Checklist and annotated bibliography of Recent Foraminiferida from the German Baltic Sea coast

(Figs 1–6; Tables 2)

Abstract. There are 96 Recent foraminiferal species reported from the German sector of the Baltic Sea. All are benthic taxa. Most species are agglutinated forms, reflecting the brackish water conditions of the southern Baltic Sea. Decreasing diversity is visible following the salinity gradient along the coast from the west to the east. The associations of the deeper water below the halocline and of shallow water above are very different with higher diversity in the deeper water. A complete species list and annotated bibliography for Recent foraminiferal species from the brackish water of the German Baltic Sea coast are presented.

Key words: Baltic Sea, brackish water, benthic foraminifera, biogeography, biodiversity, checklist, bibliography.

INTRODUCTION

Foraminiferida (Granuloreticulosea) are an important, abundant and highly diverse taxon distributed from the abysses of the world’s oceans up to the supralittoral of the sea coasts. Information on their distribution in the Baltic Sea is scarce because of weak research interest caused by the low abundance and low diversity of foraminifers in these brackish waters. To date there are only a few papers giving a general overview about the Baltic foraminiferal fauna (Brodniewicz, 1965; Lutze, 1965; Saidova, 1982; Hermelin, 1987). These papers concern almost exclusively the deep waters of the inner Baltic Sea. All other publications on foraminifers from the Baltic Sea are regional studies, scattered mostly in a broad range of regional journals or even unpublished theses and reports.

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The German coast is a region with a high number of publications and studies on foraminifers from the Baltic Sea (53 publications and 6 theses). Exceptionally well documented is the Kiel Bight, where especially in the 1960s and 70s, many studies were initiated by the research group of G. F. Lutze of Kiel University. A present project about the ostracods and foraminifers of the southern Baltic Sea and their use as bio-indicators sponsored by the German Federal Environmental Foundation (DBU) and housed at the University of Rostock enhances the collection of data on distribution and ecology of foraminifers in the study area. Hence, our knowledge about the associations at the eastern part of the German Baltic coast, where only two modern studies (Kreisel & Leipe, 1989; Frenzel, 1996) and three old ones (Schulze, 1874, 1875a, Stammer, 1928) existed before, is increasing remarkably (Frenzel & Oertel, 2002; Frenzel & Tech, 2004; Frenzel, in press; Bartholdy et al., this volume; present paper).

The last checklist for the foraminifers of the German Baltic Sea coast was given by Rhumbler in 1940 who concluded (p. 21) that “a detailed study of the Baltic Sea foraminifers would be highly appreciated.” The present paper gives an overview about the foraminiferal taxa of the German part of the Baltic Sea coast (Fig. 1) and presents an annotated bibliography for this group and area. This could be a base for further studies as well as a data file for biogeographic comparisons with other regions.

STUDY AREA

The Baltic Sea is a giant estuary bound to the marine influence of the North Sea through narrow and shallow straits (Belts and Sund) in the south-western part only (Fig. 1). The inner Baltic Sea is subdivided into several basins separated by shallower sills. The salinity of the brackish water sea depends mainly on the direction and intensity of prevailing winds, causing the temporary influx of saltier water into the basins of the inner Baltic Sea. The salinity is very variable in small time scales and decreases in general towards the north-east (Matthäus, 1996a; see below). The tidal influence is not remarkable with a maximum of 15 cm (Lass & Magaard, 1996). The water column shows a vertical thermohaline layering, with a homohaline upper layer of lower salinity, a transition layer with downward rapidly increasing salinity and decreasing temperature and a deeper water body with higher salinity and relatively stable low temperature. A repeated layering by successive intrusions of water of different temperature and salinity is also possible in the central Baltic Sea (Matthäus, 1996a). The surface layer is strongly influenced by seasonal temperature changes. Its thickness increases in general from west to east, with about 10 m in the eastern Kiel Bight, 15 to 20 m in the outer Mecklenburg Bight and 30 to 35 m in the Arkona Basin (estimation from monitoring data for the years 1991–2000; personal communication by H. U. Lass, Baltic Sea Research Institute Warnemünde). The bottom water body suffers often from oxygen deficiency through low exchange rates and a high input of nutrients causing algal and cyano-
bacterial blooms in the surface layer and an export of organic matter into the deeper water (Matthäus, 1996b).

