1 **Mediterranean-climate streams and rivers: Geographically separated but**

2 **ecologically comparable freshwater systems**

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21   **Abstract**

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23   Streams and rivers in mediterranean-climate regions (med-rivers in med-regions) are

24   ecologically unique, with flow regimes reflecting precipitation patterns. Although

25   timing of drying and flooding is predictable, seasonal and annual intensity of these

26   events is not. Sequential flooding and drying, coupled with anthropogenic influences

27   make these med-rivers among the most stressed riverine habitat worldwide. Med-rivers

28   are hotspots for biodiversity in all med-regions. Species in med-rivers require different,

29   often opposing adaptive mechanisms to survive drought and flood conditions or recover

30   from them. Thus, metacommunities undergo seasonal differences, reflecting cycles of

31   river fragmentation and connectivity, which also affect ecosystem functioning. River

32   conservation and management is challenging, and trade-offs between environmental

33   and human uses are complex, especially under future climate change scenarios. This

34   overview of a Special Issue on med-rivers synthesizes information presented in 21

35   articles covering the five med-regions worldwide: Mediterranean Basin, coastal

36   California, central Chile, Cape region of South Africa, and southwest and southern

37   Australia. Research programs to increase basic knowledge in less developed med-

38   regions should be prioritized to achieve increased abilities to better manage med-rivers.

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Preface

Streams and rivers in mediterranean climate regions of the world (med-rivers) are ecologically unique and perhaps among the most vulnerable to environmental damage from human activities. Gasith and Resh (1999) presented the first review of these systems but, in the past 15 years, scores of research articles have appeared that have expanded on or challenged some of the concepts raised in that article. This Special Issue attempts to synthetize information available on med-river ecology since that publication. It includes 21 review articles by leading scientists conducting research in mediterranean climate regions (med-regions) of the world, and covers both theoretical and applied aspects. In all articles in this Special Issue, the authors are referring to a mediterranean climate (med-climate) as a climatic type at the macroclimate scale (i.e, the climatic conditions that are a result of the interaction with large-scale processes) and only consider meso- and microclimate scale characteristics (i.e., the climatic conditions that are a result of changes in orography, altitude, orientation to the coast, and continental and oceanic influences) when considering within-region variability.

This Special Issue covers a wide variety of fundamental topics that have been widely studied in med-regions. These include hydrology, nutrient and organic matter dynamics (Bernal et al., 2013; Romaní et al., 2013), food webs (Power et al., 2013), riparian vegetation structure and function (Stella et al., 2013), and seasonal and interannual biological changes (Hershkovitz & Gasith, 2013; Resh et al., 2013; Robson et al., 2013). Moreover, particular attention has been focused on natural and human-driven disturbances and ecosystem responses. Thus, this Special Issue includes articles on drought (Hershkovitz & Gasith, 2013; Robson et al., 2013), fire (Verkaik et al.,

66   2013), land-use influences (Cooper et al., 2013), chemical pollution (López-Doval et

67   al., 2013), biological invasions (Marr et al., 2013), and climate change (Filipe et al.,

68   2013). Management and conservation issues are also covered in several articles that

69   review hydrological connectivity (Merelender & Matella, 2013), the assessment of

70   ecological status (Dallas, 2013), water management (Grantham et al., 2013), and river

71   restoration (Kondolf et al., 2013) in med-regions throughout the world.

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73   The biological diversity of med-regions is an important issue because of these

74   areas being "hotspots" of biodiversity and the threats they face because of high human

75   population density and the competition for water. Articles on this topic treat

76   biodiversity by individual med-regions (Ball et al., 2013; Davies & Stewart, 2013; de

77   Moor & Day, 2013; Figueroa et al., 2013; Tierno de Figueroa et al., 2013). All of these

78   articles have a comparable structure that includes: (1) biogeographical aspects relevant

79   for riverine organisms, (2) the current status of freshwater biodiversity knowledge, (3)

80   detailed information on richness, endemism, and biological trait characteristics by

81   taxonomic group, (4) conservation programs and practices conducted in the med-region,

82   and (5) future challenges related to taxonomic knowledge and conservation issues.

83

84   Unfortunately but not unexpectedly, not all relevant topics could be covered in

85   this compendium of articles. Litter decomposition, and plant or invertebrate invasions

86   are examples. However, some information on these topics can be found embedded in

87   several of the articles of this Special Issue. We hope that this compendium will

88   encourage others to write reviews of these topics and perhaps expand on some of the

89   topics that the articles in this review stress as needing a synthesis.

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91   In this introductory chapter, we describe the climate, the physical environment,

92   and the biological and ecosystem responses of med-rivers to a variety of abiotic

93   characteristics. We also provide an overview on challenges for med-river conservation

94   and management. All topics included here relate to the whole Special Issue and more

95   details can be found in the respective chapters we refer to. Moreover, we believe that

96   these articles may have application beyond med-regions. For example, many of the

97   issues discussed and the conclusions reached in this chapter and throughout the whole

98   Special Issue can also be applied to the monsoonal tropics, some oceanic islands, and

99   other highly seasonal areas.

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Introduction

The area surrounding the Mediterranean Sea is the origin of great cultures, the development of agriculture and resource utilization, and even the establishment of current religious beliefs. However, the climate that helped foster these developments can be also found in other areas of the world. This med-climate occurs in five different regions: the Mediterranean Basin (Med-Basin), coastal California, central Chile, the Cape region of South Africa, and the southwest and southern parts of Australia (Fig. 1). All these climatic regions lie between 32º-40º N and S of the Equator, and are located in the south or west side of these continents (Aschmann, 1973a). Although there are strong geographical differences among these areas they all conform to Aristotle's and Goethe's respective descriptions of the Mediterranean as "the only place on Earth suitable for civilized life" and "the land where orange trees are in bloom"!

The med-climate is typically defined by the high seasonality in the precipitation and temperature patterns that occur annually, with hot and dry summers, and cool and wet winters predominating (Fig. 1). The annual precipitation of the med-climate areas worldwide ranges generally from 300 to 900mm/y, with most rainfall occurring during winter months although in some med-regions spring and autumn rains often occur (Miller, 1983). Summer storms can be also frequent especially in the southern hemisphere, whereas most northern hemisphere med-regions summers are completely free of rain (Cowling et al., 2005). Winter temperatures in med-regions are generally mild (7-13ºC) with infrequent frosts and snow, whereas summers are typically hot, with a mean temperature of 14-25ºC (Paskoff, 1973). Interannual variability in precipitation is important in all med-regions, and the amount of precipitation defines dry, normal,

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128   and wet years. For example, in some areas in northern California (e.g. Sonoma

129   Country), USA, precipitation has ranged from 238 to 1518 mm/year within a 7-years

130   period (Bêche & Resh, 2007b). Overall, med-regions have been described as situated

131   along a climatic gradient between temperate and desert climate regions (see Dallman,

132   1998). Moreover, even though we can describe generalities of the med-climate, climatic

133   conditions can vary within specific areas of a med-region from mesic to xeric.

134

135   For each med-region, the geographical limits of the med-climate region depend

136   on the climate classification system used. Many climate classifications exist and some

137   have ancient origins. For example, Parmenides in the sixth century B.C. considered the

138   five regions in the world as comprising three climates types: one that was torrid, two

139   temperate, and two frigid (Sanderson, 1999). Even modern climatology has resulted in a

140   myriad of classification systems (Köppen, 1936; Holdridge, 1947; Thorthwaite, 1948;

141   Trewartha, 1968; Budyko, 1986; Prentice et al., 1992; Smith et al., 2002). The

142   pioneering attempt and still the most commonly used modern climate classification is

143   that of Köppen (1936), which was originally conceived to understand the vegetation

144   boundaries present throughout the world. This classification considers values of

145   temperature and precipitation regime based on monthly means of air temperature and

146   rainfall totals, and classifies world climates in 30 typologies. Thus, according to

147   Köppen, the med-climate would be included within the "dry-summer temperate"

148   climate typology. This is the "Cs" type, with the temperature of the hottest month >

149   10ºC, the coldest between -3 and 18ºC, and precipitation of the driest summer month

150   less that one-third of the amount in the wettest winter month. In addition, the

151   subtypologies "hot summer" ("Csa" type, with temperature of the warmest month >

152   22°C) and "warm summer" ("Csb" type, with temperature of the warmest month <

153   22°C and more than 4 months with > 10ºC) would be included as med-climates in his

154   classification (Khlebnikova, 2009). However, in following this classification, regions

155   not typically considered mediterranean also would be included, such as areas in

156   Mexico, Argentina, the northwest of Spain, or several of the Atlantic islands.

157

158   Other classifications, such as that originally proposed by Thornthwaite (1948),

159   used the relationship between the potential evapotranspiration and the precipitation (i.e.,

160   water budget) in a region. This was an improvement of Köppen's classification in that

161   the water budget provides a better measure of water availability, but it has resulted in

162   very complex and impractical maps with over 800 climate types. Further simplifications

163   of the Thornthwaite method, such as that done by Feddema (2005) seem more

164   appropriate and provide a much more restrictive distribution of med-regions than that of

165   Köppen's or Thornthwaite's classifications.

166

167   Clearly, establishment of the temperature and precipitation limits of the med-

168   climate is not an easy task and some authors also use a vegetation-based classification.

169   For example, oftentimes authors refer to med-regions as areas where the climate favors

170   a dominance of broad-leaved evergreen, sclerophylous shrubs. However, this

171   vegetation-based classification results in some misclassified areas because broad-leaved

172   evergreen sclerophylls are also common in non-med regions that receive maximum

173   precipitation in summer, such as in Arizona, USA, or northern Pakistan (Blumler,

174   2005).

175

176   In the different chapters of this review series, we have considered the

177   classification of Köppen and further simplifications to delineate med-climate areas.

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179

The abiotic characteristics of the med-regions of the world

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Below, we present a general overview of med-regions and refer to other chapters of this

Special Issue for additional information and more detailed explanations. Additional

information is presented in specific articles in the special issue and we refer to these

below.

186

Mediterranean Basin

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The med-region of this area consists of lands located around the Mediterranean

Sea, excluding the most arid areas of Libya and Egypt but including most of the

Moroccan and Portuguese Atlantic coast. It covers an area of about 1,100,000 km^2 and

is located at 31-45ºN (Grove & Rackham, 2001). The underlying geology is mainly

composed of limestone with some sandstone, metamorphosed granites, and sedimentary

deposits (Di Castri, 1981). The landscape is very heterogeneous and includes some high

mountain areas, such as the Mediterranean Alps, the Betic Cordillera, and the Taurus,

Atlas, and Kabylia Mountains. Lower hills and plains are very common on coastal areas

and some tablelands are present in the interior regions (Fig. 2). The terrestrial

vegetation is mainly dominated by evergreen trees and shrubs (usually referred to as

"maquia" or "garrigue"), savannas, or dry steppe in the driest areas of the region. The

most mountainous and wet regions have also several deciduous species (Grove &

Rackham, 2001). For a more detailed discussion of the med-region surrounding the

Med-Basin, see Tierno de Figueroa et al. (2013).

