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Review Paper

Freshwater biodiversity in the rivers of the Mediterranean Basin

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Abstract We review the diversity of freshwater organisms in the Mediterranean Basin (hereafter Med), particularly from streams and rivers. We present available information on the richness, endemicity, and distribution of each freshwater organism group within the Med, and make a comparison with Palearctic diversity. Approximately 35% of known Palearctic freshwater species and more than 6% of the World's freshwater species are present in the Med. A high degree of endemicity is found in the Med freshwater biota. These data, together with the degree to which many freshwater species are threatened, support the inclusion of the Med among World biodiversity hotspots. Nevertheless, knowledge of Med biodiversity is still incomplete, particularly for some taxa. Regarding to the spatial distribution of species within the Med, the richest area is the North, although patterns differ among groups. A comparison of the ecological and biological traits of endemic and non-endemic species of three riverine groups (Ephemeroptera, Plecoptera, and Trichoptera)

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revealed that endemic species have several strategies and mechanisms to face typical mediterranean-climate conditions, such as drought, when compared to non-endemic species. We briefly analyse the conservation status of the region's biodiversity. Finally, we present some future challenges regarding the knowledge and protection of Med freshwater biodiversity.

Keywords Freshwater organisms · Streams and rivers · Endemism · Conservation · Mediterranean diversity

Introduction

The Mediterranean Basin (hereafter Med) is one of the richest and most complex places on Earth (Blondel et al., 2010). Med biodiversity is the result of a unique combination of geography, geological history, and climate (Cuttelod et al., 2008). An important component of Med biodiversity is derived from intense human activity in this area, which had a more pronounced impact than found in most other parts of the World (Blondel et al., 2010).

The mediterranean biogeographical region is well-defined by its characteristic climatic pattern, which was established in the late Pliocene. It has a distinct cool and wet season followed by a warm and dry season and is influenced by a sequence of regular and often extreme flooding and drying periods (Gasith & Resh, 1999; Bonada & Resh, 2012). Snow fall is rare. This region includes not only the area surrounding the Mediterranean Sea but also areas in coastal California, coastal Chile, Southeast and Southwest Australia, and the Cape province of South Africa. The Med is the largest of the World's five mediterranean-climate regions (hereafter referred to as med-regions), and there is no consensus on the precise limits of this area. Many authors (e.g. Hofrichter, 2001; Olson et al., 2001; Mittermeier et al., 2004; Blondel et al., 2010) consider the Med to be a surface that covers approximately 2 million km^2. In the present paper, we will follow the limits reported in Olson et al. (2001) (Fig. 1), which include part or all of continental: Portugal; Spain; France; Monaco; Italy; the Balkan states of Slovenia, Croatia, Bosnia-Herzegovina, Montenegro, Albania, and Greece; Turkey; Jordan; Syria; Lebanon; Palestine; Israel; Egypt; Libya; Tunisia; Algeria; and Morocco; as well as about five thousand islands scattered around the Mediterranean Sea (including the states of Malta and Cyprus). West of the mainland, this region also includes the Macaronesian Islands of Canaries, Madeira, Savages, and Azores. Although not included in the present paper, Cape Verde could also be included, according to some authors (e.g. Mittermeier et al., 2004). Despite its geographical situation, because of the biogeographical particularities of the downstream part of the Nile River, most of Egypt has not been included in our study.

The particular biological and ecological diversity of this region, as well as its status as its very threatened biota, has led to the recognition of the Med as one of the first 25 Global Biodiversity Hotspots (Myers et al., 2000; Mittermeier et al., 2004). Usually, the great richness of plant species has been emphasised (approximately 30,000, with more than 43% endemic to this area), but some other land and marine groups also have high diversity (Mittermeier et al., 2004; Cuttelod et al., 2008). As noted by these and other authors, several circumstances have contributed to this high diversity: (1) its location at the intersection of two major landmasses, Eurasia and Africa; (2) its great topographical diversity, with altitudes ranging from sea level to 4,167 m.a.s.l. at Toubkal Mountain (High Atlas, Morocco); and (3) its previously referred to particular climate, which is greatly heterogeneous in this area (with rainfall ranging from less than 100 mm to more than 3,000 mm). Unfortunately, Conservation International places the Med among the four most significantly altered hotspots on the Earth because only 5% of the area's original 2 million km^2 remain unaltered (Mittermeier et al., 2004).

Despite being one of the most-studied and well-known regions in the World, the knowledge of stream organisms is not complete. Considerable information is available only for some groups (mainly vertebrates, some macroinvertebrate orders, and macrophytes) and for some places (e.g. the North, and particularly the North-West, is better known than the South). Nevertheless, for these well-studied groups, new species continue to be described (e.g. 79 new species of freshwater fishes have been described since 2000 in the Med, see below).

The main aims of the present work are: (1) to review the current knowledge on stream biodiversity

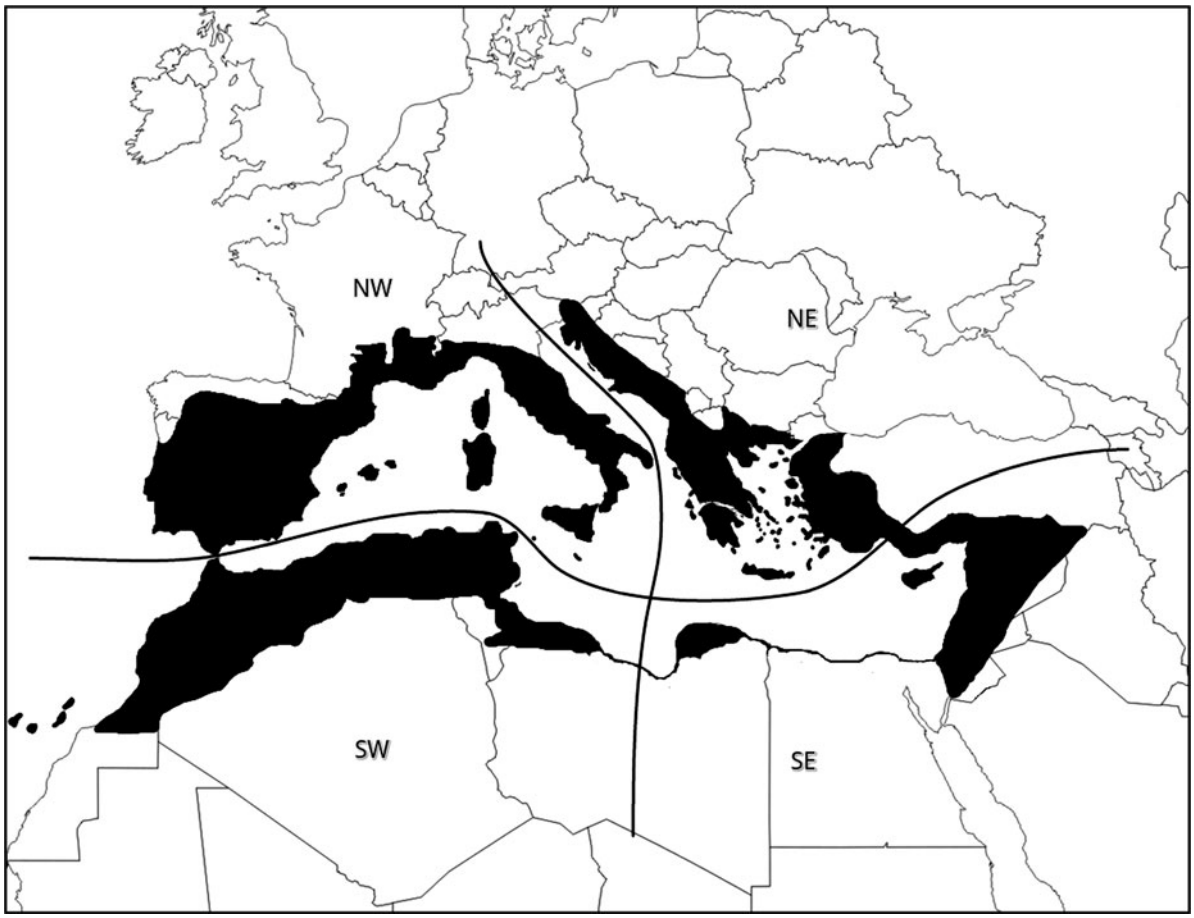

Fig. 1 Map of the Mediterranean Basin area with the limits considered here (*black* area) and divided into 4 different areas: NW (North-West; Med Europe from Portugal to Italy, both including the Balearic Islands, Corsica, Sardinia, Sicily and Malta, as all of the small West Med islands); NE (North-East; from the former Yugoslavian countries to North-West Turkey, including all of the Greek and West Turkish islands); SE (South-East; South Turkey, Cyprus, Med Near East, and East Lybia); and SW (South-West; from Morocco to West Libya, including Macaronesia)

of the Med; (2) to compare the stream biodiversity of the Med with Palearctic diversity in order to assess its richness and degree of endemicity; (3) to highlight the existing gaps in this knowledge; and (4) to identify priorities for future investigations to fill these gaps (e.g. the most- and least-studied groups or areas, current status of knowledge and future perspectives). In addition, the conservation status of the stream biodiversity of the Med will be briefly discussed and the main traits, both biological and ecological, of the Med species will be analysed by selecting some well-known groups of organisms. Particular emphasis will be placed on advances in the knowledge of stream biodiversity in this area over the last decade and the challenges to be faced in the near future.

Overview of analysis

In this review, we have evaluated biodiversity in the Med area as delineated by Olson et al. (2001) (Fig. 1). We have used the most updated and complete bibliography by means of rigorous literature searches, confirming data with specialists in many cases. For presence and distribution data, we have consulted general databases, reviews, and checklists of the taxonomic groups and studied areas, as well as specific articles and books (cited in each section of the present review). We have used Web of Knowledge (and, within it, the Zoological Record and Web of Science databases), Google Scholar (for those articles from journals that were not indexed in the Journal Citation Reports), and bibliographic catalogues of university

libraries (mainly Universidad de Granada, Università del Piemonte Orientale, and Università della Tuscia). For those cases in which information was not available, we have contacted the authors directly. Many specialists (almost 60, see the "Acknowledgments" section) have been consulted, and they have provided fundamental and valuable information.

The available information regarding Med freshwater biodiversity is enormous but distinctly distributed among organism groups and geographical areas. In this review, we have focused on every group of freshwater organisms inhabiting Med rivers, except the majority of parasites. We have treated these groups in different depth depending on the existing knowledge and available data. Some well-studied groups have been treated in greater detail to obtain a more complete and rigorous picture of Med biodiversity.

There are some obvious limitations considering the exact number of species of some groups. One limitation is the high connectivity between stream and riparian zones, or between lentic and lotic systems, which can make it difficult to delimitate strictly stream species in some taxa. When relevant, this aspect has been discussed in the appropriate sections. Another limitation is the existence of two different schools of thought regarding some microorganisms with high dispersion capacity (e.g. bacteria, protists); that is, whether there is a low number of species with a wide distribution or whether there are many different species with a narrow distribution (Moss, 2010). Finally, the main problem that we have encountered is the scarcity of taxonomical and biogeographical studies for many taxa and the accessibility of these studies.

The conservation status of the different groups of organisms has been primarily compiled from the IUCN Red List of Threatened Species (IUCN, 2011) and, in particular, some IUCN reports. Occasionally, and, when available, national red lists have been consulted.

We have performed trait analyses of three orders of aquatic insects from the Med, namely Ephemeroptera, Plecoptera, and Trichoptera (EPT). We have focused on those species with available data. EPT have been used as model organisms because they are typical freshwater inhabitants of streams and rivers (very few species are exclusively found in lentic habitats), much information is available on them, and they have a wide spectrum of strategies. For this study, we have mainly used data from Graf et al. (2008, 2009), Buffagni et al. (2009), and several more recent articles on specific species. In some databases, information was available up to the subspecies level and we have modified the original data to remain at the species level. We have selected some of the available traits (five ecological and nine biological) and information about them that we have considered to be more relevant for med-region inhabitants [for categories within each trait, see Graf et al. (2008, 2009), Buffagni et al. (2009)], such as: "stream zonation preference" (i.e. species preferentially found in a certain longitudinal zone, e.g. eurhithron, metapotamon); "altitude preference"; "microhabitat/substrate preference"; "current preference"; "temperature range preference"; "feeding type"; "resistance/resilience to droughts"; "resistance form"; "life duration"; "larval development cycle" (i.e. in which seasons the immature stages, either nymphs or larvae, are present in the stream); "emergence/flight period"; "duration of emergence period"; "reproductive life cycles per year" (i.e. voltinism); and "r–K-strategy". We have also used information from the category "rare species", which accounts for those species that are found in small numbers or locally distributed. Some of these traits coincide with those proposed by Robson et al. (2011) in a recent work on the importance of life history knowledge in macroinvertebrates inhabiting streams that are subject to drying. We have used presence/absence data, and for those traits that appeared with a ten-point assignment system in the original references, we have converted those data to presence/absence data. Thus, some species can be included in more than one category within a trait, so the sum of percentages of the categories within a trait may result in more than 100%. We have calculated percentages in relation to the number of species with available data for each trait and in relation to the total number of species present in the Med (as considered in other sections). In our analyses, we have compared species endemic to the Med with those that, though present in the basin, are also found outside the limits considered here.

Biogeography

The Med can be considered a model system for biogeographical studies because of its complex history and evolution, and a unique combination of geological and climatic factors. These factors have created highly diversified biotas. Moreover, the anthropic influence

(see "Conservation" section) on diversity has been great, whether in terms of biodiversity loss or modification, and of planned or unplanned exotic species introduction. Situated in a collision area between the African and Euro-Asiatic plates, the Med, from a geographical point of view, is one of the most complex regions of the World where different tectonic processes originated a vast system of mountains (Hofrichter, 2001). The geologic and climatic events that have affected the Med have influenced and shaped its freshwater biodiversity and created a complex biogeographical history. Beside plate techtonics, the major events are the Messinian salinity crisis and the glaciations.

The intense tectonic activity is caused by the collision and subsidence of the northward-moving African plate beneath the European plate, and by the strong East–West pressures to Asia Minor exerted by the Arabian plate. The collision originated a vast system of East–West-oriented mountains (Oligocenic Alpine orogeny). Another important factor in reconstructing the biogeography of freshwater fauna is the Oligo-Miocene drifting of the Med microplates (Corsica and Sardinia among others) that split from the Iberian plate as a single landmass and rotated to their present position (Álvarez, 1972; Álvarez et al., 1973, 1974). Subsequently, and approximately 6 million years ago (Mya) during the late Miocene, the Gibraltar strait closed and the Mediterranean Sea was reduced to a series of saline lakes for some 630,000 years. This event, known as the Messinian salinity crisis, strongly influenced the distribution of the inland water fauna and flora.

Historically, cyclic climatic changes between cold and warm periods in the Pleistocene resulted in quaternary glaciations. The glaciations strongly affected the distribution of animals and plants according to the two contrasting and dynamic responses of different groups of organisms: ones that expanded during warm periods and retracted during cold phases, while the others exhibited the opposite behaviour (Blondel et al., 2010).

Finally, a primary aspect of the Med is its long history of human presence, which spans millennia. Because of the shortage of surface water in this area, and its necessity for human-related activities, anthropic pressure has caused modifications, almost always in a negative sense, in the biodiversity and biogeography of plants and animals (Blondel et al., 2010).

In the particular biotas of the Med, different types of elements can be distinguished from a biogeographical point of view, according to their origin and singularity:

(1) Extremely reduced populations of archaic species (i.e. archaic relics) are sometimes found in remote mountain ranges (Blondel et al., 2010). In freshwater species, for instance, many genera of extant freshwater molluscs seem to be of very ancient origin, such as *Neritina*, *Planorbis*, *Lymnaea*, *Physa*, and *Unio*.

(2) The ancient Med "warm" biota was deeply modified by climatic changes during glaciations. However, few elements remained (tertiary relicts), at least in regard to freshwater organisms. Among aquatic plants, some *Marsillea* species could be considered tertiary relicts (Lorite, pers. comm.). There also are a few pre-glacial species in European freshwaters that are now confined to thermal waters. For instance, many *Melanopsis* species (Mollusca) can be found in thermal waters all across the Med. Species that colonised Oligocene subterranean freshwaters must be ascribed to an ancient tertiary fauna, which now exhibits relict distributions, e.g. the Urodela amphibians *Proteus* and *Hydromantes*, with close relatives in Central-North America.

(3) A peculiar kind of distribution originated from the disjunction and rotation of the Corso-Sardinian system from the Iberian Peninsula that occurred in the Cenozoic, beginning in the Oligocene, approximately 27–29 Mya. Several different groups of organisms presently show a vicariant distribution, with closely related species in the Iberian mainland, in the Baleares, Sardinia, and Corsica, and in North African Kabilia microplates. Examples of this distribution are: the freshwater newt genus *Euproctus–Calotriton*, with *C. asper* and *C. arnoldi* in the Pyrenees, *E. platycephalus* in Sardinia, and *E. montanus* in Corsica (Carranza & Amat, 2005); the subterranean aquatic stenasellid isopods *Stenasellus*, with a peri-Tyrrhenian distribution (Ketmaier et al., 2003); and species of the stonefly genera *Protonemura* (particularly the *corsicana* group) and *Tyrrhenoleuctra* (Fochetti, 1994; Fochetti et al., 2009).

(4) The Messinian salinity crisis also strongly influenced the distribution of inland water organisms. For instance, the colonisation of Peri-Mediterranean areas by freshwater fishes occurred immediately after the Messinian salinity crisis (about 5 Mya) when freshwater from Paratethys drained into and filled the dry or nearly dry Mediterranean Sea (Reyjol et al., 2007). Similarly, this event was hypothesised to have promoted the colonisation of freshwater by euryhaline ancestors in goby fishes (Penzo et al., 1998). Among amphibians, the distribution of *Discoglossus* species has been related to rapid radiation of their lineages during the Messinian Lago Mare phase (Zangari et al., 2006).

(5) Although the Med freshwater biota is diverse, considerable extinctions occurred during the Pleistocenic glaciations because the most important European mountain chains are East–West oriented. Thus, when ice advanced southwards, ice hindered the movement of fauna and flora to the South. Moreover, relationships between the European and Asian biotas have been limited. The presence of physical barriers between the Palaearctic region and contiguous areas (e.g. deserts, mountain chains) has hampered the dispersal of tropical and subtropical faunas and floras after the last glacial period. Thus, faunistic and floristic interchanges were only possible through Asia Minor and the mountain systems, whereas the Central European plains acted as a barrier. As a result, there are very few Afrotropical elements in the present inland water fauna and flora. For instance, Blondel et al. (2010) report that several rare chironomid midge species of Afrotropical origin reached the Med in various epochs via the Nile River valley and now occur only in isolated areas of Morocco (e.g. *Dicrotendipes collarti* and *Paratendipes striatus*). Many others species have been pushed southward by the Würm glaciation and then remained confined to suitable habitats (e.g. springs, peat-bogs). These are the "true" glacial relicts, such as the fishes *Gasterosteus aculeatus*, *Coregonus* spp., and *Salvelinus alpinus*, and many invertebrates. Among invertebrates, Spanish and Italian populations/subspecies of the decapod *Austropotamobius pallipes* could represent glacial relicts (Grandjean et al., 2001), as could many aquatic Iberian beetles (e.g. *Ochtebius figueroi*, *Acilius duvergeri*; Ribera, 2000). Among plants, species such as *Sparganium angustifolium* can be considered glacial relicts (Lorite, pers. comm.).

