

Springer Geology

Yanli Lei
Tiegang Li

Atlas of Benthic Foraminifera from China Seas

The Bohai Sea and the Yellow Sea



Science Press
Beijing



Springer

Yanli Lei · Tiegang Li

Atlas of Benthic Foraminifera from China Seas

The Bohai Sea and the Yellow Sea

 Science Press
Beijing

 Springer

Responsible editors: Meicen Meng, Peng Han

Yanli Lei
Institute of Oceanology
Chinese Academy of Sciences
Qingdao
PR China

Tiegang Li
First Institute of Oceanology, SOA
Qingdao
PR China

ISSN 2197-9545

ISSN 2197-9553 (electronic)

Springer Geology

ISBN 978-3-662-53876-0

ISBN 978-3-662-53878-4 (eBook)

DOI 10.1007/978-3-662-53878-4

Jointly published with Science Press Ltd., Beijing, China

ISBN: 978-7-03-050610-8 Science Press, Beijing

Library of Congress Control Number: 2016957496

© Science Press, Beijing and Springer-Verlag GmbH Germany 2016

This work is subject to copyright. All rights are reserved by the Publishers, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publishers, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publishers nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

This Springer imprint is published by Springer Nature

The registered company is Springer-Verlag GmbH Germany

The registered company address is: Heidelberger Platz 3, 14197 Berlin, Germany

Not for sale outside the Mainland of China (*Not for sale in Hong Kong SAR, Macau SAR, and Taiwan, and all countries except the Mainland of China*).

The book series Springer Geology comprises a broad portfolio of scientific books, aiming at researchers, students, and everyone interested in geology. The series includes peer-reviewed monographs, edited volumes, textbooks, and conference proceedings. It covers the entire research area of geology including, but not limited to, economic geology, mineral resources, historical geology, quantitative geology, structural geology, geomorphology, paleontology, and sedimentology.

More information about this series at <http://www.springer.com/series/10172>

Preface

Systematic classification and accurate identification of benthic foraminifera has been a keystone for the reconstruction of paleoceanography. However, general identification books on benthic foraminifera from the China Seas are very limited. Many Chinese geologists of old generation, for example, Yan He, Yi Chun Hao, Pin Xian Wang, etc., had made great contributions to foraminiferal research on the China Seas. With the evolution of foraminiferal taxonomy and application of molecular studies, there is a need to summarize the characteristics of foraminiferal fauna from China Seas and to report to the world. The book series “Atlas of Benthic Foraminifera from China Seas” shouldered the burden of connecting research achievements from the old generation of Chinese geologists to the modern understanding of foraminiferal taxonomy. The present book concerning the Bohai Sea and the Yellow Sea fauna is the first part of this book series on the China Seas.

In this monograph, 183 species belonging to 92 genera, 51 families, and five orders are described. Among these species, one new genus and eight new species were established; one new combination and four new statements were reported; thirteen were new records to the China Seas and two were newly redescribed since the species were established half a century ago. We also try to present an up-to-date taxonomic status with morphological details for each species, and therefore we have made extensive use of micrographs.

“The more you know, the more you don’t know (from Aristotle, Greek)”, we certainly understand that the more problems we meet in foraminiferal taxonomy, the closer we are approaching to the truth. Although there are still a lot of shortcomings and deficiencies in this monograph, we try to introduce our understanding and share our experiences on benthic foraminifera from China Seas to the world. Your comments and criticism are greatly welcomed. Please contact to the following emails: tgli@fio.org.cn; leiyanni@qdio.ac.cn.

Qingdao, PR China
August 2016

Tiegang Li
Yanli Lei

Acknowledgments

This work received financial supports from the following projects: Strategic Priority Research Program of the Chinese Academy of Sciences XDA11030104; National Program on 'Global Change and Air-Sea Interaction' (GASI-GEOGE-06-02, GASI-03-01-03-01, GASI-GEOGE-04); National Science Foundation of China No. 41476043, 41230959; Continental Shelf Drilling Program of China GZH201100202; the Paul Brönnimann Foundation 2014. Special thanks are due to Dr. Bo Lei (State Oceanic Administration People's Republic of China) for his important contributions on promoting the development of marine science and technology in China for decades.