203

204   California

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206   The med-region of the California extends to almost all coastal and inland

207   California from southern Oregon and north of Mexico. It covers an area of about

208   250,000 km^2 and is located at 28-44ºN (Grove & Rackham, 2001). The geology is

209   mainly composed of metamorphosed granites and sedimentary deposits, with some

210   small limestone areas (Grove & Rackham, 2001). The landscape includes coastal

211   mountains, the western side of the high mountains of Sierra Nevada and a central plain

212   (the Central Valley) that separates both mountain ranges (Fig. 2). Other high mountain

213   ranges, such as the Klamath and Cascade mountains, are also included in the med-

214   region area of California. The terrestrial vegetation is mainly dominated by evergreen

215   trees and shrubs called "chaparral" and patches of redwood (*Sequoia sempervirens*)

216   groves in northern coastal California (Grove & Rackham, 2001). The most mountainous

217   and wet regions also have several deciduous species of plants. For a more detailed

218   discussion of the med-region of California, see Ball et al. (2013).

219

220   Chile

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222   The med-region of Chile is located in the central part of the country, between

223   regions IV and VIII of the country's 15 administrative regions. It covers an area of

224   about 70,000 km^2 and is located at 29-40ºS (Grove & Rackham, 2001). The geology is

225   mainly composed by metamorphosed granites and sediments, together with igneous

226   batholith (Thrower & Bradbury, 1973). The landscape includes coastal ranges, a central

227   valley, and the west side of the Andes Cordillera (Fig. 2). The terrestrial vegetation is

228   constituted by evergreen trees and shrubs called "matorral" and woodlands with the

229   deciduous *Nothofagus* sp. and the evergreen *Drimys winteri* (Hajek, 1991). For a more

230   detailed discussion of the med-region of Chile, see Figueroa et al. (2013).

231

232   South Africa

233

234   The med-region of South Africa is located in the Western Cape area. It occupies

235   an area of about 40,000 km^2 and is located at 32-35ºS (Grove & Rackham, 2001). The

236   geology mainly consists of volcanic and sedimentary rocks (sandstone and shale),

237   which results in very acidic soils with very low nutrient concentrations (Thrower &

238   Bradbury, 1973; Hoffman, 1999). The landscape consists of plains, and coastal and

239   inland mountain ranges (e.g., Table Mountain and Franschoek, Drakenstein Mountains)

240   (Fig. 2). The dominant vegetation consists of different types of assemblages of

241   evergreen trees and shrubs called "fynbos" and "veld". The fynbos is divided into the

242   mountain and the coastal fynbos and includes evergreen shrubs and trees with many

243   endemic species. The veld is divided into the renosterveld and the strandveld, and

244   includes smaller evergreen shrubs located in the plain areas (Day et al., 1979). Besides

245   the fynbos and the veld, "succulent karoo" (a biome with many succulent endemic

246   plants) is found in the driest north-western areas whereas afromontane forests are relicts

247   in some coastal areas. For a more detailed discussion of the med-region of South Africa,

248   see de Moor & Day (2013).

249

250   South and southwestern Australia

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252   The med-region of Australia can be divided into a southwestern and a southern

253   area, which are separated by 1000 km. It covers an area of about 350,000 km^2 and is

254   located at 28-37ºS (Grove & Rackham, 2001). The geology is mainly sandstone,

255   granite, quartzite, and sedimentary deposits (Thrower & Bradbury, 1973). In the

256   southwest, the landscape has a very low relief with coastal plains and a large inland

257   plateau (the Darling Plateau), whereas in the south consists of plains and mountain

258   ranges (the Flinders Ranges) (Conacher & Conacher, 1988) (Fig. 2). The terrestrial

259   vegetation of the coastal areas is dominated by evergreen trees and shrubs called

260   "heath" and "mallee", whereas in the most inland areas the Jarrah and the Marri forests

261   of *Eucalyptus* dominate (Dallman, 1998). For a more detailed discussion of the med-

262   region of Australia, see Davies et al. (2013).

263

264

265   **Biological characteristics of the flora and fauna of med-regions**

266

267   The med-climate originated during the Pliocene to early Pleistocene (i.e, ~3.2 to ~2.3

268   mya). Therefore, med-regions have a very young climate-type geologically, and are of a

269   far more recent origin than some of the faunal and floral biodiversity that they contain

270   (Raven, 1973; Suc, 1984). It was previously assumed that the onset of the med-climate,

271   and the similar Holocene climate history of all med-regions of the world (Roberts et al.,

272   2001), resulted in similar selective forces that produced many of the common biological

273   characteristics of the mediterranean fauna and flora we observe today (Mooney, 1982).

274   However, recent studies on terrestrial plants have revealed that some convergent traits

275   of med-regions, such as the evergreen-sclerophyllous vegetation, belong to pre-

276   mediterranean lineages (Verdú et al., 2003). These findings suggest that ecological

277 convergences among med-regions have probably been overestimated and that trait

278 similarities may also be the result of historical and phylogenetical constraints.

279

280   Faunal and floral similarities among the med-regions of the world have long

281 been recognized. Early explorers and naturalists arriving into the Cape region of Africa,

282 central Chile, coastal and central California, and Western Australia in the mid-1700s

283 noted a strong resemblance between plants of these regions with those of the Med-

284 Basin (Di Castri, 1981). However, despite these apparent biological similarities, the

285 biogeographical concept of a mediterranean-type biome was not established until a

286 century after by Grisebach (1872), Drude (1890), and Schimper (1898). Today, most

287 authors agree that the duration of the summer dry-period and the persistence of typical

288 low but not freezing winter-temperatures seem to be the ecological factors that likely

289 result in this biological similarity among med-regions (Aschmann, 1973a; Miller,

290 1983). In addition, the high stress from seasonal differences and the water deficit

291 during the dry season implies that organisms must possess specific adaptations to cope

292 with these conditions. Consequently, most of the affinities observed among these med-

293 regions are related to physiological, morphological, or behavioral adaptations to avoid

294 the severity of dry-season conditions (Table 1). For plants and animals living in flowing

295 water systems, the effect of flooding is an additional selective stress (Hershkovitz &

296 Gasith, 2013).

297

298   Because of the stress of the dry-season conditions, resilience and resistance are

299 common attributes found among the med-region biota (Grubb & Hopkins, 1986;

300 Hershkovitz & Gasith, 2013), with resilience being found more frequently than

301 resistance (Fox & Fox, 1986). Functional similarities (i.e., adaptive biological traits)

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302   among med-regions have been widely recognized for a large variety of individual

303   species and biological traits, as have the dynamics of recovery following disturbance

304   (i.e., a measure of the resilience of these ecosystems, Carmel & Flather, 2004). This

305   overall functional convergence of individual species, which is not as clear at

306   community level (Blondel et al., 1984), suggests that ecological and evolutionary

307   patterns and processes are deterministic, and are influenced by large-scale factors (e.g.,

308   the med-climate characteristics) rather than being dependent on historical contingencies

309   (Pianka, 1975; Melville et al., 2006). Of course, small differences in biological traits

310   between med-regions of the world exist because of local factors (Shmida, 1981).

311

312   Structural comparisons using floral and faunal communities, however, are more

313   difficult because the historical and ecological contingencies of each med-region. For

314   example, studies focused on plants (Cody & Mooney, 1978; Shmida, 1981; Coleman et

315   al., 2003), lizards (Sage, 1973; Fuentes, 1976), birds (Cody, 1973; Herrera, 1995),

316   terrestrial arthropods (Di Castri, 1973; Sage, 1973; Vitali-Di Castri, 1973; Majer, 1988;

317   Stamou, 1998), and aquatic invertebrates (Banarescu, 1990; Bonada et al., 2008) have

318   shown that taxa shared between med-regions either reflect patterns in place before the

319   continents' breakup (i.e., much earlier than the origin of the climate type), from later

320   land-connections between regions, or the result of long-distance dispersion. A clear

321   example of the pre-continental breakup condition is the distribution of the ancient plant

322   families Restionaceae and Proteaceae, which are almost exclusively found in South

323   African and Australian med-regions (Deacon, 1983). In terms of later land-connections,

324   the exchange of flora and fauna between Asia and North America through the formation

325   of the Bering Land Bridge during glaciations is a clear example of shared taxa (Cook et

326   al., 2005). Finally, long-term dispersal is evident in some mayfly families that

327   originated in Africa but are now found in the Palearctic and Oriental regions, likely

328   reflecting past long-distance dispersion among continents (Edmunds, 1972).

329

330   In general, all med-regions are considered to be hotspots of biodiversity and

331   have high rates of endemism (Myers et al., 2000; Smith & Darwall, 2006; Bonada et al.,

332   2007a). The main reasons proposed for this high biodiversity are related to: (1) the high

333   levels of landscape heterogeneity found in all med-regions compared to other biomes,

334   and the consequent ecological mosaics that together comprise individual med-regions

335   (Fig. 2) (Koniak & Noy-Meir, 2009); (2) the pronounced and predictable seasonality of

336   the med-climate that results in a significant seasonal variability of biological

337   communities (Bonada et al., 2007a); (3) the position of med-regions between two

338   contrasting climates, that of the temperate climate and of the desert or xeric climates

339   (Dallman, 1998); and (4) the Pleistocene glaciations in the northern hemisphere that

340   resulted in many components of the biota using med-regions as refuge areas (Hewitt,

341   2004).

342

343   Although numerous national, regional, and international plans are being

344   considered or actually initiated to preserve this high biodiversity of med-regions, all

345   areas are currently at risk from a variety of factors, including habitat fragmentation,

346   invasive species, pollution, and global change. For example, one of the most human-

347   populated med-regions, the Med-Basin, hosts >25,000 plant species (>50% of them

348   endemic) and is considered to be the fifth most vulnerable hotspot of the 25 existing

349   areas worldwide (Cuttelod et al., 2008; Malcolm et al., 2006). Besides the enormous

350   biodiversity of med-regions, conservation decisions are usually not easy to implement,

351   specially in regions where complex biogeographical issues interfere with sociological

352   and political ones, such as in the Med-Basin (Vogiatzakis et al., 2006).

353

354

355   **Rivers in med-regions**

356

357   *In my country, the rain does not know how to rain* – Raimon, Valencian singer-

358   songwriter

359

360   Abiotic characteristics

361

362   Med-rivers have flow regimes that reflect the precipitation patterns of the med-

363   climate, and therefore result in unique freshwater ecosystems from a hydrological and,

364   consequently, biological point of view (Gasith & Resh, 1999). Because river flow is

365   mainly governed by climate and patterns of precipitation, med-rivers are characterized

366   by different levels of hydrological connectivity between seasons, with an expansion

367   phase in the wet period (i.e., autumn-winter) and a contraction phase in the dry period

368   (i.e., spring-summer) (Bernal et al., 2013). During the wet period, precipitation restores

369   longitudinal, lateral- and vertical-flow connectivity; disconnected pools disappear, and

370   the river functions again as a sequence of pools connected to riffles. In small and steep

371   basins, this flow expansion occurs with a very short time lag because precipitation

372   usually falls as intense storms that often lead to intense flash-floods from late-summer

373   to autumn (Camarasa-Belmonte & Segura-Beltrán, 2001; Llasat et al., 2010). During

374   the dry period, the lack of precipitation and the high evapotranspiration rate of med-

375   rivers result in a steadily reduction of the longitudinal-, lateral-, and vertical-flow

376   connectivity. This reduction process can be very extreme in certain circumstances

377 (Bonada et al., 2007b) and lead to a sequence of disconnected pools that may ultimately

378 lack any surface water, leaving dry riverbeds. Streams that are large enough can

379 maintain perennial flows in summer, and even some small streams can maintain flow by

380 ground water (Vidal-Abarca, 1990; Bonada et al., 2007b). Therefore, by our definition,

381 med-rivers are those with sequential seasonal flooding and drying periods, with

382 increasing loss of habitat connectivity over an annual cycle that can result in temporary

383 habitats especially during severe droughts.

