Alien foraminifers from Greek coastal areas (Aegean Sea, Eastern Mediterranean)

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Abstract

The present study provides additional data on the distributional range of six alien foraminiferal species in living assemblages from Greek coastal areas (Aegean Sea, Eastern Mediterranean). *Amphistegina lobifera* LARSEN 1976, *Sorites orbiculus* (FORSKÁL 1775) and *Coscinospira hemprichii* EHRENBERG 1839 are well established in Greek coastal areas, whereas *Triloculina fichteliana* D’ORBIGNY 1839, *Planogypsina acervalis* (BRADY 1884) and *Cymbaloporetta plana* (CUSHMAN 1924), are recorded for the first time in this paper. The occurrence of these species in a number of sites in the Aegean Sea establishes their presence in the Eastern Mediterranean.

Keywords: Benthic foraminifera; Lessepsian migration; Mediterranean Sea.

Introduction

During recent decades, hundreds of non-native vertebrate and invertebrate species have been documented in the Mediterranean Sea (GOLANI, 1998; ZENETOS *et al.*, 2005, 2008, 2009; STREFTARIS & ZENETOS, 2006). Despite the many pathways of such alien organisms (e.g., through aquaculture or via shipping), Lessepsian immigrants remain the most important invasions. Since the opening of the Suez Canal in 1869, many species of Indo-Pacific origin have been introduced and have settled in the Eastern Mediterranean (POR, 1978; GOLANI, 1998).

A number of alien species present a wide distribution, which includes both the Atlantic and the Indo-Pacific Seas. Since their pathway of introduction and/or their native status in the Mediterranean is not known, those species are termed as ‘cryptogenic’ following CARLTON (1996).

Up to now, a great number of alien benthic foraminifera species have been reported in almost all coastal areas from the Eastern Mediterranean sub-basins (e.g., BLANC-VERNET, 1969; CHERIF, 1970; CIMERMAN & LANGER, 1991; SGARRELLA & MONCHARMONT-ZEI, 1993; AVŞAR, 1997; HOLLAUS & HOTTINGER, 1997;
In particular, some foraminiferal immigrants, like *Amphistegina lobifera*, have become very successful inhabitants locally, constituting a significant section of the native epiphytic foraminiferal fauna. Thus, the alien benthic foraminiferal species have an increasingly important role in enrichment of the local biodiversity, therefore a growing focus on investigating their distribution has been noted in recent studies.

This study reports the presence and relative abundance of six cryptogenic epiphytic foraminiferal species in living assemblages from Greek coastal areas (Aegean Sea) providing useful information on the establishment success of these alien species in the Eastern Mediterranean.

**Area description and environmental setting**

The Aegean Sea is situated between Turkey and Greece and communicates with the Black Sea through the Dardanelles straits and with the open eastern Mediterranean (Levantine Sea) through the Cretan straits (Fig. 1a).

The Mediterranean climate tends to be warm-temperate and semi-arid to arid. Mediterranean waters are characterized by elevated salinities associated with high evaporation rates. The Aegean Sea, however, is strongly influenced by freshwater discharges from mainland rivers and seasonal variation in input rates of Black Sea surface water through the Strait of Dardanelles. The annual maximum sea surface temperature (SST) (>24°C) occurs around August/September; minimum SSTs in March (<13°C) are reached in winter (POULOS et al., 1997; TRIANTAPHYLLOU et al., 2004). In particular temperature increase to the

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**Fig. 1a, b:** Location of the study area in the eastern Mediterranean and the Aegean Sea.

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south; northern Aegean temperatures range between 13.4°C and 23°C, whereas in the south between 15.6°C and 25°C (World Ocean Atlas Data http://www.cdc.noaa.gov). Sea surface salinity (SSS) values vary seasonally, ranging from less than 31.0 psu to more than 39.0 psu.

The study area concerns a number of sites in the Aegean Sea (Fig. 1b); the coastal ecosystems of the southern Aegean Sea (Falasarna and Chrissi), the central Aegean Sea (Porto Heli, Mavro Lithari, Glyfada, Varkiza, Faliro, Perama, Vravron, Kalamos, the Andros-Korthi and Kastro gulfs) and the northern Aegean Sea (N. Kallikratia).