The German coast is situated in the south-western part of the Baltic Sea, close to the saltwater pathway of the Belt Sea. The westernmost part is the Kiel Bight (Fig. 1) with direct connection to the Belts, where the main saltwater input into the inner Baltic Sea comes through. It shows a surface water salinity of 13–18 (psu) and deep water salinity of 17–22 (psu) in its southern part (Lutze, 1965). The Mecklenburg Bight is separated from the Kiel Bight by the Fehmarn Belt and from the Arkona Sea by the Darss Sill. Here the salinity is 12–14 (psu) in the surface water and 19–21 (psu) in the deeper water (Niedermeyer et al., 1995). The Pomeranian Bight has contact to the Arkona Basin in the north and is a part of the Arkona Sea. The salinity of the surface water in the Arkona Basin and the Pomeranian Bight is about 8 (psu) (Niedermeyer et al., 1995). The deeper water of the Arkona Basin has

Fig. 1. The study area in the Baltic Sea. Salt water input from the North Sea comes through the Belt Sea (Great Belt mainly) and in a lesser degree through the Sund (Øresund)
a salinity of 12–17 (psu) and shows a temperature of less than 10 °C (Lutze, 1965). The sediments in the Kiel Bight area varied but are dominated by mud in the deeper parts of the Mecklenburg Bight and Arkona Basin (Lutze, 1965). Sands prevail in the shallower regions, with the exception of semi-enclosed lagoons and some estuaries where mud builds up the ground.

MATERIAL AND METHODS

The following list is based on papers given in the bibliography as well as our own observations (as yet unpublished) in and around the Mecklenburg and Pomeranian Bight. All documented foraminifers derive from superficial sediment (uppermost 1–2 cm in most cases) and were stained with Rose Bengal in general to distinguish between living individuals and empty tests. They were picked from dried residues mainly. Our own data set comprises about 160 stations checked for foraminifers between 1990 and 2004 and situated along the coast of Mecklenburg-Vorpommern. This material is still in investigation. The literature data give information for more than 1000 stations sampled mainly between the middle of the 1960s and 1990s. Hence, our picture of foraminiferal distribution is puzzled from different times and regions and gives a more general picture of the whole study area because of the temporal variability of environmental factors causing changing distribution patterns.

Most information on allogromiids is from the second half of the 19th century and is urgently in need of revision. Our placement of the old taxa into a modern classification is an attempt only, based on descriptions and pictures from the literature. The naturalists of the 19th century used a different method of sampling than we did: They put glass plates into the coastal water or into aquaria filled with Baltic Sea water and then watched these plates for foraminifers and other protists attached to the surfaces.

Calcium carbonate is highly soluble in the cold brackish water. Therefore, the fossilisation potential for calcareous foraminifers is limited. It depends strongly on sedimentation rates, bioturbation and the circulation and characteristics of the pore waters within the sediment (Jarke, 1961). Another problem is the redeposition of fossil and subfossil foraminiferal tests of mainly Late Cretaceous, Pleistocene and Holocene age. Whereas Late Cretaceous forms are easily recognizable, it is more difficult for Quaternary forms, especially those from the Holocene age. It may be that some of the very rare and less documented species are not living in the area today.

CHECKLIST

The abbreviations behind the species show their distribution along the German Baltic Sea coast: KB = Kiel Bight including Fehmarn Belt and part of Belt Sea, MB = Mecklenburg Bight up to the Darss Sill, PB = Pomeranian Bight up to the Darss Sill including southern Arkona Basin; dw = deep water (below the halocline), sw = shallow water (above the halocline), e = estuarine and semi-enclosed lagoons with
lowered salinity or salt marshes. Subfamilies are given only where species of different subfamilies within a family are present. Main taxa are figured in Figs 2–4.

