eEarth Discuss., 2, S204–S218, 2008
www.electronic-earth-discuss.net/2/S204/2008/

eEarth Discussions

eED

2, S204–S218, 2008

Interactive Comment

Interactive comment on "Environmental response of living benthic foraminifera in Kiel Fjord, SW Baltic Sea" *by* A. Nikulina et al.

A. Nikulina et al.

Received and published: 18 April 2008

Response to comments by Reviewers

A. Nikulina, I. Polovodova, J. Schönfeld

We are grateful to Frans Jorissen and Peter Frenzel for their reviews, which helped us to significantly improve our manuscript. The most important changes were done in the introduction and discussion. As the both reviewers recommended, we prepared Supplementary material, which contains the sampling stations list, foraminiferal census data from present and Lutze's studies, living-dead ratio of benthic foraminifera, foraminiferal images and a correlation matrix of sediment geochemical parameters and foraminiferal percentages. The new faunal reference list includes now more recent references.

Response to comments by Reviewer 1 (Frans Jorissen)

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

1. Title: We agree that the title might be incorrect and changed it to "Foraminiferal response to environmental changes in Kiel Fjord (south-western Baltic Sea)"

2. More references about forams and pollution are needed: We extended the introduction in order to give a more detailed description of foraminiferal distribution and its controls in the south-western Baltic Sea. Further, we summarized more accurately the effects of pollution on benthic foraminifera:

Ecological observations of foraminifera were initiated by Rhumbler (1935), who used rather descriptive than quantitative methods of investigation. Next, Rottgardt (1952) distinguished three different foraminiferal assemblages in the Baltic Sea which are distributed according to the salinity pattern: marine, brackish-marine (fjords and shallow areas of the Kiel Bight), and brackish faunas. A detailed taxonomical and ecological overview on benthic foraminifera in the south-western Baltic Sea was provided by Lutze (1965), who found out that temperature and salinity rather than substrate were the main ecological controls on foraminiferal distribution in this area. Vise versa, Wefer (1976) observed that the abundances of foraminifera in sediments off Bokniseck (open Kiel Bight) were regulated by substrate features, hydrodynamics and oxygen content of the bottom water. Foraminiferal food preferences in the open Kiel Bight were described by Schönfeld and Numberger (2007b), who reported two reproduction events of Elphidium excavatum clavatum following the spring bloom and suggested the "bloom-feeding"; strategy of this species. The benthic foraminiferal distribution in Kiel Fjord has been left out of sight, with the exception of 4 stations investigated by Lutze in 1962-1963, which were taken as reference points for our study. Over the 20th century, Kiel Fjord has experienced a strong anthropogenic impact. For monitoring purposes, the foraminiferal response to environmental changes attracts attention under the aspect of rising ecological problems.

A number of studies addressed the foraminiferal reactions to changing environmental parameters as salinity, temperature, oxygen, food availability, pH, (e.g. Bradshaw, 1957, 1961; Boltovskoy et al., 1991; Moodley and Hess, 1992; Alve and Murray 1999;

eED

2, S204–S218, 2008

Stouff et al., 1999ab; Gustafsson and Nordberg 2001; Le Cadre and Debenay, 2003), contamination by trace metals (Ellison et al., 1986; Sharifi et al., 1991; Alve, 1991; Alve and Olsgardt, 1999; Yanko et al., 1998; Debenay et al., 2001) and sewage effluents (e.g. Watkins, 1961; Schafer, 1973; Tomas et al., 2000). A decrease of population density, reproduction capability, enhanced mortality, and increasing frequency of test abnormalities were observed under the high trace metal or organic matter levels (Schafer, 1973; Samir & El Din, 2001; Bergin et al., 2006; Burone et al., 2006; Ernst et al., 2006; Di Leonardo et al., 2007). On the other hand, it was shown that populaion density of foraminifera might increase in vicinity of sewage outfalls (Watkins, 1961; Tomas et al., 2000). Culture experiments revealed that A. beccarii produces abnormal chambers at 10-20 microg/l of copper in seawater (Sharifi et al., 1991; Le Cadre & Debenay, 2006) and dies at concentrations exceeding 200 microg/l (Le Cadre & Debenay, 2006). Therefore, foraminifera appear to be a rather sensitive tool for the monitoring of pollution, though should be used with caution, because their distribution is determined by numerous environmental variables (Alve and Olsgardt; Stouff et al., 1999ab; 1999; Le Cadre & Debenay, 2006).

