

Morphological abnormalities in benthic foraminifera caused by an attached epibiont foraminifer

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Abstract: This study focused on the possible 'parasitism-like' relationship between the epibiont *Cymbaloporeta* sp. and basibiont benthic foraminifera including *Agglutinella soriformis* El-Nakhal, *Adelosina carinatastriata* Wiesner, *Pseudotriloculina* sp. and *Spiroloculina indica* Cushman & Todd from a sample collected off the east coast of Bahrain in the Arabian Gulf. There are no indications of preferential host selection, the epibiont seems to attach on to any available basibiont. However, constriction of the test and subsequent growth of the basibiont's chambers at the point of attachment of the epibiont might suggest an early link in their ontogeny. This biotic relationship has implications on the basibionts' development and ontogeny that eventually results in the development of foraminiferal abnormalities. The finding of morphological test abnormalities caused by an epibiont in an unpolluted environment has important implications for the use of the abnormalities for pollution biomonitoring. Samples from other areas of the Arabian Gulf need to be studied in order to determine the background proportion of specimens with epibionts.

Keywords: foraminifera, epibionts, basibionts, abnormalities, Arabian Gulf

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Benthic foraminiferal morphological variations and abnormalities are known to be induced by fluctuations in environmental parameters (including changes in carbonate saturation state, temperature, salinity, depth and dissolved oxygen), mechanical damage and pollution (e.g. Boltovskoy *et al.* 1991; Yanko *et al.* 1994, 1998; Geslin *et al.* 2002). Epibionts (epizoic and epiphytic) and bioeroding foraminifera appear to be well documented in the literature (Langer 1993; Langer & Bagi 1994; Vénec-Peyré 1996) but little is known about their role in formation of morphological abnormalities. This article documents a symbiotic relationship between an epibiont, *Cymbaloporeta* and several basibiont benthic foraminiferal species and the possible induction of morphological abnormalities. Parasitic behaviours and epibiont–basibiont species relationships of foraminiferal taxa have been also documented in the geological record, for instance, during the Late Cretaceous by *Talpinella cunicularia* (Baumfalk *et al.* 1982). However, no study on Recent foraminifera has quantitatively assessed this possible morphological abnormality-induction relationship.

Cymbaloporella tabellaeformis has already been inferred to be a parasite (Matteucci 1980). Other foraminiferal parasitic taxa might possibly include *Floresina*, *Rosalina*, *Fissurina marginata* (Montagu) (reported as *Entosolenia marginata*), *Cibicides refulgens* de Montfort and *Planorbulinopsis parasitica* Banner (i.e. Le Calvez 1947; Todd 1965; Banner 1971; Alexander & DeLaca 1987; Cedhagen 1994; Hallock & Talge 1994; Nielsen *et al.* 2002).

Methodology

Sample location

The study area is on the eastern coast of Bahrain in the Arabian Gulf (Fig. 1). The Arabian Gulf is notable for extremes in temperature

and salinity and provides an excellent natural laboratory to study the interplay between various ecological parameters, more importantly the deterioration of the benthic environment due to rapid urban development and pollution sources (Sheppard *et al.* 2010). We measured salinity and water temperature for the area between June 2014 and April 2015 and the range recorded was 43–45 ppt and 26–28°C, respectively. The study area has been described by Arslan *et al.* (2016), who analysed organic and inorganic pollutants and determined it is a relatively unpolluted site.

Sample collection and processing

Surficial sediment (20 ml) was collected using a piston syringe that penetrated 2 cm deep into the sediment. The location is on the foreshore and approximately 100 m from the coastline, at a water depth of 65 cm (Fig. 1). The sediment sample was preserved using laboratory-grade ethanol (70%) with Rose Bengal stain. The sediment was left in the ethanol–Rose Bengal mixture for two weeks before it was washed and wet-sieved through a 63 µm mesh sieve. It was dried and then used for benthic foraminiferal specimen picking. The dried sample was sieved through a 125 µm mesh sieve and separated into two aliquots with approximately 300 specimens using a microsampler to ensure statistically representative counts. The analysed sample is part of a larger collection of samples for a temporal and spatial study in the area. Selected specimens were imaged using scanning electron microscopy (SEM). A modified resin embedding technique (Golubic *et al.* 1970), which is based on two component epoxy resins allowing faster setting of the resin and limiting the penetration into the foraminiferal test, was used. The resin casts were further ground on a smooth glass with abrasive powder (#1000). After achieving the appropriate length, resin casts were placed in an ultrasonic water bath for 30 s to remove abrasive