Material and Methods

Samples for the present study, collected during several sampling periods between 2001 and 2009, consisted of red, brown and green algae. Algal samples were collected from depths varying between 0.2m and 3m. Sample location, date of collection and relevant temperature and salinity data are presented in Table 1.

Samples were stored in high-walled plastic bowls and stained with an ethanol-Rose Bengal solution to distinguish between living (stained) and dead (unstained) foraminifera (WALTON, 1952; MURRAY & BOWSER, 2000). In the laboratory, the algal samples were sieved through the >63 μm size fraction and dried at 60°C. At least 300 living foraminifera were separated from the micropaleontological samples, picked under a Leica S4E stereozoom binocular microscope and identified following the generic classification of LOEBLICH & TAPPAN (1988).

Concerning their establishment success, alien foraminiferal species are grouped into the following categories (according to ZENETOS et al., 2008): established/frequent F (those species recorded many times in large quantities and showing a wide range of distribution patterns) and established/rare R (those observed more than twice in several different localities but always few in number: <5%).

Living specimens of alien foraminiferal species were also examined using a Jeol JSM 6360 Scanning Electron Microscope (SEM), (University of Athens, Department of Historical Geology and Palaeontology), in order to observe external test morphological details. The specimens for SEM investigations were rinsed in distilled water, dried in a desiccator, attached to a copper electron microscope stub using a doublesided adhesive tape and coated with gold. All the samples and the SEM micrographs are kept in the collections of the Museum of Paleontology and Geology of the University of Athens.

Results

Benthic foraminifera were rich in all the studied samples. In general, the foraminiferal assemblages were dominated by genera with calcareous tests (hyaline and porcelaneous). The porcelaneous forms comprise an important component of the fauna and are mainly represented by members of the genera *Peneroplis, Quinqueloculina, Miliolinella, Sorites* and *Triloculina*. The hyaline taxa are represented mostly by the genera *Amphistegina, Rosalina, Elphidium, Ammonia, Asterigerina* and *Cymbaloporetta*. Agglutinated components are rare and mainly represented by *Textularia* species.

In total, six cryptogenic foraminiferal species have been found: *Amphistegina lobifera* Larsen, *Sorites orbiculus* (Forskål), *Cymbaloporetta plana* (Cushman), *Triloculina fichteli* d’Orbigny, *Planogypsina acervalis* (Brady) and *Coscinospira hemprichii* Ehrenberg.
Table 1
Characteristics of regression lines describing morphometric characteristics and quality indexes in relation to body weight.