3. The description of pollution surveys in Kiel Fjord and their results were presented more precisely:

Despite the long-term anthropogenic load in study area, reports on the early history of pollution of Kiel Fjord are rare. Recently, the monitoring of metals concentration at a few stations in Kiel Bight by the Institute for Marine Research, Warnemünde (IOW) indicate no significant temporal trend in trace metal content for 1998-2000 with respect to the observed high inter annual variability (e. g. Nausch et al., 2003, Pohl et al., 2005). Kiel Fjord itself is considered by LANU (The Regional Environmental Protection Agency of the Bundesland Schleswig-Holstein) as one of the most important local hot spots of cadmium, lead, copper, and zinc contamination in the coastal waters of Schleswig-Holstein. In the year 2000 for instance, the concentrations of Cu, Zn and Pb in sediment fraction $<$20 microns were 82, 300 and 130 mg/kg in the inner fjord

eED
2, S204–S218, 2008

correspondingly (Haarich et al., 2003), whereas in outer fjord Cu, Zn and Pb content was estimated to 30, 210 and 60 mg/kg respectively (LANU archive). No clear temporal trend of metals concentrations in 1995-2004 is observed in sediments of Kiel Fjord. Extremely high concentrations of organically bound tin (407 - 2556 microg TBT-Sn/kg) were found in the fjord sediments; they are supposed to cause the aberrant changes in reproduction system of the periwinkle (LANU, 2001). High concentrations of Cu and Zn were found in fish (Senosack, 1995) and mussels (ter Jung, 1992) from the inner Kiel Fjord. But the organisms in the outer fjord showed the lowest metals content for all Schleswig-Holstein waters. Kiel Fjord has been affected by eutrophication induced by a high load of nutrient and organic carbon from the city and surrounding area (Gerlach, 1984). Herein, the nutrient concentrations and primary production showed a southward increase to the inner fjord (Schiewer and Gocke, 1995). The construction of a central treatment plant (Bülk, Klärwerk) in 1972 has reduced the input of nitrogen and phosphorus significantly (Kallmeyer, 1997, Rheinheimer, 1998), but the deep-water oxygenation improved not early than in the 1990s (Gerlach, 1996; Haarich et al., 2003; LANU, 2003). Nevertheless, oxygen deficiency may occur at specific weather conditions in the fjord regularly in late summer due to stable water stratification (Gerlach, 1990).

4. Methodological differences in 2006 and 1960s studies affecting the results:

We thank both reviewers to allow us to discuss the methodological differences of our and Lutze studies and their possible effects on the results. An additional section in the discussion appeals to this problem. Indeed, the dramatic changes in population density may be referred to discrepancy in taxonomy, sampling seasons, size fractions ($>$ 63 microns in this study and $>$100 microns by G.-F. Lutze) and study of the whole samples (in 2006) vs. concentrates by flotation (1960s). Fig.5 shows E. excavatum subspecies, lumped together in 1960s, as the dominant elements of the living fauna. E. incertum had higher abundances, whereas A. cassis and R. dentaliniformis were rare. Apparently Lutze recognised E. albiumbilicatum and E. gerthi as variants of E.

excavatum. Lutze's sampling campaign started in spring 1962 and continued until fall 1963. Regarding the difference in sample numbering (342 vs. 239), it well might be that sampling in the 1960s also comprised several seasons per year, as we did in the current study. In our case, the difference in size fraction seems to play a minor role, as it was shown that no living specimens smaller than 80 microns were observed in the western Baltic Sea (Schönfeld & Numberger, 2007a). Therefore it is unlikely that G.-F. Lutze missed or washed away a significant proportion of the fauna. Most residues of Lutze's samples contained a very few or no living specimens whereas the respective flotation concentrates were very rich. Thus, even if Lutze examined only concentrates but not the whole samples, his results on the population density would not differ by two orders of magnitude to the results we obtained in our 2006 survey. We consider the differences in methods to be of minor influence on the final results.