Order Foraminiferida Eichwald, 1830

Suborder Allogromiina Loeblich and Tappan, 1961

Family Lagynidae Schultze, 1854
- Lagynis baltica Schultze, 1854 – KB, sw? (locality not stated)
- Lagynis parvum Schultze, 1875a – KB, MB, sw
- Lagynis truncata Schulze, 1875a – KB, MB, sw
- Myxotheca arenilega Schaudinn, 1893 – KB, dw
- Pilalla exigua Rhumbler, 1935 – KB, dw
- Schultzella stercomifera Rhumbler, 1935 – KB, dw

Family Allogromiidae Rhumbler, 1904

Subfamily Allogromiinae Rhumbler, 1904
- Lieberkuhnia gracilis (Möbius, 1889) – KB, sw
- Allogromia ovoides Rhumbler, 1904 – KB, sw, dw
- “Lithocolla” globosa Schulze, 1874 – KB, MB, sw? (locality not stated)
- Pleurophrys? (lageniformis Schulze, 1875a – KB, MB, sw

Subfamily Shepheardellinae Loeblich & Tappan, 1984
- Shepheardella enconmatophila Krumbiegel, 1928 – KB, dw

Subfamily Argillotubinae Avnimelech, 1952
- Micatuba flexilis (Höglund, 1947) – KB, e

Suborder Astrorhizina Jivorec, 1953

Superfamily Astrorhizacea Brady, 1881

Family Astrorhizidae Brady, 1881

Subfamily Astrorhizinae Brady, 1881
- Saccodendron heronalleni Rhumbler, 1935 – KB, dw

Subfamily Vanhoeffenellinae Saidova, 1981
- Amphifenestrella wiesneri Rhumbler, 1935 – KB, dw
- Vanhoeffenella gaussi Rhumbler, 1905 – KB, dw

Family Rhabdamminidae Brady, 1884
- Rhizammina algaeformis nuda Rhumbler, 1935 – KB, dw

Family Hippocrepinellidae Loeblich & Tappan, 1984
- Hippocrepinella heron-alleniheron Allen & Earland, 1932 – KB, dw

Family Psammosphaeridae Haeckel, 1894
- Psammophaera frankei (Rhumbler, 1935) – KB, sw, e
- Psammophaera fusca Schulze, 1875b – KB, dw
- Psammophaera sp. sensu Lehmann 2000 – KB, e

Family Saccamminidae Brady, 1884

Subfamily Saccammininae Brady, 1884
- Ovammina opaca Dahlgren, 1962 – KB, e
- Ovammina sp. sensu Lehmann 2000 – KB, e
- Saccammina decorata (Earland, 1933) – KB, dw

Subfamily Thurammininae Miklukho-Maklay, 1963
- Astrammina sphaerica (Heron-Allen & Earland, 1932) – KB, MB, PB, dw
- Leptodermella turbanica Rhumbler, 1935 – KB, dw (one specimen only!)
- Leptodermella sp. sensu Rottgardt 1952 – KB, e
- “Hippocrepinella” virgulata Rhumbler, 1935 – KB, dw (single specimen only!)

Family Polysaccamminidae Loeblich & Tappan, 1984
- Polysaccammina ipohalina Scott, 1976 – KB, e

Family Hemisphaeramminidae Loeblich & Tappan, 1961

Subfamily Hemisphaerammininae Loeblich & Tappan, 1961
- Hemisphaerammina earlandi (Rhumbler, 1935) – KB, dw
**Hemisphaerammina hemisphaerica** (Jones, Parker & Brady) – KB, dw (two specimens only)