Thus, the biogeographical history of the Med has promoted the existence of a high percentage of endemisms, although this number is variable among groups of organisms according to their ecology, history, and evolutionary potential (Blondel et al., 2010). Overall, approximately 43% of the freshwater Med species belonging to relatively well-known groups are endemic to the Med. At a finer spatial scale, the number of endemisms can also be very high. For instance, Fochetti (2012) estimated that Italian freshwater endemics could exceed 10% of the total Italian fauna, and a similar estimate can be foreseen for other Med peninsulas. For freshwater fishes, a high degree of richness and endemicity can be identified in the Med in lower Orontes in South-West Turkey, in Lake Kinneret in Israel, and in the lower Guadiana in Southern Spain-Portugal (Smith & Darwall, 2006).

Many efforts have been made to analyse the biogeography of freshwater organisms in terms of both their present-day distribution patterns, and the geographical and ecological history of their peculiar biota. However, most of the investigations have primarily addressed the study of single taxonomic groups of freshwater organisms, without regard to general aspects such as the identification of chorotypes (grouping of similar species/taxa distributions) or by zoogeographic regionalisation. In this regard, the most important attempts at a biogeographic regionalisation of Europe and neighbouring countries were those of Illies (1978) and Banarescu (1990, 1992), although these studies did not specifically address the fresh waters of the Med. More recently, regionalisation has gained attention in Europe following the Water Framework Directive 2000/60/EC (WFD), which prescribes the delineation of ecoregions.

Attempts to delineate European ecoregions, including part of the Med, were recently made on the basis of fish distribution. Reyjol et al. (2007), using a data set of 233 species, have defined seven biogeographical regions (Western Peri-Mediterranea, Central Peri-Mediterranea, Eastern Peri-Mediterranea, Ponto-Caspian Europe, Northern Europe, Central Europe,

and Western Europe), of which the Central Peri-Mediterranea and Ponto-Caspian Europe contain the highest regional species richness. Regionalisation on a smaller scale was attempted using mainly fish as descriptors in various Med areas. For example, Hernando & Soriguer (1992) proposed a division of the Iberian Peninsula into three subregions, the Ebro-Cantabrian, the Atlantic, and the Betico-Mediterranean, based on the distribution of 45 native and endemic species. Also in the Iberian Peninsula, Vargas et al. (1998) proposed a regionalisation using freshwater fish and amphibians as biogeographical markers that included three regions (Cantabrian, Atlantic, and Mediterranean). Classification and ordination analyses of 23 river-basin fish assemblages allowed Zogaris et al. (2009) to delineate natural faunal break boundaries in freshwater species assemblage distributions in the Southern Balkans. Finally, based on the distribution of cyprinid fishes, two main ichthyogeographic districts were identified by Bianco (1990) for Italy.

Because of the absence of a well-established regionalisation of the Med based on stream and river organisms representing different taxonomic groups, in the present paper we have used four main areas from a biogeographical point of view: North-West (NW; Med Europe from Portugal to Italy, both including the Balearic Islands, Corsica, Sardinia, Sicily, and Malta, as all of the small West Med islands); North-East (NE; from the former Yugoslavian countries to North-West Turkey, including all of the Greek and West Turkish islands); South-East (SE; South Turkey, Cyprus, Med Near East and East Lybia); and South-West (SW; from Morocco to West Libya). Macaronesia is included in the SW, but it has specific characteristics associated with a marked insularity that should be taken into account. Each of these areas is formed by a continuous unity with many characteristic endemisms and a clear influence of neighbouring (adjacent and transitional) areas (see Blondel et al., 2010): mainly Atlantic and Euro-Siberian bioregions for the NW; a Euro-Siberian bioregion for the NE (particularly the Pontic province for the easternmost part of the NE); mainly Tirano-Turanian and East Saharo-Arabian bioregions for the SE (but also the Pontic province for the North of the SE); and a West Saharo-Arabian bioregion for the SW.

In general, an aridity gradient is detected from North to South and from West to East, but a notable heterogeneity is observed within each area of the Med depending on the altitude, orientation of the mountain systems, and continentality, among other factors. As pointed out by Blondel et al. (2010), the striking mosaic patterns and biodiversity of the Med reflect its topographic, climatic, geological, and edaphic heterogeneity at macro-, meso-, and micro-scales of resolution.

Baroni-Urbani et al. (1978) defined "chorotype" as the pool of species that share a similar geographic distribution, but whose ranges are significantly different from those of other species. No specific attempts have been made to identify general patterns of chorotype distribution across the freshwater fauna and flora of the Med. Two articles have been published regarding West Palaearctic (particularly Italian) chorotypes (Vigna Taglianti et al., 1992, 1999) of terrestrial and aquatic species.

Current status of freshwater biodiversity knowledge

Prokaryota and heterotrophic Protista

Prokaryota species are not genetically isolated from each other, and therefore, the typical interpretation of the biological species concept does not work for these organisms (Sonea & Mathieu, 2000). Nevertheless, molecular biology tools currently provide us with unprecedented access to knowledge of the diversity and composition of freshwater Prokaryota communities (Newton et al., 2011). At present, the diversity of Prokaryota (Bacteria and Archaea) in Med freshwaters is very difficult to determine, particularly in streams and rivers, because studies are scarce in comparison with those of lakes and reservoirs. Bacterial phyla considered typical and dominant in freshwater are Cyanoprokaryota (= Cyanobacteria), Actinobacteria, Bacteroidetes, Proteobacteria, and Verrucomicrobia, while 16 other phyla [particularly Chloroflexi, OP10 (recently named Armatimonadetes), and Planctomycetes] are frequently observed in freshwater (Logue et al., 2008; Newton et al., 2011). Regarding Archaea, molecular studies conducted over the last two decades in the Med freshwaters have demonstrated that this group is ubiquitous and abundant in different environments and not restricted to live under only "extreme" conditions as usually thought (Casamayor & Borrego, 2009; Plasencia et al., 2011).

As in all other habitats of the planet, heterotrophic protists (sometimes referred to as Protozoa) are often

present in lotic environments, but the taxonomy (and especially the ecology and distribution) of these organisms remains largely unknown (Adl et al., 2005). The lack of comprehensive studies prevents any assumptions from being made about the richness, diversity, and distribution of Med species (Madoni, pers. comm.).

Algae

There are two premises that are apparently contradictory but important for a correct understanding of the algae in this region and elsewhere: (1) they are an artificial group of organisms that includes representatives from four very different groups (from different kingdoms), Bacteria, "Protozoa", Chromista, and Plants; and (2) they are a functional group of organisms that are the primary producers of aquatic environments, so hence, algae should be considered a biological entity.

Estimates of the total number of algal species are bound to be speculative, given the lack of knowledge on these species in broad areas of our planet, including the Med. Of the 40,000 species described worldwide, it is estimated that the actual number of species could be approximately 200,000 (WCMC, 1992), although the different taxonomic concepts applied in each group make it very difficult to establish reliable global estimates. Moreover, some authors question the general hypothesis about the ubiquity of these microorganisms (Logares, 2006; Foissner, 2008), based, among other evidence, on molecular studies that, in certain cases, question the traditional cosmopolitanism and eurivalence of morphospecies. Phycologists using molecular techniques suggest there is substantial genetic diversity among some morphologically identical organism, implying that many new species will be described (Andersen, 1992).

Prokariota algae, Cyanoprokaryota or Cyanobacteria

At present, there are approximately 2,000 known species of blue-green algae, which are mostly freshwater species and are classified among more than 150 genera (van den Hoek et al., 1995). Among these species, a large proportion is present in Med ecosystems, where physical factors related to temperature and the abundance of limestone favour the development of these organisms (Margalef, 1983). The beds of Med rivers are covered with mats made by species of Cyanobacteria, among others. These species are widely distributed, and so the presence of endemic species is not expected. However, in the most extreme environments, there are species with a restricted known distribution, probably because of a lack of knowledge of these species. Among the species that inhabit substrates of gypsum (gypsicolous), an outstanding example is *Asterocapsa salina*, which has been found in Tunisia and, recently, in gypsicolous soils of Southern Spain (Dominguez & Asencio, 2011).

From an applied point of view, certain freshwater cyanoprokaryotes have been of particular interest because of their toxicity, with anatoxins and microcystins being the most prevalent cyanoprokaryotic toxins. The producers are mostly planktonic species that are found Med river reservoirs that are sufficiently eutrophic as well as lakes of different types. Toxic benthic Cyanobacteria have been cited as responsible for animal deaths in localities in the Northern Hemisphere, but until the studies of Aboal & Puig (2005), the presence of toxins in typically benthic species had not been demonstrated. The potential toxicity of some of these species, which may limit the animal species that live in these environments, has been demonstrated in *Rivularia biasolettiana, R. haematites*, *Schizothrix fasciculata, Tolypothrix distorta*, and *Phormidium splendidum*, which are probably widely distributed by the calcareous streams of the Med (Aboal et al., 2005).

Mats from rivers and coastal lakes contain other widespread species that can, under certain environmental conditions, form small stromatolitic structures with the participation of species such as *Schizothrix calcicola* and *Phormidium incrustatum*, among others. The latter are often responsible for the formation of continental stromatolites in countries of the Med as well as other central European countries (Freytet & Plet, 1996). The ability to add inorganic particles to the sheaths makes stromatolites equally important in environments such as the hygropetric surfaces on which species such as *Scytonema mirabile* and *Petalonema alatum*, together with species of *Phormidium, Leptolyngbya*, and *Lyngbya*, among others, form the structures on which many other species develop. The long human history of Med cultures has created an immense monument heritage in which microalgae in general and Cyanobacteria in particular develop communities of special interest. These include

Phormidium species that often form the basis of the mats (e.g. *P. faveolarum, P. subfuscum*, and *P. retzii*) along with others, such as *Chroococcidiopsis* and *Gloeocapsa*.

Chromista Algae

Chromista Algae include a group of protists characterised by cytological structures and biochemical characteristics, and their unity is supported by molecular phylogenetic studies. Most of these algae have a yellowish-brown coloration because of the presence of the pigment fucoxanthin. Estimates of their representation in inland waters are greatly influenced by diatom species, which abound and dominate in much of the Med ecosystems.

The Ochrophyta division mainly includes the golden algae (Chrysophyceae and Synurophyceae) and diatoms. It is estimated that the number of inland water golden algae is approximately 3,000 species (Bourrelly, 1968). The simplest Chrysophyceae representatives are included in the order Ochromonadales. Among them, the most conspicuous species in Med environments are *Dinobryon divergens* and *D. sertularia*. There are a few benthic representatives within this group, such as *Hydrurus foetidus*, a species typical of cold and well-oxygenated running waters that appears as part of the vegetation common in both limestone and siliceous substrates of high mountain rivers (e.g. the Spanish Sierra Nevada). Investigations of the other benthic species in this group have been limited, but these species may be of some importance in certain Med rivers, such as *Arthrogloea annelidiformis*, which was previously known only in central Africa but has been also found in a semiarid rambla from South-Eastern Spain (Bourrelly, 1968). Among the species with a cosmopolitan distribution, some are represented in the Med, such as *Spiniferomonas bourrelly*, which has been reported in Greece, Portugal, and Spain (Cambra, 2010; Kristiansen, 1980; Santos & Leedale, 1993). Scale-bearing species are included in the class Synurophyceae and are rare in Med environments, although some species have been detected in various parts of the basin (*Mallomonas acaroides* and *M. portae-ferreae*). In general, scale-bearing species are poorly studied in the Med and are preferably linked to oligo-mesotrophic environments, although they can also occur in eutrophic waters. The class Xantophyceae includes a small Chromista group that is difficult to distinguish from green algae because of their similar colour. It is estimated that 600 species of Xantophyceae exist in inland waters (Norton et al., 1996). They live in both the plankton and benthos, although the latter are the most conspicuous, especially species of *Vaucheria* that constitute filamentous masses that are usually present in limestone Med courses with some level of eutrophication and provide excellent sediment fixation. *V. dichotoma*, *V. geminate*, and *V. sesilis* are the most frequently noted species, and paradoxically, their geographic distribution remains unclear.

Diatoms are included in the class Bacillariophyceae and are microscopic algae that populate fresh, brackish, and saline waters in planktonic and periphytic (epiphytic, epilithic, and epipelic) communities. Reports of the number of taxa that develop in continental environments are contradictory and range from the estimated 1,600 species of Krammer & Lange-Bertalot (Wehr & Sheath, 2003) for the European flora to 2,500 species for the flora of Great Britain and Ireland alone (Kelly et al., 2005). There are no data available for the entire Med area. Although Aboal et al. (2003) cited approximately 600 species for Spain and Portugal, more recently Blanco et al. (2010) expanded this list by 20% by studying only diatoms of the Duero basin. In lotic systems, benthic diatoms are one of the most important component of biofilms and are therefore a key element of primary productivity for aquatic food webs. Some species constitute monospecific macroscopic formations such as *Diatoma vulgare*, *Didimosphaenia geminata*, *Gomphonema olivaceum*, or *Melosira varians*, among others. *D. geminata* is considered an invasive diatom, with a presence in the Northern Med countries and a high N:P ratio is one of the common aspects of the localities where it grows massively (Whitton et al., 2009).

The study of diatoms has been spurred by their use in biomonitoring because diatoms are an excellent ecological indicator at the species level. Studies to date (e.g. Delgado, 2011) suggest that the diversity of diatoms in Med rivers is much higher than that in Atlantic-flowing rivers. This higher diversity could be related to the greater instability of these systems (many of which are ephemeral or experience huge seasonal changes) and to their different, natural eutrophic status. It is difficult to estimate the total biodiversity of diatoms in Med rivers for two reasons: the lack of uniformity in the taxonomic criteria and

resolution, and the existence of wide areas that have not yet been studied. Some studies show that certain species such as *Amphora margalefi* and *Fragilaria nevadensis* may be endemic, although their recent description may be one of the reasons why they do not have a more extended known distribution.

Red algae

This group is composed of representatives of the division Rhodophyta. The freshwater red algae are a small group of organisms and approximately 200 continental species with an exclusively benthic ecology, mainly from streams and rivers, are known. The richness of red algae is higher in the Western Med, at the confluence of Atlantic and Mediterranean environments (France, Portugal, and Spain). Fewer species are known among strictly Med environments (Chapuis et al., in preparation), although we must emphasise the limited knowledge of these organisms in most Med countries, especially those in Northern Africa. We consider the genus *Batrachospermum* to be the best represented in European freshwaters (Kwandrans & Eloranta, 2010) and, most likely, in Med waters in general. *Hildenbrandia rivularis* and *Paralemanea catenata* are widely cited species as present in the Med countries. The underrepresentation of certain species has led to their specific inclusion in some protection category, as is the case for *Bangia atropurpurea* in some countries.

Green algae

Recently, green algae have been segregated into two major groups of organisms. The simplest are included in the division Chlorophyta, while the more apomorphic are considered the basal group (Streptophytina subdivision) of land plants (division Streptophytya). The division Chlorophyta is the most diverse group of continental green algae and is represented in all water types and environments. A total of 3,500 freshwater species are estimated to exist. Unicellular species are included in the classes Prasinophyceae, Chlorophyceae, and Trebouxiophycea. Flagellate species common in different types of water, such as *Dunaliella salina*, *Pandorina morum*, or *Eudorina elegans*, or Coccal species, such as *Kirchneriella subcapitata*, *Scenedesmus obliquus*, or *Pediastrum boryanum*, are cosmopolitan taxa that are well-represented in the phytoplankton of eutrophic inland water bodies throughout the Med area. As the knowledge of these unicellular organisms is greater, data on distribution patterns are available. This is the case for *Botryococcus terribilis*, a species that is most likely linked to warm waters from Southern Spain and to tropical/subtropical waters from Central and South America (Fanés Treviño et al., 2009). Endemisms linked to specific areas, such as *Friedmannia israeliensis* known only in Israel (Nevo & Wasser, 2000) and Spain, are rare among unicellular species. Of particular importance in the phytobenthos of rivers are the filamentous species included in the classes Chlorophyceae and Ulvophyceae. These taxa of filamentous algae most likely constitute one of the least known and perhaps more diverse groups and can be classified into two main groups: (1) heteromorphic thallus algae, which are usually present on calcareous substrates and form encrusting communities, such as species of the genera *Chaetophora*, *Gongrosira*, and *Pseudopleurococcus*, among others; and (2) well-developed filamentous thallus algae that lead to floating masses, such as species of the genera *Cladophora*, *Microspora*, *Oedogonium*, and *Ulothrix*, among others.

The division Streptophyta, subdivision Streptophytina, is the only algae group represented exclusively in freshwaters. Approximately 12,000 species are estimated to exist, although the number of synonymous species can be very high (Corliss, 1997). Desmidiaceae is a group of green algae with a great taxonomic richness but is poorly represented in the Med area. The relatively dry and calcareous environments dominant in this area have not favoured their widespread colonisation, unlike other groups of green algae that found refuge in Med systems during the Pleistocene glaciations (Coesel, 1996). Among the well-established distribution models of Desmidiaceae, the arctic–alpine model is of note, with representatives in Med mountain systems, such as the Sierra Nevada of Spain among others, in which species such as *Cosmarium costatum*, *C. crenatum*, and *Staurastrum capitulum* are present. The presence of Desmidiaceae in these biogeographic islands is to the result of the colonisation of semi-aerial environments, where the high temperatures of the local microenvironments may explain the development of these species more than the low temperatures of the high mountain environments (Coesel & Krienitz, 2008). Some

endemic taxa have been described in mountain massifs of the Western Med (Central System and Sierra Nevada), such as *Euastrum denticulatum* var. *caballeroi*, the origin of which could also be explained by this phenomenon. Few Holarctic species, such as *E. verrucosum*, are represented in Med continental environments. Zygnemataceae species are easily recognisable at the generic level, but the need to observe reproductive characteristics makes specific identification very complex. If we add to this fact the considerable variability of the ploidy level that occurs in this group, which results in an exceedingly ambiguous concept of species, we can explain the current status of its taxonomy, which consists of more than 300 species, with a very restricted distribution. Species with a restricted area include those described in North Africa, such as *Spirogyra gharbensis*, *S. maghrebiana*, *S. moebii*, *Zygnema allorgei*, or *Z. lamellatum*. Typically they occur in shallow and ephemeral waters, and common habitats include arid and semiarid environments, such as those of Northern Africa. The family Characeae is probably the most widely studied in the Med area, where there are local floras for Spain, Portugal, and France and major regional studies for North Africa. Their populations form important grasslands submerged in rivers and lakes. In this group, we can consider *Tolypella hispanica* as a typical Med species (Cirujano et al., 2008) that is distributed throughout most of the geographic area, including Spain, France, Greece, Italy, Morocco, Algeria, and Tunisia. There are widely distributed taxa that are well-represented in the whole Med area, as is the case for *Chara vulgaris* var. *squamosa*, *C. aspera–C. galioides* complex, *C. connivens*, and *Lamprothamnium papulosum*.

Fungi

Although many fungal types can be found in inland waters, Ingoldian fungi (also called aquatic hyphomycetes) are by far the most important fungi in lotic systems. This group mostly includes taxa living in fast-flowing, well-oxygenated streams and rivers (Del Frate & Caretta, 1983). In fact, relatively small permanent streams are the most used environment for the approximately 270 known species of Ingoldian fungi (Descals & Moralejo, 2001). By contrast, studies on the presence of Ingoldian fungi in large, higher-order rivers are few, even if they could represent an important part of the microbial biomass in these systems (see Chauvet, 1997). There are so few studies of aquatic fungi of different geographical areas that little can be said about their geographical distribution patterns, except perhaps that they reveal the geographical distribution of their collectors (Shearer & Raja, 2010). In the Med, despite interesting studies in some countries (e.g. Descals & Chaltvet, 1992; Descals et al., 1995; Rodino et al., 2003), it is very difficult to estimate the diversity of aquatic fungi due to the scarcity of information.