We are indebted to many persons for assistance during the preparation of this monograph. First, the first author cannot ignore the preliminary education of foraminiferal taxonomy learnt from Prof. Shouyi Zheng and Zhaoxian Fu (Institute of Oceanology, Chinese Academy of Sciences). Next, we wish to thank Prof. Dr. Zhimin Jian (State Key Laboratory of Marine Geology, Tongji University, China) for many supports and instructions to the first author in foraminiferal research. We also want to thank Prof. Dr. Jan Pawlowski (Department of Genetics and Evolution, University of Geneva, Switzerland) for encouraging our foraminiferal studies in China. Special thanks are due to Dr. Rajiv Nigam for kind help in foraminiferal studies (National Institute of Oceanography, Goa, India). We gratefully acknowledge technicians Xuejiao Wang, Mengmeng Zheng, and Lina Cao for sample treatments (Institute of Oceanology, Chinese Academy of Sciences). Of course we would not forget our two families for their support.

Finally, we thank several international scientists: Dr. Bruce W. Hayward (Geomarine Research, University of Auckland, New Zealand), Dr. Andrew J. Gooday (National Oceanography Centre, Southampton, UK), Dr. Tomas Cedhagen (Denmark), Dr. Peter Frenzel (Germany), Dr. Mike Kaminski (Saudi Arabia), Dr. Onno Gross and the "Foraminifera.eu Team" for providing selfless assistances in network resource of foraminiferal taxonomic studies.

Material and Methods

Study Sites and General Information

The Bohai Sea

The Bohai Sea is the innermost gulf of the North Yellow Sea of China with an area $\sim 78,000 \text{ km}^2$ and high sediment loadings from river runoff. The Bohai Sea sediment samples were collected from nine stations ($38^\circ 10' - 39^\circ 00' \text{ N}$, $119^\circ 30' - 120^\circ 10' \text{ E}$) on December 18–19, 2011 (Fig. 1).

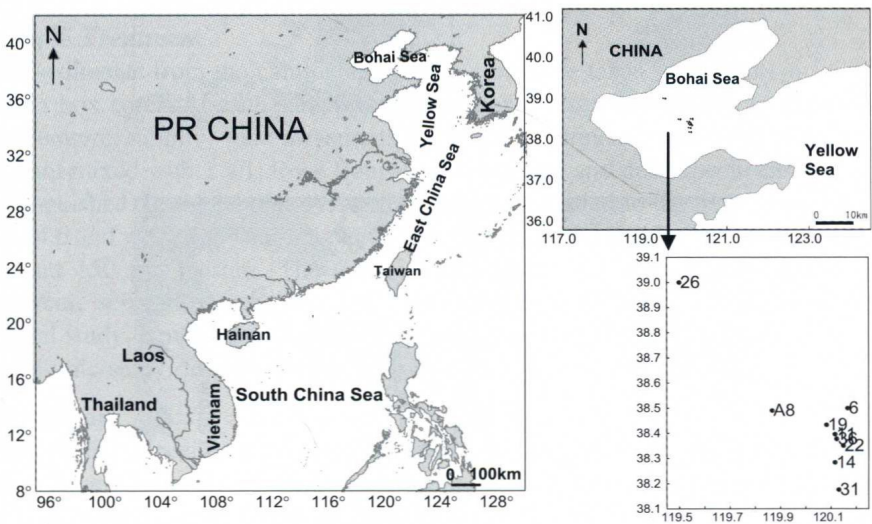


Fig. 1 Map of location and sampling stations in the Bohai Sea

The Yellow Sea

The Yellow Sea is a semi-enclosed shallow shelf sea (water depth <100 m) with an area of about 500,000 km². The average water depth is about 44 m. It is adjacent to the Bohai Sea in the northwest and to the East China Sea in the south, and geographically divided by the tip of the Shandong Peninsula into a northern and the southern parts (Fig. 2). A series of mud patches has developed under this circulation system, including the southeastern Yellow Sea mud area and the central Yellow Sea mud area, which formed the Yellow Sea Cold Water Mass. These mud deposits are valuable for high-resolution Holocene paleoenvironmental studies (Li et al. 2009).

The Yellow Sea sediment samples were collected based on several cruises from dozens of stations (31°15' to 38°50' N, 120°57' to 124°30' E) during 2008, 2009, 2012, and 2014 cruises (Fig. 2).

