them using all kinds of sampling tools and methods (sweep net, kick sampling, grab sampler, dredges, and even artificial substrates) or just by taking stones, leaf litter or macrophyte by hand or with a kitchen colander. There are rarely more than 3 species in any given site. However, it is strongly recommended to sample the different substrates because many species have different microdistribution patterns when they co-occur (Piscart et al., 2007).

In groundwaters, any kind of specific material for this environment can be used (Malard et al., 2002). Baited bottle traps or nets exposed overnight are also very efficient for many groundwater organisms.

Amphipoda can be easily fixed and preserved in 70% ethanol or another fixative for morphological analysis and in 95% ethanol for molecular analysis.

Many species can be identified under a stereomicroscope, but identification at the species level may require dissection, mounting body parts and appendages on slides, and subsequent examination using a 400x or greater magnification microscope. Specimens in glycerol or ethanol can be handled under a low-power microscope with needles. Glycerol is used as an embedding medium for short-term slides. Baths in clearing solution (e.g. soft acids) or permanent mounting media are only required for depositing museum specimens. A same specimen can be used for both studies: the abdomen for DNA extraction and the other parts for dissection and mounting. This procedure ensures that the sequenced genes correspond to the same morphotype.

Taxonomic identification to the species level is generally only possible in males, but females can be used for higher taxonomic levels. The most important body parts for identification are the antennae, mouthpart, coxae, gnathopods, pereopods 5 and 7, epimera, telson, and uropods; but additional body parts need to be examined to identify certain species.

LIMITATIONS

Amphipoda are a highly diversified group with almost 600 known species, and even more remain undescribed. The keys below are designed to cover the 14 families and 49 genera; keys at the species level are provided only for the genera with a low number of species (usually less than 15). Rare records are included, unless they are insufficiently documented. Taxonomic synonymy has been updated, but taxonomy is not well established for some genera (e.g. *Echinogammarus*, *Laurogammarus*, and *Typhlogammarus*,) and even families (e.g. Pontogammaridae), especially following recent molecular studies. For those genera and till a clear consensus is found, we assume the use of the most parsimonious point of view, even if alternate classifications may be found in other keys. As a consequence, some family, genus and species names may change in the future.

Finally, even if our keys were designed to be as clear as possible, we should never forget that identifying certain groups of amphipods (especially groundwater species) can be very difficult and requires strong expertise. Do not hesitate to use alternative information or keys to consolidate your conclusions. We should keep in mind that keys, even at the family level, are designed for species of the Mediterranean basin; they are not adapted to other amphipods worldwide.

KEYS TO AMPHIPODA

Key to Amphipoda families

1 Antenna 1 significantly shorter than antenna 2 ……..……...…….. 2

1’ Antenna 1 subequal or longer than antenna 2 ...……. 4

2(1) Antenna 1 accessory flagellum absent; eyes well developed …….…… 3
2’ Antenna 1 accessory flagellum small, eyes absent ……..……. Sensonatoridae (one genus: *Sensonator*)
[Spain]

3(2) Antenna 2 enlarged; mandibular palp present; urosomite dorsally flat …… Corophiidae
[North-Eastern Mediterranean, Central Europe]

3’ Urosomite enlarged, antenna 2 not enlarged, mandibular palp absent……Talitridae
[Peri-Mediterranean]

4(1) Sternal gills absent ……..…… 5

4’ Sternal gills present ……..……..……. Crangonyctidae
[Europe, Morocco]

5(4) Mandibular palp normally developed; eyes present or absent ……..…….…… 6

5’ Mandibular palp vestigial; eyes absent .....…….……..Metacrangonyctidae
[Peri-Mediterranean]

6(5) Coxae 1-3 subequal or size progressively increasing, coxae 4-5 of various size; uropod 1-2 peduncles with lateral spines; eyes present or absent ……..……...……7

6’ Coxae 1-3 small, size progressively decreasing, and coxa 4-5 larger; uropod 1-2 peduncles without lateral spines; eyes absent .....……..…. Salentinellidae
[Peri-Mediterranean]

7(6) Antenna 1 longer than antenna 2; maxilla 1 inner plate with at least one apical setae and/or marginal setae, telson notched, emarginate or entire…….....…….……..… 8

7’ Antenna 1 and 2 equal or subequal in length; maxilla 1 inner plate reduced with only 0 or 1 apical setae; telson entire……..……Ischyroceridae (one genus *Jassa*)
[Sicily]

8(7) Telson lobes almost completely separated, rami of uropod 3 lanceolate .....…….... 9

8’ Telson lobes partially fused, even sometime very slightly; uropod 3 rami straight more or less long ……...……..…….. 10

9(8) Coxae 1-3 longer than wide or sub-rectangular; gnathopod 2 propodus elongated slightly stronger than gnathopod 1; labium inner lobe vestigial or absent; uropod 3 rami sub-equal ……..……..……..…….. Hadziidae [Western Europe]

9’ Coxae 1-3 small wider than long; gnathopod 2 propodus much stronger than gnathopod 1; labium inner lobe normally developed, except in the genus *Gammaropisa*; uropod 3 rami unequal, exopodite much longer than endopodite …….…….……Eriopisidae [Turkey, Tunisia]

10(8’) Telson entire or slightly emarginate (notch < 30% of the lobe), eyes absent ……..…. 11

10’ Telson deeply notched almost entirely, eyes present or absent …….……....… 12

11(10) Pleopods uniramous or inner ramus reduced or vestigial; uropod 3 rami subequal in length ..……..……. Bogidiellidae [cosmopolitan]

11’ Pleopods biramous, inner ramus well developed; uropod 3 exopodite much longer than endopodite ……..….. Pseudoniphargidae [Western Europe and North Africa]

12(10’) Inner lobe of maxilla 2 with oblique row of facial setae; eyes generally present of various sizes …...…..……..……..… 13

12’ Inner lobe of maxilla 2 without oblique row of facial setae ; Labium without a more or less developed inner lobes, eye absent ……...…….…….…….…. Niphargidae [Southern and Eastern Europe, Minor Asia]

13(12) Maxilla 1 outer plate with apical spines comb-like with few lateral teeth (except *Longigammarus*); pereopod 7 longer than 5; uropod 3 endopodite shorter than exopodite; eyes present or absent ……...…….……. 14

13’ Maxilla 1 outer plate with apical spines comb-like with numerous lateral teeth (>10); pereopod 7 subequal in length than 5; uropod 3 sub-equally biramous; eyes absent …….....Typhlogammaridae [Balkan and Eastern Europe]

14(13) Antenna 2 peduncle article 1 enlarged, bulbous; antenna 1 longer or sub-equal in length than antenna 2, antenna 1 slender, generally longer than a half of the body length, the diameter of the articles of the peduncle is not much different; uropod 1 with or without basofacial robust setae; urosomite 2 with multiple small robust setae across the somite .....……..……..…….. Gammaridae [Cosmopolitan]

14’ Antenna 2 peduncle article 1 subequal than article 3; antennae 1-2 sub-equal in length and short (≤ an half of the body length), antenna 1 stout, shorter than a half of the body length, the diameter of the articles of the peduncle strongly decrease in length and in width from

article 1 to article 3; uropod 1 without basofacial robust setae; urosomite 2 without dorsal setae ……..……..……..…….…… Pontogammaridae [Western Europe (invasive), Eastern Europe and Minor Asia]

Key to Bogidiellidae genera

1 Molar non-triturative; maxilla 1 palp with 2 articles ……..……..……...…. 2

1’ Molar triturative; maxilla 1 palp with 1 or 2 articles ……..……...…… 3

2(1) Epistomal ridge with a sclerified subcircular area; pleopod rami very long with 9 articles ….……..…… *Maghrebidiella* (one species: *M. maroccana* Diviacco & Ruffo, 1985) [Morocco]

2’ Epistomal ridge without slcerified area; pleopod rami with 3 articles ……..……..... *Hebraegidiella* (one species: *H. bromleyana* G. Karaman, 1988) [Israel]

3(1) Pleopods 2, ramus article 2 of males with a modified seta ……..…. *Stygogidiella* (one species: S. cypria G. Karaman, 1989) [Cyprus]

3’ Pleopods 2, ramus article 2 of males without modified seta …….……..... 4

4(3) Uropods not sexually dimorphous, uropods without transformed spines, pleopods endopodites small, vestigial or absent ……....……...…...…… 5

4’ Uropods sexually dimorphous, uropod 1 or 2 rami with transformed (rasp-like, spoon-like) spines; pleopods endopodites absent ……..…..…… *Medigidiella* [Western Mediterranea]

5(4) Maxilla 1 outer lobe with 6 distal spines, telson deeply cleft ……..…… *Racovelia* (one species: *R. birramea* Jaume, Gràcia & Boxshall, 2007) [Balearic Islands]

5’. Maxilla 1 outer lobe with 7 distal spines, telson entire or weakly cleft (<30%) … *Bogidiella* [cosmopolitan]

Key to species of *Medigidiella*

1 Lenticular organ ≤ a half of the basis width or absent (not visible) ……..…. 2

1’ Lenticular organ very large, almost as large as the basis of pereopods 3-6, absent on pereopod 7 ……..…. *M. paolii* Hovenkamp, 1983

2(1) Lenticular organ absent (not visible) ….……..…… 3

2’ Lenticular organ visible on pereopod 3-7……..……..…….……...… 7

3(2) Pleopod inner rami absent; telson with apical spines only; basis of gnathopods 1 and 2 with only one posterior setae ……..…...…….…… 4

3’ Pleopod inner rami reduced but present; telson with apical and subapical spines; basis of gnathopods 1 and 2 with 2 posterior setae ……..…… *M. hebraea* (Ruffo, 1963)

4(3) Antenna 2 without groups of setae on peduncle articles; maxilliped outer lobe with 2 spines; gnathopod 1 propodus without short spines; uropod 1 peduncle with one spine 5

4’ Antenna 2 with groups of setae on peduncle articles; maxilliped outer lobe with 3 spines; gnathopod 1 propodus with 2 or 3 short spines; uropod 1 peduncle without spine ……..…… *M. paraichnusae* (Karaman, 1979)

5(4) Gnathopod 2 propodus with 2 short spines; pereopod 7 propodus with 4-6 anterolateral setae; uropod 3 rami with 7-11 lateral spines …….……...… 6

5’ Gnathopod 2 propodus with 3 short spines; pereopod 7 propodus with 7-9 anterolateral setae; uropod 3 rami with 3-6 lateral spines ……..… *M. dalmatina* (S. Karaman, 1953)

6(5) Gnathopods 1-2 propodi short; uropods 1-2 rami with short distal spines ……..…… *M. chappuisi chappuisi* (Ruffo, 1952)

6’ Gnathopods 1-2 propodi longer; uropods 1-2 rami with relatively long distal spines ……..…… *M. chappuisi pescei* (G. Karaman 1989)

7(2’) Antenna 1 accessory flagellum ≤ two articles of the flagellum, peduncle articles with two spines; maxilliped outer lobe with bifid spines; gnathopod 1 propodus with 4-5 short spines ……...…… 8

7’ Antenna 1 accessory flagellum longer than the three articles of the flagellum, peduncle articles without spine; maxilliped outer lobe with simple spines; gnathopod 1 propodus with 7 short spines …… *M. antennata* Stock & Notenboom, 1988

8(7) Antenna 2 with aesthestascs; maxilla 2 without plumose setae; gnathopod 1 basis with only one long posterior seta; gnathopod 2 propodus with 4 short spines; telson with 4 plumose setae ...……...… 9

8’ Antenna 2 without aesthestascs; maxilla 2 without plumose setae; gnathopod 1 basis with 2 long posterior setae; gnathopod 2 propodus with 3 short spines; telson with at least 6 plumose setae ……..…..…… *M. aquatica* Karaman, 1990

9(8) Lenticular organ small, about 1/3 of the basis width; labium outer lobe with spines; pereopod 7 propodus with less than 9 anterolateral setae, dactylus equal or longer than a half of the propodus; uropod 2 rami with modified distal spines in males ……
……..…… *M. minautorus* Ruffo & Schiecke, 1976

9’ Lenticular organ large, about 1/2 of the basis width; labium outer lobe with spines; pereopod 7 propodus with at least 9 anterolateral setae, dactylus shorter than a half of the propodus uropod 2 rami with unmodified distal spines in males ……..…… ……..……..…… *M. uncanata* Stock & Notenboom, 1988

Key to Corophiidae genera and species

1 Antenna 2 article 2 with gland very small ……...…….. 2 (genus: *Chelicorophium*) [invasive in Western Europe]

1’ Antenna 2 article 2 with gland cone large, conspicuous ……..…… ……...……...……...…… *Corophium* (one species: *C. oriental* Schellenberg 1928)
[Southern Europe]

2(1) Antenna 2 peduncle article 5 with 1 distal teeth or without teeth …….……..… 3

2’ Antenna 2 peduncle article 5 with 2 distal teeth on the lower margin …… ...……...… *Ch. maeticum* (Sowinsky, 1898)

3(2) Antenna 2 peduncle article 5 with 1 distal teeth (short or long) ……..…….……. 4

3’ Antenna 2 peduncle article 5 without distal teeth on the lower margin ….…… …….……...…….. *Ch. sowinskyi* (Martynov, 1924)

4(3) Antenna 2 peduncle article 5 with 1 long distal teeth; uropod 2 outer rami with 6 marginal spines ……..……..… *Ch. robustum* (G.O. Sars, 1895)

4’ Antenna 2 peduncle article 5 with 1 short distal teeth; uropod 2 outer rami with 3 marginal spines ……..……. *Ch. curvispinum* (Martynov, 1924)

Key to Crangonyctidae genera and species

1 Urosomites coalesced; uropod 3 inner ramus absent …..... 2

1’ Urosomites free; uropod 3 inner ramus small or scale-like …….…… 6 (genus: *Crangonyx*) [Morocco, Invasive in Western Europe]

2(1) Body pigmented; pleopods with 2 coupling spines (retinacules); uropod 3 endopodite without terminal “squamous knob” ……..…….. 3 (genus: *Synurella*)
[Balkan, Central Europe]

2’ Body not pigmented; pleopods with 5-6 coupling spines (retinacules); uropod 3 endopodite with a terminal “squamous knob” …… *Pontonyx* (one species: *P. osellai* (Ruffo, 1974))
[Turkey]

3(2) Epimera 2 with spines at distal margin but never setae …… 3 (*Synurella ambulans*)

3’ Epimera 2 with numerous setae at distal margin ……*S. longidactylus* S. Karaman, 1929

4(3) Females’s oostegite broader; Eyes present or absent; pereopod dactyls in males longer and slenderer than in females …..……. 4

3’ Female’s oostegite narrow; Eyes absent; pereopod dactyls subequal in shape between males and females ……..…. *S. ambulans montenegrina* (G. Karaman 1974)

5(4) Eyes present; gnathopod 2 propodus in females is short and broad than in males …… ……..…… *S. ambulans ambulans* (F. Müller, 1846)

5’ Eyes absent; gnathopod 2 propodus in males is strongly dilated ……..…… ……... *S. ambulans subterranean* (S. Karaman, 1931)

6(1’) Eyes present, epigean species; gnathopod 2 palm with notched spines; pereopod 6 propodus much shorter than basis ……..…..…… *C. pseudogracilis* Bousfield, 1958

6’ Eyes absent, hypogean species; gnathopod 2 palm with simple spines; pereopod 6 propodus longer than basis and carpus ……..…….. *C. africanus* Messouli, 2006

Key to Eriopisidae genera and species

1 Labium inner lobe absent; gnathopod 1 carpus slightly shorter than propodus; pleopod 3 greatly modified in males ……..... *Gammaropisa*
(one species: *G. argonoi* Ruffo & Vigna-Taglianti, 1988)*
[Turkey]

1’ Labium inner lobe present; gnathopod 1 carpus longer than propodus; pleopod 3 not modified ……..……...…..…..…… *Tunisopisa*
(one species: *T. seurati* (Gauthier, 1936))
[Tunisia]

* the position of *Gammaropisa* in Eriopisidae remains doubtful because it did not match to the revision of Lowry and Myers 2013, who defined Eriopisidae with an internal lobe in the labium but this lobe is not drawn by Ruffo 1987.

Key to Gammaridae genera

1 Antenna 2 gland cone small, conical and straight ……...…… 2

1’ Antenna 2 gland cone extremely elongated and recurved going back toward coxae 1 ……...……...……..… *Laurogammarus*
(one species: *L. scutarensis* (Schaferna, 1922))
[Skadar Lake drainage]

2(1) Pleonites and pereonites without mediodorsal keels; pereopod 7 basal article with or without large posteriodistal lobe, urosome generally not carinate (except in some *Gammarus* and *Echinogammarus*) ……..……..…..…… 3

2’ Pleonites and some pereonites with mediodorsal keels; pereopod 7 basal article with a large posteriodistal lobe, urosome carinate ……..… *Amathillina*
(one species: *A. cristata* Sars, 1894)
[Turkey]

3(2) Uropod 3 endopodite well developed, overreaching 25% of the exopodite …..…… 4

3’ Uropod 3 endopodite very reduced, scale like, <25% of the exopodite …….…….. 6

4 Maxilla 1 outer lobe with 17 curved spines; coxal gill 7 absent; eyes absent ……
…….....……. *Albanogammarus*
(one species: *A. inguscioi Ruffo, 1995*)
[Balkans]

4’ Maxilla 1 outer lobe with straight simple or pectinate spines; coxal gill 7 present; eyes present or absent ……..……..……. 5

5 Gnathopod 1 propodus in males larger than gnathopod 2; Gnathopod 2 carpus elongated …….
……..……..……...…… *Iberogammarus*
[Spain, France]

5’ Gnathopod 1 in male propodus smaller than gnathopod 2; uropod 3 endopodite ≥ 25% exopodite ……..……. *Gammarus*
[Cosmopolitan]

6 Uropod 1 reduced, not reaching apices of uropod 2, rami without lateral spines ……..…… 7

6’ Uropod 1 longer than uropod 2 ……...……..……. 8

7 Maxilla 1 outer lobe with many densely pectinate setae (like Typhlogammaridae), inner lobe wider than long ……..….. *Longigammarus*
[Peri-Mediterranean]

7’. Maxilla 1 outer lobe with less densely pectinate setae (like Gammaridae), inner lobe longer than wide, pereopod 7 base elongated more than twice as long as wide … *Rhipidogammarus*
[Peri-Mediterranean]

8(6’) Uropod 1 longer than uropod 2 and reaching its apex, uropod 1 rami with several distal spines ……..……..……..…… 9

8’ Uropod 1 longer than uropod 2 but not reaching its apex, uropod 1 rami with only one strong distal spine ……..……..……..… *Tyrrhenogammarus*
[Sardinia, Sicily]

9(8) Urosomites 1 et 2 without dorsal elevations ……..……..……..... 10

9’ Urosomites 1 et 2 with dorsal humps or cones with some apical spines …… *Dikerogammarus* [Turkey, invasive in Western Europe]

10(9) Pereopod 7 ventroposterior lobe absent or small; uropod 1 outer ramus subequal to the inner ramus ……..…….…..……..... 11

10’ Pereopod 7 ventroposterior lobe well developed, uropod 1 outer ramus reaching at least 60% of inner ramus ….……..……13

11(10) Setae on at least either on pereopods 5 to 7, urosomite and/or epimera ……...…… 12

11’ Setae almost completely lacking on pereopods 5 to 7, urosomites and epimeron ……..... ……...…….. *Chaetogammarus* (one species: *C. saisensis* Fadil et al, 2009) [Morocco]

12(11) Gnathopod 1 propodus in males much larger than gnathopod 2, eyes elongate 2x longer than wide ……...…….……..…….. *Echinogammarus sensu stricto* [Peri-Mediterranean]

12’ Gnathopod 1 propodus in males equal of slightly longer than gnathopod 2, eyes ovoid or 1.5x longer than wide ……... *Echinogammarus* / *Homoeogammarus* [Peri-Mediterranean]

13(10’) Pereopod 7 ventroposterior lobe broad and rounded; uropod 1 outer ramus reaching 60% of inner ramus; uropod 3 with very long setae and marginal spines; telson with marginal spines …….…... *Ilvanella* (one species: *I. inexpectata* Vigna-Taglianti, 1971) [Italia, Tuscan Archipelago]

13’ Pereopod 7 ventroposterior lobe rounded-triangular; uropod 1 outer and inner rami subequal in length; uropod 3 with very few setae; telson without marginal spines …… ……...…….……. *Jugogammarus* (one species: *J. kusceri* S. Karaman, 1931) [Slovenia]

Key to species of *Dikerogammarus*

1 Antenna 1 peduncle segments long and slender ……...……..…… 2

1’ Antenna 1 peduncle segments short and swollen ……..... *D. gruberi* (Mateus & Mateus, 1990)

2(1) Pereopod 7 basal segment with setae in the inner surface ……..… 3

2’ Pereopod 7 basal segment without setae in the inner surface ……..…….. 4

3(2) Antenna 1 peduncle segment 2 and antenna 2 segment 4-5 with few short setae (shorter than the diameter of the segment) on the inferior margin …… …… *D. istanbulensis* Özbek and Özkan, 2011

3’ Antenna 1 peduncle segment 2 and antenna 2 segment 4-5 with many long setae (longer than the diameter of the segment) on the inferior margin ……. *D. bispinosus* Martynov, 1925

4(2’) Antenna 2 flagellum with long setae forming a brush, urosomites 1 et 2 with dorsal humps well developed and armed with 3-6 upright apical spines and forming like a crater ……..……. *D. villosus* (Sowinskyi, 1894)

4’ Antenna 2 flagellum with short setae never forming a brush, urosomites 1 et 2 with small dorsal humps armed with 1-3 apical spines slightly oriented towards the telson …… ……...……..…….. *D. haemobaphes* (Eichwald, 1841)

Key to species of *Iberogammarus*

1 Antenna 2 of male with many groups of long and densely implanted curled setae. Third segment of mandible palp with less than 6 terminal setae ……..……..…2

1’ Antenna 2 of male with straight setae. Third article of mandible palp with more than 6 terminal setae …….……... *I. anisocheirus* (Ruffo, 1959)

2(1) Gnathopod 1 propodus of males without the medial palmar spine. Basis of P7 with strong backward projecting ventro-posterior corner …… *I. macrocarpus* (Stock, 1969)

2’ Gnathopod 1 propodus of males with a strong medial palmar spine. Basis of P7 with rounded, non-projecting, ventro-posterior corner …… *I. toletanus* (Pinkster & Stock, 1970)

Key to species of *Longigammarus*

1 Eyes present; maxilla 1 outer plate with 11 apical spines, slightly recurved ……..……..… *L. bruni* G. Karaman, 1969

1’ Eyes present; maxilla 1 outer plate with 22 apical spines distally spatulate ……. ……..……. *L. planaisae* Messana & Ruffo, 2001

Key to species of *Rhipidogammarus*

1 Antenna 1 peduncle article 2 with at least 4 groups of setae …….. 2

1’ Antenna 1 peduncle article 2 with 2-3 groups of setae …..……...……. 3

2(1) Coxae 1-5 with long ventral setae, anterior margin of carpus of P7 with setae longer than spines ……..…….. *Rh. triumvir* Nottenboom, 1985

2’ Coxae 1-5 with short ventral setae only, anterior margin of carpus of P7 without long setae ……...……...…….. *Rh. gordankaramani* Özbek & Sket 2019

3(1’) Antenna 1 flagellum with more than 35 articles; uropod 3 exopodite shorter (no more than 7x longer than endopodite) without seta or few long setae ...……..…….…… 4

3’ Antenna 1 flagellum with more than 30 articles; uropod 3 exopodite long (10x longer than endopodite) with many long setae (2x longer than spines) …….. *Rh. variicauda* Stock, 1978

4(3) Mandibular palp article 2 with long setae reaching the setae type D on the article 3; uropod 3 exopodite without seta ……..…….. *Rh. karamani* Stock 1971

4’ Mandibular palp article 2 with setae never reaching the setae type D on the article 3; uropod 3 exopodite with few setae 2x longer than spines ……...….. *Rh. rhipidiophorus* (Catta, 1878)

Key to species of *Tyrrhenogammarus*

1 Pereopod 3 carpus with a fan of long setae; uropod 1 with sub-equal rami; epimera 3 with a slightly marked ventroposterior corner …… *Th. catacumbae* (G. Karaman & Ruffo, 1977)

1’ Pereopod 3 carpus without long setae; uropod 1 inner ramus longer than outer ramus; epimera 3 without distinct ventroposterior corner …..……. *Th. sardous* Karaman & Ruffo, 1989

Key to Hadziidae genera and species

1 Uropods 1 and 2 with row of 5 plumose setae, exopodite with dorsal setae; telson with only apical spines ……..…… 2

1’ Uropods 1 and 2 with row of 5 plumose setae, exopodite with dorsal setae; telson with marginal spines …….……. *Parhadizia*
(one species: *P. sbordonii* Vigna Taglianti, 1988)
[Turkey]

2 Mandibular palp article 2 as long as article 1 .....…..…….……... 3 (genus: *Hadzia*)

2’ Mandibular palp article 2 longer than article 1 …….…...…….. 7 (genus: *Metahadzia*)

3(2) Gnathopod 2 propod in females with entire convex palm; gnathopod 2 propod in males as wide as carpus; uropod 3 rami broad ……..4

3’ Gnathopod 2 carpus in females with excavated, propodus palm concave; gnathopod 2 propodus in males wider than carpus; uropod 3 rami narrow …….…….……. 6

4(3) Pleopods 1-3 each with 2 retinacula accompanied by one strong seta …….. 5

4’ Pleopods 1-3 each with 2 retinacula without strong seta ……...……
……..…… *H. fragilis stocki* G. Karaman, 1989

5 Pereopods 3-7 and antennae long and slender, including dactyl of pereopods 3-7; telson lobes with 2, occasionally 3 distal spines and without outer marginal spines ……..…..
……..……..…… *H. fragilis fragilis* S. Karaman, 1932

5’ Pereopods 3-7 and antennae shorter and stouter; telson lobes with 3-4 distal spines and 0-1 outer marginal spines ……..…….. *H. fragilis drinensis* G. Karaman, 1984

6(3') Pleopod 3 peduncle with 1-2 median spine on posterior margin ……...……
…… *H. gjorgjevici crispata* G. Karaman, 1974

6' Pleopod 3 peduncle without median spine on posterior margin ……
……..... *H. gjorgjevici gjorgjevici* S. Karaman, 1932

7(2') Uropod 2 peduncle distal end with a protuberance ……..……. 8

7' Uropod 2 peduncle without protuberance ……. 9

8(7) Uropod 2 endopodite of males with transformed apical spine, peduncle with dorsomedial comb-like spines …….…….. *M. uncispina* Notenboom, 1988

8'. Uropod 2 endopodite of males without transformed apical spine, peduncle without dorsomedial comb-like spine…..……..……..…….. *M. tavaresi* (Mateus & Mateus, 1972)

9(7') Lobe of telson with spines along both margins ……...… 10

9' Lobe of telson without spine along outer margin …… *M. minuta* Ruffo, 1947

10(9) Maxilla 1 inner lobe long reaching the basis of spines of outer lobe, distally prominent
…….. *M. adriatica* Pesce, 1979

10' Maxilla 1 inner lobe short never reaching the basis of spines of outer lobe ……..
…… *M. helladis* Pesce, 1980

Key to Metacrangonyctidae genera and species

1 Gnathopod 2 propodus not modified, palm slightly convex; gnathopod 1 merus without brush; coxae 1-3 sub-equal and longer than coxae 4-5 ……..… 2 (Genus *Metacrangonyx*) [peri-Mediterranean]

1' Gnathopod 2 propodus modified in males, palm strongly concave; gnathopod 1 merus with many short setae forming a brush; coxae 1-5 decreasing progressively in length
……... *Longipodacrangonyx* (one species: *L. maroccanus* Boutin & Messouli, 1988)
[Morocco]

2(1) Uropod 3 exopodite longer than peduncle, marginal spines present ..…….……... 3

2' Uropod 3 exopodite equal or shorter than peduncle, marginal spines absent …...…….….. 4

3(2) Uropod 1 peduncle basofacial robust setae present ……..….
……..…. *M. spinicaudatus* Karaman & Pesce, 1980

3' Uropod 1 peduncle basofacial robust setae absent ……..…. *M. longicaudatus* Ruffo, 1954

4(2') Uropod 3 exopodite with several terminal robust setae …...…….…… 5

4' Uropod 3 exopodite without one terminal robust seta …..……...…….. 7

5(4) Antenna 1 accessory flagellum with 2-3 articles ……. 6

5’ Antenna 1 accessory flagellum with 5 articles ……. *M. longipes* Chevreux, 1909

6(5) Telson with distal spines ……..…..…… *M. remyi* Balazuc & Ruffo, 1953

6’ Telson without apical spines ……. *M. knidiiri* Oulbaz et al., 1998

7(4’) Uropod 1 peduncle basofacial robust setae present ……...…..……..…… 8

7’ Uropod 1 peduncle basofacial robust setae absent ……... *M. ortali* G. Karaman 1989

8(7) Mandibular palp with 2 or 3 articles ……..…. 9

8’ Mandibular palp with only one article …….…….…….…. 10

9(8) Antenna 1 flagellum with only 10 articles in females (male unknown) ……
……..... *M. ilvanus* Stoch, 1997

9’ Antenna 1 flagellum with 14 articles in females .....……. *M. sinaicus* Ruffo, 1982

10(8’) Antenna 1 flagellum with 11-14 articles …..……..…… 11

10’ Antenna 1 flagellum with more than 15 articles ……..……..…… 13

11(10) Uropode 3 endopodite present but reduce, scale-like ……..……..…….. 12

11’ Uropode 3 uniramous, endopodite absent ……..
……..…….. *G. ruffoi* Messouli, Boutin & Coineau, 1991

12(11) Antenna 1 article 1 with 2 fines facial spines; uropod 3 peduncle with 1 or 2 spines and one seta on ventral margin …… *M. aroudanensis* Messouli, Boutin & Coineau, 1991

12’ Antenna 1 article 1 with 3 or 4 facial spines; uropod 3 peduncle with 2 spines and without seta on ventral margin …….……. *M. gineti* Boutin & Messouli, 1988

13(10’) Uropod 1 endopodite without baso-facial seta, telson with 2 apical setae clearly separated to each other, peduncle with one terminal seta …….……..…….14

13’ Uropod 1 endopodite with a slender baso-facial seta, telson with 2 apical setae very close to each other ……..... *M. panousei* Ruffo, 1953

14(13) Habitus stocky; antenna 2 peduncle article 1 with 2 sub-terminal spines; uropod 3 peduncle with 1-3 dorso-apical spines ; telson apex flat of slightly emarginate ...……..… *M. delamarei* Messouli, Boutin & Coineau, 1991

14’ Habitus slender; antenna 2 peduncle article 1 with 2 sub-terminal spines; uropod 3 peduncle with 1 dorso-apical spine; telson apex rounded …….
……...…… *M. goulminensis* Messouli, Boutin & Coineau, 1991

Key to Niphargidae genera

1 Urosomite not enlarged, not carminate; uropod 3 biramous, outer ramus with one or 2 articles ……..….. 2

1’ Urosomite enlarged, dorsally carinate, hiding urosomites 2 and 3; uropod 3 very short, outer ramus with 1 article, inner ramus absent …… *Carinurella*
(one species: *C. paradoxa* Sket, 1964)
[Italia, Slovenia]

2(1) Uropod 3 exopodite of one article ……..…… 3

2’ Uropod 3 exopodite of two articles ……..…….. 6

3(2) Uropod 3 exopodite very short, twice as long as its terminal spines; maxilla 1 palp with one article ……..…….……... 4

3’ Uropod 3 exopodite long, several times longer than peduncle; maxilla 1 palp with 2 articles ..……..……..……...….. *Haploginglymus*
[Iberian Peninsula]

4(3) Mandibular palp with 3 noticeable articles ……..……..…… 5

4’ Mandibular palp very short, reduced to only one small article …… *Chaetoniphargus*
(one species: *C. lubuskensis* Karaman G.S. & Sket, 2019)
[Croatia]

5(4) Antenna 1 accessory flagellum with one article; mandibular palp article 3 with only terminal E-setae; telson slightly cleft ...……..……..… *Niphargobates*
(one species: *N. orophobata* Sket, 1981)
[Slovenia]

5’ Antenna 1 accessory flagellum with two articles; mandibular palp article 3 with A, B, C, D and E-setae; telson deeply cleft ……..……..… *Niphargobatoides*
(one species: *N. lefkodemonaki* (Sket, 1990))
[Crete Island]

6(2’) Maxilliped palp article 4 with one, rarely 2 distal nails …… 7

6’ Maxilliped palp article 4 with 3 distal nails …….…….. *Exniphargus*
(one species: *E. tzanisi* G. Karaman, 2016)
[Crete Island]

7. Maxilliped inner and outer plate short and broad; maxilla 2 both plates are short and broad; maxilla 1 inner plate very strong, broader than palpus, outer plate with 9-10 pectinate spines, palp short, not exceeding basis of outer plate spines …… *Foroniphargus*
(one species: *F. pori* G. Karaman 1985)
[Israel]

7’ Maxilliped inner and outer plate slender; maxilla 2 both plates are slender; maxilla 1 inner plate is slender, narrowed distally, outer plate with 7-9 simple to pectinate spines, palpus longer, exceeding basis of outer plate spines …… *Niphargus* [peri-mediterranean except North Africa]

Key to Pontogammaridae

1 Urosomites 1 et 2 with dorsal humps armed with apical spines (as in *Dikerogammarus*, but differing from it by strongly setose margins of coxae 1-4 and pereopods 5-7 basis) ……..……...…… 2 (genus : *Turcogammarus*) [Greece, Turkey]

1’ Urosomites 1 et 2 without dorsal elevations ……..... 3 (genus : *Pontogammarus*) [Central Europe, Turkey]

2(1) Presence of a keel on the dorsum; telson lobes with setae longer than spines; antenna 1 peduncle with short setae, antenna 2 and pereopod 5-7 much less setose…. *T. spandli* (S. Karaman 1931)

2’ No keel on the dorsum; telson lobes with setae shorter than spines; antenna 2 peduncle with some long setae; antenna 2 and pereopod 5-7 very setose …… *T. turcarum* (Stock, 1974)

3(1’) Mandibular palp article 3 with 3 rows of setae type B and articles 2-3 with less and shorter setae; urosomite 2 with spines ……..……. 4

3’ Mandibular palp article 3 with 5 rows of setae type B and articles 2-3 with very long and numerous setae, much longer than the width of articles; Urosomite 2 without spines ……..…… *P. maeticus* (Sowinsky, 1894)