<table>
<thead>
<tr>
<th>Site</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Date of collection</th>
<th>Water depth (m)</th>
<th>mean monthly Temperature (°C)</th>
<th>mean monthly Salinity (%)</th>
<th>Alien foraminiferal species (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>southern Aegean Sea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chrissi</td>
<td>34.58</td>
<td>25.39</td>
<td>7/06</td>
<td>0-3</td>
<td>24.45</td>
<td>39.03</td>
<td>Amphistegina lobifera (42.5) Sorites orbiculus (2.0)</td>
</tr>
<tr>
<td>Falasarna</td>
<td>35.29</td>
<td>23.34</td>
<td>7/06</td>
<td>0-3</td>
<td>24.16</td>
<td>38.86</td>
<td>Sorites orbiculus (7.5) Triloculina fichteliana (0.5)</td>
</tr>
<tr>
<td>central Aegean Sea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porto Heli</td>
<td>37.27</td>
<td>23.06</td>
<td>9/07</td>
<td>0-3</td>
<td>23.05</td>
<td>38.40</td>
<td>Amphistegina lobifera (32.0) Planogypsina acervalis (0.5)</td>
</tr>
<tr>
<td>Vlacholimni Mavro Lithari</td>
<td>37.43</td>
<td>23.56</td>
<td>10/06</td>
<td>0-3</td>
<td>21.07</td>
<td>38.51</td>
<td>Amphistegina lobifera (34.0) Cymbaloporetta plana (4.5) Planogypsina acervalis (1.0) Triloculina fichteliana (0.5) Sorites orbiculus (0.5)</td>
</tr>
<tr>
<td>Glyfada</td>
<td>37.54</td>
<td>23.44</td>
<td>10/09</td>
<td>0-3</td>
<td>21.07</td>
<td>38.51</td>
<td>Amphistegina lobifera (43.6) Cymbaloporetta plana (2.0)</td>
</tr>
<tr>
<td>Varkiza</td>
<td>37.49</td>
<td>23.51</td>
<td>10/09</td>
<td>0-3</td>
<td>21.07</td>
<td>38.51</td>
<td>Amphistegina lobifera (68.0) Cymbaloporetta plana (4.0) Sorites orbiculus (2.5)</td>
</tr>
<tr>
<td>Falira</td>
<td>37.56</td>
<td>23.52</td>
<td>11/09</td>
<td>0-3</td>
<td>18.85</td>
<td>38.60</td>
<td>Amphistegina lobifera (24.2) Sorites orbiculus (1.5)</td>
</tr>
<tr>
<td>Perama</td>
<td>37.59</td>
<td>23.35</td>
<td>1/09</td>
<td>0-3</td>
<td>18.85</td>
<td>38.60</td>
<td>Planogypsina acervalis (0.5)</td>
</tr>
<tr>
<td>Vravron</td>
<td>37.56</td>
<td>24.03</td>
<td>5/06</td>
<td>0-3</td>
<td>18.26</td>
<td>38.38</td>
<td>Amphistegina lobifera (55.5) Planogypsina acervalis (0.5) Sorites orbiculus (0.5) Coscinospira hemprichii (0.1)</td>
</tr>
<tr>
<td>Korthi Andros</td>
<td>37.46</td>
<td>24.58</td>
<td>8/01</td>
<td>0-3</td>
<td>24.04</td>
<td>38.18</td>
<td>Amphistegina lobifera (36.8) Planogypsina acervalis (0.5) Sorites orbiculus (0.1)</td>
</tr>
<tr>
<td>Kastro Andros</td>
<td>37.51</td>
<td>24.57</td>
<td>8/01</td>
<td>0-3</td>
<td>24.04</td>
<td>38.18</td>
<td>Amphistegina lobifera (34.5) Cymbaloporetta plana (0.5) Coscinospira hemprichii (0.1) Sorites orbiculus (0.1)</td>
</tr>
</tbody>
</table>
(continued)
Amphistegina lobifera LARSEN 1976
Plate I, Figs 1, 2


A. lobifera Larsen belongs to the family Amphisteginidae Cushman and the genus Amphistegina d’Orbigny. This species is a flat trochospiral, biconvex, lenticular, large foraminifer. The test is characterized by thick-walls, often globular, with the spiral side being more pronounced than the umbilical side. The main distinctive features of the species are the lobate septa visible on both sides of large adult tests. Younger individuals do not show these strong lobes, and very small specimens are extremely similar to the related species A. lessonii (HOHENEGGER et al., 1999).