5. Reinspection of Lutze samples: The recalculated abundances of foraminifera are provided in fig. 5 and Supplement, table 2.

6. The taxonomical identification of Ammonia in Kiel Fjord:

We have already discussed in the response to review by Frans Jorissen. Morphologically Ammonia encountered in Kiel Fjord is close to the molecular types T1 and T2 described by Hayward et al. (2004, p. 256, pl. III-IV) originated from the Playa Balien (Cuba) and Venice Lagune. The only similar specimen, living under the similar ecological conditions as in Kiel Fjord, is group T6 from the German Wadden Sea illustrated by Holzmann (2006, p. 33, pl. 2, fig. 8ab). As we initiated the DNA analysis of some Ammonia individuals found in the Kiel Bight, we prefer to name it Ammonia beccarii until we get the results of the genetic analysis.

Most of the technical comments were followed as the reviewer suggested. The main of them are below:

p192, l14-15: Ammotium cassis disappeared, possibly due to low salinity that prevailed 10 years ago -> Ammotium cassis had disappeared that reflects apparently the

eED

2, S204–S218, 2008

Interactive Comment

changes in salinity over the last 10 years.

p193, l8: In view of rising ecological problems, the environmental response of benthic foraminifera comes into focus of investigation. -> For monitoring purposes, the foraminiferal response to environmental changes attracts attention under the aspect of rising ecological problems.

p194, l6: debouching into -> discharging fresh water into

p194, l10: may be as low as -> may decrease to

p198, l18: <But it apparently provided sufficient space and relatively good oxygen conditions for benthic foraminiferal populations> was deleted

p198, l24: the seasonal increase of Corg in March -> At fig. 2, the maps of organic compounds were redrawn, according to productional seasons in Kiel Fjord, to emphasize the seasonal changes though they were quite smooth.

p198, l21: The reviewer suggests to use the square R to express correlation. We prefer to use the correlation coefficient instead of the coefficient of determination. The first one provides additional information whether a correlation is positive or negative.

p199, l2: The reviewer request to add the C:N ratios in fig. 2 -> the C:N ratios distribution figure was incorporated in fig. 2.

p201, l21: Reviewer suggests that high Sn concentrations may result from the different methodologies. The metals contents compared in our study were obtained by the same methods, otherwise it was indicated. In order to focus on Kiel Fjord we changed the section: In the southwestern Baltic Sea, tin contents of 2 to 2.5 mg/kg were found (Cato and Kjellin, 2005). The concentrations of tin measured in the 1970s in Flensburg Fjord also did not exceed 2.5 mg/kg (Untersuchungen, 1973). With reference to these data, tin content in the inner part of Kiel Fjord has strongly elevated levels. -> In Kiel Fjord the concentration of tin in the sediment fraction $<$2000 microns (LANU archive) was 24 mg/kg in 2004 whereas in other fjords and bays of Kiel Bight it varied from 4 to 17

eED

2, S204–S218, 2008

mg/kg. Our measurements range from 0.2 to 18 mg/kg and confirm the elevated levels for the inner fjord.

p202, l9: A. beccarii and E. excavatum excavatum presumably substitute each other in Kiel Fjord -> The stations with a predominance of A. beccarii generally have a lower abundance of E. excavatum excavatum and vice versa. We do not recognize any physical, biological or chemical parameter that would explain this spatial change in dominance. But we cannot entirely rule out, that these species occupy different ecological niches. As such, we can presume a substitution of these species.

p203, l12: A/E index... authors should cite Sen Gupta -> ...was firstly described by Sen Gupta et al. (1996) as a proxy of hypoxia.

p203, l14: E. albiumbilicatum may have special capabilities to withstand the higher water turbulences in this sound, which the other foraminiferal species could not cope with and were swept away -> Tests of E. albiumbilicatum posess the numerous pustules in apertural and umbilical areas making the test surface rough and enabling this species to withstand the higher water turbulences in this sound.

