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Alien and cryptogenic Foraminifera in the Mediterranean Sea: A revision of taxa as part of the EU 2020 Marine Strategy Framework Directive

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Abstract

The human-mediated translocation of marine alien species beyond their natural ranges started as early as people began navigating the sea and is of growing concern to nature conservation. The Mediterranean Sea is among the most severely affected areas by biological invasions, a phenomenon that has been fostered by the opening and recent extension of the Suez Canal, the transport and release of ballast water, aquaculture and aquarium trade, ichthyochory and other active or passive dispersal mechanisms. The increase of marine invasions has stimulated considerable research, but for some important groups, in particular microorganisms, data are still limited. In this paper we have reviewed the current status of marine alien foraminifera in the Mediterranean Sea. Our survey includes a comprehensive taxonomic revision of previously recognized alien taxa, and new information obtained from the fossil record and from molecular studies. Our survey and reexamination of alien benthic foraminifera yielded a total of 44 validly recognized species and two species of cryptogenic taxa and reduces the number of previous recordings. The revised list includes both larger symbiont-bearing and smaller benthic foraminifera, including 16 hyaline-perforate, 3 agglutinated and 25 porcelaneous taxa. The vast majority of alien foraminifera recorded so far have become established in the Eastern and Central Mediterranean Sea, indicative for translocation and introduction via the Suez Canal pathway. Only one species, Amphistegina lobifera, causes significant ecological impacts and fulfills the criteria to be considered as an invasive alien. This species is a prolific carbonate producer, and displays extreme forms of ecosystem invasibility with capabilities to reduce native diversity and species richness. The proliferation and rates of recently observed range extensions, track contemporary sea surface temperature increases, provide strong support for previous species distribution models, and corroborate findings that rising water temperatures, global climate change and the extension of climate belts are major drivers fueling the latitudinal range expansion of larger symbiont-bearing and smaller epiphytic foraminifera. Intensified efforts to study alien foraminifera on a molecular level, in dated cores and in ballast water are required to trace their source of origin, to identify vectors of introduction and to verify their status as true aliens.

Keywords: Alien foraminifera; invasive species; taxonomy; biogeography; Mediterranean Sea.

Introduction

Alien or non-indigenous species (NIS), as defined in the European Union’s Regulation 1143/2014 (EU, 2014a), are organisms introduced outside their natural range and dispersal potential. While most of them have little impact and are not a cause of concern, others can become invasive and pose a serious threat to biodiversity, ecosystem services, and coastal economies. More than 1400 marine species are currently recognized to be alien, cryptogenic or questionable to European waters, among which the Mediterranean Sea is the most impacted (Tsiamis et al., 2019, 2020; Galil et al., 2015; Zenetos & Galanidi, 2020; Zenetos, 2017). The number of marine alien species introductions continues to grow as global trade, shipping, fishing, travel, commercial mariculture, and aquarium trade allow species to be transported over large distances and to reach regions outside their native range not previously accessible to them.

The transfer of species started as early as shipping trade, and ballast water has been recognized as a major vector for the translocation of aquatic species across biogeographic boundaries. A substantial number of alien species are also translocated as hitchhikers by using floating objects for attachment and dispersal [e.g. ship hulls, marine plastic litter, trash, mollusk veliger shells (Gollasch, 2002; Nessbit, 2005; Rech et al., 2016)]. Today, more than 80% of global trade is transported by commercial shipping (UNCTAD, 2019) and maritime transport will remain the most important transport mode in the
foreseeable future. International shipping is responsible for transporting and discharging ~3-12 billion tons of ballast water and 100 million tons of sediment each year (UNCTAD, 2019), and Cohen (1998) estimated that up to 10,000 aquatic alien species are transported in ships around the world per day. The rise of alien species around the globe is a consequence of an increasingly connected world and the result of human population growth (Pyšek et al., 2020).

Biological invasions are now recognized as a major driver of biodiversity change across the globe (Vitousek et al., 1996; Ojaveer et al., 2015). The capacity to mitigate potential risks posed by alien species depends on precise, up-to-date and easily accessible information. To increase awareness and to facilitate effective prevention and management activities, comprehensive databases were established through large-scale international collaborations and advances in analytical bioinformatic tools. Comprehensive accounts are now available for plants, bryophytes, terrestrial snails, ants, spiders, amphibians, birds and mammals (Pyšek et al., 2020). For some important groups of organisms, in particular microorganisms, data are still limited. Here we provide a comprehensive review of alien and invasive benthic foraminifera from the Mediterranean Sea. Foraminifera are a highly diverse group of single-celled eukaryotes, characterized by granular pseudopodia and a test that can be organic, agglutinated or calcareous. They are among the most abundant testate protists in the world’s ocean, have an excellent fossil record and their shells represent a major and globally significant sink for calcium carbonate (Langer, 2008). To assess the current state, we carefully reviewed the presence of NIS benthic foraminifera in the Mediterranean Sea.