Lichen

Although lichens predominantly colonise terrestrial habitats, some species are restricted to aquatic habitats and colonise coarse substrata of springs, streams, rivers, and lakes (Aptroot & Seaward, 2003; Nascimbene et al., 2009). These organisms are usually difficult to identify, and the taxonomic position of several species still awaits further research because the morphological characteristics used for identification are not clear or shared by specialists. In particular, the diversity of aquatic lichens is probably underestimated, and additional studies are necessary to clarify the taxonomic concept of species within numerous groups (Nascimbene, pers. comm.). At present, it is almost impossible to evaluate the diversity of this group in the Med. To give an indication, Nascimbene (pers. comm.) estimated that 52 species are present in Italy, with some endemic Med species, such as *Aspicilia hydrocharis*, only known from Sardinia.

Bryophyta

Bryophyta, or mosses and liverworts, are particularly abundant in low-order river environments, which are characterised by coarse and stable substrate, cold water, high shading of the riverbed and elevated concentrations of dissolved carbon dioxide. Approximately 100–125 species of bryophytes, belonging to 22 genera, are truly aquatic and require submergence in water to complete their life cycle (Cook, 1999). Information about lotic bryophytes in the Med is scattered and, for some countries, scarce. In Spain, France, and Italy, approximately 10 truly aquatic mosses and 15 aquatic liverworts have been reported (Tacchi, pers. comm.).

Vascular plants

Two phyla (divisions) are included under the category of vascular plants or vascular macrophytes, the Pteridophyta and Spermatophyta. They are typically land organisms, and only a fraction (approximately 1%) can be considered aquatic (Chambers et al., 2008). According to Chambers et al. (2008), the Palearctic region is not particularly diverse in comparison with other biogeographical regions and includes only 497 species belonging to 154 genera and 59 families. Nevertheless, this number can be very different according to the definition of an aquatic vascular plant. Because there is a gradient of water dependence for different species, it is difficult to determine whether some species should be considered aquatic or not.

Regarding the Med, a recent project evaluated the conservation status of 473 taxa (453 at the specific level and 20 at the subspecific level; 460 species in total) of aquatic vascular plants (Hydrophytes and Helophytes) in this area (IUCN, 2010). This study provides the most complete and comprehensive review of this plant group in the Med, despite not including all known Med aquatic plants (some data is lacking, mainly from the Eastern Med). Although the geographical limits were not identical to those of our study, the differences are relatively small and their results are very relevant here. They found a high degree of endemisms (150 taxa, 32%), especially for aquatic plants that were historically considered widely distributed (Cook, 1985; Santamaría, 2002). No family of aquatic vascular plants is endemic to the Med. Biogeographically, almost all of the families present in the Med have a wide distribution area that extends beyond the Palearctic region. Even particular species, such as *Lemna aequinoctialis* or *Ceratophyllum demersum*, can be found in all continents except Antarctica (Cook, 1985; Chambers et al., 2008).

In the IUCN study (IUCN, 2010), the authors note the presence of 8 families and 14 species of Pteridophyta in the Med. The Marsileaceae is the most diverse (4 spp.), followed by Isoetaceae, Thelypteridaceae, and Sellaginaceae (2 spp. of each), and Blechnaceae, Pteridaceae, Adiantaceae, and Osmundaceae (1 sp. of each). Note that the families Adiantaceae, Sellaginaceae, and Osmundaceae were not considered aquatic macrophytes by Chambers et al. (2008). At least 56 families of Spermatophyta with aquatic vascular plants have been recorded in the Med (IUCN, 2010). Cyperaceae (73 taxa), Poaceae (= Graminaceae, 52 taxa), Juncaceae (30 taxa), Ranunculaceae (19 taxa), Umbelliferae (23 taxa), and Compositae (23 taxa), of which the last two were not considered by Chambers et al. (2008), are the richest families in species number. Alismataceae, Hydrocharitaceae, Lentibulariaceae, Lythraceae, Onagraceae, Polygonaceae, and Potamogetonaceae, with 8 or more taxa in each, are also relatively diversified [although not considered in Chambers et al. (2008), the families Cruciferae, Labiatae, Plumbaginaceae, and Scrophulariaceae would also belong to this group]. The most diversified genera are *Juncus* and *Carex*, followed by *Ranunculus*, *Cyperus*, and *Potamogeton*.

At the global scale, several aquatic vascular plants have been introduced in new areas and can be considered among the worst invasive species in freshwater habitats (Chambers et al., 2008). In fact, freshwater invasive species can become major pests. Some invasivespecies that can be found in the Med are *Azolla filiculoides*, *Salvinia natans*, *S. molesta*, *Myriophyllum aquaticum*, *Hydrocotyle ranunculoides*, and *Ludwigia peploides* native to America, *Hydrilla verticillata* to Asia, and *Lagarosiphon major* to Africa.

Porifera

A few species of freshwater sponges, mainly from lotic systems (including low-current parts of the rivers), inhabit the Med. They are only a small part of the Palearctic fauna, in which 59 species, including 21 genera and 4 families (plus 1 species as *Incertae sedis*) have been recorded (Manconi & Pronzato, 2008). Data on the distribution of the 13 species (included in 2 families, Spongillidae and Malawispongiidae, and 7 genera: *Spongilla*, *Ephydatia*, *Eunapius*, *Heteromeyenia*, *Sanidastra*, *Trochospongilla*, and *Cortispongilla*) of freshwater Porifera in the Med can be found in Manconi & Prozano (2001, 2002, 2007, 2008) and in Tendal (2004). North African fauna of freshwater Porifera are scarcely known. Gugel (1993) cited 6 species of this group in Northern Egypt, but they were out of the limits considered in this study. Some species of freshwater Porifera are being incidentally introduced in new locations, and in many cases, it is difficult to delimit their natural distribution area.

Cnidaria

Cnidaria, the jellyfish and hydras, is a mainly marine phylum with less than 40 freshwater species worldwide, and among them, only 12–18 species in 7 genera are in the Palearctic region (Jankowski et al., 2008). In the Med, at least 7 freshwater species belonging to the Hydrozoa class are present. The family Olindiidae is represented by 1 species, *Craspedacusta sowerbyi*, which is currently cosmopolitan but most likely originated in China (Jankowski et al., 2008). The family Hydridae includes 4 valid species that are present in this area (Schuchert, 2010). The family Cordylophoridae includes a species present in the Med, *Cordylophora lacustris* (currently included in *C. caspia*), that can be found in freshwaters (despite also being a brackish inhabitant). Finally, *Velkovrhia enigmatica* (family Bougainvilliidae) is a freshwater species that inhabits Balkan cave systems (Schuchert, 2007).

Turbellaria

Platyhelminthes are traditionally separated in 2 clades: the Neodermata, which includes 3 (or 4) classes of parasites (not treated here) and the free-living (or symbionts) Turbellaria. At present, 6,500 turbellarian species are recognised, of which approximately 1,300 live in freshwaters (Schockaert et al., 2008). At the moment, it is likely that the distribution and diversity of freshwater flatworms more closely reflects the scientific activity of various regions than the true biogeographical picture. Almost 700 species are reported for Europe, of which approximately 200 inhabit Med freshwaters (Noreña Janssen, pers. comm.).

Gastrotricha

Although more common in lentic environments, some Gastrotricha species can be found in lotic systems. At present, approximately 318 inland water gastrotrichs have been reported in the World, with 222 species identified in the Palearctic (Balsamo et al., 2008). The diversity of freshwater Gastrotricha in the Med is particularly difficult to estimate because of their sporadic presence in freshwater habitats and their high intraspecific variability. The presence of endemic species is also difficult or almost impossible to estimate, mostly because of the scarcity of studies on their actual distribution (Balsamo, pers. comm.).

Rotifera

Rotifera is a speciose phylum of small Metazoan that is particularly diffuse in terrestrial or lentic habitats and less represented in streams and rivers. The phylum contains two major groups, Monogononta and Bdelloidea. Monogononts are adapted to different biotopes in continental waters. At present, 1,570 species have been recorded worldwide, of which approximately 95% populate freshwaters (Segers, 2008). Bdelloids populate limnic and terrestrial wet habitats. A total of 461 species are recognised (Segers, 2008), but very few can be found in rivers. Rotifera seems to be more diffuse and diverse in the Northern Hemisphere, but this impression may result from more studies having been conducted in those regions (Fontaneto et al., 2011). It is difficult to discuss their diversity in the Med because the taxonomic and biogeographical knowledge of either group is currently unsatisfactory (Bertani et al., 2011). Furthermore, 99% of the studies are focused exclusively on Monogononta, while Bdelloidea are rarely classified at the species level because they can be identified only when alive. The most abundant and widespread monogononts in Med rivers are Brachionidae, Synchaetidae, Lecanidae, and Trichocercidae. The families Notommatidae, Dicranophoridae, and Lepadellidae are often present with a high number of species, but in general, they are rare in their abundance or distribution (Bertani, pers. comm.).

Nemertean

Nemertea is a mainly marine phylum that includes only 22 freshwater species in the entire World, 14 of which are present in the Palearctic region (Sundberg & Gibson, 2008). The freshwater species are usually found in lentic systems. In the Med, 1 endemic species, *Prostoma hercegovinense*, which inhabits caves in Bosnia-Herzegovina, and 2 species with wide distributions in and out of Europe are recorded (Gamo, 1986; Sundberg & Gibson, 2008). *P. puteale* was

previously recorded in France and Switzerland and may be present in the Med (Sundberg, pers. comm.).

Entoprocta

Globally, only 2 freshwater species of Entoprocta are known: *Urnatella gracilis* (family Barentsiidae) and *Loxosomatoides sirindhornae* (family Pedicillinidae). While the latter is only known in Thailand (Wood, 2005), *U. gracilis* has a cosmopolitan distribution (Nielsen, 2004; Wood, 2005). In the Palearctic region, *U. gracilis* has been recorded in several European countries, but almost no data exist in the Near East, North Africa, and Southern Europe (Gugel, 1993; Nielsen, 2004). Thus, its presence in the Med has not yet been confirmed. Gugel (1993) cited its presence in Egypt, but this record is outside the limits considered here. According to some authors, *U. gracilis* is one of the freshwater species that migrated into Europe at the beginning of the twentieth century, most likely from North America, but its distribution is still not well known (Grigorovich et al., 2002; Skolka & Preda, 2010).

Bryozoa

Massard & Geimer (2008) cited 44 species (in 29 genera and 11 families) of freshwater bryozoans (Ectoprocta) in the Palearctic Region. In the Med, at least 22 species have been reported (Massard et al., 1992; Woss, 2004; Wood & Okamura, 2005; Rubini et al., 2011), which belong to 10 or 11 genera and 7 families: Cristatellidae (1 sp.), Fredericellidae (1 sp.), Lophopodidae (3 spp., 2 genera), Paludicellidae (1 sp.), Pectinatellidae (1 sp.), Plumatellidae (12 spp., 2 genera), and Victorellidae (3 spp., 2–3 genera). However, the taxonomic status of some of these species should be reviewed.

Despite their widespread distribution and abundance, freshwater bryozoans remain relatively poorly studied (Wood & Okamura, 2005), and taxonomic and faunistic works are needed (for instance, 3 new species have been cited in the Med in the last decade). The few locations that are relatively well-studied exhibit great diversity. For instance, in Northern Italy alone, 12 species have been cited (Rubini et al., 2011), representing 55% of all the species recorded in the Med, while other Med countries, such as Portugal, Greece, and Albania, remain practically unexplored (Massard & Geimer, 2008).

Bivalvia

Freshwater Bivalvia is a polyphyletic group representing many freshwater colonisation events by different mussel taxa (Bogan, 2008). According to Bogan (2008), there are 187 species belonging to 39 genera and 7 families in the Palearctic region, although some families include more brackish than freshwater species. Moreover, estimates of the diversity are difficult mainly because of the variation in taxonomical and systematic approaches and the need for integrative (morphological, anatomical, reproductive, and molecular) studies (e.g. Korniushin, 2004; Bogan, 2008; Schultheiß et al., 2008). Of the 7 Palearctic families, 5 are present in the Med: Margaritiferidae, Unionidae, Corbiculidae, Sphaeridae, and Dreissenidae. We do not consider here the family Cardiidae, following Araujo (2004) for the European Fauna, because it includes a few brackish species (not truly freshwater) in the Med and the family Corbulidae, of which the only species considered to be a freshwater inhabitant is not present in the Med.

In the Med, 12 genera and 46–49 species belonging to these 5 families have been cited (Table 1). Distribution data for the Med have been mainly obtained from Araujo (2004), Albrecht et al. (2007), Araujo

Table 1 Diversity of Bivalvia in Med rivers

Families	Genera (*N* species, *N* endemisms) in the Med
Margaritiferidae	*Margaritifera* (3,1)
Unionidae[a]	*Anodonta* (6,3), *Leguminaia* (2,1), *Microcondylaea* (1,0), *Potomida* (1,0), *Unio* (12,7)
Corbiculidae	*Corbicula* (2, 0)[b]
Sphaeridae	*Musculium* (1,0), *Sphaerium* (2,1), *Pisidium* ($\approx$ 15,3)
Dreissenidae[c]	*Congeria* (1,1), *Dreissena* (2,2)

[a] The species *Sinanodonta woodiana* (= *Anodonta woodiana*) has been introduced in the Med

[b] The taxonomy of this genus is under review (Araujo et al., 1993; Korniushin, 2004; Bogan, 2008). In the Med, *C. fluminalis* and *C. fluminea* have been cited, but these species exhibit many similarities, and their taxonomic status is not completely clear (Araujo et al., 1993; Korniushin, 2004)

[c] Two other species that belong to this family, *D. polymorpha* and *Mytilopsis leucophaeata*, have been introduced in the Med

et al. (2009), Van Damme et al. (2010), and Graf & Cummings (2011).

As pointed out by Van Damme et al. (2010), compared to other parts of the Med, the degree of endemicity is particularly high in the SW, even though the total number of species is lower than in the NW and NE and slightly higher than in the SE. Nevertheless, as previously noted, many taxonomic studies are necessary to obtain a better understanding of the true freshwater Bivalvia diversity in the Med.

Gastropoda

Approximately 4,000 species of Gastropoda are present in freshwater systems worldwide. Despite their ecological importance, this group remains poorly understood because of the lack of specialists and critical reference data regarding taxonomy, distribution, life history, physiology, morphology, and diet (Strong et al., 2008). Although they are probably more abundant and diversified in lentic, semi-lentic or groundwater environments, gastropods are also widely distributed in many lotic environments.

The Palaearctic region has the most diverse freshwater gastropod fauna, with 35–45% of currently described species (Strong et al., 2008). In the Med, Strong et al. (2008) reported the presence of some important biodiversity hotspots for freshwater gastropods. However, the highest diversity is found not for truly lotic organisms but for organisms inhabiting springs and groundwaters. These hotspots are the mountainous regions of Southern France and Spain, the Southern Alps, Northern Italy, the former Yugoslavia, and Greece. In the Med, the greatest diversity is most likely found in the northern regions because, in Northern Africa, Gastropoda taxa are usually confined to rare perennial springs and rivers and are better-represented in wells and groundwaters (Van Damme et al., 2010).

Here, we summarise some of the data presented by Strong et al. (2008) and emphasise the most relevant data for the Med. Information on species distribution has been obtained mainly from Bank (2004), Van Damme et al. (2010), and IUCN (2011).

Neritimorpha has one family in the Med, Neritidae. This family (represented in the Palaearctic by 45–55 inland spp.) is represented in the Med by some marine or estuarine species and by the diffused genus *Theodoxus*. In addition to the widespread *T. fluviatilis*, this genus contains numerous endemic species that occur in streams and rivers.

Caenogastropoda has 9 families in the Med. Viviparidae (20–25 spp. in the Palearctic) is represented by species in the genera *Viviparus* and *Bellamya*. The family Melanopsidae (20–50 spp. in the Palearctic) exhibits a high degree of endemicity, particularly in the genus *Melanopsis*. Unfortunately, current knowledge prevents the characterisation of the diversity of this group in the study area. The family Amnicolidae is present, with 150–200 spp. in the Palaearctic and approximately 40 species in Central and South Europe. Thiaridae is particularly diverse in subtropical and tropical areas and is represented in the Med at least by 1 invasive species, *Melanoides tuberculatus*. The family Bithyniidae (with 45 spp. in the Palearctic) lives in both running and standing water bodies and has a high rate of endemic species. Cochliopidae (17 spp. in the Palearctic) is present in the Med with species of the genus *Heleobia*. Moitessieriidae (55 Palearctic spp.) exhibits a high degree of endemicity and diversity in the Med, particularly in its western part, but these gastropods occur in subterranean waters and only exceptionally can they be found in streams and rivers. Lithoglyphidae (30 Palearctic spp.) is present in some Med lotic systems (Balkanic area), including approximately 5 species of *Lithoglyphus* and some cave endemics. Hydrobiidae (700–750 Palearctic spp.) is a very diverse and widespread family, but its diversity in Med lotic systems is difficult to estimate because of the lack of studies and because many species are present in the area but not in surface running waters, instead inhabiting mainly lakes, ponds and groundwaters (Bodon et al., 1999). *Potamopyrgus antipodarum* is an invasive hydrobiid that is widely diffused in Western Med lotic systems.

Med Heterobranchia include only Valvatidae (60 Palearctic spp.), which includes species in the genus *Valvata*.

Pulmonata has 4 families in the Med. Acroloxidae (40 spp. in the Palearctic) is commonly found in quiet waters but also inhabits slow-moving areas of rivers and canals, and at least 2 species are present in the Med, one of them endemic. Lymnaeidae is a large and relatively poorly characterised family of Pulmonata, with 40–120 spp. in the Palaearctic; *Radix* and *Lymnaea* are probably the most represented genera in Med lotic systems. In the Med, Physidae

(15 Palearctic spp.) is represented by 3 species. Planorbidae (100–200 Palearctic spp., including the former Ancylidae) is mostly present in vegetation-rich, slow or lentic environments, but this family includes one of the most commonly observed gastropods in fast-running water environments, the genus *Ancylus*.

Polychaeta

Polychaeta is a class of Anellida that is mainly distributed in salt waters. A total of 197 freshwater species, belonging to 78 genera and 26 families, have been recognised worldwide (Glasby et al., 2009). In the Palearctic region, 67 species representing 32 genera are currently reported (Glasby & Timm, 2008). In the freshwaters of the Med, approximately 14 species of Aeolosomatidae, 1 species of Potamodrilidae, 1 species of Nerillidae, and 2 species of Ampharetidae are currently recorded. There are a total of 18 polychaete species, none of which are endemic to the Med (Timm, pers. comm.).

Oligochaeta

Oligochaeta is a well-diversified and well-represented group in running waters. Approximately 1,100 species of aquatic Oligochaeta are currently known worldwide. Among these, about one-half belong to the family Tubificidae, while the rest belong to other microdrile families, of which only 60 species are large-sized, earthworm-like megadriles (Martin et al., 2008). The Palaearctic region hosts a rich and diverse freshwater oligochaete fauna, with 616 species belonging to 113 genera and a high percentage of endemics (approximately 80%).

Estimations of the total number of freshwater Med Oligochaeta species is very difficult because information is very scattered and, in some cases, scarce. It is also difficult to estimate the number of European or Med species by using the available web databases (e.g. faunaeuropaea.org) because some families include freshwater, marine, and terrestrial species. For example, Di Chiara Paoletti & Sambugar (1996) reported the presence of 57 genera and 130 species of aquatic Oligochaeta in Italy, but this number also includes subterranean and marine taxa. At a minimum, the following families with aquatic representatives are present in the Med (Martínez-Ansemil & Giani, 1987; de Jong, 2004; Martin et al., 2008): Lumbricidae (including the common and widespread *Eiseniella tetraedra*); Criodrilidae [see Blakemore (2008) for a recent review of this family]; Megascolecidae; Ocnerodrilidae; Dorydrilidae; Enchytraeidae; Haplotaxidae; Lumbriculidae; Parvidrilidae; Propappidae; Naididae [included as a subfamily of Tubificidae by some authors (see Martin et al., 2008)]; and Tubificidae. The density of Naididae and Tubificidae in organic-rich sediments can be impressive in that the former can represent 80% of macroinvertebrates in some polluted Med streams, with a density of approximately 25,000 individuals/m^2 (Bo & Fenoglio, 2011).