4(3) Uromosite 1 armed without setae only; coxae 1-4 and pereopods 3-5 bases with dense and numerous long setae ….…… *P. aestuarius* (Derzhavin, 1924)

4’ Urosomite 1 armed with spines and setae; coxae 1-4 and pereopods 3-5 bases with shorter and less numerous setae …….…….. *P. robustoïdes* (Sars, 1894)

Key to Pseudoniphargidae genera

1 Body compressed and strongly curved; head anterior lobe strongly developed; coxa 1 ventrally wide; uropod 3 short, exopodite slightly (1.5 times) longer than peduncle ...……...…… *Parapseudoniphargus* (one species: *P. baetis* Notenboom, 1988) [Spain]

1’ Body outspread; head anterior lobe weakly developed; coxa 1 sub-rectangular; uropod 3 long, exopodite much longer than peduncle, at least 3 times …… *Pseudoniphargus* [Western Mediterranean Basin]

Key to Salentinellidae genera and species

1 Uropod 1 longer than uropod 2; epimeral plates 2-3 as long as wide; telson cleft, elongated ……..…….…… 2 (genus: *Salentinella*)
[Western Mediterranean Basin]

1’ Uropod 1 shorter than uropod 2; epimeral plates 2-3 elongated forming plates; telson uncleft with concave margins ……..……. *Parasalentinella*
(one species: *P. rouchi* Bou, 1971)
[France]

2(1) Posterodistal lobe of pereopod 7 merus almost reaching end of carpus …… 3

2’ Posterodistal lobe of pereopod 7 merus not reaching beyond half the length of carpus ...… 4

3(2) Telson partially cleft ……..…….…….. *S. seviliensis* Platvoet, 1987

3’ Telson uncleft ……..…….. *S. carracensis* Platvoet, 1987

4(3’) Antennae 1 and 2 peduncles without distal spines; pleopod peduncles with coupling spines; telson longer than wide ….…….…….……..… 5
4’ Antennae 1 and 2 peduncles with distal spines; pleopod peduncles without coupling spines; telson wider than long …….……. *S. anae* Messouli, Coineau & Boutin, 2002

5(4) Urosomite 3 lengthened, about 1.5 times as long as high …..…… 6

5’ Urosomite 3 not lengthened, about as long as high …….…….. 7

6(5) Telson with dorsal setae implanted near apex of lobes ……..…. *S. petiti* Coine!au, 1968

6’ Telson with dorsal setae not implanted near apex of lobe ….. *S. longicaudata* Platvoet, 1987

7(5’) Telson deeply cleft over more than a half of lobes ….……...…….…. 8

7’ Telson not cleft over 1/3 of lobes ……..……...…….…… *S. delamarei* Coineau, 1962

8(7) Uropod 3 endopodite more than 15% of the exopodite …….……...9

8’ Uropod 3 endopodite less than 15% of the exopodite …… *S. meijersae* Platvoet, 1987

9(8) Uropod 1 peduncle without ventrodistal projection …….……..……10

9’ Uropod 1 peduncle with a strong ventrodistal projection ……. *S. cazemierae* Platvoet, 1987

10(9) Antenna 1 and 2 sub-equal in length, accessory flagellum shorter than the first peduncle article; Uropod 3 endopodite longer than a half of the exopodite, exopodite article 2 less developed ……...…….……... 11

10’ Antenna 1 shorter than antenna 2, accessory flagellum longer than the first peduncle article; Uropod 3 endopodite shorter than a half of the exopodite, exopodite article 2 well developed ..……...… *S. angelieri* Ruffo & Delamare Deboutteville, 1952

11(10) Uropod 3 short, endopodite egal or less than 2/3 of exopodite; gnathopod 2 propodus palm strongly convex asymmetrically (largest part at 1/3 of the palm) ……..……..…... 12

11’ Uropod 3 slender, endopodite around 3/4 of exopodite; gnathopod 2 propodus palm convex symmetrically (largest part in the middle of the palm) …… *S. gracillima* Ruffo, 1947

12(11) Pereopod 4 dactylus shorter than a half of the propodus …… ……..… *S. formenterae* Platvoet, 1984

12’ pereopod 4 dactylus equal to a half of the propodus …….…...…….. *S. gineti* Balazuc, 1957

Key to Typhlogammaridae genera and species

1 Body not carinate; maxilla 1 palp symmetric; uropod 3 exopodite article 2 vestigial or absent ……...…… 2

1’ Body dorsally carinate, third mesosome segment and all metasome segments with one pair of dorso-lateral teeth each; maxilla 1 palp asymmetric (right maxilla different from the left one); uropod 3 exopodite article 2 ordinary …….……. *Metohia* (one species: *M. carinata* Absolon, 1927)
[Balkans]

2(1) Antenna 2 gland cone shorter than article 3 of the peduncle; coxae 1-7 short diamond shaped or trapezoïdal; uropod 3 longer, much exceeding the top of uropods 1-2 …… ……..…… *Typhlogammarus* (one species: *A. mrazeki* (Schäferna, 1907))
[Balkans]

2’ Antenna 2 gland cone very long overreaching article 3 of the peduncle; coxae 1-7 elongated sub-rectangular; uropod 3 short, not exceeding the top of uropods 1-2 …. *Accubogammarus* (one species: *A. algor* (G. Karaman, 1973), subspecies not include in the key)
[Balkans]

REFERENCES

Bauzà-Ribot, M.M., C. Juan, F. Nardi, P. Oromí, J. Pons & D. Jaume. 2012. Mitogenomic Phylogenetic Analysis Supports Continental-Scale Vicariance in Subterranean Thalassoid Crustaceans. Current Biology 22: 2069–2074.

Copilaş-Ciocianu, D., D. Sidorov & A. Gontcharov. 2019. Adrift across tectonic plates: molecular phylogenetics supports the ancient Laurasian origin of old limnic crangonyctid amphipods. Organisms Diversity & Evolution 19: 191–207.

Horton, T., A. Kroh, S. Ahyong, N. Bailly, … & Z. Zhao. 2020. World Register of Marine Species (WoRMS). WoRMS Editorial Board, http://www.marinespecies.org. [Accessed 2020 December 31]

969 Hou, Z. & B. Sket. 2016. A review of Gammaridae (Crustacea: Amphipoda): the family extent,
970 its evolutionary history, and taxonomic redefinition of genera. Zoological Journal of the
971 Linnean Society 176: 323–348.

972 Hou, Z., B. Sket & S. Li 2014. Phylogenetic analyses of Gammaridae crustacean reveal
973 different diversification patterns among sister lineages in the Tethyan region. Cladistics 30:
974 352–365.

975 Malard, F., M.-J. Dole-Olivier, J. Mathieu & F. Stoch. 2002. Sampling Manual for the
976 Assessment of Regional Groundwater Biodiversity. Report of the European Project Pascalis.
977 110 pp.

978 McMenamin, M.A.S., L.P. Zapata & M.C. Hussey. 2013. A Triassic Giant Amphipod from
979 Nevada, USA. Journal of Crustacean Biology Oxford Academic 33: 751–759.

980 Piscart, C., A. Manach, G.H. Copp & P. Marmonier. 2007. Distribution and microhabitats of
981 native and non-native gammarids (Amphipoda, Crustacea) in Brittany, with particular reference
982 to the endangered endemic sub-species *Gammarus duebeni celticus*. Journal of Biogeography
983 34: 524–533.

984 Stokkan, M., J.A. Jurado-Rivera, P. Oromí, C. Juan, D. Jaume & J. Pons. 2018. Species
985 delimitation and mitogenome phylogenetics in the subterranean genus *Pseudoniphargus*
986 (Crustacea: Amphipoda). Molecular Phylogenetics and Evolution 127: 988–999.

987 Väinölä, R., J.D.S. Witt, M. Grabowski, J.H. Bradbury, K. Jazdzewski & B. Sket. 2008. Global
988 diversity of amphipods (Amphipoda; Crustacea) in freshwater. Hydrobiologia 595: 241–255.

989

3. Malacostraca: Bathynellacea

Ana I. Camacho
Museo Nacional de Ciencias Naturales (CSIC), Dpto. Biodiversidad y Biología Evolutiva, C/ José Gutiérrez Abascal 2, 28006- Madrid, Spain; mcnac22@mncn.csic.es
Phone: +34 914111328 ext. 1215

Nicole Coineau
67 Avenue du Puig del Mas, 66650 Banyuls-sur-Mer, France.
n.coineau@orange.fr

INTRODUCTION

Bathynellacea Chappuis, 1915 are obligate groundwater inhabitants (stygobionts) (limnic and oligo- to polyhaline waters) of all continents except Antarctica. Their interstitial life style would correlate with a decrease of the body size as well as with the reduction or loss of appendages and other organs (Coineau & Camacho 2013), these features may be interpreted as evidence of an evolutionary process involving progenesis (Schminke 1981a; Schram 1982).

The origin of Bathynellacea could be pre-Pangean. They might have been highly diversified in the Paleozoic seas, especially during the Carboniferous period. Some of these ancestors may have colonized the continental subterranean freshwaters of the Pangea as early as in the Permian and Triassic periods, and also part of the Gondwana (Camacho *et al*., 2018c) before the Pangea break up. Thereafter, the fragmentation of Laurasia and Gondwana during the Mesozoic period (Golonka 2007) led to the current disjunct distribution of syncarids (Schram, 1977), and induced their independent evolution on each landmass. All the genera belonging to Parabathynellidae Noodt, 1965 from peninsular India show a Gondwanan heritage (Ranga Reddy 2011, Bandari *et al*., 2016). The most recent common ancestor of bathynellaceans can be dated back to the Triassic or Jurassic periods, as showed by our analysis (Camacho *et al*., 2021).

Their current distribution is important, because they are restricted to freshwaters from remote geological times. They are one of the oldest groups of freshwater fauna and have no marine relatives for future colonizations, so they serve as indicators of ancient connections between the continents. They are considered a very suitable group for zoogeography studies, as they are old enough phylogenetically speaking, their capacity for dispersal is severely limited, and even today they are represented by a high number of species distributed worldwide. They can provide information on possible dispersal routes in past and present geological periods.

GENERAL ECOLOGY AND DISTRIBUTION

Bathynellacea exclusively live in groundwater sensu lato (caves, springs, wells and hyporrheic zones of rivers): they are interstitial stygobionts (they inhabit in the water filling the interstices between sand grains and gravels in sediments). Little is know about their life cycles. They live long, e.g. *Paraiberobathynella fagei* (Delamare Deboutteville & Angelier, 1950) can live up to two and a half years. Fertilization is internal, but copulation has not been observed; they are K-strategists, i.e. the female produces a single large egg that occupies almost its entire abdomen for almost nine months (in the few cases observed to date), deposits it on the substrate and a larva identical to the adult is immediately born but with only 3 or 4 pairs of legs, depending on the species. Metamorphosis takes place inside the egg. Due to the absence of a swimming larva, their ability to disperse is very low. The post-embryonic development or parazoeal phase (Schminke, 1981a) (= larval phase 1, Serban, 1985), which occurs after birth, consists of 8 to 11 stages marked by molts, depending on the species.

They do not generally swim, except some species (e.g. Cho & Humphreys 2010 observed *Brevisomabathynella uramurdaliensis* swimming quite powerfully in an aquarium). They walk with

their thoracopods. Some species show a swimming escape reaction. They touch the sand grains with their antennules, explore the interstices, resulting in discontinuous movements interrupted by frequent stops. Then they flex their pleon and leaning on their uropod and furca, they suddenly launch themselves forward, or change direction and move backwards. Thanks to their body flexibility, they can clean their antennae with the spines of their uropods and furca (personal observation). Their thigmotaxis will generally keep them in contact with the sandy sediment so that they can know their position (they are devoid of statocysts).

They graze and scrape deposits from sediment grains and also eat protists, fungi and bacterial films. According to Serban (1980), Bathynellidae Grobben, 1905 comprise "filter and large food feeders", whereas Parabathynellidae would be "large food feeders". Some parabathynellids are carnivorous, eat harpacticoid copepods (*Iberobathynella* Schminke, 1973) or ostracods (*Brevisomabathynella*). Cannibalism has been observed by Morimoto (1970), who reported large specimens of *Allobathynella* Morimoto & Miura, 1957 preying on young ones (Schminke & Cho 2013).

Bathynellacea are preyed upon by amphipods and subterranean fish.

They live in freshwater, although some species have been found in brackish groundwater, near the sea coastline. They can be considered cold stenotherms, they do not usually survive above 20ºC. However, the genus *Thermobathynella* Capart, 1951 has been found in a hot spring (water at 55ºC) and we found *Paraiberobathynella* cf *fagei* in the Sima de la Higuera (Murcia, Spain) living at 27ºC.

Bathynellacea have been found from Alaska (Camacho *et al*., 2016b) to New Zealand (Schminke 1973) and their distribution is worldwide with high degrees of local endemic species (Camacho 2019) and cryptic species (Camacho *et al*., 2011, 2012, 2018c). The order Bathynellacea is composed of three families (338 species and 89 genera) (Camacho *et al*., 2021): Parabathynellidae, Bathynellidae and Leptobathynellidae Noodt, 1965. Parabathynellidae (210 species, 45 genera) are currently known in temperate to tropical zones in both hemispheres; Bathynellidae (110 species, 37 genera) are known mainly in temperate zones of the northern hemisphere and some areas of the southern hemisphere (they are very frequent in Australia); while Leptobathynellidae (18 species,7 genera) are only known in South America (Brazil, Argentina, Paraguay and Chile), Africa (Ivory Coast and South Africa), California and India. Parabathynellidae are most frequently found in samples than members of the other two families are, perhaps due to their larger size and consistency. Furthermore, their study is easier not only because of their size, but also because their morphological variability is greater and therefore it is easier to discriminate between genera and species. All Leptobathynellidae species are very thin and fragile, their dissection is very difficult and their identification almost impossible; to date they are not known in the Mediterranean area, but perhaps they have gone unnoticed in the samples, or have escaped from the sampling nets or perhaps they live in areas without sampling coverage, but maybe they will be found one day. The same happened in India: as soon as the sampling effort intensified, three *Parvulobathynella* Schminke, 1973 species were found. The Bathynellidae family is characterized by its great homogeneity, so that it is very difficult to find characters that differentiate morphotypes. Large collections of specimens from this family collected all over the world have not yet been studied, because they are too difficult to identify. Morphological studies need to be supplemented with molecular data for researchers to discriminate species.

Following the emergence of molecular studies, cryptic species are being discovered in the group, both in Europe and Australia, and show that diversity is even greater than suspected. To this we must add a significant unexplored and unsampled "underground aquatic world" (in caves and unconsolidated sediments), which will give many surprises.

In the Mediterranean area in question, 71 species belonging to 20 genera are formally described: 36 Parabathynellidae species (7 genera) and 35 Bathynellidae species (13 genera). The Iberian Peninsula is the area exhibiting the highest diversity: 41 species altogether, 30 Parabathynellidae species (5 genera) and 11 Bathynellidae species (5 genera). The *Iberobathynella* genus, with 22 species belonging to 3 sub-genera from the Iberian Peninsula, is one of the most diverse in the world, behind *Allobathynella* with 25 species, and the cosmopolitan *Hexabathynella* Schminke, 1972 with 23 species distributed throughout the world (5 species in the area and four of them in the Iberian Peninsula) (Camacho, 2019).

The greatest Bathynellidae diversity is found in France; thanks to the work of Serban, Coineau & Delamare Deboutteville (1971, 1972), 17 species (8 genera) are well known; however, only 3 species of the family Parabathynellidae live in France (several populations of *Parabathynella stygia* Chappuis, 1926 (= phreatica), *Paraiberobathynella fagei* and *Hexabathynella knoepfflery* (Coineau, 1964) from Corsica). The other findings are sporadic: one species in Israel, one in Morocco, and one in southern Tunisia.

All known species are short-range endemisms, as recent molecular studies revealed. Some species considered to be widely distributed in Spain, such as *Iberobathynella imuniensis* Camacho, 1987 (inhabitant of the Cantabrian coast, from the Pyrenees to Galicia) and *Paraiberobathynella fagei* (described in France, in the Roussillon regin, and believed to live throughout eastern Spain, in Andalusia and Mallorca), only live in the type locality and areas nearby, while the rest of the populations is surely composed of different cryptic species, morphologically indistinguishable from the type species.

A small territory like the Iberian Peninsula is the most diverse area on Earth in terms of bathynellids. The Ojo Guareña Natural Monument (Burgos) (a karst complex with more than 110 km of development), where eight species of Bathynellacea have been found (4 are still undescribed: a new genus, two cryptic species of *Vejdovskybathynella edelweiss* and a cryptic species of *I. imuniensis*), is the most diverse place in the world and the biodiversity hotspot of the group (Camacho *et al*., 2010).

TERMINOLOGY AND MORPHOLOGY

Microscopic Malacostraca are 0.5-3.0 mm in length, sometimes up to 6.3 mm, e.g. *Billibathynella humphreysi* Cho, 2005. Eumalacostraca do not have a carapace and have biramous thoracopods. Their body is elongate and more or less straight (Fig. 7.5), worm-like and depigmented, female do not have a brood pouch. Eyes and statocysts are absent.

Their body is divided into the: head, eight free thoracic segments with eight pairs of biramous thoracopods (thoracopod VIII is modified as a copulatory organ in the male and reduced in the female), five free abdominal segments without pleopods or with one or two uniramous pleopods and a pleotelson with biramous uropods and furcal rami with spines (Fig. 7.5).

Head longer than wide, with a fine cephalic capsule (Fig. 7.5). Anterior part with a couple of antennules (A.I) (article with sexual dimorphism in some genera) and a pair of antennae (A.II) with a variable number of articles. The five mouth pieces are located ventrally: labrum (single piece), a pair of paragnathes (present in all Bathynellidae species and a few species of genera belonging to Parabathynellidae and Leptobathynellidae) (Camacho *et al*., 2021), mandibles (Md), maxillules (Mx.I) and maxillae (Mx.II). (Fig. 7.5).

The oral opening is located at the posterior end of the rostral third.

Thorax (Fig. 7.5), with eight well-defined segments (ancestral structure); circular cross section of segments; diameter and length increasing towards the distal end. Eight pairs of thoracopods: the first seven ones are used for locomotion and the eighth one is transformed into a copulatory organ (penis) in males, and is greatly reduced (or even absent) in females. Limit between thorax and abdomen not very clear. Thoracopod I (Fig. 7.5) is the smallest, thoracopods II to IV or V increasing in length and the last ones of the same length. Biramous thoracopods (ThI, ThII… ThVII), with exopod (1-12 articles in Parabathynellidae, two in Leptobathynellidae, and one in Bathynellidae) and endopod (four articles in Parabathynellidae and Leptobathynellidae, and three or four articles in Bathynellidae) which can exhibit sexual dimorphism on the third article of Th VI (*Pacificabathynella* Schminke & Noodt, 1988 and *Paradoxibathynella* Serban, 2000) and on coxa of ThVII (*Altainella* Camacho, 2020); respiratory epipod (absent on ThI and sometimes on ThII and/or III), connected with coxa and basipod. Usually ctenidiae present at the base of the setae on the exopod and along one of the articles on the endopod.

ThVII absent in *Hexabathynella* and *Hexaiberobathynella*.

Female ThVIII (Fig. 7.5) smaller than other legs. Very reduced in *Hexabathynella* and *Iberobathynella* (Fig. 7.5B), remains of articles indistinguishable. It is still possible to identify the articles in some Bathynellidae (Fig. 7.5A) genera, although they are always very reduced.

Male ThVIII: massive, more or less rounded or curved; strongly modified but distinguishable articles (like lobes) of a typical leg. The terms used to designate each part are equivalent in the three families: a) protopod, penial complex and basipod; basal region, outer lobe, inner lobe and dentate lobe constitute the penial complex (these last 3 lobes are well distinguishable in Parabathynellidae (Fig. 7.5B)); genital opening located between the lobes; some setae usually on basipod; b) endopod, only one article and setae; c) exopod, only one article with some setae on ventral edge. Some structures such as basipod and penial complex are complicated in the Bathynellidae family (Fig. 7.5A).

Five segments on abdomen and pleotelson with furcal rami and uropods (Fig. 7.5 Habitus). Sometimes vestigial pleopods on first and second segments. Setae smooth, barbed or plumose basidorsally or basiventrally present on pleotelson. Uropod lateral: sympod (with spines), exopod and endopod, with specific setation. Furcal rami (with spines) located on pleotelson lobes.

Anus located in the terminal part of the pleotelson and covered by an operculum (anal operculum) in some Parabathynellidae species.

COLLECTION, PREPARATION AND IDENTIFICATION

The specific methods for collecting samples depend on the specific habitat where the fauna is found in groundwater *sensu lato*. However, almost all of them are based on substrate removal and on filtration of the cloudy water with hand nets of *ad hoc* designs and a mesh size < 0.1mm.

The aquatic environments sampled within caves are gours, puddles, pools, drips, lakes and underground rivers. Outside, springs, wells, boreholes, permanent cores (for example in mining surveys) that intersect aquifers and a hyporheic substratum (in lakes and rivers) are sampled. Bathynelids have recently been found in samples from the Mesovoid Shallow Substratum (MSS) of the Sierra de Guadarrama (Madrid, Spain) arranged for the collection of terrestrial fauna (Camacho & Ortuño, 2019). Therefore, sampling methods and devices are numerous and varied. A comprehensive compilation can be viewed at: *Sampling Manual for the Assessment of Regional Groundwater Biodiversity*, PASCALIS 2002 (Ed. by F. Malard, Asociate editors: Dole-Olivier, M.-J., J. Mathieu & F. Stoch).

Field samples can be kept alive in a refrigerator or frozen in absolute or 70% ethanol (this is a conservative liquid, but not a fixative one, so that the specimens deteriorate over time). In the case of living samples, it is convenient to wash and separate them as soon as possible. In this way, each type of fauna can be fixed in the most suitable fixative and according to the subsequent study you want to carry out. For morphological studies it is appropriate to use 4% formalin for 48 hours, while keeping the specimens in a refrigerator at 4ºC. After washing, they can be prepared for dissection right away and assembled in permanent preparations (Perina & Camacho, 2016), or the entire specimens can be preserved in 70% ethanol for subsequent studies. Bathynels have thin and fragile cuticles. If the specimens are to be preserved for long-term morphological studies, they must be fixed properly before being stored in the preservative liquid. When absolute or 70% ethanol is used for field samples, the specimens should also be washed and processed as soon as possible and thus be suitable for immediate molecular studies and short-term morphological studies as well. This way, the same specimen can and should be used for both studies: the abdomen for DNA extraction and the other parts for dissection and mounting in permanent preparations (after dipping in 4% formalin for 48 hours), with the same routine as in the previous case (Perina & Camacho, 2016). This procedure ensures that the sequenced genes correspond to a given morphotype. Samples frequently contain a mixture of species indistinguishable under the binocular microscope. If some specimens are used entirely for morphological studies and others are entirely destroyed by DNA extraction, it will be impossible to associate each gene sequence to a specific morphotype.

Taxonomic identification and the description of new species require a complete morphological study of specimens, males and females if possible. Anatomical observations can be performed using an oil immersion lens (100× magnification) with an interference microscope equipped with a drawing tube. Photographs are not a substitute for drawings in taxonomic works but can complement them.

Well-prepared permanent preparations ensure good preservation of the specimens in scientific collections. They guarantee their survival and availability, at least on the medium term just as well-preserved DNA extracts and DNA collections of public institutions ensure access to them for future scientific studies.

ACKNOWLEDGEMENTS

We gratefully acknowledge C. Puch who helped us in different ways and Christophe Piscart for his valuable comments. This work was supported by PID2019-110243GB-I00 MICINN/FEDER project.

KEYS TO BATHYNELLACEA

Key to Bathynellacea families

1 Lengthened powerfully cephalic capsule; AI with 6 or 7 articles; 6 to 8 articles in AII, directed forward or perpendicular, with very well developed exopod (Fig. 7.5A); labrum with smooth distal free edge (Fig. 7.6D); paragnathes present; Md, length/width= 3 (very long) (Fig. 7.6G), prehensile palp with 1 to 3 articles (Fig. 7.6H) in antero-ventral position, reduced *pars incisiva* (in antero medial part) and typical lobe (plate like) of *pars molaris* absent; MxII not prehensile (Fig. 7.6K); exopod of thoracopods with 1 article (Fig. 7.7A,B); male ThVIII remenbers "a leg" (Fig. 7.6D); pleopods of 2 articles; 3 or more oblique spine rows on sympod of uropod (Fig. 7.7F,H); dorsal seta on pleotelson …….. ……..……...……..…. Bathynellidae (Fig. 7.5)

2 Weakly elongated cephalic capsule; AI with 6 to 10 articles; 1 to 6 articles in AII, directed backwards, without exopod (Fig. 7.6B); labrum with dentate distal free edge (Fig. 10.2.E); paragnathes absent or rarely present; Md, length/width= 0.8 (high), with palp not prehensile of 1 article (Fig. 7.6I) in antero-dorsal position, large *pars incisiva* (occupying entire distal part) and typical lobe (plate like) of *pars molaris* present; MxII not prehensile (Fig. 7.6L); exopod of thoracopods multiarticled (Fig. 7.7C); male ThVIII different of "a leg" (Fig. 7.7E); when present (rarely) pleopod reduced; 5 to 30 inner spine row on sympod of uropod (Fig. 7.7G); ventral or dorso-lateral seta on pleotelson …… ……..……...……...……..… Parabathynellidae (Fig. 7.6)

3 Elongated cephalic capsule; AI with 6 articles; 5 to 7 articles in AII, directed backwards, with very rudimentary exopod (Fig. 7.6C); labrum with poory armed distal free edge (Fig. 7.6F); paragnathes present; Md, length/width= 1.5 (long), palp not prehensile with 1 or 2 articles (Fig. 7.6J), in antero-dorsal position, reduced *pars incisiva* (occupying antero-distal part) and typical lobe (plate like) of *pars molaris* absent; MxII prehensile (Fig. 7.6M); exopod of thoracopods with 2 articles; male ThVIII not remenbering "a leg"; absent pleopods; 2 similar distal spines on sympod of uropod; no seta on pleotelson ……..……..……..…….. Leptobathynellidae (Fig. 7.7)

Key to Bathynellidae sub-families

1 Penial region of male ThVIII with 3 lobes; AI with 7 articles; AI >, = or < AII; 3 articles in mandibular palp without sexual dimorphism; endopod of ThI to VII with 4 articles; female ThVIII with 1 article; 4 spines as minimum on sympod of uropod; 3-4 claws on endopod of uropod (Fig. 7.7H) ..... Bathynellinae

1' Penial region of male ThVIII with 1 lobe; AI with 6 or 7 articles; AI > or = AII; 1 to 3 articles in mandibular palp with or no sexual dimorphism; endopod of ThI to VII with 3 or 4 articles; endopod of female ThVIII with 1 or 2 articles; 4 spines as maximum on sympod of uropod; 2-4 claws on endopod of uropod (Fig. 7.7F) …….. Gallobathynellinae

Key to Bathynellinae genera

1 Six similar spines on sympod of uropod (Fig. 7.7I); 4 claws on endopod of uropod; 1st & 2^{d} spines of furca the largest (Fig. 7.7J); mandibular palp without sexual dimorphism with 3 articles; 7 articles in AII; AI=AII; seta on medial segment of exopod of AII; 4 articles in endopod of ThI to VII …… ……..... *Bathynella*

1' Four different spines on sympod of uropod (Fig. 7.7H); 3 claws on endopod of uropod; 2^{d} spines of furca the largest (1.1 times 3th) (Fig. 7.7K); mandibular palp with sexual dimorphism and 3 articles; 7

articles in AII; AI=AII; seta on medial segment of exopod of AII; 4 articles in endopod of ThI to VII ……..…….…..… *Antrobathynella*
(one species: *A. stammeri* (Jakobi, 1954))
[Slovenia]

Key to Gallobathynellinae genera

1 AI with 6 articles; AII with 6 or 7 articles; AI>AII; Md palp with 3 articles without sexual dimorphism; ThI endopod with 4 articles ……...…….…..……. 2

1’ AI with 7 articles; 7 or 8 articles in AII; AI>, < or =AII; Md palp of 3 articles, with or without sexual dimorphism; ThI endopod with 3 or 4 articles …….…….....……...… 4

2(1) AI with 6 articles; medial seta absent on exopod of AII; 3 articles on Md palp; ThI endopod of 4 articles; ThII to V endopod with 3 articles and ThVI-VII endopod with 3 or 4 articles; female ThVIII of 1 simplified article, without epipod ……...…….…….. 3

2’ AII with 7 articles; medial seta present on AII exopod; Md palp of 3 articles; endopod ThI to VII with 4 articles; large female ThVIII epipod with 2 articles ……. *Parameridiobathynella*
(one species: *P. gardensis* Serban & Leclerc, 1984
[France: Gard]

3(2) ThII to VII with 3 articles; 5 spines on furca, the second longest ……..… *Meridiobathynella*

3’ ThII to V endopod with 3 articles; ThVI-VII endopod with 4 articles; 5 spines on furca, the second very, very long ……..... *Hispanobathynella*
(one species: *H. catalanensis* (Serban, Coineau & Delamare Deboutteville, 1971))
[Spain: Gerona]

4(1) AI with 7 articles; AII with 7 articles; AI> or =AII; Md palp sexually dimorphic with 3 articles; ThI-V four-segmented endopod ….……..……..……. 5

4’ AI with 7 articles; AII with 7 or 8 articles; AI>, < or =AII; Md palp sexually or not dimorphic with 1 to 3 articles; ThI-VII endopod with 4 articles or ThI to V endopod with 3 articles ……. 6

5(4) ThI-VII with 4 articles on endopod; epipod present on female ThVIII; 4 spines on sympod and 2 claws on endopod of uropod; 5 spines of different size on furca ……..……..……..…….. *Vejdovskybathynella*

5’ ThI-V endopod with 4 articles and ThVI and VII endopod with 3 articles; female ThVIII without epipod; 3 spines on sympod and 4 claws on endopod of uropod; 5 spines of similar size on furca ..... *Sardobathynella*
(one species: *S. cottarelli* Serban, 1973)
[Italy: Sardinia]

6(4’) AI with 7 articles; AII with 7 or 8 articles; ThI to V endopod with 3 articles; 1 to 3 articles on Md palp (dimorphic or not) ……...……...……..….... 7

6’ AI with 7 articles; AII with 8 articles; ThI-VII endopod with 4 articles; Md palp sexually dimorphic with 3 articles ……..……...…….. 10

7(6) AI with 7 articles; AII with 7 articles; AI=AII; Md palp with 2 articles; well developed endopod and exopod of female ThVIII; 4 spines on sympod and 2 claws on endopod of uropod; 5 spines of different size on furca ……..……. *Clamousella* (one species: *C. delayi* (Serban, Coineau & Delamare Deboutteville, 1971))
[France: Hérault]

7’ AI with 7 articles; AII with 8 articles; AI> or < AII; Md palp with 1 to 3 articles; endopod and exopod of female ThVIII well developed or endopod absent; 3 or 4 spines on sympod and 2 or 3 claws on endopod of uropod; 5 spines of similar or different size on furca ……..... 8

8(7) AI>AII; medial seta of AII exopod absent or present; Md palp with 2 or 3 articles; female ThVIII with well developped endopod and exopod; 4 spines on sympod and two or three claws on endopod of uropod; 5 spines of similar or different size on furca …..... 9

8’ AI<AII; medial seta of exopod of AII present; Md palp of 1 article; endopod and exopod of female ThVIII absent; 3 spines on sympod and 2 claws on endopod of uropod; 5 spines of similar size on furca ……..……..…..……..…...…… *Vandelibathynella* (one species: *V. vandeli* (Delamare Deboutteville & Chappuis, 1954))
[France: Ariège]

9(8) Medial seta of exopod of AII absent; Md palp not dimorphic with 2 or 3 articles; female ThVIII with large endopod and exopod; 4 spines on sympod and 2 or 3 claws on endopod of uropod; 5 spines of similar or different size on furca ……..……..….. *Gallobathynella*

9’ Medial seta of exopod of AII present; Md palp dimorphic or not, with 3 articles; very small endopod of female ThVIII; 4 spines on sympod and 2 claws on endopod of uropod; 5 spines of similar size on furca ……..…… *Paradoxiclamousella*

10(6) Medial seta of exopod of AII present; sexual dimorphism on mandibular palp; very short basipodal seta and well developed endopod and exopod of female ThVIII; 3 or 4 spines on sympod and 4 claws on endopod of uropod ……...……....…… *Pseudobathynella* (one species: *Ps. magniezi* (Serban, Coineau & Delamare Deboutteville, 1972))
[France: Allier]

10’ Medial seta of exopod of AII absent; sexual dimorphism on labrum and mandibular palp; *pars molaris* of Md with complex morphology; very long basipodal seta and well developed endopod and exopod on female ThVIII; 4 spines on sympod and 2 claws on endopod of uropod ……..……..……..... *Delamareibathynella*

Key to species of *Delamareibathynella*

1 One dentate lobe on *pars molaris* of Md …… *D. debouttevillei* Serban, 1989
[France: Ardéche]

1’ Two dentate lobes on *pars molaris* of Md ……...…… *D. motasi* Serban, 1992
[France: Allier]

Key to species of *Gallobathynella*

1 Three or 4 teeth on *pars molaris* of Md ……..……..…… 2

1’ Two teeth on *pars molaris* of Md ……..…. *G. hispanica* (Delamare Deboutteville, 1954) [Spain: Tarragona]

2(1) Pars molaris of Md with 3 teeth and 2 setae on mandibular palp of Md; 2 claws and 3 or 4 setae on endopod and 3 or 4 setae on exopod of uropod ……...……..…….…...…. 3

2’ *Pars molaris* with 4 teeth and 3 setae on mandibular palp of Md; 2 claws and 4 setae on endopod and 2 setae on exopod of uropod; second spine three times longer than first spine which is twice as long as dorsal spine and similar to fourth of furca ……..... ..... *G. juberthie* Serban, Coineau & Delamare Deboutteville, 1971 [France: Pyrénées-Orientales]

3(2) Similar 3 or 4 spines on sympod of uropod; 3 setae on exopod of uropod; epipod longer than basipod of female ThVIII ……...……..…….....…….…….. 4

3’ Uropod sympod with 4 spines, first the longest; 4 setae on exopod of uropod; epipod as long as basipod and exopod similar to endopod of female ThVIII; second spine 2.5 times longer than first spine which is as long as dorsal and fourth spines of furca ……...…… …… *G. boui* Serban, Coineau & Delamare Deboutteville, 1971 [France: Hérault]