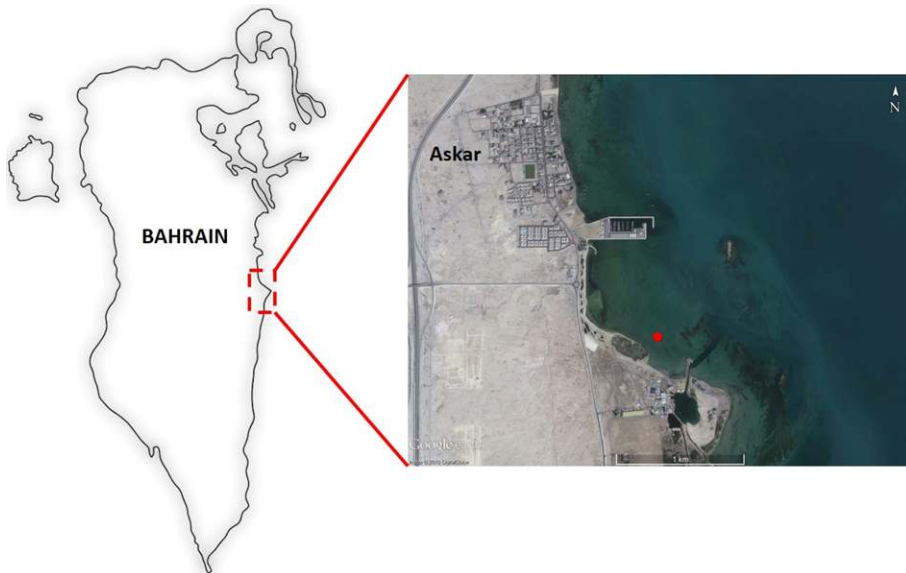


Fig. 1. Location of the sample station indicated by the solid circle on the right image (26° 02' 40.1" N, 50° 37' 35.2" E).

powder residue and then dried under an incandescent lamp. The resin cast provides support for handling the specimen and produces the desired precise smoothness. The faunal reference slides are currently housed in the authors' collection at KFUPM; these will be permanently archived in the European Micropaleontological Reference Center at Micropress Europe in Kraków (Poland).

Results

Foraminiferal specimens (1.94% or 11 out of 567 specimens) exhibit varying degrees of morphological abnormalities as a possible result of a symbiotic association between an attached epibiont foraminifer and its basibiont foraminiferal host. SEM images revealed test morphological abnormalities found at spots characterized by the exclusively occurrence of the epibiont *Cymbaloporeta* sp. (Fig. 2). The host species include *Agglutinella soriformis* El-Nakhal, 1983 (Fig. 3a–c), *Adelosina carinatastriata* Wiesner, 1923 (Fig. 3d–f), *Pseudotriloculina* sp. (Fig. 3g–i) and *Spiroloculina indica* Cushman & Todd, 1944 (Fig. 3j–l) and most of them show various degrees of morphological abnormalities. The apertural view of *A. soriformis* (Fig. 3a), on the more evolute side, shows the stunted growth of the middle chamber, i.e. *Cymbaloporeta* sp. is attached on the chamber as opposed to having been 'agglutinated' by the basibiont. *Adelosina carinatastriata* (Fig. 3d–f) is severely malformed, with the epibiont deeply embedded within the test of the basibiont and likely promoting the

modification of the shape and coiling directions of all the chambers. *Pseudotriloculina* sp. (Fig. 3g–i) appears to have accommodated the epibiont with minor modification. In *S. indica* (Fig. 3j), on the more evolute side, there is an abrupt change in the direction of the final chamber, with the epibiont embedded towards the posterior end. Cross-sections taken at two planes through *A. carinatastriata* (Fig. 4a–c) show test abnormalities as a result of the host accommodation of the epibiont. *Agglutinella soriformis* (Fig. 4d–f) also exhibits abnormal chambers at the point of epibiont attachment.