In terms of Oligochaeta diversity within the Med, the poorest area is the SW (the communities of which are very similar, although less diverse than those of Southern Europe), while the SE and N are considerably more diversified (Martínez-Ansemil & Giani, 1987).

Hirudinea

Leeches (Hirudinea) are more abundant in lentic, warm waters, although some species, such as *Piscicola geometra*, can also be found in very fast currents. Of the 680 species described, approximately 15% are marine, and a slightly lower percentage are terrestrial. The remaining species live in freshwater, and are divided among 91 genera (Sket & Trontelj, 2008). Currently, no synthesis exists on Med leeches, although a worldwide list of Hirudinea is in progress (Sket, pers. comm.). In the Palearctic, 185 species (belonging to 47 genera) are currently listed (Sket & Trontelj, 2008), of which 87 species are reported in Europe (Minelli, 2004). It is very difficult to estimate the number of species in the Med because leech taxonomy (especially at the species and genus levels) is currently at an early stage. At present, it is likely that at least 40 species are present in the Med: Erpobdellidae, including *Dina* (6 spp.), *Erpobdella* (3 spp.), *Trocheta* (5 spp.), and *Croatobranchus mestrovi*, which inhabits hypogean Croatian rivers and exhibits unique morphological features; Haemopidae, including *Haemopis sanguisuga* (mainly found in lentic or semilentic habitats); Xerobdellidae, including *Xerobdella* (3 spp.); Hirudinidae, including *Hirudo* (3 spp.) and *Limnatis* (2 spp.); Glossiphonidae, including *Alboglossiphonia* (1 sp.), *Batracobdella*

(1 sp.), *Glossiphonia* (3–4 spp.), *Helobdella* (1 sp.), *Hemiclepsis* (1 sp.), and *Theromyzon* (1 sp.); and Piscicolidae, including *Cystobranchus* (2 spp.), *Italobdella* (1 sp.), and *Piscicola* (1–2 spp.).

Nematoda

Nematoda is likely the most widespread, abundant, and diverse Metazoan group in freshwater sediments, with approximately 1,900 species recorded worldwide in inland aquatic habitats (with 1,020 recorded in the Palearctic; Abebe et al., 2008). The most common and diverse nematodes in freshwaters primarily belong to the orders Dorylaimida and Mononchida. Discussions on the distribution or endemicity of Nematoda in the Med (and in most zoogeographic areas) are still premature, mainly because of the incompleteness of nematodological surveys in many countries (Abebe et al., 2006). Furthermore, considering the phylum as a whole, it is likely that as many as 97% of species have not been described!

Nematomorpha

Nematomorpha is represented in freshwater habitats by the family Gordiaceae. In the Palearctic region, the estimated number of species is 250 (Poinar, 2008), with 99 species reported in Europe. Probably at least one-half of the European species are present in the Med (Poinar, pers. comm.). Some Med species have been recently described (Schmidt-Rhaesa, 2010).

Tardigrada

Tardigrada are, in general, limno-terrestrial animals, but a few are exclusively aquatic, and some that might be considered 'accidentals' that can tolerate a wet environment. Forty-nine species belonging to 6 genera are reported in freshwater Palearctic habitats (Garey et al., 2008). Approximately 44 species fall into the aquatic/tolerant group in the Med, and approximately 6 are either locally endemic or endemic to the Med (McInness, pers. comm.). However, this low number may be the result of few specific studies.

Araneae

Of the 38,000 currently known Araneae species, only 1 can be considered truly aquatic. In fact, although some Pisauridae and Lycosidae (such as representatives of the genera *Dolomedes*, *Pardosa*, and *Pirata*) live near water bodies, only *Argyroneta aquatica* (Cybaeidae) spends its entire existence under water (Schütz & Taborsky, 2003). *A. aquatica* is a Palearctic species that is also distributed in the Med, where it preferentially colonises non-polluted freshwater environments with vegetation and modest currents.

Acari

Among Acari, freshwater taxa are mainly found in the Prostigmata (Trombidiformes) and Oribatida (Sarcoptiformes). Among the Prostigmata, the Hydrachnidia or water mites represent the most important group of Arachnida in freshwater ecosystems, with a total of 57 families, 400 genera, and over 6,000 species described worldwide (1,642 species recorded for the Palearctic, Di Sabatino et al., 2008; see also http://www.watermite.org/). Water mites are highly diversified and inhabit almost every aquatic habitat in lotic and lentic systems, reaching high densities and ecological importance in environments such as springs and epirithral environments (Di Sabatino et al., 2000, 2003). More than 1,100 species (114 genera and 40 families) are listed in the Western Palearctic, mostly (about 800 species) from Med countries (Di Sabatino & Gerecke, unpublished data; Di Sabatino, pers. comm.).

Another group of Prostigmata, the Halacaridae, comprises 56 species inhabiting continental freshwater (Bartsch, 2008). The high number of genera (14) and species (34) reported for the Palearctic is likely to reflect the amount of sampling activity rather than the diversity in this region. In the Med, approximately 22 species and 11 genera are currently recorded, including species that live in more or less stagnant waters. Most of the Med species of halacarids are spread worldwide, but 4 are probably Med endemics (Bartsch, pers. comm.).

Oribatida are primarily terrestrial mites, although many species prefer or tolerate wet habitats or can survive inundation or flooding for a certain period. Only some families and taxa are restricted to freshwater (e.g. Hydrozetidae, Limnozetidae, some Malaconothridae), and few of those are known in the Med. Oribatids have been found only on very rare occasions in river environments (Schatz, pers. comm.).

Crustacea

Crustacea is a large group of arthropods that currently includes nearly 50,000 species distributed among 800 families. They are the dominant marine arthropods, but some groups have adapted to life in freshwater environments and a few to terrestrial life. Many freshwater crustaceans inhabit lentic or semi-lentic environments, but few taxa are specialised for life in lotic systems. Here, we emphasise some larger forms of the class Malacostraca because of their relevance in running water environments. Furthermore, we also briefly consider some other group of meiofaunal crustaceans.

Worldwide, 500 species of Branchiopoda are recorded, of which 175 species in 30 genera have been recorded in the Palearctic (Brendonck et al., 2008). The most diverse and speciose group is Anostraca, while the most widespread, despite the small number of species, is most likely Notostraca. Members of this class usually inhabit standing as well as ephemeral water environments and thus cannot be considered representative lotic crustaceans.

No freshwater Cumacea and Tanaidacea are listed for Med inland waters.

Thermosbaenacea is a small Peracarida group, with only 18 freshwater species recognised worldwide. They inhabit caves, artesian wells, thermo-mineral springs and the interstitial areas of river sediments and alluvia (Jaume, 2008). In the Med, 3 presumed lotic species and some other species inhabiting oligohaline wells and caves, and rarely, springs are known (Jaume, pers. comm.).

Syncarida is a small group (approximately 250 known species, of which 128 are listed in the Palearctic) that is mainly distributed in freshwater, with only a few taxa (Bathynellacea and Stygocarididae) that live in estuaries (Camacho & Valdecasas, 2008). With the exception of a few Anaspididae that live in surface lotic and lentic bodies of water in the Australasian region, the great majority of syncarids are stygobionts and inhabit groundwaters and thus are not included in this review. In this context, we only report the presence of 2 Syncarida that inhabit some Med springs, *Delamareibathynella debouttevillei* and *Cteniobathynella calmani* (Camacho, 2006).

Although more than 90% of Mysida are exclusively marine, this group includes 72 freshwater species that primarily colonise not only groundwaters but inhabit lacustrine and riverine systems. Three families include inland water species. Lepidomysidae and Stygiomysidae contain species living in subterranean or transitional waters, and both are monogeneric. Mysidae hosts the greater diversity in freshwaters, with 23 genera. In Palearctic inland waters, 15 genera, and 39 species of Mysida are known (Porter et al., 2008), but it is quite difficult to make an estimate for Med lotic systems.

The Ostracoda are one of the most successful crustacean groups, with approximately 8,000 living species, a quarter of whom live in inland waters. Among the freshwater species, the most speciose families are Cyprididae (approximately 1,000 species) and Candonidae (approximately 550 species), with 11 other families comprising the remaining 25% of the diversity. The Palearctic region encompasses the highest absolute non-marine ostracod diversity, with 702 described species, of which approximately 88% are endemic to this biogeographical region (Martens et al., 2008). The diversity of Med lotic ostracods is quite difficult to estimate because: (1) ostracods typically inhabit lentic or semi-lentic freshwater environments, but in some cases, they can also be found in springs and rivers (Pieri et al., 2007) and, unfortunately, very few researchers have investigated the ostracodofauna of running waters (e.g. Mezquita et al., 1999); and (2) in riverine systems, these crustaceans prefer areas with low current speed, but their greatest diversity in lotic systems most likely occurs in the interstitial environments, which are generally poorly studied (Rossetti, pers. comm.); (3) in Med countries, there have been only sporadic studies of river ostracod fauna.

Copepoda is a primarily marine group, with 2,814 freshwater species (330 of which are parasites; Boxshall & Defaye, 2008). The Palearctic region hosts the richest and most diverse freshwater copepod fauna, with 1,204 species recorded. The number of endemic freshwater copepods seems remarkable because the great majority of species occur in a single region (84.7% of Palearctic species are endemics). Copepoda constitutes an important component of planktonic communities in standing waters, but they are also present in lentic-lotic benthic and groundwater communities. It is impossible to quantify the diversity of copepods in Med rivers, for the same reasons reported earlier for ostracods.

Branchiura is a small subclass of fish ectoparasites that is diffused in all continents except Antarctic but that contains a single family (Argulidae), with 4 genera and approximately 130 species. Eight species of the genus *Argulus* are listed in the Palearctic (Poly, 2008). In Med lotic systems, at least 2 species are present.

Isopoda is a diffuse and diverse order of Malacostraca, with more than 10,000 species distributed in marine, freshwater, and also terrestrial habitats. Approximately 1,000 species inhabit inland waters, from springs to rivers, lakes, and groundwaters. The most speciose group is Asellota, with 942 described species, mostly belonging to the families Asellidae and Stenasellidae (Wilson, 2008). In the Palearctic, 475 species belonging to 45 genera are currently listed (including all freshwater isopods as well as those living in lentic and hypogean water bodies or with parasitic habits). In Med freshwaters, the most important isopod families are the epigean Asellidae and the interstitial or stygobites Janiridae, Microparasellidae, Stenasellidae, and Microcerberidae. At present, it is very difficult to estimate the diversity of freshwater Med Isopoda. In many countries, there are no sufficient data, and groundwater-dependent isopods are likely much more speciose than currently recognised. Moreover, the multiple subspecies of *Asellus aquaticus* seem to be substantially different from a genetic point of view, suggesting the existence of a complex of many species (Prevorcnik et al., 2009). Finally, considering microendemisms (taxa with very restricted distribution, e.g. to a single mountain range), the number of distinct genetic lineages that may be counted is potentially huge (Wilson, pers. comm.).

Amphipods are peracarid crustaceans that are mainly marine, but they are also present in many freshwater environments, with higher diversity in subterranean habitats and in temperate, cool lotic systems. Approximately 9,400 Amphipoda species (and subspecies) are known, of which 20% inhabit inland waters, almost half being hypogean (Väinölä et al., 2008). In the Palearctic, 1,319 species (and subspecies) are currently reported. The majority of river amphipods in the Palearctic belong to the superfamily Gammaroidea and, more specifically, in the Med, to the genera *Echinogammarus* and *Gammarus*. Most Med groundwater amphipods belong to the family Niphargidae. In Med freshwater environments, there are likely approximately 400 amphipod species, of which 80% are hypogean or troglophilic. There is a high percentage of endemic taxa, particularly among troglophilic organisms (Väinölä, pers. comm.).

Decapoda has Med representatives in three groups: Caridea, Brachyura, and Astacidea. Caridea includes 31 families and 2,500 described species, of which 655 species live in freshwaters. The 2 most speciose families are the freshwater shrimps Atyidae and Palaemonidae. In the Palearctic, 47 species belonging to 14 genera are known for these two families (De Grave et al., 2008). It is difficult to estimate the true species richness of freshwater shrimps in the Med, as studies are lacking in many countries and, moreover, the systematics of this group has changed dramatically in recent times with the advent of genetic research techniques that have led to the discovery of some lineages of cryptic speciation (García Muñoz et al., 2009). In Med inland waters, *Palaemon*, *Palaemonetes*, and *Atyaephyra* are probably the most widely distributed genera. An increasing number of endemic species are reported but mainly from subterranean systems. An alien species, *Palaemon macrodactylus*, which is native to Japan, Korea, and China, has been found in several Med waters (González-Ortegón & Cuesta, 2006; Tricarico, pers. comm.).

Brachyura, or crabs, is a highly diversified group of decapods that are mainly marine but include representatives in freshwaters. More than 6,700 species are currently known, of which 1,300 are true freshwater crabs. The highest freshwater crab diversity is present in tropical and subtropical areas. In the Palearctic, only 97 species belonging to 14 genera are reported, mostly belonging to the family Potamidae (Yeo et al., 2008). The Aegean area represents the Med biodiversity hotspot for Brachyura (Jesse et al., 2011). The taxonomy of Med crabs remains a subject of debate, but at present, 15 species of freshwater crabs, all from the genus *Potamon* (family Potamidae: subfamily Potaminae), have been reported (Jesse et al., 2011). Ten of these species are strictly Med endemics, while the remainder are also known in the Middle and Near East (Yeo, pers. comm.). Jesse et al. (2011) also reported the existence of a cryptic *Potamon* lineage in the Northern Aegean area. Some species of *Potamon* may have been spread by human introduction (Brandis et al., 2000).

Freshwater crayfishes are mainly represented by 2 large superfamilies, one of which (Astacoidea) is distributed in the Northern Hemisphere and composed

of the families Cambaridae (420 species) and Astacidae (39 species). In the Palearctic, 31 native species of Astacidae and 7 of Cambaridae are reported (Crandall & Buhay, 2008). In the Med, at least 5 freshwater crayfish species belonging to the family Astacidae are known: *Astacus astacus*, *A. leptodactylus*, *Austropotamobius torrentium, A. pallipes,* and *A. italicus*. The latter two species have been recently segregated by genetic analyses from the *A. pallipes* species-complex (Fratini et al., 2005; Bertocchi et al., 2008). Other crayfish species have been introduced in the Med, such as *Pacifastacus leniusculus* (Astacidae) and *Orconectes limosus* and *Procambarus clarkii* (Cambaridae).

Collembola

Collembola, the springtails, are small and ubiquitous organisms and have the widest distribution of any hexapod group. Collembola occur in all continents, including Antarctica. Springtails are basically terrestrial animals, but specialised aquatic species are present in several families. In the Palearctic region, Deharveng et al. (2008) reported the presence of 338 hydrophilous species belonging to 71 genera. The same authors reported that the Med region presents one of the highest percentages of endemisms, many of them undescribed (Deharveng et al., unpublished data). Probably as a result of quaternary glaciations, hydrophilous endemisms seem to be absent in other Palearctic areas. In fact, the number of aquatic or hydrophilous species in the Med is difficult to establish because taxonomic and ecological data on many species, particularly in some Med countries, are lacking. At present, it can be hypothesised that more than 1,000 species of Collembola are present in the Med (Fiera & Ulrich, 2012), of which 150 are aquatic and inhabit freshwater systems, including streams.

Ephemeroptera

Ephemeroptera, or mayflies, is a primitive order of aquatic insects that, together with Odonata, forms the Paleoptera. Adults are poor flyers (Brittain & Sartori, 2009), but they have reached several oceanic islands, such as the Macaronesian. Although some species are found in lentic and even brackish waters, they typically inhabit freshwater lotic ecosystems.

In the whole Palearctic, there are approximately 790 species of Ephemeroptera in 78 genera belonging to 22 different families (Barber-James et al., 2008). Of these, at least 278 species are noted to occur in the Med. These belong to 43 genera and 15 families.

It is difficult to make a complete overview of the diversity of this group as taxonomic and systematic research remains very active, particularly in recent years (e.g. since 2000 to 2011, 9 new species have been described in the Med), and molecular approaches have produced new data. To assess species presence and distribution, we have used information from Stoch (2003), Thomas & Belfiore (2004), Barber-James et al. (2008), and Brulin (2011), as well as several other references such as original descriptions and faunistic works (Table 2). Only 2 species are recorded throughout the whole Med, *Choroterpes picteti* and *Baetis rhodani*. The area with highest species richness is the NW with approximately 178 spp., followed by the NE with approximately 132 spp., the SW with 52 spp., and the SE with only 28 spp. However, these numbers may be underestimates, as Thomas (1998) recorded 69 species of mayflies in North Africa alone. A high percentage of species are endemic to the Med (approximately 99 species, i.e., approximately 36% of the species recorded in the Med).

Odonata

Odonata (damselflies and dragonflies) is the best-studied order of aquatic insects, and the taxonomy and distribution of species inhabiting the Med is relatively well known. Although this group is mainly associated with still waters such as ponds, many taxa can also be found in stream and rivers, particularly for species inhabiting seasonal streams that act as isolated lentic environments at certain times of the year. Although the richness is considerably higher in tropical areas, 560 species belonging to 137 genera and 20 families are present in the Palearctic region (Kalkman et al., 2008). The presence, distribution, and conservation status of the Med Odonata have been recently exhaustively reviewed by Riservato et al. (2009) with the complete atlas on 50×50 km^2 published by Boudot et al. (2009) on Odonata of the Med and North Africa. As our limits do not completely coincide with those of Riservato et al. (2009), we have reviewed the distribution of all species according to Boudot et al. (2009) to include or exclude them in our study. Within the limits considered, Odonata includes 11 families, 44 genera, and 155 species in the Med (Table 3) [a number

Table 2 Diversity of Ephemeroptera in Med rivers

Families	Genera (*N* species, *N* endemisms) in the Med
Prosopistomatidae	*Prosopistoma* (3,1)
Ameletidae	*Ameletus* (1,0), *Metreletus* (1,0)
Baetidae	*Acentrella* (3,1), *Alainites* (1,0), *Baetis* (51,19), *Baetopus* (1,0), *Centroptilum* (4,3), *Cheleocholeon* (1,1), *Cloeon* (6,1), *Diphetor* (1,1), *Procloeon* (8, 4), *Pseudocentroptiloides* (1,0)
Siphlonuridae	*Siphlonurus* (10,5)
Caenidae	*Brachycercus* (2,1), *Caenis* (16,3)
Neoephemeridae	*Neoephemera* (1,0)
Ephemerellidae	*Drunella* (1,0), *Ephemerella* (3,0), *Eurylophella* (1,0), *Serratella* (6,2), *Torleya* (1,0)
Ephemeridae	*Ephemera* (7,1)
Palingeniidae	*Palingenia* (2,0)
Polymitarcyidae	*Ephoron* (1,0)
Potamanthidae	*Potamanthus* (1,0)
Heptageniidae	*Afronurus* (1,0), *Ecdyonurus* (31,16), *Electrogena* (15,9), *Epeorus* (7,1), *Heptagenia* (5,0), *Kageronia* (1,0), *Rhithrogena* (39,17)
Isonychiidae	*Isonychia* (1,0)
Oligoneuriidae	*Oligoneuriella* (6,2), *Oligoneuriopsis* (1,0)
Leptophlebiidae	*Calliarcys* (1,0), *Choroterpes* (9,5), *Euthraulus* (2,1), *Habroleptoides* (11,3), *Habrophlebia* (6,2), *Leptophlebia* (2,0), *Paraleptophlebia* (5,1), *Thraulus* (1,0)

Table 3 Diversity of Odonata in Med rivers

Families	Genera (*N* species, *N* endemisms) in the Med
Calopterygidae	*Calopteryx* (7,3)
Epallagidae	*Epallage* (1,0)
Lestidae	*Lestes* (8,1), *Sympecma* (2,0)[a]
Coenagrionidae	*Agriocnemis* (1,0), *Ceriagrion* (2,0), *Coenagrion* (9,2), *Enallagma* (2,1), *Erythromma* (3,0), *Ischnura* (9,1), *Pseudagrion* (3,1), *Pyrrhosoma* (2,1)
Platycnemidae	*Platycnemis* (6,1)
Aeshnidae	*Aeshna* (6,0), *Anax* (4,1), *Boyeria* (2,1), *Brachytron* (1,0), *Caliaeschna* (1,0)
Gomphidae	*Anormogomphus* (1,0), *Gomphus* (9,2), *Lindenia* (1,0), *Onychogomphus* (7,2), *Ophiogomphus* (2,0), *Paragomphus* (2,0)
Cordulegastridae	*Cordulegaster* (8,3)
Macromiidae	*Macromia* (1,0)
Corduliidae	*Cordulia* (1,0), *Epitheca* (1,0), *Oxygastra* (1,0), *Somatochlora* (6,0)
Libellulidae	*Acisoma* (1,0), *Brachythemis* (2,0), *Crocothemis* (3,0), *Diplacodes* (1,0), *Leucorrhinia* (2,0), *Libellula* (4,0), *Orthetrum* (11,1), *Pantala* (1,0), *Rhyothemis* (1,0)[b], *Selysiothemis* (1,0), *Sympetrum* (13,1), *Trithemis* (4,0), *Urothemis* (1,0), *Zygonyx* (1,0)

[a] *S. paedisca* could be extinct in the Med

[b] *R. semihyalina* is regionally extinct in the Med

slightly lower than that indicated by Boudot et al. (2009), 179 spp., and Riservato et al. (2009), 165 spp.].