384

385   Temporary rivers are not exclusive to med-regions; in fact, temporary rivers are

386 very abundant in all climate regions in the world. For example, 59% of the total river

387 length in United States and 39% in France is temporary (Nadeau & Rains, 2007;

388 Snelder et al., 2013). However, when compared to temporary rivers in med-region,

389 those in other climate regions are considered to be more impredictible (i.e., only in

390 extremely dry summers in most humit climates) or to last for longer periods (e.g., in

391 desert, xeric, or polar climates) (Williams, 2006).

392

393   Although the timing of drying and flooding is very predictable in med-rivers,

394 the intensity of these events is not. Some years have longer dry periods than others, or

395 have a higher frequency of floods that reflect another characteristic of med-rivers: their

396 high interannual variability (Resh et al., 2013). This is particularly important in med-

397 regions where El Niño and La Niña periods govern stream flows, such as in California

398 or central Chile (Dettinger et al., 2000).

399

400   Med-rivers are also highly variable spatially, and consequently usually present a

401 mosaic of flow conditions, even within a small section of stream. Thus, Gallart et al.

402   (2012) proposed a classification of temporary rivers depending on the degree of flow

403   connectivity. These authors subdivided temporary rivers in six different *aquatic states*,

404   depending on the degree of longitudinal and vertical connectivity. The extremes of

405   these states range from edaphic (without surface and subsurface water and dry

406   hyporheic zone) to hyperrheic (the state during high flood conditions). These different

407   states can occur simultaneously in the same river depending on the local conditions.

408   Thus, reaches with riffles over a sand and gravel substrate have a higher probability to

409   have an hyperrheic state than reaches with dominating pools over bedrock, where water

410   will be retained for a longer time (Bonada et al., 2007b). Therefore, hydrological

411   regimes in med-rivers are strongly determined by three dimensions: seasonal,

412   interannual, and spatial.

413

414   As with designations of med-climate areas, the definition of med-rivers is thus

415   much more simple than their delineation. While our definition can be applied generally

416   to small- and intermediate-sized rivers, large rivers often cross non-mediterranean

417   climate areas or are large enough to display less seasonal variability in their discharge

418   patterns. For example, the source of the Ebro River basin is located in a temperate

419   climate region. However, further downstream it drains a med-climate region before it

420   reaches the Mediterranean Sea. Thus, although the whole river does not fit into our

421   specific definition of a med-river it is usually considered to be one from it's overall

422   characteristics (Cooper et al., 2013).

423

424   Med-rivers are not considered as a separate entity among the freshwater

425   ecoregions proposed by the WWF (http://www.feow.org), which identify groups of

426   freshwater systems having distinct freshwater species or communities. Thus, several of

427 their ecoregions designations include med- and non-med rivers, such as the "Cantabric

428 coast-Languedoc" (WWF ecoregion number 403), which includes both a Spanish non-

429 med region and a French med-region. As with the climatic distinctions described above,

430 this lack of a single med-river entity is a problem of scale in that the WWF ecoregions

431 are delineated at a mesoscale. Thus, the geographical limits of med-rivers are difficult

432 to establish, especially if floristic and faunistic criteria are considered over hydrologic

433 characteristics.

434

435 In all chapters of this special issue, authors refer to studies performed in med-

436 rivers from different regions of the world. Below, we present a general overview of

437 med-rivers characteristics of each particular med-region with notes on the abiotic

438 features, such as hydrology, physico-chemistry features, predominant river typologies,

439 and instream-habitat characteristics. For some med-regions, the lack of basic

440 information on the rivers and/or the large variability on some of these features prevent

441 generalizations, and thus are not presented.

442

443 Mediterranean Basin

444

445 Med-rivers of the Med-Basin are characterized by two annual peaks of flow,

446 which occur in spring and autumn (Guidicelli et al., 1985). River beds have a wide

447 variety of substrates, and bedrock is quite common in some areas, which result in the

448 persistence of isolated pools in summer (Bonada et al., 2007b). Both siliceous and

449 calcareous river basins occur, although the latter are much more frequent than the

450 former. Many rivers supply the karstic aquifers present in the northern side of the Med-

451 Basin. Natural saline rivers with high levels of sulphates and chloride are also found in

some areas, such as in the most arid areas of south Spain, North Africa, and Sicily

(Moreno et al., 2001; Gómez et al., 2005). Regions with coastal ranges have short and

steeped-sloped rivers (Robles et al., 2002), whereas inland mountain regions harbor

longer and wider rivers, some of which converge into big delta plains, such as the Po,

the Rhône, and the Ebro.

Temporary rivers are part of the socio-cultural landscape. Thus, these temporary

rivers have received popular names in almost all countries: *oueds* in north Africa,

arroyos or *cañadas* in Spain, *ravins* in France, and *rambles, torrents, rieres* and *rierols*

in the eastern part of the Iberian Peninsula and Balearic Islands (Vidal-Abarca, 1990).

Some of these temporary rivers have been highly impacted by human activities. A

popular example is the "Rambla de Barcelona", a concrete covered street popular

among the local population and tourists that was a hydrologically active stream until

1477, when water was diverted outside of the medieval wall and then completely

channelized through underwater pipes in 1900 (Casassas-Simó & Riba-Arderiu, 1992)!

California

Med-rivers in California are mainly characterized by a single annual flow peak

in winter, although those with snowmelt influence (e.g., those draining Sierra Nevada

mountains) may have a second flow peak in spring (Erman, 1988; Carter & Resh,

2005). Flow regimes are influenced by the El Niño/Southern Oscillation (ENSO)

phenomenon, with higher flows than normal during El Niño years and lower flows

during La Niña years, especially in the southern areas (Dettinger et al., 2000). River

beds have a wide variety of substrates and bedrock is quite common in some southern

477   California med-rivers (Cooper et al., 1986). Siliceous and calcareous river basins are

478   present, although the calcareous geology is much more frequent and karstic rivers are

479   common in the southern California (Mount, 1995). The state of California, together

480   with Alaska, are those with many of the longer streams and rivers in United States

481   (Barbour, 2003).

482

483   Med-rivers in the coastal area are short and steep-sloped, and drain medium

484   altitude mountains, whereas rivers draining higher altitude inland mountains (e.g., those

485   from Sierra Nevada) are larger, with most converging to the Sacramento-San Joaquin

486   River Delta system (Carter & Resh, 2005; Mount, 1995). This river-delta system is

487   currently considered to be one of the major ecological issues in the US. In California,

488   most water is located in the northern part of the state but most of the population is in the

489   large cities of the southern part (e.g., Los Angeles, San Diego). Furthermore, the

490   Central Valley of California is the US "breadbasket", supplying fruits, vegetables, and

491   other agricultural products to the entire country. Consequently, a massive water

492   diversion system was developed in the later part of the 20th century to supply the human

493   and agricultural needs of the central and southern parts of the state. The presence of

494   endangered fish species in the northern rivers and the Delta, the declining quality of

495   water available to Southern California, and the risk of levee failure from earthquakes

496   (and constant disruption of water transfers) have underscored the urgency of dealing

497   with these problems in a timely fashion.

498

499   Chile

500

501   Med-rivers in Chile are very similar to those found in California because the

502   landscape configuration and geology of these two regions are similar. Thus, most river

503   basins are orientated longitudinally from north to south, with headwaters in the Andes

504   foothills and midstream reaches draining the Central Valley and the coastal ranges

505   (Figueroa et al., 2013). In addition, several smaller and steep river basins are located in

506   the coastal ranges. The annual flow peak occurs during the winter months and med-

507   rivers are also influenced by the El Niño and La Niña episodes (Dettinger et al., 2000).

508   River beds are also diverse in substrate and generally are either short and steep coastal

509   rivers (called *quebradas*) or longer and wider inland rivers draining from the Andes

510   (Thrower & Bradbury, 1973; Campos, 1985).

511

512   The med-region of Chile is the most fertile of the country and has 2/3 of the

513   whole population in the country. Landscapes have been largely transformed to different

514   crops that, together with livestock farming, forest plantations, industrial activities and

515   the high population densities have significantly modifying the natural flows and the

516   physico-chemical parameters of river ecosystems (Figueroa et al., 2013). In addition, a

517   large percentatge of the hydroelectric power generation of the country comess from the

518   med-region. For example, the larger river basin in the area, the Biobío, which drains an

519   area of 24,260 km^2 produces more than 50% of all the hydroelectric power consumed in

520   the whole country (Goodwin et al., 2006). Water treatment and sustainable river

521   management is still at the very early stages and the protection of freshwater species is

522   limited (Figueroa et al., 2013; Grantham et al., 2013).

523

524   South Africa

525

526   Med-rivers of the Cape region have some unique characteristics and, similar to

527   some other med-regions, there is a single annual flow peak in winter (e.g., see Fügel &

528   Kienzle, 1989). Med-rivers draining from the Table Mountain are short and steeped,

529   whereas others from inland mountains drain larger territories. Given the particular

530   geology and soils characteristics of the Cape region, dissolved solids, nutrients, and

531   conductivity are very low in headwaters but increase in downstream reaches (King et

532   al., 1979; Midgley & Schafer, 1992). Rivers located in areas with fynbos vegetation are

533   of brown color and have very low pH because of the high amount of polyphenolic

534   substances leached from dead vegetation, and the low calcium and magnesium

535   concentrations in soils (de Moor & Day, 2013). In contrast, natural saline rivers are also

536   present in some areas of the Berg and Breede river basins flowing over saline

537   Malmesbury Shales (de Moor & Day, 2013). Most rivers have dense canopies and river

538   beds have a diverse substrate, with large boulder dominating headwater reaches (Brown

539   & Dallas, 1995; de Moor & Day, 2013). Very often, dense masses of Palmiet (*Prionium*

540   *serratum*), an endemic reed of this med-region and of KwaZulu Natal, are present in the

541   river edges.

542

543   Anthropogenic disturbances of south African med-rivers started relatively

544   recently, with the arrival of the Dutch during the 17th century. Rivers draining the

545   Table Mountain were channelized rapidly and landscape modifications have not

546   stopped since then (de Moor & Day, 2013). The dominant and extensive wheat and

547   grape production has considerably modified the physico-chemistry of rivers from the

548   natural conditions, increasing the pH and the amount of nutrients. In addition, the

549   inefficient performance of the Waste-Water Treatment Plants located in urban areas

550   exacerbates the situation (de Moor & Day, 2013). All these disturbances reduce the

551 habitat for native species in this med-region, the smallest in the world but the one

552 harboring the highest level of endemic freshwater species (de Moor & Day, 2013).

553

554 South and southwestern Australia

555

556   Australian med-rivers also present a flow peak during the winter months and

557 have waters with slightly lower pH compared to northern hemisphere med-rivers or

558 Chilean ones (Bunn et al., 1986). Despite the low reliefs present in this med-region,

559 streams and rivers arise from the highest areas (Davies & Stewart, 2013). Thus, rivers

560 that occur in the plain, drain from the Darling Plateau in Southwestern Australia, and

561 slightly steep-sloped rivers in South Australia drain from the Flinger Ranges. In this last

562 med-region, many rivers flow into the Murray-Darling River Basin. This basin was the

563 prime European settlement area in Australia, and developed into the fruit farms,

564 vineyards, and grazing land that was the center of the Australian agricultural economy.

