

New Observations of Alien Foraminifera on the Turkish Coasts of the Aegean Sea (2008-2011)

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Abstract

Invasion of the Mediterranean Sea by alien species is an ongoing process. Each year new alien species are being recorded in the Levantine basin. To date, 37 alien foraminifer species are known to inhabit Turkish coastline. Because of low water temperature it is hard of survive for the thermophilic alien species in the Aegean Sea. Until 2008, only 12 alien foraminifers have been reported from the Aegean coasts, however the recent studies increased this number to 31. The reports of *İridia diaphana* Heron-Allen and Earland, *Quinqueloculina* sp. C, *Triloculina affinis* d'Orbigny, *Triloculina* sp. A, *Euthymonacha polita* (Chapman), *Coscinospira acicularis* (Batsch), *Polymorphina fistulosa* Cushman and *Brizalina simpsoni* (Heron-Allen ve Earland) constitutes first records. Besides, *Haddonina* sp., *Nodopthalmidium antillarum* (Cushman), *Spiroloculina antillarum* d'Orbigny, *Hauerina diversa* Cushman, *Triloculina fichteliana* d'Orbigny, *Peneroplis arietinus* (Batsch), *Sorites variabilis* Lacroix, *Cymbaloporetta plana* (Cushman), *C. squamosa* (d'Orbigny), *Amphistegina lessonii* d'Orbigny are first records for the Turkish Aegean fauna.

Keywords: Foraminifera, Aegean Sea, Diversity, Turkish Coasts

Introduction

Invasion of the Mediterranean Sea by alien species is getting increasingly prominent every day. 37 species of alien foraminifera have been reported from the coasts of Turkey (Zenetos et al., 2008; Meriç et al., 2010a; Meriç et al., 2010b; Meriç et al., 2011). Majority of these species are suggested to be introduced via Suez Canal. Because of their thermophilic characteristics, most of them are only observed on the Mediterranean coasts. Only a few species which have broad range of environmental preferences are widely distributed in the Aegean Sea (Meriç et al. 2008). But, abundant populations of thermophilic alien foraminifers are locally observed around the submarine springs on the

Aegean coast of Turkey, suggesting that the environmental conditions created by the warm springs help the thermophilic aliens to extend their range of distribution towards the northern Aegean coasts (Meriç et al 2010a). Until 2008 only 12 alien foraminifer species have been recorded on the Turkish Aegean coastline (Table1) (Meriç et al., 2008; 2009a; 2010a). In the frame work of this study the alien foraminiferal fauna of Kuşadası, Çeşme, Karaburun and Ayvalık were investigated between 2008-2011.

Materials and Methods

Two submarine springs (named, Kuşadası-1 and Kuşadası-2) are found 200m off the shore in Pamucak Cove, located 50m apart from each

other (Kuşadası, Aydın), at a depth of 12.40m. Kuşadası-1 was chosen for investigation. The spring was taken as the center and four vertical lines were set on south, north, east and west directions. A total of 45 sediment samples were collected at different points on the lines. On the south and north lines samples were collected at each 5, 10, 15, 20, 25, 30, 35, 40, 45, 50 m distances according to the spring (Figure 1). Because of the suitable benthic structure, it was able to collect more samples on the east line; samples were collected at 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100 m distances. 50m distance couldn't be collected on the west line and samples were taken at 5, 10, 15, 20, 25, 30, 35, 40, 45 m distances. One sample was also taken from the spring.

A similar research was conducted in Çeşme, west of Karaburun Peninsula on November 6, 2008. Three lines were set; A (210°), B (120°) and C (290°). A total of 38 samples were collected at each 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90 ve 100. m distances to the center. But, because of the jetty it couldn't be possible to collect samples after 40m on Line A. The temperature of the spring was measured as 28.4 °C.

A total of 90 samples have been collected in Karaburun-1 station (NW of Karaburun Peninsula) and Karaburun-2 (SE of Karaburun Peninsula) on 07.11.2008. In both stations sampling have been performed on three transects, in Karaburun-1: Transect A (210°), Transect B (125°) and Transect C (290°); in Karaburun-2: Transect A (80°), Transect B (10°) and Transect C (160°). Samples have been collected at each 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90 and 100. m, starting from the intersection of the transects.