Compared to other aquatic invertebrates, the Odonata is better characterised in the Med, and only 2 new species have been described since 2000; however, the status of some taxa have changed according to recent studies. Faunistic and taxonomic studies continue to refine the knowledge about this group, and other taxonomic changes are expected in the next years. In fact, with the advent of molecular techniques, even revisions of family-level classifications at the global scale may be expected (Kalkman et al., 2008).

From a biogeographical point of view, strictly Palearctic and Afrotropical species (the latter reaching Northern Africa and, sometimes, Southern Europe) predominate. There also are some Holarctic species and even some typically Oriental taxa and Circumtropical migrants. Some species have a wide global distribution, as is the case for *Pantala flavescens*, a well-known migratory dragonfly that can be found almost anywhere (Askew, 2004). Because of their high flight capacity and migratory habits, Odonata are present in all of the Med islands, including the Macaronesian islands, where 1 species, *Sympetrum nigrifemur*, is endemic and 12 others can be found.

The species distribution of odonates around the Med is very homogeneous. The richest area is the SE (99 spp.), followed by the NW (92 spp.), the NE (90 spp.), and the SW (72 spp.). However, the number of endemic Med taxa is low in comparison with other insect groups such as Plecoptera and Ephemeroptera. Only 22 species can be considered endemic to this area (14.2% of the total): 7 species from the SW, 7 from the SE, 4 from the NE, 2 from the NW, and 2 from the W (both the NW and SW).

Plecoptera

Plecoptera (stoneflies) is the aquatic insect order that is most-often associated with running waters. In fact, only a few species are present in lakes and other lentic ecosystems. Stoneflies traditionally live in clean, well-oxygenated and cold streams, but certain species have adapted to temporary water courses, particularly some Med stoneflies. Nevertheless, because of restricted nymphal ecological requirements that greatly limit their dispersal capacity and the reduced flight ability of adults, stoneflies exhibit a high percentage of endemisms (Fochetti & Tierno de Figueroa, 2008). Globally, the highest diversity of Plecoptera can be found in the Palearctic region, where 1,628 species, 108 genera, and 11 families are present (Fochetti & Tierno de Figueroa, 2008). In the Med, 340 species belonging to 32 genera and 7 families have been recorded (Table 4). Data on their presence and distribution have been obtained from many different sources (including original descriptions and many faunistic papers, particularly from the Near East and Northern Africa), for example, Fochetti & Tierno de Figueroa (2004) and Graf et al. (2009).

Biogeographically, the most diverse area is the NW with 192 spp., followed by the NE (157 spp.), SE (41 spp.), and SW (33 spp.). A high percentage of species, 40.3% of the total (137 of 340 spp.), can be considered endemic to the Med, and this value could be higher if we consider some species that are mainly found in the Med but are also present slightly outside the considered limits of this area (e.g. North-Western Iberian Peninsula, Eastern Balkans, North-Eastern Turkey). The highest number of endemisms (including the genera *Afroperlodes*, *Guadalgenus*, *Helenoperla*, *Tyrrhenoleuctra* and the barely endemic *Eoperla* and *Hemimelaena*) occurs in the NW (51 spp.), followed by the NE (39 spp.), the SE (16 spp.), the SW (15 spp.), the W (10 spp.), the E (5 spp.), and the N (1 sp.). Nevertheless, proportionally, the most endemic fauna is that of the SW, where approximately 76% of the present species are endemic to the Med and 60% of these endemisms are exclusive to the SW.

Despite being a relatively well-studied group, new Plecoptera species continue to be described (28 species since 2000 to mid 2011), particularly in the

Table 4 Diversity of Plecoptera in Med rivers

Families	Genera (*N* species, *N* endemisms) in the Med
Taeniopterygidae	*Brachyptera* (23,9), *Rhabdiopteryx* (5,1), *Taeniopteryx* (7,1)
Nemouridae	*Amphinemura* (8,2), *Protonemura* (64,38), *Nemoura* (33,14), *Nemurella* (1,0)
Capniidae	*Capnia* (6,0), *Capnioneura* (9,3), *Capnopsis* (1,0)
Leuctridae	*Leuctra* (92,38), *Pachyleuctra* (2,0), *Tyrrhenoleuctra* (4,4)[a]
Perlidae	*Dinocras* (3,0), *Eoperla* (1,0), *Helenoperla* (1,1), *Marthamea* (3,1), *Perla* (11,2)[b]
Perlodidae	*Afroperlodes* (1,1), *Arcynopteryx* (1,0), *Besdolus* (5,3), *Bulgaroperla* (1,0), *Dictyogenus* (2,0), *Guadalgenus* (1,1), *Hemimelaena* (1,0), *Isogenus* (1,0), *Perlodes* (3,0), *Isoperla* (32,15)
Chloroperlidae	*Chloroperla* (8,0), *Pontoperla* (1,0), *Siphonoperla* (8,3), *Xanthoperla* (1,0)

[a] The genus *Tyrrhenoleuctra* is being intensively revised (e.g. Fochetti et al., 2009)

[b] The genus *Perla* is undergoing a taxonomic review (e.g. Sivec & Stark, 2002), and many records are likely misidentifications

E (11 spp. from the NE, 6 spp. from the SE, and 3 spp. from both the NE and SE) but also in the SW (2 spp.), and even in the best-studied NW (6 spp.).

Orthoptera

Crickets and grasshoppers (Orthoptera) are generally terrestrial, with very few species adapted to life on aquatic plants. In this context, according to Amédégnato & Devriese (2008), we consider aquatic species to be those that cannot develop without freshwater, especially for egg laying and nymphal development. Because the behavioural and life cycle traits of only a few species are well known, it is at present very difficult to assess the degree of water dependency of many Orthoptera species. Apart from some tropical Ensifera, most aquatic Orthoptera belong to Caelifera. Tetrigoidea, also called pygmy grasshoppers, are commonly found along rivers and other aquatic habitats, where they feed mostly on algae. Some species can swim and dive into the water when alarmed. In the Med, apart from *Paratettix meridionalis* (a truly Med species), we can report the presence of at least some other Tetrigoidea belonging to the genera *Depressotetrix*, *Uvarovitettix*, and *Tetrix*. Although all of these species are encountered near rivers and ponds, it is not certain whether they can be considered strictly water dependent. Freshwater-associated Acridoidea are particularly diffused in large floodplains of tropical areas (particularly in the Neotropics) and are almost completely unrepresented in the Palearctic. In the Med, some species of Oedipodinae are commonly found in riparian areas.

Heteroptera

Aquatic or semiaquatic bugs (Heteroptera, included in the order Hemiptera) occur on all continents except Antarctica, with the highest diversity found in tropical regions. Although most aquatic Heteroptera prefer lentic habitats, some species also inhabit running waters, with a particular preference for pools, slow-flowing environments, and floodplain systems. The Palearctic region has 16 families and 496 species (Polhemus & Polhemus, 2008). Three subgroups of aquatic bugs are known and all represented in the Med, Gerromorpha, Leptopodomorpha, and Nepomorpha. It is quite difficult to indicate the number of species (and endemic taxa) from the Med, but we can report some information.

In the Med, many species of Gerromorpha are recorded. Water striders (Gerridae) are represented at least by some species of *Aquarius* and *Limnophorus*. At least 7 of the 11 species of European *Gerris* (including *Gerriselloides*) are reported in the Med. The family Veliidae is represented by different species of Microveliinae, Veliinae, and Rhagoveliinae [of which the sole species, *Rhagovelia nigricans*, was observed in the Med (Grozeva & Simov, 2008)]. This family includes some Med endemics. Species of Hebridae, Hydrometridae, and Mesoveliidae are also found in the Med.

The Leptopodomorpha group is represented in the Med by Saldidae and Leptopodidae. However, a scarcity of information, especially in some countries, prevents any additional analysis.

Nepomorpha is the largest group of aquatic Heteroptera. The Aphelocheiridae include the most adapted species to life in streams and rivers, which spends its entire life cycle underwater. In the Med, *Aphelocheirus aestivalis* is widespread, while other species have narrower distributions (Miguelez & Valladares, 2010; Carbonell et al., 2011). The Belostomatidae, large water bugs with a mainly tropical distribution, are represented in the Med by the species *Lethocerus patruelis* (Convertini, pers. comm.). Corixidae, the water boatman, is the largest family of the group, and is well diversified and diffused throughout the Palearctic region with a number of Med species currently difficult to estimate. Naucoridae is a tropical family with few representatives in the Med. At present, at least 2 species are known in the area. Nepidae, or water scorpions, are present in the Med with 2 genera *Nepa* and *Ranatra*. Notonectidae, or back swimmers, is an important family of predaceous water bugs that colonise lentic, semi-lentic or slow-flowing habitats. While some species, such as *Notonecta glauca*, have a broad European distribution, other Notonectidae are restricted to the Med. Some species of the genus *Anisops* are distributed almost exclusively in the Med. In the Med, the family Ochteridae is represented by the cosmopolitan genus *Ochterus*. Pleidae is a cosmopolitan family comprising small aquatic Heteroptera, represented in the Med by *Plea minutissima*.

Neuropteroidea

Neuropteroidea is a group that includes 3 related insect orders: Megaloptera, Planipennia, and Raphidioptera. Megaloptera larvae are aquatic, and Planipennia larvae are mainly terrestrial but include a few families with aquatic or water dependent species. Raphidioptera larvae are all terrestrial. Megaloptera is represented by 2 families (Sialidae and Corydalidae, the only 2 included in this order) and 44 species in the Palearctic region, while Planipennia includes 2 families (Sisyridae and Nevrorthidae) and 18 species with aquatic larvae and 1 family (Osmylidae) with 16 species of water-dependent larvae (Cover & Resh, 2008) in this region. For the species list in the Med, we have used the works of Aspock & Aspock (2004a, b), Aspöck & Hölzel (1996), Oswald (2007), Canbulat (2007), and Dobosz (2007).

Sialidae in the Med is represented by 4 species of the genus *Sialis*. The family Sisyridae includes 5 species of the genus *Sisyra* in the Med. The family Nevrorthidae has an extremely disjunct distribution that is limited to the Med countries, Japan, Taiwan, and Australia (Cover & Resh, 2008). In the Med, 4 species of the genus *Nevrorthus* are present. The family Osmylidae includes in the Med 3 species of the genus *Osmylus*.

In total, 4 families, 4 genera, and 16 species of aquatic and water-dependent Neuropteroidea are present in the Med. Five species (31%) are endemic to this area. The most diversified zones are the NW and NE (10 species in each one), while only 3 species can be found in the SE and only 2 can be found in the SW. Nevertheless, as pointed out by Aspöck & Hölzel (1996), the degree of knowledge of the Neuropteroidea fauna in general is very heterogeneous in the Med (including North Africa, Mediterranean Asia and Europe) and some areas remain poorly investigated.

Coleoptera

Coleoptera is the largest group of species on earth, with more than 350,000 spp. currently described. They dominate almost every terrestrial habitat, but unexpectedly, they are not as diverse and abundant in freshwaters, particularly in lotic systems. Coleoptera is one of the few insect groups (with Heteroptera) with members that live in water both as larvae and/or adults. Aquatic beetles inhabit almost all freshwater habitats, such as streams, rivers, lakes, and man-made environments, but whereas some families mostly prefer lentic environments (such as Noteridae), others prefer running water systems (such as Elmidae). Jäch & Balke (2008) reported that approximately 30 Coleoptera families have aquatic representatives and 25 families are predominantly aquatic. The same authors reported that truly aquatic Coleoptera could number as many as 18,000 species worldwide and 3,346 species in the Palaearctic. Here, we consider as aquatic beetles those families in which more than 50% of the species are aquatic in at least one stage of life (larvae, pupa, or adult). Three suborders of Coleoptera have important aquatic families in the Med: 2 families among Myxophaga [Hydroscaphidae and Sphaerusidae (the former Microsporidae)]; 5 among Adephaga (Dytiscidae, Hygrobiidae, Gyrinidae, Haliplidae, and Noteridae); and 9 among Polyphaga (Helophoridae, Hydrochidae, Spercheidae, Hydrophilidae, Hydraenidae, Scirtidae, Elmidae, Dryopidae, and Psephenidae). Although mainly terrestrial, we could add two families to this list, Curculionidae and Chrysomelidae, that have some water-dependent representatives. We report here information on the diversity and diffusion of some families in the Med, but the picture we present is quite incomplete because of the lack of satisfactory studies, that the ecology and life cycles of many taxa are poorly known or unknown, and because a great number of species are likely still undescribed.

In the Med, Myxophaga is represented by a few species of Hydroscaphidae and Sphaerusidae. Among Adephaga, most Noteridae and Hygrobiidae (=Paelobiidae) prefer lentic habitats, but some also inhabit lotic environments. Noteridae is a unique family, with Med members that typically spend their entire life in the water. Hygrobiidae is present in the Med with the sole species *Hygrobia hermanni* (Jäch, 2003). Gyrinidae, or whirligig beetles, is present in the area with probably 15–20 species. Haliplidae is a widespread family that can be found preferentially in lentic environments of temperate regions. Two hundred species are recognised worldwide, and according to Rocchi (2004), approximately 30 are likely present in the Med. In the Med lotic systems, Dytiscidae are represented by a considerable (but difficult to estimate) number of small-sized taxa (Hydroporinae), a discrete number of medium-sized ones (Colymbetinae), and only 2 large-sized species (Dytiscinae). The Med Dytiscidae species with the greatest preference

for running currents include the following: in the subfamily Hydroporinae, the genera *Deronectes* and *Oreodytes*; almost all of the species of the genus *Nebrioporus* (still referred to by some authors as *Potamonectes*); most of the species of the genus *Bidessus*, *Yola bicarinata* (monospecific genus in Europe), some species of *Rhithrodytes*, *Scarodytes*, *Stictonectes*, and *Boreonectes* (= *Stictotarsus*); in the subfamily Colymbetinae, some species in the genus *Agabus*; in the subfamily Dytiscinae, only 2 species of the *Dytiscus* genus are frequently found in running waters (Bosi, pers. comm.). Overall, Dytiscidae have many endemic forms to the Med. For instance, 34 out of the 164 species reported for the Iberian Peninsula are endemic (Ribera, 2000).

Among Polyphaga, Spercheidae, and Helophoridae are mainly present in lentic water bodies and only occasionally occur in running waters; Scirtidae, Dryopidae, Hydraenidae, Hydrophilidae, and Hydrochidae are usually present in both lentic and lotic systems, and Psephenidae and Elmidae are among the beetles with the most typical lotic preferences. Psephenidae, abundant and diverse in the oriental part of the Palaearctic, is represented in the Med by the sole species *Eubria palustris*. Scirtidae is represented in this area by approximately 20 species of the genus *Hydrocyphon*, of which the greatest part is endemic to the Med (Hernando et al., 2004; Sapiejewski, 2004). The genus *Elodes* has representatives in Med streams and rivers. Elmidae, or riffle beetles, is the largest group of Dryopoidea and is widely distributed throughout the world (1,330 species and 146 genera in total). A large number of undescribed species are currently deposited in various museum collections, and so it is difficult to estimate Med diversity (Jäch & Balke, 2008). The most typical genera of Elmidae in the Med streams and rivers are *Elmis*, *Limnius*, *Esolus*, *Oulimnius,* and *Riolus*. Dryopidae is present in the Med with at least 27 species, approximately a quarter of which are endemics, of the genera *Dryops* and *Pomatinus*. Hydraenidae (e.g. genera *Hydraena*, *Ochthebius*, and *Limnebius*) has a large number of undescribed species, but we can report that approximately 380 species (of which 63% belong to the subfamily Hydraeninae and 37% to the subfamily Ochthebiinae) are currently listed in the Med, of which 57% are endemics (Jäch, 2004). Hydrophilidae occurs in a wide variety of aquatic environments, with the genera *Anacaena* and *Laccobius* frequent in streams. The family Spercheidae is represented by a single genus worldwide, *Spercheus*, and a unique species in the Med, *S. emarginatus*. Hydrochidae is represented in the Med by the genera *Hydrochus* and *Georissus,* and Helophoridae by the genus *Helophorus.* These two families, together with Sperchiidae, are included within the family Hydrophilidae as subfamilies by some authors (see Jäch & Balke, 2008).

Although not typically aquatic, the families Curculionidae and Chrysomelidae are also Polyphaga and are represented in Med freshwaters by aquatic species mainly belonging to the genera *Bagous* and *Donacia*.

Trichoptera

Caddisflies (Trichoptera) is an order of holometabolous insects that include more species than any other primarily aquatic order of insects (Morse, 2009). Immature stages are found in all types of aquatic environments, from high-mountain streams to large rivers and even in brackish waters (de Moor & Ivanov, 2008), but they are more abundant in lotic systems with relatively clean, cool and highly oxygenated waters (Morse, 2009).

The species distribution and presence data used for this group have been obtained from many different sources, such as articles, electronic catalogues, and checklists. Some of the main references are González et al. (1992), Cianficconi (2002), Stoch (2003), Malicky (2004a, b), Tobias & Tobias (2008), Coppa (2011), González & Martínez (2011), and Morse (2011). Since 2000 to mid 2011, 29 new Med species have been described, and the status of some others has been reconsidered. Here, we present a tentative account of species. Furthermore, differences in the study effort in some regions or the availability of some data may be reflected in an underestimation of the caddisfly fauna of those areas.