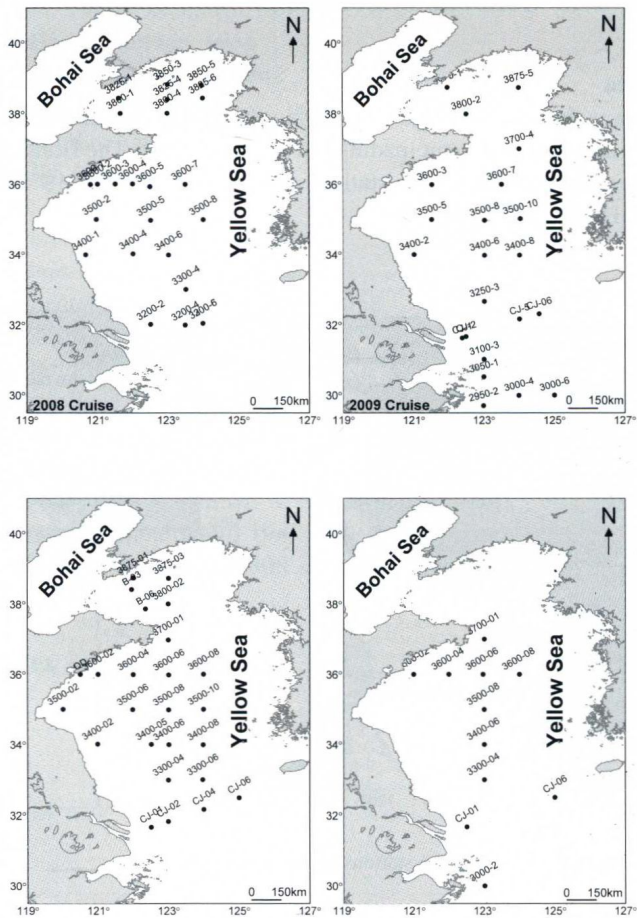


Fig. 2 Map of location and sampling stations in the Yellow Sea during 2008, 2009, 2012 and 2014 cruises

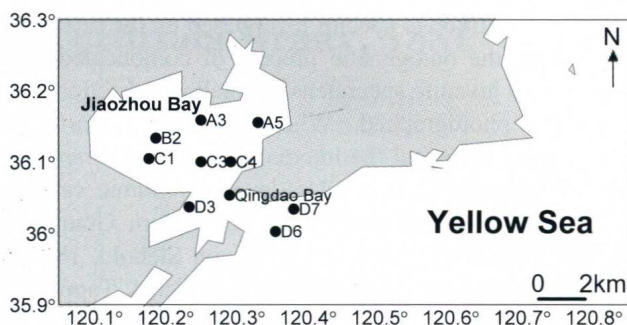


Fig. 3 Map of location and sampling stations in the Jiaozhou Bay and the Qingdao Bay

The Jiaozhou Bay and the Qingdao Bay

The Jiaozhou Bay is located on the southern coast of the Shandong Peninsula in the eastern China (Fig. 3). It is a semi-enclosed bay of the Yellow Sea that has undergone extensive environmental changes in recent years, due to natural factors such as sediment supplies and human activities such as farming and real estate development and operation of the city constructions.

The Qingdao Bay is an intertidal flat, located in the bay mouth of the Jiaozhou Bay. It is often severely affected by the local tourist industry and the blooming of drifting green tide, *Enteromorpha prolifera*, in the summer season. The sediment samples from the Jiaozhou Bay (36°00' to 36°09' N, 120°10' to 120°22' E) and the Qingdao Bay (36°00' N, 120°30' E) were collected during 2011 to 2014.

Sample Treatment

The sediments from the continental shelf region were taken using a 0.1 m² Gray–Ohara box corer. At each sampling station, environmental variables (water depth, temperature, salinity) were measured. The surface sediments were fixed using 95 % ethanol mixed with 1 g/L Rose Bengal such that live and dead specimens could be distinguished. In the laboratory, each sediment was dried in the oven below 50 °C for 24 h and weighed. The sediments were soaked in water and were sieved through 63 and 150 µm meshes. The foraminiferal specimens were concentrated by an isopycnic separation technique using tetrachloromethane ($D = 1.59$). For the ecological study, benthic foraminifera were counted in >150 µm size fraction. For the taxonomic study, foraminifera in both size fractions were observed.