565 It provides the majority of water for irrigation and hydropower for the southeastern

566 portion of the continent.

567

568   Because of the ancient origin of the continent, Australian med-rived beds are

569 mainly composed by highly eroded materials with gravels and sand being the most

570 abundant substrates (Bunn, 1988). Moreover, these rivers have gone dry during

571 recorded periods of Australia's history.

572

573

574 **Biodiversity in med-rivers**

575

576   This special issue includes chapters that analyze freshwater biodiversity of each med-

577   region in detail and thus the specific characteristics of each of these regions are not

578   presented here. Information for California can be found in Ball et al. (2013), for the

579   Med-Basin in Tierno de Figueroa et al. (2013), for Chile in Figueroa et al. (2013), for

580   South Africa in de Moor & Day (2013), and for Australia in Davies et al. (2013).

581   Biodiversity of riparian vegetation is not specifically analyzed in the above-mention

582   chapters but a summary for all med-regions can be found in Stella et al. (2013). All

583   these chapters highlight that med-rivers have an enormous biodiversity with a high level

584   of endemism. However, the current taxonomic knowledge is not homogeneous among

585   groups and new species are still being described. Vertebrates, riparian plants, and

586   macrophytes typically have been studied in greater detail than invertebrates and algae in

587   all med-regions.

588

589   Adaptations for floods and droughts

590

591   The stress experienced by the fauna of med-rivers, especially that occurring in

592   small streams, is among the most severe experienced by any lotic fauna. Sequential

593   flooding and drying, anthropogenic impacts from high human population density, and

594   the consequent competition between water needs for agriculture and domestic use, and

595   the environment, make these systems the most diversely stressed of any riverine habitat

596   in any climate type worldwide.

597

598   Because med-rivers throughout the world are subject to sequential and often

599   severe periods of flooding and drying, the fauna present must adapt to unique stresses

600   that require totally different adaptive mechanisms. For example, response to flooding

601 may require strong morphological attachment features. However, these would not be

602 useful in drying conditions where desiccation mechanism would be favored. Because

603 neither morphological nor behavioral adaptations are rarely if ever suitable for both

604 types of stresses, tradeoffs and multiple types of adaptations are required (Hershkovitz

605 & Gasith, 2013).

606

607 　　　　Adaptations of freshwater organisms to floods and droughts have been largely

608 reported in the literature, and some specific examples have been presented for med-

609 rivers (Table 1; Bonada et al., 2007a; Bonada et al., 2007b; Romaní et al., 2013).

610 Survival during high floods and severe droughts is always a challenge for freshwater

611 organisms. There are multiple strategies that organisms can adopt to cope with these

612 disturbances and the ones selected for may be a function of the timing, predictability,

613 and magnitude of these disturbances (Lytle & Poff, 2004). Lytle and Poff (2004)

614 suggested that freshwater organisms can adapt to floods and droughts through particular

615 life history traits, behaviors, or morphological features. Although not specifically

616 referring to med-rivers, they report that, in seasonal rivers, life-history traits

617 synchronized with floods and droughts have been identified for fish, aquatic insects,

618 and riparian plants. In contrast, in non-seasonal river types where flow disturbances are

619 not predictable, bet-hedging strategies or specific behaviors to immediately cope with

620 the disturbance (e.g., moving outside the river to find a temporary terrestrial refuge until

621 the flood has receded) could have evolved. Thus the evolution of morphological

622 features could be more related to the frequency and magnitude of the flow disturbances

623 than to their predictability (Lytle & Poff, 2004).

624

625   In med-rivers, life history, behavioral, or morphological adaptations to resist

626   floods and droughts through endurance or avoidance have been observed for a wide

627   variety of organisms (Hershkovitz & Gasith, 2013; Romaní et al., 2013; Stella et al.,

628   2013). All these resistance strategies imply the organisms need to find refuges to shelter

629   them during the disturbance (Robson et al., 2013). Endurance strategies refer to those

630   that allow organisms to withstand flow disturbance. For example, some invertebrates

631   find shelter in the hyporheic zone during a flood or survive as resistant forms in the dry

632   river beds in summer (Franken et al., 2006; López-Rodríguez et al., 2009; Robson et al.,

633   2011). Riparian vegetation in med-rives can have a high flexibility and low shoot-to-

634   root biomass, which avoid being pull up by floods and provides access to deeper water

635   tables in summer (Stella et al., 2013). Alternatively, avoidance strategies allow

636   organisms to escape from flow disturbance by actively or passively moving to a refuge

637   (Hershkovitz & Gasith, 2013).

638

639   Avoidance strategies against drought are much more common in med-rivers

640   than endurance ones, probably because med-river species are relicts from cooler times

641   rather than the products of evolution under dryer climate conditions (Hershkovitz &

642   Gasith, 2013; Robson et al., 2013). For example, riparian vegetation in med-rivers

643   shows a wide variety of strategies to avoid summer drought, such as higher root

644   biomass, small leaf sizes, or more frequent branch abscission, among others (Stella et

645   al., 2013). Similarly, pool-dwelling aquatic insects have winged adults that can easily

646   disperse to other pools as they dry out (Bonada et al., 2007a) or fish can actively

647   migrate to perennial reaches in search of refuges as soon as the river begins to fragment

648   (Aparicio & Sostoa, 1999; Magoulick & Kobza, 2003).

649

650   Besides the strategies that allow resistance to floods and droughts in med-rivers,

651   resilience is also an important feature in med-rivers. Resilience (the ability to recover

652   from a disturbance) and resistance (the ability to not succumb to a disturbance) are

653   strongly related and usually confused, as many strategies that allow resistance facilitate

654   further resilience (Bonada et al., 2007a; Hershkovitz & Gasith, 2013). For example, the

655   presence of life history stages or adaptations that are resistant to droughts enable rapid

656   re-establishment of biota with the first autumn rains.

657

658   Community changes

659

660   The effect of the seasonal hydrological variability on biological communities in

661   med-rivers has been well described (Gasith & Resh, 1999; Hershkovitz & Gasith, 2013;

662   Resh et al., 2013; Robson et al., 2013). These studies emphasize the coupling of

663   biological patterns and processes with the predictable timing of floods and droughts.

664   However, many of these biological and ecosystem responses are not only the result of

665   the predictable hydrological periods but also the result of changes in the number and

666   type of available macrohabitats over the course of a year. Thus, the typical riffle-pool

667   sequences that characterize many small med-rivers during the wet period become

668   fragmented, resulting in a mosaic of pools during the dry period before, and when, the

669   river dries completely. Therefore, there is a seasonal community shift, with riffle-like

670   taxa dominating the wet period and pool-like taxa domination the dry period (Bêche et

671   al., 2006; Bonada et al., 2007b). Although several core taxa can persist throughout the

672   year (Rieradevall et al., 1999), macroinvertebrate communities in the wet period are

673   characterized by an assemblage of Ephemeroptera, Plecoptera, and Trichoptera that

674   shift to Odonata, Coleoptera, and Heteroptera during the dry period (Bonada et al.,

2007b). Richness and abundance also change seasonally. These latter orders tend to increase just after the river is fragmented into isolated pools but then decreased over time because of changes in the environmental conditions of the pools (Acuña et al., 2005). Local pool conditions and the time since the last connection of pools to riffles might serve as determinates of the community composition, richness, and abundance in pools (Bonada et al., 2006b).

Fish may show changes in community characteristics as well. Bêche et al. (2009), Marchetti & Moyle (2000), Bernardo et al. (2003), and others have generally found a pattern where fish abundance was lowest during drought years and highest during wet years. Likewise, fish communities may show marked seasonality in their abundance (Pires et al., 2000). In California, this may be attributed to differences in the timing of reproduction of native compared to non-native fishes (Moyle et al., 2003). In Portugal, Magalhaes et al. (2003) reported that the magnitude of wet-season floods also may affect resulting abundance.

Biological communities in med-rivers undergo seasonal differences in their metacommunity dynamics. During the wet period, communities form metacommunities with a hierarchical network, with downstream reaches being connected to headwaters through drift and upstream faunal movements (Brown & Swan, 2010). With habitat fragmentation during the dry period in med-rivers, however, the hierarchical structure of river ecosystems is broken and communities form metacommunities in pools connected randomly to other pools. During the dry-season, however, isolated pools act as islands. The composite metacommunity then is constrained by local environmental heterogeneity and connected by aerial dispersal (e.g., for insects). In contrast, although

700 the few metacommunities studies done in rivers suggest that hierarchical networks are

701 governed by species sorting in headwaters and mass effects downstream (Brown &

702 Swan, 2010), there is no information about controls during either the dry period or the

703 transition between both periods.

704

705   Seasonal changes in community traits are also expected in med-rivers because

706 species present have different strategies to cope with a particular stress or disturbance

707 that temporally can vary in its influence. As expected in med-rivers, some community

708 traits enable them to cope with or recover from floods and droughts (Bêche et al., 2006;

709 Bêche & Resh, 2007a; Bêche & Resh, 2007b). However, research suggests that

710 communities in med-rivers are characterized by a dominance of strategies that allows

711 them to cope better with droughts at the annual scale, whereas rivers in temperate

712 regions have community traits typically enabling them to cope better with perennial

713 conditions (Bonada et al., 2007a).

714

715   Other secondary adaptations can be related to the resources available along the

716 year. Thus, filter-feeders can be more important during the wet period, when floods

717 mobilize inorganic and organic materials and move them downstream. Shredders follow

718 the deposition of course organic material in riverbeds when floods recede. In contrast,

719 during the dry period, pool conditions favor the presence of predators (Hershkovitz &

720 Gasith, 2013), and the high temperature and insolation lead to a proliferation of algae

721 that are consumed by scrapers (Power et al., 2013). Species interactions in med-rivers

722 are thus dynamic and coupled to the hydrological characteristics. Pulsed floods reset

723 food webs by bringing communities to initial successional states, but species

724 interactions became more complex as med-rivers move from winter to spring (Power et

725   al., 2013). Species interactions dominate over abiotic controls during the contraction

726   phase and spatially are highly variable during the isolated-pool phase. Finally, in dry

727   summer beds, aquatic food webs are replaced by terrestrial food webs until the first

728   autumn rains connect river reaches and thus provide terrestrial subsidies to downstream

729   permanent reaches that are used by fish and some aquatic invertebrates (Power et al.,

730   2013).

731

732   In addition to these seasonal changes in community composition, long-term

733   changes of biological communities of med-rivers are also significant (Resh et al., 2013).

734   As with the seasonal community changes, dry years in med-rivers have communities

735   dominated by pool-like taxa and wet years by riffle-like taxa (Pace et al., 2013).

736   Community changes during the dry period are also more accentuated during dry, low-

737   rainfall years than during wet years (Acuña et al., 2005). Bêche et al. (2009), using 20-

738   years of data from two California med-streams, found that the reduction in flow during

739   a prolonged, multi-year drought resulted in increased abundance of in-stream and

740   riparian vegetation, altering the stream habitat drastically. These physical changes

741   resulted in a directional change in community composition and no clear recovery to pre-

742   drought conditions occurred. Likewise, drought can shift biological communities with

743   different species-trait composition (Lawrence et al., 2010). These continuing

744   disturbances may result in irreversible regime shifts and a change from one stable

745   community state to another (Bêche et al., 2009).