The Mediterranean is a semi-enclosed sea at the crossroads between Europe, Africa and Asia and a global hotspot of marine alien species (Costello et al., 2010; Molnar et al., 2008; Edelis et al., 2013; Katsanevakis et al., 2014a). During the 10th meeting of the Conference of the Parties at Nagoya in 2010, a New Strategic Plan for Biodiversity 2011-2020 was adopted in the Convention on Biological Diversity (CBD, 2012, 2014). This included Aichi Target 9 on alien species, with the requirement that “By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled and eradicated and measures are in place to manage pathways to prevent their introduction and establishment”. The Marine Strategy Framework Directive (MSFD) of the European Union (Directive 2008/56/EC), initiated to achieve Good Environmental Status (GES) in the EU’s marine waters by 2020, included the assessment of Non-Indigenous Species (NIS) as key Descriptor D2 (EU, 2008). In 2014, the EU Regulation 1143/2014 on Invasive Alien Species (IAS) has been implemented to oversee the detection, main pathways and early control or eradication until 2020 (EU, 2014a). To satisfy the need and in partial fulfillment to achieve the goals set by the EU Directive and Aichi Target 9, this survey provides a comprehensive reexamination, status-report and overview of NIS benthic foraminifera morphospecies and molecular types currently recognized in Mediterranean waters.

### Material and Methods

The European Alien Species Information Network (EASIN) was launched with the aim to enable easy access to data and information on alien species in Europe and to assist scientists and policy makers in their efforts to prevent, control and manage alien invasions (Katsanevakis et al., 2012). EASIN is an initiative of the Joint Research Centre (JRC) of the European Commission and has been established as a platform upon the recognition of the increasing serious threat posed by alien species in Europe. The EASIN information system facilitates the implementation of the EU Regulation 1143/2014 on Invasive Alien Species (EU, 2014a), and entered into force to fulfill Action 16 of Target 5 of the EU 2020 Biodiversity Strategy, as well as Aichi Target 9 of the Strategic Plan for Biodiversity 2011-2020 under the Convention of Biological Diversity.

EASIN (2020) currently contains the most complete register of foraminifera considered to be alien to the Mediterranean Sea. Primary data inserted into the EASIN database originate from published resources and contain the scientific name of the species, coordinates where the species was found, notes on the location, the date of observation, and a reference to a scientific publication/data source to allow proper citation and to link data to its original source. To respect high standards, quality assurance of the EASIN catalogue is provided by the EASIN Editorial Board (EB), a group of taxonomic experts responsible for specific groups of species. In an effort to update the existing account on invasive alien foraminifera in the Mediterranean Sea, we have conducted a large-scale survey on the existing literature. This includes a careful revision of the current taxonomic status of species, records and observations from new core material, and recent findings from molecular genetic analysis. The bulk of data have been carefully extracted from literature records published by generations of micropaleontologists. Literature data have been carefully surveyed and with a few exceptions include only adequately illustrated studies to assure taxonomic consistency. Because species-level taxonomy may vary from author to author and affects biogeography, all literature records have been critically reevaluated by the authors. The uniformity of nomenclature thus provides a framework of recognizable species that minimizes human-created taxonomic and identification weaknesses.

According to the Convention on Biological Diversity (CBD, 2012), alien species “refers to a species, subspecies or lower taxon, introduced outside its natural past or present distribution; including any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce”. Because foraminifera are extremely abundant and provide an excellent fossil record, past occurrences can be traced from dated fossil material, a feature potentially masked by recent invasions through the opening of the Suez Canal in 1869, an artificial waterway connecting the Indian Ocean and the Mediterranean Sea. Thus, our survey includes fossil records from dated cores (0.3-120 m) using OSL, $^{14}$C and $^{210}$Pb (Toueg, 1996; Avital, 2002; Tapiero, 2002; Tapiero et al.,
with a focus on sites from the shallow Mediterranean coast of Israel: Achziv, Haifa, Dor, Beit-Yanai, Caesarea, Herzliya, Palmachim and Ashkelon. Benthic foraminifera obtained from material of other cores in the Mediterranean Sea apart from Israel (e.g. Koukousioura et al., 2012; Milker & Schmiedl, 2012; Melis et al., 2015) were also examined to verify the presence and identity of species pre-dating the opening of the Suez Canal in 1869. In the following we discuss the foraminifera species listed in the EASIN database together with new additions recently reported in the literature. For each species we provide the first record and locality, original citation, references, a synonymy, occurrence records in Mediterranean subregions, and discuss their status classified as alien, invasive, native, cryptogenic, or absent in respect to previously published studies on alien foraminifera (Table 1, Table 2, Fig. 1). Potential pathways for the introduction (Table 1) are inferred from habitat preferences, live modes (epiphytic, epifauna, infauna), field and laboratory studies (Finger 2017; Langer, 1993; Jorissen, 1987; Hyams et al., 2002; Alve & Goldstein, 2003; Langer et al., 2009; Guy-Haim et al., 2017; Weinmann et al., 2019; McGann et al. 2020). Additional information is provided when a species was recorded in fossil or core material and when new molecular genetic data were available. The taxonomy adopted here generally follows Cimerman & Langer (1991), Hottinger et al. (1993), and Langer & Schmidt-Sinns (2006), with additional modern revisions provided by Parker (2009), Förderer & Langer (2018, 2019), WORMS (2020), and Fajemila et al. (2020).

