

## Preface to the First Edition

Studies on meiobenthos, the motile microscopic fauna of aquatic sediments, are gaining in importance, revealing trophic cycles and allowing the impacts of anthropogenic factors to be assessed. The bottom of the sea, the banks of rivers and the shores of lakes contain higher concentrations of nutrients, more microorganisms and a richer fauna than the water column. Calculations on the role of benthic organisms reveal that the “small food web”, i.e., microorganisms, protozoans, microphytobenthos, and smaller metazoans, play a dominant role in the turnover of organic matter (Kuipers et al. 1981). New animal groups—even those of high taxonomic status—are often of meiobenthic size and continue to be described. Two of the most recent animal groups ranked as phyla, the Gnathostomulida and the Loricifera, represent typical meiobenthos.

Up to now, a textbook introducing the microscopic organisms of the sediments, their ecological demands and biological properties has not existed, despite the significance of meiobenthos indicated above. A recent book entitled *Introduction to the Study of Meiofauna* (Higgins and Thiel 1988) gives valuable outlines for practical investigation, and *Stygofauna Mundi*, a monograph edited by Botosaneanu (1986a), focuses on zoogeographical aspects of mainly freshwater forms, but neither was intended to be a comprehensive text on the subject of meiobenthology.

The purpose of this book is to provide a general overview of the framework and the theoretical background of the scientific field of meiobenthology. The first of three major parts describes the habitat of meiobenthos and some of the methods used for its investigation; the second part deals with morphological and systematic aspects of meiofauna, and the third part reports on the meiofauna of selected biotopes and on community and synecological aspects of meiobenthos. However, a monographic text cannot include an adequate survey of general benthic ecology, or be a textbook on the zoology of microscopic animal groups. The primary purpose of this text is to provide an ecologically oriented scientific basis for meiobenthic studies. Further advice for practical investigations is found in important compilations by Higgins and Thiel (1988), Holme and McIntyre (1984), and Gray (1981). Hence, aspects of sampling procedures and strategies, statistical treatment and fauna processing will be treated here only briefly. In these fields, the present work should be considered a supplement to the books mentioned above and instead focuses on some critical hints, methodological limitations, and a few neglected practical aspects.

Writing this book was particularly difficult because the literature on meiofauna is so widely dispersed in journals and congress proceedings and has so rapidly increased in volume that complete coverage is impossible. Regardless of my efforts, therefore, there is no pretence that this text is absolutely comprehensive. Where it is important for the general context, the major chapters of the book contain some overlap in terms of information. This is deliberate; it provides the reader with chapters that are complete in themselves and avoids the need for too many cross-references. Also, in order to maintain a readable, coherent style, citations of specific references had to be restricted. Thus, the "reference list" of this text does not represent all of the sources drawn upon during the production of this book.

The selection of topics and the emphasis given to them is admittedly subjective. In particular, the brief treatment of freshwater meiobenthos (Chapter 8.2) by no means reflects the exhaustive achievements and importance of this field of meiobenthology. This book does not include the nanobenthos, since this represents a microbiota that is completely different from the meiobenthos in its size range, methodology, and taxonomical composition (mainly prokaryotes, often autotrophic protists and fungi). Where appropriate, references compiled in a "Recommended reading" paragraph are given at the ends of many chapters. They will serve as supplementary information and, hopefully, will compensate for my own subjectivity. Should incorrect or misunderstood data be reported in the text, I would be most grateful to be informed of this.

This book resulted from a series of lectures for advanced students given by the author over a period of several years at the University of Hamburg. Studying the tiny organisms living in sand and mud fascinated many of the students and provided the encouragement and persistent stimulus needed to write this book. It will achieve its goal if it further promotes interest in the diverse and cryptic microscopic world of meiobenthic animals, emphasizes their ecological importance, from both theoretical and practical viewpoints, and contributes to the awareness that small animals often play a key role in large ecosystems, which are becoming increasingly threatened.

**Acknowledgements** I am deeply obliged to Dr. Robert P. Higgins (Washington, DC), who critically reviewed the entire text, and not only for linguistic flaws. My thanks go out to my graduate students who supported me in selecting figures and designing graphs. I am grateful to several of my colleagues for their valuable comments on parts of the text, and for providing me with manuscripts that were sometimes still in press and for other helpful hints. It was my intention to include only originals or redrawn figures. This was possible through the patient work of A. Mantel and M. Hänel (both in Hamburg), for which I am most grateful.