A. lobifera is a well-known algal symbiont-bearing benthic foraminifer that thrives in warm, clear and nutrient deficient environments (HALLOCK, 1988). The thick-walled test allows it to live in the highest light-water energy levels (HALLOCK, 1981). The geographical distribution of this species comprises the shallow water environments in the Indian, Pacific and Atlantic Oceans (LANGER & HOTTINGER, 2000). According to MORARIU & HOTTINGER (1988) and LANGER & HOTTINGER (2000) the occurrence of living amphisteginids is delimited by the 14° C winter isotherm. Previous studies have shown that A. lobifera is a successful Lessepsian immigrant (ZENETOS et al., 2008, 2009) that has
been widely distributed in the coastal ecosystems of the Eastern Mediterranean. It has been recorded in Greece (CHERIF, 1970; TRIANTAPHYLLOU et al., 2009) and Cyprus (LANGER & HOTTINGER, 2000), Israel (HYAMS et al., 2002; GRUBER et al., 2007), Lebanon (MONCHARMONT-ZEI, 1968), the Mediterranean coasts of Turkey (AVŞAR, 1997; MERİÇ et al., 2008), the Sea of Marmara (MERİÇ et al., 2005) and on the coasts of the Maltese Islands (YOKES et al., 2007). In Greece, BLANC-VERNET (1969) has recorded *Amphistegina madagascariensis* in the southern part of the Peloponneseus, Castellorizo, Crete and different islands of the southern Aegean Sea, whereas HOLLAU & HOTTINGER (1997) reported *Amphistegina lessonii* in Crete. These species were not found in our samples, although it must be noted that in a previous study by TRIANTAPHYLLOU et al. (2005), *A. lobifera* was incorrectly identified as *A. lessonii*, due to difficulties in distinguishing the younger individuals that do not bear strong lobes. Later, TRIANTAPHYLLOU et al. (2009) emended this identification to *A. lobifera*.

In the present study, *A. lobifera*, is the dominant foraminifer species at the southern and central Aegean sites (Fig. 2, Table

![Distribution of alien migrants in the Greek coastal areas.](image-url)
Table 2
Origin, pathway and establishment success of the studied alien foraminiferal species in the Greek coastal areas.

<table>
<thead>
<tr>
<th>Alien foraminiferal species</th>
<th>Origin</th>
<th>Pathway</th>
<th>Establishment success within Greek coastal areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphistegina lobifera Larsen</td>
<td>Indo- Pacific, possibly Atlantic</td>
<td>via Suez/ via Gibraltar</td>
<td>F</td>
</tr>
<tr>
<td>Sorites orbiculus Forskål</td>
<td>Indo- Pacific, possibly Atlantic</td>
<td>via Suez/ via Gibraltar</td>
<td>F</td>
</tr>
<tr>
<td>Coscinospira hemprichii Ehrenberg</td>
<td>Indo- Pacific, possibly Atlantic</td>
<td>via Suez/ via Gibraltar</td>
<td>R</td>
</tr>
<tr>
<td>Cymbaloporetta plana Cushman</td>
<td>Indo- Pacific, possibly Atlantic</td>
<td>via Suez/ via Gibraltar</td>
<td>R</td>
</tr>
<tr>
<td>Planogypsina acervalis Brady</td>
<td>Indo- Pacific, possibly Atlantic</td>
<td>via Suez/ via Gibraltar</td>
<td>R</td>
</tr>
<tr>
<td>Triloculina fichteliana D’ Orbigny</td>
<td>Indo- Pacific, possibly Atlantic</td>
<td>via Suez/ via Gibraltar</td>
<td>R</td>
</tr>
</tbody>
</table>

for origin and pathway see references in the text, establishment success is based on the results of this study

1, 2), usually rising to more than 30% of the foraminiferal assemblages (establishment success: F). In the northern site (N. Kalikratia) it is present with very low abundances (Table 1).

Sorites orbiculus (FORSKÅL 1775)
Plate I, Figs 4, 5

Nautilus orbiculus FORSKÅL 1775 p. 125.
Sorites orbiculus (Forskål) EHRENBerg 1839 p. 134. -LEUTENEGGER 1977 p. 10, text-fig. 2a. -CHENG & ZHENG 1978 p. 198, pl. 17, figs 1-9; pl. 31, figs. 1-3; pl. 32, fig. 1. -REISS & HOTTINGER 1984 p. 205, figs 65a-d. -CIMERMAn & LANGER 1991 p. 50, pl. 51, figs 1-5. -HATTA & UJIIE 1992 p. 80, pl. 17, figs 5a, 6b; pl. 18, figs. 5, 6. -HOTTINGER et al. 1993 p. 72, 73, pl. 83, figs 1-13. -MERIÇ et al. 2004 p. 115, pl. 17, fig. 8. -MERIÇ et al. 2008 p. 315-316, pl. 6, figs 8-14.