4(3) Three spines on sympod of uropod; 4 setae on endopod of uropod; longer than basipod seta of the coxopod and exopod >> than endopod of female ThVIII; very small endopod of male ThVIII; second spine 4 times longer than first spine which is as long as dorsal spine of furca ……. *G. coiffaiti* (Delamare Deboutteville, 1961) [France: Hérault]

4’ Four spines on sympod of uropod; 3 setae on endopod of uropod; no seta on coxopod and exopod > than endopod of female ThVIII; distal mamill on frontal projection of basipod and small endopod of male ThVIII; second spine almost as long as first spine which is longer than third and fourth, similar length of dorsal spine of furca ……. *G. tarissei* Serban, Coineau & Delamare Deboutteville, 1971 [France: Aude]

Key to species of *Paradoxiclamousella*

1 Barbed terminal claws of Md palp; two barbed setae on basipod of ThI-II; 12 setae on endopod of ThI; 4 setae on third article of endopod of ThII to IV; 5 setae on exopod of ThI to VII; almost square basipod of male ThVIII without seta; epipod and coxal seta smaller than basipod of female ThVIII; exopod as long as basipod of female ThVIII; 2 setae on endopod of female ThVIII (Fig. 7.7L); 6 setae on pleopod; third spines twice as long as the first and second on furca …..……. ……... *P. pirata* Camacho, Dorda & Rey, 2013 [Spain: Cantabria]

1’ Smooth terminal claws (very long on male) of Md palp; 2 smooth setae on basipod of ThI-II; 10 setae on endopod of ThI; ThII to IV endopod with 3 setae on third article; ThI to VII exopod with 4 setae; rectangular basipod of male ThVIII with one seta; epipod and coxal seta longer than basipod of female ThVIII; exopod as long half basipod of female ThVIII; one seta on very small endopod of female ThVIII (Fig. 7.7M); 5 setae on pleopod; third spines slightly longer than others of furca ……..... ……..….. *P. fideli* Camacho, Dorda & Rey, 2013

[Spain: Asturias]

Key to species of *Vejdovskybathynella*

1 Fifth article without setae and 1 or 2 setae on second article of AII; medial seta of exopod of AII absent or present; no or 1 seta on first article and 1 or 2 setae on second article of ThIV endopod; very large, large or small frontal projection with spur on basipod of male ThVIII; 3 or 4 spines on sympod and 2 or 3 claws on endopod of uropod; furca with second spine longer than first ……...……..... 2

1' Second article of AII without setae and one seta on fifth article; medial seta of AII exopod absent; 2 setae on first and second articles of endopod of ThII to IV; very large, frontal projection without spur on basipod of male ThVIII; 4 spines on sympod and 2 claws on endopod of uropod; second spine twice as long as the first on furca ……..…….. *V. leclerci* Serban, 1989 [France: Ardèche]

2(1) One seta on second article of AII; medial seta of exopod of AII absent or present; ThIII to V endopod with 3 setae on fourth article; dorsal spine as long as first spine and second spine four times as long as the first on furca …….……..…...……. 3

2' Two setae on second article of AII; medial seta of exopod of AII absent or present; ThI to IV endopod with 4 setae on fourth article; dorsal spine > or < than first spine and second spine 1.5, 2.0 or 2.5 times as long as the first on furca ……..……..…….. 5

3(2) AII exopod with medial seta; exopod > endopod of female ThVIII; large endopod of male ThVIII; 5 or 7 setae on pleopod; 4 similar spines on sympod of uropod; 2 claws on endopod of uropod ….... 4

3' AII exopod without medial seta; exopod >> endopod of female ThVIII; small endopod of male ThVIII; six setae on pleopod; uropod sympod with distal spines longer than other three spines; 3 claws on endopod of uropod ……..…..…… *V. caroloi* Camacho, 2007 [Spain: Cantabria]

4(3) Very large frontal projection of basipod of male ThVIII; exopod of male ThVIII four times longer than wide; 5 setae on pleopod …….. *V. balazuci* Serban & Leclerc, 1984 [France: Ardèche]

4' Male ThVIII basipod with large frontal projection; exopod of male ThVIII three times longer than wide; 7 setae on pleopod ……..…….. *V. espattyensis* Serban & Leclerc, 1984 [France: Ardèche]

5(2') AII exopod with or without medial seta; Md palp with sexual dimorphism; exopod = or >> endopod of female ThVIII; male ThVIII with small outer protuberance; male ThVIII exopod two or three times longer than wide; 4 spines on sympod and 2 or 3 claws on endopod of uropod; dorsal spine > than first spine of furca ……...……. 6

5' AII exopod with medial seta; Md palp without sexual dimorphism; exopod < endopod of female ThVIII; male ThVIII with medium sized outer protuberance; exopod of male ThVIII four times longer than wide; 3 similar spines on sympod and 2 claws on endopod of uropod; dorsal spine < than first spine of furca …….……..... *V. vasconica* Camacho, Dorda & Rey, 2013 [Spain: Vizcaya]

6 (5) Fourth article of AII with one seta and no seta on first article; AII exopod with medial seta; exopod = endopod of female ThVIII; male ThVIII with small frontal projection on basipod and large endopod;

exopod of male ThVIII two times longer than wide; 4 similar spines on sympod and 3 claws on endopod of uropod …… ……. *V. edelweiss* Camacho, 2007 [Spain: Burgos]

6' Fourth article of AII with two setae and one seta on first article; AII exopod without medial seta; exopod >> endopod of female ThVIII; male ThVIII with large frontal projection on basipod and very large endopod; exopod of male ThVIII three times longer than wide; 4 different spines (the basal smallest) on sympod and 2 claws on endopod of uropod …….. *V. pascalis* Camacho, 2007 [Spain: Cantabria]

Key to Parabathynellidae genera

1 Six pairs of thoracopods 2
1' Seven pairs of thoracopods 3

2(1) AI with 6 articles; AII with 5 articles (Fig. 7.8A) ..... *Hexabathynella*
2' AI with 7 articles; AII with 3 articles (Fig. 7.8B) ..... *Hexaiberobathynella*

3(1) AI with 6 or 7 articles; AII with 4 or 5 articles (Fig. 7.8C) ……..... 4
3' AI with 6 or 7 articles; AII with 3 articles (Fig. 7.8D) 5

4(3) AI with 6 articles; AII with 5 articles (Fig. 7.8C); Furca with 3 spines (Fig. 7.8E) ……..…
……..... *Cteniobathynella*
(one species: *Ct. Calmani* (Por, 1968))
[Israel: Tiberias Lake]

4' AI with 7 articles; AII with 4 or 5 articles; furca with 5 or 6 spines (Fig. 7.8F) …….. *Parabathynella*

5(3') AI with 6 or 7 articles; 2 articles on exopod of ThII to V 6
5' AI with 7 articles; 3 or 4 articles on exopod of ThII to V ……..…… *Paraiberobathynella*

6(5) AI with 6 or 7 articles; labrum with hook-like teeth (Fig. 7.8G); claws very curved on distal endite of MxI (Fig. 7.8I) ……..…… *Guadalopebathynella*
(one species: *G. puchi* Camacho & Serban, 1998)
[Spain: Teruel]

6' AI with 7 articles; labrum with "normal teeth" (Fig. 7.8H); "normal claws" on distal endite of MxI (Fig. 7.8J) ……...…..……...…… *Iberobathynella*

Key to species of *Hexabathynella*

1 Md *pars molaris* with 5 or 6 teeth; 4 teeth on distal endite of Mx; 1 or 2 setae on first article of MxII; article fourth of ThI endopod with 2 or 3 setae; first pleopod absent or present; uropod inhomonomous or homonomous with 3 to 7 spines on sympod; uropod with 3 or 4 setae on exopod and 2 or 3 on endopod; 3 or 9 to 13 spines on furca ..……...….. 2

1' Md *pars molaris* with 4 teeth; distal endite of Mx with 5 teeth; one setae on first article of MxII; fourth article of ThI endopod with 3 setae; first pleopod present; 2 spines on sympod of inhomonomous uropod; uropod with 2 setae on exopod and 2 on endopod; 6-7 spines on furca ……

……. *H. knoepffleri* (Coineau, 1964) [France: Corsica]

2(1) Md *pars molaris* with 5 or 6 teeth; 2 setae on first article of MxII; fourth article of ThI endopod with 2 setae; first pleopod absent or present; 6 or 7 spines on inhomonomous or homonomous sympod of uropod; 3 spines on furca ……..…...…….…... 3

2’ Md *pars molaris* with 5 teeth; 1 setae on first article of MxII; fourth article of ThI endopod with three setae; first pleopod present; 3 spines on inhomonomous sympod of uropod; 3 setae on exopod and 3 on endopod of uropod; 9 to 13 spines on furca……..……...… *H. minuta* (Noodt & Galhano, 1969) [Portugal: Barça. Spain: Sevilla]

3(2) Fourth article of AII without seta or 1 seta; Md *pars molaris* with 5 teeth; first pleopod absent; sympod of uropod inhomonomous ……..……..…….. 4

3’ Fourth article of AII with 2 setae; Md *pars molaris* with 6 teeth; first pleopod present; sympod of uropod homonomous; 3 setae on exopod and 2 on endopod of uropod …… ……..…… *H. sevillaensis* Camacho, 2003 [Spain: Sevilla]

4(3) Fourth article of AII with 1 seta; distal spine of Md not modified; second article of MxII with 3 setae; 4 setae on exopod and 3 on endopod of uropod ……..…. *H. valdecasasi* Camacho, 2003 [Spain: Toledo]

4’ Fourth segment of AII without seta; distal spine of Md modified; second segment of MxII with 4 setae; 3 setae on exopod and 2 on endopod of uropod ……... *H. nicoleiana* Camacho, 1986 [Spain: Madrid, Guadalajara]

Key to species of *Hexaiberobathynella*

1 Mandibular palp not exceeding distal part of Md *pars incisiva*; 1 tooth on female ThVIII (Fig. 7.8K); 5 to 8 spines on sympod of uropod; 5 to 8 spines on furca …… *Hi. mateusi* (Galhano, 1967) [Portugal: Coimbra, Barcelos. Spain: Castellón, Granada, Guadalajara, Huesca, Jaén, Madrid, Soria, Teruel, Toledo]

1’ Mandibular palp exceeding distal part of Md *pars incisiva*; 3 teeth on female ThVIII (Fig. 7.8L); 10 to 13 spines on sympod of the uropod; 8 to 10 spines on furca …… …….. *Hi. hortezuelensis* Camacho & Serban, 1998 [Spain: Soria]

Key to species of *Parabathynella*

1 AII with 5 articles; 9 teeth on labrum; 5 teeth on distal endite of MxI; 1 seta on first article of MxII; 2 setae on second and third articles of endopod of ThI; 5 spines on furca …….…… ……..…. *P. motasi* Dancau & Serban, 1973 [Slovenia]

1’ AII with 4 articles; 12 teeth on labrum; 6 teeth on distal endite of MxI; 2 setae on first article of MxII; 3 setae on second and 1 on third article of ThI endopod; 6 spines on furca ……..... *P. stygia* Chappuis, 1926 [Slovenia]

Key to species of *Paraiberobathynella*

1 Labrum with 8 main teeth; Md *pars incisiva* with 6 to 8 teeth; Md *pars molaris* with 6 to 11 teeth; inhomonomous sympod of the uropod; 7 or 8 spines on furca; exopod of ThI with 2 or 3 articles… 2

1’ Labrum with 9 to 11 teeth; Md *pars incisiva* with 5 to 9 teeth; Md *pars molaris* with 12 teeth; homonomous sympod of the uropod; 8 to 12 spines on furca; exopod of ThI, II, VI and VII with 3 articles (Fig. 7.7C), and ThIII to V with 4 articles ……..…. *Pi. notenboomi* (Camacho, 1989) [Spain: Alicante]

2(1) Exopod of ThI, II and VI with 3 articles and 4 on ThIII to VI ……..……..... …….. *Pi. fagei* (Delamare Deboutteville & Angelier, 1950) [France: Le Boulou. Spain: Alicante, Almería, Asturias, Cádiz, Castellón, Gerona, Granada, Huesca, León, Lérida, Málaga, Mallorca, Murcia, Navarra, Orense, Teruel, Valencia]

2’ Exopod of ThI with 2 articles and 3 on ThIII to VII ……..……..…….. ……..…… *Pi. maghrebensis* (Boutin & Coineau, 1987) [Morocco: Marrakech, Nador]

Key to species of *Iberobathynella*

1 Distal endite of MxI with 7 teeth (Fig. 7.8J); 0 or 1 seta on first article on MxII; 1 or 2 articles on exopod of ThI; inhomonomous or homonomous sympod of the uropod ……...…… 2

1’ Distal endite of MxI with 6 teeth (Fig. 7.8M); 0 or 1 seta on first article of MxII; 1 article on exopod of ThI; cuticle of female ThVIII smooth (Fig. 7.8N) or wrinkled (Fig. 7.8P); inhomonomous (Fig. 7.8Q) sympod of the uropod …...……..……. *Iberobathynella* (*Asturibathynella*)

2(1) One seta on first article on MxII; 1 or 2 articles on exopod of ThI; cuticle of female ThVIII smooth or wrinkled ……..…….……..……...……. 3

2’ Zero seta on first article of MxII; 1 article on exopod of ThI; cuticle of female ThVIII smooth ……...…….……..……. *I. pedroi* Camacho, 2003 [Portugal: Coimbra]

3(2) First article of ThII to VII endopod without dorsal seta; 2 setae on first article of ThII to VII exopod; 2 or 3 setae on second article of ThI endopod; 1 or 2 articles on ThI exopod; cuticle of female ThVIII smooth (Fig. 7.8R) or wrinkled (Fig. 7.8S); (Fig. 7.8T) uropod sympod inhomonomous or homonomous; 4 to 6 setae on exopod and 0, 1 or 3 on endopod of uropod …… ……..….. *Iberobathynella* (*Espanobathynella*)

3’ First article of ThII to VII endopod with 1 dorsal seta; 3 setae on first article of ThII to VII exopod; 3 setae on second article of ThI endopod; ThI exopod with 2 articles; cuticle of female ThVIII smooth (Fig. 7.8U); uropod sympod homonomous (Fig. 7.8V); 4 to 8 setae on exopod and 3 on endopod of uropod ……...… *Iberobathynella* (*Iberobathynella*)

Key to species of *Iberobathynella* (*Asturibathynella*)

1 AI with 6 articles……..…...……..…….. 2

1’ AI with 7 articles ……..…..……..…… 3

2(1) First article of MxII with 1 seta; first article of ThI endopod with 2 setae; cuticle of female ThVIII smooth; 5 spines on sympod of uropod; 5 setae on exopod and 3 on endopod of uropod ……..…….. *I.* (*A*) *celiana* Camacho, 2003 [Spain: Sevilla]

2’ First article of MxII without seta; first article of ThI endopod with 1 seta; cuticle of female ThVIII wrinkled; 9 spines on sympod of uropod; 4 setae on exopod and 2 on endopod of uropod ……....…… *I.* (*A*) *guarenensis* Camacho, 2003 [Spain: Burgos]

3(1’) First article of MxII with 1 seta; first article of ThI endopod with 2 setae; cuticle of female ThVIII smooth or wrinkled; anal operculum protuded or not …….....……. 4

3’ First article of MxII without seta; first article of ThI endopod with 1 or 2 setae; cuticle of female ThVIII smooth or wrinkled; anal operculum protuded ……... 6

4(3) Md *pars molaris* with 7 teeth; Md *pars distales* with 6 or 7 teeth; cuticle of female ThVIII smooth or wrinkled; 7 or 8 spines on sympod of uropod; 4 or 5 setae on exopod and 1 or 3 on endopod of uropod; 6 to 10 spines on furca; anal operculum not protuded ……..…… 5

4’ Md *pars molaris* with 5 teeth; Md *pars distales* with 4 teeth; cuticle of female ThVIII smooth; 6 spines on sympod of uropod; 5 setae on exopod and no seta on endopod of uropod; 5 spines on furca; anal operculum protuded …… *I.* (*A*) *cornejoensis* Camacho, 2005 [Spain: Burgos]

5(4) Md *pars distalis* with 7 teeth; cuticle of female ThVIII wrinkled; 7 spines on sympod of uropod; 4 setae on exopod and 3 on endopod of uropod; 7 to 10 spines on furca ..……..... *I.* (*A*) *rouchi* Camacho & Coineau, 1987 [Spain: Teruel, Huesca]

5’ Md *pars distalis* with 6 teeth; cuticle of female ThVIII smooth; 8 spines on sympod of uropod; 5 setae on exopod and 1 on endopod of uropod; 6 or 7 spines on furca ……. ……..…….. *I.* (*A*) *imuniensis* Camacho, 1987 [Spain: Álava, Asturias, Burgos, Cantabria, Huesca]

6(3’) Md *pars molaris* with 6 to 7 teeth, *pars distalis* with 5 to 7 teeth; first article of ThI endopod with 1 setae; cuticle of female ThVIII wrinkled or smooth; 5 to 9 spines on sympod of uropod; 3 or 4 setae on exopod and 1 or 2 on endopod of uropod ……..……..……..... 7

6’ Md *pars molaris* with 5 teeth, *pars distales* with 4 teeth; first article of ThI endopod with two setae; cuticle of female ThVIII wrinkled; 9 or 10 spines on sympod of uropod; 4 setae on exopod and 2 on endopod of uropod …… *I.* (*A*) *parasturiensis* Camacho & Serban, 1998 [Spain: Asturias, Cantabria]

7(6) Md *pars molaris* with 7 teeth, *pars distalis* with 5 to 7 teeth; cuticle of female ThVIII smooth or wrinkled; 5 to 7 spines on sympod of uropod; 3 or 4 setae on exopod and 2 on endopod of uropod ……..……...…….……... 8

7’ Md *pars molaris* with 6 teeth, *pars distalis* with 5 teeth; cuticle of female ThVIII smooth or wrinkled; 5 to 9 spines on sympod of uropod; 3 or 4 setae on exopod and one or two on endopod of uropod ……...……...……...……. 9

8(7) Cuticle of female ThVIII wrinkled; setules on distal end of inner lobe of male ThVIII present; 6 to 7 spines on sympod of uropod; 4 setae on exopod and 2 on endopod of uropod ……. ……... *I.* (*A*) *asturiensis* Serban & Comas, 1978 [Spain: Asturias, Cantabria, León]

8’ Cuticle of female ThVIII smooth; distal part of inner lobe of male ThVIII without setules; 5 to 6 spines on sympod of uropod; 3 setae on exopod and 2 on endopod of uropod …… ……..……... *I.* (*A*) *cavadoensis* (Noodt & Galhano, 1969) [Portugal: Barcelos. Spain: León, Pontevedra]

9(7’) Cuticle of female ThVIII smooth; 5 to 7 spines on sympod of uropod; 3 or 4 setae on exopod and 1 or 2 on endopod of uropod …….....…….…...…….... 10

9’ Cuticle of female ThVIII wrinkled; 9 spines on sympod of uropod; 4 setae on exopod and 2 on endopod of uropod ……..… *I.* (*A*) *lamasonensis* Camacho, 2005 [Spain: Cantabria]

10(9) Five spines on sympod of uropod; 4 setae on exopod and 2 on endopod of uropod ……..……..…. *I.* (*A*) *ortizi* Camacho, 1989 [Spain: Lugo]

10’ Seven spines on sympod of uropod; 3 setae on exopod and 1 on endopod of uropod ……..……... *I.* (*A*) *serbani* Camacho, 2003 [Portugal: Oporto]

Key to species of *Iberobathynella* (*Espanobathynella*)

1 ThII to VII exopod with 2 articles; ThI with 1 or 2 articles; ThI endopod with 2 or 3 setae on second article; setules on distal part of inner lobe of male ThVIII present or absent; cuticle of female ThVIII smooth or wrinkled; sympod of uropod inhomonomous or homonomous …..... 2

1’ ThII, III and VI, VII exopod with 2 articles and ThIV and V exopod with 3 articles; ThI exopod with 2 articles; second article of ThI endopod with 3 setae; no setules on distal part of male ThVIII inner lobe; cuticle of female ThVIII smooth; 12 or 13 spines on homonomous sympod, 6 setae on exopod and 1 seta on endopod of uropod ……... *I.* (*E*) *magna* Camacho & Serban, 1998 [Spain: Asturias, Cantabria]

2(1) Uropod with sympod inhomonomous; 1 or 2 articles on exopod of ThI; 3 setae on second article of ThI endopod; cuticle of female ThVIII smooth; anal operculum not pronounced ……. 3

2’ Sympod of the uropod homonomous; 1 or 2 articles on exopod of ThI; second article of ThI endopod with 2 setae; cuticle of female ThVIII smooth or wrinkled; anal operculum pronounced or not ……..……..……... 4

3(2) ThI exopod with 2 articles; setules on distal part of male ThVIII inner lobe present; 5 or 6 setae on exopod and 1 seta on endopod of uropod; anal operculum not pronounced ……...…

..…….. *I.* (*E*) *espaniensis* Serban & Comas, 1978
[Spain: Asturias, Guadalajara]

3’ ThI exopod with 1 article; no setules on distal part of male ThVIII inner lobe; 5 setae on exopod and 3 setae on endopod of uropod; anal operculum pronounced …… *I.* (*E*) *andalusica* Camacho, 2007
[Spain: Córdoba, Sevilla]

4(2’) ThI exopod with 1 article; cuticle of female ThVIII smooth; 7 to 9 spines on sympod, 5 setae on exopod and 1 seta on endopod of uropod ……. *I.* (*E*) *cantabriensis* Camacho & Serban, 1998
[Spain: Asturias, Cantabria]

4’ ThI exopod with 2 articles; cuticle of female ThVIII wrinkled; 10-12 spines on sympod, 4 setae on exopod and no seta on endopod of uropod ……...… *I.* (*E*) *burgalensis* Camacho, 2005
[Spain: Burgos]

Key to species of *Iberobathynella* (*Iberobathynella*)

1 Md *pars incisiva* with 9 to 12 teeth, *pars molaris* with 6 to 16 teeth; 2 or 3 setae on first article of ThI exopod; 9 to 27 spines on sympod, 5 setae on exopod and 3 seta on endopod of uropod ……..... 2

1’ Md *pars incisiva* with 6 teeth, *pars molaris* with 10 teeth; 2 setae on first article of ThI exopod; 12 or 13 spines on sympod, 6 to 8 setae on exopod and 3 setae on endopod of uropod ……
……..……...… *I.* (*I*) *valbonensis* (Noodt & Galhano, 1969)
[Portugal: Areinho de Valbom, Spain: Salamanca]

2 (1) Md *pars incisiva* with 7 or 8 teeth, *pars molaris* with 6 to 10 teeth; 2 or 3 setae on first article of ThI exopod; 9 to 12 spines on sympod of uropod …...……...……..…….. 3

2’ Md *pars incisiva* with 7 to 12 teeth, *pars molaris* with 8 to 16 teeth; 3 setae on first article of ThI exopod; 16 to 27 spines on sympod of uropod ……..……..…….... 4

3 (2) First article of ThI exopod with 2 setae; Md *pars incisiva* with 7 teeth, *pars molaris* with 6 to 8 teeth; 9 to 12 spines on sympod of uropod; 9 to 13 spines on furca …….....
..... *I.* (*I*) *lusitanica* (Braga, 1949)
[Portugal: Porto]

3’ First article of ThI exopod with 3 setae; Md *pars incisiva* with 7 or 8 teeth, *pars molaris* with 8 to 10 teeth; 9 to 11 spines on sympod of uropod; 10 spines on furca …….....
..... *I.* (*I*) *barcelensis* (Galhano, 1970)
[Portugal: Barcelos]

4 (2) First article of ThVI exopod with 3 setae; Md *pars incisiva* with 10 teeth, *pars molaris* with 8 to 10 teeth; 16 to 19 spines on sympod of uropod; 6 or 7 spines on furca ……..... *I.* (*I*) *gracilipes* (Braga, 1960)
[Portugal: Beira-Baixa]

4’ First article of ThVI exopod with 2 setae; Md *pars incisiva* with 9 to 12 teeth, *pars molaris* with 8 to 16 teeth; 18 to 27 spines on sympod of uropod; 9 to 12 spines on furca …….....
..... *I.* (*I*) *paragracilipes* Camacho & Serban, 1998
[Spain: Huelva]

REFERENCES

Camacho, A.I. 2019. Diversity, morphological homogeneity and genetic divergence in a taxonomically complex group of groundwater crustaceans: the little known Bathynellacea (Malacostraca). Bulletin de la Société d'Histoire Naturelle de Toulouse 154: 105–160.

Camacho, A.I., B.A. Dorda & I. Rey. 2011. Identifying cryptic speciation across groundwater populations: first COI sequences of Bathynellidae (Crustacea, Syncarida). Graellsia 67: 7–12.

Camacho, A.I., P. Mas-Peinado, S. Watiroyram, A. Brancelj, E. Bandari, B.A. Dorda, A. Casado & I. Rey. 2018. Molecular phylogeny of Parabathynellidae (Crustacea, Bathynellacea) and three new species from Thai caves. Contributions to Zoology 87 (4): 227–260.

Camacho, A.I., P. Mas-Peinado, S. Iepure, G. Perina, B.A. Dorda, A. Casado & I. Rey. 2020. Novel sexual dimorphism in a new genus of Bathynellidae from Russia, with a revision of phylogenetic relationships. Zoologica Scripta 49: 47–63.

Camacho, A.I., P. Mas-Peinado, Y. Ranga Reddy, E. Bandari, S. Shaik, G. Perina, B.A. Dorda, A. Casado & I. Rey. 2021. An integrated approach to re-evaluate the validity of the family Leptobathynellidae (Crustacea, Bathynellacea). Zoological Journal of the Linnean Society XX: 1–43. doi/10.1093/zoolinnean/zlaa121/6144087.

Coineau, N. & A.I. Camacho. 2013. *Superorder Syncarida Packard, 1885*. Pages 357–449 *in*: J.C. von Vaupel Klein, M. Charmantier-Daures & F.R. Schram, (eds), Treatise on Zoology-Anatomy, Taxonomy, Biology. The Crustacea. Traité de Zoologie, Vol. 4 part A. Koninklijke Brill, Leiden, Netherland.

Malard, F., M.-J. Dole-Olivier, J. Mathieu, & F. Stoch, 2002. Sampling Manual for the Assessment of Regional Groundwater Biodiversity. Report of the European Project Pascalis. 110 pp.

Perina, G. & A.I. Camacho, 2016. Permanent slides for morphological studies of small crustaceans: Serban's method and its variation applied on Bathynellacea (Malacostraca). Crustaceana 89(10): 1161–1173.

Schminke, H.K. 1973. Evolution, System und Verbreitungsgeschichte der Familie Parabathynellidae (Bathynellacea, Malacostraca). Akademie der Wissenschaften und der Literatur Mainz, Mathematisch-Naturwissenschaftliche Klasse, Mikrofauna des Meeresbodens 24: 1-192.

Schminke, H.K. 1981. Adaptation of Bathynellacea (Crustacea, Syncarida) to life in the Interstitial ('Zoea Theory'). International Revue Ges. Hydrobiologie Hydrographie 66**:** 575–637.

Schminke, H.K. 2011. Arthropoda: Crustacea: Malacostraca: Bathynellacea: Parabathynellidae. In: Flora and Fauna of Korea. Invertebrate Fauna of the World. National Institute of Biological Resources, Ministry of Environment, Republic of Korea V 21(1): 1–244.

Schram, F. 1984. Fossil Syncarida. Transaction San Diego Society Natural History 20: 189–246.

Serban, E. 1972. Bathynella (Podophallocarida, Bathynellacea). Travaux de l'Institut de Spéologie "Émile Racovitza" 11: 11–225.

Serban, E., N. Coineau & C. Delamare Deboutteville. 1972. Recherches sur les Crustacés souterrains et mésopsammiques. I. Les Bathynellacés (Malacostraca) des régions méridionales de l'Europe occidentale. La sous-famille des Gallobathynellinae. Mémoires du Muséum National d'Histoire Naturelle, sér. A, zoologie 75: 1–107.

4. Malacostraca: Decapoda

Magdalini Christodoulou

German Centre for Marine Biodiversity Research (DZMB), Senckenberg am Meer, Südstrand 44, 26382 Wilhelmshaven, Germany
magdalini.christodoulou@senckenberg.de

INTRODUCTION

Decapoda Latreille 1802 is the most species-rich order within Malacostraca with nearly 15,000 species (De Grave *et al*., 2009). The order includes many familiar groups such as crabs, shrimps, crayfish, lobsters and hermit crabs that live in an impressive diversity of marine, freshwater, subterranean and terrestrial habitats. The majority of decapod species are found in marine habitats, whereas approximately 3,000 species live exclusively in freshwater habitats on almost all continents (Cumberlidge *et al.*, 2015). These include over 1,450 species of brachyuran crabs (Cumberlidge *et al.*, 2015), about 800 species and subspecies of caridean and sergestoid shrimps (De Grave *et al*., 2015), around 669 species of crayfish (Crandall & De Grave, 2017) and 75 species of anomuran crabs (Cumberlidge *et al.*, 2015; Bueno *et al.*, 2016).
Freshwater crabs have a circumtropical distribution restricted to warm habitats covering five zoogeographical regions, from the Neotropical region to the Australasian region (Cumberlidge *et al.*, 2015). Evolutionary studies suggest that freshwater crabs diverged early in the brachyuran phylogenetic tree. They are thought to have at least two independent origins, with four of the five freshwater crab families sharing common ancestry (Klaus *et al*., 2011; Tsang *et al*., 2014). Freshwater crabs are estimated to have diverged from their closest marine sister taxa after the break-up of Pangaea (~200 Mya), around 135 Mya (Tsang *et al*., 2014). Although the origin of Mediterranean crabs (*Potamon* spp.) still remains unknown, their species diversity argues in favor of an East Asian origin (Jesse *et al.*, 2011). Freshwater crayfish and anomuran crabs are distributed in temperate parts of the two hemispheres (Cumberlidge *et al.*, 2015; Bueno *et al.*, 2016). The oldest crayfish fossils date back to the Permian and early Triassic periods, suggesting a widespread Pangaea distribution followed by a number of vicariance events that allowed the ancient crayfish population to diversify and spread throughout the continents of Laurasia and Gondwana (Crandall *et al*., 2000; Cumberlidge *et al.*, 2015). Freshwater anomuran crabs, which mostly include *Aegla* species, seem to have a more recent origin – the early Tertiary period, about 60 Mya (Pérez-Losada *et al*., 2004). Finally, freshwater shrimps occur in both tropical and temperate freshwater habitats. Phylogenetic studies have shown a distant affinity among freshwater shrimp families implying that each family independently invaded continental and subterranean waters from an ancestral marine stock at different times (De Grave *et al*., 2008). The Mediterranean basin was colonized through multiple ancient transoceanic dispersal or vicariance events (von Rintelen *et al*., 2012; Carvalho *et al*., 2016).

Three groups of freshwater decapods are found in the Mediterranean basin, namely crabs, shrimps, and crayfish. They belong to six families, 15 genera and 63 species (1 family, 3 genera and 3 species are non-native), representing about 2.1% of global diversity; most species are endemic to the region.

GENERAL ECOLOGY AND DISTRIBUTION

Freshwater decapods successfully colonized a very diverse array of epigean and hypogean freshwater habitats reflected by a wide range of life histories as well as morphological and physiological adaptations. Because of their abundance and high biomass, they are integral components of food webs, represent a food source for a wide range of predators and play an important role in nutrient recycling in freshwater ecosystems (Cumberlidge *et al.*, 2015; De Grave *et al*., 2015).

A rich and highly endemic decapod fauna is found in the freshwater habitats of all countries and most islands of the Mediterranean basin (Jesse *et al.*, 2011; Kouba *et al*., 2014; Christodoulou *et al*., 2016). Their diversity comprises six families (15 genera, 63 species and subspecies) in this region. The freshwater crab family Potamidae (1 genus, 15 species) is found in the surface waters of North Africa and the eastern Mediterranean basin (Brandis *et al*., 2000; Jesse *et al*., 2011). Crayfish are represented in the Mediterranean basin by one native family – Astacidae (4 genera, 7 species) – and one non-native family – Cambaridae (2 genera, 2 species). Native crayfish species are distributed in the northern Mediterranean basin but are absent from continental North Africa (Kouba *et al*., 2014; Cumberlidge *et al.*, 2015). The distribution of crayfish in the Mediterranean basin has been under great anthropogenic influence, resulting in three invasive species currently found in the western Mediterranean region, while numerous translocations of the native species took place across Europe (Kouba *et al*., 2014). The largest shrimp family is Atyidae (6 genera, 26 species and subspecies) with representatives in epigean and subterranean systems throughout the Mediterranean basin (Christodoulou *et al*., 2016), while Palaemonidae (1 genus, 9 species) are restricted to epigean systems throughout the basin (Christodoulou *et al*., 2016). Both families occur in all biogeographical regions, except Antarctica, but are most diverse in the Indo-Malayan region where the majority of palaemonid species live in marine and brackish waters whereas Atyidae almost exclusively live in freshwater (De Grave *et al*., 2015). The areas immediately surrounding the Mediterranean Sea harbour the world highest stygobiotic species diversity within Atyidae (16 species and subspecies) (Sket & Zakšek 2009; Christodoulou *et al*., 2016). Finally, Typhlocarididae (1 genus, 4 species) are strictly subterranean and are the only endemic decapod family in the basin (Christodoulou *et al*., 2016), with species distributed in Israel, Italy and Libya.

TERMINOLOGY AND MORPHOLOGY

Decapods exhibit a great variability in size and body form. Their size in freshwaters can vary from 1.0 cm for the bee shrimp (*Caridina cantonensis*) to more than 80 cm and 6 kg for some of the largest and heaviest freshwater invertebrates such as Tasmanian giant crayfish (*Astacopsis gouldi*). Mediterranean basin decapods are small- to medium-sized, from about 2 cm (e.g. *Atyaephyra orientalis*) to about 20 cm (e.g. *Pontastacus leptodactylus*).

The general decapod body is composed of a head, thorax, and abdomen (Fig. 7.9). The body is compressed laterally in shrimps, compressed dorsoventrally in crayfish, but strongly depressed and flattened in brachyuran crabs. The first three of the eight thoracic segments of shrimps, crayfish, and crabs are fused with the head to form a cephalothorax covered by a shield – the carapace that extends over the whole head and thorax. The carapace extends laterally along the sides of the cephalothorax forming branchial chambers that enclose the gills.

