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LANGER & HOTTINGER, 2000; HYAMS *et al.,* 2002, SAMIR *et al.,* 2003; MERIÇ *et al.,* 2005, 2008; TRIANTAPHYLLOU *et al.,* 2005; GRUBER *et al.,* 2007; YOKEŞ *et al.,* 2007; LANGER, 2008; TRIANTAPHYLLOU *et al.,* 2009; ZENETOS *et al.,* 2009). 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

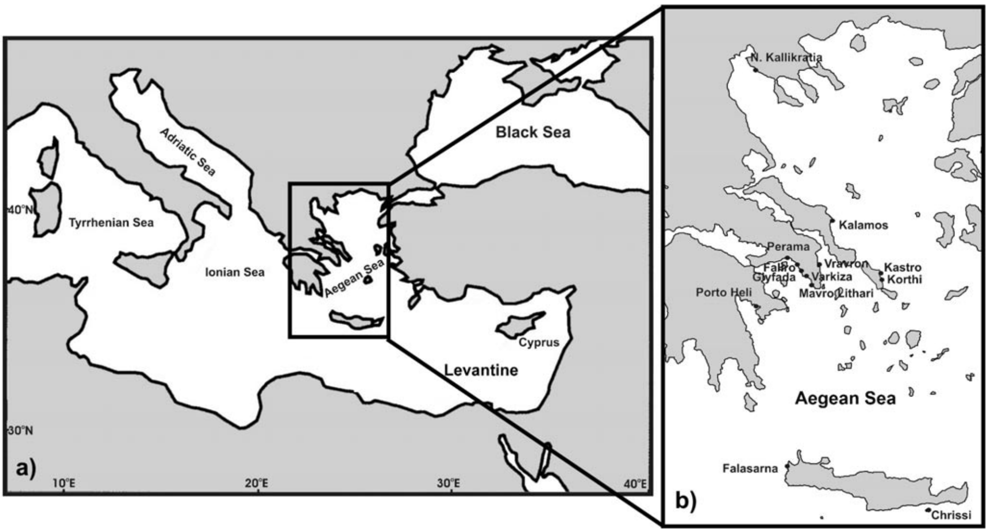

Fig. 1a, b: Location of the study area in the eastern Mediterranean and the Aegean Sea.

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 double-sided 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 fichteliana* 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.

Site	Latitude	Longitude	Date of collection	Water depth (m)	mean monthly Temperature (˚C)	mean monthly Salinity (‰)	Alien foraminiferal species (%)
southern Aegean Sea							
Chrissi	34.58	25.39	7/06	0-3	24.45	39.03	*Amphistegina lobifera* (42.5) *Sorites orbiculus* (2.0)
Falasarna	35.29	23.34	7/06	0-3	24.16	38.86	*Amphistegina lobifera* (26.5) *Sorites orbiculus* (7.5) *Triloculina fichteliana* (0.5)
central Aegean Sea							
Porto Heli	37.27	23.06	9/07	0-3	23.05	38.40	*Amphistegina lobifera* (32.0) *Planogypsina acervalis* (0.5)
Mavro Lithari	37.43	23.56	10/06	0-3	21.07	38.51	*Amphistegina lobifera* (34.0) *Cymbaloporetta plana* (4.5) *Planogypsina acervalis* (1.0) *Triloculina fichteliana* (0.5) *Sorites orbiculus* (0.5)
Glyfada	37.54	23.44	10/09	0-3	21.07	38.51	*Amphistegina lobifera* (43.6) *Cymbaloporetta plana* (2.0)
Varkiza	37.49	23.51	10/09	0-3	21.07	38.51	*Amphistegina lobifera* (68.0) *Cymbaloporetta plana* (4.0) *Sorites orbiculus* (2.5)
Faliro	37.56	23.52	11/09	0-3	18.85	38.60	*Amphistegina lobifera* (24.2) *Sorites orbiculus* (1.5)
Perama	37.59	23.35	1/09	0-3	18.85	38.60	*Planogypsina acervalis* (0.5)
Vravron	37.56	24.03	5/06	0-3	18.26	38.38	*Amphistegina lobifera* (55.5) *Planogypsina acervalis* (0.5) *Sorites orbiculus* (0.5) *Coscinospira hemprichii* (0.1)
Korthi Andros	37.46	24.58	8/01	0-3	24.04	38.18	*Amphistegina lobifera* (36.8) *Planogypsina acervalis* (0.5) *Sorites orbiculus* (0.1)
Kastro Andros	37.51	24.57	8/01	0-3	24.04	38.18	*Amphistegina lobifera* (34.5) *Cymbaloporetta plana* (0.5) *Coscinospira hemprichii* (0.1) *Sorites orbiculus* (0.1)