Four core samples were collected around Ayvalık, three from the north of Alibey Island and one from the east of Maden Island. Each core sample was longitudinally cut sliced at each two centimeters. 5 gr of wet sediment sample were taken from each slice. Wet sediment samples were weighed and treated with 10 % H₂O₂ for 24 hours. The samples were washed with pressurized water on 0.063 sieve and dried at 50 °C oven. The dried samples were further sieved with 2.00, 1.00,

0.500, 0.250, 0.125 mm mesh sizes. The foraminifer individuals were separated under binocular microscope.

Results

Alien foraminifer fauna was investigated in four locations. It was observed that the known species have enlarged their range of extensions since 2008. *Triloculina fichteliana* d'Orbigny, *Peneroplis arietinus* (Batsch), *Sorites variabilis* Lacroix are new records for Turkish Aegean coasts, the previously recorded *İridia diaphana* Heron-Allen and Earland was found to enlarge its range of extension towards south (Meriç et al., 2009a). *Amphistegina lessonii* d'Orbigny is the first record from the Turkish coasts where as *Coscinospira acicularis* (Batsch) and *Polymorphina fistulosa* Cushman constitute the first records for the Mediterranean (Figure 2).

The distribution of aline foraminifers among stations:

Gulf of Kuşadası: *İridia diaphana* Heron-Allen and Earland, *Haddonina* sp., *Nodophthalmidium antillarum* (Cushman), *Hauerina diversa* Cushman, *Quinqueloculina* sp. C, *Triloculina affinis* d'Orbigny, *Triloculina* sp. A, *Euthymonacha polita* (Chapman), *Sorites orbiculus* Ehrenberg, *S. variabilis* Lacroix, *Pyramidulina catesbyi* (d'Orbigny), *Brizalina simpsoni* (Heron-Allen and Earland), *Cymbaloporeta plana* (Cushman), *Amphistegina lessonii* d'Orbigny, *A. lobifera* Larsen (Table 2).

Çeşme: *Nodophthalmidium antillarum* (Cushman), *Spiroloculina antillarum* d'Orbigny, *Triloculina fichteliana* d'Orbigny, *Euthymonacha polita* (Chapman), *Coscinospira acicularis* (Batsch), *Peneroplis arietinus* (Batsch), *Amphisorus hemprichii* Ehrenberg, *Sorites orbiculus* Ehrenberg, *Polymorphina fistulosa* Cushman, *Cymbaloporeta plana* (Cushman) (Table 3).

North of Karaburun Peninsula: *İridia diaphana* Heron-Allen and Earland, *Nodophthalmidium antillarum* (Cushman), *Triloculina fichteliana* d'Orbigny, *Euthymonacha polita* (Chapman), *Peneroplis arietinus* (Batsch), *Sorites orbiculus* Ehrenberg,

S. variabilis Lacroix, *Cymbaloporeta plana* (Cushman), *C. squamosa* (d'Orbigny), *Amphistegina lobifera* Larsen (Table 4).

inhaerens Schultze, *Amphistegina lobifera* Larsen (Table 5).

Ayvalık: *Iridia diaphana* Heron-Allen and Earland, *Spirnoloculina antillarum* d'Orbigny, *Sorites orbiculus* Ehrenberg, *Acervulina*

Dardanelles: *Polymorphina fistulosa* Cushman.