S. orbiculus (Forskål) belongs to the family Soritidae Ehrenberg and the genus Sorites Ehrenberg. This species is characterized by discoidal test. The initial test part is evolute and planispirally coiled. Annular chambers constructing the main test, surround the older test parts in an evolute manner. All chambers are subdivided into chamberlets by short septula bearing connections to chamberlets of the same and the succeeding chamber (GUDMUNDSSON, 1994). The aperture forms a single row of openings with protruding rims and 8-shaped apertures resulting from cross-like oblique stolons (LOEBLICH & TAPPAN, 1988; RENEMA et al., 2001).

S. orbiculus has been reported as epiphytic on sea grasses and macro-algae usually in shallow warm (14°C-34°C) water
(HOHENEGGER, 1994, 1996; TROELSTRA et al., 1996). This species hosts symbiont dinoflagellates (LEUTENEGGER, 1977; LEE & ANDERSON, 1991). It is a cosmopolitan species; common in the Indo-Pacific, the Red Sea and in the Atlantic (LANGER & HOTTLINGER, 2000). In the Mediterranean Sea, it is present throughout the entire eastern Mediterranean [e.g., in Israel (YANKO, 1995), Turkey (AVŞAR et al., 2001; MERIÇ, et al., 2008) and Egypt (SAMIR et al., 2003)], but also in the Adriatic (CIMERMAN & LANGER, 1991) and the Tyrrhenian Seas (HOFKER, 1930; LANGER & HOTTLINGER, 2000; LANGER, 2008). Furthermore, *S. orbiculus* has been reported from even the Balearic Islands (CRESPI, 1922a, 1922b; COLOM, 1942, 1964, 1974; MATEU, 1970; MATEU-VICENS et al., 2010), and the area off Nice (LANGER & HOTTLINGER, 2000), indicating that it survives temperatures even lower than 13 °C. *S. orbiculus* is among the larger symbiont-bearing foraminifera which has the widest latitudinal distribution (LANGER & HOTTLINGER, 2000; LANGER, 2008). In particular in Greece, *S. orbiculus* presents wide distribution within the Aegean Sea (BLANC-VERNET, 1969), also CHERIF (1970) reported the presence of this species in Naxos, HOLLAUS & HOTTLINGER (1997) in Crete and TRIANTAPHYLLLOU et al. (2005) in Andros. The species was included among the alien immigrants which have penetrated into the Mediterranean Sea (ZENETOS et al., 2008, 2009).

In the present study, *S. orbiculus* was found regularly (Fig. 2) at the central Aegean and southern Aegean sites (establishment success: F), with somewhat higher percentages at Falasarna (7.5% of the foraminiferal fauna; Table 1, 2).

*Coscinospira hemprichii* EHRENBERG 1839

*Coscinospira hemprichii* EHRENBERG 1839 p. 131, pl. 2, fig. 2.

*Spirulina arietina* (Batsch), CUSHMAN 1930 p. 43, pl. 15, figs. 45 -CHENG & ZHENG 1978 p. 196, pl. 16, figs. 1, 2 – HATTA & UJIIE 1992 p. 79, pl. 16, figs. 4a, b.

*Peneroplis pertusus* (Forskål) var. *arietinus* (Batsch), CUSHMAN 1917 p. 88, pl. 36, fig. 2; pl. 37, fig. 5 -BACCAERT 1987 pl. 19, figs. 3a, b; pl. 20, figs. 1, a, b; 3a,b,c; 4a, b, c, d; pl. 21, figs. 1a, b.

*Peneroplis arietinus* (Batsch), MERIÇ et al. 2008 p. 314, pl. 4, figs 17-19, pl. 5, figs 1-7.

*C. hemprichii* Ehrenberg belongs to the family Peneroplidae Schultze and the genus *Coscinospira* Ehrenberg. In this species the early chambers are planispirally enrolled and later are uncoiled. The aperture consists of numerous rounded or irregular openings, which are rimmed by strong, everted peristomes. It strongly resembles the genus *Peneroplis*, however easily distinguished by the distinctive ornamental patterns present on the exterior of the shell and by the apertural features (LANGER, 2008).