(continued)

Table 1 (continued)

Site	Latitude	Longitude	Date of collection	Water depth (m)	mean monthly Temperature (oC)	mean monthly Salinity (‰)	Alien foraminiferal species (%)
Kastro Andros	37.51	24.57	7/03	0-3	23.26	38.53	***Amphistegina lobifera* (24.6)** ***Coscinospira hemprichii* (1.5)** ***Cymbaloporetta plana* (1.0)** ***Planogypsina acervalis* (1.0)**
Kalamos	38.31	24.14	6/08	0-3	21.53	38.01	***Amphistegina lobifera* (71.2)**
northern Aegean Sea							
Nea Kallikratia	40.23	22.55	6/08	0-3	21.44	37.07	***Cymbaloporetta plana* (10.3)** ***Amphistegina lobifera* (3.0)** ***Coscinospira hemprichii* (0.5)**

Geographical distribution of the determined species is presented in Figure 2; relative percentages are included in Table 1.

***Amphistegina lobifera* LARSEN 1976**
Plate I, Figs 1, 2

Amphistegina lobifera, LARSEN 1976 p. 4, pl. 3, figs. 1-5; pl. 7, fig. 3; pl. 8, fig. 3. -REISS & HOTTINGER 1984 p. 217, fig. G11, G 12 a-c. -MORARIU & HOTTINGER 1988 p. 695, fig. 1 A, B, fig. 2. -HOTTINGER *et al.* 1993 p. 133, pl. 186, figs. 1-10; pl. 187, figs. 1-7; pl. 188, figs. 1-6. –AVŞAR 1997 p. 71, 79. -AVŞAR *et al.* 2001 p. 101-102. -HYAMS *et al.* 2002 p. 174, pl. 1, figs. 2-4. -MERIÇ *et al.* 2004 p. 191, pl. 29, figs. 7-10. –TRIANTAPHYLLOU *et al.* 2009 p. 79, pl.1. figs 1-6.

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

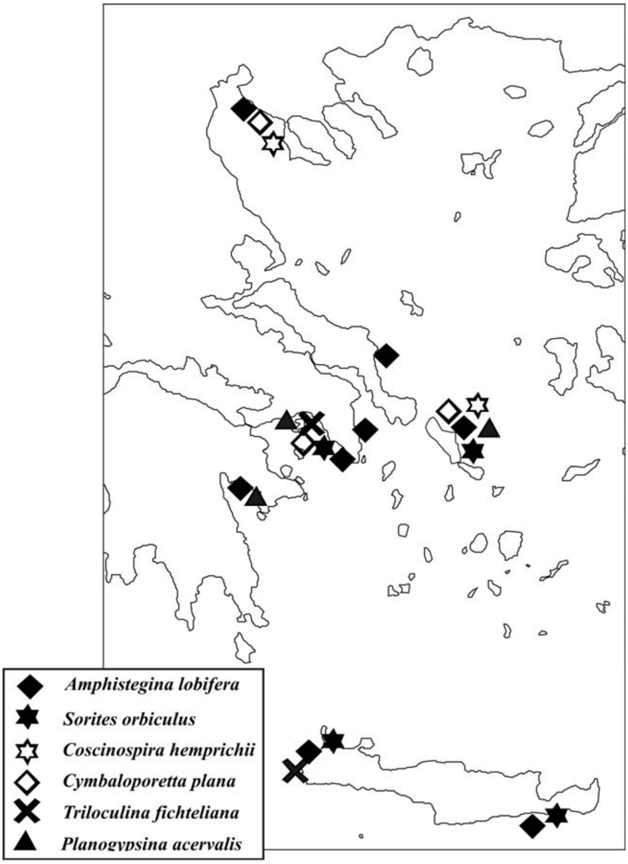

Fig. 2: Distribution of alien migrants in the Greek coastal areas.

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; MERIÇ *et al.,* 2008), the Sea of Marmara (MERIÇ *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 Peloponnesus, Castellorizo, Crete and different islands of the southern Aegean Sea, whereas HOLLAUS & 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

Table 2
Origin, pathway and establishment success of the studied alien foraminiferal species in the Greek coastal areas.