**Tholosina bulla** (Brady, 1881) – KB, sw, dw

**Tholosina protea** Heron-Allen & Earland, 1932 – KB, sw, e

**Tholosina vesicularis** (Brady, 1879) – KB, dw

Subfamily Crititionininae Hofker, 1972

**Crititionina heinckei** Rhumpler; 1928 – KB, dw

**Subfamily Hippocrepininae Cushman, 1927**

**Hippocrepina flexibilis** (Wiesner, 1931) – KB, MB, PB, dw

**Hippocrepina indivisa** Parker, 1870 – KB, dw (one specimen only!)

Superfamily Ammodiscacea Reuss, 1862

**Family Ammodiscidae Reuss, 1862**

**Ammodiscus rhumbleri** Rottgardt, 1952 – KB, sw, dw

**Ammodiscus slesvicus** Rottgardt, 1952 – KB, e

Suborder Haplophragmiina Wedekind, 1937

**Superfamily Rzehakinacea Cushman, 1933**

**Rzehakininae Cushman, 1933**

**Miliammina fusca** (Brady, 1879) – KB, MB, PB, sw, (dw)

**Subfamily Hormosininae Cushman, 1927**

**Nodulina dentaliformis** (Brady, 1881) – KB, MB, PB, dw

**Neoplagia mansoni** (Brady, 1879) – KB, dw (three specimens only!)
Fig. 2. Calcareous foraminifers from the German Baltic Sea coast. 1 – *Cribroelphidium incertum* (Williamson, 1858), southern Mecklenburg Bight, side view; 2 – *Cribroelphidium gunteri* (Cole, 1931), southern Mecklenburg Bight, side view; 3 – *Cribroelphidium excavatum* (Terquem, 1875), southern Mecklenburg Bight, side view; 4 – *Quinqueloculina seminulum* (Linnaeus, 1758), central Mecklenburg Bight, side view; 5 – *Ammonia batava* Hofker, 1931, southern Mecklenburg Bight, umbilical view; 6 – *Ophthalmina kilianensis* Rhumbler, 1936, central Mecklenburg Bight, side view; 7 – *Cribroelphidium albiumbilicatum* (Weiss, 1954), Wismar Bight, side view; 8 – *Cribroelphidium williamsoni* (Haynes, 1973), Wismar Bight, side view; 9 – *Haynesina germanica* (Ehrenberg, 1840), Wismar Bight, side view; 10 – *C. albiumbilicatum*, Wismar Bight, side view.
Fig. 3. Agglutinated foraminifers from the German Baltic Sea coast (part 1). 1, 2 – *Trochammina inflata* (Montagu, 1808), 1: Salzhauff, spiral view; 2: Strelasund, umbilical view; 3 – *Jadammina polystoma* (Bartenstein & Brand, 1938), Salzhauff, umbilical view; 4 – *Ammoscalaria raniana* (Heron-Allen & Earland, 1916), southern Mecklenburg Bight, side view; 5 – *Eggerelloides scabrus* (Williamson, 1858), southern Arkona Basin, side view; 6 – *Haplophragmoides manilaensis* Andersen, 1953, Salzhauff, side view; 7, 8 – *Balticammina pseudomacrescens* Brönnimann, Lutze & Whittaker, 1989, 7: Strelasund, spiral view; 8: Warnow estuary at Rostock, umbilical view; 9 – *Haplophragmoides wilberti* Andersen, 1953, oblique apertural view, Strelasund
Subfamily Jadamininae Saidova, 1981

*Balticammina pseudomacrescens* Brönnimann, Lutze & Whittaker, 1989 – KB, MB, e

*Jadammina polystoma* Bartenstein & Brand, 1938 – KB, MB, e

Subfamily Arenoparrellinae Saidova, 1981

*Arenoparrella mexicana* (Kornfeld, 1931) – KB, e

Suborder Textulariina Delage et Hérouard, 1986

Superfamily Textulariaceae Ehrenberg, 1838

Family Eggerellidae Cushman, 1937

*Eggerelloides scabrus* (Williamson, 1858) – KB, MB, dw

*Martinottiella gracilis* (Cushman & Brönnimann, 1948) – KB (without location)