There are 2,349 described species belonging to 229 genera and 28 families in the Palearctic region (de Moor & Ivanov, 2008). In the West Palearctic in particular, there are 1,520 species and 149 genera in 23 families (de Moor & Ivanov, 2008). Of these, 926 are present in the Med and 423 are endemic, i.e. almost 46% of the total number of species recorded. They belong to 108 genera and 22 families (Table 5). Only 1 Trichoptera species has been recorded in the four regions, *Mesophylax aspersus*, and 29 are present in three regions simultaneously. The highest number of

Table 5 Diversity of Trichoptera in Med rivers

Families	Genera (*N* species, *N* endemisms) in the Med
Rhyacophilidae	*Rhyacophyla* (84,37)
Glossosomatidae	*Agapetus* (25,14), *Glossosoma* (15,8), *Synagapetus* (14,4), *Catagapetus* (2,1)
Hydroptilidae	*Agraylea* (2,0), *Allotrichia* (7,3), *Hydroptila* (66,34), *Ithytrichia* (4,2), *Microptila* (1,0), *Orthotrichia* (6,2), *Oxyethira* (13,6), *Stactobia* (23,15), *Stactobiella* (1,0), *Tricholeiochiton* (1,0)
Ptilocolepidae	*Ptilocolepus* (4,0)
Philopotamidae	*Chimarra* (1,0), *Philopotamus* (9,2), *Wormaldia* (23,9)
Hydropsychidae	*Cheumatopsyche* (2,0), *Diplectrona* (4,2), *Hydropsyche* (74,41)
Ecnomidae	*Ecnomus* (5,2)
Psychomiidae	*Lype* (3,0), *Paduniella* (1,0), *Psychomyia* (6,2), *Tinodes* (64,45)
Polycentropodidae	*Cyrnus* (4,1), *Holocentropus* (3,0), *Neureclipsis* (1,0), *Plectrocnemia* (11,3), *Polycentropus* (26,15), *Pseudoneureclipsis* (3,2)
Phrygaenidae	*Agrypnia* (3,0), *Oligotricha* (1,0), *Phryganea* (3,0), *Trichostegia* (1,0)
Brachycentridae	*Brachycentrus* (3,0), *Micrasema* (13,6)
Lepidostomatidae	*Crunoecia* (4,2), *Lasiocephala* (1,0), *Lepidostoma* (5,3)
Limnephilidae	*Allogamus* (16,6), *Anabolia* (1,0), *Anisogamus* (1,0), *Annitella* (7,6), *Anomalopterygella* (1,0), *Astratodes* (1,1), *Chaetopteroides* (2,1), *Chaetopterygopsis* (3,1), *Chaetopteryx* (8,4), *Chionophylax* (2,1), *Colpotaulius* (1,0), *Consorophylax* (1,0), *Cryptothrix* (1,0), *Drusus* (45,28), *Ecclisopteryx* (2,0), *Enoicyla* (3,1), *Enoicylopsis* (1,1), *Glyphotaelius* (1,0), *Grammotaulius* (2,0), *Halesus* (7,2), *Leptodrusus* (1,1), *Limnephilus* (35,7), *Melampophylax* (3,1), *Mesophylax* (5,3), *Metanoea* (2,1), *Micropterna* (14,3), *Monocentra* (1,0), *Parachiona* (1,0), *Platyphylax* (1,0), *Potamophylax* (14,8), *Psilopteryx* (4,4), *Rhadicoleptus* (2,0), *Stenophylax* (14,4)
Apataniidae	*Apatania* (7,4), *Apataniana* (3,3)
Uenoidae	*Thremma* (4,1)
Goeridae	*Goera* (1,0), *Larcasia* (1,0), *Lithax* (2,0), *Silo* (7,3), *Silonella* (1,1)
Leptoceridae	*Adicella* (11,3), *Athripsodes* (18,7), *Ceraclea* (8,1), *Erotesis* (3,2), *Homilia* (1,0), *Leptocerus* (4,1), *Mystacides* (3,0), *Oecetis* (11,5), *Parasetodes* (1,0), *Setodes* (10,4), *Triaenodes* (5,3), *Ylodes* (4,1)
Calamoceratidae	*Calamoceras* (2,1)
Odontoceridae	*Odontocerum* (3,0)
Sericostomatidae	*Notidobia* (6,5), *Oecismus* (3,2), *Schizopelex* (5,2), *Sericostoma* (14,7)
Beraeidae	*Beraea* (18,11), *Beraeamyia* (11,8), *Beraeodes* (1,0), *Beraeodina* (1,1), *Ernodes* (7,4)
Helicopsychidae	*Helichopsyche* (5,2)

species is found in the NW (535 spp.), followed by the NE (432 spp.), the SW (134 spp.), and the SE (64 spp.).

Lepidoptera

The order Lepidoptera (butterflies and moths) is primarily terrestrial, but there are a few species in the superfamily Pyraloidaea that have aquatic stages. In the Palearctic region, Mey and Speidel (2008) reported the presence of 81 species of aquatic Lepidoptera, while the European fauna includes 24 species, 11 of which are introduced from other parts of the World (Goater et al., 2005). Although aquatic Lepidoptera in the Med, especially in the southern and eastern regions, have been poorly studied, we can report that there are approximately 10 native species in this area (Karsholt, pers. comm.). At present, we can include in the freshwater fauna of Med lotic systems some Acentropinae (Crambidae), including the genera *Elophila* and *Parapoynx*.

Diptera

Diptera, or true flies, is one of the richest and most diverse insect orders, with almost 150,000 species described. This order contains several important aquatic groups with impressive morphological and ecological diversification.

Blephariceridae, or net-winged midged, includes 124 species recorded in the Palearctic (Wagner et al., 2008). In the Western Paleartic, the diversity of this group increases from North to South, and reaches its maximum in the mountains of the Med (approximately 40 species and subspecies), which are rich in endemisms (Zwick, pers. comm.).

The family Ptychopteridae, with 27 species in the Palearctic (Wagner et al., 2008), appears to be represented in the Med by some species with broad European distributions, such as *Ptychoptera albimana*, and some restricted endemisms.

Dixidae is a cosmopolitan family of the Culicoidea, with more than 40 species in the Western Palaearctic and 67 species in the Palearctic (Wagner et al., 2008). At present, approximately 20 species have been recorded from the Med (Wagner, pers. comm.), with a high diversity in the western part of the Med (Wagner et al., 2008) and few endemisms.

Chaoboridae, or phantom midges, has larval stages inhabiting lentic or semilentic habitats, which are rarely found in lotic environments. At least 3 species of the *Chaoborus* genus are present in the Med from the 10 species recorded in the Palearctic (Wagner et al., 2008).

Mosquitoes or Culicidae, with 492 species in the Palearctic (Rueda, 2008), are not particularly distributed in lotic environments but are abundant in swamps, lakes, and semilentic habitats. Because of their medical importance, abundant information about mosquitoes from various regions of the World is available. In a pioneering work, DuBose & Curtin (1965) reported the presence of 83 species of mosquitoes in the Med, but this number has certainly grown. In fact, in a much more recent paper, 67 species are reported for the African coast of the Med alone (Brunhes et al., 2000).

Simuliidae larvae live as filter-feeders in various running water environments, where they often constitute a key component of the benthic community. This large family includes more than 2,000 species worldwide (Currie & Adler, 2008) and 699 species in the Palearctic (Currie & Adler, 2008). In the Med, approximately 105 species are reported, of which 54 are endemic to this area (see Aadler & Crosskey, 2010), but these numbers may be underestimates (Crosskey, pers. comm.).

Chironomidae is probably the most diffused and ubiquitous aquatic insect family. They colonise almost every sort of freshwater habitat in all continents, including Antarctica. They can be collected in a wide variety of environments. Their diversity is also impressive; 4,147 species are currently recognised worldwide, and the number continues to increase. The Palaearctic area is one of the richest taxonomically (probably because of the long history of taxonomic research efforts), with 1,321 currently recognised species belonging to 181 genera (Ferrington, 2008). In the Med countries, Laville & Reiss (1992) reported that approximately 703 Chironomidae species are known and 97 of the species are exclusive to this area. This number has increased significantly in recent years.

Lonchopteridae is a small family for which the main distribution centre is probably South-East Asia (Wagner et al., 2008). There is only 1 genus (*Lonchoptera*) distributed in the Med, including the cosmopolitan *L. bifurcata*.

The families Deuterophlebiidae, Nyphomyiidae, Tanyderidae, and Corethrellidae, are recorded in the Palearctic (Wagner et al., 2008) but have no representatives in the Med. In the family Scatopsidae, a few species with aquatic larvae have been discovered in Europe only recently, but so far none have been cited in the Med (Haenni & Vaillant, 1994). Information in the Med for some families as Psychodidae, Thaumaleidae, Ceratopogonidae, Stratiomyidae, Empididae, Syrphidae, Ephydridae, Muscidae, Sciomyzidae, Tipulidae, Cylindrotomidae, Limoniidae, Pediciidae, Athericidae, Rhagionidae, Tabanidae, and Dolichopodidae is scarce, and it is not possible to assess their diversity at this time.

Hymenoptera

Aquatic taxa among Hymenoptera are very rare, representing only 0.13% of the total described species in that order. About 150 species are reported worldwide, with 60 in the Palearctic (Bennett, 2008). All aquatic Hymenoptera are members of the suborder Apocrita, group Parasitica, and are represented by

parasitoids of aquatic insects. Unfortunately, traditional Hymenoptera studies did not usually consider aquatic environments, and this lack of knowledge makes it practically impossible to present a clear and complete picture about the diversity of aquatic wasps in the Med. Most aquatic Hymenoptera colonise lentic environments, but at least one-third of the species are associated with running water habitats, as are many Ichneumonidae. *Agriotypus armatus* is an idiobiont ectoparasite of the prepupae and pupae of the Trichoptera families Goerideae and Odontoceridae. In the Med, this species seems to be restricted to the NW. Other species are also strictly related to freshwaters, such as *Gambrus carnifex* and *Scambus arundinator*, which are parasitoids of stem-boring aquatic Lepidoptera and *Sulcarius biannulatus*, which oviposits on *Limnephilus* caddisflies. Furthermore, some Mymaridae can also be included in aquatic Hymenoptera of the Med because they are egg-parasitoids of aquatic insects (Bennett, pers. comm.).

Pisces

Under the name freshwater Pisces (fishes) and considering just the Med, we are including members of two groups, Cephalaspidomorphi and Actinopterygii. Pisces, broadly speaking, is a paraphyletic group that includes some other extant Vertebrata groups, such as hagfishes (Myxini), lobe-finned fishes (Sarcopterygii), and Condrictia, but no other groups such as tetrapods (Nelson, 2006). The distribution of the species included in the Med has been compiled from Kottelat & Freyhof (2007) and Froese & Pauly (2011). In this review of the Med diversity of freshwater fishes, we have included all of the species naturally present in continental waters, as it is difficult to separate species that exclusively inhabit lotic ecosystems from those that inhabit mainly lentic ecosystems but also make incursions in streams and rivers connected to ponds and lakes. Records of those species that are introduced have not been considered, nor are species that are primarily marine but that occasionally enter freshwaters, as these provide little information about distribution and diversity patterns. Nevertheless, those species that are generally present in estuaries and enter rivers during part of their life have been included.

According to these criteria, a total of 460 species (subspecies have not been considered) belonging to 101 different genera are recorded in the Med (Table 6), and 452 species if we do not count those that are now considered Extinct or Extinct in the Wild, of 1844 species from 380 genera of strictly freshwater fishes registered in the Palearctic region (Lévêque et al., 2008). In the Med, 23 of the 106 families documented in the Paleartic region are present (Lévêque et al., 2008). Cyprinidae is the best-represented family in the Med (277 spp.), as also occurs at a global scale (Nelson, 2006), followed by Cobitidae (32 spp.) and Balitoridae (31 spp.).

Since 2000, 79 new species present in the Med have been described, 67 of which have been considered endemic. In recent years, several studies (using both molecular and morphological approaches) have also focused on solving systematic and taxonomic problems, such as those of the barbels (*Barbus* spp., Tsigenopoulos & Berrebi, 2000), but others, such as those regarding *Salmo trutta*, remain unresolved (Apostolidis et al., 2007).

Considering all the species together, the highest number of species is found in the NE (315 spp.), followed by the NW (119 spp.). In the south, few species are recorded (35 spp. in the SW and 74 spp. in the SE). Only 13 species are widely distributed and are found in the four areas.

The Med counts 292 endemic species, 64% of the species recorded in this area, with 234 belonging to the Cypriniformes order. This number has increased considerably since 2006, when 253 species were assessed in terms of threats to their conservation by the IUCN (Smith & Darwall, 2006). This difference mainly occurs because 52 new species endemic to the Med have been described since 2006 and because the limits considered in that evaluation are slightly different than those considered here. These endemic species are mainly found in the NE, where 202 species are recorded, a much higher number in comparison with the other areas (47 spp. in the NW, 37 spp. in the SE, and 11 spp. in the SW). Only one species endemic to the Med is widely distributed in the four areas, *Aphanius fasciatus*.

The principal reason why the Med has such a high proportion of endemic species is because it comprises the main regions of Europe where fishes refuged during the last Ice Age. Thus, the presence of high mountain ranges, such as the Pyrenees or the Alps, acted as a barrier to northern expansions of fishes in

Table 6 Diversity of Pisces in Med rivers

Families	Genera (*N* species, *N* endemisms) in the Med
Petromyzontidae	*Caspiomyzon* (1,1), *Eudontomyzon* (3,1), *Lampetra* (3,0), *Petromyzon* (1,0)
Acipenseridae	*Acipenser* (4,0), *Huso* (1,0)
Anguillidae	*Anguilla* (1,0)
Atherinidae	*Atherina* (1,0)
Clupeidae	*Alosa* (6,3)
Balitoridae	*Barbatula* (14,10), *Nemacheilus* (2,1), *Nun* (1,1), *Oxynoemacheilus* (7,5), *Paracobitis* (1,0), *Schistura* (3,2), *Seminemacheilus* (2,2), *Triplophysa* (1,0)
Cobitidae	*Cobitis* (30,24), *Sabanejewia* (2,0)
Cyprinidae[a]	*Abramis* (1,0), *Acanthobrama* (7,6), *Achondrostoma* (4,2), *Alburnoides* (5,4), *Alburnus* (27,19), *Anaecypris* (1,1), *Aspius* (2,0), *Aulopyge* (1,1), *Barbus* (27,16), *Barilius* (1,0), *Blicca* (1,0), *Capoeta* (13,9), *Carasobarbus* (2,1), *Carassius* (1,0), *Chondrostoma* (14,9), *Crossocheilus* (1,1), *Cyprinion* (3,0), *Delminichthys* (4,4), *Garra* (2,1), *Gobio* (9,5), *Hemigrammocapoeta* (3,3), *Iberochondrostoma* (4,4), *Iberocypris* (2,2), *Kosswigobarbus* (1,1), *Ladigesocypris* (2,2), *Leucalburnus* (1,0), *Leucaspius* (1,0), *Leuciscus* (3,0), *Luciobarbus* (13,11), *Pachychilon* (2,1), *Parachondrostoma* (4,2), *Pelasgus* (7,7), *Petroleuciscus* (2,0), *Phoxinellus* (3,3), *Phoxinus* (5,1), *Protochondrostoma* (1,0), *Pseudochondrostoma* (3,2), *Pseudophoxinus* (20,19), *Rhodeus* (2,0), *Romanogobio* (2,0), *Rutilus* (12,8), *Scardinius* (9,6), *Schizothorax* (1,1), *Squalius* (32,25), *Telestes* (11,9), *Tropidophoxinellus* (3,3), *Vimba* (2,0)
Cyprinodontidae	*Aphanius* (19,14)
Valenciidae	*Valencia* (2,2)
Gasterosteidae	*Gasterosteus* (2,0), *Pungitius* (2,1)
Mugilidae	*Chelon* (1,0), *Liza* (3,0), *Mugil* (1,0)
Blenniidae	*Salaria* (2,1)
Cichlidae	*Haplochromis* (2,1), *Oreochromis* (1,0), *Sarotherodon* (1,0), *Tilapia* (1,0), *Tristramella* (4,4)[b]
Gobiidae	*Babka* (1,0), *Economidichthys* (2,2), *Gobius* (1,0), *Knipowitschia* (11,9), *Neogobius* (1,0), *Padogobius* (2,1), *Pomatoschistus* (1,0), *Ponticola* (2,2), *Proterorhinus* (2,0)
Moronidae	*Dicentrarchus* (2,0)
Percidae	*Gymnocephalus* (1,0), *Perca* (1,0), *Sander* (1,0), *Zingel* (1,0)
Pleuronectidae	*Platichthys* (1,0), *Pleuronectes* (1,0)
Salmonidae	*Salmo* (19,14)[c], *Thymallus* (1,0)
Cottidae	*Cottus* (3,2)
Bagridae	*Mystus* (1,0)
Clariidae	*Clarias* (1,0)
Siluridae	*Silurus* (2,1)

[a] Cyprinidae comprises the highest number of extinct species in the Med, 4 (*Acanthobrama hulensis*, *Alburnus akili*, *Chondrostoma scodrense,* and *Telestes ukliva*), and the only species classified as "Extinct in the Wild" in this area, *A. telavivensis* (IUCN, 2011)

[b] Two species has been catalogued as Extinct in this family, *Tristramella intermedia* and *T. magdelainae* (IUCN, 2011)

[c] One species of *Salmo*, *S. pallaryi*, has been classified as Extinct by the IUCN (2011)

these areas and recolonisation of these zones from the North (Lévêque et al., 2008).

Many exotic species of fishes have been introduced in the Med for angling, food, or aesthetic reasons (Kottelat & Freyhof, 2007). The number of these invasive species can be very high in some Mediterranean areas. For instance, Tierno de Figueroa et al. (2007) noted that approximately 40% of fishes present in Med rivers of the Iberian Peninsula are exotic.

Amphibia

Amphibians (Lissamphibia) are highly water-dependent animals, at least during the reproductive stage (mating, and egg and larva development usually occur in freshwater) and occasionally throughout their life cycles. In the Med, some species, such as green frogs (genus *Pelophylax*) and many newts (Salamandridae), are frequent inhabitants of streams and rivers, but even

species living far away from these habitats (such as some toads of the *Bufo* genus) can use streams and rivers for reproductive purposes. In addition, although many Med amphibians prefer lentic waters (ponds, lakes, etc.), all species are able to use streams and rivers. Therefore, we include all amphibian species inhabiting within the limits considered in our study.

The taxonomic study of Amphibia is a very active research area, particularly in the last two or three decades (Frost et al., 2006; Vences & Köhler, 2008). Since 2000, many nomenclature changes have occurred, and new species have been described. In the Med area alone, at least 6 species have been described during this period, and this number increases considerably if we also consider restored species (previously synonymised) or subspecies now elevated to species. Other nomenclature changes have also occurred and this activity inevitably causes some disagreements among specialists, and some of the most vocal critics have begun to speak of a taxonomic inflation problem, while others usually consider the increase in the number of new species a consequence of taxonomic progress (e.g. Padial & De la Riva, 2006; Vences & Köhler, 2008). Unfortunately, the current global decline of populations overshadows the notable advances in the knowledge of amphibian species diversity (Frost et al., 2006; AmphibiaWeb, 2011; IUCN, 2011). Obviously, this idea is also true for species in the Med (Cox et al., 2006), where a considerable number of taxa are considered threatened.