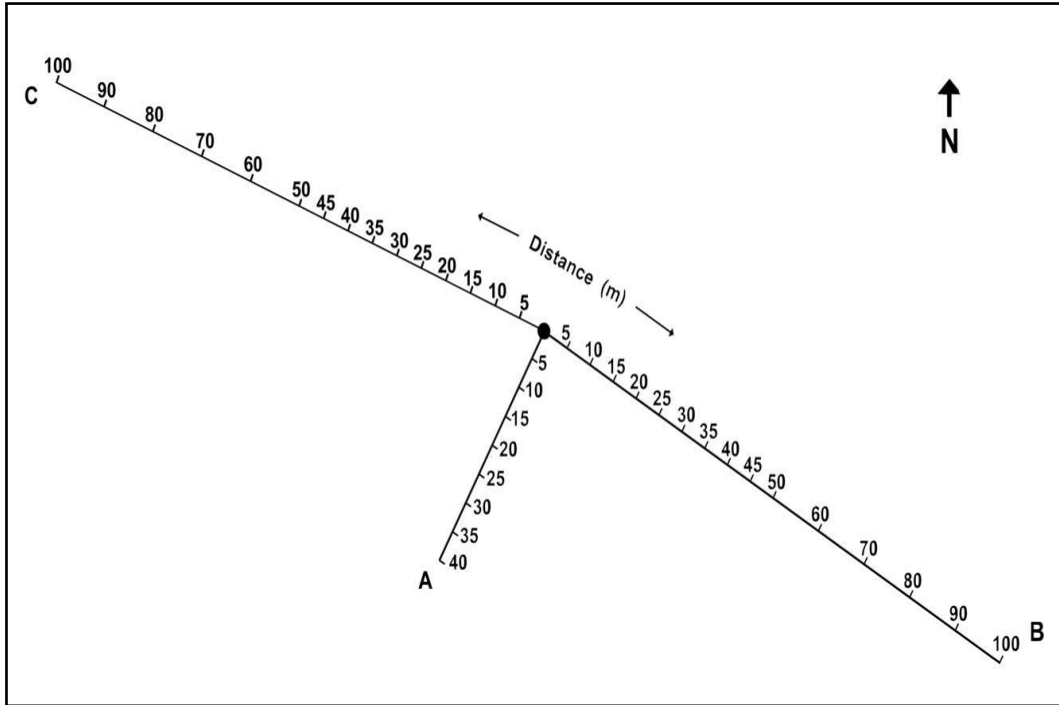


Figure 1. Transects and sampling points in Kuşadası.