Systematic descriptions

Genus *Cymbaloporeta* Cushman
Cymbaloporeta cf. *C. bradyi* (Cushman, 1915)
 (Fig. 2)

1915 *Cymbalopora poeyi* (d'Orbigny) var. *bradyi* Cushman: 25, pl. 10, fig. 2; pl. 14, fig. 2.

2012 *Cymbaloporeta bradyi* (Cushman); Debenay: 236, 316 (with synonyms)

Description. Test convex on spiral side, trochospiral, peripheral margin rounded, chambers become bigger as added, first trochospirally arranged later added in an annular arrangement, irregularly globular on the spiral side. Wall coarsely perforated on the spiral side except on earliest chamber. Sutures depressed on both sides; curved on spiral side.

Genus *Agglutinella* El-Nakhal
Agglutinella soriformis El-Nakhal, 1983
 (Fig. 3a–c)

1983 *Agglutinella soriformis* El-Nakhal: 130, pl. 1, figs 7–9, pl. 2, figs 16–18.

1993 *Agglutinella soriformis* El-Nakhal; Höttinger *et al.*: pl. 30, figs 7–10, pl. 31, figs 1–4.

Description. Test broadly subelliptical in lateral view, polygonal in end view, laterally slightly compressed. Chambers U-shaped in section, initially arranged in distinct quadriloculine and later in a triloculine manner. Aboral end of chamber strongly overlaps preceding chamber. Aperture terminal, broadly drop-shaped, bordered by peristomal lip and provided with a spur-shaped bifid tooth with a long base. Wall porcelaneous with a coarsely agglutinated outer layer.

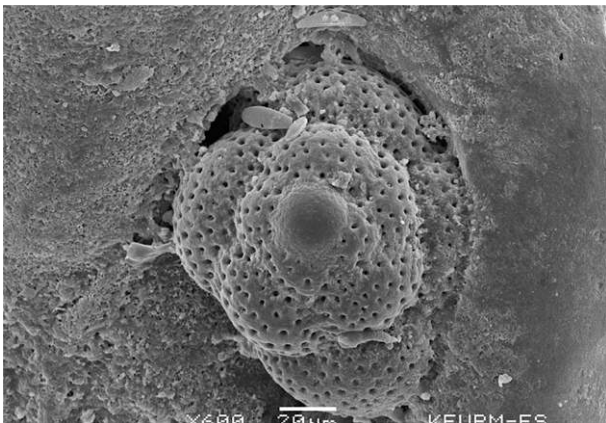


Fig. 2. *Cymbaloporeta* sp. embedded in the wall of *Adelosina carinatastriata* Wiesner, 1923.



Fig 3. (a–c) *Agglutinella soriformis* El-Nakhal, 1983: (a) apertural view, (b) lateral view of more evolute side, (c) lateral view of more involute side. (d–f) *Adelosina carinatastriata* Wiesner, 1923: (d) lateral view of more evolute side, (e) apertural view, (f) lateral view of more involute side. (g–i) *Pseudotriloculina* sp.: (g) lateral view of more evolute side, (h) lateral view of more involute side, (i) apertural view. (j–l) *Spiroloculina indica* Cushman & Todd, 1944: (j) apertural view, (k) lateral view, (l) lateral view opposite side of (k) with attached epibiont. All scale bars are 100 μm .

Genus *Adelosina* d'Orbigny
Adelosina carinatastriata Wiesner, 1923
 (Fig. 3d–f)

1923 *Adelosina milletti* Wiesner var. *carinata-striata* Wiesner: 76–77, pl. 14, figs 190, 191.
 2005 *Adelosina carinatastriata* Wiesner; Debenay, Millet & Angelidis: pl. 1, fig. 15.