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

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. Kallikratia) 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 matter. 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 & HOTTINGER, 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 & HOTTINGER, 2000; LANGER, 2008). Furthermore, *S. orbiculus* has been reported from even the Balearic Islands (CRESPÍ, 1922a, 1922b; COLOM, 1942, 1964, 1974; MATEU, 1970; MATEU-VICENS *et al.,* 2010), and the area off Nice (LANGER & HOTTINGER, 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 & HOTTINGER, 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 & HOTTINGER (1997) in Crete and TRIANTAPHYLLOU *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**

Plate I, Fig. 3

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

Spirolina arietina (Batsch), CUSHMAN 1930 p. 43, pl. 15, figs. 4,5 -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 (HOTTINGER *et al.,* 1993). In the Western Mediterranean, this species has been reported in the Balearic Islands and the Catalan coast (CRESPÍ, 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 *Peneroplis 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; HATTA & UJIIE, 1992) and Red Sea (SAID, 1949). In the Mediterranean Sea, it has been described from the Adriatic and Tyrrhenian Seas (CIMERMAN & LANGER, 1991; SGARRELLA & 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

Planogypsina acervalis BRADY 1884 p. 657, pl. 92, fig. 4. -HOTTINGER *et al.* 1993 p. 125, pl. 169, figs. 1-9. -MERIÇ *et al.* 2004 p. 187. -MERIÇ *et al.* 2008 p. 321, pl. 8, figs 9-11.

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.,* 2005, 2008; GRUBER *et al.,* 2007; YOKEŞ *et al.,* 2007; LANGER, 2008; TRIANTAPHYLLOU *et al.,* 2009; ZENETOS *et al.,* 2009). 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 (THEOCHARIS, 2008; VARGAS-YÁÑEZ *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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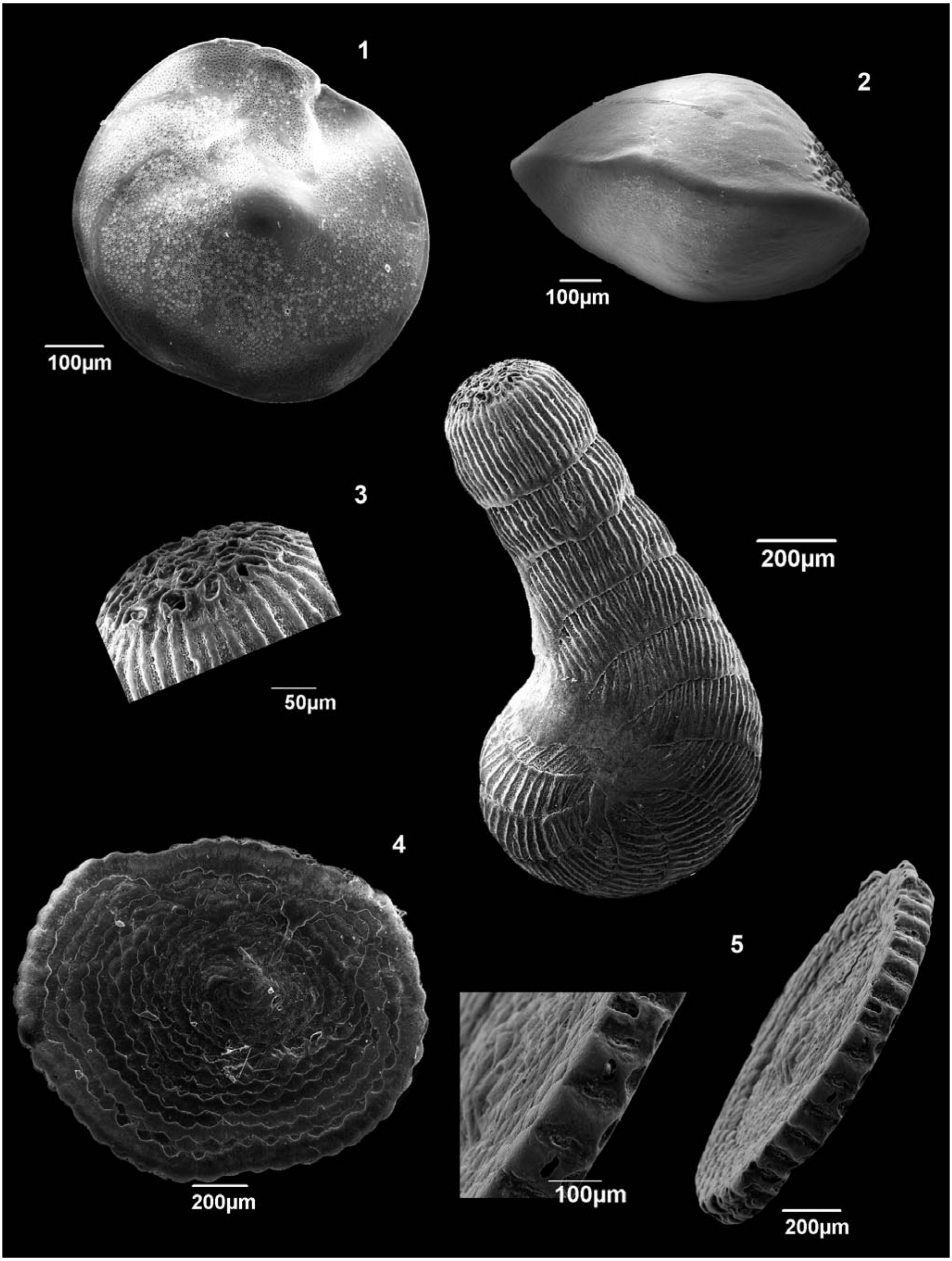

Plate I

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.