Vences & Köhler (2008) identified 160 species (belonging to 26 genera) in the Palearctic region, while Cox et al. (2006) counted 106 species in the Med. Nevertheless, our data differ from those of Cox et al. (2006) because the Med limits considered by Cox et al. are wider than ours (they defined the region politically rather than biogeographically), and many taxonomic changes have occurred in the last 5 years. For species taxonomy and distribution, we have mainly followed Dubois (2004), Cox et al. (2006), AmphibiaWeb (2011), and Frost (2011). In the Med, 7 families of Anura (plus 1 introduced) and 3 of Urodela are present (Table 7). Some species of frogs have been translocated among different Med countries. In addition, 2 species, *Aquarana catesbeiana* (family Ranidae) from America and *Xenopus laevis* (family Pipidae) from Africa, have been introduced in some areas of the Med.

Table 7 Diversity of Amphibia in the Med rivers

Families	Genera (*N* species, *N* endemisms) in the Med
Bombinatoridae	*Bombina* (3,1)
Bufonidae	*Bufo* (11,5)[a]
Alytidae (= Discoglossidae)	*Alytes* (5,4), *Discoglossus* (7, 6)[b]
Hylidae	*Hyla* (8,4)[c]
Pelobatydae	*Pelobates* (4,1)
Pelodytidae	*Pelodytes* (2,1)
Ranidae	*Rana* (14,9), *Pelophylax* (8,3)
Plethodontidae	*Hydromantes* (8,8)[d]
Proteidae	*Proteus* (1,0)
Salamandridae	*Calotriton* (2,1), *Euproctus* (2,2), *Lissotriton* (4,1), *Lyciasalamandra* (7,7), *Mesotriton* (1,0), *Neurergus* (1,1), *Ommatotriton* (1,1), *Pleurodeles* (3,3), *Salamandra* (6,2), *Salamandrina* (2,2), *Triturus* (6,2)

[a] Some authors separate the genus *Pseudepidalea* from *Bufo*

[b] *D. nigriventer* was considered extinct up to the end of 2011 (IUCN, 2011) but recently rediscovered (Kloosterman, 2012)

[c] *H. heinzsteinitzi* (endemic to Israel and Palestine) is possibly extinct

[d] The Med species have been ascribed to two subgenera (*Atylodes* and *Spelomanthes*) within the genus *Hydromantes* (Carranza et al., 2008)

According to our data, a total of 106 species (62 Anura and 44 Urodela), plus 2 introduced frog species, are present in the Med. All of the native species have a more or less reduced distribution within the Palearctic Region, and only 2 species that are also present in the Afrotropical region can be found in the SW. This particular distribution is the result of the relatively low dispersion ability of this animal group, which favours the formation of endemisms with relatively small distribution areas. Thus, 64 species (60,4% of the total), 34 of the order Anura (54,8%), and 30 of the order Urodela (68,2%), can be considered endemic to the Med. Almost 30% of the genera (*Alytes*, *Discoglossus*, *Euproctus*, *Lyciasalamandra*, *Pleurodeles*, and *Salamandrina*), 2 subgenera (*Atylodes* and *Spelomantes*), and 1 family (Discoglossidae) can also be considered endemic or almost endemic to this area.

The richest area within the Med is the NW with 62 spp., followed by the NE with 38 spp., the SW with 16 spp., and the SE with 13 spp. The higher diversity in the N, particularly in the NW, is related to higher rainfall and water availability. The higher endemicity

rate of the SW is to the result of the isolation of this area and the limited ability of amphibians to cross the existing frontiers (the Mediterranean Sea in the North and the Sahara desert in the South and East). Thus, of the 16 species present, only 2 are also present in the Afrotropical region and 4 in Southern Europe. In general, many endemisms are associated with Med islands, particularly the Tyrrhenic ones, while no Amphibia are present naturally in the Macaronesian Islands (although some species, such as *Hyla meridionalis* or *Pelophylax perezi*, have been introduced).

Reptilia

Reptiles are a paraphyletic group that includes the extant Chelonii, Squamata, Sphenodontida, and Crocodilia orders. We will treat here under this name all extant Sauropsida groups, except birds, which will be treated in another section.

Bour (2008) cited only 8 species and 6 genera of aquatic Chelonii (of the 257 species included in 79 genera found worldwide) that inhabit the Palearctic region. In the Med, 7 species are present (Rhodin et al., 2010; IUCN, 2011; Uetz et al., 2011): 2 species of the *Emys* genus, one of them recently described as a cryptic species (Fritz et al., 2005) and endemic to the Med but of controversial taxonomical validity because different molecular approaches (mitochondrial vs nuclear DNA studies) show contradictory results (Spinks & Shaffer, 2009); 1 species of the *Rafetus*; 1 species of the *Trionyx* genus; and 3 species of the *Mauremys* genus. Some other species of Chelonii have been introduced in the Med, but *Trachemys scripta* is particularly widely distributed.

Aquatic Squamata is represented in the Palearctic region by only 5 genera and 6 species of Serpentes, according to Pawuels et al. (2008). Only the genera *Natrix*, with 3 species, is present in the Med (IUCN, 2011; Uetz et al., 2011).

Finally, only 1 of the 3 species of Crocodilia present in the Palearctic region could be found in the Med (Martin, 2008), *Crocodylus niloticus*. Although typically African, this species was also present in the Near East. In fact, only fairly recently was it extirpated from Israel (Uetz et al., 2011), and in antiquity, it occurred in the Zarqa River (Jordan) (IUCN, 2011).

From the biogeographical point of view, 5 species can be considered almost endemic to the Med (in some cases, their geographical limits extend slightly outside this area), 4 species have a Palearctic distribution, and 2 species are mainly Ethiopic but are also punctually present in the Palearctic region. According to Cox et al. (2006), almost one half of the reptiles of the Med (both aquatic and terrestrial) are endemic to this region, and this high percentage of endemisms does not differ considerably from the exclusively aquatic Reptilia.

In the Med, species richness is higher in the SE (7 spp., 64%) [as occurs for reptiles in general (Cox et al., 2006)], intermediate in the NW (6 spp., 55%) and the NE (5 spp., 45%), and lower in the SW (4 spp., 37%). These results do not coincide with data obtained for reptiles in general (Cox et al., 2006), which exhibit high species richness in the SW and relatively lower richness in the NW. These differences are an obvious consequence of arid areas in the SW, which favour terrestrial but not aquatic species.

Aves

It is difficult to precisely determine which species should be included among the stream and river Med birds for the following reasons: (1) many freshwater birds are associated with lentic waters (lakes, marshes, etc.), but they are sometimes present in middle and, mainly, lower sections of rivers where the current is slow; (2) the great dispersion capacity of birds frequently results in the presence of vagrant individuals; (3) many birds inhabit the river mouth, and it is difficult to determine whether they are marine or fluvial birds; (4) many birds are migratory, and species that spend only a small part of their time in this area either could or could not be included; and (5) different species depend on these environments in different ways (some of them feed on fluvial material, others make their nests in the riparian vegetation or sandy or rocky banks, etc.) and to a different degree (some species are absolutely dependent on streams and rivers, while others use them only occasionally).

Thus, we consider Med fluvial birds those species that typically spend (1) all year, (2) the reproductive period or the wintertime in this area, (3) occupy streams and rivers (including the river mouth, but not exclusively coastal, and the riparian vegetation), and (4) exhibit a medium–high degree of dependence on this habitat despite also being able to exist in other habitats. Although our definition differs slightly from the one adopted by Dehorter & Guillemain (2008),

which is more restricted and for freshwaters in general, we can make comparisons with their data with a low margin of error.

Dehorter & Guillemain (2008) identified the presence of 154 species, 68 genera, and 25 families of freshwater birds in the Palaearctic region. In the Med, we have estimated the presence of 130 species, 72 genera, and 27 families following Svensson et al. (2009) and IUCN (2011) (Table 8). Despite the small differences in criteria, we can affirm that a very high percentage of Palaearctic freshwater birds are present in the Med. The families Gaviidae and Gruidae are not included in this review because when they are present in the Med (mainly during winter) they do not behave as freshwaters species. *Anhinga rufa* (family Anhingidae) is now considered extinct in the Med (Birdlife International, 2009) and is not considered in our study.

Regarding global distribution, almost all of the fluvial Med birds are widely distributed in the Palaearctic region or in more than one biogeographical region. The Palaearctic–Afrotropical–Oriental species are particularly abundant, but some also range to the Australasian and/or Nearctic regions or are nearly cosmopolitan (only absent from Antarctica and some isolated islands). Only a few species can be considered to have a relatively narrow worldwide distribution area, such as *Phalacrocorax pygmaeus*. Within the Med, species distributed all around the area

Table 8 Diversity of Aves in Med rivers

Families	Genera (*N* species) in the Med (No Med endemisms are present)
Anatidae	*Anas* (7), *Anser* (4), *Aythya* (3), *Branta* (1), *Bucephala* (1)[a], *Cygnus* (3), *Marmaronetta* (1), *Melanitta* (2)[a], *Mergus* (2)[a], *Mergellus* (1)[a], *Netta* (1), *Oxyura* (1), *Somateria* (1)[a], *Tadorna* (2)
Podicipedidae	*Podiceps* (4), *Tachybaptus* (1)
Pelecanidae	*Pelecanus* (2)
Phalacrocoracidae	*Phalacrocorax* (2)
Ardeidae	*Ardea* (2), *Ardeola* (1), *Botaurus* (1), *Bubulcus* (1), *Butorides* (1), *Casmerodius* (1), *Egretta* (2), *Ixobrychus* (1), *Nycticorax* (1)
Threskiornithidae	*Platalea* (1), *Plegadis* (1)
Ciconidae	*Ciconia* (2)
Accipitridae[b]	*Circus* (1), *Haliaeetus* (1), *Pandion* (1)
Rallidae	*Fulica* (2), *Gallinula* (1), *Porphyrio* (1), *Porzana* (3), *Rallus* (1)
Charadriidae	*Charadrius* (3), *Vanellus* (1)
Glareolidae	*Glareola* (1)
Recurvirostridae	*Himantopus* (1)
Scolopacidae[c]	*Actitis* (1), *Calidris* (2), *Gallinago* (2), *Lymnocryptes* (1), *Limosa* (2), *Numenius* (1), *Philomachus* (1), *Tringa* (5), *Xenus* (1)
Laridae	*Larus* (8), *Sterna* (2), *Chlidonias* (3)
Strigidae	*Ketupa* (1)
Alcedinidae	*Alcedo* (1), *Ceryle* (1)
Picidae	*Jynx* (1)
Cinclidae	*Cinclus* (1)
Emberizidae	*Emberiza* (2)
Hirundinidae	*Riparia* (2)
Motacillidae	*Motacilla* (2), *Anthus* (1)
Muscicapidae	*Luscinia* (2)
Troglodytidae	*Troglodytes* (1)
Remizidae	*Remiz* (1)
Timaliidae	*Panurus* (1)
Oriolidae	*Orioulus* (1)
Sylviidae	*Acrocephalus* (7), *Cettia* (1), *Hippolais* (3), *Locustella* (1)

[a] These genera are mainly marine, although their presence in the mouth of rivers is not unusual

[b] *Milvus migrans* is occasionally found in freshwater habitats but is not considered here because of its wide ecological tolerance

[c] With the exception of *A. hypoleucos*, which can be considered a frequent inhabitant of Med rivers, the Scolopacidae, like other Charadriiformes birds, are mainly coastal species that can also be found in the mouths of rivers and, in particular, marshes

predominate (94 spp., 72% of the total). This wide distribution is explained by the high dispersion capacity, which is related to flight and the frequent migratory behaviour of birds. In addition, the richness is relatively homogeneous in different parts of this area, with 113 spp. in the NW, 120 in the NE, 113 in the SE, and 101 in the SW. Slight differences in diversity composition are the result of a higher influence of European winter migrants in the North, Asiatic winter migrants in the North-East, and the presence of typically Afrotropical elements in the South and Oriental-East Palaearctic elements in the East.

The list of bird species in Med streams and rivers would be significantly increased if we consider vagrant taxa (coming from Sub-Saharan Africa, Asia, or even America) that can be found regularly in this area. In addition, vagrant individuals are frequently present within the Med from North to South, East to West, or vice versa. Notably, in recent years, an increase in the presence of individuals of southern species has been detected in the Med, particularly in the European part (e.g. some Ciconidae, Ardeidae, or Pelecaniidae species). Although many more studies are needed to obtain stronger support, this increase may be related to climate change (along with other factors of anthropic origin), as shown in many studies of phenological changes in bird migration and reproduction (e.g. Sanz, 2002; Gordo, 2007).

Mammalia

A small percentage of mammals in the world can be considered freshwater organisms (aquatic or aquatic-dependent), with slightly more than 124 species in 65 genera (of more than 5,500 described species) according to Veron et al. (2008). These authors reported that 18 species (in 8 genera) have a Palearctic distribution.

In the Med, 9 species in 6 genera belonging to 3 different mammalian orders are present in streams and/or rivers: *Galemys pyrenaicus*, *Neomys anomalus*, and *N. fodiens* (in the Eulypotyphla); *Castor fiber*, *Arvicola amphibius*, *A. sapidus*, and *A. scherman* (Rodentia); and *Lutra lutra* and *Mustella lutreola* (Carnivora). Three other species have been introduced and are widely distributed in this area: *Ondatra zibethicus* and *Neovison vison* from North America, and *Myocastor coypus* from South America. *C. fiber*, which is a native species that is currently scarce in the Med (e.g. it is considered extinct in Portugal and Turkey), has been reintroduced in some Med areas.

From a biogeographical point of view, 2 species have a restricted West European distribution but are not limited to the Med, 2 have a European distribution, 1 is West Palearctic, 3 are Palearctic, and 1 is distributed both in the Palearctic and Oriental regions. In the Med, the current species richness is higher in the NW (9 spp., 100%) and decreases in a clockwise direction, with 5 spp. in the NE, 3 spp. in the SE, and only 1 sp. in the SW.

Med endemisms and biodiversity hot spot

The percentage of endemisms in Med freshwater biota can be estimated as approximately 43% (of 3,551 species belonging to 22 animal and plant groups that have been well analysed in this regard, Table 9). The percentage ranged from 0% in groups such as Aves and Cnidaria, which have a high dispersion capacity, to more than 50% in other groups such as Hydraenidae (57%), Amphibia (60%), or Pisces (63%). Although the percentages could be lower because many species are known only from their type locality and future findings could reveal that they are not Med endemic, this can be surpassed by the high number of local endemisms that continue to be described in poorly studied areas. Moreover, the current taxonomic changes caused by the increasing application of molecular techniques will permit the identification of criptic species, increasing the number of known endemisms. Finally, we must also consider that many species that are almost endemic to the Med have not been included here. Unfortunately, for many groups, such as Protista and Prokaryota, it is currently impossible to evaluate their degree of endemicity (or even their specific richness), making the above estimate applicable only to macroscopic organisms. When comparing freshwater endemicity with global endemicity in the Med (Blondel et al., 2010), some mainly terrestrial groups, such as birds or vascular plants, have comparatively lower endemicity values in freshwater. Nevertheless, as a whole, the groups with the highest percentages of endemicity in the Med are mainly freshwater groups such as amphibians or freshwater fishes.

The categorisation of the Med as a biodiversity hotspot is supported not only by its degree of endemism but also by its freshwater biota richness

Table 9 Data on diversity and endemicity for selected taxa present in the Med

Group	Palearctic spp.[a]	Med spp.	Endemic spp.
Vascular plants	497[b]	460	150
Porifera	59	13	3
Cnidaria	12–18	7	0
Nemertea	14	3	1
Bryozoa	44	22	–
Bivalvia	187	46–49	19
Polychaeta	67	18	0
Hirudinea	185	40	–
Tardigrada	49	44	6
Halacaridae (Acari)	34	22	4
Potamidae (Crustacea)	97	15	10
Astacidae (Crustacea)	31	5	1
Collembola	338	150	–
Ephemeroptera	790	278	99
Odonata	560	155	22
Plecoptera	1,628	340	137
Neuropteroidea	78	16	5
Hydraenidae (Coleoptera)	800	380	217
Trichoptera	2,349	926	423
Lepidoptera	81	10	–
Simuliidae (Diptera)	699	105	54
Pisces	1,844	460	292
Amphibia	160	106	64
Reptilia	17	11	5
Aves	154[b]	130	0
Mammalia	18	9	0

[a] Data from Balian et al. (2008)

[b] Criteria to define groups are slightly different between the Palearctic and the Mediterranean (see text for an explanation)

and, unfortunately, by the risks that threaten it. Thus, 35% of the known Palearctic freshwater species (data obtained from 26 plant and animal groups; Table 9) and 6.3% of the World freshwater species (considering the same 26 plant and animal groups, and comparing with data obtained from Balian et al., 2008) are present in the Med. Although the Med biota is relatively well known compared to those from some other Palearctic or World areas, these percentages are notable.

Regarding the spatial distribution within the Med, the richest area, as well as the most-studied, is the North, although the patterns differ among groups (Fig. 2). For instance, birds and dragonflies (Odonata), which have a wide dispersion capacity, are almost homogenously distributed throughout the Med. However, for freshwater fishes, the NE seems to be an important area for speciation. Amphibians and stoneflies (Plecoptera) are considerably scarcer in the dryer areas (SW and SE), and this is also true for fishes.

Species traits in the Med: a case study with macroinvertebrates

A species trait is a characteristic that reflects the adaptation of a species to its environment (Menezes et al., 2010). There is a direct relationship between traits and environmental constraints and the environment acts as a filter for biological traits (Statzner et al., 2001). Several authors have indicated that regions with similar climates have different taxonomic groups (both animal and plant) that have similar biological traits (e.g. growth, form) and increasing

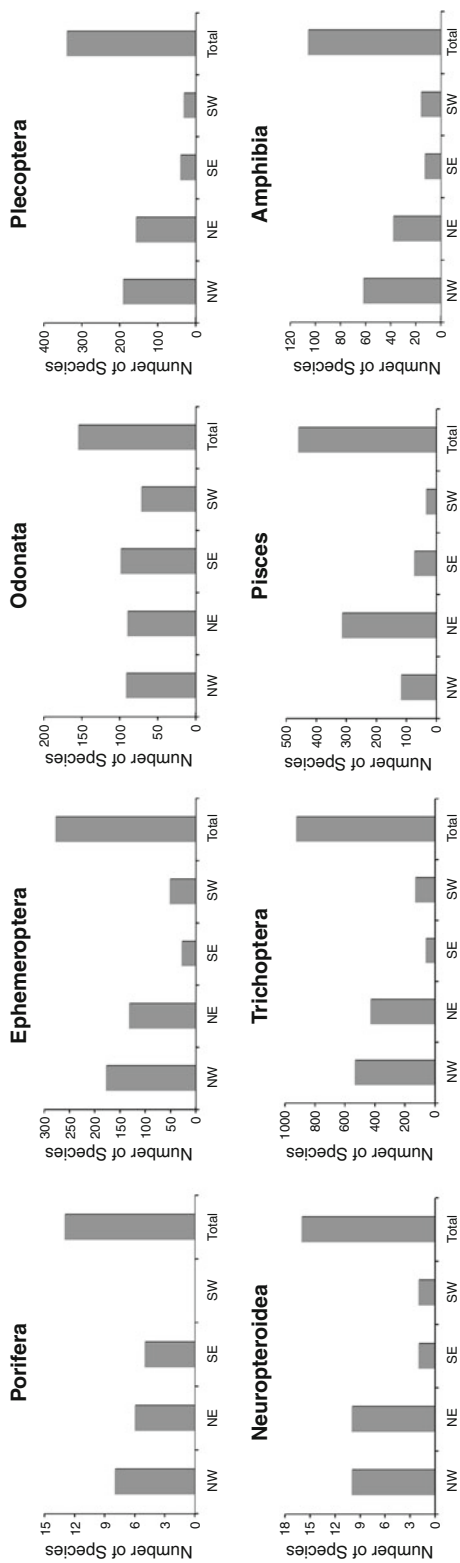

Fig. 2 Bar charts of freshwater species richness in the different Med areas for selected taxa. See legend of Fig. 1 for areas covered

environmental harshness produces similar traits in animal communities (see Statzner et al., 2001 for a complete review). Thus, the study of traits in the mediterranean climate regions increases our understanding of their diversity and can help explain some of the patterns of diversity.