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Olav Giere

## Preface to the Second Edition

*Also bestimmt die Gestalt die Lebensweise des Thieres,  
und die Weise zu leben sie wirkt auf alle Gestalten mächtig zurück.*

*So the shape of an animal patterns its manner of living,  
likewise their manner of living exerts on the animals' shape  
massive effects.*

GOETHE 1806: *Metamorphose der Thiere*

Encouraged by the friendly acceptance of the first edition and stimulated by numerous requests and comments from the community of meiobenthologists, this second edition updates my monograph on meiobenthology. The revised text emphasizes new discoveries and developments of relevance; it has been extended by adding chapters on meiofauna in areas not covered before, such as the polar regions, mangroves, and hydrothermal vents. As I attempted to keep up with the actual literature for the whole field of meiobenthos—taxonomy and ecology, marine and freshwater—I became a little discouraged upon noticing the flood of literature that had appeared in the few years after the publication of the first edition. Has there been a multiplication of new meiobenthologists or an inflation of their industrious efforts? How could I compile this plethora of new data; how to select, what to omit? The need to extract general information from the details, and to modify and amalgamate them within a greater context; this difficult “condensation” process was the key to my approach. It forced me to be selective, to focus on one goal: to write a readable compendium that will serve the interested biologist, the fellow benthologist and the student alike. Avoiding a style with constructions that are too sophisticated should also enhance the comprehension of those readers that are not natively familiar with the English language.

Since the first edition, meiofaunal research has made, I believe, major progress in three general areas: (a) systematics, diversity, and distribution; (b) ecology, food webs

and energy flow; and (c) environmental aspects, including studies of anthropogenic impacts.

- (a) In the area of systematics, diversity and distribution, molecular biological studies suggest that some of the “smaller” meiobenthic groups, such as Kinorhyncha, Gastrotricha and Rotifera, hold key positions in metazoan phylogeny, linking various invertebrate lines into new units (e.g., Ecdysozoa, Scalidophora, Cycloneuralia, Lophotrochozoa). Genetic fine-scale diversification has become an indispensable tool for understanding distribution processes and biogeographic patterns. With enhanced studies in exotic and remote areas, the meiobenthos continues to be a haven for the discovery of unknown animals, even of high taxonomic rank, e.g., Micrognathozoa. Reports on meiofauna from polar or tropical regions, deep-sea bottoms or hydrothermal vents were limited in the first edition due to the scarcity of pertinent studies. Recent comprehensive publications have now recognized these formerly exotic areas as being in the research mainstream, and are covered here in separate chapters. Problems of principal biological relevance, such as the study of distribution patterns or the relation of body size to distribution, have been tackled using meiofauna as tools. The high number of meiobenthic species found under even extreme or impoverished ecological conditions puts meiobenthos at the forefront of biodiversity and “census of life” studies. Taxonomic, functional and genetic diversity as influenced by ecological and/or anthropogenic variables are widely acknowledged matters of concern. Molecular screening methods allow large numbers of species to be recorded upon expending reasonable effort.
- (b) Today, essays on aquatic environments mostly consider the relevant role of meiobenthos. Mucus agglutinations and microorganisms are increasingly recognized to be important components that structure the sediment texture and provide the basis for many meiobenthic food chains. Trophic fluxes can be followed using new techniques, such as by assessing isotopic signatures. Metabolic pathways visualized by fluorescence imaging enable us to broaden our limited knowledge of the physiology of meiobenthos. Combined with advanced statistics, such as multivariate analyses, we can achieve results that link meiobenthos to general ecological paradigms.
- (c) The reactions of biota to environmental threats are increasingly based on evaluations of the meiofauna, underlining their inherent advantages (small size, ubiquity, abundance). With improved processing and culturing methods, pollution experiments are now often based on meiobenthic animals, apply population dynamics and use micro-/mesocosm studies. Standardized bioassays include meiofauna and have become commercially available. The increased role of meiofauna in this field is reflected by new chapters on the impact of metal compounds and pesticides. The use of molecular techniques can alleviate the problem of rapid mass identification, e.g., in nematodes.