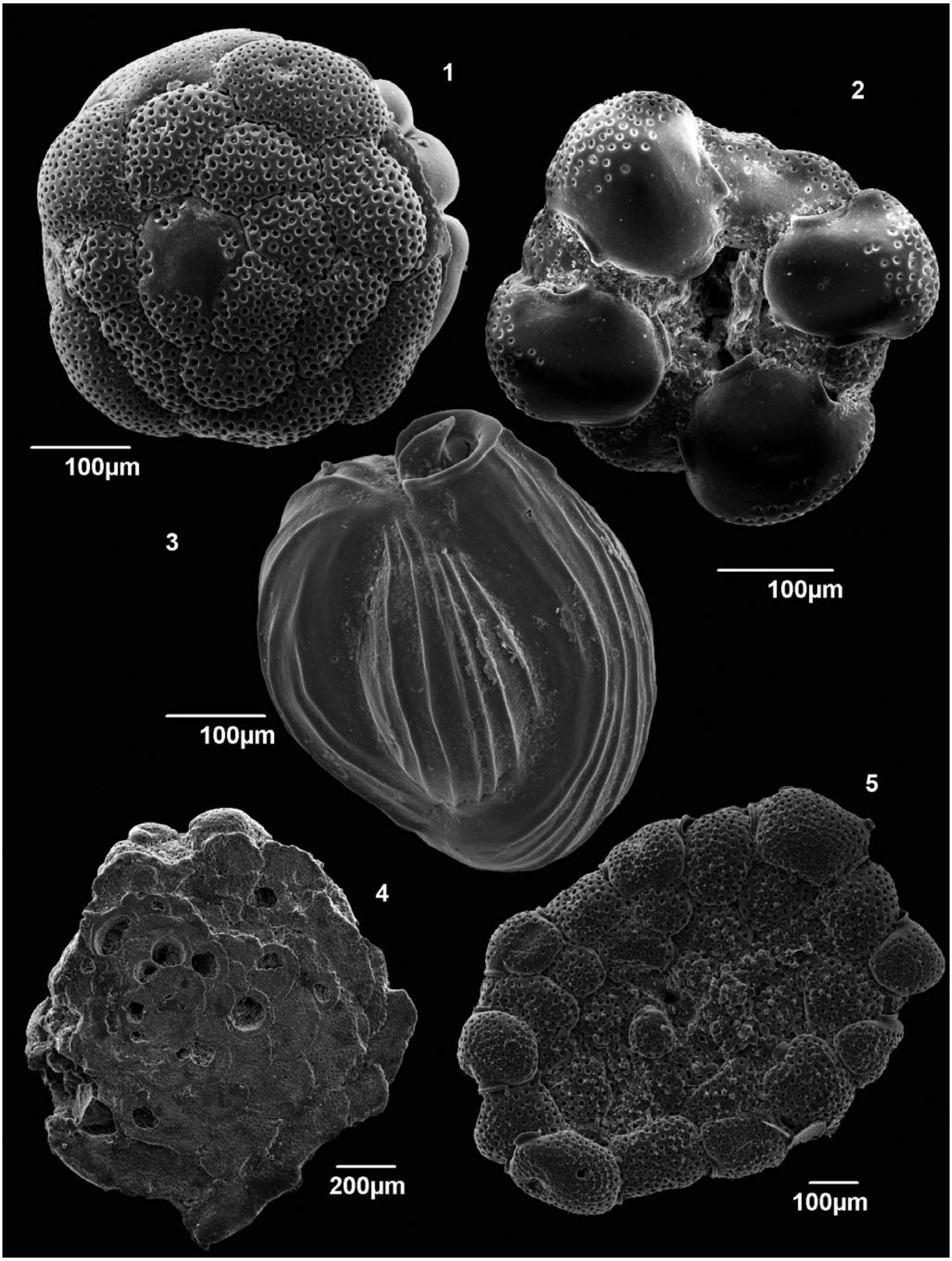

Plate II

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.