In Europe, species traits (both biological and ecological) have been widely used for many different purposes, such as the characterisation of community structure, biomonitoring, assessment of human-induced alterations, interregional comparisons of macroinvertebrate communities, or the assessment of sensitivity or vulnerability of some macroinvertebrate groups to climate change (e.g. Bonada et al., 2007; Hering et al., 2009; Morais et al., 2009; Menezes et al., 2010; Tierno de Figueroa et al., 2010). For instance, Bonada et al. (2007), comparing the taxonomic richness and trait composition of river macroinvertebrate assemblages (including Trichoptera) in the Med and temperate Europe, found that climate change could produce large changes in the taxonomic composition of macroinvertebrate communities but weak changes in their trait composition. Particularly in the Med, Bonada & Dolédec (2011) compiled trait information on several Med-exclusive genera and found that these taxa exhibited specific traits that could explain their exclusivity to the Med region compared with those of temperate region genera.

By comparing endemic with non-endemic species of EPT, we observe that only a low percentage of endemic species are rare in abundance (2.4%), while a higher percentage of non-endemic species are found in low numbers (12.8%). Thus, the great majority of truly Med species are relatively more numerous (in number of individuals) than those species found in the Med that have a wider distribution. This trend may indicate that many of the latter are not under optimal conditions in the Med.

The study of the ecological traits (Table 10) of these groups suggests a general trend for these species to occupy the upstream-most parts within streams. For the endemic species, the highest percentages of species are found above the hyporhitron (the lowest section of the upper reaches). Non-endemic species are also widely represented in downstream zones, such as the epipotamon and even the metapotamon. In both cases, the maximum number of species is recorded in the epirhithron. In the potamon section, there are more non-endemic species than endemic.

Regarding altitude, many endemic and non-endemic species are represented in montane, submontane, and collin areas (from 1,900 to 300 m a.s.l.). The highest proportion of species was preferentially found in micro-mesolithal (coarse gravel and cobbles from 2 to 20 cm) and macro-megalithal substrates (stones and boulders larger than 20 cm), with some non-endemic species also occupying macrophytes. Most of them are rheophil, cold stenotherm species, but in the case of non-endemic species, there is also a high proportion of eurithermic species.

Biological traits (Table 11) reveal that the highest proportion of endemic species are in the functional-feeding groups of collector-gatherers, grazers/scrapers, and shredders, and that there are a scarcer number of predators. For non-endemic species, there is a higher proportion of grazers/scrapers, collector-gatherers, and shredders, in that order. Predators are also well-represented among non-endemic species.

Several of the endemic species are known to possess some form of resistance (mainly diapause) to droughts, which are common events that occur in Med streams. Some non-endemic species also have these mechanisms, but a high proportion does not have any resistance form. Curiously, many of these non-endemic species have this resistance form in the aerial stage and not in the strictly aquatic stage. Many species face adverse conditions, such as drought, with a *r*-strategy life history. In fact, the highest proportion of both endemic and non-endemic species are *r*-strategists, although, in endemic species, the proportional differences with *K*-strategists are lower than in non-endemic species. Nevertheless, these results should be taken with caution, as information on this trait was not available for many species.

The highest proportion of species studied, both endemic and non-endemic, develop in less than 1 year and are univoltine. Immature stages, i.e. aquatic stages, are mainly found in spring, winter, summer, and autumn, respectively, and very few species have immature stages that are found throughout the year. This proportion is slightly higher in non-endemic species than in endemic ones. Endemic species emerge mainly in spring but also in summer, while the opposite is true for non-endemic species, i.e. the highest proportion of species emerges in summer but also in spring, and most species have a short emergence period of less than 2 months.

Table 10 Proportion of selected ecological traits of Med endemic and non-endemic Ephemeroptera, Plecoptera and Trichoptera species

Ecological traits	Endemic		Non-endemic	
	% spp. with available data	% Med spp.	% spp. with available data	% Med spp.
Stream zonation preference				
Eucrenal	32.93	5.42	26.54	12.23
Hypocrena	57.43	9.45	48.06	22.14
Epirhithral	77.11	12.69	66.43	30.60
Metarhithral	64.66	10.64	60.26	27.76
Hyporhithral	42.97	7.07	50.65	23.33
Epipotamal	12.85	2.12	35.15	16.19
Metapotamal	3.61	0.59	21.38	9.85
Hypopotamal	0.80	0.13	4.02	1.85
Littoral	2.01	0.33	19.08	8.79
Profundal	0.40	0.07	0.86	0.40
Altitude preference				
Nival (>3,100 m)	0.78	0.13	0.33	0.13
Subnival (2,900–3,100 m)	3.10	0.53	7.01	2.78
Alpine (2,400–2,900 m)	11.24	1.92	24.04	9.52
Subalpine (1,900–2,400 m)	32.95	5.62	50.58	20.03
Montane (1,000–1,900 m)	58.14	9.91	79.13	31.33
Submontane (800–1,000 m)	55.81	9.52	86.81	34.37
Collin (200–800 m)	58.91	10.05	84.31	33.38
Planar (<300 m)	38.76	6.61	63.77	25.25
Microhabitat/substrate preference[a]				
Pelal	1.62	0.26	14.89	5.35
Argyllal	0.81	0.13	5.70	2.05
Psammal	6.48	1.06	20.59	7.40
Akal	8.10	1.32	25.00	8.99
Micro-/mesolithal	79.35	12.95	70.04	25.18
Macro-/megalithal	74.49	12.16	59.19	21.28
Hygropetric habitats	3.64	0.59	2.21	0.79
Algae	10.53	1.72	9.93	3.57
Macrophytes	19.03	3.11	37.68	13.55
Particulate organic matter	2.43	0.40	20.96	7.53
Woody debris (xylal)	16.60	2.71	21.14	7.60
Madicol habitats	1.62	0.26	2.21	0.79
Other habitats	0.00	0.00	0.55	0.20
Current preference				
Limnobiont	0.93	0.20	6.84	3.04
Limnophil	4.32	0.93	8.77	3.90
Limno- to rheophil	10.80	2.31	10.10	4.49
Rheo- to limnophil	15.12	3.24	19.32	8.59
Rheophil	56.48	12.10	41.60	18.51
Rheobiont	13.27	2.84	11.29	5.02
Indifferent	0.31	0.07	2.23	0.99

Table 10 continued

Ecological traits	Endemic		Non-endemic	
	% spp. with available data	% Med spp.	% spp. with available data	% Med spp.
Temperature range preference				
Cold stenotherm (<10°C)	72.73	4.23	49.65	13.95
Warm stenotherm (>18 °C)	13.64	0.79	20.24	5.68
Eurytherm (wide T range)	13.64	0.79	30.35	8.53

Variables and categories from Graf et al. (2008)

[a] Pelal: mud (grain size < 0.063 mm); argyllal: silt, loam, clay (grain size < 0.063 mm); psammal: sand (grain size 0.063–2 mm); akal: fine- to medium-sized gravel (grain size 0.2–2 cm); micro-/mesolithal: coarse gravel to hand-sized cobbles (grain size 2–20 cm); macro-/megalithal: stones, boulders, bedrock (grain size > 20 cm); hygropetric habitats: thin layers of water over bedrocks, waterfalls; algae: micro- and macroalgae; macrophytes: macrophytes, mosses, Characeae, living parts of terrestrial plants; particulate organic matter: coarse and fine particulate organic matter; woody debris (xylal): woody debris, twigs, roots, logs (size > 10 cm); madicol habitats: edge of water bodies, moist substrates; other habitats: e.g. host of a parasite

Conservation and future challenges

According to a recent review on World freshwater biodiversity (Dudgeon et al., 2006), the threats to global freshwater biodiversity can be grouped under five main interacting categories: (1) destruction or degradation of habitat, (2) invasion by exotic species, (3) water pollution, (4) flow modification, and (5) overexploitation. Increases in nitrogen deposition, warming, and shifts in precipitation and runoff patterns, acting at a global scale, should also be added to these threat categories (Kernan et al., 2010). Med freshwaters also are facing similar threats as biota in other regions: eutrophication resulting from urban sewage; agricultural runoff; industrial pollution; water withdrawals and drainage for irrigation and drinking water; dam construction that limits sediment and nutrient flow downstream to deltas that affect species migrations and fishery productivity; overfishing; and introduction of exotic species (either planned or accidental).

Freshwaters are facing a massive global loss of biodiversity. Estimates suggest that at least 10,000–20,000 freshwater species are extinct or at risk, with loss rates that could be of the same magnitude as those of previous transitions between geological epochs, such as the Pleistocene to Holocene (Vörösmarty et al., 2010). For instance, in 2008, 510 freshwater fish species were included on a red list, while in 2009, 3,120 species were included (Chadwick, 2010). In the Med, 164 of the 460 freshwater fish species recorded (36%) were included as threatened (CR, EN, or VU) on the IUCN Red List, 7 species are EX and 1 is EW (IUCN, 2011; Fig. 3). These threatened species include the European eel (*Anguilla anguilla*), which was once very common and in which recruitment in streams and rivers has decreased 95–99%. This species has been recently included in Appendix II of the Washington convention (C.I.T.E.S. 2007, effective March 13, 2009). The situation for some other freshwater vertebrates is similar: 30 of the 106 Med amphibian species (28%) are threatened, and 1 species appears as EX [although it has been recently rediscovered (Kloosterman, 2012)]; 3 of the 9 Med freshwater mammal species (33%) are threatened (IUCN, 2011, Fig. 3). Reptiles (9% of species are threatened); birds (5% of species are threatened), however, present a more favourable situation (IUCN, 2011, Fig. 3). Intermediate values are found in Med aquatic vascular plants, of which approximately 16% are threatened and 1 species is regionally extinct (IUCN, 2010; Fig. 3).

Conservation status data at the global scale are scattered and scarce for many other organisms (many invertebrate groups, fungi, algae, etc.). Two important exceptions are freshwater Mollusca (both Gastropoda and Bivalvia) and Odonata. Within Mollusca, 8 of the 46–49 species of Med freshwater Bivalvia (17–16%) are considered threatened, and 270 of the 590 studied species of Med freshwater Gastropoda (46%) are considered threatened and 18 EX (IUCN, 2011, Fig. 3). Odonata includes 25 threatened species of the 155 Med taxa (16%). For many other groups, even when they are important in streams and rivers in terms

Table 11 Proportion of selected biological traits of Med endemic and non-endemic Ephemeroptera, Plecoptera, and Trichoptera species

Biological traits	Endemic		Non-endemic	
	% spp. with available data	% Med spp.	% spp. with available data	% Med spp.
Feeding type				
Grazers and scrapers	79.46	5.88	69.10	24.39
Miners	0.00	0.00	0.00	0.00
Xylophagous	0.00	0.00	0.94	0.33
Shredders	77.68	5.75	48.50	17.12
Collector-gatherers	89.29	6.61	58.99	20.82
Active filter feeders	0.00	0.00	1.31	0.46
Passive filter feeders	1.79	0.13	10.86	3.83
Predators	20.54	1.52	39.89	14.08
Parasites	0.00	0.00	0.00	0.00
Other feeding types	0.00	0.00	2.25	0.79
Resistance/resilience to droughts				
No drought resilience	0.00	0.00	26.55	1.98
Egg diapause	26.67	0.26	23.89	1.78
Larvae diapause	26.67	0.26	9.73	0.73
Adult diapause	20.00	0.20	32.74	2.45
Unknown resistance type	33.33	0.33	7.08	0.53
Resistance form				
Eggs, statoblasts	42.86	0.20	17.58	1.06
Cocoons	0.00	0.00	5.49	0.33
Housings against desiccation	0.00	0.00	9.89	0.59
Diapause or dormancy	100.00	0.46	28.57	1.72
Quiescence	14.29	0.07	13.19	0.79
None	0.00	0.00	14.29	0.86
Life duration				
$\leq$1 year	98.90	5.95	87.22	20.75
>1 year	1.10	0.07	12.78	3.04
Larval development cycle				
Winter	42.42	0.93	59.29	8.86
Spring	66.67	1.45	80.09	11.96
Summer	42.42	0.93	57.08	8.53
Autumn	24.24	0.53	48.23	7.20
All year	18.18	0.40	30.53	4.56
Emergence/flight period				
Winter	16.42	2.97	14.08	6.35
Spring	77.37	14.01	74.63	33.64
Summer	63.50	11.50	89.44	40.32
Autumn	38.32	6.94	56.45	25.45
Duration emergence period				
Short (aprox. <2 months)	70.50	12.16	56.28	25.18
Long (aprox. >2 months)	29.89	5.16	44.61	19.96

Table 11 continued

Biological traits	Endemic		Non-endemic	
	% spp. with available data	% Med spp.	% spp. with available data	% Med spp.
Reproductive life cycles per year				
Semivoltine	9.09	0.13	9.76	1.92
Univoltine	63.64	0.93	82.15	16.13
Bivoltine	31.82	0.46	13.13	2.58
Trivoltine	13.64	0.20	2.02	0.40
Multivoltine	0.00	0.00	1.01	0.20
Flexible	0.00	0.00	6.06	1.19
r–K-strategy				
r strategist	66.67	0.26	94.23	3.24
K strategist	33.33	0.13	5.77	0.20

Variables and categories from Graf et al. (2008)

of number of species (e.g. Trichoptera, Ephemeroptera, Plecoptera), no broad data exist on risk of extinction and population dynamics, so they have not been included in the IUCN Red List despite their demonstrated threat status in regional-scale studies. For instance, Fochetti & Tierno de Figueroa (2006) indicated that 15% of Plecoptera species were considered threatened with extinction in Italy (islands included), and 4 species were considered already extinct in this country. Furthermore, a recent study in which 516 species and/or subspecies of European stoneflies were evaluated for vulnerability to climate change according to their autoecological data demonstrated that at least 62% could be included in one or more categories of vulnerability. Moreover, the most diverse areas, concentrated in the South of the continent, are also where most vulnerable taxa are present (Tierno de Figueroa et al., 2010).

Inland waters have only recently been addressed by conservation politics, and a smaller portion of their biota is involved in preservation measures. European legislation is still lacking in this regard. A very few freshwater species, mainly vertebrates and plants, are included in Annex II and IV of Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. We can safely say that the protection politics regarding freshwater organisms have been poorly addressed. For instance, among animals, 986 European vertebrate species (64.0% of the European vertebrates) are included in a European or World protection directive; 100% of European birds (533 species) are somewhat protected, as are 66.2% of amphibians (51 species), and 53.2% of reptiles (82 species). Unfortunately, only 0.1% of European invertebrates are protected (154 species), and we can easily imagine that the percentage of freshwater invertebrates that are protected is even lower. The situation is even worse for other freshwater organisms, such as algae and fungi.

The first step in protecting aquatic ecosystems is to fill the gap of knowledge regarding their biodiversity. The freshwater floral/faunal inventory must be completed (some projects have been developed in recent years, such as Fauna Europaea, Encyclopedia of Life, GBIF, BioFresh, etc.), but this should now be coupled with the study of the biology of threatened species, such as estimates of a population's structure. The priority is to formulate long-term national plans and provide them with funds to create taxonomic experts and support the expertise where it already exists.

The second compulsory step is, generally speaking, to lower the anthropogenic pressure on freshwaters. Directive 2000/60/EC of the European Parliament has now established a legal framework for community action in the field of water policy and management in some Med countries. The purpose of this Directive is the protection of (among other ecosystems) inland surface waters. Member States must protect, enhance and restore all bodies of surface water, with the aim of achieving good surface water status by 2015. To achieve this goal, a huge effort is needed to: reduce pollution of agricultural, urban, or industrial origin; to

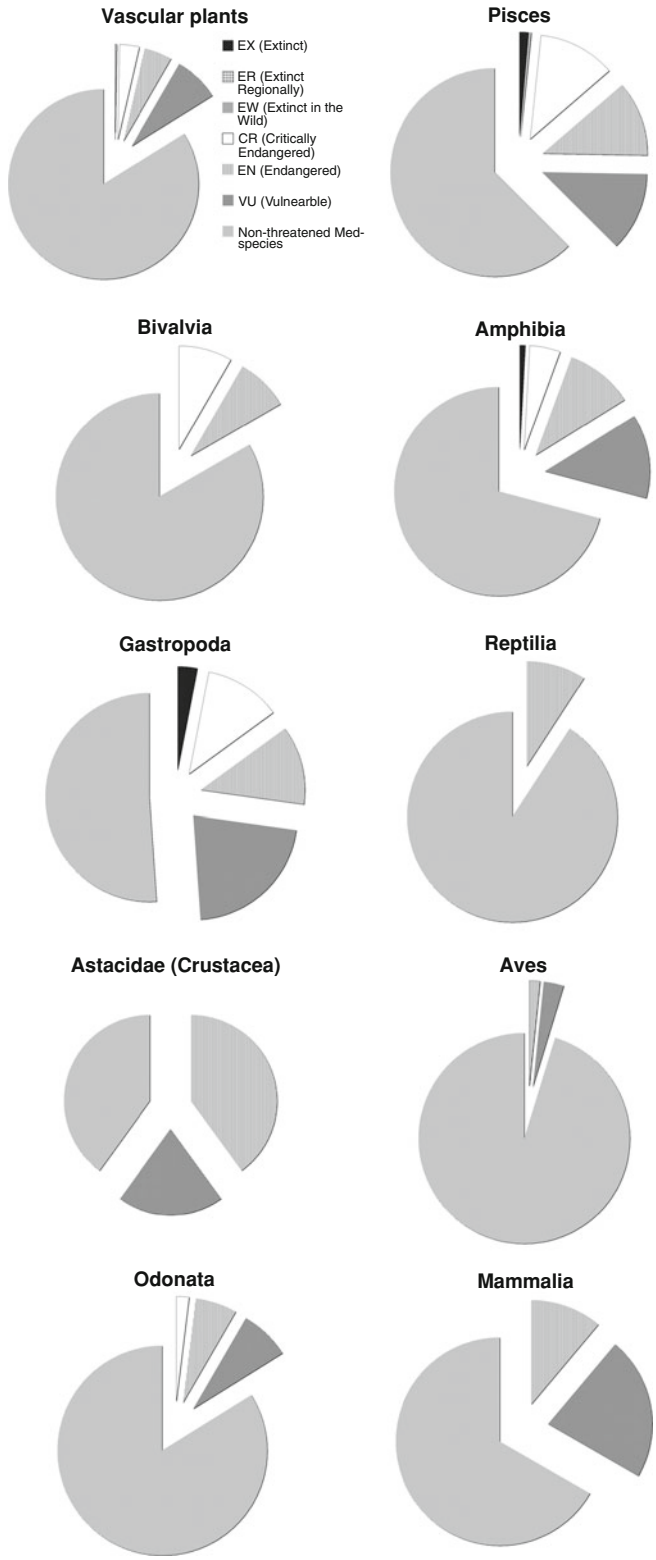

Fig. 3 Pie charts of threat categories for selected freshwater Med taxa. Data from IUCN (2011)

establish ecosystem flow requirements; to check extraction activities; and to ensure the integrity of river banks and stretches. A river basin management plan (RBMP) must be produced for each national river basin district and, by December 2009, should have been available in all River Basin Districts across the EU. However, in many cases, the aim of achieving good surface water status in 2015 is a theoretical aim. In some Med countries, freshwater environmental quality is so compromised that good water quality cannot be foreseen in the near future. In general, the situation for non-European Med countries is even worse, due to the lack of appropriate conservation politics.

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