Suborder Spirillinina Hohenegger & Piller, 1975

Family Spirillinidae Reuss & Fritsch, 1861

*Spirillina vivipara* Ehrenberg, 1843 – KB, sw

Suborder Miliolina Delage & Hérouard, 1896

Superfamily Cornuspiracea Schultze, 1854
Family Cornuspiridae Schultze, 1854
Cornuspira involvens (Reuss, 1850) – KB, sw (single specimen only)

Family Fischerinidae Millett, 1898
Glomulina fistulescens Rhumbler, 1936 – KB, dw (a few specimens only)

Family Ophthalmidiidae Wiesner, 1920
Ophthalmina kilianensis Rhumbler, 1936 – KB, dw, sw; MB, dw

Superfamily Mioliacea Ehrenberg, 1839
Family Spiroloculinidae
Spiroloculina hyalina Schulze, 1875a – KB, e, sw; MB, e

Family Hauerinidae Schwager, 1876
Subfamily Hauerininae Schwager, 1876
Pateoris hauerinoides (Rhumbler, 1936) – KB, dw
Quinqueloculina seminulum (Linnaeus, 1758) – KB, MB, dw
Quinqueloculina subrotunda (Montagu, 1803) – KB, dw

Subfamily Miliolinellinae Vella, 1957
Miliolinella labiosa (d’Orbigny, 1839) – KB, sw
Triloculina circularis Rhumbler, 1936 – KB, dw
Triloculina oblonga (Montagu, 1803) – KB, e

Subfamily Sigmoilinitinae Luczkowska, 1974
Sigmoilina sigmoidea (Brady, 1884) – KB, dw (rare)

Suborder Lagenina Delage & Hérouard, 1896
Superfamily Nodosariacea Ehrenber, 1838
Family Polymorphinidae d’Orbigny, 1839
Globulina gibba d’Orbigny, 1825 – KB, dw
Guttulina lactea (Walker & Jacob, 1798) – KB, dw
Guttulina spicaeformis? (Roemer, 1838) – KB, dw (a few specimens only)
Pyrolina thouini (d’Orbigny) – KB, dw (one specimen only!)

Family Glandulinidae Reuss, 1860
Subfamily Glandulininae Reuss, 1860
Laryngosigma hyalascidea Loeblich & Tappan, 1953 – KB, MB, dw
Subfamily Entolingulininae Saidova, 1981
Entolingulina sp. – KB, sw

Suborder Rotaliina Delage & Hérouard, 1896
Superfamily Buliminacea Jones, 1875
Family Buliminellidae Hofker, 1951
Buliminella elegansitissa (d’Orbigny, 1838) – KB, dw (one mention only)

Superfamily Discorbacea Ehrenberg, 1838
Family Rosalinidae Reiss, 1963
Rosalina sp. A sensu Lutze 1974 – KB, sw

Superfamily Planorbulinacea Schwager, 1877
Family Cibicididae Cushman, 1927
Lobatula vulgaris Fleming, 1828 – KB, dw

Superfamily Asterigerinacea d’Orbigny, 1839
Family Asterigerinatidae Reiss, 1963
Eoeponidella pulchella (Parker, 1952) – KB, sw

Superfamily Nonionacea Schultze, 1854
Family Nonionidae Schultze, 1854
Haynesina depressula (Walker & Jakob, 1798) – KB, MB, PB, e (determination uncertain!)
Haynesina germanica (Ehrenberg, 1840) – MB, sw

Superfamily Rotaliacea Ehrenberg, 1839
Family Rotaliidae Ehrenberg, 1839
Ammonia bataova Hofker, 1951 – KB, MB, sw, e; PB, sw
Ammonia beccarii (Linnaeus, 1758) – KB, MB, dw