*C. hemprichii* is a symbiont-bearing foraminifer exhibiting a global tropical distribution (LANGER, 2008). It is reported from the Indo-Pacific (BACCAERT, 1987; HATTA & UJIIE, 1992), and the Red Sea (HOTTLINGER et al., 1993). In the Western Mediterranean, this species has been reported in the Balearic Islands and the Catalan coast (CRESPI, 1922a, 1922b; COLOM, 1935, 1942, 1964, 1974; MATEU, 1970; MATEU-VICENS et al., 2010) and the coasts of Provence, France (BLANC-VERNET, 1969), whereas in the Eastern Mediterranean it covers the coastline from
the Adriatic Sea to Greece, Turkey, Lebanon, Israel, the Palestinian Gaza strip, Egypt, Libya and Tunisia. (LANGER, 2008). MERIÇ et al. (2008) also reported the presence of this species at several sites along the in the Mediterranean coasts of Turkey under the synonym name Penerolpis arietinus. In particular in Greece, C. hemprichii has been found in Crete (HOLLAUS & HOTTINGER, 1997), and BLANC-VERNET (1969) recorded it in samples from the Aegean Sea under the name Spirolina arietina.

In the present study, C. hemprichii is mainly found in the central and northern Aegean sites (Fig. 2, Table 1) in very low abundances, less than 2% (establishment success: R, Table 2).

**Cymbaloporetta plana** (CUSHMAN 1924)

Plate II, Figs 1, 2

*Cymbalopora bulloides* (d’Orbigny), BRADY 1884 p. 638, pl. 102, fig. 7.

*Trethomphalus bulloides* (d’Orbigny), CUSHMAN 1915 p. 26, pl. 14, figs 3, 4.

*Trethomphalus bulloides* (d’Orbigny) var. *plana*, CUSHMAN 1924 p. 36, pl. 10, fig. 8.

*Cymbaloporetta plana* (Cushman), WHITTAKER & HODGIKINSON 1979 p. 103, pl. 4, figs 19, 20. -MERIÇ et al. 2008 p. 318, pl. 8, figs 2-5.

*C. plana* (Cushman) belongs to the family Cymbaloporidae Cushman and the genus *Cymbaloporetta* Cushman. In this species the chamber arrangement is trochospiral in early stage, whereas in the later part chambers develop in annular series. Numerous apertures present usually as small circular pores.

*C. plana* thrives in the shallow water environments of the Pacific Ocean (CUSHMAN, 1915, 1924; CUSHMAN et al., 1954; GRAHAM & MILITANTE, 1959; TODD, 1965; CHENG & ZHENG, 1978; WHITTAKER & HODGIKINSON, 1979; HATTÀ & UJIE, 1992) and Red Sea (SAID, 1949). In the Mediterranean Sea, it has been described from the Adriatic and Tyrrenhian Seas (CIMERMAN & LANGER, 1991; SCHARRELLA & MONCHARMONT-ZEI, 1993; LANGER & SCHMIDT-SINNS, 2006). Recently, MERIÇ et al. (2008) reported this species on the Mediterranean coasts of Turkey, however in the present study it is reported for the first time in the Greek coastal environments.

In this study, *C. plana* occurs mainly at the northern and central Aegean sites (Fig. 2), displaying a peak in relative abundance (4.5%; Table 1) at the site of Mavro Lithari (establishment success: R, Table 2).

**Planogypsina acervalis** (BRADY 1884)

Plate II, Figs 4, 5


*Planorbulina mediterranensis* d’Orbigny, SAID 1949 p. 44, pl. 4, fig. 25.

*Planorbulina acervalis* Brady, PEREIRA 1979 p. 287, pl. 41, figs L, M. -REISS & HOTTINGER 1984 p. 252, figs G 32 a-b.