Taxonomy

Foraminiferal specimens were isolated and mounted on slides, and were identified and enumerated under stereomicroscope Nikon SSZ1500, with continuous zooming to a maximum amplification of 225×. Specimens were studied and photographs were taken under the microscopes Nikon SSZ1500 and Nikon SMZ25 (with continuous zooming to a maximum amplification of 315×). Size measurements were taken during photographing.

Foraminifera were identified to species level based on the relevant literature. For better understanding of the ontogenetic process of complicated species and new species, some larval and juvenile specimens in small size fraction were studied and were microscopically photographed. When necessary, pouring chamber and grinding slice were done to reveal the internal structure of foraminifera.

In our book, "Foraminifera" as a Class-level taxonomic category, i.e., Class Foraminifera Lee, 1990, was affiliated with the Phylum Granuloreticulosa Lee, 1990, Kingdom PROTOZOA (Goldfuss, 1818) von Siebold, 1846. Foraminiferal classification systematics was based on those of Loeblich & Tappan (1987) and Lee (1990), as to the genus and the species levels we also referred to Hayward et al. (2015).

Contents

Order Astrorhizida Brady, 1881	1
Family Saccamminidae Brady, 1884	1
Genus <i>Lagenammina</i> Rhumbler, 1911	1
Genus <i>Saccammina</i> Carpenter, 1869	5
Genus <i>Thurammina</i> Brady, 1879	6
Family Ammodiscidae Reuss, 1862	8
Genus <i>Ammodiscus</i> Reuss, 1862	8
Order Textulariida Delage et Hérouard, 1896	11
Family Hormosinidae Haeckel, 1894	11
Genus <i>Reophax</i> de Montfort, 1808	11
Family Ammosphaeroidinidae Cushman, 1927	17
Genus <i>Cribrostomoides</i> Cushman, 1910	17
Family Haplophragmoididae Maync, 1952	20
Genus <i>Haplophragmoides</i> Cushman, 1910	20
Family Discamminidae Mikhalevich, 1980	24
Genus <i>Ammoscalaria</i> Höglund, 1947	24
Family Lituolidae de Blainville, 1827	27
Genus <i>Ammobaculites</i> Cushman, 1910	27
Family Haplophragmiidae Eimer & Fickert, 1899	29
Genus <i>Haplophragmium</i> Reuss, 1860	29
Family Spiroplectamminidae Cushman, 1927	31
Genus <i>Spiroplectammina</i> Cushman, 1927	31
Genus <i>Spiroplectinella</i> Kisel'man, 1972	33
Family Nouriiidae Chapman & Parr, 1936	35
Genus <i>Nouria</i> Heron-Allen & Earland, 1914	35
Family Trochamminidae Schwager, 1877	37
Genus <i>Ammoglobigerina</i> Eimer & Fickert, 1899	37
Genus <i>Paratrochammina</i> Brönnimann, 1979	39
Genus <i>Trochammina</i> Parker & Jones, 1859	41
Genus <i>Arenoparrella</i> Andersen, 1951	46