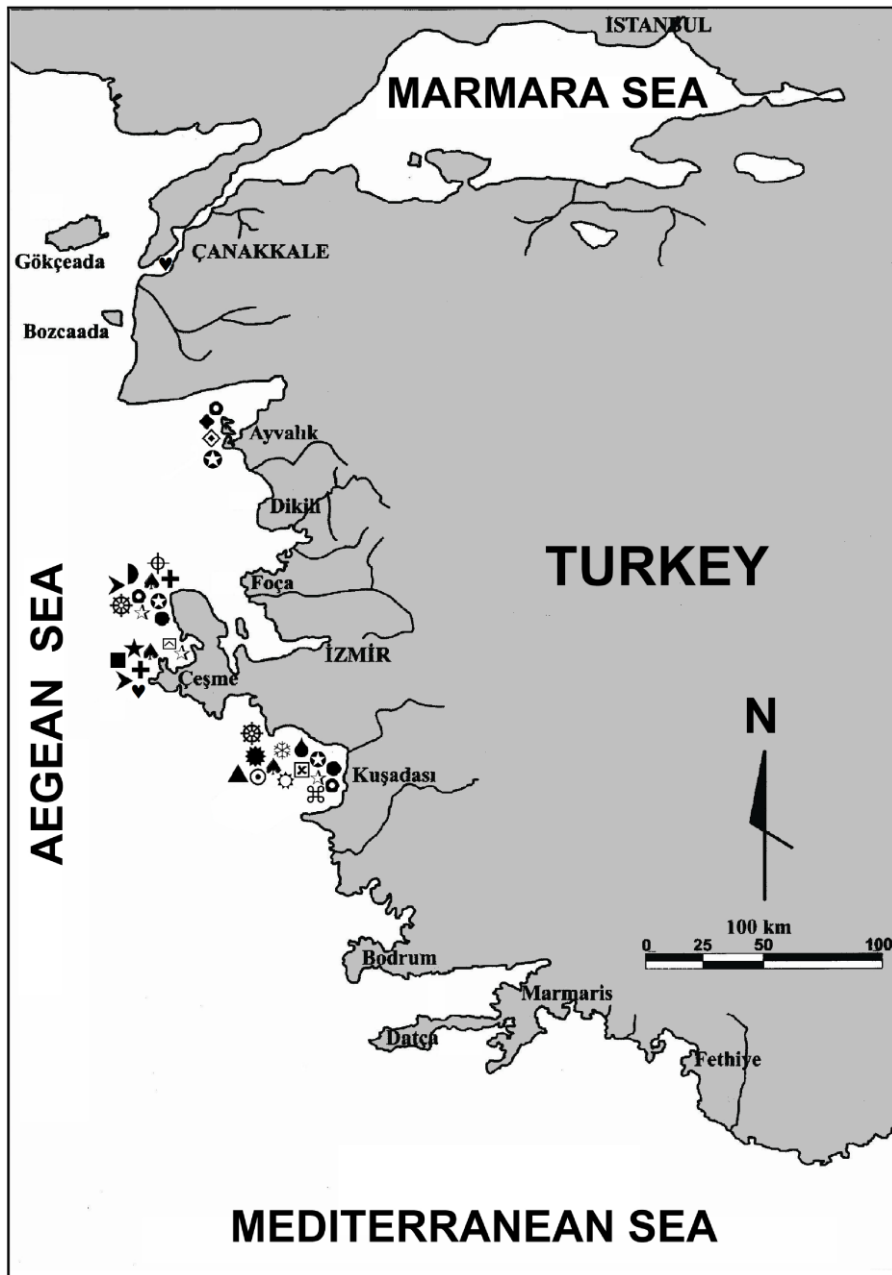


Figure 2. ⊕ *Iridia diaphana* Heron-Allen and Earland, * *Haddonina* sp., ♠ *Nodopthalmidium antillarum* (Cushman), ◆ *Spiroloculina antillarum* d'Orbigny, ⊙ *Hauerina diversa* Cushman, ☒ *Quinqueloculina* sp. C, ◆ *Triloculina affinis* d'Orbigny, † *T. fichteliana* d'Orbigny, ☿ *Triloculina* sp. A, ☆ *Euthymonacha polita* (Chapman), ☒ *Coscinospira acicularis* (Batsch), ★ *Amphisorus hemprichii* Ehrenberg, + *Peneroplis arietinus* (Batsch), ● *Sorites orbiculus* Ehrenberg, ⊗ *S. variabilis* Lacroix, ▲ *Pyramidulina catesbyi* (d'Orbigny), ♥ *Polymorphina fistulosa* Cushman, ⊛ *Brizalina simpsoni* (Heron-Allen and Earland), ► *Cymbaloporetta plana* (Cushman), ⊕ *C. squamosa* (d'Orbigny), ◆ *Acervulina inhaerens* Schultze, ⊗ *Amphistegina lessonii* d'Orbigny, ● *A. lobifera* Larsen.

Table 1. Alien foraminifer species recorded on the Turkish Aegean coastline until 2008 (Meriç et. 2008).

Alien species	Gulf of Saros	Gökçeada	Ayvalık	Dikili	Foça	Gulf of İzmir	Çeşme	Gulf of Gökova	Gulf of Datça	Gulf of Marmaris
<i>Edentostomina cultrata</i>										+
<i>Spiroloculina cf. angulata</i>		+								
<i>Spiroloculina antillarum</i>							+			
<i>Articulina alticostata</i>									+	
<i>Amphisorus hemprichii</i>								+	+	
<i>Sorites orbiculus</i>		+					+	+		+
<i>Pyramidulina perversa</i>						+				
<i>Astacolus sublegumen</i>			+					+		
<i>Acervulina inhaerens</i>	+		+	+	+		+			+
<i>Planogypsina acervalis</i>	+									
<i>Planogypsina squamiformis</i>	+			+						
<i>Amphistegina lobifera</i>		+						+	+	+

Table 1. Alien foraminifer species recorded on the Turkish Aegean coastline after 2008.