*P. acervalis* Brady belongs to the family Planorbulinidae Schwager and the genus *Planogypsina* Bermudez. The test of this species is composed of numerous chambers, in the early stages it is developed in a spiral, whereas in the later part chambers are arranged in an irregularly annular way. The ventral surface often is covered by a mass of small acervuline chambers. Aperture lipped, in adult forms, at either side of the chamber.

*P. acervalis* seems to be common in the Atlantic (RICHARDSON, 2006), Indian (PEREIRA, 1979) and Red Seas (SAID,
1949; REISS & HOTTINGER, 1984; HOTTINGER et al., 1993). BLANC-VERNET (1969) described this species from the coasts of Provence, France, whereas MERIÇ et al. (2004, 2008), reported this species on the Mediterranean coasts of Turkey. However, we report it for the first time in the Greek coastal environments.

In the present study, *P. acervalis* was found rarely at the central Aegean sites (Fig. 2), and always in very low abundances (establishment success: R); never making up more than 1% of the foraminiferal fauna (Table 1, 2).

*Triloculina fichteliana* D’ORBIGNY 1839
Plate II, Fig. 3

*Triloculina fichteliana* D’ORBIGNY 1839, p. 171, pl. 9, figs 8, 10. -GRAHAM & MILITANTE 1959 p. 53, pl. 7, fig. 10. -HOTTINGER et al. 1993 p. 65, pl. 66, figs 10-15.

*Triloculina* cf. *T. fichteliana* d’Orbigny, MERIÇ et al. 2008 p. 313, pl. 4, figs 8-12.

*T. fichteliana* d’Orbigny belongs to the family Hauerinidae Schwager and the genus *Triloculina* d’Orbigny. This species is characterized by subcircular test in front view, somewhat compressed. The wall is ornamented by numerous longitudinal costae. Aperture is terminal, semicircular with a slight tooth.

*T. fichteliana* thrives in the shallow water environments of the Atlantic Ocean (CUSHMAN, 1922), Pacific Ocean (GRAHAM & MILITANTE, 1959) and Red Sea (HOTTINGER et al., 1993). In the Mediterranean Sea, MERIÇ et al. (2008) reported the presence of this species on the Mediterranean coasts of Turkey as *Triloculina cf. T. fichteliana*.

In this study, *T. fichteliana* occurs rarely (establishment success: R) at the southern and central Aegean sites (Fig. 2), and always in very low abundances (less than 1% of the foraminiferal fauna; Table 1, 2).

**Discussion**

In this study, we identified six alien cryptogenic epiphytic foraminiferal species in the Greek coastal areas (Aegean Sea, Eastern Mediterranean). *A. lobifera, S. orbiculus* and *C. hemprichii* are typical symbiont-bearing species, whereas *C. plana, P. acervalis* and *T. fichteliana* are included among the smaller heterotrophic species.

According to LANGER (2008), the modern foraminiferal fauna of the Mediterranean Sea is mainly of Atlantic origin. *A. lobifera, P. acervalis, S. orbiculus* and *C. plana* have been found in the Atlantic (e.g., LANGER & HOTTINGER, 2000) and western Mediterranean (e.g., BLANC-VERNET, 1969; CIMERMAN & LANGER, 1991; SGARRELLA & MONCHARMONT-ZEI, 1993; LANGER & SCHMIDT-SINNS, 2006; MATEU-VICENS et al., 2010). Furthermore, MERIÇ et al. (2007) have already reported *C. hemprichii* and *A. lobifera* in Middle-Late Holocene coastal deposits of the Bosphorus Marmara Sea, whereas *C. hemprichii* and *S. orbiculus* have also been found in low abundances in middle Aegean coastal deposits of approx. 1.0 Ka BP (TRIANTAPHYLLOU et al., unpublished data). Their presence can be attributed to migration from the Atlantic during warm Pleistocene - Holocene events (Table 2).