Family Verneuilinidae Cushman, 1911	50
Genus <i>Siphogaudryina</i> Cushman, 1935	50
Family Globotextulariidae Cushman, 1927	52
Genus <i>Verneuilinulla</i> Saidova, 1975	52
Family Eggerellidae Cushman, 1937	56
Genus <i>Eggerelloides</i> Haynes, 1973	56
Family Textulariidae Ehrenberg, 1838	58
Genus <i>Sahulia</i> Loeblich & Tappan, 1985	58
Genus <i>Textularia</i> Defrance, 1824.	61
Genus <i>Siphotextularia</i> Finlay, 1939	70
Family Pseudogaudryinidae Loeblich & Tappan, 1985.	71
Genus <i>Pseudoclavulina</i> Cushman, 1936	71
Genus <i>Pseudogaudryina</i> Cushman, 1936	73
Family Valvulinidae Berthelin, 1880	84
Genus <i>Clavulina</i> d'Orbigny, 1826	84
Order Miliolida Delage et Hérouard, 1896	89
Family Cornuspiridae Schultze, 1854.	89
Genus <i>Cornuspira</i> Schultze, 1854	89
Family Miliamminidae Saidova, 1981	91
Genus <i>Miliammina</i> Heron-Allen & Earland, 1930	91
Family Spiroloculinidae Wiesner, 1920	93
Genus <i>Spiroloculina</i> d'Orbigny, 1826	93
Family Hauerinidae Schwager, 1876	98
Genus <i>Cycloforina</i> Luczkowska, 1972	98
Genus <i>Massilina</i> Schlumberger, 1893.	100
Genus <i>Quinqueloculina</i> d'Orbigny, 1826	103
Genus <i>Biloculinella</i> Wiesner, 1931	117
Genus <i>Triloculina</i> d'Orbigny, 1826	123
Genus <i>Sigmoilopsis</i> Finlay, 1947.	131
Order Lagenida Delage et Hérouard, 1896	135
Family Nodosariidae Ehrenberg, 1838	135
Genus <i>Dentalina</i> Risso, 1826	135
Genus <i>Laevidentalina</i> Loeblich & Tappan, 1986	137
Family Vaginulinidae Reuss, 1860	143
Genus <i>Lenticulina</i> Lamarck, 1804	143
Genus <i>Saracenaria</i> Defrance, 1824	146
Genus <i>Astacolus</i> de Montfort, 1808.	148
Genus <i>Amphicoryna</i> Schlumberger, 1881	151
Family Lagenidae Reuss, 1862	153
Genus <i>Lagena</i> Walker & Jacob, 1798	153
Genus <i>Procerolagena</i> Puri, 1954.	173
Family Polymorphinidae d'Orbigny, 1839	177
Genus <i>Globulina</i> d'Orbigny, 1839.	177

Genus <i>Guttulina</i> d'Orbigny, 1839	180
Family Ellipsolagenidae A. Silvestri, 1923	183
Genus <i>Favulina</i> Patterson & Richardson, 1987	183
Genus <i>Oolina</i> d'Orbigny, 1839	185
Genus <i>Fissurina</i> Reuss, 1850	187
Genus <i>Parafissurina</i> Parr, 1947	192
Family Glandulinidae Reuss, 1860	194
Genus <i>Glandulina</i> d'Orbigny, 1839	194
Genus <i>Laryngosigma</i> Loeblich & Tappan, 1953	196
Order Rotaliida Delage et Hérouard, 1896	199
Family Bolivinidae Glaessner, 1937	199
Genus <i>Bolivina</i> d'Orbigny, 1839	199
Genus <i>Bolivinellina</i> Saidova, 1975	210
Family Cassidulinidae d'Orbigny, 1839	212
Genus <i>Globocassidulina</i> Voloshinova, 1960	212
Family Stainforthiidae Reiss, 1963	214
Genus <i>Hopkinsina</i> Howe & Wallace, 1932	214
Family Siphogenerinoididae Saidova, 1981	216
Genus <i>Siphogenerina</i> Schlumberger, 1882	216
Family Buliminidae Jones, 1875	218
Genus <i>Bulimina</i> d'Orbigny, 1826	218
Family Buliminellidae Hofker, 1951	224
Genus <i>Buliminella</i> Cushman, 1911	224
Family Uvigerinidae Haeckel, 1894	226
Genus <i>Uvigerina</i> d'Orbigny, 1826	226
Family Fursenkoinidae Loeblich & Tappan, 1961	230
Genus <i>Fursenkoina</i> Loeblich & Tappan, 1961	230
Genus <i>Neocassidulina</i> McCulloch, 1977	234
Family Bagginidae Cushman, 1927	236
Genus <i>Cancris</i> de Montfort, 1808	236
Family Eponididae Hofker, 1951	238
Genus <i>Poroeponides</i> Cushman, 1944	238
Family Rosalinidae Reiss, 1963	240
Genus <i>Rosalina</i> d'Orbigny, 1826	240
Family Glabratellidae Loeblich & Tappan, 1964	246
Genus <i>Murrayinella</i> Farias, 1977	246
Family Parrelloididae Hofker, 1956	248
Genus <i>Cibicidoides</i> Thalmann, 1939	248
Family Pseudoparrellidae Voloshinova, 1952	252
Genus <i>Epistominella</i> Husezima & Maruhasi, 1944	252
Family Discorbinellidae Sigal, 1952	255
Genus <i>Discorbinella</i> Cushman & Martin, 1935	255
Family Planulinidae Bermúdez, 1952	256
Genus <i>Hyalinea</i> Hofker, 1951	256