Alien species	Dardanelles	Ayvalık	Karaburun	Çeşme	Kuşadası
<i>İridia diaphana</i>		+	+		
<i>Haddonina sp.</i>					+
<i>Nodopthalmidium antillarum</i>				+	+
<i>Spiroloculina antillarum</i>		+		+	
<i>Hauerina diversa</i>					+
<i>Quinqueloculina sp. C</i>					+
<i>Triloculina affinis</i>					+
<i>Triloculina fichteliana</i>			+	+	
<i>Triloculina sp. A</i>					+
<i>Euthymonacha polita</i>			+	+	+
<i>Coscinospira acicularis</i>				+	
<i>Coscinospira hemprichii</i>		+		+	
<i>Peneroplis arietinus</i>			+	+	
<i>Amphisorus hemprichii</i>				+	
<i>Sorites orbiculus</i>		+	+	+	+
<i>Sorites variabilis</i>			+		+
<i>Pyramidulina catesby</i>					+
<i>Polymorphina fistulosa</i>	+			+	
<i>Brizalina simpsoni</i>					+

Continued Table 1					
<i>Acervulina inhaerens</i>		+			
<i>Cymbaloporetta plana</i>			+	+	+
<i>Cymbaloporetta squamosa</i>			+		
<i>Amphistegina lessonii</i>					+
<i>Amphistegina lobifera</i>		+	+		+

Table 2. Distribution of alien foraminifer species observed around the submarine springs in Kuşadası (Meriç et al., 2009c; 2010a).

Species	Transect	Distance (m)	Depth (m)	Number of specimens
<i>Haddonia</i> sp.	South	15	9.70	1
<i>Nodopthalmidium antillarum</i>	South	15-30	9.5-11.3	3
	North	5-50	8.90-20.10	7
	West	5-45	9.10-22.30	14
	East	70	19.10	1
<i>Hauerina diversa</i>	North	20	9.00	1
<i>Quinqueloculina</i> sp. C	West	10	9.30	1
<i>Triloculina affinis</i>	West	35	17.90	1
<i>Triloculina</i> sp. A	East	45	19.10	1
<i>Euthymonacha polita</i>	South	10-30	9.7-11.3	3
	North	15	8.7	1
	West	15	11.3	1
	East	70, 100	19.1-20.2	2
<i>Sorites orbiculus</i>	South	35	12.30	2
	West	5-40	9.1-18.2	3
	East	40	18.10	1
<i>Sorites variabilis</i>	West	10	9.30	1
<i>Pyramdulina catesby</i>	West	45	22.30	1
<i>Brizalina simpsoni</i>	North	25	10.10	1
<i>Cymbaloporetta plana</i>	North	25-40	10.1-13.1	2
	West	10-20	9.3-12.8	2
	East	25-60	14.7-19.4	2
<i>Amphistegina lessonii</i>	Spring	0	12.4	1
	West	30	17.3	3
	East	25-100	14.4-20.20	2
<i>Amphistegina lobifera</i>	Spring	0	12.4	305
	South	5-50	9.2-14.9	4496
	North	5-50	8.9-20.1	320
	West	5-45	9.1-22.3	3716
	East	5-100	11.5-20.20	956

Table 3. Distribution of alien foraminifer species observed around the submarine springs in Çeşme (Ilica Bay) (Meriç et al., 2010b; 2011).