P204, l1: 29-fold increase -> 67-fold increase in foraminiferal population densities from 23 ind/10cm3 on average in 1963 to 1582 ind/10cm3 on average.

Response to comments by Reviewer 2 (Peter Frenzel):

1. Living/Dead foraminiferal ratio: As it was suggested, we added the data on living-dead foraminiferal ratios in Supplement, table 3.

2. The living/dead ratios showed a 5-fold increase on average since the 1960s (see Suppl., table 3). According to Lutze (1965), it varied from zero in the central Kiel Fjord to 0.3 in the area of Friedrichsort Sound. Our survey showed the distinctly higher living/dead ratios ranging from 0.3 in the inner part to 3.2 in the outer fjord. Such changes over the last 40 years may be explained by two factors, which simultaneously control living and dead foraminiferal distributions in the Kiel Bight. First, the distinct higher

eED

2, S204–S218, 2008

Interactive Comment

numbers of living foraminifera in 2006 reflect a 67-fold increase in population density since the 1960s. On the other hand, the more living individuals we have, the more dead ones should be deposited in the sediment, if the reproduction, frequency and standing stock are kept in balance, due to original balance. The decrease in the abundance of dead specimens may also result from shell loss due to enhanced test dissolution (Jarke, 1961, Wefer & Lutze, 1978, Grobe and Fütterer, 1981). Test dissolution is promoted by increased decay of organic matter in near-surface sediments. It well could be, that the high actual productivity has amplified this process.

3. Microhabitats: We did not discuss the microhabitats, because we considered only the uppermost centimeter of sediments, and therefore we cannot say how deep the certain species inhabits the sediment column and what the controlling factors are.

4. The depth of sampling: The suggestion of reviewer is right. We did not observe any trochamminids and Milliamina fusca inhabited very shallow areas as the sampling depths varied from 4.5 to 18 meters.

5. Taxonomy: As we already mentioned, we included SEM images of foraminifera in supplementary material. The Ammonia tests are presented at the Plate 1 (Fig. 1-7). The distinction between Elphidium excavatum subspecies and Elphidium gerthi was done according to the thickness of the tests in the aperture view. E. gerthi has very thin test, as compared to E. excavatum excavatum and E. excavatum clavatum. Also, the sutures of E. gerthi are distinctly curved towards the peripheral margin of the test.

7. Methodological differences: see above in response to the reviewer 1 (paragraph 4).

8. Comparison of thanatocoenoses: The comparison of thanatocoenoses from Lutze and our studies showed the same results as for living assemblages. Both, living and dead faunas were composed of the same species in the 1960s and 2006. Our main purpose was to study the living assemblages as they reflect present environmental conditions.

eED

2, S204–S218, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

9. Lutze counting sheets: Unfortunately the station list and counting sheets of Lutze's sampling campaign are not available anymore at the Institute of Geosciences in the University of Kiel.

10. Biomass, size and microhabitat of Ammonia beccarii and Ammotium cassis: at the section of "Disappearance of A. cassis", a new paragraph was added: It is conceivable that with faunal change from very large A. cassis to much smaller A. beccarii, the total biomass might has decreased. However, as the population density increased significantly since 1960s, we may assume that biomass today is higher than it was in 1960s and 1990s, when Ammotium cassis was abundant in the Kiel Bight.

11. More detailed comparison with old Lutze data: see response to reviewer 1, paragraphs 4 and 5.

12. Correlations: the correlation matrix is presented in Supplement, table 4.

13. Pore water oxygen: We changed and extended hydrography section: The oxygen content of near-surface sediments was measured with a Unisense microelectrode (Revsbech, 1989) in a short core taken from the inner fjord at the beginning of December 2005. The overlying water had oxygen saturation of 71 %; the sediments were muddy-sand.