The anterior part of the cephalothorax (head) carries a pair of compound stalked eyes, two pairs of antennae (antenna and antennula), and three pairs of mouth parts (mandible, maxillula, maxilla). The carapace of freshwater shrimps, crayfish and aeglids (not present in the Mediterranean basin) protrudes between the eyes and forms a rostrum, while it forms a front

in freshwater crabs. The carapace can be ornamented with various spines, grooves and depressions. The first three abdominal segments bear three pairs of maxillipeds – specialized appendages for feeding and locomotion. The next abdominal segments bear five pairs of pereiopods (ambulatory legs) modified either as walking legs or as chelate limbs (equipped with pinchers or setal brushes) termed chelipeds. In crayfish, the first three pairs of pereiopods are chelate, while in caridean shrimps only the first two pairs are chelate and in brachyuran crabs only the first pair is chelate. The name of the group Decapoda (=ten legs) derives from the presence of ten pereiopods. The pereiopods have the typical biramous form of a crustacean limb composed from their proximal-most end to their distal-most end of a protopod with two podomeres (basis and coxa), an endopod with five podomeres (ischium, merus, carpus, propodus and dactylus), and an exopod that can be fully developed, vestigial or absent. A small process – the epipod – and multidenticulate setae – setobranch setae – can be present on coxae.

The abdomen (pleon) follows the thorax. It is folded beneath the body in crabs, or extends posteriorly in shrimps and crayfish. Pleopods, modified for swimming, brooding eggs, ventilation and burrowing appendages extend in pairs from the first five abdominal segments. The abdomen terminates in a telson, with a uropod on each side. Both the pleopods and the uropods are biramous, composed of a basal peduncle bearing two branches – the endopod and the exopod. The first two pleopods are sexually modified in male decapods.

COLLECTION, PREPARATION, AND IDENTIFICATION

Freshwater decapods are found in lotic, lentic, and subterranean environments. Different sampling methods are utilized depending on the species and the habitat. The freshwater shrimps that dwell in epigean waters are usually collected using strong, long-handled, fine-meshed dip nets, while dredges, seine nets and sweep net electrofishing have also been reported as sampling techniques. In subterranean habitats, shrimps are caught with baited (e.g. with strips of raw beef) traps or by hand or with short hand nets and torchlight to illuminate the animals while scuba diving (Jaume & Brehier, 2005). Freshwater crayfish in shallow waters are collected by hand by turning rocks over. A dip net can be used in deeper waters while snorkeling or scuba diving, and seine nets or fyke nets can be used too. Finally, baited wire traps have proven especially efficient in deeper waters, especially at night. Crabs can be caught during the day by turning flat rocks over in rivers and streams. In deeper waters, baited traps or fyke nets can be used.

After collection, shrimps, crayfish, and crabs should be preserved in 70% ethanol for morphological analyses and in 95% ethanol for molecular analyses. Mediterranean decapods can be identified under a stereomicroscope down to the genus level. However, determination at the species level most often requires dissection and mounting of the mouthparts and appendages on slides and examination using a microscope (10x-40x magnification). Specimens or body parts can be dyed using different stains or cleared by submersion in weak acid (HCl, chlorine). The morphological identification of shrimps at the species level requires adult individuals; as for freshwater crabs, only males can be identified at the species level. Key morphological characteristics include among others rostrum armature, mouthparts, male pleopods, gonopods, telson armature, and pereiopod armature. Once the appendages are dissected, they are kept in smaller vials in the vial containing the specimen. It should be noted that many decapod species of the Mediterranean basin can only be identified with certainty by DNA barcoding (Sket & Zakšek 2009; Jesse *et al*., 2011; Christodoulou *et al*., 2016).

LIMITATIONS

The taxonomy of freshwater decapods in the Mediterranean basin has been somewhat neglected in the past and has only recently grown more stable, as collections include more remote locations and molecular data are taken into account. Furthermore, high intra- and interspecific variability and sexual dimorphism complicate the morphological identification of decapods (Sket & Zakšek 2009; Jugovic *et al*., 2010). Primary and secondary sexual characters in many decapods (Atyidae, Potamidae) are taxonomically important, but these characters are poorly developed in young animals (Sket & Zakšek, 2009; Jugovic *et al*., 2010; Christodoulou *et al*., 2016). Moreover, reliable identification of many species requires examining adult males because characters of taxonomic value have not been observed so far in females (Brandis *et al*., 2000; Jugovic *et al*., 2010). The current increased interest in Mediterranean epigean and hypogean decapods is based on more comprehensive sampling, molecular studies, and *a posteriori* examination of morphological characters that altogether improved taxonomy. Over the past two decades, the number of epigean freshwater shrimp species in the Mediterranean region has more than doubled, although controversies still remain about the precise number of species (e.g., *Atyaephyra* spp.), while new species may well still be awaiting discovery. Likewise, the number of troglobitic species has more than tripled, and more species are still awaiting description (Sket & Zakšek, 2009). Despite the increased interest in Mediterranean epigean and hypogean atyids and the new available methods, the taxonomy of these shrimps still remains unsettled.

A number of Mediterranean decapods are cryptic species. Although they are genetically quite distinct, they appear morphologically identical to other species. Our keys can identify most species, but for some of them the key concludes to a species complex that molecular and geographical data can further distinguish. Finally, the keys are designed for Mediterranean freshwater decapods, they are not adapted for a global use.

KEY TO DECAPODA

Key to Decapoda infraorders

1 Abdomen projecting posteriorly 2

1´Abdomen folded beneath body, tightly pressed to thorax ..... Brachyura, Potamidae [North Africa, Italian and Balkan Peninsulas, Middle East]

2(1) Abdomen laterally compressed; pleuron of second abdominal somite overlapping pleura of second and third somite ..... Caridea [Mediterranean basin]

2´ Abdomen compressed dorsoventrally; pleuron of second somite not overlapping pleura of second and third somite …..…..... Astacidea [Europe]

Key to Potamidae genera and species

This *Potamon* key relies on the morphology of male first gonopod thus not suitable when only female specimens are present (Brandis *et al.* 2000). The key includes a total number of 15 species presented in Brandis *et al*. (2000) and Jesse *et al.* (2010, 2011). Four cryptic species exist within the genus where no morphological characters have been found yet to distinguish them and COI gene nucleic acid sequence differences are required to distinguish them to species level (*).

1 Terminal article of first gonopod broad, more or less oval; mesial portion distinctly tumid; apex long and slightly curve 2

1´ Terminal article of first gonopod conical or slender; mesial part not tumid 3

2(1) Flexible zone of first gonopod V-shaped ..... …… *Potamon fluviatile* (Herbst, 1785) species complex (*Potamon fluviatile*, *Potamon pelops**)
[Albania, Croatia, Greece, Italy, Macedonia, Malta, Montenegro]

2´ Flexible zone of first gonopod distinctly bilobed ..... *Potamon algeriense* Bott, 1967
[Algeria, Morocco, Tunisia]

3(1') First gonopod with conical, cylindrical or triangular terminal article 4

3' First gonopod with very slender and elongated fusiform terminal article; flexible zone of first gonopod broad or only narrowed only in its lateral part ..... ……..…….. *Potamon ibericum* (Bieberstein, 1809) species complex (*P. ibericum*, *P. kretaion**)
[Greece, Turkey]

4(3) Terminal article of first gonopod elongated and conical, mesial edge slightly bulging 5

4´ Terminal article of first gonopod stout and triangular; subterminal part with projecting mesial edge ……..…..... 8

5(4) Flexible zone of first gonopod flexible not symmetrically bilobed 6

5´ Flexible zone of first gonopod symmetrically bilobed ..... ……..…….. *Potamon potamios* (Olivier, 1804) species complex (*P. hippocratis*, *P. karpathos*, *P. potamios**)
[Cyprus, Greece, Israel, Turkey]

6(5) Flexible zone of first gonopod not distinctly V-shaped 7

6´ Flexible zone of first gonopod distinctly V-shaped ..... *Potamon rhodium* Parisi, 1913
[Greece, Turkey]

7(6) Flexible zone of first gonopod with only one linguiform elongate lobe .... *Potamon setigerum* Rathbun, 1904 [Lebanon, Syria, Turkey]

7´ Flexible zone of first gonopod slender, terminal article subcylindrical and narrow ……..... ..... *Potamon bileki* Pretzmann, 1971 [Turkey]

8(4) Flexible zone of first gonopod V-shaped or with one mesial or lateral lobe 9

8’ Flexible zone of first gonopod bilobed; terminal article of first gonopod asymmetric in shape, mesial margin bulging in its proximal half ……..... *Potamon magnum* Pretzmann, 1962 [Turkey]

9(8) Flexible zone of first gonopod distinctly V-shaped 10

9´ Flexible zone of first gonopod with one lateral located linguiform elongated lobe; subterminal part of first gonopod with low mesial edge ……. ……..... *Potamon hueceste* Pretzmann, 1962 [Turkey]

10(9) Terminal article of first gonopod almost triangular; anterolateral margin of carapace broad, serrated with unequally large teeth ……..... ……. *Potamon mesopotamicum* Brandis, Storch & Türkay, 1998 [Syria, Turkey]

10´ Terminal article of first gonopod proximal half with straight mesial margins, in distal half becoming sharply deflected; anterolateral margin of carapace narrow serrated with very small regular teeth ..... *Potamon persicum* Pretzmann, 1962 [Turkey]

Key to Caridea families

1 First and second pereopod with chelae fingers lacking dense apical setal tufts …..... 2

1´ First and second pereopod with chelae bearing dense apical setal tufts ……..... Atyidae [peri-mediterranean]

2(1) Carapace lacking longitudinal sutures; flagellum of first antenna with rami fused basally .. .. Palaemonidae, *Palaemon* [peri-mediterranean]

2´ Carapace bearing pair of straight, longitudinal, dorsolateral sutures; cavernicolous …..... ..... Typhlocaridae, *Typhlocaris* [Israel, Italy, Tunisia]

Key to Atyidae genera

1 At least first three pereiopods bearing exopods 2

1' Only first and second pereiopods bearing exopods ..... *Atyaephyra*
[Peri-Mediterranean]

2(1) Appendix masculina of male second pleopod bearing spines longer than appendix diameter ……... 3

2´ Appendix masculina of male second pleopod bearing spines much shorter than appendix diameter ……..…….…….……... 5

3(2) Supraorbital spines on carapace present; exopods of fifth pereiopods absent or reduced .....
……..…… 4

3' Supraorbital spines on carapace absent; exopod of fifth pereiopods well developed ...…….....
…….…… *Typhlatya*
[France, Spain]

4(3) Eyes reduced, pigment absent; pterygostomian spine absent; rostrum short unarmed; dactylus of fifth pereiopod with less than 10 spiniform spines ..... *Gallocaris*
(one species: *G. inermis* (Fage, 1937))
[France]

4´ Eyes developed and pigmented; pterygostomian spine present; rostrum long and armed; dactylus of fifth pereiopod with more than 10 spiniform spines (comp-like) ..... *Dugastella*
[Morocco, Spain]

5(2') Endopod of male first pleopod as a slightly bent plate, its appendix interna vestigial ….....
…….. *Troglocaris*
[Balkans, Italy]

5´ Endopod of male first pleopod shaped as '9', i.e. with a long, subapically-laterally positioned appendix interna ..... *Spelaeocaris*
[Balkans]

Key to species of *Atyaephyra*

This *Atyaephyra* key it is based on Christodoulou *et al.* (2012) and Jablonska *et al*. (2018) and it refers to individuals of carapace length ≥ 5.0mm (≥ 3.5 mm for *A. orientalis*) but the reader should keep in mind that this genus is still under taxonomic revision. Two cryptic species exist within the genus where no morphological characters have been found yet to distinguish them and COI gene nucleic acid sequence differences are required to distinguish them to species level (*).

1 Propodite of third maxilliped bearing 8–38 (rarely 8) strong mesial spiniform setae …..... 2

1´ Propodite of third maxilliped bearing 0–8 (rarely 8) strong mesial spiniform setae 3

2(1) Endopod terminal part of first male pleopod slender, tapering; merus of third pereiopod with 4–6 (rarely 3–9) spiniform setae; merus of fourth pereiopod with 3–5 (rarely 2–7) spiniform setae 4

2’ Endopod terminal part of first male pleopod broad; merus of third pereiopod with 7–9 (rarely 6–10) spiniform setae; merus of fourth pereiopod with 6–8 (rarely 5–9) spiniform setae .... *Atyaephyra orientalis* Bouvier, 1913 [Israel, Syria, Turkey]

3(1’) Absence of post orbital teeth, leaving an unarmed proximal gap on dorsal surface of rostrum; basal endite of first maxilliped failing to reach or reaching distal end of exopod ..... ……... *Atyaephyra strymonensis* Christodoulou, Antoniou, Magoulas & Koukouras, 2012 [Greece]

3´ Post orbital teeth present without an unarmed proximal gap on dorsal surface of rostrum; basal endite of first maxilliped over-reaching distal end of exopod ……..... .....……. *Atyaephyra desmarestii* (Millet, 1831) species complex (*A. acheronensis*, *A. desmarestii*, *A. tuerkayi*) [Croatia, France, Italy, Montenegro, Portugal, Slovenia, Spain, Greece, Syria]

4(2) Propodite of third maxilliped bearing 16-30 (rarely 11-38) strong mesial spiniform setae ……... 5

4’ Propodite of third maxilliped bearing 9-12 (rarely 8-20) strong mesial spiniform setae ……..... *Atyaephyra vladoi* Jabłońska, Mamos, Zawal & Grabowski, 2018 [Albania, Montenegro]

5(4) Stylocerite length 1.02-1.19 (rarely 0.97-1.19) times first antenullar segment length; fifth pleuron distal end pointed with acute angle ..... ……. *Atyaephyra thyamisensis* Christodoulou, Antoniou, Magoulas & Koukouras, 2013 [Greece: Ipeiros, Ionian Islands]

5´ Stylocerite length 0.82-1.0 (rarely 0.82-1.08) times first antenullar segment length; fifth pleuron distal end rounded, pointed with abtuse angle (rarely with acute) ……..... *Atyaephyra stankoi* Karaman, 1972 [Greece]

Key to species of *Typhlatya*

1 Rostrum scarcely developed, shorter than reduced eye stalks; dactylus of fifth pereopod with row of 36 slender spiniform setae on flexor margin .... *Typhlatya miravetensis* Sanz & Platvoet, 1995 [Spain]

1´ Rostrum length subequal to reduced eye stalks; dactylus of fifth pereopod with row of 19 – 28 stout spiniform setae on flexor margin ..... *Typhlatya arfaea* Jaume & Bréhier, 2005 [France]

Key to species of *Dugastella*

1 Rivers and springs in Morocco ……..... *Dugastella marocana* Bouvier, 1912

1´ Rivers, springs and lagoons in southern Spain ……. ..... *Dugastella valentina* (Ferrer Galdiano, 1924)

Key to species of *Troglocaris*

This *Atyaephyra* key it is based on Sket & Zaksek (2009). Two cryptic species exist within the genus where no morphological characters have been found yet to distinguish them and COI gene nucleic acid sequence differences are required to distinguish them to species level (*).

1 Endopod of male first pleopod with more than 30, partially grouped, and long, inner marginal setae; rostrum with usually 15 ventral teeth ..... *Troglocaris bosnica* Sket & Zakšek, 2009 [Bosnia Herzegovina]

1´ Endopod of male first pleopod with shorter and scarcer marginal setae; rostrum with fewer than ten ventral teeth ……..... *Troglocaris anophthalma* (Kollar, 1848) species complex (*T. anophthalma, T. planinensis**) [Bosnia Herzegovina, Croatia, Italy, Slovenia]

Key to *Spelaeocaris* species

This *Spelaeocaris* key it is based on Sket & Zaksek (2009) with the addition of one more species (*Spelaeocaris hercegovinensis*) according to the genetic study of Marin (2017).

1 Supraorbital spines on carapace absent; pereopod chelae and dactyli very stout 2

1’ Supraorbital spines on carapace present; pereopod chelae and dactyli very narrow ……..... *Spelaeocaris hercegovinensis* (Babić, 1922) [Bosnia Herzegovina, Montenegro]

2(1) Dactylus of fifth pereopod with more than 15 spines, comb-like; at least third and fourth mature male pereopods differentiated ……..... 3

2' Dactylus of fifth pereopod with fewer than 15 spiniform setae, not comb-like; mature male pereopods not differentiated; rostrum reduced, not serrated .... *Spelaeocaris neglecta* Sket & Zakšek, 2009 [Croatia]

3(2) Rostrum long or very short, but always with dorsal teeth; in mature males, only third and fourth pereopods differentiated; endopod lamina of first male pleopod apically strongly lobate 4

3' Rostrum very short and not serrated; in mature males, apical parts of third, fourth and fifth pereopods widened; endopod lamina of male first pleopod apically and obliquely cut and not (or feebly) lobate ..... *Spelaeocaris pretneri* Matjašič, 1956 [Bosnia Herzegovina, Croatia]

4(3) Appendix masculina of male second pleopod only a slightly longer than appendix interna; in adult males, propodi of third and fourth pereopod only slightly differentiated .... *Spelaeocaris kapelana* Sket & Zakšek, 2009 [Croatia]

4´ Appendix masculina of male second pleopod nearly twice as long as appendix interna; in adult males, propodi of third and fourth pereopod strongly differentiated .... *Spelaeocaris prasence* Sket & Zakšek, 2009 [Bosnia Herzegovina, Montenegro]

Key to species of *Palaemon*

This *Palaemon* key it is based on a recent revision (Tzomos & Koukouras 2015) of the freshwater members of the genus in the Mediterranean basin.

1 Fifth pleuron distal end not rounded 2

1´ Fifth pleuron distal end rounded 7

2(1) Fifth pleuron distal end strongly pointed 3

2´ Fifth pleuron distal end subquadrate and not pointed 6

3(2) Telson posterior margin with two plumose setae; third maxilliped exopod equal or longer than isciomerus; endopod of male first pleopod clearly shorter than exopod; appendix masculina shorter than the endopod of second pleopods 4

3´ Telson posterior margin with 2–6 plumose setae; third maxilliped exopod shorter than isciomerus; endopod of male first pleopod slightly shorter than exopod; appendix masculina longer than the endopod of second pleopod ..... *Palaemon mesogenitor* (Sollaud, 1912) [Algeria, Tunisia]

4(3) Telson plumose setae fail to overpass the inner spiniform setae; first maxilliped endites separated with their inner edges forming an obtuse angle; branchiostegal tooth originating just before anterior margin of carapace 5

4´ Telson plumose setae over pass the inner spiniform setae; first maxilliped endites arranged almost in a straight line forming just a notch between them; branchiostegal tooth marginal ..... *Palaemon varians* Leach, 1814
[Algeria, France, Morocco, Portugal, Spain, Tunisia]

5(4) Telson with 40–50 pairs of marginal lanceolate setae; endopod of male first pleopod deeply concave on the mesial portion of inner margin; endopod of female first pleopod with concave inner margin and rounded tip ..... *Palaemon colossus* Tzomos & Koukouras, 2015
[Greece: Rhodos Island, Turkey]

5´ Telson with 0–6 pairs of marginal lanceolate setae only on its proximal part; endopod of male first pleopod lightly concave on the mesial portion of inner margin; endopod of female first pleopod lanceolate ..... *Palaemon antennarius* H. Milne Edwards, 1837
[Albania, Croatia, Italy, Montenegro, Slovenia, Greece]

6(2') Telson posterior margin with two plumose setae; endopod of male first pleopod almost as long as exopod; appendix masculina longer than the endopod of the male second pleopods …… ..... *Palaemon turcorum* (Holthuis, 1961)
[Turkey]

6´ Telson posterior margin with 4–6 plumose setae; endopod of male first pleopod clearly shorter than the exopod; appendix masculina shorter than the endopod of male second pleopods ..... *Palaemon zariquieyi* (Sollaud, 1938)
[Spain]

7(1') Telson posterior margin with 4–12 plumose setae ……..... 8

7' Telson posterior margin always with two plumose .....
……..…….. *Palaemon minos* Tzomos & Koukouras, 2015
[Greece: Crete Island]

8(7) Telson posterior margin with 10–12 plumose setae; third maxilliped exopod shorter than ischiomerus; outer margin of scaphocerite concave .....
……..……. *Palaemon mesopotamicus* Brandis, Storch & Türkay, 1998
[Syria, Turkey]

8´ Telson posterior margin with 4–7 plumose setae; third maxilliped exopod equal or longer than ischiomerus; outer margin of scaphocerite straight ……
…….. *Palaemon migratorius* (Heller, 1862)
[Egypt]

Key to species of *Typhlocaris*

The genus *Typhlocaris* is in need of a revision as the descriptions of the genus species are based mainly on historical papers and the key characteristics are not well defined.

Key to Astacidea families

For the Astacidea we follow the classification of Crandall & De Grave (2017). The reader should keep in mind that some controversary exist on the status and validity of species which is further complicated with the presence of invasive species and the many human translocations of native species.

1 Ischium of male third and/or fourth pereiopods bearing conical hooks; females with annulus ventrali ……..... Cambaridae

1´ Ischium of male pereiopods not bearing hooks; females lacking annulus ventralis …… ……..... Astacidae

Key to Cambaridae genera and species

1 First pleopod of mature males terminating in two rounded lobes and spiniform structure; females with movable annulus ventralis, not fused anteriorly to sternum ……..... ..... *Procambarus clarkii* (Girard, 1852)
[Invasive: Cyprus, Egypt, France, Israel, Italy, Malta, Morocco, Spain, Tunisia]

1´ First pleopod of mature males terminating in two triangular or elongate lobes; females with annulus ventralis fused anteriorly to sternum ….....*Faxonius limosus* (Rafinesque, 1817)
[Invasive: France, Italy, Spain]

Key to Astacidae genera

1 Telson with transverse suture 2

1´ Telson without transverse suture …….....*Pacifastacus*
(One species: *Pa. leniusculus* (Dana, 1852)
[Invasive in Europe]

2(1) Two pairs of postorbital ridges; first pleopod distal lobes unequal; second pleopod exopodite length subequal to endopod; third maxilliped merus with one medial spine, occasionally also with distal spine 3

2´ Only one pair of postorbital ridges, or (rarely) with extremely reduced second pair; first pleopod distal lobes subequal; second pleopod exopod length distinctly smaller than endopod length; third maxilliped merus typically with medial spine row, rarely with one spine .....*Austropotamobius*
[Europe]

3(2) Second to fourth abdominal somites with pleura bearing acute spines; second pleopod with ventral process (talon) ……..... *Pontastacus* (one species: *Po. Leptodactylus* (Eschscholtz, 1823))
[Bosnia Herzegovina, Croatia, France, Greece, Italy, Turkey]

3´ Second to fourth abdominal somites with pleura rounded or angular, lacking spines, fourth somite with pleura bearing obscure spine or not; second pleopod without ventral process ….. *Astacus*
[Europe]

Key to species of *Austropotamobius*

This *Austropotamobius* key it is based on Souty-Grosset *et al.* (2006) but the reader should keep in mind that this genus is under constant revision. The separation of *A. fulsianus* which was considered a subspecies of *A. pallipes* is not clear. COI gene nucleic acid sequence differences are required to distinguish the two species (*).

1 Area behind cervical groove smooth, cervical spines absent; rostral borders triangle; chelae surface granulation very strong and rough; lower surface of antennal scale with denticulation ..... *Austropotamobius torrentium* (von Paula Schrank, 1803)
[Italian and Balkan Peninsulas]

1´ Area behind cervical groove with cervical spines present; rostral borders triangle or trapezoid; chelae surface granulation small; lower surface of antennal scale with no denticulation ..... *Austropotamobius pallipes* (Lereboullet, 1858) species complex (*A. pallipes*, *A. fulsianus**)

Key to species of *Astacus*

The key of *Astacus* is based on Storobogatov (1996). There is controversy whether *A. balcanicus* is a species or a subspecies of *A. astacus*.

1 Posterior part of telson completely separated from anterior part by a weak furrow; shape of posterior part roundly trapeziform; posterior pair of postorbital ridges with spinules at anterior ends; presence of few acute spines on each side immediately posterior to cervical groove ..... *Astacus balcanicus* (Karaman, 1929)

1´ Posterior part of telson incompletely separated from anterior one by a hardly distinct furrow; shape of posterior part semi-circular; posterior part of postorbital ridges devoid of spinules; presence of only one acute spine (usually) on each side immediately posterior to cervical groove ..... *Astacus astacus* (Linnaeus, 1758)

REFERENCES

Brandis D., V. Storch & M. Türkay. 2000. Taxonomy and zoogeography of the freshwater crabs of Europe, North Africa, and the Middle East (Crustacea, Decapoda, Potamidae). Senckenbergiana Biologica 80(1): 5–56.

Bueno de S.L.S., R.M. Shimizu & J.C.B. Moraes. 2016. A remarkable anomuran: The taxon Aegla Leach, 1820. Taxonomic remarks, distribution, biology, diversity and conservation. Pages 23–64 *in*: T. Kawai & N. Cumberlidge (eds), A Global Overview of the Conservation of Freshwater Decapod Crustaceans. Springer, Cham. https://doi.org/10.1007/978-3-319-42527-62

Carvalho F., S. De Grave & F.L. Mantelatto. 2016. An integrative approach to the evolution of shrimps of the genus *Palaemon* (Decapoda, Palaemonidae). Zoologica Scripta 46(4): 473–485. https://doi.org/10.1111/zsc.12228

Christodoulou M., C. Anastasiadou, J. Jugovic & T. Tzomos. 2016. Freshwater shrimps (Atyidae, Palaemonidae, Typhlocarididae) in the broader Mediterranean region: Distribution, life strategies, threats, conservation, challenges and taxonomic issues. Pages 199–236 *in*: T. Kawai & N. Cumberlidge (eds), A Global Overview of the Conservation of Freshwater Decapod Crustaceans. Springer, Cham. https://doi.org/10.1007/978-3-319-42527-67

Crandall K.A. & S. De Grave. 2017. An updated classification of the freshwater crayfishes (Decapoda: Astacidea) of the world, with a complete species list. Journal of Crustacean Biology 37(5): 615–653. https://doi.org/10.1093/jcbiol/rux070

Crandall K.A., D.J. Harris & J.W. Fetzner Jr. 2000. The monophyletic origin of freshwater crayfish estimated from nuclear and mitochondrial DNA sequences. Proceedings of the Royal Society of London 267: 1679–1686. https://doi.org/10.1098/rspb.2000.1195

Cumberlidge N., H.H. Hobbs & D.M. Lodge. 2015. Chapter 32. Class Malacostraca, Order Decapoda. Pages 797–847 *in*: J. Thorp & D.C. Rogers (eds), Ecology and general Biology: Thorp and Covich's freshwater invertebrates. Academic Press, San Diego, U.S.A. https://doi.org/10.1016/B978-0-12-385026-3.00032-2

De Grave S., Y. Cai & A. Anker. 2008. Global diversity of shrimps (Crustacea: Decapoda: Caridea) in freshwater. Hydrobiologia 595: 287–293. https://doi.org/10.1007/s10750-007-9024-2.

De Grave S., N.D. Pentcheff, S.T. Ahyong, T.-Y Chan, K.A. Crandall, P.C. Dworschak, D.L. Felder, R.M. Feldmann, C.H.J.M. Fransen, L.Y.D. Goulding, R. Lemaitre, M.E.Y. Low, J.W. Martin, P.K.L. Ng, C.E. Schweitzer, S.H. Tan, D. Tshudy & R. Wetzer. 2009. A classification of Recent and fossil genera of decapod crustaceans. Raffles Bulletin of Zoology 21:1–109.

De Grave S., K.G. Smith, N.A. Adeler, D.J. Allen, F. Alvarez, A. Anker, Y. Cai, S.F. Carrizo, W. Klotz, F.L. Mantelatto, T.J. Page, J.-Y. Shy, JL. Villalobos & D. Wowo. 2015. Dead Shrimp Blues: A Global Assessment of Extinction Risk in Freshwater Shrimps (Crustacea: Decapoda: Caridea). PLoS ONE 10: e0120198. https://doi.org/10.1371/journal.pone.0120198

Jablonska A., T. Mamos, A. Zawal & M. Grabowski. 2018. Morphological and molecular evidence for a new shrimp species, *Atyaephyra vladoi* sp. nov. (Decapoda, Atyidae) in the ancient Skadar Lake system, Balkan Peninsula - its evolutionary relationships and demographic history. Zoologischer Anzeiger - A Journal of Comparative Zoology, 275: 66–79. https://doi.org/10.1016/j.jcz.2018.05.004

Jaume D. & F. Bréhier. 2005. A new species of *Typhlatya* (Crustacea: Decapoda: Atyidae) from anchialine caves on the French Mediterranean coast. Zoological Journal of the Linnean Society 144: 387–414. https://doi.org/10.1111/j.1096-3642.2005.00175.x.

Jesse R., M. Grudinski, S. Klaus , B. Streit & M. Pfenninger. 2011. Evolution of freshwater crab diversity in the Aegean region (Crustacea: Brachyura: Potamidae). Molecular Phylogenetics and Evolution 59: 23–33. https://doi.org/10.1016/j.ympev.2010.12.011

Jugovic J., S. Prevorčnik & B. Sket. 2010. Development of sexual characters in the cave shrimp genus *Troglocaris* (Crustacea: Decapoda: Atyidae) and their applicability in taxonomy. Zootaxa 2488: 1–21. https://doi.org/10.5281/zenodo.195554

Klaus S., D.C.J. Yeo & S.T. Ahyong. 2011. Freshwater crab origins - laying Gondwana to rest. Zoologischer Anzeiger 250: 449–456. https://doi.org/10.1016/j.jcz.2011.07.001

Kouba A., A. Petrusek, P. Kozák. 2014. Continental-wide distribution of crayfish species in Europe: update and maps. Knowledge and Management of Aquatic Ecosystems 413: 05. https://doi.org/10.1051/kmae/2014007

Pérez-Losada M., Bond-Buckup G., Jara C.G. & Crandall K.A. (2004). Molecular systematics and biogreography of the southern South American freshwater "crabs" *Aegla* (Decapoda, Anomura, Aeglidae) using multiple heuristic tree search approaches. *Systematic Biology*, **53(5)**, 767–780. https://doi.org/10.1080/10635150490522331

Sket B., V. & Zakšek. 2009. European cave shrimp species (Decapoda: Caridea: Atyidae), redefined after a phylogenetic study; redefinition of some taxa, a new genus and four new *Troglocaris* species. Zoological Journal of the Linnean Society 155: 786–818. https://doi.org/10.1111/j.1096-3642.2008.00473.x.

Souty-Grosset C., D.M. Holdich, P.Y. Noël, J.D. Reynolds & P. Haffner. 2006. Atlas of Crayfish in Europe, Muséum national d'Histoire naturelle, Paris. Patrimoines naturels 64, 187 pp.

Storobogatov Ya.I. 1996. Taxonomy and geographical distribution of crayfishes of Asia and East Europe (Crustacea: Decapoda: Astacoidei). Arthropoda Selecta 4 (3/4): 3–25.

Tsang L.M., C.D. Schubart, S.T. Ahyong, J.C.Y. Lai, E.Y.C. Au, T.-Y. Chan, K.L.P. Ng & K.H. Chu. 2014. Evolutionary History of True Crabs (Crustacea: Decapoda: Brachyura) and the Origin of Freshwater Crabs. Molecular Biology and Evolution 31 (5): 1173–1187. https://doi.org/10.1093/molbev/msu068

Tzomos T. & A. Koukouras. 2015. Redescription of *Palaemon antennarius* H. Milne Edwards, 1837 and *Palaemon migratorius* (Heller, 1862) (Crustacea, Decapoda, Palaemonidae) and description of two new species of the genus from the circum-Mediterranean area. Zootaxa 3905(1): 27–51. https://doi.org/10.11646/zootaxa.3905.1.2

Von Rintelen K., Page T.J., Cai Y., Roe K., Stelbrink B., Kuhajda B.R., Iliffe T.M., Hughes J. & von Rintelen T. (2012). Drawn to the dark side: a molecular phylogeny of freshwater shrimps (Crustacea, Decapoda, Caridea, Atyidae) reveals frequent cave invasions and challenges current taxonomic hypotheses. Molecular Phylogenetics and Evolution 63(1): 82–96. https://doi.org/10.1016/j.ympev.2011.12.015

5. Malacostraca: Ingolfiellida

Christophe Piscart
French National Centre for Scientific Research (CNRS), University of Rennes 1, France
christophe.piscart@univ-rennes1.fr

INTRODUCTION

Since their first discovery by Hansen at the beginning of the 1900's (Hansen, 1903) and until recently, Ingolfiellids had been considered as a suborder of Amphipods. Several authors objected, and Lowry and Myers (2017) proposed to raise Ingolfiellids to the order status only recently, after a large revision of Amphipoda. This Ingolfiellida order is a sister group of Amphipoda characterized by the lack of a carapace and coxal gills and the presence of vestigial pedunculate eyes ("eye-stalks" noticed by Hansen), a pleosome composed of six segments devoid of epimera, and reduced pleopod/uropod appendages.

This small order remains largely unknown and includes only two families – Ingolfiellidae (51 species) and the very rare Metaingolfiellidae (one species) –, among which 20 are present in freshwaters (Horton et al., 2020). Species of this group are known on all continents and confirm that Ingolfiellida is a very old lineage that emerged around the Triassic Pangea (237 Mya) and diversified in interstitial freshwaters before further colonizing brackish and marine environments following evolutionary processes (Vonk and Schram, 2003).

The presence of the sole representative of Metaingolfiellidae – *Metaingolfiella mirabilis* – in Italy and species of the *Ingolfiella* genus with ancestral morphological characteristics (Vonk and Schram, 2003) suggests ancient colonization of the Mediterranean basin by species of this order. The two Ingolfiellida families are present in this region and are represented by 9 species belonging to two genera (*Metaingolfiella* and *Ingolfiella*) that represent 45% of the total number of known freshwater Ingolfiellida.

GENERAL ECOLOGY AND DISTRIBUTION

Their ecology remains almost unknown, and most of the species are know from only one specimen (Vonk and Jaume, 2013). Despite a wide distribution in fresh and marine waters, a few species have a euryhaline distribution, and only *Ingolfiella manni* was observed both in fresh and brackish water environments in Chile.

Despite the small number of known species, Ingolfiellida are one of the most widespread groups in the crustacean world and have colonized an exceptional diversity of groundwaters and interstitial habitats ranging from deep sea water (-3,521 m on the deep sea bottom for *Ingolfiella abyssi*) to the top of mountainous freshwater streams (2,000 m asl. in the Andes Mountains for *Ingolfiella uspallatae*).