Species	Transect	Distance (m)	Depth (m)	Number of specimens
<i>Nodophthalmidium antillarum</i>	A	5-15	3.1-3.2	5
	B	5-80	3.3-3.7	18
	C	5-100	1.6-2.5	19
<i>Spiroloculina antillarum</i>	A	5-40	2.0-3.2	18
	B	5-100	3.3-3.9	48
	C	5-100	1.6-2.5	69
<i>Triloculina fichteliana</i>	B	80-100	3.7-3.9	2
	C	5-90	1.6-2.5	4
<i>Euthymonacha polita</i>	A	5-40	2.0-3.2	4
	B	5-25	3.3-4.1	6
<i>Coscinospira acicularis</i>	A	5-40	2.0-3.2	7
	B	5-100	3.3-3.9	20
	C	5-90	1.6-2.5	28
<i>Coscinospira hemprichii</i>	A	5-40	2.0-3.2	27
	B	5-100	3.3-4.1	99
	C	5-100	1-2.5	81
<i>Peneroplis arietinus</i>	A	5-40	2.0-3.2	7
	B	15-90	3.8-4.1	11
	C	5-100	1.6-2.5	18
<i>Amphisorus hemprichii</i>	A	10	3.0	1
	B	70-100	3.9-4.0	2
	C	5-15	1.8-2.5	2
<i>Sorites orbiculus</i>	A	5-25	3.2	6
	B	5-100	3.3-3.9	14
	C	5-100	1.6-2.5	27
<i>Polymorphina fistulosa</i>	C	100	3.9	1
<i>Cymbaloporetta plana</i>	A	10-25	3.0-3.2	3
	B	10-90	3.8	9
	C	5-60	1.3-2.5	11

Table 4. Distribution of alien foraminifer species observed in Karaburun Peninsula.

Species	Transect	Distance (m)	Depth (m)	Number of specimens
<i>Iridia diaphana</i>	2B	80	3.2	2
<i>Nodophthalmidium antillarum</i>	2A	80	5.6	1
<i>Triloculina fichteliana</i>	1A	40	6.6	1
	1C	80-90	2.9-3.1	3
	2B	80	3.2	4
<i>Euthymonacha polita</i>	1C	100	2.7	1
<i>Peneroplis arietinus</i>	1A	35	4.9	2
<i>Sorites orbiculus</i>	1A	35	4.9	1
	1C	80	3.1	1
	2B	60	2.6	1
<i>Sorites variabilis</i>	2B	90	2.3	1
<i>Cymbaloporeta plana</i>	1A	10-100	1.1-19.3	9
	1C	60-80	3.1-3.4	4
<i>Cymbaloporeta squamosa</i>	1C	70-100	2.7-3.5	4
<i>Amphistegina lobifera</i>	1A	5-100	1.0-19.3	505
	1B	5-80	1.0-1.9	32
	1C	5-100	1.2-2.7	165
	2A	15	1.2	1
	2B	5-90	1.0-2.8	37
	2C	10-45	1.0-2.5	7

Table 5. Distribution of alien foraminifer species observed in Ayvalık (2009a).

Species	Core	Distance (m)	Depth (m)	Number of specimens
<i>Iridia diaphana</i>	2C	0-38	8.00	30
<i>Spiroloculina antillarum</i>	1C	42-45	1.50	3
	3A	0-18	2.70	8
	4B	2-46	0.80	5
<i>Sorites orbiculus</i>	1C	8-10	1.50	1
	2C	0-40	8.00	12
	3A	0-2	2.70	1
	4B	34-36	0.80	1
<i>Acervulina inhaerens</i>	2C	34-36	8.00	5
<i>Amphistegina lobifera</i>	1C	16-18	1.50	1

Discussion

In recent years, many Indo-Pacific originated benthic foraminifer species were recorded on the Aegean coasts of Turkey. Some of them extended their ranges of distribution northwards and some even entered the Sea of Marmara through Dardanelles (Meriç et. al., 2005; 2009a and b). *Iridia diaphana* Heron-Allen and Earland was the only Atlantic originated alien species observed on the Turkish Aegean coasts.

Its absence in the western Mediterranean Sea suggests an introduction via ballast waters.

Nodophthalmidium antillarum was previously reported from Gulf of Iskenderun (Meriç et al 2008) and it is also found on the Mediterranean coast of Israel (unpublished data). On the Aegean coasts, it is observed around Kuşadası, Karaburun and common in Çeşme. It has not been yet recorded on the southwestern coasts of Turkey (Antalya), where detailed investigations

have been conducted, suggesting that either the region lacks suitable environmental factors to live or it is very rare to find along the western Mediterranean coast of Turkey.