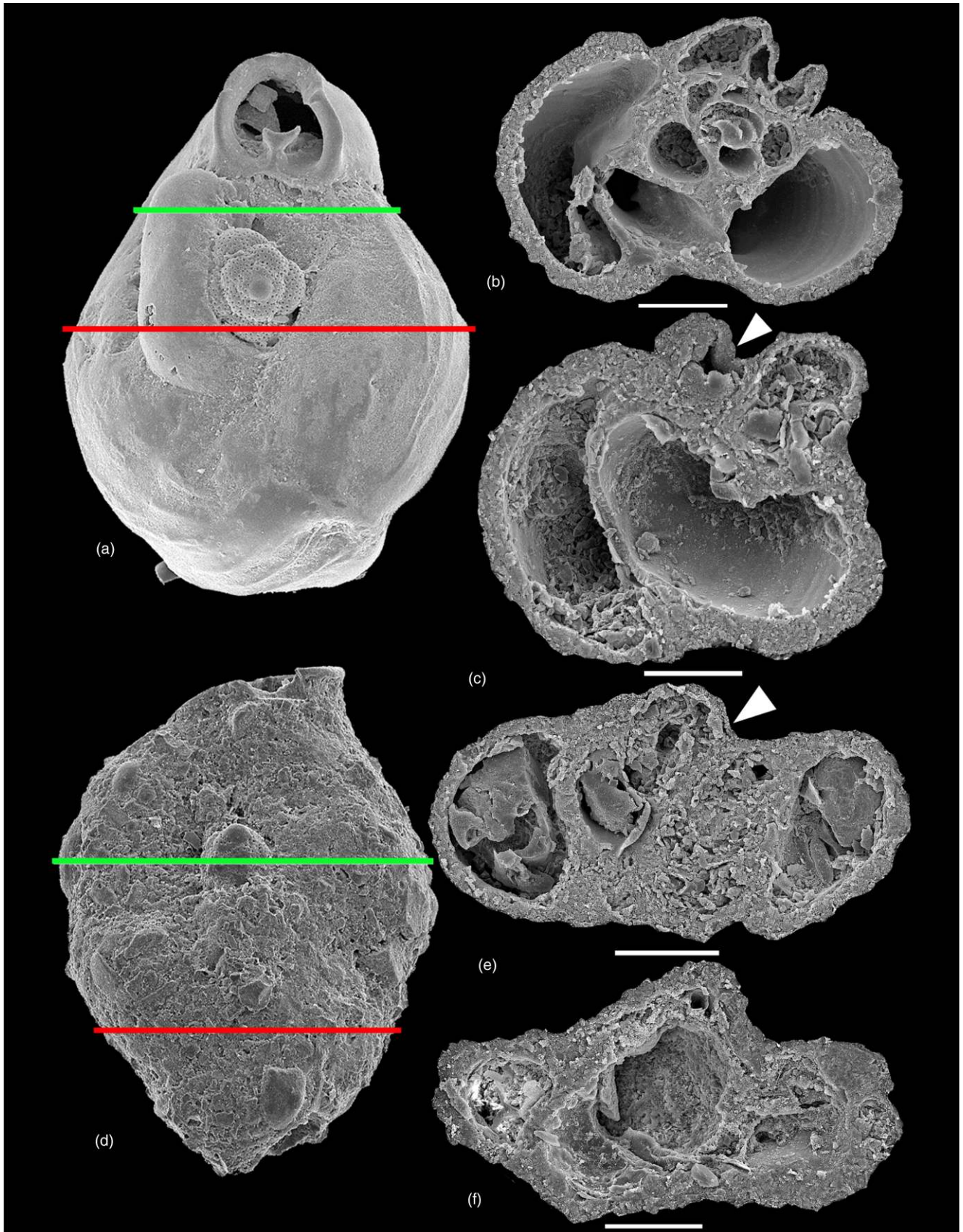


Fig. 4. (a–c) *Adelosina carinatastriata*: (a) the two lines depict the cross-sections shown in (b) and (c); (b) the anterior part, indicated by the green/upper line on (a); (c) the posterior part, indicated by the red/lower line in (a). (d–f) *Agglutinella soriformis*: (d) the two lines depict the cross-sections shown in (e) and (f); (e) the anterior part, indicated by the green/upper line on (d); (f) the posterior part, indicated by the red/lower line on (d). Inserted solid white arrows in (c) and (e) point towards the epibiont attachment. All scale bars where provided are 100 μ m.