Family Elphidiidae Galloway, 1933

Cribroelphidium albiumbilicatum (Weiss, 1954) – KB, MB, dw, sw, e; PB, dw, sw
Cribroelphidium asklundi (Brotzen, 1946) – KB, MB, PB, sw, (dw)
Cribroelphidium excavatum (Terquem, 1875) – KB, MB, PB, sw (f. selseyensis), dw (f. clavatum)
Cribroelphidium gerthi (Voorthuysen, 1957) – KB, MB, sw
Cribroelphidium gunteri (Cole, 1931) – MB, PB, sw, e
Cribroelphidium incertum (Williamson, 1858) – KB, dw, sw; MB, PB, dw
Cribroelphidium williamsoni (Haynes, 1973) – KB, MB, PB, sw, e

DIVERSITY

There are 96 reported species of foraminifers in the German sector of the Baltic Sea. A slight decrease in the total number of species could be noted after a critical evaluation of older taxa, especially those reported and described by Rhumbler (1935, 1936). The diversity (Fisher $\alpha$ index) of single stations lies mostly below 1 and does not exceed 2.

The salinity gradient running from the west to the east in the southern Baltic Sea causes a similar diversity and abundance trend within the foraminiferal fauna (see Table 1 and Fig. 5). There are 94 species living in shallow and deeper water along the coast of Schleswig-Holstein in the west and only 33 species at the coast of Mecklenburg Bight and even fewer (15 species) in the Arkona basin and Pomeranian Bight in Mecklenburg-Vorpommern in the east. The highest number of species can be found in the deeper water, where higher salinity values and relatively stable environmental conditions occur (Table 1). The shallow water of the open sea and

<table>
<thead>
<tr>
<th>Environment</th>
<th>Kiel Bight and Fehmarn Belt</th>
<th>Mecklenburg Bight</th>
<th>Pomeranian Bight and Arkona basin</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep water</td>
<td>133 + 18 = 51</td>
<td>7 + 8 = 15</td>
<td>5 + 4 = 9</td>
<td>34 + 18 = 52</td>
</tr>
<tr>
<td>Shallow water</td>
<td>14 + 15 = 29</td>
<td>6 + 8 = 14</td>
<td>1 + 6 = 7</td>
<td>14 + 17 = 31</td>
</tr>
<tr>
<td>Estuaries</td>
<td>23 + 6 = 29</td>
<td>7 + 6 = 13</td>
<td>3 + 3 = 6</td>
<td>24 + 6 = 30</td>
</tr>
<tr>
<td>Total</td>
<td>64 + 30 = 94</td>
<td>18 + 15 = 33</td>
<td>7 + 8 = 15</td>
<td>64 + 32 = 96</td>
</tr>
</tbody>
</table>

The calculation is based on the presented bibliography and, in addition to this, on our as yet unpublished distribution data on the coast of Mecklenburg-Vorpommern. Deep water means habitats below the halocline in the open Baltic Sea and its straits. Shallow water describes localities above the halocline, normally nearshore. The class “Estuaries” includes localities within the estuaries and in semi-enclosed lagoons along the coast. We regard the Darss sill as the border between the Mecklenburg Bight and the region of the Arkona Basin and Pomeranian Bight, the Fehmarn Belt as the border between the Kiel and the Mecklenburg Bight.
the estuaries, lagoons and salt marshes shows a similar number of species. There are only a few species common to both deep and shallow water, pointing to distinctly different environmental conditions related to the strong salinity gradient.

The agglutinated species are in general dominant in abundance as already reported by Lutze (1965) and Brodniewicz (1965). However, they show a decreasing proportion of species with decreasing salinity. On the other hand, the estuaries and salt marshes are characterized by a higher proportion of agglutinated taxa (Fig. 6). This is probably caused by high carbonate dissolution rates in those sediments very rich in organic matter.