Technical comments: P196, l10-12: In outer, middle and inner part of the Schwentine river, 3 CTD-profiles were done with10 WTW Profiline 197 TS in 1-m intervals to locate the boundary between riverine fresh water and higher- saline fjord waters -> In the Schwentine river mouth, at three stations CTD-profiles were done with WTW Profiline 197 TS in 1-m intervals to locate the boundary between riverine fresh water and higher-saline fjord waters.

P198, l6-7: Reference to discharge value of Schwentine river: Schulz, 2000.

P201, l4-5: References for sedimentation rate: Erlenkeuser et al., 1979, Balzer et al., 1987

P203, l3-5: A/E index is explained above; see response to technical comments by reviewer 1.

P204, l29: As such, the deep boundary layer, which is a necessary condition for successful reproduction of A. cassis as suggested by Olsson (1976), cannot establish in Kiel Fjord. -> As such, the deep boundary layer, which is a necessary condition for nutrition of A. cassis cannot establish in Kiel Fjord (Olsson, 1976).

All linguistic corrections suggested by Reviewer 2 were performed.

References:

Alve, E.: Benthic foraminifera in sediment cores reflecting heavy metal pollution in Soerfjord, Western Norway, J Foramin Res, 21, 1-19, 1991.

Alve, E., Murray, J.W.: Marginal marine environments of the Skagerrak and Kattegat: a baseline study of living (stained) benthic foraminifera, Paleogeogr Paleoclimatol Palaeoecol, 146, 171-193, 1999.

Alve, E., Olsgardt, F.: Benthic foraminiferal colonisation in experiments with copper-contaminated sediments, J Foram Res, 29, 186-195, 1999.

Balzer, W., Erlenkeuser, H., Hartmann, M., Müller, P.J., Pollehne, F.: Diagenesis and exchange processes at the benthic boundary, Coastal and Estuarine Studies, 13, 111-161, 1987.

Bergin, F., Kucuksezgin, F., Uluturhan, E., Barut, I.F., Meric, E., Avsar, N., and Nazik, A.: The response of benthic foraminifera and ostracoda to heavy metal pollution in Gulf of Izmir (Eastern Aegean Sea), Estuar Coast Shelf S, 66, 368-386, 2006.

Boltovskoy, E., Scott, D.B., Medioli, F.S., 1991. Morphological variations of benthic foraminiferal tests in response to changes in ecological parameters: a review. J Paleontol, 65: 175-185.

Bradshaw, J.: Laboratory studies on the rate of growth of the foraminifer Streblus bec-

eED

2, S204–S218, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

carri (Linne) var. tepida (Cushman), J Paleontol, 31, 1138-1147, 1957.

Bradshaw, J.: Laboratory experiments on the ecology of foraminifera, Contributions from the Cushman Foundation for Foraminiferal Research, 7 (3), 87-106, 1961.

Burone, L., Venturini, N., Sprechmann P., Valente, P., and Muniz, P.: Foraminiferal responses to polluted sediments in the Montevideo coastal zone, Uruguay, Mar Pollut Bull, 52, 61-73, 2006.

Debenay, J.-P., Tsakiridis, E., Soulard, R., Grossel, H.: Factors determining the distribution of foraminiferal assemblages in Port Joinville Harbour (Ile d'Yeu, France): the influence of pollution, Mar Micropaleontol, 43, 75-118, 2001.

Di Leonardo, R., Bellanca, A., Capotondi, L., Cundy, A., and Neri, R.: Possible impacts of Hg and PAH contamination on benthic foraminiferal assemblages: an example from the Sicilian coast, central Mediterranean, Sci Total Environ, 388, 168-183, 2007.

Ellison, R., Broome, R., and Ogilvie, R.: Foraminiferal response to trace metal contamination in the Patapsco River and Baltimore Harbour, Maryland, Mar Pollut Bull, 17, 419-423, 1986.

Ernst, S.R., Morvan, J., Geslin, E., Le Bihan, A., Jorissen, F.J.: Benthic foraminiferal response to experimentally induced Erika oil pollution, Mar Micropaleontol, 61, 76-93, 2006.