However, after the opening of the Suez Canal, a number of tropical Red Sea foraminifera slowly migrated into the eastern Mediterranean Sea (HYAMS et al., 2002; LANGER, 2008). Nowadays, many foraminiferal species of Indo-Pacific origin have been documented in the eastern Mediterranean (e.g., AVŞAR, 1997; HYAMS et al., 2002; SAMIR et al., 2003; MERIÇ et al.,
The larger symbiont-bearing foraminifera species prefer warm, saline, tropical seas and their distribution is strongly constrained by water temperature (LANGER & HOTTINGER, 2000). In addition, the smaller non-symbiont-bearing tropical foraminifera, although lacking in endosymbionts, exhibit distributional limitations affected by temperature (LANGER, 2008). If we consider the alien epiphytic foraminiferal species in the Greek coastal areas as Lessepsian immigrants, during their invasion into the eastern Mediterranean Sea, they extended their range along a pathway of introduction similar to many other Red Sea aliens, i.e. from Suez Canal eastwards, along the Levantine coast and then northwards along the Turkish coast to the Aegean Sea.

Our findings present additional data on the distributional range and settlement of *A. lobifera*, *S. orbiculus* and *C. hemprichii* and extend the range of *C. plana*, *P. acervalis* and *T. fichteliana* in the Greek coastal ecosystems. The foraminiferal assemblages at the southern and central Aegean sites are characterized by a high proportion of alien immigrants that particularly account for more than 30% of the assemblages. In the northern site the alien species present an abrupt decrease, in agreement with the lower sea temperature values. Concerning their establishment success in the studied coastal ecosystems, they are considered as rare except for *A. lobifera* and *S. orbiculus*, which are frequent (see Table 2). Their distribution can be associated with several pathways, via the Atlantic during the interglacial warm periods of the Pleistocene-Holocene or fairly recent invasions, now well established, most probably via the Suez Canal (LANGER, 2008; present study).

Their high relative abundance is the result of the very successful adaptation of these species to local conditions in the coastal environments, in relation to an increasing trend in Mediterranean water temperatures over the last 30 years, as a possible result of human-induced global warming (THEOCARIS, 2008; VARGAS-YÁNEZ et al., 2008; LEJEUSNE et al., in press).

The importance of alien immigrants in terms of abundance and distribution range as reported by this study, suggest that particularly *A. lobifera* and *S. orbiculus* are now well established in the Aegean coastal ecosystems, representing a mixed Atlantic-Mediterranean and Red Sea (up to approx. 70%) foraminiferal composition. Future studies on a seasonal basis will reveal the role of environmental conditions and climate change on the alien species composition and biogeography in the Aegean Sea.

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**References**


BACCAERT, J., 1987. Distribution patterns and taxonomy of benthic foraminifera in the Lizard Island Reef Complex, north-


Biogeography of selected "larger" foraminifera, Micropaleontology, 46 (Suppl. 1): 105-126.


from the Spermonde Archipelago (Sulawesi, Indonesia). Scripta Geologica, 113: 93-120.


YANKO, V., 1995. Benthic foraminifera as indicators of heavy metal pollution along Israeli Coasts (Cruise AVI-1, May, 1993), In: Yanko, V. (Ed.), Avicenna (AVI CT92-0007), Benthic foraminifera as indicators of heavy metal pollution—a new kind of biological monitoring for the Mediterranean. Task 5, 58-152 Tel Aviv.


Plate I

1 *Amphistegina lobifera* Larsen, dorsal view, Mavro Lithari site, 2 *Amphistegina lobifera* Larsen, peripheral view, Chrissi site, 3 *Coscinospira hemprichii* Ehrenberg, side view and apertural detail, N. Kallikratia site, 4 *Sorites orbiculus* Forskål, side view, Mavro Lithari site, 5 *Sorites orbiculus* Forskål, peripheral view and detail of the single row of apertures, Vravron site.
Plate II

1 Cymbaloporetta plana Cushman, dorsal view, Mavro Lithari site, 2 Cymbaloporetta plana Cushman, ventral view, Mavro Lithari site, 3 Triloculina fichteliana D’Orbigny, side view, Mavro Lithari, 4 Planogypsina acervalis Brady, ventral view, Vravron site, 5 Planogypsina acervalis Brady, dorsal view, Mavro Lithari site.