746

747

748   **Ecosystem processes in med-rivers**

749

750   Ecosystem function in med-rivers is highly modulated by the seasonality of flow. A

751   remarkable phenomenon in med-rivers is the asynchrony between inputs of

752   allocthonous resources arriving into rivers and the biological assimilation ability. This

753   has been called the biogeochemical *heartbeat* (Bernal et al., 2013). At the beginning of

754   the wet period, rainfall drains into river basins, increasing the longitudinal and lateral

755   connectivity of rivers. This brings nutrients and allocthonous organic matter into rivers.

756   The increase of stream flow and velocity reduce the contact between the water column

757   and the benthos, where biological activity is mainly accomplished. Under these

758   conditions, and independent of the level of resources available for the organisms

759   present, most nutrients and organic matter is transported downstream via the high flows

760   rather than being locally assimilated. Nutrient cycling is then characterized by a high

761   nutrient export and long nutrient uptake lengths (Bernal et al., 2013).

762

763   Flash floods may have a major effect on nutrient cycling. These high-energy

764   floods not only export nutrients downstream faster but also greatly disturb the

765   biological communities responsible to processing them (Bernal et al., 2002). In contrast,

766   during the dry period following regular or flash floods, stream flow and velocity is

767   reduced, increasing the contact with the benthos and facilitating nutrient retention. In

768   addition, the increase in water temperature and light conditions during the dry period

769   increases autochthonous organic matter and accelerates microbial activity, promoting

770   nutrient uptake (Romaní et al., 2013). Therefore, allocthonous and autochthonous

771   organic matter inputs shift from the wet to the dry period in med-rivers, resulting in the

772   differentiation of two periods of biofilm functioning (Romaní et al., 2013), and

773   Dissolved Organic Matter (DOM) quality (Catalán et al., 2013), among other functional

774   properties. However, in addition to autochthonous inputs being predominate during the

775   dry period, allocthonous inputs can also increase in med-rivers as a consequence of

776   water stress (von Schiller et al., 2011; Romaní et al., 2013).

777

778   Water stress during the dry period also diminishes the uptake and denitrification

779   occurring in riparian forests, thereby reducing the ability of these forests to control

780   nutrient inputs into rivers (Bernal et al., 2013). These situations are even more dramatic

781   when rivers are fragmented into isolated pools during the dry period, and in these cases

782   nutrient dynamics might depend on the local characteristics of each pool (von Schiller

783   et al., 2011; Bernal et al., 2013). Local pool conditions can also modify processing rates

784   of organic matter, and ecosystem metabolism may even change from aerobic to

785   anaerobic pathways if oxygen is limited (Romaní et al., 2013). Finally, nutrient

786   dynamics present when rivers are completely dry should not be ignored in future

787   studies, because the few existing studies have shown that riverbeds are still

788   biogeochemically active, especially in fungal communities (Zoppini & Marxen, 2011),

789   and the colonizing terrestrial plants could also promote nutrient mobilization. Wetted

790   microhabitats (e.g., sediments) in dried riverbeds can also be refuges for heterotrophic

791   biofilm communities that can rapidly respond to the organic matter inputs during the

792   rewetting period (Romaní et al., 2013). Algae communities can also recover quickly,

793   producing peaks of primary production just after the rewetting (Romaní & Sabater,

794   1997).

795

796

797   **Disturbance in med-rivers**

798

799   Med-rivers are subjected to many types of disturbances, both natural and human-

800   induced. Seasonal floods and droughts themselves can be considered as natural

801   disturbances, although in many cases their effects have been exacerbated by human

802   activities, such as water diversions and inputs (Gasith & Resh, 1999). Other natural

803   disturbances include bush fires, many of these are also the result of human activities

804   (Verkaik et al., 2013).

805

806   Organisms in med-rivers seem to have evolved strategies to resist or recover

807   from these natural disturbances (Hershkovitz & Gasith, 2013). However, compared to

808   terrestrial vegetation in med-regions, there are no apparent adaptive strategies to fire in

809   med-river in-stream and riparian communities beyond a higher resilience ability (Stella

810   et al., 2013; Verkaik et al., 2013). Like flooding and drying, fire is another predictable

811   disturbance in med-regions, and mainly occurs in summer when med-rivers and riparian

812   vegetation are dry (Verkaik et al., 2013). Likely, evolutionary consequences of drought

813   disturbance have been much more important in terms of selective pressure to drying

814   than to those traits acquired from fire.

815

816   Anthropogenic disturbances are numerous in med-rivers. Med-regions

817   throughout the world have been affected for centuries, and in some cases millennia, to

818   human activities. The type and extent of human impact differ among the med-regions of

819   the world because of the different times of human colonization and densities of

820   habitation (Aschmann, 1973b). The Med-Basin is by far the region that has received the

821   longest human impact. Neolithic settlements were already present in the eastern regions

822   of the Basin 10,000 years ago. Moreover, for example, the first water diversions for

823   irrigation and human consumption, and non-native fish introductions, had already

824   started at the beginning of Roman times (Copp et al., 2005; Cabrera & Arregui, 2010).

825   Since then, landscape modifications, with their consequent effects on river ecosystems,

826   have been continuous in the Med-Basin. The other med-regions received human

827   impacts later, and these increased dramatically after the arrival and settlement of

828   Europeans between the fifteen and eighteen centuries (Conacher & Sala, 1998).

829

830   Today, all med-regions suffer similar types of disturbances derived from

831   agriculture and livestock, industrial practices, and human population growth and other

832   accompanying activities. Changes in land use associated with human activities in med-

833   rivers (and worldwide) have resulted in declines in discharge, changes in fluvial

834   geomorphology, and increases in temperature and amount of light (Cooper et al., 2013).

835   In addition, nutrients loads, pollutants, and salinity have increased, and organic matter

836   dynamics has been affected (Cooper et al., 2013). Land use changes have also increased

837   habitat fragmentation and the associated human population growth have promoted

838   human-induced fires and biological invasions (Merelender & Matella, 2013; Verkaik et

839   al., 2013). All these human impacts have and continue to significantly impair aquatic

840   biota, changing species biodiversity and composition, promoting faunal

841   homogenization, and facilitating risk of species extinction .

842

843   Future climate change scenarios in med-regions predict an exacerbation of

844   drought conditions and an increase of the occurrence of extreme events such as floods,

845   heat waves, and wildfires (IPCC, 2007). Thus, for example, regional predictions for all

846   med-regions indicate that warming will be larger than the global average, annual

847   precipitation will decrease, and temperature will increase (Cayan et al., 2006;

848   Christensen et al., 2007; Giorgi & Lionello, 2008; Giannakopoulos et al., 2009). Even

849   though flashflood events are expected to occur more frequently in med-rivers, annual

850   runoff is expected to decrease, and records since the 1950's agree with these forecasts

851   (Milliman et al., 2008). Consequently, the decrease inriver discharge likely will be more

852   related to temperature increases than to precipitation decreases because of the high

853   potencial evapotranspiration of vegetation in med-regions (Tague et al., 2009).

854   Forecasts of land use changes and increases in water demand will aggravate the present

855   situation by reducing river discharge even further (Merelender & Matella, 2013).

856   Species will face a trade-off between adaptation to new conditions or migration to new

857   habitats, although the particular life-history traits of species in med-rivers might allow

858   them to cope with climate changes up to a certain threshold (Filipe et al., 2013). In any

859   event, med-rivers will experience shifts in community richness and composition,

860   modifications of life-history traits, and, most likely will suffer local and regional

861   extinctions (Filipe et al., 2013).

862

863   Besides the human-related disturbances mentioned above, new forms of

864   disturbances are also appearing in med-regions and other areas of the world. Advances

865   on analytical techniques have enabled the detection of new contaminants in water and

866   sediments, such as xenobiotics or emerging organic pollutants (e.g., pharmaceuticals,

867   personal-care products, hormones) (López-Doval et al., 2013). These contaminants are

868   reported to have a wide variety of effects on organisms that may eventually be found to

869   have lethal or sublethal effects. For example, the presence of hormones in water and

870   sediment samples caused endocrine disruption and intersexuality in freshwater fish in

871   med-rivers (Petrovic et al., 2002; Lavado et al., 2004), and sympatholytics and non-

872   steroidal anti-inflammatory drugs resulted in changes in biomass and growth of the

873   midge larvae *Chironomus riparius* in laboratory experiments (López-Doval et al.,

874   2012). These contaminants also have indirect effects on ecosystem functions. Thus,

875   although nutrients generally increase leaf litter decomposition rates in med-rivers by

876   stimulating microorganism activity (Menéndez et al., 2008), organic pollutants have

877   been shown to have the opposite effect (Moreirinha et al., 2011). The seasonal

878   variability in hydrology of med-rivers makes them more vulnerable to pollution and

879   water extraction during the dry season (Cooper et al., 2013; López-Doval et al., 2013).

880

881   The aquatic fauna is declining more rapidly in med-regions than anywhere else

882   in the world (Moyle & Leidy, 1992). Moreover, the ecological status is med-rivers is

883   very poor in European-wide comparisons of streams (Prat & Munné, 2000). Med-

884   regions also are more prone to be invaded by exotic species because natural disturbance

885   often provides new chances for them to colonize after severe floods or droughts (Davis

886   et al., 2000). Thus, taxonomic and functional similarity has significantly increased

887   among med-regions because of species introductions. This has reduced the important

888   biodiversity feature of med-rivers, which is their high levels of endemicity (Marr et al.,

889   2013). In terms of fish, for example, all med-regions have currently more introduced

890   species than endemic species (Marr et al., 2010).

891

892   To avoid human disturbances, organisms in med-rivers may be able to find and

893   use refuges as they do with natural disturbances (Robson et al., 2013). However, some

894   disturbances may provide less evident refuges than others and many of them can last

895   much longer than the life span of species. For example, available refuges to avoid

896   salinization in a river may be scarcer than refuges to cope with hydrological

897   disturbances. This is because salinization is a landscape-level disturbance whereas

898   hydrological disturbances can occur locally (Robson et al., 2013). Recovery from

899   human disturbances ultimately depends on the tolerance of species to a particular

900   disturbance (i.e., endurance strategies), their ability to find refuges during the

901   disturbance (i.e., avoidance strategies), and the presence of nearby non-disturbed

902   habitats.

903

904

905   **Conservation and management in med-rivers**

906

907   River conservation and management in highly populated regions with high levels of

908   biodiversity is a challenge, and clearly impose a difficult trade-off between

909   environmental and human uses. Seasonal patterns of floods and droughts of med-rivers

910   make this endeavor even more complex because management strategies should

911   disentangle natural- from human-induced flow variation. Loss of habitat connectivity,

912   for example, is part of the natural dynamics of med-rivers and contributes to their high

913   biodiversity (Bonada et al., 2007a; Merelender & Matella, 2013). Habitat connectivity,

914   however, is often disrupted, or made continuous, by human activities such as water

915   abstraction or augmentation, respectively.