Grobe, H., and Fütterer, D.: Zur Fragmentierung benthischer Foraminiferen in der Kieler Bucht (Westliche Ostsee). Meyniana, 33: 85-96, 1981.

Gustafsson, M. and Nordberg, K.: Living (stained) benthic foraminiferal response to primary production and hydrography in the deepest part of the Gullmar Fjord, Swedish west coast, with comparison to Hoeglund's 1927 material, J Foramin Res, 31, 1, 2-11, 2001.

Haarich, M., Pohl, C., Leipe, T., Grünwald, K., Bachor, A., v. Weber, M., Petenati,

eED

2, S204–S218, 2008

T., Schröter-Kermani, C., Jansen, W., Bladt, A. Anorganische Schadstoffe, in: Meeresumwelt 1999-2002. Ostsee. Bund-Länder-Messprogramm für die Meeresumwelt von Nord- und Ostsee, Kiel, 167-194, 2003.

Hayward, B.W., Holzmann, M., Grenfell, H.R., Pawlowski, J., and Triggs, C.M.: Morphological distinction of molecular types in Ammonia – towards a taxonomic revision of the world’s most commonly misidentified foraminifera, Mar Micropaleontol, 50, 237-271, 2004.

Holzmann, M.: Species concept in foraminifera: Ammonia as a case study, Micropaleontol., 46, 21-37, 2000.

Jarke, J.: Beobachtungen über Kalkauflösung an Schalen von Mikrofossilien in Sedimenten der westlichen Ostsee, Deutsche Hydrographische Zeitschrift, 14, 6-11, 1961.

Kallmeyer, T.: Probleme der Abwasserentsorgung und Gewässerbelastung aus historischer Sicht am Beispiel Kiels und der Kieler Förde, Diplomarbeit, Kiel University, Germany, 76 pp., 1997.

LANU: Organozinnverbindungen in Hafensedimenten und biologische Effekte, Untersuchungen in Sedimenten und an der Strandschnecke (Littorina littorea L.) in schleswig-holsteinischen Küstengewässern. Landesamt für Natur und Umwelt des Landes Schleswig-Holstein, Open Rep. 55 pp., available online at: http://www.lanu.landsh.de, 2001.

LANU: Sauerstoffmangel in der westlichen Ostsee im Sommer und Herbst 2002. In: Jahresbericht 2002. Landesamt für Natur und Umwelt des Landes Schleswig-Holstein, Flintbek, 133-139, 2003.

Le Cadre, V., Debenay, J.P.: Morphological and cytological responses of Ammonia (foraminifera) to copper contamination: Implication for the use of foraminifera as bioindicators of pollution, Environ Pollut, 143, 304-317, 2006. Lutze, G.: Zur Foraminiferen-Fauna der Ostsee, Meyniana, 15, 75-142, 1965.

Nausch, G., Feistel, R., Lass, H.U., Nagel, K., Siegel, H.: Hydrographisch-chemische Zustandseinschätzung der Ostsee 2002, Meereswiss. Ber., Warnemünde, 55, 2003.

Olsson, I.: Distribution and ecology of foraminiferan Ammotium cassis (Parker) in some Swedish estuaries, Zoon, 4, 137-147, 1976.

Pohl, C., Hennings, U., Leipe, T.: Ostsee-Monitoring die Schwermetall-Situation in der Ostsee im Jahre 2004, IOW, Warnemünde, 36 pp., 2005.

Revsbech, N.P.: An oxygen microelectrode with a guard cathode. Limnol Oceanogr, 34, 472-476, 1989.

Rheinheimer, G.: Pollution in the Baltic Sea, Naturwissenschaften, 85, 318-329, 1998.

Rhumbler, L.: Rhizopoden der Kieler Bucht, gesammelt durch A. Remane, 1. Teil, Schriften des Naturwissenschaftlichen Vereins Schleswig-Holstein, 21, 143-194, 1935.

Rottgardt, D.: Mikropaläontologisch wichtige Bestandteile rezenter brackischer Sedimente an den Küsten Schleswig-Holsteins. Meyniana, 1, 169-228, 1952.