All Mediterranean species are distributed among the northern countries located between Spain and Greece. They have been found either in river sediments (*I. catalanensis*, *I. macedonica*, *I. thibaudi* and *I. vandeli*), or in wells (*M. mirabilis*, *I. acherontis*, *I. petkovskii*), and caves (*I. cottarellii*, *I. beatricis*). The distribution of many species is restricted to a very small area, and several species are known only from one river or one well.

TERMINOLOGY AND MORPHOLOGY

Ingolfiellida are small/medium-sized Malacostraca ranging from 1.5 up to 23 mm in length worldwide but less than 2.5 mm in the Mediterranean basin, except *M. mirabilis* which can reach 18.7 mm. Females are generally larger than males (when they are known). Their body is vermiform and adapted to life in interstitial environments such as those of bathynellacean and bogidiellid amphipods. Their body is divided into 13 segments, which can be grouped into the head, the mesosome, the metasome, and the urosome (Fig. 7.10). The cephalothorax is composed of the head fused either with the first segment of the mesosome for Ingolfiellidae or with segments 1 and 2 of the mesosome for Metaingolfiellidae (Fig. 7.10). Their general morphology is similar to that of Amphipoda (cf. section Amphipoda of the book). However, Ingolfiellida differ from Amphipoda by the absence of eyes in all species. A vestigial pedunculate eye can be present is many Ingolfiellid species but is rarely observed in European species. Mouthparts are also similar, but the maxilliped does not have the ischial endite (outer plate). The shape of their gnathopods strongly differs from the shape of Amphipoda gnathopods: the "hand" of their gnathopods is formed by the 5th article (carpus) and the "finger" consists of two articles (propodus and dactyl) instead of one, whereas the "hand" of Amphipoda gnathopods consists of the 6th article (propodus) and the "finger" corresponds to the sole dactyl. Their mesosome also differs by the absence of coxal gills on their pereopods, unsegmented and uniramous pleopods and the absence of epimera on their urosome.

COLLECTION, PREPARATION, AND IDENTIFICATION

Ingolfiellida are distributed worldwide but are very rare locally. In the Mediterranean basin, all species are obligate groundwater species and can be sampled using any kind of sampling method adapted to hypogean species. Several kinds of specific materials (pumps, nets, traps) for this environment can be used (Malard et al., 2002).

Ingolfiellida can be easily fixed and preserved in 70% ethanol or another fixative for morphological analysis, and in 95% ethanol for genetic analysis.

The family and the genera can be identified under a stereomicroscope, but identification at the species level requires dissection, mounting of body parts and appendages on slides, and subsequent examination using a 400x or higher-magnification microscope. Specimens kept in glycerol or ethanol can be handled under a low-power microscope with needles. Glycerol is used as an embedding medium for short-term slides. Baths in clearing solution (e.g. soft acids) or permanent mounting media are only required when depositing museum specimens. The same specimen can be used for both studies: the abdomen for DNA extraction and the other parts for dissection and mounting. This procedure ensures that the sequenced genes correspond to the same morphotype.

Taxonomic identification at the species level is generally possible using males, but only females are known for some species (*I. acherontis*, *I. beatricis*, *I. macedonica*). The most important body parts for identification are the head, mouthparts, gnathopods, pleopods and uropods. Additional body parts need to be examined to identify certain species.

LIMITATIONS

The key below is designed to cover all currently recognized freshwater ingolfiellid species of the Mediterranean basin. Taxonomic synonymy has been updated. Rare records are included,

unless they are insufficiently documented. For example, *Ingolfiella* (*Balchanella*) *acherontis* is included in the key, but it is not clearly described and its identification key should be used with caution. Species-specific secondary sexual characteristics (modified gnathopods or uropod 2, oostegites, etc….), are important for the taxonomy of Ingolfiellida but limited because several species are only known based on one sex (male or female). Another limitation of the key is that most species are only known from a small number of specimens, so that intraspecific variability generally remains unknown.

KEY TO ORDER INGOLFIELLIDA

Key to Amphipoda families

1 Cephalothorax composed of head and first and second segment fused together; uropod 3 peduncles of right and left uropods fused together ……..…… Metaingolfiellidae (one species: *Metaingolfiella mirabilis* (Ruffo, 1969))

1’ Cephalothorax composed of head and first segment fused together; uropod 3 peduncles free ……..... Ingolfiellidae (one genus : *Ingolfiella*)

Key to species of Ingolfiella

1 Cephalic ocular lobes developed ……. 2

1’ Cephalic ocular lobes absent ……. 3

2(1) Gnathopods 1 and 2 with 4 denticles on posterior margin of dactylus ……. ……..…….. *I. beatricis* Ruffo & Vonk, 2001

2’ Gnathopods 1 and 2 with 3 denticles on posterior margin of dactylus ……..….. ……. *I. acherontis* (S. Karaman, 1933)

3(1’) First pereonite (second thoracic segment) free …….…….……...…… 4

3’ First pereonite (second thoracic segment) fused to cephalon ……..... *I. vandeli* Bou, 1970

4(3) Maxilla 1 palp sub-equal to outer lobe, inner lobe with 1 or 2 setae …… … 5

4’Maxilla 1 palp longer than outer lobe, inner lobe with 3 setae …..……..……...… ……. *I. petkovskii* S. Karaman, 1957

5(4) Maxilla 1 inner lobe with 2 setae; gnathopods 1 and 2 with 3 denticles; pleopods 1-3 absent in females ……..…….……..……...……. 6

5’ Maxilla 1 inner lobe with one seta; gnathopods 1 and 2 with 4 denticles on posterior margin of dactylus, pleopods 1-3 present in females ……..…… *I. macedonica* S. Karaman, 1959

6(5) Uropod 1 outer ramus less than half of inner ramus length; uropod 2 longer than uropod 1; pereopod 3-4 claw simple ……..... 7

6’ Uropod 1 outer ramus more than half of inner ramus length; uropod 1-2 sub-equal; pereopod 3-4 claw dentate or bifid ……..…….... *I. catalanensis* Coineau, 1963

7(6) Antenna 1 accessory flagellum hardly longer than the first articles of the flagellum; peduncle uropod 2 with 6-7 rows of setae ..... ……...…….. *I. cottarellii* Ruffo & Vigna Taglianti, 1989

7’ Antenna 1 accessory flagellum longer than the two first articles of the flagellum; peduncle uropod 2 with 5 rows of setae ……..…… *I. thibaudi* Coineau, 1968

REFERENCES

Hansen, H.J. 1903. The Ingolfiellidæ, fam. n., a new Type of Amphipoda. Journal of the Linnean Society of London, Zoology 29: 117–133.

Horton, T., A. Kroh, S. Ahyong, N. Bailly, …, & Z. Zhao. 2020. World Register of Marine Species (WoRMS). WoRMS Editorial Board, http://www.marinespecies.org.

Lowry, J.K. & A.A. Myers. 2017. A Phylogeny and Classification of the Amphipoda with the establishment of the new order Ingolfiellida (Crustacea: Peracarida). Zootaxa 4265: 1–89.

Malard, F., M.-J. Dole-Olivier, J. Mathieu, & F. Stoch. 2002. Sampling Manual for the Assessment of Regional Groundwater Biodiversity. Report of the European Project Pascalis. 110 pp.

Vonk, R., & D. Jaume. 2013. A new ingolfiellid amphipod from sandy beaches of the Gura Ici Islands, Western Halmahera (North Moluccas). The Raffles Bulletin of Zoology 62: 547–560.

Vonk, R., & F.R. Schram. 2003. Ingolfiellidea (Crustacea, Malacostraca, Amphipoda): a phylogenetic and biogeographic analysis. Contributions to Zoology 72: 39–72.

6. Malacostraca: Isopoda

Giuseppe Messana
Istituto di Ricerca sugli Ecosistemi Terrestri (CNR-IRET), Sesto Fiorentino, Firenze, Italy.
giuseppe.messana@cnr.it

Christophe Piscart
French National Centre for Scientific Research (CNRS), University of Rennes 1, France
christophe.piscart@univ-rennes1.fr

INTRODUCTION

Isopoda Latreille, 1817 are a very diverse order both in the number of species and in their morphology. About 10% of all isopods – more than ten thousand described species – live in continental waters, mostly in groundwater (Wilson 2008). They are easily recognizable in the field from their typical dorsally and ventrally flattened body shape, even if some groups of groundwater isopods (e.g. Microcerberidae) differ from this general habitus with a more or less thin and vermiform body.

Biogeographic analysis indicates that isopods, like Amphipoda, were likely widespread in Pangea, Gondwana, and Laurentia (Wilson 2008). Freshwater colonization by isopods likely resulted from successive events, with the oldest events occurring during the Palaeozoic period (540-250 Mya) and involving ancestors of a few Asellota families and the entire suborder Phreatoicidea (not present in the Mediterranean basin nowadays). The most ancient fossil records – *Hesslerella shermani*, a Phreatoicidea – dates back to 307 Mya (Schram, 1970). This hypothesis is congruent with molecular studies suggesting diversification events in freshwaters 400 to 500 Mya (Lins et al., 2012).

Among the 1,000 species described in freshwaters, 336 are present in the Mediterranean basin. The main taxonomic groups are Cirolanidae (8 genera), Asellidae (5 genera), Stenasellidae (5 genera), and Sphaeromatidae (5 genera). A few taxa belonging to Janiridae, Lepidocharontidae, Microcerberidae and Microparasellidae are also present (Boyko et al. 2008).

GENERAL ECOLOGY AND DISTRIBUTION

Mediterranean freshwater isopods inhabit streams, rivers, ponds, lakes, and temporary pools where they can be found on the substrate or in the interstitial systems beneath the river bed (hyporheon). Most of the 299 described species are obligatory inhabitants of groundwaters (stygobionts), found in caves or other habitats where subterranean waters flow through; they are strictly endemic. Some taxa inhabit thermal waters (Rogers & Lewis 2019). Only the epigean genus *Proasellus* (Asellidae) is widely distributed along the entire Mediterranean basin; one species – *P. coxalis* – is represented by various subspecies whose taxonomic rank should be accurately revised.

The suborder Asellota includes the highest number of described freshwater species, mostly in the Asellidae and Stenasellidae families. Out of the five genera composing Stenasellidae, which are all strictly subterranean without any epigean relative, *Stenasellus* has the widest distribution: it is present in the groundwaters of the Far East, Middle East, East Africa and the

western Mediterranean basin, showing a biogeographic pattern linked to the ancient Thetys sea (Henry & Magniez 1983, Messana et al 2019). Some genera are much diversified but geographically restricted, e.g. *Bragasellus* (20 species), *Synasellus* (35 species), both restricted to the Iberian Peninsula. The janirid *Jaera sarsi*, originally from the Ponto-Caspian fauna but widely distributed in Western Europe has been included, even if it is invasive and present only in the largest rivers.

The five genera of the 'Flabellifera' *sensu lato* group (e.g. Cymothoidea and Sphaeromatidea) present in the Mediterranean basin are the result of multiple colonizations of continental groundwater habitats (Thalassostygobionts) during several ancient marine ingressions (Baratti et al. 1999, Wilson 2008). The genus *Sphaeromides* has a north Mediterranean distribution, *Typhlocirolana* a south-western one, while *Turcolana* has an eastern one. *Botolana* and *Moroccolana* are confined to Moroccan groundwaters with a strict relationship with *Typhlocirolana*, while *Faucheria* and *Kensleylana* are found in the groundwaters of southern France and the northern Iberian Peninsula, respectively.

The subterranean taxa are represented by several mostly scavenger or omnivorous taxa, with a carnivorous tendency. Epigean taxa feed on the periphyton or on detritus.

TERMINOLOGY AND MORPHOLOGY

Freshwater taxa include the typical dorso/ventral flattened isopods or narrow-bodied forms, and a few vermiform ones (Fig. 7.11). Adaptations mostly depend on colonized habitats.

Epigean species are variously pigmented, while their subterranean counterparts are unpigmented and whitish. Likewise, eyes are present in the surface species and vary from reduced to completely absent in subterranean species.

The body is composed of three main sections (Fig. 7.12). In epigean taxa, the globular head (cephalon) has a couple of big composed dorso-lateral sessile eyes and two pairs of unramous antennae (A1 and A2); antenna 2 bears a rudimental exopodite (squama) in the more primitive taxa. The mouthpart is on the ventral surface of the head and is composed of the labrum, labium, mandibles, maxillae I and II, and maxilliped. The first thoracic segment is always fused to the cephalon and bears a couple of modified legs (maxillipeds).

The thorax (or pereon) is formed of 7 very similar thoracic metamers (2 to 8) bearing seven pairs of walking legs (pereopods). The first pair is usually modified for grasping in most species. A couple of genital openings are present on the sternal face of pereionite 7 in males (genital papillae) and 6 in females. The abdomen (pleon) has 6 well-developed segments. The first 5 segments are usually free, the sixth one is fused to the telson to form a pleotelson. The 5 couples of appendices (pleopods) are biramous and mostly identical in the two sexes. Their rami have a respiratory and potential swimming role. The second pair of pleopods is modified into a copulatory organ in males (Fig. 7.13), to transfer sperm to the female genital opening. It has a unique construction in each species, and is frequently surrounded by accessory processes. The identification of most Isopoda, particularly Asellota, relies on the examination of this structure. The sixth pair (uropods) is variously modified in the diverse taxa.

Fertilized eggs develop in a ventral marsupium of the female, formed by the imbrication of lamellae originating from the coxopodites of pereiopods: the oostegites. Isopoda have a typical biphasic moulting: the rear part of the body moults before the anterior part.

COLLECTION, PREPARATION, AND PRESERVATION

Collection methods vary depending upon the habitat. For surface and cave species, small hand nets with an appropriate mesh dimension or baited traps can be used. For interstitial hyporheic taxa, the most effective methods are the Bou-Rouch pump and the Karaman-Chappuis method (Malard et al. 2004). Isopods can be easily fixed and preserved in 70% ethanol or another fixative for morphological analysis and in 95% ethanol for molecular analysis. If many specimens are taken, ethanol should be replaced after a few days to prevent dilution by the animal's body water content. For conservation purposes, an ethanol (70/75°) plus a 5% glycerol mix is best suited to avoid articulations hardening, and also avoids accidental desiccation.

Specimens are best examined and viewed under low magnification for family or sometimes genus level identification. Species identification requires dissecting various parts of the body, which can be done by handling the specimen with fine forceps and pins. The simplest procedure consists in transferring the appendages into a drop of glycerin on a microscope slide. To see the fine details in heavily chitinized specimens, a semi-permanent slide with a clearing liquid such as Hoyers medium can be prepared (the slide should stay a few days at 35°C and then the cover should be sealed). Once dissected, the specimen is ready for examination, which may require a magnification of 100/1,000x for detailed examination depending on the size of the specimen. Scanning electron microscopy (SEM) observation is the best examination tool for fine details.

LIMITATIONS

Isopoda are a much diversified group of taxa with almost 1,000 known freshwater species, and many more that remain undescribed. The keys proposed here are designed to cover the four sub-orders, the 8 families and the 33 genera. Oniscidea are not dealt with, although a few aquatic and several amphibious species are present in the Mediterranean basin. Keys at the species level are only provided for genera with a low number of species (usually less than 15). Rare records are included, unless they are insufficiently documented. Taxonomic synonymy has been updated, but taxonomy remains unclear for some genera. However, several cirolanid, sphaeromatid and asellid genera are badly described and need revision. As a consequence, some family, genus and species names may change in the future.

Finally, even if our keys were designed to be as clear as possible, we should never forget that identifying certain groups, especially groundwater species, can be very difficult and requires strong expertise. Do not hesitate to use alternative information or keys to consolidate your conclusions. We should keep in mind that keys, even at the family level, are designed for species of the Mediterranean basin, they are not adapted to other isopods worldwide.

KEYS TO ISOPODA

Key to Isopoda suborders and Families

1 Uropods styliform, inserted terminally on pleotelson ……..…….. 2

1' Uropods lamellar, inserted at pleotelson base …….……. 8

2625
2626 2(1) Antennules normal, or if reduced not minute; pleon variable, with or without fused
2627 pleonites ……..……..……. 3

2628 2’ Antennules vestigial, minute; pleon always of 5 free pleonites, plus the pleotelson ……..
2629 ……...…..…. Oniscidea

2630
2631 3(2) One or two, free pleonites; body length variable; antenna peduncle usually with a scale;
2632 antennule rarely reduced, peduncle and flagellum distinct; maxilliped almost always with
2633 coupling setae on endite; female pleopod 2 uniramous; male pleopod 2 endopod large and
2634 geniculate ……..... 4 (Asellota)

2635 3’ Two long pleonites, and a pleotelson, all cylindrical; body length at least six times width;
2636 antenna peduncle without a scale; antennule reduced, peduncle indistinguishable from
2637 flagellum; maxilliped without coupling setae on endite; female pleopod 2 biramous; male
2638 pleopod 2 endopod not geniculate; interstitial …….….. Microcerberidea
2639 (one family: Microcerberidae)

2640
2641 4(3) Two free pleonites …...……..…..…..…… 5

2642 4’ One or zero free pleonites ……..…… 6

2643
2644 5(4) Antenna 2 with an exopod; pleonite 1 and 2 wide, pronounced in dorsal view; pleopods 2
2645 bi-articulated ……..……..…….. Stenasellidae

2646 5’ Antenna 2 without exopod; pleonite 1 and 2 short and narrow, not pronounced in dorsal view;
2647 pleopods 2 with one article ….……..…….……... Asellidae

2648
2649 6(4’) Pleotelson lateral margins parallel; uropods longer than pleotelson; body elongate, length
2650 at least 6 times width ……..… 7

2651 6’ Pleotelson lateral margins converging; uropods shorter than pleotelson; body broad, length
2652 less than four times width ……..….. Janiridae (one genus: *Jaera*)

2653
2654 7(6) Uropods biramous, large; antennal podomeres shorter than flagellum; rostrum small or
2655 absent ……..……..……..….. Lepidocharontidae (one genus: *Microcharon*)

2656 7’ Uropods uniramous; antennal podomeres longer than flagellym; head with prominent
2657 rostrum ……..……. Microparasellidae

2658
2659 8(1’) Uropods not modified as a ventral operculum ……..... 9

2660 8’ Uropods modified as opercula, covering the entire pleopodal chamber; males with penes
2661 arising on sternum of pleonite 1, or on articulation between pereonite 7 and pleonite 1;
2662 mandibular molar process a stout, flattened grinding structure ..... Valvifera

2663

9(8) Uropods articulating mediolaterally; pleon dorsally with four or five free pleonites plus the pleotelson ..... Cymothoida (one family: Cirolanidae)

9’ Uropods, particularly the peduncle/protopod, articulating dorsoventrally; pleon dorsally with four or fewer free pleonites plus the pleotelson ……
…….....……. Sphaeromatidea (one family: Sphaeromatidae)

Key to Asellidae genera

1 Coxae not obscured by pereonite, visible dorsally ….……..…….…….…… 2

1’ Coxae reduced not visible dorsally ……..……..... *Bragasellus* [Iberian Peninsula]

2 Pleopod 1 peduncles fused at base on at least 20% …….…….... 3

2’ Pleopod 1 peduncles free attached by at least 2 coupling hooks ……..4

3 Mandibular palp absent ……. *Synasellus* [Iberian Peninsula]

3’ Mandibular palp present ……..… *Chthonasellus* (one species: *C. Bodoni* Argano & Messana, 1991) [Italy]

4 Pleopod 2 endopod with basal spur and pronounced basal apophysis ……..… *Asellus* [Europe]

4’ Pleopod 2 endopod without basal spur and without pronounced basal apophysis ……..
……...……. *Proasellus* [Peri-Mediterranean]

Key to species of *Jaera*

1 Maxilliped palp article 2 wider than long; uropod exopodite and endopodite well developed, overlapping more than a half of the propodite ……..……...……. 2

1’ Maxilliped palp article 2 almost as long as wide; uropod exopodite and endopodite minute, not overlapping a half of the propodite width ……...…….. *J. sarsi* Valkanov, 1936

2(1) Pleopod 1 ♂ praeoperculum narrow and pointed ……...…… 3

2’ Pleopod 1 ♂ praeoperculum T-shaped ……..……..…… *J. italica* Kesselyak, 1938

3(2) Pereopods 1 and 7 not sexually dimorphic; pleopods 1 praeoperculum wider at its distal end ..……. *J. schellenbergi* Kesselyak, 1938

3’ Pereopod 1 and 7 sexually dimorphic; pleopods 1 praeoperculum restangular ……
……..…….…… *J. nordmanni* (Rathke, 1837)
(super-species including 3 sub-species *J. n. nordmanni*, *J. n. balearica*, *J. n. brevicaudata* not included in this key)

Key to Microparasellidae genera and species

1 Somite lateral margins with denticles ……..……..……..…… 2 (*Microparasellus*)
[Balkans, Greece, Middle East]

1’ Somite lateral margins smooth …… *Angeliera*
(one species: *A. pheraticola* Chappuis & Delamare-Deboutteville, 1952)
[France, Italy]

2(1) Uropods visible dorsally ……...……...…….. 3

2’ Uropods not visible dorsally ……..… 4

3(2) Pleopod 1 ♂ sub-triangular distally; transverse section of the pleotelson ovoid ……...……
…….…… *M. puteanus* Karaman, 1933

3’ Pleopod 1 ♂ rounded distally; transverse section of the pleotelson sub-circular ……
……..……..…… *M. hellenicus* Argano & Pesce, 1979

4(3’) Lateral expansion of the first thoracic segment lacking; uropods exopodite reduce, scale like ……..……..…… *M. aloufi* Coineau, 1968

4’. Lateral expansion of the first thoracic segment present; uropods exopodite developed ……
...……..…….. *M. libanicus* Chappuis & Delamare-Deboutteville, 1954

Key to Stenasellidae genera and species (except *Stenasellus*)

1 Body thinner than the preceding; uropods longer than 1/3 of Pleotelson ……...…….. 2

1’ Body short, length around 2.5 width; uropods short, less than 1/5 of Pleotelson ……
…….. *Johanella* (one species: *J. purpurea* Monod, 1924)
[Algeria]

2(1) Pleopod 2 endopodite ♂ composed by two article free, the proximal well developed, the distal never jointed on its internal margin …….……..….. 3

2’ Pleopod 2 endopodite ♂ composed by two articles fused, proximal article very small, the distal furrowed …….…… *Metastenasellus* (one species: *M. leysi* Magniez, 1986)
[Algeria]

3(2) Pleopod 1 ♂ propodite subquadrangular and well developed, exopodite flat …… 4

3’ Pleopod 1 ♂ exopodite externally curved ……..…… *Balkanostenasellus* (one species: *B. skopljensis* (Karaman, 1937), super-species including 4 sub-species: *B. s. croaticus, B. s. meridionalis, B. s. skopljensis, B. s. thermalis* not included in this key) [Balkan]

4(3) Pleopod 2 endopodite ♂, distal article as a flat oval lamina, with a similar external appendix; pleopod 1 ♂ sympodite without coupling hooks …… *Magniezia* (one species: *M. gardei* Magniez, 1978) [Morocco]

4’. Pleopod 2 endopodite ♂, distal article long and thin, longitudinally folded with proximally divergent margins, sometimes distally fused; pleopod 1 ♂ sympodite with or without coupling hooks ……..…… *Stenasellus* [Western Europe]

Key to species of Stenasellus

1 Pleopod 2 ♂ endopodite, proximal article of the long and thin ……..……..…....…. 2

1’ Pleopod 2 ♂ endopodite, proximal article short and stubby ……..…… 9

2(1) Pleopod 1 ♂ protopodite without coupling hooks or with simple seta; pleopod 2 ♂ endopodite almost isodiametric with a large and denticulate terminal part; pleopods 4 and 5 exopodites ovoids, larger than endopodite ……...……. 3 (*S. breuili*-group)

2’ Pleopod 1 ♂ protopodite with coupling hooks; pleopod 2 ♂ endopodite, distal article fusoïd with acute apex; distal article of exopodite medially bented and bearing about 15 marginal setae; pleopods 4 and 5 exopodites varying from large and lamellar to thin or styliform …….……..……..……. 7 (*S. virei*-group)

3(2) Pereopod 1 propodite robust …….. 4

3’ Pereopod 1 propodite thin and fragile …….……. *S. bragai* Magniez, 1976

4(3) Pleopod 2 sympodite subquadrangular, endopodite distal article falciform with about 20 sternal setae ……..…….. 5

4’ Pleopod 2 sympodite subpentagonal, endopodite distal article strong with a disto-externak expansion ……...……..…….. 6

5(4) Pereopods 2-7 dactyli with one sternal spine …… *S. escolai* Magniez, 1977

5’ Pereopods 2-7 dactyli with two sternal spines ……..……. *S. magniezi* Escola, 1975

6(4') Pleopod 2 ♂ exopodite subovoid with 7 distal marginal plumose setae, endopodite distal article with a disto-external rounded expansion bearing 4 tiny spines ……. ……. *S. galhanoae* Braga, 1962

6' Pleopod 2 ♂ exopodite rounded with 18 distal marginal plumose setae, endopodite distal article with an external expansion bearing 8 spines and an internal lobe covered by tiny setae ……..…….…… *S. breuili* Racovitza, 1924

7(2') Pleopod 2 ♂ endopodite distal part stretched but not as an elongated beak ……..…..… 8

7' Pleopod 2 ♂ endopodite distal part stretched as an elongated beak …….. *S. builí* Remy, 1949

8(7) Pleopod 5 exopodite large almost totally covering endopodite and distally rounded …….…… *S. racovitzai* Razzauti, 1925

8‘ Pleopod 5 exopodite styliform, 5-6 times longer than large, always thinner than endopodite ……...…….…… *S. virei* Dollfus, 1897

9(1') Pleopod 2 ♂ distal article almost isodiametric, with an obtuse ending and a large terminal orifice, distal external part more or less pointed ……...……. *S. nuragicus* Argano, 1968

9‘ Pleopod 2 ♂ distal article almost isodiametric, with an obtuse ending and a large terminal orifice, distal external part large ……. *S. assorgiai* Argano, 1968

Key de Cirolanidae genera

1 Eyes absent ……..…… 2

1' Eyes minute; body length 5 mm ……..... *Saharolana* (one species: *S. seurati* Monod, 1930) [Tunisia]

2(1) Pleotelson completely fused to pleon; uropods with one terminal ramus; body length ≤ 5 mm ……..…….. 3

2' Pleotelson not as above; five free pleonite; uropods with two terminal rami; body length variable ……..…… 4

3(2) Pleotelson with two sutures visible laterally for the fused segments; uropod peduncle flattened dorsoventrally ……..… *Faucheria* (one species: *F. faucheri* (Dollfus, A. and Viré, A. 1900)) [France]

3' Pleotelson with only one suture visible laterally; uropod peduncle elongate and cylindrical, with a single, minute ramus …….……. *Kensleyana* (one species: *K. briani* Bruce & Herrando-Perez, 2005) [Spain]

4(2') Pleonite 5 covered by pleonite 4; body length 1-10 mm ……..…. 5
4' All five pleonite free; body length 10-33 mm …….……. *Sphaeromides*
[France, Balkans]

5(4) Not rolling into a ball; pleopods 1 not forming an operculum; pleotelson somewhat produced …….…….…….. 6

5' Adapted to roll into a ball; pleopods 1 forming an operculum; pleotelson never produced ….
……...…..……. *Turcolana*
[East Mediterranean]

6(5) Cephalon not laterally overlapped by pereonite 1 ……..…… 7

6' Cephalon posterior 50% embraced by pereonite 1; body length 7 mm ……..… *Marocolana*
(one species *Ma. delamarei* Boutin, 1993)
[Morocco]

7(6) Clypeus not projecting; pleonite 5 overlapped by pleonite 4 ……..……... 8

7' Clypeus projecting; pleonite 5 overlapped by pleonite 4 ……...…… *Metacirolana*
(one species: *Me. ponsi* Jaume & Garcia, 1992)
[Spain]

8(7) Uropod rami dorsoventrally flattened, triangular, subequal in length to peduncle, and shorter than pleotelson …….…….....…. *Typhlocirolana*
[South Europe, North Africa]

8' Uropod rami subcylindrical, styliform, length/width 1.5x peduncle, longer than pleotelson .
…….……..……...…. *Botolana*
(one species: *B. leptura* (Botosaneanu, Boutin & Henry, 1985))
[Morocco]

Key to species of Sphaeromides

1 Pleonite 3 wider than others …….…….…….……. 2

1' Pleonite 3 not wider than the others …….…….……. 3

2(1) Fifth antennal article with straight margins ……. *S. bureschi* Strouhal, 1963

2' Fifth antennal article with inflate margins ….……....……. *S. polateni* Angelov, 1968

3(1') Pleotelson apex truncate ……...…..……. *S. virei* (Brian, 1923)

3' Pleotelson apex acute …….……..…….……. *S. raymondi* Dollfus, 1897

Key de Sphaeromatidae genera and species (except *Monolistra*)

1 Pleopod 4 and 5 endopods smooth lacking pleats or fold …… 2

1’ Pleopod 4 and 5 endopods with pleats or fold …… 5

2(1) Pleotelson preceded by two or more pleonites fused at least dorsomedially ……3

2’ Pleotelson preceded by two free and articulated pleonites …… *Monolistra* [Italy, Balkans]

3(2) Uropod short, around 0.25x the pleotelson length …… *Merozoon vestigatum* Sket, 2012 [Croatia]

3’Uropod length around 0.5x pleotelson length …… 4 (*Caecosphaeroma*) [France]

4(3) All pleonite fused with telson; pleopods short; uropod short, exopodite distinct …… *C. (Caecosphaeroma) virei* Dolfus, 1896

4’ First pleonite partially free; pleopod well developed; uropod reduce scale like, exopodite not visible …… *C. burgundum* (*Vireia*) *burgundum* Dollfus, 1898

5(1’) Maxilliped articles 2-4 lacking lobes, inferior margins with dense fringes of plumose setae …… *Sphaeroma* (one species: *S. podicipitis* Monod, 1931) [South Europe, North Africa]

5’ Maxilliped articles 2-4 more or less lobed, inferior margins with simple setae only …… 6 (*Lekanesphaera*) [Morocco]

6(5) Pereopod 1 propodus with few to many distal setae next to rostrodistal spine …… 7

6’ Pereopod 1 propodus without distal setae next to rostro-distal spine …… *L. hookeri* Leach, 1814

7(6) Pereopod 1, setae on ischium and merus smooth or sparsely plumose only on their distal part …… 8

7’ Pereopod 1, setae on ischium and merus entirely plumose, ending with long setules on their distal part …… *L. monodi* (Arcangeli, 1934)

8(7) Pereopod 1 propodus with more than 3 setae inserted distally in transverse row next to rostro-distal spine. Antenna flagellum articles with fringe of long setae at distal interior angle, seta 2-3 times length of article …… 9

8’ Pereopod 1 propodus with 2-3 setae inserted distally in transverse row next to rostro-distal spine. Antenna flagellum articles with fringe of few short setae, seta 1.5 times length of article …… *L. rugicauda* (Leach, 1814)

9(8) Pleotelson subapically concave, slightly upcurved, dorsal surface slightly granular; Uropod exopod, external margin with 5-7 little teeth, giving it crenate appearance ……..…… ……..… *L. hoestlandti* (Daguerre de Hureaux, Elkaim & Lejuez, 1965)

9’ Pleotelson subapically concave but not upcurved, dorsal surface with row of 6-7 partly fused tubercles on each side of midline; Uropod exopod, external margin with 6-7 distinct teeth … ……. *L. panousei* (Daguerre de Hureaux, Elkaïm & Lejuez, 1964)

Key de Microcerberidae genera and species

1 Coxae of pereiopods 2-4 ring-shaped; male pleopod 2 with saber-shaped endopod with pointed and laterally curved apex; Pleopod 4 with elongate sympod, with 3 rami of similar size, only proximally covered by pleopod 3……..…. *Microcerberus stygius Karaman, 1933*

1’ Coxae of pereiopods 2-4 more or less pointed; male pleopod 2 with elongate rectangular sympod, tiny rounded exopod, and apically bifid; Pleopod 4 well covered by pleopod 3, biramous, without articulations ……..……..…… *Coxicerberus ruffoi* (Chappuis, 1953)

REFERENCES

Boyko C.B., N.L. Bruce, K.A. Hadfield, K.L. Merrin, Y. Ota, G.C.B. Poore, S. Taiti, M. Schotte & G.D.F. Wilson. 2020. World Marine, Freshwater and Terrestrial Isopod Crustaceans database. http://www.marinespecies.org [Accessed 2020 December 31].

Brusca R.C. & G.D.F. Wilson. 1991. A phylogenetic analysis of the isopoda with some classificatory recommendations. Memoirs of the Queensland Museum 31: 143–204. https://doi: 10.2298/CSIS140330090M

Henry J. & G. Magniez. 1983. Introduction pratique à la systématique des organismes des eaux continentales françaises - 4. Crustacés Isopodes (principalement Asellotes). Bullettin Mensuel de la Société Linnéenne de Lyon 10: 319–357.

Magniez G. 1975. Observations sur la Biologie de *Stenasellus virei* (Crustacea Isopoda Asellota des eaux souterraines). International Journal of Speleology 7: 79–228.

Malard, F., M.-J. Dole-Olivier, J. Mathieu, & F. Stoch, 2002. Sampling Manual for the Assessment of Regional Groundwater Biodiversity. Report of the European Project Pascalis. 110 pp.

Messana G., K. Van Damme & R. Argano. 2019. A new stygobiotic *Stenasellus* Dollfus, 1897 (Asellota: Stenasellidae) from Socotra Island, Yemen. Zootaxa 4683: 552–562.

Rogers C., J.J. Lewis. 2019. Malacostraca: Isopoda. Pages 837–844 *in*: D.C. Rogers & J.H. Thorp (eds), Freshwater Invertebrates. Vol. 4. Keys to Palearctic fauna. Academic Press. https://doi: 0.1016/B978-0-12-385024-9.00022-8

Wilson G.D.F. 2008. Global diversity of Isopod crustaceans (Crustacea; Isopoda) in freshwater. Hydrobiologia 595: 231–240. https://doi:10.1007/s10750-007-9019-z

7. Malacostraca: Mysida and Stygiomysida

Karl J. Wittmann
Department of Environmental Health, Medical University of Vienna, Austria
karl.wittmann@meduniwien.ac.at

INTRODUCTION

Mysida

Peracarid crustaceans of the order Mysida are recognizable by their shrimp-like habitus, by separate, stalked eyes, fused cephalothorax, well-developed carapace and tail fan, by swimming and respiratory currents driven by rotating movements of their thoracic exopods, and by the absence of gills and of true chelae. The author's own global census (19 Feb. 2021) yielded a total of 178 genera and 1,190 species considered valid. Doubtful cases excluded, an additional three genera and nine species are known from the Miocene down to the Triassic (Voicu 1974; San Vicente & Cartanyà 2017). The main taxonomic groups are the family Petalophtalmidae with the subfamilies Petalophthalminae and Hansenomysinae, and the family Mysidae with ten subfamilies, namely Boreomysinae, Erythropinae, Gastrosaccinae, Heteromysinae, Leptomysinae, Mysidellinae, Mysinae, Palaumysinae, Rhopalophthalminae, and Siriellinae.