916

917   High water demand, together with water scarcity in med-regions, have resulted

918   in numerous water management infrastructures, such as the building of large dams and

919   reservoirs, or from systems enabling water transfers. These constructions have:

920   modified habitat connectivity; changed natural flow regimes, water quality, and

921   geomorphology; and facilitated the establishment of non-native species and created new

922   species interactions (Cooper et al., 2013; Grantham et al., 2013; Kondolf et al., 2013;

923   Merelender & Matella, 2013; Power et al., 2013; Robson et al., 2013; Stella et al.,

924 2013). Alternatively, increasing habitat connectivity during the normal contraction

925 phase in med-rivers also affects native species in med-rivers and may further promote

926 non-native invasions (Merelender & Matella, 2013). Although the loss of natural- and

927 human-induced habitat connectivity can apparently act as similar disturbances,

928 differences in the timing, frequency, and duration of these disturbances may produce

929 different effects. Thus, med-river species that have acquired traits to cope with the

930 highly seasonal and predictable habitat connectivity losses might not be adapted to

931 other disturbance regimes and can be seriously imperiled by them.

932

933   Management strategies should also be coupled with seasonal patterns of flow

934 variation. Current water management approaches in med-regions do not account for

935 these seasonal patterns, in that winter peak flows have been reduced and low summer

936 flows have been increased in several river basins (Grantham et al., 2013). Med-rivers

937 that dry up in summer during dry years but flow during wet years impose an extra

938 constraint on planning water allocations. Moreover, streams having summer low or no-

939 flow conditions require specific reference conditions for biomonitoring programs in

940 med-regions while, at the same time, low flow conditions enhance the effect of

941 pollutants or organic matter on them (Dallas, 2013; López-Doval et al., 2013; Robson et

942 al., 2013). Bioassessment approaches in med-rivers should account for this seasonal

943 pattern, as methods used in one season may be inappropriate to another season (Feio et

944 al., 2006). Similarly, bioassessment metrics should also consider interannual variability,

945 and combination metrics and multivariate models seem to be better because their long-

946 term accuracy (Mazor et al., 2009). Recently, several initiatives to assess the ecological

947 status of temporary rivers in med-rivers have been developed (Prat et al., 2013).

948   However, more efforts are needed in this regard, especially under the dramatic climate-

949   change scenarios that are forecasted.

950

951   Bioassessment methods to assess the ecological status of med-rivers have been

952   developed independently in each med-region and for different organisms types (Dallas,

953   2013; Stella et al., 2013). Because all med-regions face similar threats and constrains,

954   collaborative efforts among stakeholders and policy makers may help to ensure

955   satisfactory management of water resources and to avoid repetition of the mistakes of

956   the past. However, there are big gaps in sustainable water management strategies

957   among and within med-regions, especially between developed and less-developed

958   countries. In Chile, for example, the "Integration Era" of water management

959   (characterized by a more sustainable water use) started recently when compared to

960   those of other med-regions such as California or Spain (Grantham et al., 2013). Basic

961   knowledge of med-river ecology in the less-developed countries is, however, scarce and

962   direct implementation of strategies used in developed countries may not necessarily be

963   appropriate.

964

965   Species conservation planning is another important issue to consider in med-

966   region biodiversity hotspots. Med-regions are considered to have the most rapid loss of

967   freshwater biodiversity (Moyle & Leidy, 1992). The International Union for

968   Conservation of Nature (IUCN) provides lists of species that are vulnerable, near-

969   threatened, threatened, or endangered. Many species of macrophytes, molluscs,

970   crustaceans, Odonata, amphibians, and fish in med-regions have been classified in the

971   above categories (Ball et al., 2013; Tierno de Figueroa et al., 2013). However, other

972   freshwater groups with many endemic species are overlooked (e.g., algae, fungi, most

973 aquatic insect groups), likely because of the taxonomical difficulties to conduct

974 identifications at the species level. In parallel, each med-region also has its own

975 strategies to preserve native biodiversity by creating regional lists of vulnerable species

976 or by protecting habitats. Just as important, species conservation approaches need to

977 conserve refuges and maintain refuge connectivity to prevent biodiversity loss (Robson

978 et al., 2013). Pro-active approaches that conserve habitats are required, especially in

979 med-regions were there are still many taxonomic gaps and many species may pass from

980 being unknown to being lost. Conservation measures usually are the result of reactive

981 rather than pro-active activities, despite this approach having higher economic costs

982 (Drechsler et al., 2011).

983

984   Restoration in med-rivers is a challenge because of the highly dynamic flow

985 regimes of these systems. Oftentimes, traditional restoration projects in med-rivers that

986 have entailed the control of the flow regimes in attempts to make med-rivers more

987 stable and aesthetically pleasing from a societal point of view, have had disastrous

988 results for natural communities (Kondolf et al., 2013). Allowing river channels of med-

989 rivers to behave as highly dynamic ecosystems is probably the most effective

990 restoration strategy to maintain the trade-off between environmental and human water

991 uses (Kondolf et al., 2013). Future restoration strategies should also consider habitat

992 connectivity and the creation of refuges to maintain med-river characteristics

993 (Merelender & Matella, 2013; Robson et al., 2013). In addition, restoration projects

994 should consider the multiple stressors currently impacting med-rivers. However, this is

995 usually not the case, because the least costly to repair stressors and/or those that have

996 the least political resistance often are those that are prioritized (Kondolf et al., 2013). In

997 some cases, restoration of natural river channels is unimaginable because of the high

998   societal and economical values now placed on what were formerly natural river

999   systems. This is the case, for example, of the ephemeral med-river "Rambla de

1000   Barcelona" (see above), that has become a commercial and tourist corridor with an

1001   extraordinary economic value, far greater than when it was an actual stream in the 15th

1002   century!

1003

1004   Finally, the pessimistic climate-change forecasts impose a constraint on future

1005   mitigation and conservation measures. Models on species distribution shifts may

1006   provide useful information on how and where these measures should be implemented.

1007   However, these models are still far from realistic because they usually overpredict

1008   species distributions. The incorporation of elements such as dispersal abilities, biotic

1009   interactions, long-term population or community variability, or complementary data on

1010   environmental requirements of species from laboratory experiments is necessary to

1011   provide more reliable results for management purposes (Filipe et al., 2013). The

1012   problem, in any case, is that climate change will favor species with higher temperature

1013   and pollution tolerance, and enable the establishment of new species introductions. This

1014   novel community composition will lead to homogenization, poorer ecological status,

1015   and, likely, to a redefinition of reference conditions and bioassessment methods that are

1016   appropriate for monitoring changes (Dallas, 2013). Surprisingly, even though scientific

1017   and management communities recognize the critical consequences of climate change,

1018   current policies are not designed to address climate change issues (Filipe et al., 2013;

1019   Johnson et al., 2001).

1020

1021

1022   **Comparisons to temperate climate rivers**

1023

1024   Med-regions have characteristics that fall between, and include aspects of, both

1025   temperate and desert climate regions (Dallman, 1998; Romaní & Sabater, 1997; Bernal

1026   et al., 2013). In particular, they behave more like streams in temperate regions during

1027   the wet period and more like those in desert regions during the dry period. At the same

1028   time, they show unique ecological patterns and responses produced by a well-defined

1029   and predictable seasonality on water availability (Hershkovitz & Gasith, 2013).

1030   Compared to research done in temperate rivers (temp-rivers), there are far fewer studies

1031   in desert climate rivers, and in most studies med-river characteristics have been

1032   compared to temperate ones. Based on general literature and information in this Special

1033   Issue, we present a summary of the main differences between med- and temp-rivers

1034   (Table 2). All the topics included in that table highlight the particular characteristics of

1035   med-rivers and may help to develop parallel, future studies in desert regions to better

1036   elucidate the uniqueness of both med-rivers and temp-rivers.

1037

1038   Med-rivers differ from temp-rivers in several physico-chemical parameters,

1039   such as their hydrologic regime and nutrient dynamics. Organic matter dynamics also

1040   differs between these two climatic regions, especially for variables related to the

1041   contraction phase or the quality of the allochthonous inputs. In terms of their biofilm

1042   communities, many structural and functional parameters also differ between med- and

1043   temp-rivers. Diversity measures are usually higher in med- than in temp-rivers for

1044   several types of organisms, as are seasonal and interannual community changes. Given

1045   that human disturbances affecting river ecosystems are universal, med- and temp-rivers

1046   display fewer differences in this regard. However, the vulnerability of the biota seems

1047   to be greater in med-rivers despite their higher ability to cope with disturbances (Table

1048   2).

1049

1050

1051   **Similarities and differences among med-rivers worldwide**

1052

1053   Based on the description of med-rivers provided above, the few studies comparing med-

1054   river communities of the world (e.g., Bonada et al., 2008; Stella et al., 2013), and the

1055   information in this Special Issue, we prepared a summary that synthesizes the relative

1056   similarity among med-rivers in the world (Fig. 3). This summary is based on general

1057   characteristics among the med-regions and does not consider variation within the

1058   different med-regions.

1059

1060   The pair-wise comparisons of med-rivers in regions worldwide indicate that no

1061   2 med-regions are completely similar for all of the characterisitcs considered (Fig. 3).

1062   For example, the Med-Basin and the South Africa med-regions appear to be the most

1063   different in these characteristics, followed by the southern hemisphere med-regions.

1064   California and Chile are similar but this level is lower than that observed between

1065   California and the Med-Basin. Organic matter inputs and the level of impairment are

1066   similar among med-regions, with the latter indicating that human disturbances have

1067   similar effects worldwide. However, river typology and physico-chemistry show more

1068   differences between paired med-regions, which is likely related to non-climatic related

1069   features, such as regional geology and topography.

1070

1071   For biological communities, studies reveal that there are several taxa shared by

1072   2 or more med-regions as a result of past historical connections and similar current

1073   climatic characteristics among med-regions (Bonada et al., 2008). Unless we consider

1074   invasive species, some of which can be found in all med-regions, these common taxa do

1075   not occur at the species level but rather at the genus or at higher taxonomic levels

1076   (Bonada et al., 2008; Stella et al., 2013). For riparian species, several genera are shared

1077   between med-regions and even between hemispheres, such as *Salix* for the Med-Basin,

1078   California, and Chile (Stella et al., 2013). California and the Med-Basin share more

1079   riparian genera, following by Australia and Chile (Stella et al., 2013). A similar global

1080   pattern is present for macroinvertebrates (Bonada et al., 2008), in that richness and

1081   composition of aquatic organisms in California are closer to the Med-Basin than to

1082   Chile. This pattern is evident despite the higher similarities in landscape

1083   geomorphology, river typology, and physico-chemical characteristics (Fig. 3), and

1084   contradicts what is known for terrestrial vegetation in these regions (Di Castri, 1981; Di

1085   Castri, 1991).

1086

1087   The level of impairment and the effects on natural communities also differ

1088   among med-regions. Non-native fish introductions, for example, are most important in

1089   California but fish taxonomic and functional homogenization is highest in Chile and the

1090   Med-Basin (Marr et al., 2013). Land use patterns are also different among med-regions,

1091   mostly depending on difference in human population density (Cooper et al., 2013).

1092   Climate change forecasts vary among med-regions, and expansions of med-regions are

1093   expected in the Med-Basin and the Chilean med-regions, whereas contractions are

1094   expected in the South Africa and Australia med-regions (Klausmeyer & Shaw, 2009).

1095   Likewise, spatial responses of aquatic biota to climate change also are expected to vary

1096   among med-regions. Thus, for example, poleward migration to higher latitudes, one of

1097   the expected distributional shifts of species, will not be possible for species in the South

1098   African and Australian med-regions because freshwater habitats in the higher southern

1099   latitudes are non-existent (Dallas & Rivers-Moore, 2012).