Two species were found at the coast of Mecklenburg-Vorpommern in the east only: *Haynesina germanica* and *Cribroelphidium gunteri* which are missing in the Kiel Bight area. We suppose that both species were misinterpreted in the west so far. There are several published reports of *Haynesina depressula*, which could be *H. germanica* instead. *C. gunteri* is rare in our samples and may have been misinterpreted in the Kiel Bight area as *C. williamsoni*, which is much more abundant and is normally associated with *C. gunteri*. We can state a general decrease of foraminiferal species number along the salinity gradient to the east and without species restricted to these eastern regions.

**Associations**

Main taxa in the oligohaline to lower mesohaline salinity range of the German coast are *Miliammina fusca, Cribroelphidium williamsoni* and trochamminids. The principal factor affecting their distribution is the character of the substrate. Trochamminids are typically found in phytal habitats and in sediment with plant detri-
M. fusca lives on sediment stations and is the most abundant foraminiferal species of the shallow water in general. The lowermost documented salinity limit for the foraminifers is about 5 (psu) in the study area – we found living (stained) trochamminids and C. williamsoni in the Barther Bodden in a reed fringe.

In detail Lehmann (2000) described the foraminifers of a salt marsh in the Bottsand lagoon, Schleswig-Holstein. He found a special fauna, with Trochammina inflata, Haplophragmoides manilaensis, M. fusca and Tiphotrocha comprimata as the most abundant species.

The shallow water above the halocline in the open Baltic Sea is dominated by Cribroelphidium excavatum f. selseyensis in the Kiel and Mecklenburg Bight. Other abundant taxa are C. albiumbilicatum/asklundi, M. fusca and Haynesina germanica, the latter at least in the Mecklenburg Bight.

The substrate of the open Baltic Sea below the halocline is settled mainly by Ammotium cassis and Cribroelphidium excavatum f. clavatum. Other important species are Cribroelphidium incertum and Nodulina dentaliformis. Under higher salinity conditions, Eggerelloides scabrus plays an important role, too.

Murray (1991) distinguishes eight principal associations typical for lagoons and estuaries and five marsh associations at the European Atlantic coast based on literature data. Five of these associations are also found in the Baltic Sea (Table 2). Two additional associations are documented by Lutze (1965) and are listed by Murray (1991) as minor associations (Table 2). The lower salinity limit of the E. williamsoni and M. fusca associations does not seem to apply to the inner Baltic Sea. They could not be found below 5 (psu). This may be because the higher salinity levels necessary for reproduction are not reached in this microtidal environment during hydrographical variation.
Table 2

Foraminiferal associations of the inner Baltic Sea arranged in order of increasing continental character of habitats. The values and habitat descriptions are from Murray (1991) and Lutze (1965) respectively. The associated species are from Lutze (1965) and own observations.