Most extant species inhabit marine waters of all major sea basins from the shore down to the deep sea, usually with greatest species diversity in sublittoral habitats. Most marine and freshwater species live on or closely above the bottom, often in swarms; a few are pelagic. Some species burrow just below the sediment surface, others are associated with benthic invertebrates. Many species hide during the daytime and emerge at night to feed, mate, moult, and release young. Most species are omnivorous, some are micro-phytophagous, saprophagous, or carnivorous; none is parasitic. Dense populations can have marked effects on near-bottom plankton communities. High individual densities occur in turbid, meso- to oligohaline waters of lagoons and estuaries. Such habitats can provide main pathways for immigration and adaptation to freshwater. Quantitatively less important pathways involve marine and brackish groundwater. Reddell (1981) assumes a marine origin of the troglobitic mysids (*i.e.* Stygiomysida and Mysida) of Mexico, mainly found in brackish groundwater, less frequently in fresh groundwater. Such a distribution also holds true for the two Mediterranean Stygiomysida species (see below); however, the only troglobitic Mysida species (*Troglomysis vjetrenicensis*) of the Mediterranean lives exclusively in fresh groundwater.

A total of 26 genera and 75 species of Mysidae (and no Petalophthalmidae) are recorded in freshwater globally, in part based on single freshwater records of euryhaline species. Within Mysidae, as many as 71 species belong to the subfamily Mysinae, two to Leptomysinae (*Americamysis almyra* and *Tenagomysis chiltoni*), one to Heteromysinae (*Deltamysis holmquistae*), and one to Rhopalophthalminae (*Rhopalophthalmus chilkensis*). The remaining six subfamilies have not been recorded in freshwater.

The bulk of freshwater records includes 24 Ponto-Caspian endemics, followed by 12 species from Amazonia and adjacent freshwater systems, nine Mexican, Central American and Caribbean endemics, nine boreo-arctic species including extrazonal glacial relicts, and six Mediterranean endemics.

Including species of NE-Atlantic and Ponto-Caspian origin, ten species (adult body size 3–13 mm) have been recorded in Mediterranean freshwaters so far: all belong to the subfamily

Mysinae within the family Mysidae. Among these, four Mediterranean endemics are restricted to freshwater, and two other endemics occur in fresh as well as brackish water. Among these six species, as many as four are stenoendemic in the Adriatic Sea, another one in the Eastern Mediterranean including the Adriatic. The predominance of Adriatic endemics in Mediterranean freshwaters may have been favoured by alternating marine, lagoonary, and terrestrial phases (Correggiari *et al*., 1996) of the shallow N-Adriatic shelf during Pleistocene sea-level changes.

One brackish to marine NE-Atlantic species of Mysidae (*Neomysis integer*) occurs marginally in freshwaters of the Mediterranean basin. Two freshwater Ponto-Caspian endemics (*Hemimysis anomala* and *Limnomysis benedeni*) have recently expanded to the Rhône Delta on the Mediterranean coast of France. Finally, the details of when and how a third Ponto-Caspian endemic (*Paramysis lacustris*) arrived in an isolated freshwater lake without natural surface drainage in the highlands of Anatolia remain unknown.

Stygiomysida

Two families (Stygiomysidae and Lepidomysidae), only two genera, and 16 species of Stygiomysida are known globally. They show a Tethyan distribution, extending from Central America and the Caribbean to Mediterranean and Indian basins (Porter *et al*., 2008). Both known Mediterranean species (adult body size 6-13 mm) are stenoendemic in brackish groundwater in SE- Italy and are rarely found there in freshwater.

GENERAL ECOLOGY AND DISTRIBUTION

Stygiomysida

This order is represented by only two species in European waters. Both are stenoendemic of brackish groundwater in SE-Italy and are rarely found in freshwater. Although their eyes are rudimentary, unpigmented, *Spelaeomysis bottazzii* and to a minor extent also *Stygiomysis hydruntina* are not strictly photophobic: the former species is regularly found in the dimly lit zone of wells, where it feeds on photoautotrophic organisms (Ariani & Wittmann 2010).

Stygiomysis hydruntina has been reported from a few caves and wells near the Adriatic and Ionian coasts of the Salento Peninsula (SE-Italy). It occurs mainly in deep brackish groundwater, rarely in near-surface low-salinity waters. Pesce *et al*. (1978) published three potential freshwater records without indication of salinity; however, a salinity of "0.3‰" is labelled on the slide containing parts of a male specimen from station PU/23 (own inspection of material kept at the Museo Civico di Storia Naturale, Verona). Besides, Pesce *et al*. (1978) indicated Monte Mario coordinates instead of Greenwich coordinates.

Spelaeomysis bottazzii has been reported from a number of caves, dolinas, wells, and springs near the Adriatic and Ionian coasts of the Salento Peninsula and from the Adriatic coast of Apulia (SE-Italy). It occurs in deep brackish groundwater up to various near-surface mesohaline to anhaline waters (Inguscio 1998). Breeding females are rare near the surface; most of them probably inhabit deep groundwater for more than three months of incubation. Laboratory females assume strongly reduced brood lamellae at the moult following incubation. This is interpreted as a strategy to replenish the trophic reserves required for sustaining a long incubation period in deep and trophically poor groundwater (Ariani & Wittmann 2010).

Mysida

Only ten species have so far been found in true freshwater (0.0–0.5 psu) of the Mediterranean. The other two species given in the key below are expected but have not yet been recorded there in freshwater. Only four Mediterranean endemics are restricted to freshwater habitats:

Diamysis lacustris is stenoendemic in Lake Scutari on the SE-coast of the Adriatic Sea, altitude 6 m; *Troglomysis vjetrenicensis* is stenoendemic in subterranean waters in the Vjetrenica cave system in Herzegovina, near the E-Adriatic coast, altitude about 224 m; *Paramysis* (*Longidentia*) *adriatica* is known only from tributaries along the northern and eastern coasts of the Adriatic Sea, altitude 0–2 m. *Paramysis* (*Serrapalpisis*) *kosswigi* was reported from Lake Isikli and associated running waters of W-Anatolia draining into the Aegean Basin, altitude 135–1,007 m; previous records from tributaries of the Black Sea were referred to the sister species *P.* (*S.*) *lacustris* by Wittmann *et al*. (2016).

An additional Mediterranean endemic, *Diamysis fluviatilis*, occurs mainly in freshwater and to a lesser extent in brackish running waters, wells and estuaries along the northern coasts of the Adriatic Sea, altitude 0–16 m. Freshwater populations of *D. mesohalobia heterandra* are confined to the Adriatic basin, altitude 0–3 m. Nonetheless, many more populations inhabit brackish waters of the E-Mediterranean and Marmora seas.

The Mediterranean endemic *D. hebraica* has not yet been reported from true freshwater. It has been found in three oligohaline streams and their springs on the coast of Israel (salinity 0.7–5 psu). An occurrence in the anhaline range appears plausible during potential periods of strong freshwater input.

Paramysis (*Serrapalpisis*) *lacustris* is indigenous in anhaline to mesohaline waters of the Ponto-Caspian and Marmora basins. Within the boundaries of the Mediterranean climate, it is found in the freshwater lakes Kus Gölü and Uluabat Gölü near the southern coast of the Marmora Sea. Material from the isolated freshwater Lake Beyşehir in the highlands of Anatolia, altitude 1,115 m, was described as a separate subspecies, the here not acknowledged *Paramysis lacustris turcica* Băcescu, 1948. The hydrological situation is quite complex: according to Günay (2010), at least part of the runoff enters the Mediterranean catchment through underground connections. This provides sufficient support for attributing this population to the Mediterranean fauna. Intensive intentional introductions of *P. lacustris* were made in the 1960s–1970s in waters of Eastern Europe, wherefrom it established in Lithuania and the Gulf of Finland (Audzijonytė *et al.*, 2017). Non-intentional expansion occurred from the lower to the middle reach of the Danube River (Borza *et al*., 2019). If this expansion continues, this species may follow the below-discussed route to the Mediterranean coast of France.

Two other Ponto-Caspian endemics, *Hemimysis anomala* and *Limnomysis benedeni*, occur mainly in freshwater but have also been reported in brackish waters. They expanded from the Black Sea westward along the rivers Danube, Rhine, Rhône, and their associated artificial canals, and finally southward down to the delta of the Rhône on the Mediterranean coast of France, where they were first detected in 2007 and 2009, respectively (Wittmann & Ariani 2009; Wittmann *et al.*, 2014).

Two indigenous NE-Atlantic species inhabit brackish to marine waters, and marginally also freshwaters. *Neomysis integer* inhabits the Mediterranean coasts of Spain and France, but not elsewhere in the Mediterranean. It occurs marginally in freshwater of the Rhône River delta. *Mesopodopsis slabberi* is present in great numbers in brackish and marine, rarely in metahaline waters of the NE-Atlantic, Baltic, Mediterranean, Marmora Sea, Black Sea, and the Sea of

Azov. The lowest salinities for the Mediterranean (0.9–1.4 psu) were reported in the estuaries of the Rhône and Po rivers and in a brackish drain in Corfu Island (Pesta 1935; Aguesse & Bigot 1960; Brun 1967). True freshwater records stem only from the Black Sea coast in waters of the delta and 'Predelta' of the Danube (Dedju & Polischtuk 1968; Begun & Gomoiu 2007; Wittmann *et al*., 2016). Based on studies in Lake Sinoe, a barrier lagoon of the Predelta, Begun & Gomoiu (2007) concluded that this species is episodically found in freshwater but cannot form stable populations there. *M. slabberi* was recorded in this lagoon only under oligohaline conditions (1.1–2.1 psu) upon own sampling in 1985, 1998, and 2008.

TERMINOLOGY AND MORPHOLOGY

The terminology used here is according to Wittmann *et al*. (2016). Only features using standard microscopy without dissection are considered below. Gross morphology and additional features are available in Daneliya *et al*. (2019), with a focus on Ponto-Caspian species.

Among Malacostraca, the orders Stygiomysida and Mysida were formerly lumped together in the order Mysidacea based on their shared separate, stalked eyes at least in postnauplioid larvae (known so far), a respiratory carapace fused only with anterior thoracic somites, first and second antennae each with a three-segmented trunk, eight pairs of mostly biramous thoracopods (including maxillipeds), and the absence of gills. To our knowledge, the inner rami (endopods) are used for feeding and climbing, generally not for walking, and the outer rami (exopods) for swimming and driving respiratory currents through rotating movements. Both orders show five pairs of non-respiratory, non-natatory pleopods. A marsupium is formed by 1–7 pairs of oostegites (marsupial plates) arising as epipods in continuous series, starting with the ultimate thoracopod. The young pass through one embryonic (egg) and two non-feeding larval stages in the marsupium, where they receive parental care rather than being merely stored, at least Mysida do so.

Based on genetic analyses, Meland & Willassen (2007) positioned the family Stygiomysidae closer to Mictacea than to Mysida, and proposed to establish Stygiomysida and Mysida as separate orders. The post-larval stages of Stygiomysida are distinguished from those of Mysida by reduced eyes, the presence of a spiny ventral lobe on the endopod of uropods (Figs. 7.16A,B; together with the telson forming a strong tail fan), by two laminar lobes flanking the male genital orifice instead of tubular penes, and by the absence of statocysts. All the Mysida dealt with here belong to the family Mysidae and are characterized by a large statocyst at the basis of the endopod of uropods. This organ contains one exceptionally large statolith (Fig. 7.16C) in the animal kingdom. The statoliths of most freshwater species, here represented by certain species of *Hemimysis*, *Limnomysis*, *Diamysis*, and *Paramysis*, are opaque because they are mineralized with vaterite, a metastable form of calcium carbonate. The statoliths of most marine and brackish-water species, and of just a few freshwater species (dealt with below: *Troglomysis*; rare in freshwater: *Mesopodopsis*, *Neomysis*) appear transparent and vitreous because they are mineralized with fluorite (CaF_2). However, statoliths can be damaged and may even vanish as fixation and preservation artefacts.

Both Stygiomysida species known in the Mediterranean are readily distinguished by body shape (Figs. 7.14, 7.15) and size of the ventral lobe on the endopod of uropods (Figs. 7.16A, B). Careful inspection of antennal scale (Fig. 7.18) and telson (Fig. 7.19) are sufficient for identification of three Mysida species living in freshwaters of the Mediterranean. Among additional features, the strongly reduced, obviously dysfunctional cornea (Fig. 7.20B) is a key feature to identify *Troglomysis*, whereas the structure of the carapace (Fig. 7.20) and of the

thoracic exopods (Fig. 7.21) are important diagnostic features for *Diamysis*. For certain *Paramysis*, inspection of the paradactylary setae (Fig. 7.22; modified setae flanking the dactylus of thoracic endopods 3–8) is necessary for identification.

COLLECTION, PREPARATION, AND PRESERVATION

Mysids are sampled during day and night with nets operated from the shore, with diver-operated nets, bottom nets, and epibenthic sledges. Baited bottle traps exposed overnight, and empty mollusc shells, stones with holes, discarded bottles etc. collected during the day are treated *ex situ* with a few drops of clove oil to expel the animals. Fixation and preservation are performed with ethanol 80% for morphological analysis or 95% for genetic analysis. Identification at species level may require dissection, mounting of body parts and appendages on slides, and subsequent examination using a 400x or higher-magnification microscope. Specimens in propylene glycol, glycerol, or ethanol can be handled under a low-power microscope with needles. Glycerol is used as an embedding medium for short-term slides, particularly for inspection of mineral statoliths that can be damaged by other media. The water-tolerant Swan-medium makes minute, superimposed objects well discernible owing to its strong bleaching power. After hardening at 60°C for about 15 h, it requires very careful sealing within about one month to obtain multi-annual slides. Canada-Balsam requires dehydration in ascending ethanol series. It is recommended for permanent slides intended for deposition of museum specimens.

LIMITATIONS

The key below is designed to cover all currently recognized freshwater mysidacean species of the Mediterranean. Rare records are included, unless they are insufficiently documented. Taxonomic synonymy is updated. Secondary sexual characteristics are crucial for the taxonomy of Mysida, but are restricted here in order to obtain a short-cut key applicable to specimens of any sex and stage of maturity (except juveniles in some cases).

Freshwater is defined as water with a salinity range of 0.0–0.5 practical salinity units (psu). Two species occurring in brackish waters of the Mediterranean (but so far recorded only in near but not pure freshwater) are included for potentially prolonging the validity of the key: *Diamysis hebraica* from a documented lowest salinity of 0.7 psu, and *Mesopodopsis slabberi* found at a minimum of 0.9 psu. The latter species repeatedly found in true freshwaters of the Danube Delta along the Black Sea coast but not elsewhere in freshwater.

ACKNOWLEDGMENTS

The author is greatly indebted to Salvatore Inguscio (Nardò) for providing photos of Stygiomysida. Sincere thanks to Mikhail Daneliya (Helsinki) and to W. Wayne Price (Tampa) for important information about freshwater distribution of mysids.

KEY TO MYSIDA AND STYGIOMYSIDA

Key to orders Mysida and Stygiomysida

1 Endopod of uropods with very large statocyst; sympod without ventral lobe (Fig. 7.16C); cornea mostly well-developed (Figs. 7.17; 7.20A, C–F), rarely reduced (Fig. 20B) …… ……..…….. Mysida (one family: Mysidae)

1’ Endopod of uropods without statocyst; sympod with spiny ventral lobe (Figs.7.16A,B); cornea reduced (Figs. 7.14, 7.15) …..……..... Stygiomysida

Key to species of Stygiomysida

1 Habitus vermiform (Fig. 7.14), resembling the co-occurring thermosbaenacean *Monodella stygicola* Ruffo, 1949; sympod of uropods with ventral lobe more than half length of unsegmented exopod (Fig. 7.16A) ……... ……..……..… Stygiomysidae
(One species: Stygiomysis hydruntina Caroli, 1937)
[SE-Italy; mostly in brackish groundwater, occasionally also in freshwater]

1’ Habitus moderately stout, shrimp-like (Fig. 7.15); sympod of uropods with ventral lobe less than 1/4 length of two-segmented exopod (Fig. 7.16B) ..... ……..… Lepidomysidae
(One species: *Spelaeomysis bottazii* Caroli, 1924)
[SE-Italy; mostly in brackish groundwater, also in freshwater]

Key to Genera of Mysidae

1 Antennal scale setose all around (Figs. 7.18C–H) 3

1’ Antennal scale with setose margins except for a proximal bare portion of outer margin (Figs. 7.18A,B) ……... 2

2(1’) Outer margin of antennal scale with smooth portion ending in setae (Fig. 7.18B) …… ……..…..... *Hemimysis*
(One species: *H. anomala* G.O. Sars, 1907)
[Ponto-Caspian endemic; invasive in large parts of Europe and North America; expansion in the Rhône system down to the Mediterranean coast; mainly in freshwater]

2’ Outer margin of antennal scale with s

mooth portion ending in a tooth (Fig. 7.18A) …… ……...……. *Paramysis*

3189
3190 3(1) Telson entire, slender, subtriangular (Fig. 7.19A) …..... *Neomysis*
3191 (One species: *N. integer* (Leach, 1814))
3192 [NE-Atlantic and NW-Mediterranean; mainly in brackish and marine waters, marginally in
3193 freshwater]

3194 3’ Telson rhombohedral to subrectangular, with apical cleft (Figs. 7.19B, D–H) ……..…….. 4

3195
3196 4(3) Telson without median lobe (Figs. 7.19D–H); eyestalks less than three times length of
3197 cornea (Figs. 7.20C–F) …….. 5

3198 4’ Telson with large median lobe emerging from broad apical cleft (Fig. 7.19B); eyestalks 3–4
3199 times as long as cornea (Fig. 7.20A) ……..... *Mesopodopsis*
3200 (One species: *M. slabberi* (Van Beneden, 1861))
3201 [NE-Atlantic, Baltic, Mediterranean, Marmora, and Ponto-Azov Seas; in oligo- to euhaline,
3202 rarely metahaline waters, episodically in freshwater of only the Danube Delta]

3203
3204 5(4) Apical segment less than 20% antennal scale length; scale terminally broadly rounded in
3205 both sexes (Figs. 7.18G, H) ……...……..... 6

3206 5’ Apical segment of antennal scale 25–33% of scale length; scale terminally rounded in
3207 females (Fig. 7.18F), bluntly pointed in males (Fig. 7.18E) ……..… *Limnomysis*
3208 (One species: *L. benedeni* Czerniavsky, 1882)
3209 [Ponto-Caspian endemic; introduced in Lake Balaton, Lake Aral, and waters of
3210 Turkmenistan; expansion to large parts of Europe, including the Rhône Delta at the
3211 Mediterranean coast; mainly in freshwater, also brackish]

3212
3213 6(5) Cornea rudimentary, without pigment (Fig. 7.20B) ……..…… *Troglomysis*
3214 (One species: *T. vjetrenicensis* Stammer, 1933)
3215 [subterranean freshwaters in the cave Vjetrenica system, near the E-Adriatic coast]

3216 6’ Cornea normal, well pigmented (Figs. 7.20 C–F) ……...…….…….. *Diamysis*

3217

3218 **Key to species of *Diamysis***

3219 1 Rostrum well rounded or forming a wide convex angle with rounded tip (Figs. 7.20 D–F) .. 2

3220 1’ Rostrum angular, with acute or narrowly rounded tip (Fig. 7.20 C) ……..…
3221 ……...……. *Diamysis lacustris* Băcescu, 1940
3222 [freshwater Lake Scutari at the SE-coast of the Adriatic Sea]

3223

3224 2(1) Basal plate of thoracic exopods 1–3 terminally ending in a spiniform projection (Fig.
3225 7.21A) ……...…..……..…… 3

3226 2’ Basal plate of thoracic exopods 1–3 terminally well rounded (Fig. 7.21B) ….……....
3227 ……..……...….. *Diamysis hebraica* Almeida Prado-Por, 1981
3228 [oligohaline streams at the coast of Israel; not yet found in true freshwater]

3229

3230 3(2) Rostrum well rounded; male carapace with fringes arranged in only one pair of submedian
3231 stripes (Fig. 7.20D); female carapace without fringes ……...
3232 ……..…… *Diamysis fluviatilis* Wittmann & Ariani, 2012
3233 [tributaries of the N-Adriatic; mainly in freshwater]

3234 3’ Rostrum forms a wide convex angle with rounded tip; male carapace with fringes arranged
3235 in 1–2 pairs of submedian stripes plus a transverse row shortly in front of the posterior
3236 margin (Fig. 7.20E); female carapace without fringes …….
3237 ……..…… *Diamysis mesohalobia heterandra* Ariani & Wittmann, 2000
3238 [Adriatic, Ionian, and Marmora Seas; fresh and brackish waters]

3239

3240 **Key to species of *Paramysis***

3241 1 Telson with shallow cleft forming an angle of more than 120° (Fig. 7.19G) ……...…..…… 2

3242 1’ Telson with strong, subrectangular cleft (Fig. 7.19H) ……..……..…
3243 …… *Paramysis* (*Longidentia*) *adriatica* Wittmann, Ariani & Daneliya, 2016
3244 [freshwater tributaries of the Adriatic Sea]

3245

3246 2(1) Denticulate paradactylary setae of thoracic endopods 5–8 'serrated' only along proximal
3247 50–65% length (Fig. 7.22A); cephalic region swollen (if well preserved) ……
3248 ……..…… *Paramysis* (*Serrapalpisis*) *kosswigi* Băcescu, 1948
3249 [freshwaters of W-Anatolia draining into the Aegean Basin]

3250 2’ Denticulate paradactylary setae of thoracic endopods 5–8 'serrated' over 70–80% length (Fig.
3251 7.22B); cephalic region not swollen ……..
3252 ……..…….. *Paramysis* (*Serrapalpisis*) *lacustris* (Czerniavsky, 1882)
3253 [expansive Ponto-Caspian endemic, also in (near)-Mediterranean freshwater lakes of
3254 Turkey]

3255

3256 **ACKNOWLEDGMENTS**

3257 The author is greatly indebted to Salvatore Inguscio (Nardò) for providing photos of
3258 Stygiomysida. Sincere thanks to Mikhail Daneliya (Helsinki) and to W. Wayne Price (Tampa)
3259 for important information about freshwater distribution of mysids.

3260

3261 **REFERENCES**

3262 Aguesse, P. & L. Bigot. 1960. Observations floristiques et faunistiques sur un étang de
3263 Moyenne Camargue: la Baisse Salée de la Tour du Valat. Vie et Milieu 11: 284-307.

3264 Almeida Prado-Por, M.S. de 1981. Two new subspecies of the *Diamysis bahirensis* Sars species
3265 group (Crustacea: Mysidacea) from extreme salinity environments on the Israel and Sinai
3266 coasts. Israel Journal of Zoology 30: 161-175.

Ariani, A.P. & K.J. Wittmann. 2010. Feeding, reproduction, and development of the subterranean peracarid shrimp *Spelaeomysis bottazzii* (Lepidomysidae) from a brackish well in Apulia (southeastern Italy). Journal of Crustacean Biology 30: 384-392.

Audzijonytė, A., L. Baltrūnaitė, R. Väinölä & K. Arbačiauskas. 2017. Human-mediated lineage admixture in an expanding Ponto-Caspian crustacean species *Paramysis lacustris* created a novel genetic stock that now occupies European waters. Biological Invasions 19: 2443-2457.

Begun, T. & M.-T. Gomoiu. 2007. New data on cumacean and mysid populations (Crustacea – Peracarida) in Razelm – Sinoie lagoon complex. Page 69 *in*: Aquatic Biodiversity International Conference, Sibiu, Romania, 04-07 October 2007.

Borza, P., K. Kovács, A. György, J.K. Török & Á. Egri. 2019. The Ponto-Caspian mysid *Paramysis lacustris* (Czerniavsky, 1882) has colonized the Middle Danube. Knowledge & Management of Aquatic Ecosystems 420: 4 pp.

Brun, G. 1967. Etude écologique de l'estuaire du Grand Rhône. Bulletin de l'Institut Océanographique de Monaco 66 (1371): 1-46.

Correggiari, A., M. Roveri & F. Trincardi. 1996. Late Pleistocene and Holocene evolution of the North Adriatic Sea. Il Quaternario - Italian Journal of Quartenary Sciences 9: 697–704.

Dedju, I.I. & W. Polischtuk. 1968. Fauna der höheren Krebsartigen im sowjetischen Donauabschnitt und ihre Rolle bei der Bildung der Bodenfauna des Pruth. Pages 277-283 *in*: A. Valkanov, B. Russev, and W. Naidenow (eds.), Limnologische Berichte der X. Jubiläumstagung der Arbeitsgemeinschaft Donauforschung. Bulgarien 10.-20. Oktober 1966. Verlag der Bulgarischen Akademie der Wissenschaften, Sofia.

Günay, G. 2010. Chapter 10.6 - Geological and hydrogeological properties of Turkish karst and major karst springs. Pages 479-497 *in*: N. Kresic and Z. Stevanovic (eds.), Groundwater Hydrology of Springs: Engineering, Theory, Management and Sustainability. Butterworth-Heinemann: Elsevier, Oxford, UK.

Inguscio, S. 1998. Misidacei stigiobionti di Puglia. ideemultimediali, Nardò, Italia. 95 pp.

Meland, K. & E. Willassen. 2007. The disunity of "Mysidacea" (Crustacea). Molecular Phylogenetics and Evolution 44: 1083-1104.

Pesce, G.L., G. Fusacchia, D. Maggi & P. Tetè. 1978. Ricerche faunistiche in acque freatiche del Salento. Thalassia Salentina 8: 1-51.

Pesta, O. 1935. Ein Mysidaceen-Nachweis auf der Insel Korfu (Griechenland). Zoologischer Anzeiger 111: 332-333.

Porter, M.L., K. Meland & W. Price. 2008. Global diversity of mysids (Crustacea-Mysida) in freshwater. Hydrobiologia 595: 213-218, suppl.

Wittmann, K.J. & A.P. Ariani. 2009. Reappraisal and range extension of non-indigenous Mysidae (Crustacea, Mysida) in continental and coastal waters of eastern France. Biological Invasions 11: 401-407.

Wittmann, K.J., A.P. Ariani & J.-P. Lagardère. 2014. Chapter 54. Orders Lophogastrida Boas, 1883, Stygiomysida Tchindonova, 1981, and Mysida Boas, 1883 (also known collectively as

Mysidacea). Pages 189-396, 404-406 *in*: J.C. von Vaupel Klein, M. Charmantier-Daures, and F.R. Schram (eds.), Treatise on Zoology - Anatomy, Taxonomy, Biology. The Crustacea. Revised and updated, as well as extended from the Traité de Zoologie, Vol. 4 Part B. Koninklijke Brill NV, Leiden.

8. Malacostraca: Thermosbaenacea

Christophe Piscart
French National Centre for Scientific Research (CNRS), University of Rennes 1, France
christophe.piscart@univ-rennes1.fr

INTRODUCTION

Thermosbaenacea Monod 1927 are an obscure group of small crustaceans living in groundwaters. Their taxonomic position was debated over for a long time before they were finally classified with Peracarida (see Wagner, 1994 for details). Their small size makes them difficult to identify in the field, and their elongate vermiform and somewhat dorsoventrally flattened body makes them look like microisopods or copepods. However, they are easily recognizable under a stereomicroscope from the presence of an obvious dorsal carapace. They differ from Mysidacea and Decapoda in that they are eyeless and have reduced pleopods present only on their first two abdominal segments.

The biogeographic origin of Thermosbaenacea still remains to be elucidated because available information is very scarce. We already know that their distribution area falls within the boundaries of the ancient Tethys belt, indicating that they may have had a very old ancestor in the Mesozoic period (252 to 66 Mya), close to Halosbaenidae that are the only known family distributed worldwide.

However, the diversification process likely occurred in the Mediterranean basin between the marine regression of the late Miocene period and the Messinian salinity crisis (≅ 5.5 Mya) for the *Tethysbaena atlantomaroccana* group and the marine transgression during the Pliocene period (2.5-5 Mya) for the *Tethysbaena argentarii* group (Wagner, 1994).

Among the 40 Thermosbaenacea species recorded worldwide (Horton et al., 2020), less than 20 occur in freshwaters, among which 12 are present in the Mediterranean basin. A total of 3 families, 4 genera and 12 species are recorded in the Mediterranean basin, all of them endemic to the region.

GENERAL ECOLOGY AND DISTRIBUTION

Thermosbaenacea are all obligate groundwater species and colonize all types of marine and continental waters, even if they are always located close to the sea and are more frequent in marine and brackish waters. Some species can colonize hot water springs; for example, the type locality of *Thermosbaena mirabilis* has a temperature ranging from 44.5 to 48°C. They have a strong affinity to low oxygen concentrations and are resistant to high temperatures and the presence of hydrogen sulfide (H_2S); near-anoxic conditions are even more favourable to them (Wagner, 2012). They are mainly found is detritus, but likely feed on bacteria and algae growing on detritus.

TERMINOLOGY AND MORPHOLOGY

Thermosbaenacea are small-sized Malacostraca, generally less than 5 mm long. Their body is elongate, vermiform and slightly flattened dorsoventrally, except *T. mirabilis* whose body is wider and looks like a flabelliform isopod.

Their body consists of a more or less developed carapace, a thorax formed of 8 segments (thoracomeres 1-8), a pleon with generally 6 segments (except Thermosbaenidae whose sixth pleonite is fused with the telson forming a pleotelson) (Figure 7.23).

The cephalic capsule is fused with the thoracic tergum through the maxillipedal metamere, and partly fused with the second thoracomere to form the carapace. The upper pair is antennae 1, with a basal peduncle of three articles and a distal flagellum of several articles with aesthetascs. The third peduncular article also bears an accessory flagellum on its distal end, usually composed of a reduced number of tiny cylindrical articles. The second pair of antennae is shorter than the first one; it has a flagellum of 8-11 small articles and a peduncle of five articles. Eyes are absent, but ocular scales can be present in some genera (e.g. *Limnosbaena*). A dorsal brood pouch is formed in ovigerous females, as an extension of the carapace, wherein eggs and juveniles are incubated. Their mouthpart is on the ventral surface below their carapace and is composed of the labrum, labium, mandibles, maxillae I and II, and maxilliped, all laterally connected to the carapace (see Wagner, 1994 for details).

The thorax bears different kinds of legs generally eight pairs of biramous appendages, except for *Limnosbaena* (uniramous), the first of which are used as accessory mouthparts. One pair of gnathopods (modified pereopod 1) is possibly used for grasping detritus, the next six pairs are walking legs (pereopods 2 – 7), except in *Thermosbaena* only has 5 pereopods.

The pleon is composed of six segments (only five in *Thermosbaena*), but only three pairs of appendages. The first two pleonites bear a pair of reduced pleopods (pleopods 1-2); the first pair is scale-like in Halosbaenidae, and the last pleonite has a well-developed pair of biramous uropods. In *Thermosbaena*, the uropod is attached to the pleotelson and the endopodite is strongly reduced. Finally, a free telson (or pleotelson) is attached to the last pleonite and corresponds to the last part of the body. The shape and armature of the telson are typical of each genus and of each species to a lesser extent.

COLLECTION, PREPARATION, AND IDENTIFICATION

Thermosbaenacea are very rare and present only in groundwaters (aquifers, caves or springs). Therefore, any kind of specific material for this environment (Malard et al., 2002) can be used to collect them. Some species were even collected using a suction bottle or jars operated by divers in caves. Thermosbaenacea can be easily fixed and preserved in 2% buffered glutaraldehyde or in 95% ethanol for genetic analysis.

Determination at the species level requires dissection, mounting of body parts and appendages on slides, and subsequent examination using a 400x or higher-magnification microscope or even observation in scanning electron microscopy (SEM) (e.g. *Tethysbaena argentarii* group). Specimens in glycerol or ethanol can be handled under a low-power microscope with needles. Baths in clearing solution (e.g. soft acids) and cuticular staining (e.g. black chlorazol B) can be helpful. A same specimen can be used for both studies: the abdomen for DNA extraction and the other parts for dissection and mounting. This procedure ensures that the sequenced genes correspond to the same morphotype.

Taxonomic identification to the species level is generally based on males (if available), but females can be used too. Chaetotaxy is complex but very important for identification. The most important body parts for identification are the antennae, mouthparts, pereopod, pleopods, uropods and telson, but additional body parts need to be examined to identify certain species.

LIMITATIONS

Thermosbaenacea remain a poorly known order, with only ~ 40 species described worldwide and hardly any molecular study to confirm their taxonomy. As a consequence, some families, genera and species names may change in the future, and many species are still to be found. The keys below are designed to cover the 12 species inhabiting fresh and brackish waters of the Mediterranean basin. Rare records are included, unless they are insufficiently documented.

Even if our keys were designed to be as clear as possible, we should keep in mind that identifying certain groups (e.g. the *Tethysbaena argentarii* group) is difficult and requires strong expertise. Do not hesitate to use alternative information or keys (e.g. Wagner 1994) to consolidate your conclusions. We should remain aware that the keys are designed for species of the Mediterranean basin; they are not adapted to other amphipods worldwide, even at the family level.