Samir, A.M., and El-Din, A.B.: Benthic foraminiferal assemblages and morphological abnormalities as pollution proxies in two Egyptian bays: Mar Micropaleontol, 41, 193-127, 2001.

Schafer, C.T.: Distribution of foraminifera near pollution sources in Chaleur Bay, Water Air Soil Poll, 2, 219-233, 1973.

Schulz F.: Trendauswertung der stofflichen Belastung schleswig-holsteinischer Fließgewässer, in: Landesamt für Natur und Umwelt Jahresbericht 1999, LANU Flintbek, 59-65, 2000.

Sharifi, A.R., Croudace, L.W., and Austin, R.L.: Benthic foraminiferids as pollution indicators in Southampton Water, southern England, United Kingdom: J Micropaleontol, 10 (1), 109-113, 1991.

eED

2, S204–S218, 2008

Interactive Comment

Schiewer, U., Gocke, K.: Ökologie der Bodden und Förden, in: Meereskunde der Ostsee, 2, Rheinheimer G. (ed.), Springer Verlag, Berlin, 216-221, 1995.

Schönfeld, J., Numberger, L.: Seasonal dynamics and decadal changes of benthic foraminiferal assemblages in the western Baltic (NW Europe), J Micropaleontol, 26, 47-60, 2007a.

Schönfeld, J., Numberger, L.: The benthic foraminiferal response to the 2004 spring bloom in the western Baltic Sea, Mar Micropaleontol, 65, 78-95, 2007b.

Senocak, T.: Schwermetalluntersuchung an Fischen der deutschen Ostseekäste (Kliesche, Limanda limanda; Flunder, Platichthys flesus; Hering Clupea harengus und Dorsch, Gadus morhua), Berichte aus dem Institut fur Meereskunde an der Christian-Albrechts-Universität Kiel, 270, 177 pp., 1995.

Stouff, V., Debenay, J.-P. and Lesourd, M.: Origin of double and multiple tests in benthic foraminifera: observations in laboratory cultures, Mar. Micropaleontol., 36, 189-204, 1999a.

Stouff, V., Geslin, E., Debenay, J.-P. and Lesourd, M.: Origin of morphological abnormalities in Ammonia (Foraminifera): studies in laboratory and natural environments, J.Foramin. Res., 29 (2), 152-170, 1999b.

ter Jung, C.: Beitrag zum Schwermetallgehalts-Monitoring (Yn, Cd, Hg, Cn, Ag, Pb, Cr, Ni) in Miesmuscheln an der schleswig-holsteinischen Ostseeküste (1988-1989), Berichte aus dem Institut fur Meereskunde an der Christian-Albrechts-Universität Kiel, Kiel, 221, 89 pp., 1992.

Tomas, E., Gapotchenko, T., Varekamp, E.C., Mecray, E.L., and Buchholtz ten Brink, M.R.: Maps of benthic foraminiferal dustribution and environmental changes in Long Island Sound between 1940s and 1990s, in: Paskevich, V.F. and Poppe, L.J. (eds), US Geological Survey Open-File Report 00-304, USGS, Woods Hole, MA, available online at: http://pubs.usgs.gov/of/2000/of00-304/htmldocs/chap09/index.htm, 2000.

Wefer, G.: Umwelt, Produktion und Sedimentation benthischer Foraminiferen in der westlichen Ostsee. Reports Sonderforschungsbereich 95 Wechselwirkung Meer-Meeresboden, 14, 1-103, 1976.

Wefer, G., and Lutze G.F.: Carbonate production by benthic Foraminifera and accumulation in the western Baltic. Limnol Oceanogr, 23(5), 992-996, 1978.

Yanko, V., Ahmad, M., Kaminski, M.: Morphological deformities of benthic foraminiferal tests in response to pollution by heavy metals: implications for pollution monitoring, J. Foramin. Res., 28, 177-200, 1998.

Interactive comment on eEarth Discuss., 2, 191, 2007.