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EDITORIAL

Biodiversity and ecology of meiofauna in extreme and changing environments

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Meiofauna (small interstitial animals and protists living in aquatic sediments) are ubiquitous. Owing to their high abundance and diversity, widespread distribution, rapid generation times and fast metabolic rates, meiofaunal organisms are important contributors to ecosystem processes and functions, including nutrient cycling and provision of food to higher trophic levels, among others (Woodward 2010; Schratzberger and Ingels 2017). Meiofauna, however, have typically received less attention than the larger and more easily studied macro- and megafauna, and more needs to be done to train the next new generation of meiobenthologists. In order to bridge this gap, the second meiofauna summer school, "MeioScool2016 - a dive in a microscopic world", was held in Brest, France, 27 June −1 July 2016, and attracted 131 scientists and students from 26 countries (Fig. 1; https://meioscool2016.sciencesconf.org/). Like the first summer school held in 2013, the objectives of MeioScool2016 were to bring together meiofaunal experts in several meiofauna-related sub-disciplines from all over the world to: (1) increase awareness of researchers, students and general public to the fundamental role of meiofauna in marine ecosystems from the coastal zone to the deep sea, and (2) train students and researchers in the identification and description of meiofaunal communities through several complementary disciplines (taxonomy, ecology, molecular biology). The first 2 days were devoted to oral and poster presentations by invited speakers, researchers, and students, while the three other days consisted of practical workshops and field and laboratory work. Two sessions of this summer school were devoted to the meiofauna of extreme and changing environments: "Session 4: Deep-sea and extreme meiofauna" and "Session 5: Meiofauna response to anthropogenic impacts".

Extreme environments (i.e., environments characterised by one or more environmental parameters permanently close to the lower or upper limits for life; CAREX 2011) cover more than 50% of the Earth's surface (Zeppilli et al. 2017), and offer many opportunities for investigating the biological responses and adaptations of organisms to stressful life conditions (Rothschild and Mancinelli 2001). The fauna adapted to extreme environments may be particularly sensitive to environmental changes (Catalan et al. 2006; Bellard et al. 2012) and can be used as biological indicators of pollution and global change (Zeppilli et al. 2015). Among the communities present in extreme natural environments, we constantly find meiofauna organisms. This Special Issue of Marine Biodiversity comprises studies and reviews related to extreme environments including taxonomy of extreme meiofauna, and biodiversity and ecology of meiofauna in extreme or changing environments (Table 1).

The first contribution to this Special Issue provides a description of a new marine arthrotardigrade species (Gomes-Júnior et al. 2017). *Ligiarctus alatus* sp. nov. was discovered in sediments of the Brazilian continental shelf in the Southwestern Atlantic Ocean, from sites located in the major oil extraction basins in Brazil (Campos and Potiguar basins). The review of Rosli et al. (2017) describes trends in the ecology of deep-sea meiofauna with focus on patterns and processes at small to regional spatial scales described in studies published since the last review of deep-sea meiofauna of Soltwedel (2000), and highlights areas needing further research. Zeppilli et al. (2017) present an integrated review of the biodiversity, ecology and physiological responses of marine meiofauna inhabiting extreme marine environments, including mangroves, submarine caves, polar ecosystems, hypersaline areas, hypoxic/anoxic environments, hydrothermal vents, cold seeps, carcasses/sunken woods, deep-sea canyons,

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Fig. 1 Group photograph of on-site participants of the MeioScool2016 Summer School

deep hypersaline anoxic basins and hadal zones. Singh et al. (2017) present a study of the vertical distribution of living benthic foraminiferans from the oxygen minimum zone of the Gulf of Mannar, Southeastern Arabian Sea, which shows how oxygen concentrations impact vertical benthic living foraminiferal distribution. A pilot deep-sea colonisation experiment on the Lucky Strike vent field (Mid-Atlantic Ridge) by Baldrighi et al. (2017) shows that the complex structure of inorganic sponge substrata may favour settlement of juveniles and larvae, and may provide a useful sampling

Table 1 List of papers presented in this Special Issue of Marine Biodiversity

Reference	Topic	Taxon	Geographic area	Ecosystem
Baldrighi et al. (2017)	Ecology and biodiversity of meiofauna in extreme environments	Meiofauna and Macrofauna	Lucky Strike, Mid Atlantic Ridge, Atlantic Ocean	Deep sea
Chen et al. (2017)	Ecology and biodiversity of meiofauna in changing environments	Nematodes	Malaysia	Polluted area
Gomes-Júnior et al. (2017)	Taxonomy of meiofauna in extreme and changing environments	Tardigrada	Brazilian Continental Shelf, Southwestern Atlantic Ocean	Oil and gas impact area
Polese et al. (2017)	Ecology and biodiversity of meiofauna in changing environments	Meiofauna	Thyrrenian Sea, Mediterranean Sea	Polluted area
Quang et al. (2017)	Ecology and biodiversity of meiofauna in changing environments	Nematodes	Sai Gon River harbours, Vietnam	Polluted area
Rosli et al. (2017)	Ecology and biodiversity of meiofauna in extreme environments	Meiofauna	Worldwide	Deep sea
Semprucci et al. (2017)	Ecology and biodiversity of meiofauna in changing environments	Meiofauna and Nematodes	Adriatic Sea, Mediterranean Sea	Polluted area
Singh et al. (2017)	Ecology and biodiversity of meiofauna in extreme environments	Foraminifera	South-Eastern Arabian Sea	Deep sea and Oxygen Minimum Zone
Zeppilli et al. (2017)	Ecology and biodiversity of meiofauna in extreme environments	Meiofauna	Worldwide	Mangroves, submarine caves, Polar ecosystems, hypersaline areas, hypoxic/anoxic environments, hydrothermal vents, cold seeps, carcasses/sunken woods, deep-sea canyons, deep hypersaline anoxic basins and hadal zones

method for ecological studies. Two studies within this special issue show that meiobenthic and nematode assemblages can be used to determine the ecological quality (EcoQ) of highly impacted areas (Semprucci et al. 2017; Chen et al. 2017). Finally, Polese et al. (2017) describe a study of meiofauna from the Phlegraean archipelago (Southern Italy) comparing pristine (Nisida islet) and highly impacted area (Bagnoli), and Quang et al. (2017) describe the impact of toxic tributyltin (TBT) compounds on free-living nematode communities in the Sai Gon River.

The discovery of abundant and well-adapted meiofaunal communities in several environments with extreme conditions has provided new insights into the ecology and physiology of species thriving in challenging settings (e.g., Danovaro et al. 2010; Fontaneto et al. 2015). As well as natural processes, human activities may generate stressful conditions, including deoxygenation, acidification and rises in temperature. The behaviour and physiology of different meiofaunal taxa, such as some foraminiferans, nematode and copepod species, can provide vital information on how organisms may respond to these challenges and can provide a warning signal of anthropogenic impacts. From an evolutionary perspective, the discovery of new meiofauna taxa from extreme environments often sheds light on phylogenetic relationships, while understanding how meiofaunal organisms are able to survive or even flourish in these conditions can explain evolutionary pathways. Finally, there are multiple potential economic benefits to be gained from ecological, biological, physiological and evolutionary studies of meiofauna in extreme environments. Given the many insights to be gained from studies of meiofauna of extreme and changing environments, there is a clear need to continue research capability in this area through multidisciplinary courses such as Meioscool.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with animals performed by any of the authors.

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