KEYS TO THERMOSBAENACEA

Adapted from (Wagner, 1994)

Key to family of Thermosbaenacea

1 Body elongate; 7 pairs of pereopods; telson separate from pleonite 6 ……..……. 2

1’ Body distinctly wider than high; 5 pairs of pereopods; telson fused with pleonite ……. ……..…..…… Thermosbaenidae
(one species: *Thermosbaena mirabilis* Monod, 1924)
[Tunisia]

2(1) Ocular scales absent; gnathopods with one strong serrate seta forming the unguis; propodus of gnathopods with spur; pleopod 1 with basal articulation ……...…..... Monodellidae
[Peri-Mediterranean]

2’ Ocular scales present; gnathopods with two or three (more or less modified) strong serrate seta forming a claw; propodus of gnathopods lacking spur; pleopod 1 with a small unarticulated lobe ……Halosbaenidae
(one species: *Limnosbaena finki* (Mestrov & Lattinger-Penko, 1969))
[Balkan]

Key to Monodellidae genera and species

1 Antenna 1 with 6 to 12 articles on the main flagellum; carpus of gnathopods with three long teasel setae; second segment of exopodite of pereopod 5 with medial plumose setae and with or without vestigial lateral seta; telson with group of three cuspidate setae on the distal corners ……. 2 (genus *Tethysbaena*)
[peri-mediterranean]

1’ Antenna 1 with 10 articles on the main flagellum; carpus of gnathopods with four long strong teazel setae; second segment of exopodite of pereopod 5 without medial and lateral plumose setae; telson with group of two cuspidate setae on the distal corners ……. ……..……..…….. *Monodella*
(one species *M. stygicola* Ruffo, 1949)

[Italy]

2(1) Telson wider than long; anal lobes protruding beyond the terminal stretch of the telson ……...…… 3

2’ Telson longer than wide; anal lobes not protruding beyond the terminal stretch of the telson ..……...……..…….……... 4

3(2) Antenna 1 main flagellum with 7 articles; Maxilla 1 palp second article with 9 setules; Uropod endopodite with 18-22 plumose setae ……..…… *T. ophelicola* Wagner 2012

3’ Antenna 1 main flagellum with 8 articles; Maxilla 1 palp second article with 4 setules; Uropod endopodite with 18-22 plumose setae …… *T. relicta* (Pór, 1962)

4(2’) Terminal stretch of the telson with one or more protuberances ……... 5

4’Terminal stretch of the telson with one or more protuberances ……... *T. argentarii*-group (*T. argentarii* (Stella, 1951), *T. aiakos* Wagner, 1994, *T. halophile* (S. Karaman, 1953), *T. scabra* (Pretus, 1991) and *T. siracusae* Wagner, 1994)*

*The accurate identification of each species of the group needs SEM microscopy.

Article 2 of the mandibular palp with 6 plumidenticulate setae; Maxilla 2 outer lobe with 17 rake-like terminal setae; the presence of an additional dorsolateral subplumose seta on pleopod 2; Medial margin of the first segment of the exopodite of uropod with 5 stout plumose setae ……..……... *T. atlantomaroccana* (Boutin & Cals, 1985)

5’. Article 2 of the mandibular palp with 5 plumidenticulate setae; Maxilla 2 outer lobe with 25 rake-like terminal setae; the absence of an additional dorsolateral subplumose seta on pleopod 2; Medial margin of the first segment of the exopodite of uropod with 4 stout plumose setae ….…….…….. *T. tarsiensis* Wagner, 1994

REFERENCES

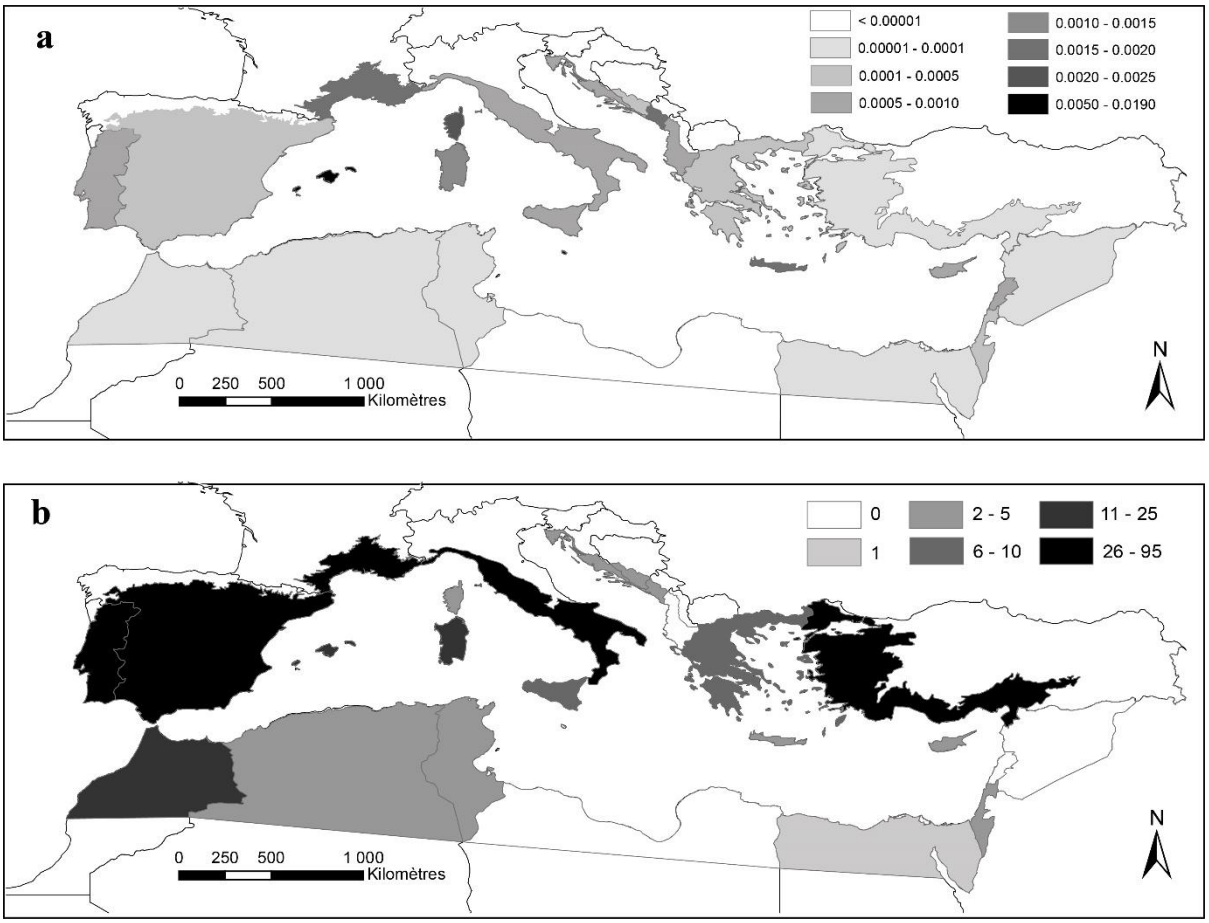
Malard, F., M.-J. Dole-Olivier, J. Mathieu & F. Stoch. 2002. Sampling Manual for the Assessment of Regional Groundwater Biodiversity. Report of the European Project Pascalis. 110 pp.

Wagner, H. 1994. A Monographic review of the Thermosbaenacea (Crustacea: Peracarida). A study on their Morphology, Taxonomy, Phylogeny and Biogeography. 291 pp.

Wagner, H.P. 2012. *Tethysbaena ophelicola* n. sp. (Thermosbaenacea), a new prime consumer in the Ophel biome of the Ayyalon Cave, Israel. Crustaceana 85: 1571–1587. https://doi.org/10.1163/156854012X651646

Table 1. Mediterranean and global species diversity per order belonging to Malacostraca. The reference values of global diversity are those provided in (Balian *et al.*, 2008) and updated with the World Register of Marine Species (Horton *et al.*, 2020) and the present study.

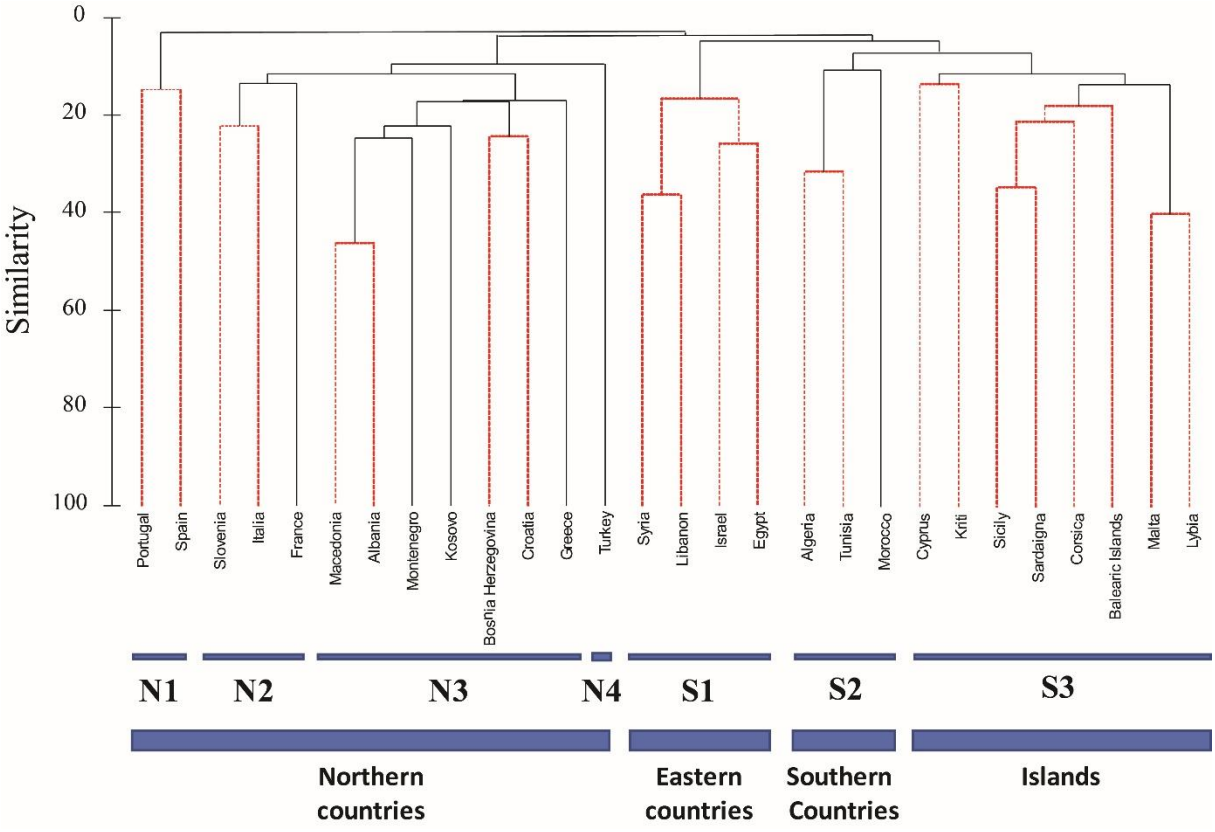
	Mediterranean basin	**Global**
Amphipoda	**581**	**1,866**
Bathynellacea	**71**	**219**
Decapoda	**63**	**2,832**
Ingolfiellida	**9**	**20**
Isopoda	**336**	**994**
Mysida	**12**	**60**
Stygiomysida	**2**	**5**
Thermosbaenacea	**12**	**20**
Total	**1,084**	**6,014**



3490

3491 Fig. 7.1. Geographic distribution of Malacostraca in the Mediterranean bioclimatic area. A,
3492 species richness was weighted by the country area (species.km-²); B, the number of endemic
3493 species is given for each country.

3494



3495

3496 Fig. 7.2. Results of the hierarchical cluster analysis of Bray Curtis similarity of faunal lists.
3497 Solid lines indicate significant differences ($P < 0.05$) using SIMPROF tests (Clarke, Somerfield
3498 & Gorley, 2008) and dashed lines indicate groups of samples not significantly separated by the
3499 test.

3500

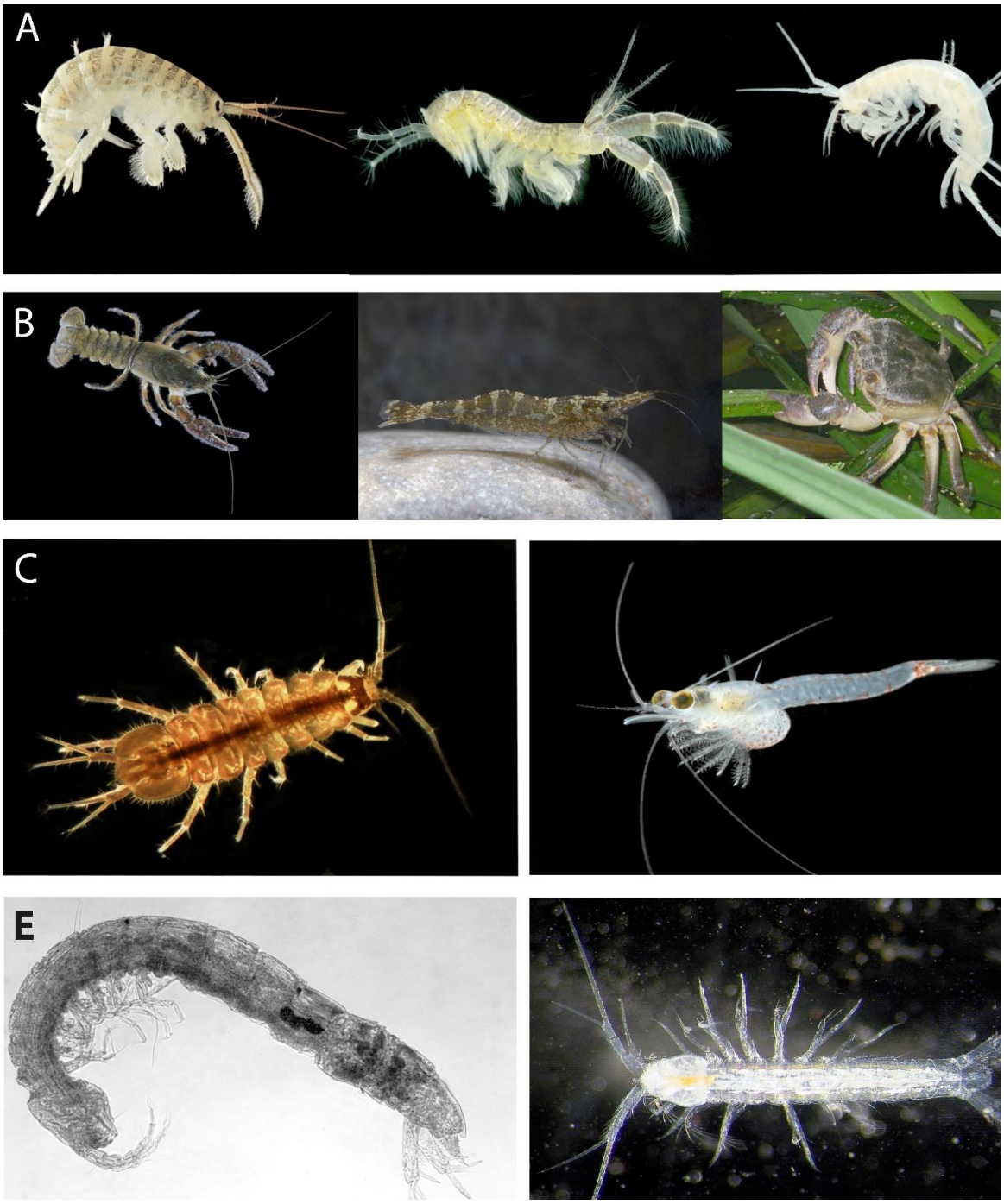


Fig. 7.3. General aspect of Malacostraca. A, from left to right *Dikerogammarus villosus* (Amphipoda, Gammaridae), *Chelicorophium robustum* (Amphipoda: Corophiidae) and *Niphargus schellenbergi* (Amphipoda: Nirphargidae), photogaph courtesy of JF Cart; B, from left to right *Pascifastacus leniusculus* (Decapoda: Astacidae), photograph courtesy of J.F. Cart, *Atyaephyra thyamisensis* (Decapoda: Atyidae) and *Potamon hippocratis* (Decapoda: Potamidae), photograph courtesy of W. Klotz; C, *Asellus aquaticus* (Isopoda: Asellidae), photograph credit of C. Piscart; D, *Hemimysis anomala* (Mysida: Mysidae), photograph courtesy of J.F. Cart; E, *Iberobathynella andalusica* (Bathynellacea: Parabathynellidae), photograph credit of I Camacho; F, *Tethysbaena ledoyeri* (Thermaosbaenacea: Monodellidae), photograph courtesy of P. Chevaldonné/CNRS.

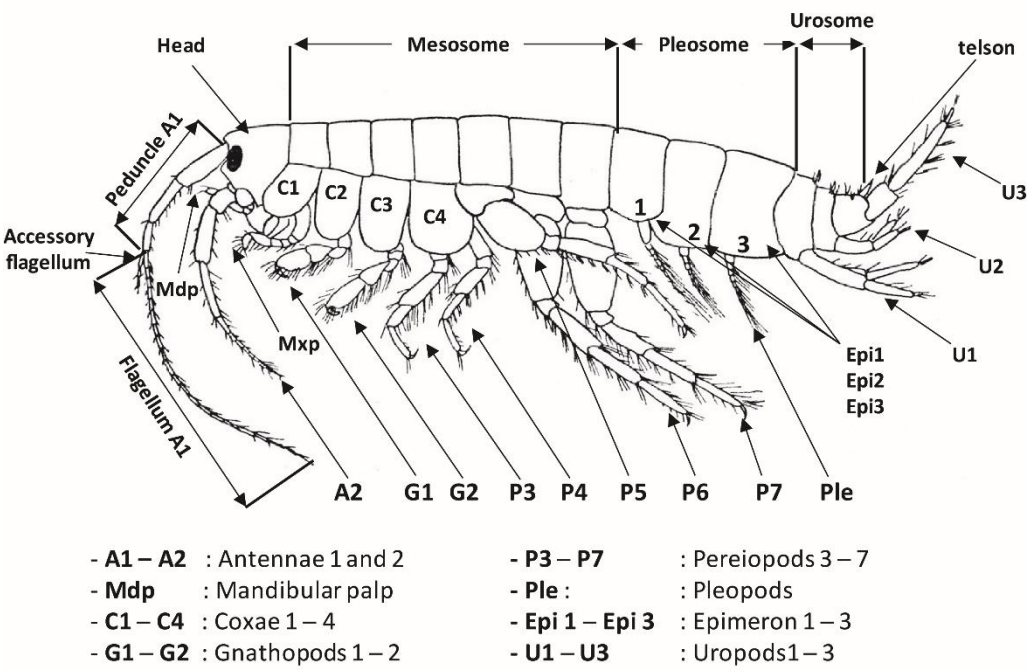


Fig. 7.4. General morphology of Amphipoda.

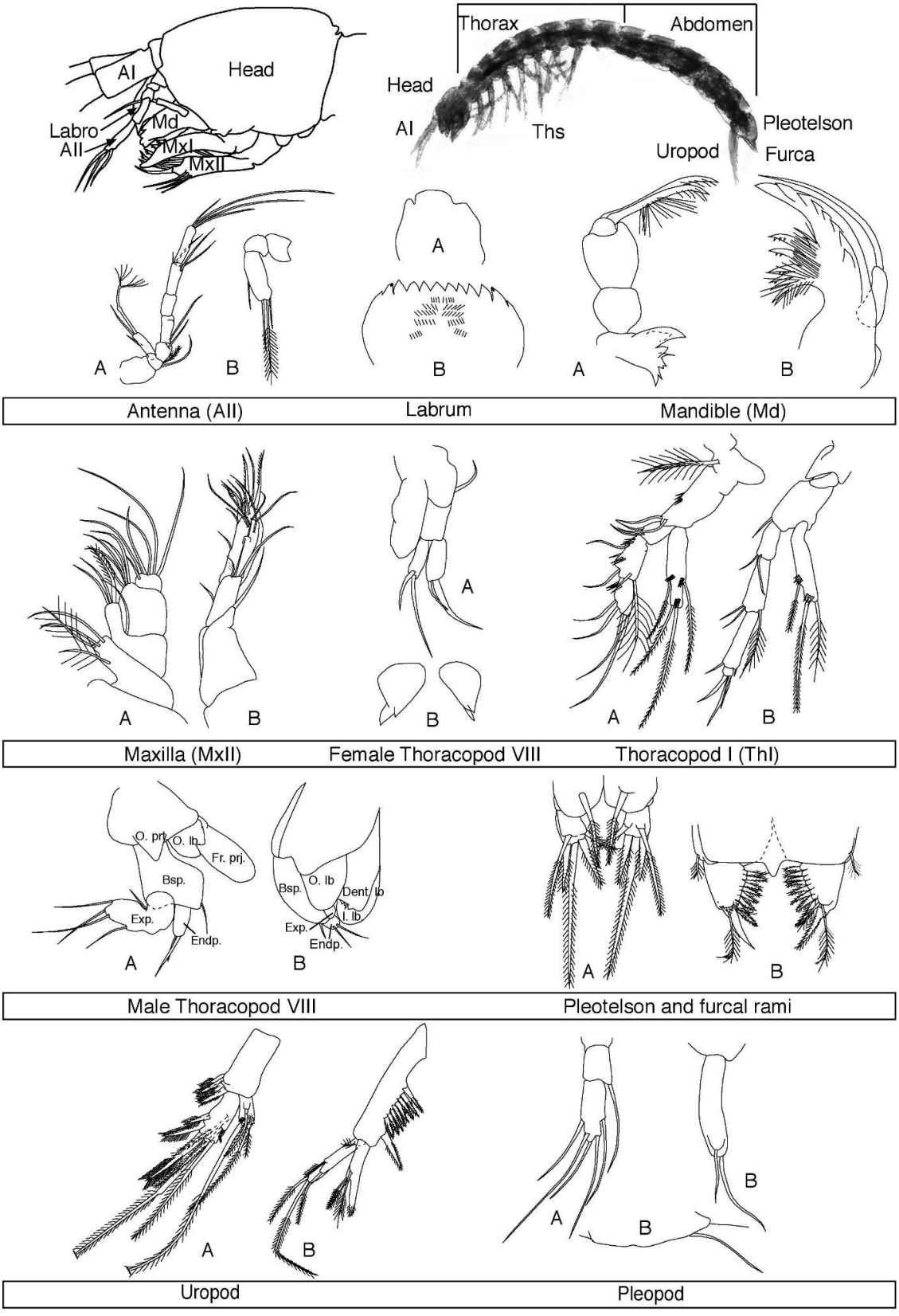


Fig. 7.5. Head of Parabathynellidae and habitus of *Iberobathynella*. Schematic parts of Bathynellacea body. A Bathynellidae family and B Parabathynellidae family.

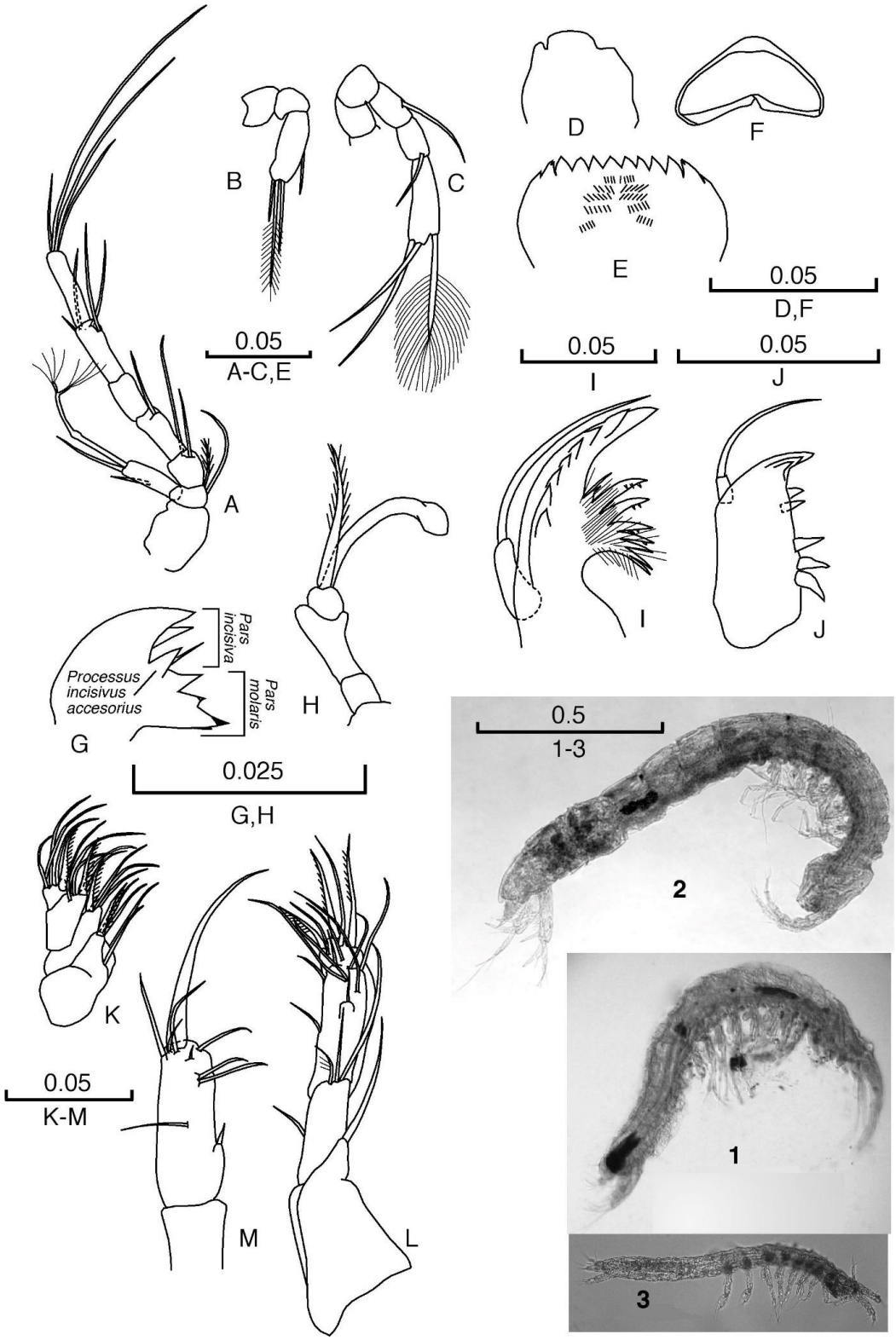


Fig. 7.6. Habitus: 1, *Vejdovskybathynella edelweiss* Camacho, 2007; 2, *Iberobathynella andalusica* Camacho, 2007 and 3, *Parvulobathynella distincta* Ranga Reddy, Bandari & Totakura, 2011. AII: A, *Vejdovskybathynella edelweiss*; B, *Iberobathynella andalusica* and C, *Parvulobathynella distincta*. Labrum: D, *Vejdovskybathynella edelweiss*; E, *Iberobathynella andalusica* and F, *Parvulobathynella distincta*. Md: D, E, *Vejdovskybathynella edelweiss*; I, *Iberobathynella andalusica* and J, *Parvulobathynella distincta*. MxII: K, *Vejdovskybathynella edelweiss*; L, *Iberobathynella andalusica* and M, *Parvulobathynella distincta*.

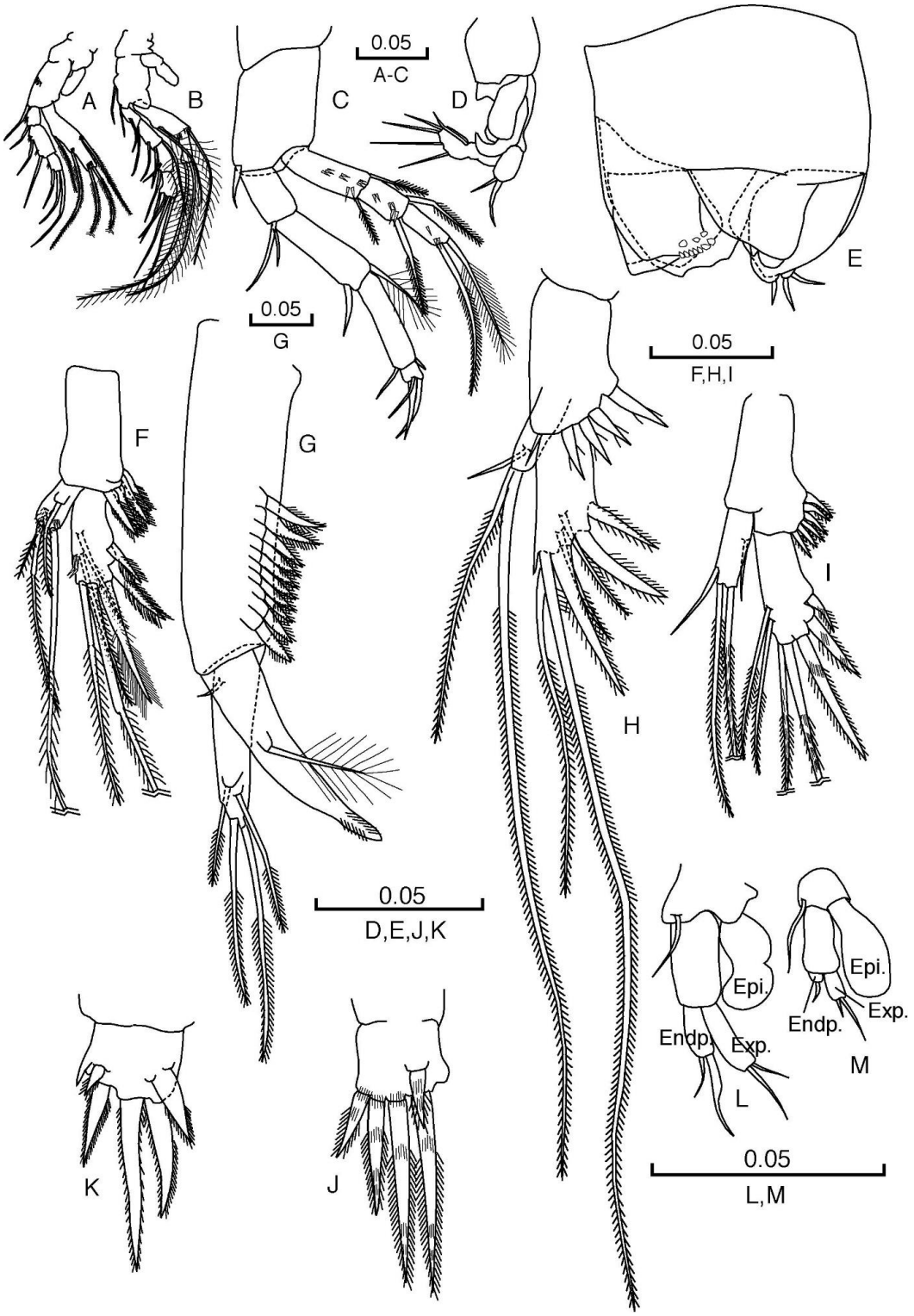


Fig. 7.7. Thoracopods: A, ThIII *Gallobathynella coiffaiti* (Delamare Deboutteville, 1961); B, ThIII *Vejdovskybathynella edelweiss*; C, ThI *Paraiberobathynella notenboomi* (Camacho, 1989). Male ThVIII: D, *Vejdovskybathynella edelweiss*; E, *Paraiberobathynella notenboomi.* Uropods: F, *Vejdovskybathynella edelweiss*; G, *Paraiberobathynella notenboomi*; H, *Antrobathynella stammeri* (Jakobi, 1954); I, *Bathynella paranatans* Serban, 1971. Furca: J, *Bathynella paranatans*; K, *Antrobathynella stammeri.* Female ThVIII: L, *Paradoxiclamousella pirata* Camacho, Dorda & Rey, 2013; L, *Paradoxiclamousella fideli* Camacho, Dorda & Rey, 2013

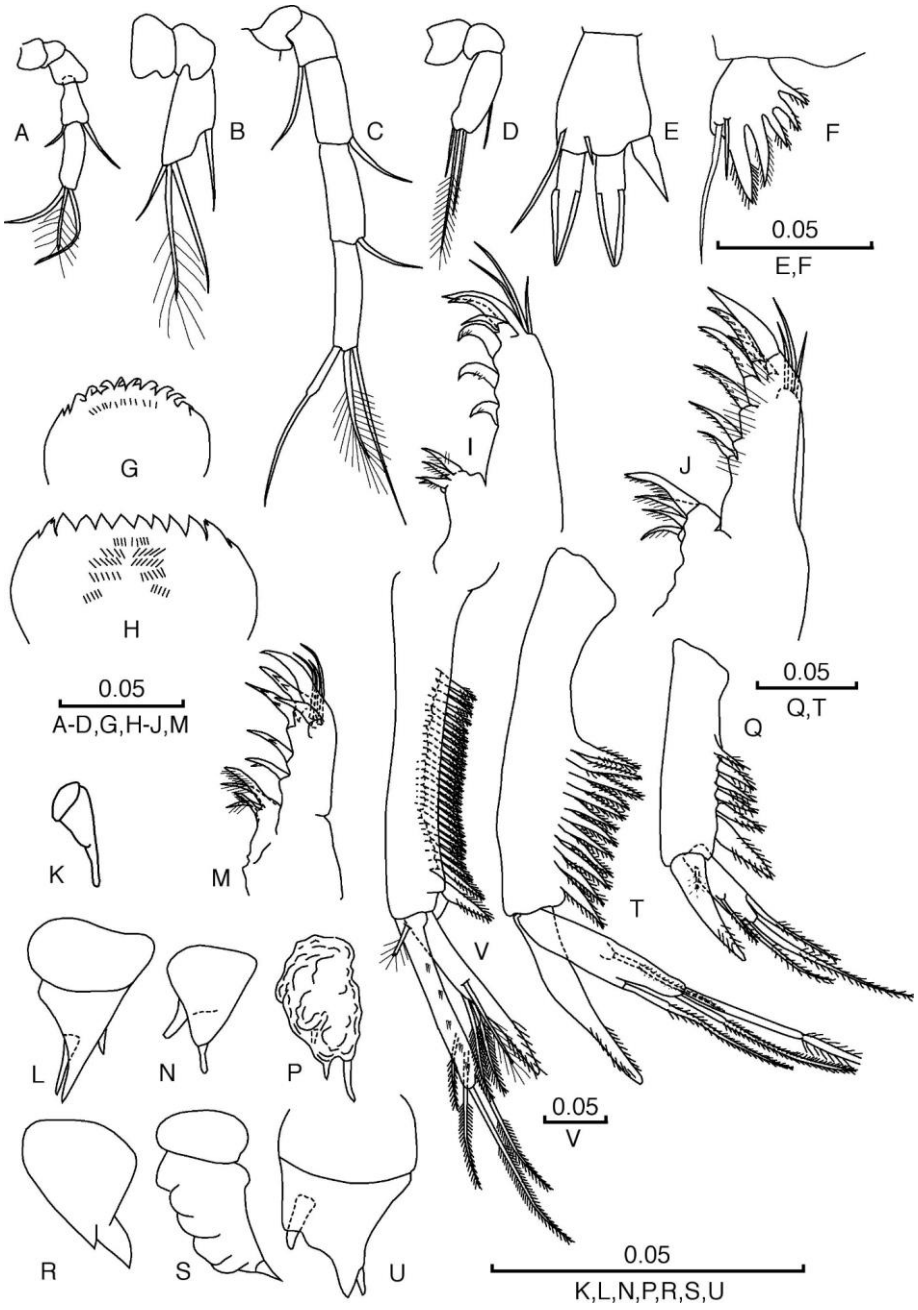


Fig. 7.8. AII: A, *Hexabathynella sevillaensis* Camacho, 2005; B, *Hexaiberobathynella hortezuelensis* Camacho & Serban, 1998 and C, *Cteniobathynella* Schminke, 1973. Furca: E, *Cteniobathynella* and F, *Parabathynella*. Labrum: G, *Guadalopebathynella puchi* Camacho & Serban, 1998 and H, *Iberobathynella andalusica*. MxI: I, *Guadalopebathynella puchi*; J, *Iberobathynella andalusica* and M, *Iberobathynella* (*Asturibathynella*) *lamasonensis* Camacho, 2005. Female ThVIII: K, *Hexaiberobathynella mateusi* (Galhano, 1967); L, *Hexaiberobathynella hortezuelensis* Camacho & Serban, 1998; N, *Iberobathynella* (*Asturibathynella*) *ortizi* Camacho, 1989; P, *Iberobathynella* (*Asturibathynella*) *parasturiensis* Camacho & Serban, 1998; R, *Iberobathynella* (*Espanobathynella*) *andalusica*; S, *Iberobathynella* (*E.*) *burgalensis* Camacho, 2007; U, *Iberobathynella* (*Iberobathynella*) *paragracilipes* Camacho & Serban, 1998. Uropod: Q, *Iberobathynella* (*Asturibathynella*) *cornejoensis* Camacho, 2005; T, *Iberobathynella* (*Asturibathynella*) *burgalensis*; V, *Iberobathynella* (*Iberobathynella*) *paragracilipes* Camacho & Serban, 1998.