All of these research fields tie meiobenthology closer to the “mainstream,” which should be a main goal of future meiobenthic research. If this second edition can

synthesize these modern scientific achievements, meiobenthology could indeed play a key role in assessing the health of our environment, and will not just represent a playground for singular interests.

Several comprehensive publications on meiobenthos published in the last few years are contributing to this goal. Of broad interest are monographic publications on freshwater meiobenthos (Hakenkamp and Palmer 2000; Hakenkamp et al. 2002; Robertson et al. 2000a; Rundle et al. 2002). The new edition of the classic treatise *Methods for the Study of Marine Benthos* (Eleftheriou and McIntyre 2005) contains competent contributions to sediment analysis, sampling strategies and meiofauna techniques (Somerfield et al. 2005). It also covers statistical and analytical methods that assess ecosystem functioning and measure energy flow through benthic populations. Therefore, in this edition of *Meiobenthology* I have condensed the information in some chapters referring to “Methods for the Study of Marine Benthos.” Lesser known are the meiofauna reviews of Galhano (1970, in Portuguese) and Gal’tsova (1991, in Russian), which were not mentioned in the first edition. In other chapters of this edition (e.g., on polluted sites), the scope has been expanded by adding short accounts of the impacts of metals and pesticides on meiobenthos. The most conspicuous novelty is the highlighted boxes, which either contain the essence of a particular section or comment on special aspects.

The figures have been redesigned for higher clarity, and some outdated paragraphs have been shortened or omitted. To maximize readability not all of the publications on which I drew are cited; on the other hand, on several occasions the same publication is cited in a different context in order to make the chapters independently readable and understandable. The resulting reference list is meant to provide an archive of detailed studies in all fields of meiobenthology. A comprehensive index and a glossary explaining specific terms facilitate the use of this book. Because of their ease of accessibility for the general reader, I accentuate references in widely distributed, English-dominated journals. As much as all this may help to improve the distribution and didactic impact of this book, I especially hope, for the sake of the student reader, that Springer-Verlag publishes this new edition at a competitive price that is affordable to all interested in the great world of small organisms. I hope that this edition will be considered as readable and received as warmly by the readers as the 1993 edition.

Despite all the care that I have taken, I could not consider every contribution, and so I apologize especially to those colleagues who have published in less common native languages or in journals with restricted distributions, whose results have not been considered here. My particular regrets remain realizing how much valuable knowledge is “hidden” to most of us in the numerous publications that have appeared in Russian over the last few years, much of it unnoticed by many of us. Mistakes in the first edition, for which I apologize, have hopefully been eliminated. I regret and take the responsibility for remaining omissions or erroneous interpretations.

Should this book draw the attention of benthic ecologists to the relevance of meiobenthos and foster further research in this field, it has accomplished its goals. Perhaps it represents the last chance to write a monographic textbook that amalgamates bits of information into a coherent context before electronic databases,

pictures and information networks produce a glut of innumerable details and publications—an information jungle in which the beginner especially can easily become lost.

Meiobenthology is now increasingly represented on the Internet: the International Association of Meiobenthologists (I.A.M.) and also many colleagues have often designed comprehensive homepages with address and publication lists. New editions of the I.A.M. newsletter *Psammonalia* are regularly published online (<http://www.meiofauna.org/>) and include pictures and even short movie galleries. Also, CD-ROMs and databases of computer-based pictorial identification keys have attained increasing importance (European Limnofauna; European Register of Marine Species, ERMS; separate databases for Nematoda, Harpacticoida, Turbellaria).

With this book I conclude many of my activities in meiobenthology. To express my feelings I could do worse than adopting the words of a good friend and protagonist of meiobenthos research, Prof. Bruce C. Coull, who upon his retirement wonderfully characterized his feelings and probably those of many other fellow meiobenthologists of our peer group: “I maintain an interest in all things meiofaunal and it has been a great life studying them. I hope that the next generation of researchers will learn much more about these creature friends and that the researchers have as much fun as I have had trying to understand our ubiquitous and omnipresent aquatic denizens.”

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