1100

1101   Bioassessment approaches used in med-regions worldwide, also show many

1102   similarities (Dallas, 2013). Without considering Chile, where information and routine

1103   use of bioasssessment methodologies are still in their early stages of development,

1104   benthic macroinvertebrates are the organisms most used in the other med-regions.

1105   Reference conditions are also identified and defined in a common way, and multivariate

1106   model approaches have been also developed (Dallas, 2013). Despite these similarities,

1107   not all med-regions include temporary rivers in their routine assessments, and there are

1108   also differences in how temporal variability is incorporated (Dallas, 2013). All these

1109   bioassessment approaches are being implemented in planning water policy although

1110   some countries, such as the European Med-Basin one, are ahead of others. This is likely

1111   because of the influence of the nearby temperate European countries, where the

1112   application ofbiological indices to water quality monitoring have a very long history

1113   (Bonada et al., 2006a).

1114

1115

1116   **Conclusions**

1117

1118   All articles included in this Special Issue have identified specific areas where

1119   knowledge is incomplete and where research efforts are needed. Together with Chile,

1120   North African and Middle Eastern countries are less studied than the other med-region

1121   countries. Basic ecological and biological information is still lacking for rivers in these

1122   countries, which also are slower in the implementation of sustainable river management

1123   policies and species conservation programs. In addition, there is a large contrast in the

1124   amount of information available on med-river ecology between northern and southern

1125   hemisphere med-regions, which is likely related to the larger number of researchers in

1126   northern med-regions. International research programs to fund research in med-regions

1127   worldwide and to promote exchange of researchers between these med-regions should

1128   be encouraged. Regional funding programs should also include funds for long-term

1129   studies in med-regions to gather temporal information that might assist in

1130   understanding, predicting, and managing future impacts that occur in med-rivers.

1131

1132   Taxonomic studies must also remain a priority. Although most programs

1133   requesting research proposals in freshwater biodiversity assume that taxa currently can

1134   be identified with high certainty at the species level, this level of accuracy cannot be

1135   done in most med-regions of the world. Moreover, this assumption will never be

1136   realistically fulfilled unless further investments in taxonomy and identification ofof

1137   freshwater   biota   are   allocated.   Platforms,   such   as   BioFresh

1138   (www.freshwaterbiodiversity.eu), that allow storage of freshwater biodiversity data

1139   from museums or researchers will help to increase our knowledge on biodiversity and

1140   species distribution in med-regions, and to design policies to preserve it.

1141

1142   After reviewing the last decade on med-river research, we can conclude that

1143   although we have significantly advanced our knowledge of med-rivers since Gasith and

1144   Resh's (1999) review, much research remains to be done. We hope that the entries in

1145   this Special Issue will help guide current and future researchers toward an

1146 understanding of how more sustainable river management can be accomplished in these

1147 highly diverse and ecologically vulnerable regions.

1148

1149

1150 **Acknowledgements**

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1684

1685   Tables

1686

1687   **Table 1.** List of biological trait-characteristics from mediterranean plants, terrestrial

1688   arthropods, algae, riparian plants, and aquatic invertebrates. All these traits show

1689   strategies designed to avoid and to recover rapidly from droughts.

Organism	Biological traits
Terrestrial plants (Dallman, 1998)	Sclerophyll foliage
	Summer deciduous
	Geophytes important
	Annuals important
	Root growth adapted to drought
	Sprouting after fire
	Fire-enhanced seed germination
Terrestrial arthropods (Stamou, 1998)	Less permeable cuticle
	Higher water content
	Burrowing or sheltering strategies in summer
	Cryptobiosis
	Low metabolic rates
	Shorter life span
	Early maturity
	Parthenogenesis
Algae (Romaní et al., 2013)	Protective structures (carbonates, stromatolitic-like mats)
	Crust or muscilaginous formations
	Thick cell walls
	High extracellular polymeric substances
	Dormant zygospores
	Persisting rizoids
	Photosinthetic inactivity
	Photooxidative protection and photoinhibition by carotenoids
	High colonization abilities
Riparian plants (Stella et al., 2013)	Shrub formation
	Closed-canopy species
	Low shoot-to-root biomass
	Rapid root extension
	Low leaf size and specific leaf area
	Crown dieback
	Branch abscission
	Reduced diameter growth
Aquatic invertebrates (Bonada et al., 2007a,b)	Small and large sizes
	Short life cycle duration
	Multivoltinism frequent
	Terrestrial egg-laying
	Asexual reproduction
	Resistance forms to drought
	Aerial respiration
	Flyers and swimmers
	Aerial active dissemination

1690

Table 2. Main differences in several ecological attributes between rivers in med-regions (M) and temperate climate regions (T), indicating in which river type each is dominant or more important.

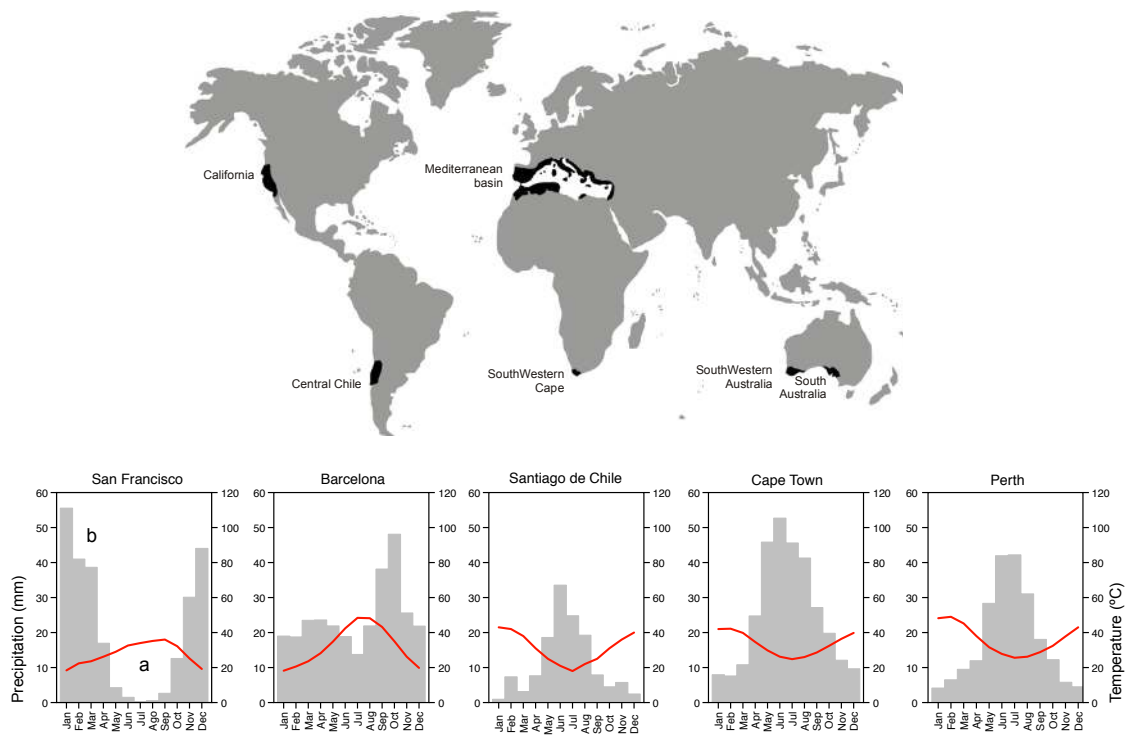|	M vs. T	Comments	References
Physical and chemical parameters			
Seasonal fluctuation of physical and chemical variables	M > T		Sabater et al., 2008; Hershkovitz & Gasith, 2013; Verkaik et al., 2013
Interannual fluctuation of physical and chemical variables	M > T		Resh et al., 2013
Flood timing	M ≠ T	autumn and winter in MED, spring in TEMP	Verkaik et al., 2013
Large floods shape the geomorphic form of river channels	M > T		Kondolf et al., 2013
Wet period hydrological connectivity	M = T		Bernal et al., 2013
Dry period hydrological connectivity	M < T		Bernal et al., 2013
Groundwater-to-stream hydrological flowpaths	M < T		Bernal et al., 2013
Nutrient retention	M < T		Bernal et al., 2013
Nutrient export	M > T		Bernal et al., 2013
Riparian role on nutrient input regulation	M < T		Bernal et al., 2013
Seasonal variability in nutrient uptake lengths	M > T		von Schiller et al., 2008
Organic matter dynamics			
Inputs and retention of OM	M > T		Sabater et al., 2008
Processing of DOM in dry periods	M < T		Romaní et al., 2013
Processing of DOM in wet period	M = T		Romaní et al., 2013
Recalcitrance of allochthonous OM	M > T		Romaní et al., 2013
Seasonal pulse of allochthonous OM	M = T		Romaní et al., 2013
Duration of allochthonous OM inputs	M > T		Romaní et al., 2013
Summer allocthonous OM inputs	M > T		Romaní et al., 2013
Biofilm communities			
Colonizatin rates by algae and bacteria	M > T		Romaní et al., 2013
Bacterial/Algal biomass	M > T		Romaní & Sabater, 2000
Polysaccharide decomposition capacity	M > T		Romaní & Sabater, 2000
Bacterial biomass and production	M < T	in rewetted sediments	Marxsen et al., 2010
Bacterial diversity	M < T	in rewetted sediments	Marxsen et al., 2010
Extracellular polymeric substances	M > T		Artigas et al., 2012
Benthic organic matter storage	M > T		Alvarez & Pardo, 2006
Biomass of benthic primary producers	M > T	measured as Chlorophyll concentration	Sabater et al., 2008
Seasonal variation in chlorophyl concentration	M > T		Sabater et al., 2008
Macroinvertebrate, fish and riparian communities			
Regional diversity	M > T		Bonada et al., 2007a; Ferreira et al., 2007; Stella et al., 2013
Alpha diversity	M = T	but see Sabater et al. (2008) for M < T	Bonada et al., 2007a; Ferreira et al., 2007; Stella et al., 2013
Beta diversity	M > T		Bonada et al., 2007a; Ferreira et al., 2007; Stella et al., 2013
Rarity	M > T	in terms of abundance and occurrence	Filipe et al., 2013
Endemicity	M > T		Filipe et al., 2013; Marr et al., 2013
Abundance	M < T	sligthly higher in T, no significant differences	Sabater et al., 2008
Seasonal changes in taxa composition	M > T	more exacerbated in dry years	Hershkovitz & Gasith, 2013; Verkaik et al., 2013
Seasonal changes in trophic structure	M > T		Sabater et al., 2008
Grazers/Shredders	M > T		Sabater et al., 2008
Interannual changes in composition	M > T	more exacerbated in dry years	Resh et al., 2013
Biological adaptations			
Flood adaptations	M = T		Bonada et al., 2007a
Drought adaptations	M > T		Bonada et al., 2007a
Resistance by endurance	M = T		Bonada et al., 2007a
Resistance by avoidance	M > T		Bonada et al., 2007a
Resilience	M = T		Bonada et al., 2007a
Human-induced disturbances			
Human-induced changes to hydrology, geomorphology, and hydrochemistry	M = T	similar but more extensive and intensive in MED	Cooper et al., 2013
Community responses to land use changes	M = T	similar but more extensive and intensive in MED	Cooper et al., 2013
Immediate effects of fire on streams	M = T		Verkaik et al., 2013
Mid- and long term effects of fire on streams	M = T	but recovery is faster in MED	Verkaik et al., 2013
Resilience to fire of biota	M > T		Verkaik et al., 2013
Recovery of stream geomorphology and substrate after fire	M > T	faster in MED	Verkaik et al., 2013
Fire timing	M = T	in summer or autumn	Verkaik et al., 2013
Time between fires and flood period	M ≠ T	1-6 months in MED, 9-10 in TEMP	Verkaik et al., 2013
Role of vegetation condition for fire	M < T	higher accumulation of debris and understory plants	Verkaik et al., 2013
Catchment vegetation recovery after fire	M < T		Verkaik et al., 2013
Erosion propensity after fire	M < T	potentially lower because of the rapid recovery of vegetation	Verkaik et al., 2013
Effects of prescribe fires vs wild fires	M = T		Verkaik et al., 2013
Vulnerability to extinction by climate change	M > T		Verkaik et al., 2013
Forecasted climate change effects	M > T	because the high levels of endemicity but higher environmental tolerance and dispersal abilities in MED	Filipe et al., 2013