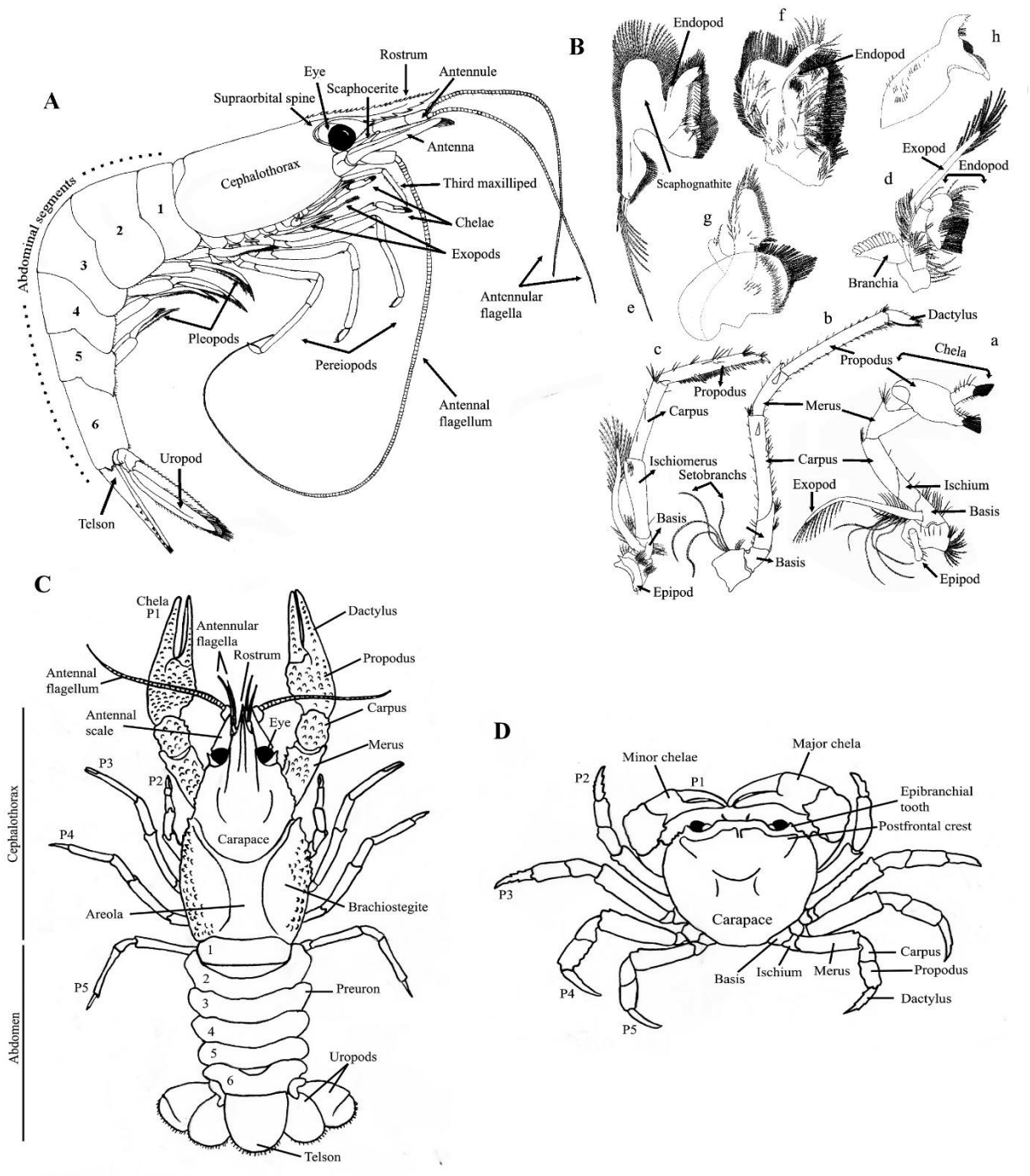


Fig. 7.9. A, General morphology of Caridea; B, Mouthparts and Pereiopods of Caridea: a, first pereiopod (Chela); b, fifth pereiopod; c, third maxilliped; d, second maxilliped; e, maxilla; f, maxillula; h, mandible; C, General morphology of Astacidea; D, General morphology of Brachyura.

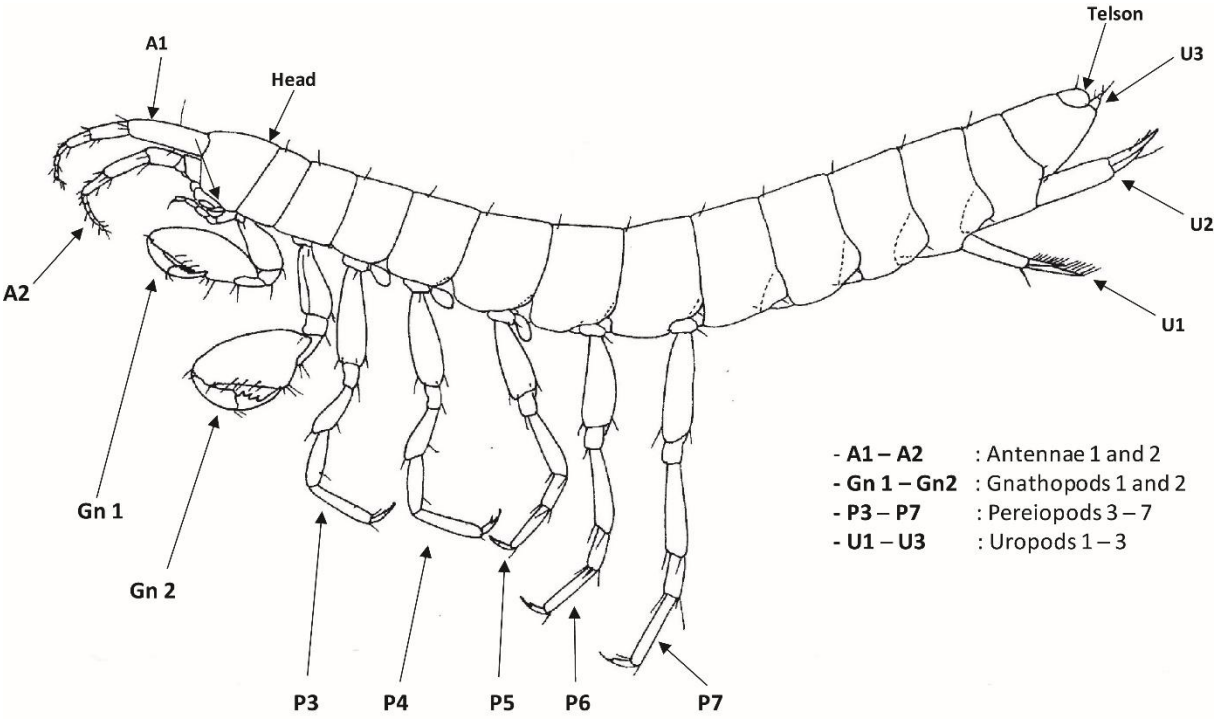


Fig. 7.10. Habitus of *Ingolfiella cottarellii* Ruffo & Vigna Taglianti, 1989 (modified after Karaman 1993).

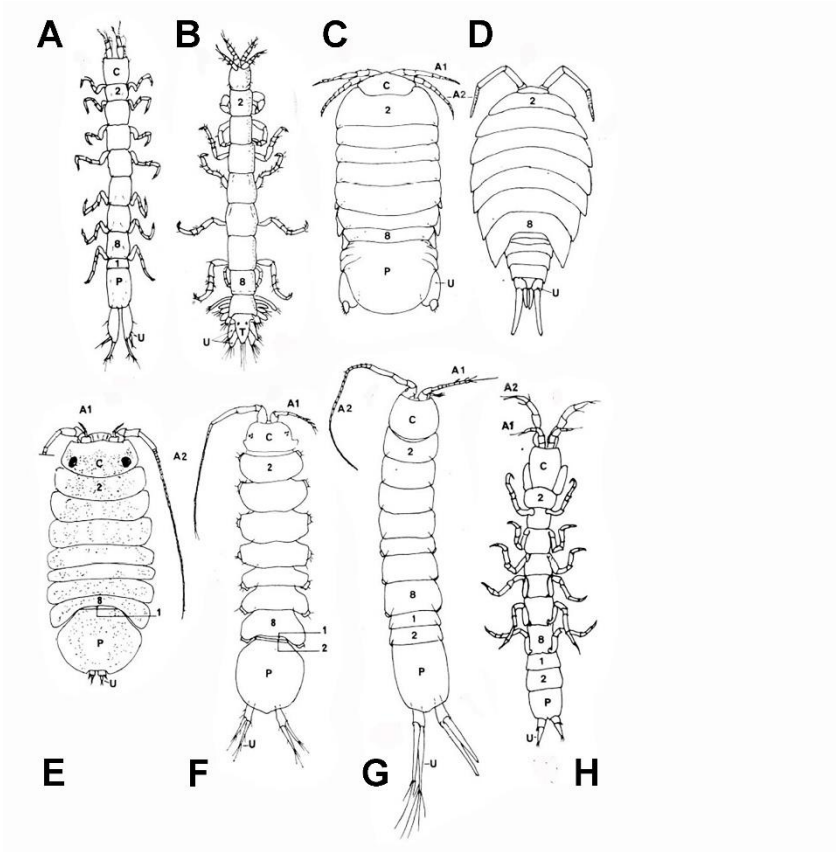


Fig. 7.11. A, a psammic *Microcharon* sp. (Lepidocharontidae); B, a stygobiotic *Stygocyathura milloti* (Anthuridae); C, *Faucheria faucheri* (Cirolanidae); D, scheme of an Oniscidae from Vandel 1966; E, *Jaera* sp. (Janiridae); F, scheme of an Asellidae; G, scheme of a Stenasellidae;

H, scheme of a Microparasellidae. C = cephalon; P = pleotelson; U = uropod; 2-8 = pereonites; 1-2 = pleonites.

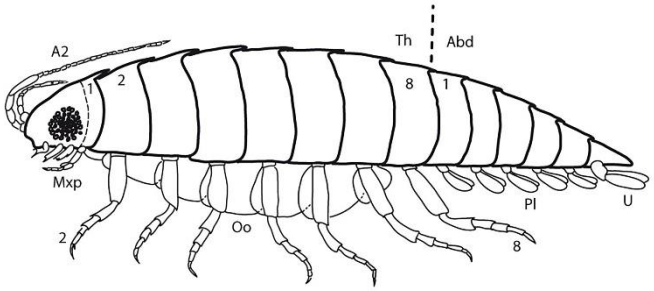


Fig. 7.12. Schematic left lateral view of a female isopod. A2 = antennae; Abd = pleon; Mxp = maxilliped; Oo = oostegites; P = pleopods; U = uropods. 2-8 = free pereonites bearing pereopods (the first one fused to the cephalon bears the maxilliped); 1-5 = pleonites.

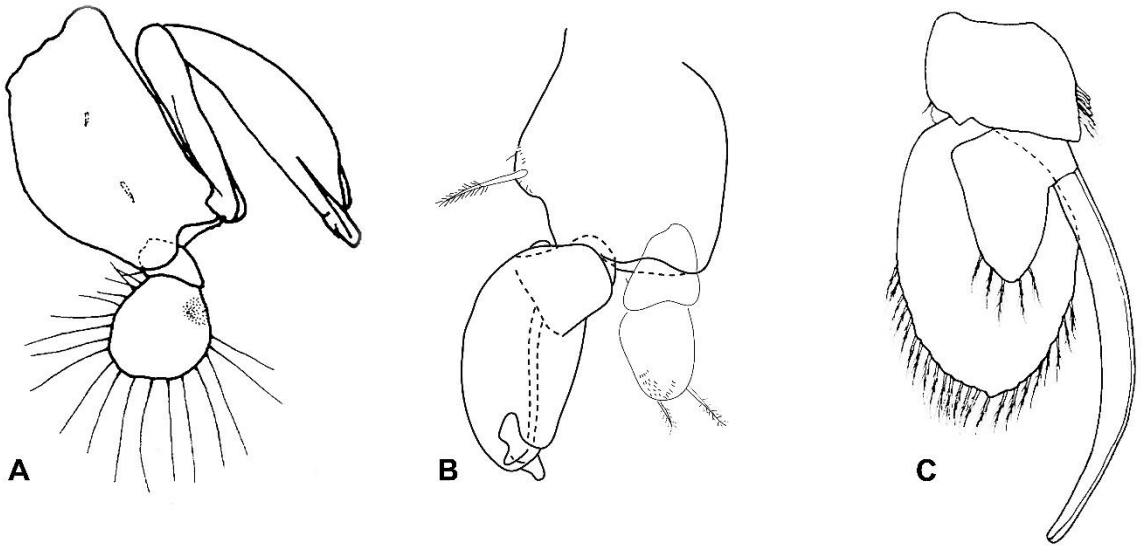


Fig. 7.13. Second pleopod male of three different genera: 1. *Stenasellus*; 2. *Proasellus*; 2. *Typhlocirolana*.

Fig. 7.14. *Stygiomysis hydruntina*. Photograph courtesy of Salvatore Inguscio.

Fig. 7.15. *Spelaeomysis bottazzii*. Photograph courtesy of R. Pepe.

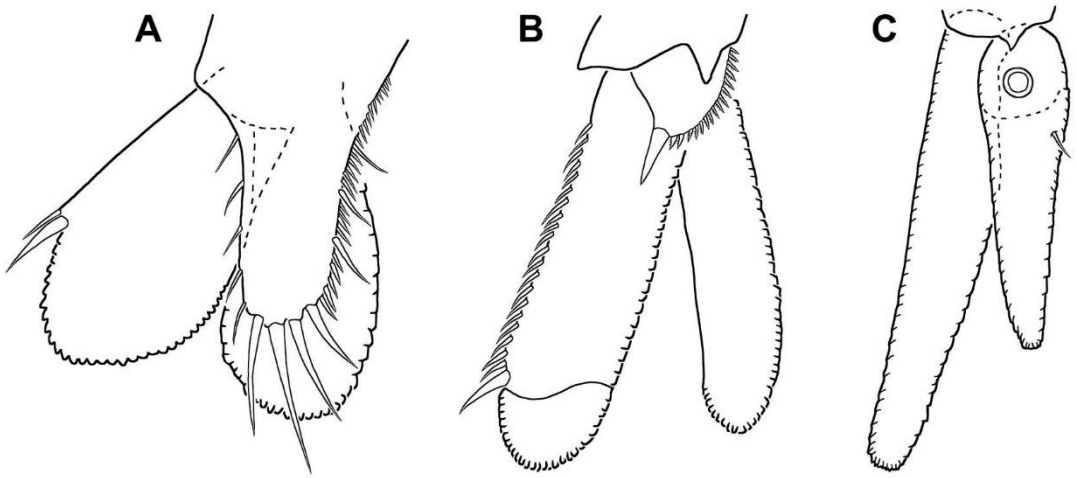


Fig. 7.16. Uropods of (A) *Stygiomysis hydruntina*, (B) *Spelaeomysis bottazzii*, and (C) *Troglomysis vjetrenicensis*; (A–C) ventral view, setae omitted.

Fig. 7.17. *Neomysis integer*, ventral.

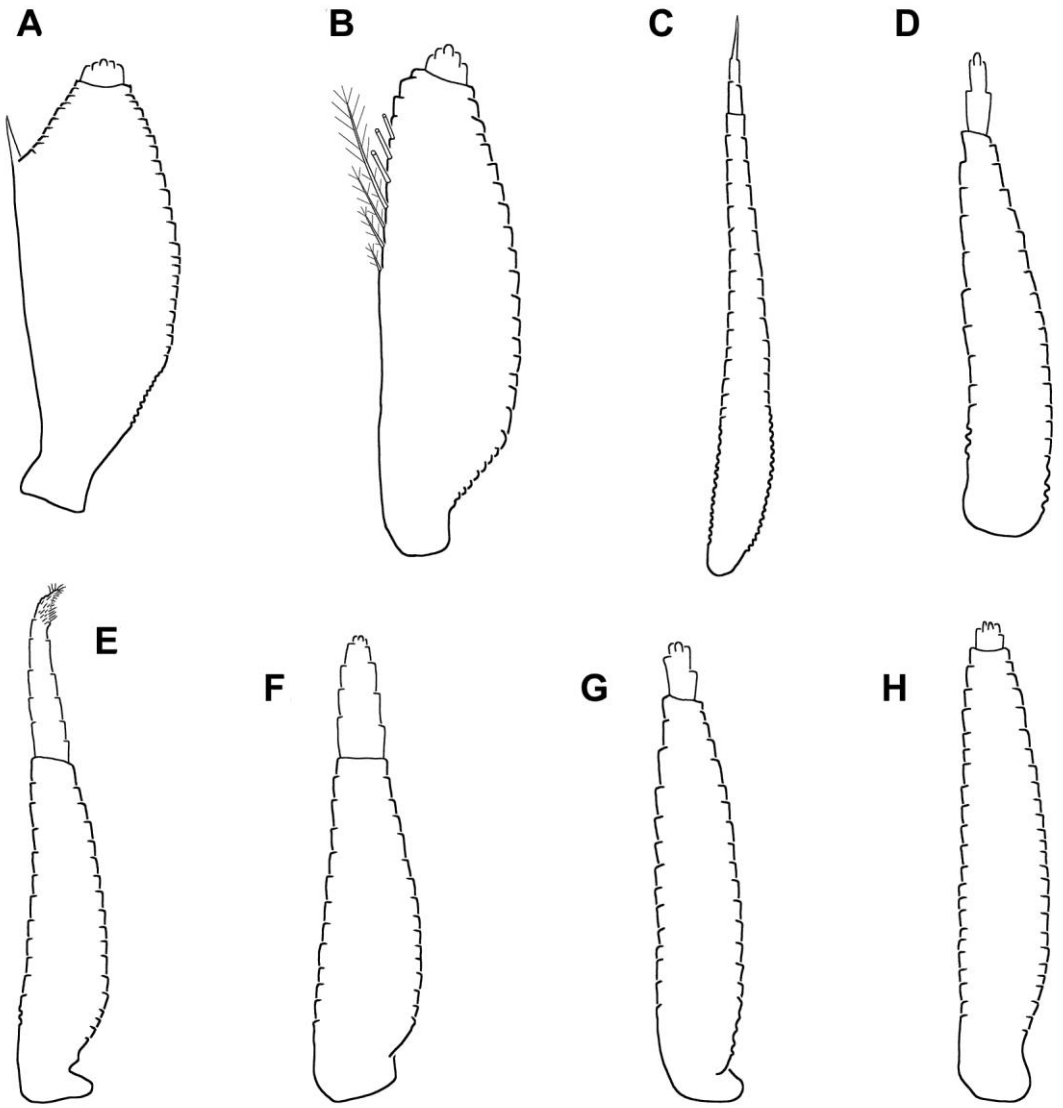


Fig. 7.18. Antennal scale of (A) *Paramysis (Longidentia) adriatica*, (B) *Hemimysis anomala*, (C) *Neomysis integer*, (D) *Mesopodopsis slabberi*, (E) male *Limnomysis benedeni*, (F) female *L. benedeni*, (G) *Diamysis fluviatilis*, and (H) *Troglomysis vjetrenicensis*. Most (B and E) or all (A, C, D, and F–H) setae omitted, respectively.

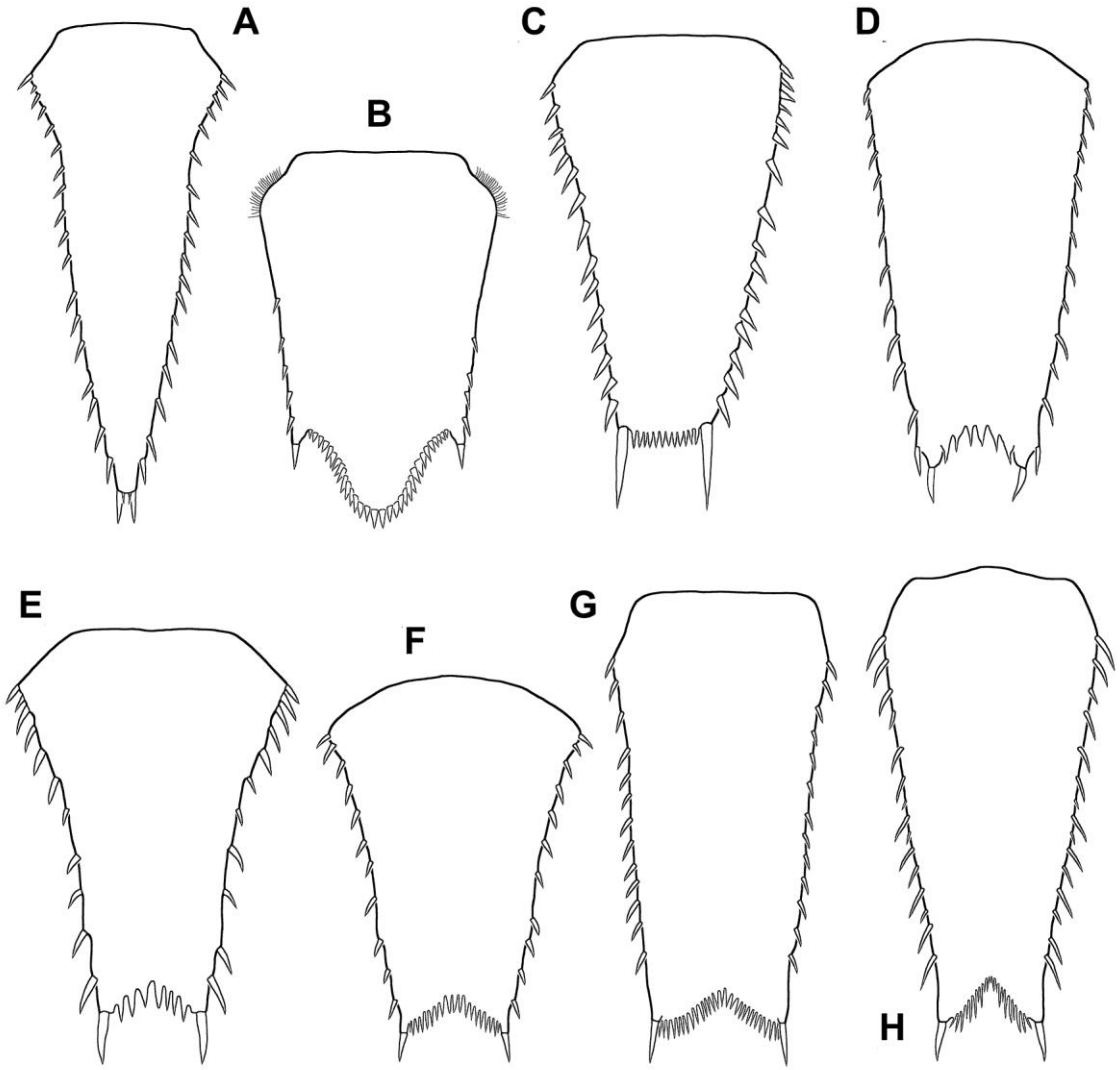


Fig. 7.19. Telson of (A) *Neomysis integer*, (B) *Mesopodopsis slabberi*, (C) *Hemimysis anomala*, (D) *Troglomysis vjetrenicensis*, (E) *Limnomysis benedeni*, (F) *Diamysis lacustris*; (G) *Paramysis (Serrapalpisis) kosswigi*, and (H) *Paramysis (Longidentia) adriatica*.

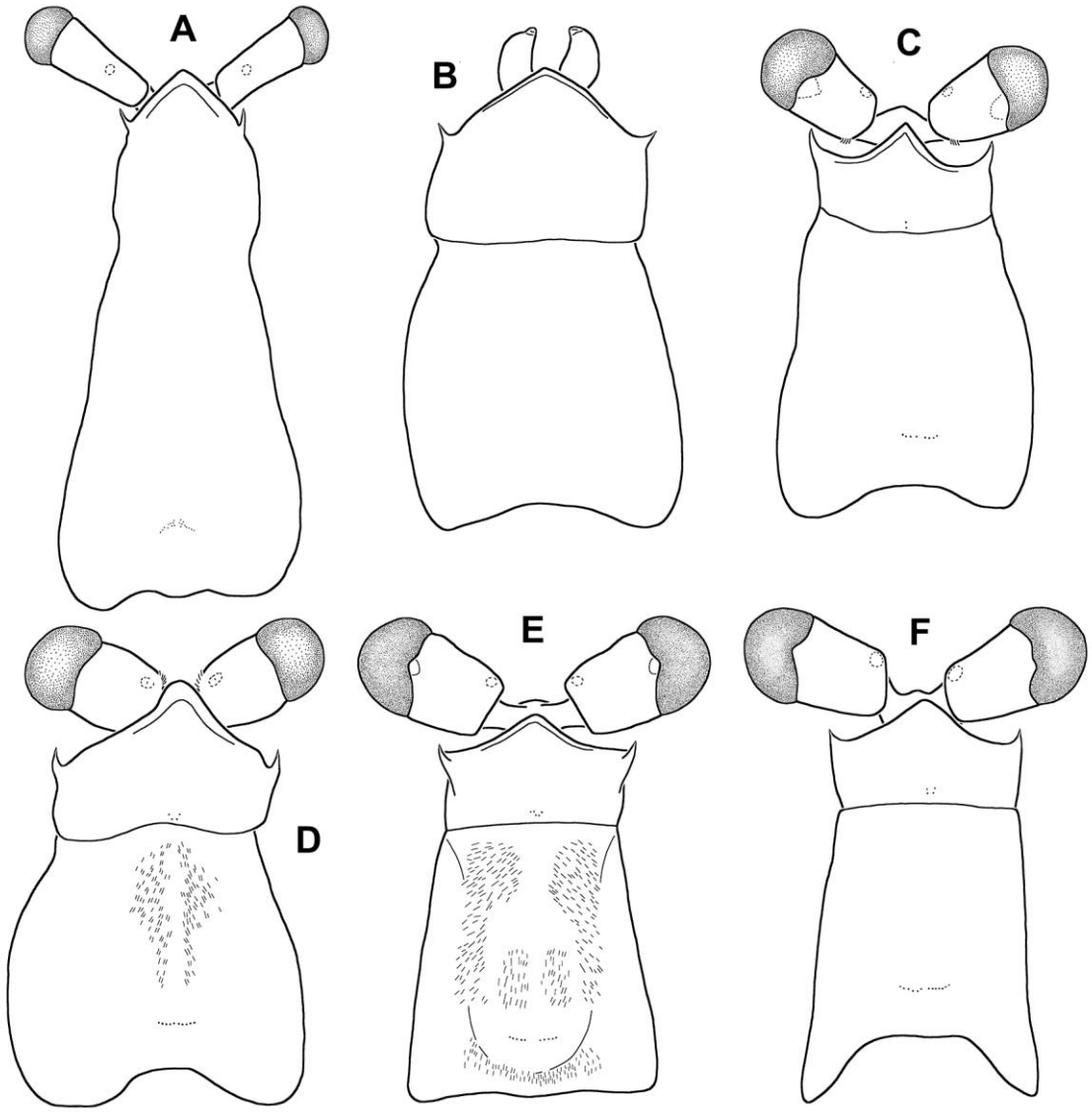


Fig. 7.20. Eyes and carapace of (A) *Mesopodopsis slabberi*, (B) *Troglomysis vjetrenicensis*, (C) *Diamysis lacustris*, (D) male *Diamysis fluviatilis*, (E) male *Diamysis mesohalobia heterandra*, and (F) *Diamysis hebraica*.

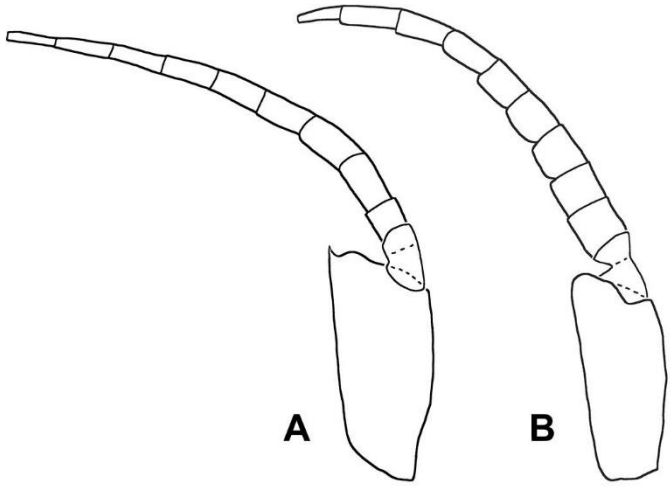


Fig. 7.21. Third thoracic exopods of (A) *Diamysis fluviatilis* and (B) *Diamysis hebraica*; (A and B) setae omitted.

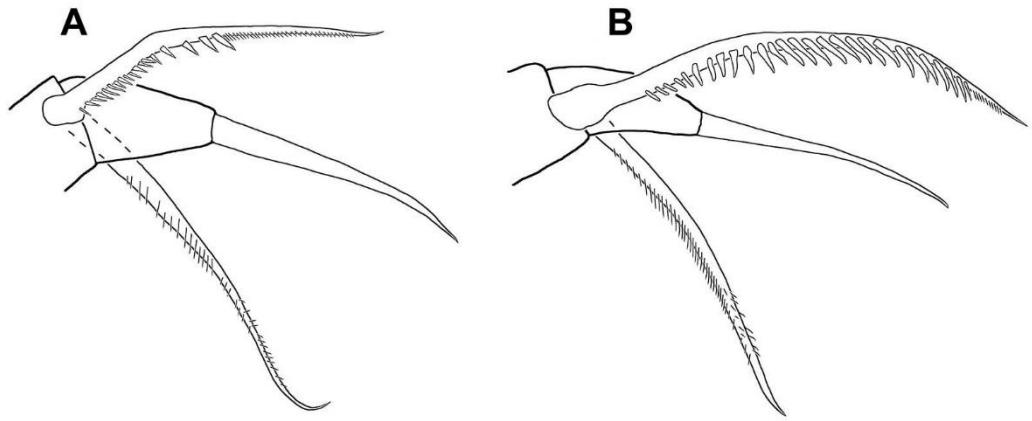


Fig. 7.22. Dactylus with claw and paradactylary setae of fifth thoracic endopods of (A) *Paramysis (Serrapalpisis) kosswigi* and (B) *Paramysis (Serrapalpisis) lacustris*; (A and B) other types of setae omitted.

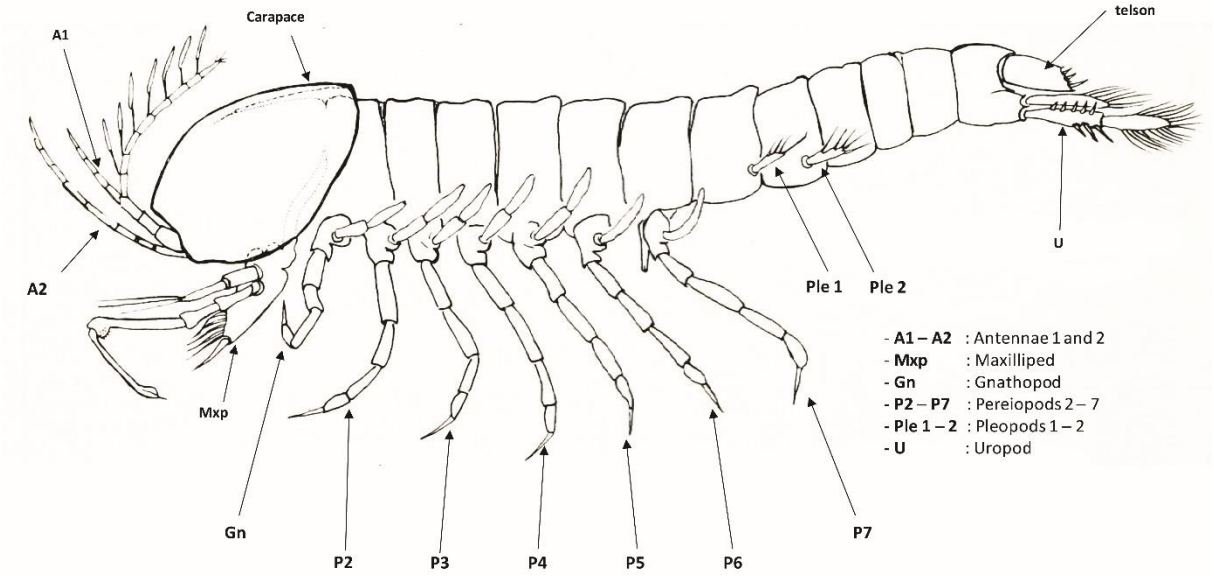


Fig. 7.23. General morphology of Monodellidae (modified after Monod & Cals 1988).