<table>
<thead>
<tr>
<th>No.</th>
<th>Association</th>
<th>Associated species</th>
<th>Described by</th>
<th>Salinity range (psu)</th>
<th>Temperature range [°C]</th>
<th>Water depth [m]</th>
<th>Substrat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ammotium cassis</td>
<td>Cribroelphidium excavatum f. clavata, Cribroelphidium incertum, Nodulina dentaliformis, Ammoscalaria runiana, Egerella scabra, Haynesina germanica</td>
<td>Murray, 1991</td>
<td>17-29</td>
<td>0-19</td>
<td>4-30</td>
<td>sediments rich in organic matter</td>
</tr>
<tr>
<td>2</td>
<td>Eggerelloides scabrus</td>
<td>Cribroelphidium excavatum f. clavata, Ammotium cassis, Ammoscalaria runiana, Cribroelphidium incertum, Haynesina germanica</td>
<td></td>
<td>17-29</td>
<td>1-20</td>
<td>1-30</td>
<td>sand and mud</td>
</tr>
<tr>
<td>3</td>
<td>Cribroelphidium albiumbilicatum</td>
<td>Cribroelphidium excavatum f. clavata, Nodulina dentaliformis</td>
<td>Lutze, 1965 (minor associations in Murray, 1991)</td>
<td>12-28</td>
<td>2-12</td>
<td>20-25</td>
<td>sediment</td>
</tr>
<tr>
<td>4</td>
<td>&quot; Reophax &quot; (Nodulina dentaliformis)</td>
<td>Ammotium cassis, Cribroelphidium excavatum f. clavata, Cribroelphidium albiumbilicatum</td>
<td></td>
<td>13-17</td>
<td>2-12</td>
<td>&gt;15</td>
<td>mud</td>
</tr>
<tr>
<td>5</td>
<td>Cribroelphidium excavatum</td>
<td>Cribroelphidium incertum, Ammonia batavus, Haynesina germanica</td>
<td></td>
<td>12-21</td>
<td>4-17</td>
<td>&lt;16</td>
<td>sediments and algae</td>
</tr>
<tr>
<td>6</td>
<td>Cribroelphidium williamsoni</td>
<td>Miliammina fusca, Ammonia batavus, Jadammina polystoma, Trochammina inflata, Cribroelphidium excavatum f. seleyensis</td>
<td>Murray, 1991</td>
<td>2-35</td>
<td>0-32</td>
<td>&lt;2</td>
<td>silty to sandy sediment and phytal</td>
</tr>
<tr>
<td>7</td>
<td>Miliammina fusca</td>
<td>Cribroelphidium excavatum f. seleyensis, C. williamsoni, Ammolium salsum, Ammonia batavus, Trochammina inflata</td>
<td></td>
<td>0-35</td>
<td>0-20</td>
<td>0-2</td>
<td>silt</td>
</tr>
<tr>
<td>8</td>
<td>Balticammina pseudomacrescens</td>
<td>Cribroelphidium williamsoni, Trochammina inflata</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>brackish</td>
</tr>
<tr>
<td>9</td>
<td>Trochammina inflata</td>
<td>Balticammina pseudomacrescens, Cribroelphidium williamsoni, Miliammina fusca</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>salt marsh</td>
</tr>
</tbody>
</table>

Muddy silts rich in plants debris
Some associations from Murray’s (1991) compilation and missing from our study area need higher salinities as given in the southern Baltic Sea, which explains their absence. Exceptions are his *Ammonia beccarii* association and his *Haynesina germanica* association. Both species occur in the study area but are not dominating. Subfossil associations of Holocene Litorina stage sediments from the Isle of Usedom (Pomeranian Bight), the Strelasund (a strait between the Isle of Rügen and the mainland of Mecklenburg-Vorpommern) and Rosenhof (close to the Fehmarn Belt) show assemblages with dominating *A. beccarii* and *H. germanica*. The accompanying fauna reflects higher salinity conditions than today. We suppose that both species are not dominating today because of the low salinity, which is relatively stable in comparison with macrotidal environments (cf. higher salinity minimum for *E. williamsoni* and *M. fusca* as given above).

The pattern of foraminiferal distribution in the inner Baltic Sea is not found within the general models of foraminiferal distribution in estuaries and lagoons given by Debenay *et al.* (2000) because they did not incorporate temperate microtidal brackish water environments.

Concluding, we state that the foraminiferal associations of the Baltic Sea are representative for marginal marine brackish water environments and comparable with associations from such environments but show a special situation caused by the microtidal reaction of a large restricted water body.

**Outlook**

The distribution of foraminifers in the Baltic Sea is better known in the west. Concerning the east, our knowledge is scarce. We need more data about their distribution in the study area, especially in the Pomeranian Bight. A look into the older literature confirms the occurrence of species of Allogromiina in our region. However, the taxonomy is confused and based on only a few localities. This is due to the fact that most earlier studies were carried out by palaeontologists, more interested in hard tests than soft parts. Most allogromiids collapse when dried. A taxonomic review and further studies are necessary. Taxonomical work is also needed on Rotaliidae. This includes the discrimination between morphologically similar species as well as the higher systematics of this group with classical and molecular phylogenetic work.

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surface sediments of two stations in the Pomeranian Bight]

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