Figure legends

Fig. 1 Location of the five mediterranean-climate regions in the world with graphs showing monthly patterns of annual temperature and rainfall. For each graph "a" indicates the water deficit period whereas "b" is the water surplus period. Climate data was obtained from www.worldclimate.com for all regions except for Chile, which was obtained from www.worldweatheronline.com. Med-Basin data was from the weather station located at the Barcelona International Airport (El Prat) at ~ 41.42°N 2.10°E and included temperature records from 1835 to 1987 and rainfall records from 1861 to 1987. Californian data was from the weather station located at the San Francisco International Airport (San Mateo County) at ~37.61°N 122.38°W and included temperature records from 1961 to 1990 and rainfall records from 1948 to 1995. South African data was from a weather station in Cape Town at ~33.90°S 18.50°E and included temperature records from 1857 to 1992 and rainfall records from 1837 to 1989. Australian temperature data was from a weather station located at the Perth International Airport at about 31.90°S 116.00°E and included records from 1944 to 1992. Australian rainfall data come was a weather station located in Northam at about 31.65°S 116.60°E and included records from 1877 to 1988. Finally, Chilean data was from Santiago de Chile from an unknown weather station.

Fig. 2 Landscape variability within each mediterranean-climate region in the world. Redrawn from Thrower & Bradbury (Thrower & Bradbury, 1973).
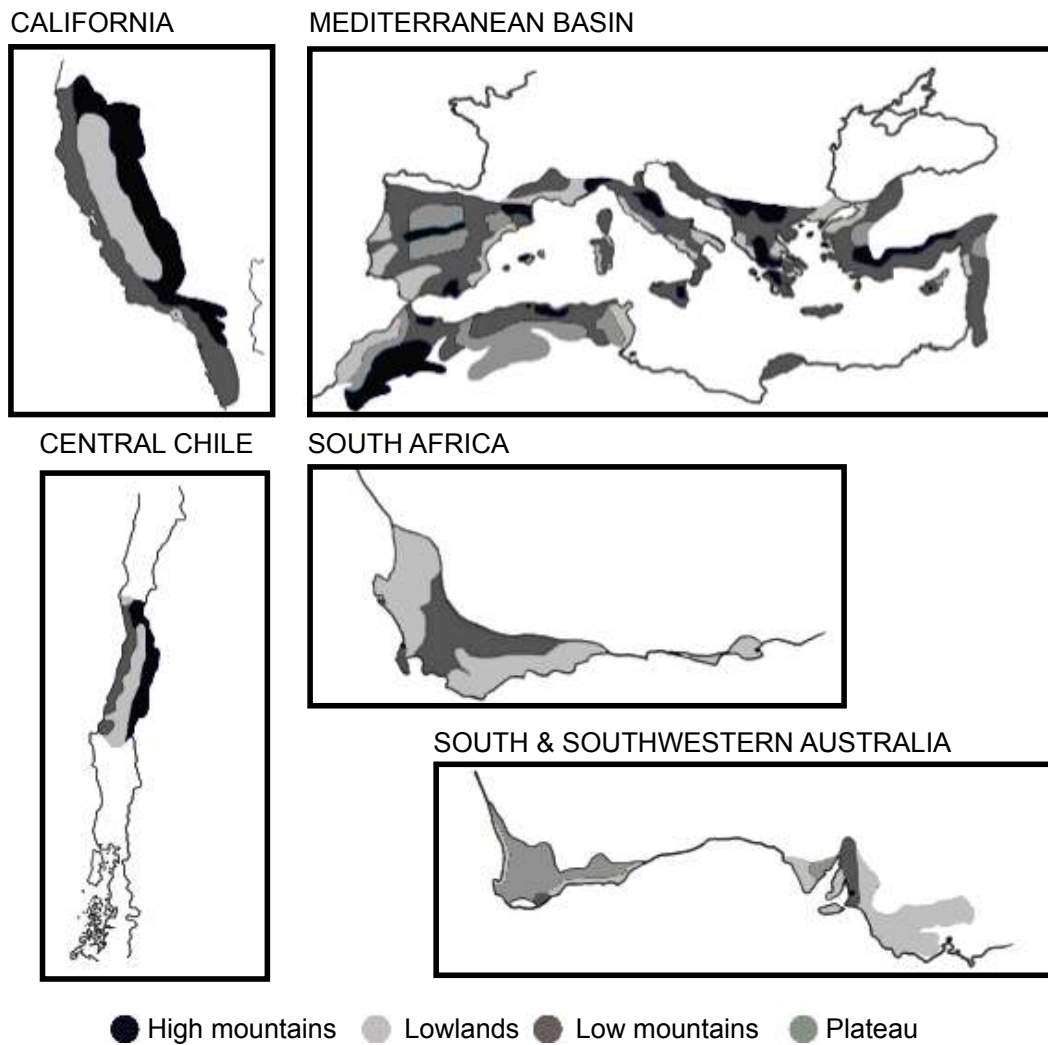
Fig. 3 Similarities among the five mediterranean-climate regions of the world (MB for the Mediterranean Basin, CA for California, SA for South-Africa, CH for Chile and AU
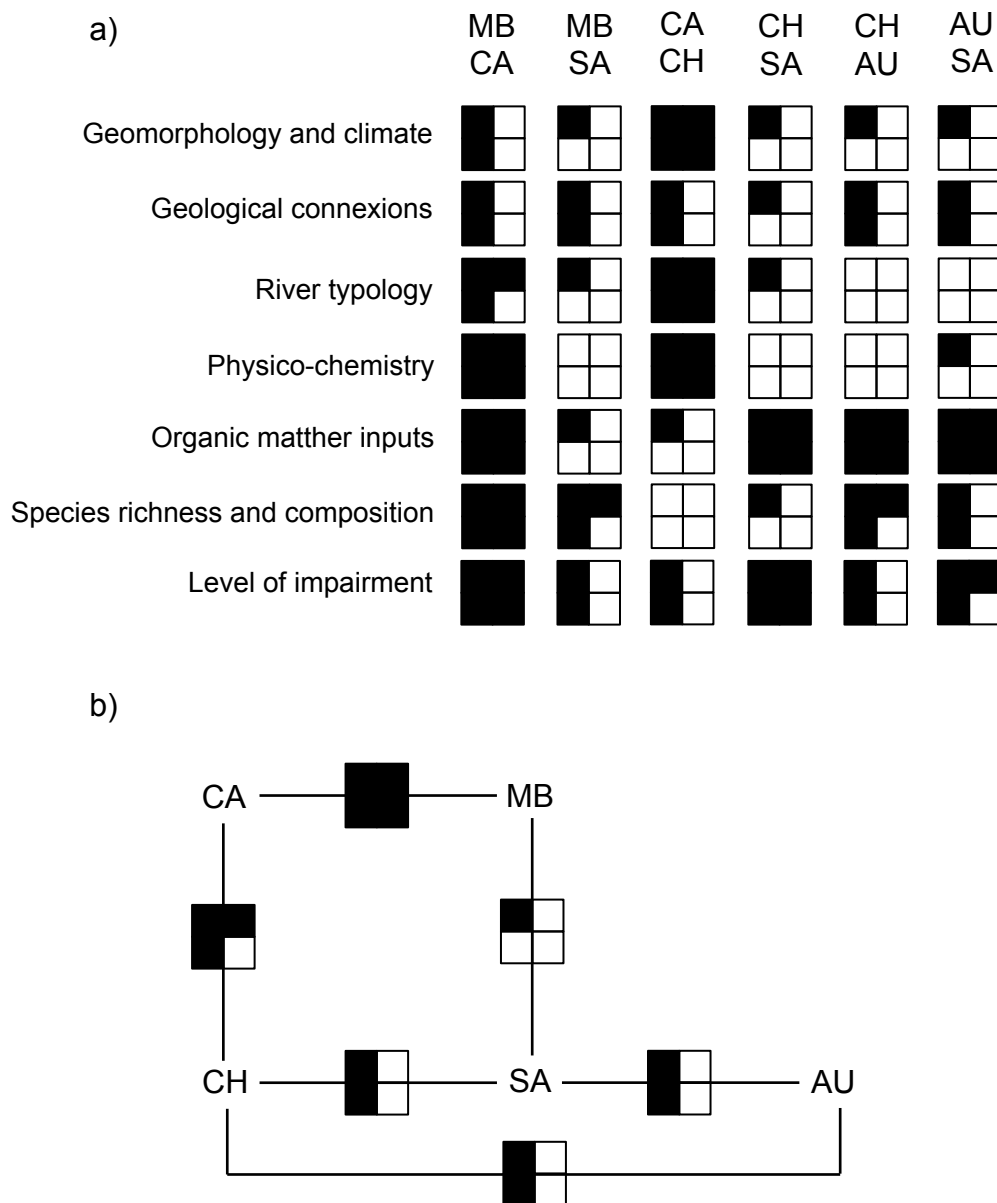
for Southwestern and South Australia) based on information providedin the different chapters of this Special Issue and other references. Southern and Southwestern Australian med-regions are considered together because the few studies in South-Australia. Each large square corresponds to 100% and it is divided in intervals of 25% units. The number of black squares between pairwise comparisons indicates the degree of similarity. (a) Degree of similarity considering several topics related to rivers or organisms. See text for rationales. (b) Overall degree of similarity considering all topics. This design is based on that proposed by Di Castri (Di Castri, 1981; Di Castri, 1991) for terrestrial ecosystems. Note that we have only considered pairwise comparisons of med-regions that are currently connected or have had past geological connections (i.e., connections between MB and CH, MB and AU or CA and SA or CA and AU are not considered although current human induced connections, such as invasive species, have and continue to occur).

Fig. 1 (Bonada & Resh)

CALIFORNIA

MEDITERRANEAN BASIN

CENTRAL CHILE

SOUTH AFRICA

SOUTH & SOUTHWESTERN AUSTRALIA

● High mountains   ● Lowlands   ● Low mountains   ● Plateau

Fig. 2 (Bonada & Resh)

a)

	MB CA	MB SA	CA CH	CH SA	CH AU	AU SA
Geomorphology and climate						
Geological connexions						
River typology						
Physico-chemistry						
Organic matther inputs						
Species richness and composition						
Level of impairment						

b)

Fig. 3 (Bonada & Resh)