Description. Test quinqueloculine, oval in outline, numerous costae run obliquely along the chambers and unite peripherally. The aperture is terminal, at the end of a short neck, bordered by a small peristomal rim, with a small bifid tooth.

Genus *Pseudotriloculina* Cherif
Pseudotriloculina sp.
(Fig. 3g–i)

1993 *Pseudotriloculina* sp. B. Höttinger *et al.*: pl. 49, figs 1–7.

Description: Test porcelaneous, elongate, narrow elliptical in lateral view. Chambers arranged in a quadriloculine manner, sutures rather indistinct. Aperture terminal, rounded, at the end of a distally narrowing extension of the chamber, producing a short, stout neck lacking a distinct lip and provided with a broadly bifid, spoon-like tooth with a very short base.

Genus *Spiroloculina* d'Orbigny
Spiroloculina indica Cushman & Todd, 1944
(Fig. 3j–l)

1944 *Spiroloculina indica* Cushman & Todd: 71, pl. 9, fig. 32.

1993 *Spiroloculina indica* Cushman & Todd; Höttinger *et al.*: pl. 26, figs 10–14.

Description. Test porcelaneous, biloculine, evolute, fusiform in lateral view, strongly biconcave. The aperture is circular, situated at the end of a stout neck, surrounded by a peristomal lip and provided with two teeth, an anvil-shaped bifid one at the inner margin and a primitive bifid tooth at the outer margin.

Discussion

The percentages of abnormalities (1.94%) recorded for all the picked specimens in this study is higher than the 1% value, which has been suggested as the typical background value representing a natural undisturbed population in previous studies (Yanko *et al.* 1998; Stouff *et al.* 1999). During the sample preparation of the cross-section of *Agglutinella soriformis* (Fig. 4d–f), the internal content appeared pinkish, suggesting that the foraminifera was recently alive. There are no indications of preferential host selection; the epibiont seems to attach on to any available basibiont like *A. soriformis*, *Pseudotriloculina* sp., *A. carinatastriata* and *S. indica*. Constriction of the test and subsequent growth of the basibiont's chambers at the point of attachment of the epibiont may suggest an early attachment in their ontogeny. Studies have documented symbiotic feeding relationships (i.e. predation, symbiosis and commensalism) between foraminifera and other organisms (Hallock & Talge 1994; Nielsen *et al.* 2002). However, little is known about intraspecific biotic factors, such as parasitism, affecting them. This study, therefore, underlines the importance of biotic factors (such as parasitism) in foraminiferal ecology, which has been previously largely underestimated (Murray 2006). In the Arabian Gulf region, this study may have a direct implication on the determination of foraminiferal abnormality percentages – which have been previously correlated to levels of pollution in marine environments (i.e. Yanko *et al.* 1998; Frontalini *et al.* 2009).

Conclusions

The finding of morphological test abnormalities most likely caused by an epibiont in an unpolluted environment has important implications for the use of the morphological abnormalities for pollution biomonitoring. A possible parasite–host (parasitism)

relationship of the epibiont cannot be ruled out. Possible evidence of a parasitic mode of life is inferred from the modification of the host chambers. Cross-sections of *A. carinatastriata* and *A. soriformis* show some modifications of host chambers at the point of attachment to accommodate the epibiont. Future studies are needed to separate test abnormalities caused by epibionts from those attributable to different types of pollution and to better constrain the possible parasitic v. epibiont relationship of *Cymbaloporeta* sp.. Due to the sample size considered in this study there is a need to conduct a systematic study of the area based on additional samples.

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