Family Cibicididae Cushman, 1927	259
Genus <i>Cibicides</i> de Montfort, 1808	259
Genus <i>Lobatula</i> Fleming, 1828	261
Family Acervulinidae Schultze, 1854	263
Genus <i>Planogypsina</i> Bermúdez, 1952	263
Family Epistomariidae Hofker, 1954	265
Genus <i>Pseudoeponides</i> Uchio, 1950	265
Family Nonionidae Schultze, 1854	267
Genus <i>Haynesina</i> Banner & Culver, 1978	267
Genus <i>Nonion</i> de Montfort, 1808	271
Genus <i>Nonionella</i> Cushman, 1926	275
Genus <i>Protelphidium</i> Haynes, 1956	284
Genus <i>Astrononion</i> Cushman & Edwards, 1937	288
Genus <i>Melonis</i> de Montfort, 1808	290
Genus <i>Pullenia</i> Parker & Jones, 1862	294
Family Gavelinellidae Hofker, 1956	296
Genus <i>Gyroidinoides</i> Brotzen, 1942	296
Genus <i>Hanzawaia</i> Asano, 1944	298
Family Trichohyalidae Saidova, 1981	302
Genus <i>Buccella</i> Andersen, 1952	302
Family Rotaliidae Ehrenberg, 1839	309
Genus <i>Pararotalia</i> Le Calvez, 1949	309
Genus <i>Ammonia</i> Brünnich, 1772	311
Genus <i>Pseudorotalia</i> Reiss & Merling, 1958	335
Genus <i>Rotalidium</i> Asano, 1936	337
Genus <i>Rotalinoides</i> Saidova, 1975	339
Subfamily Ammoniinae Saidova, 1981	341
Genus <i>Hemirootalia</i> nov. gen	341
Family Elphidiidae Galloway, 1933	348
Genus <i>Criboelphidium</i> Cushman & Brönnimann, 1948	348
Genus <i>Cribrononion</i> Thalmann, 1947	353
Genus <i>Elphidium</i> de Montfort, 1808	356
References	379
Systematic Index	397

Order Astrorhizida Brady, 1881

Family Saccamminidae Brady, 1884

Genus *Lagenammina* Rhumbler, 1911

Lagenammina atlantica (Cushman, 1944) (Fig. 1)

Proteonina difflugiformis Cushman & Parker (non Brady), 1931, p. 2, pl. 1, Fig. 1.

Proteonina atlantica Cushman, 1944, p. 5, pl. 1, Fig. 4; Parker et al., 1953, p. 11, pl. 1, Fig. 4; Boltovskoy, 1959, p. 39, pl. 1, Fig. 1; Micropaleontology Group in Marine Geology Department of Tongji University, 1978, p. 68, pl. I, Figs. 1, 6; Wang et al., 1980, p. 197, pl. XI, Fig. 1; Zheng, 1988, p. 33, pl. IX, Fig. 2.

Proteonella atlantica (Cushman), Fursenko et al., 1979, p. 9, pl. 1, Figs. 7, 8; Zheng, 1988, p. 33, pl. 9, Fig. 2.

Lagenammina atlantica (Cushman, 1944), Lankford & Phleger, 1973, p. 123, pl. 1, Fig. 1; Snyder, 1990, p. 264, pl. 1, Fig. 4; Ujiie, 1995, p. 55, pl. 1, Fig. 16; Zheng & Fu, 2001, p. 235, pl. VI, Figs. 9, 10.

Measurement

Specimens	Body length (μm)	Body width (μm)	Body thickness (μm)
H30-01	451	250	250
H30-02	466	277	277
H30-03	523	323	323
H30-04	533	330	330

Occurrence and Ecology

The Yellow Sea (St CJ-04, St 3400-05, St 3500-02, St 3500-06, St 3500-10, St 3600-02, St 3600-04, St 3800-02, St 3875-01, St 3875-03, St B-03) (32°10'–38° 44' N, 120°00'–127°00' E), water depth 30.00–81.00 m, temperature 7.39–17.02 ° C, salinity 30.82–33.39 ‰, abundance 0.08–33.84 ind./g sed.