Only a single specimen of the Pacific originated alien species *Euthymonacha polita* (Chapman) was found in Gulf of Kuşadası (Meriç et al., 2010a). However, recent studies show that its range of distribution extended to Karaburun and Çeşme. It has not yet been recorded elsewhere in the Mediterranean, most probably introduced via ballast waters.

In 38 core samples collected from the submarine spring in Ilica Bay an Indo-Pacific originated alien species *Coscinospira acicularis* (Batsch) was recorded for the first time in the Mediterranean Sea. Although it is commonly found around the spring, it is not recorded elsewhere along the Turkish coastline. Only a single specimen was observed in Haifa (unpublished data). It has been recorded in Timor Sea (Loeblich and Tappan, 1994) and also in the Gulf of Aqaba, as *Monalysium acicularis* (Batsch) (Hottinger et al. 1993).

Peneroplis arietinus (Batsch) has been first recorded in the Mediterranean on the southwestern coast of Antalya (Meriç et al. 2008). It was also found on in Ilica Bay (Çeşme) and on the northwest of Karaburun Peninsula. It is also rarely observed in Haifa, Israel and Hayat, Turkey (unpublished data). Hottinger et al., 1993 has reported this species as *Peneroplis* cf. *planatus* (Fichtel and Moll) from Gulf of Aqaba (Plate 80, figure 6-8). Thus, Suez Canal is the most probable vector for this species.

Polymorphina fistulosa Cushman is widely distributed in the Indo-Pacific (Cushman, 1914; Yassini and Jones, 1995; Loeblich and Tappan, 1994; Hottinger et al., 1993). Cimerman and Langer (1991) have reported *Polymorphina* sp. from Vulcano Island, NE Sicily, Italy. A single *Polymorphina fistulosa* Cushman individual was recently observed in the foraminiferal assemblage collected around a hot water submarine spring in Ilica Bay (Çeşme, Turkey). Seven specimens were also found in one

sediment sample collected from the western entrance of Dardanelles (Çanakale, Turkey). These records constitute the first record of this Pacific originated species in the Aegean Sea.

Amphistegina lobifera Larsen is the dominant species on the southwestern coast of Turkey and abundantly found along the mediterranean coast. It is also widely distributed in the Aegean Sea, recorded from Gökçeada, Gulf of Gökova, Gulf of Datça and Gulf of Marmaris. But its abundance decreases northward because of low water temperatures. However it is very abundant around submarine springs in Gulf of Kuşadası and northwest of Karaburun Peninsula (Meriç et al., 2009c). But, surprisingly it was found to be very rare in samples collected from Dilek Peninsula (Avşar et al., 2009) and not found in Ilica Bay, Çeşme. The temperature of the submarine spring in Gulf of Kuşadası was 19.6 °C, where as it was measured 28.4 °C in Ilica Bay, indicating that environmental factors other than temperature is needed.

Indo-Pacific originated alien species, such as *Triloculina fichteliana* d'Orbigny, *Sorites orbiculus* Ehrenberg, *Cymbaloporeta plana* (Cushman), *Planogypsina acervalis* (Brady) and *Amphistegina lobifera* Larsen were also recorded in western Aegean Sea and on the coasts of Crete Island (Koukousioura et al., 2010). Some of these species were suggested to be of Atlantic origin and introduced via Gibraltar (Koukousioura et al., 2010 Table 2), but there is no evidence for the the presence of *Irídia diaphana* Heron-Allen and Earland in the western Mediterranean.

Up to 2008, only 12 alien foraminifer species have been recorded in the Aegean Sea. This number increased to 31 with the studies conducted between 2008-2011. The reason of this increase may be related to the population expansions of the alien species inhabiting Mediterranean coasts of Turkey and spreading northwards. An other explanation is the increase of the studies on alien foraminifera. In both cases new records of species and range extensions are expected to in the Aegean Sea in the very near future.



Figure 3. Main migration patterns of the Indo-Pacific originated alien species in the Eastern Mediterranean.

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