Fig. 1: Mediterranean marine subregions according to the MSFD (Directive 2008/56/EC) as delineated by Article 4 of the MSFD (Jensen et al., 2017; modified after Servello et al., 2019). The border between ADRIA and CMED is defined by a line that runs from Capo Santa Maria di Leuca (Italy) (39.8° N, 18.36666° E) to the west coast of Corfu (Greece) (39.75194° N, 19.62777° E); the border between CMED and WMED is defined by a line that joins Capo Bon (37.08333° N, 11.05° E) (Tunisia) with Capo Libico (37.8° N, 12.43333° E) (Sicily, Italy); between Sicily and the mainland of Italy, the border of WMED is a line that connects Capo Peloro (North-East Sicily, Italy) (38.26666° N, 15.65° E) to Capo Paci (Calabria, Italy) (38.25° N, 15.7° E) on the mainland. The border between the Central Mediterranean Sea and Eastern Mediterranean Sea (=Aegean-Levantine Sea) subregions is based on the reporting of Greece of its marine waters in 2012 under MSFD Article 8, 9 and 10 and runs from the Greek mainland to the Island of Kithira (Greece), to the western coast of Crete and to Ras Al Hilal (Libya).
Table 1. Alphabetical list of currently recognized alien foraminifera in the Mediterranean Sea.

Abbreviations: Year=Year of first detection in the Mediterranean Sea as reported for the collection of the material in the publication; REF=References for the first year of detection in the Mediterranean Sea; NDR=Native distribution (Oceanic region from where the holotype was described); RS=Red Sea, IO=Indian Ocean, IP=Indo-Pacific, PTW=Pacific Tropical West, PTE=Pacific Tropical East, PT=Pacific Tropical, PO=Pacific Ocean, PW=Pacific West, PN=Pacific North, PS=Pacific South, PSE=Pacific Southeast, PSW=Pacific Southwest, PNE=Pacific Northeast, PNW=Pacific Northwest, ASE=Atlantic Southeast, ASW=Atlantic Southwest, ANE=Atlantic Northeast, ANW=Atlantic Northwest, ATW=Atlantic Tropical West, ATE=Atlantic Tropical East, AT=Atlantic Tropical, AO=Atlantic Ocean, AW=Atlantic West, AN=Atlantic North, ArO=Arctic Ocean, CoT=Cosmopolitan Temperate, UNK=Unknown; Success=population success, CAS=casual, EST=established, Inv=invasive, PP=Potential Pathway; COR=Transport via the Suez Canal Corridor; TC/AN=Transport Contaminant: Contaminant on animals (species transported by host/vector); TS=TRANSPORT STOWAWAY: (Ship/boat ballast water, Ship/boat hull fouling); TS/AFS=TRANSPORT STOWAWAY: Attached to floating substrates (wood, seagrass leaves, rhizomes, algae) including plastic waste; Occurrence records of alien foraminifera in MSFD subregions of the Mediterranean Sea (for details see Servello et al., 2019): MSFD subregions: the Adriatic (ADRIA), the central Mediterranean (CMED), the western Mediterranean (WMED), and the eastern Mediterranean (EMED).

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Year</th>
<th>REF</th>
<th>NDR</th>
<th>MSFD subregions</th>
<th>Success</th>
<th>PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agglutinella compressa El-Nakhal, 1983</td>
<td>1998</td>
<td>Hyams-Kaphzan et al., 2008</td>
<td>RS</td>
<td>EMED</td>
<td>CAS</td>
<td>COR, TS</td>
</tr>
<tr>
<td>Amphistegina lessonii d’Orbigny, 1826</td>
<td>1974</td>
<td>Hollaus &amp; Hottinger, 1997</td>
<td>IO</td>
<td>CMED, WMED</td>
<td>EST</td>
<td>COR, TS, TC/AN, AS/AFS</td>
</tr>
<tr>
<td>Borelis schlumbergeri (Reichel, 1937)</td>
<td>1999</td>
<td>Hyams (2000)</td>
<td>IO</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td>Brizalina simpsoni (Heron-Allen &amp; Earland, 1915)</td>
<td>2007</td>
<td>Meriç et al., 2010*, Meriç et al., 2014</td>
<td>IO</td>
<td>EMED</td>
<td>CAS</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td>Clavulina cf. C. multicamerata Chapman, 1907</td>
<td>1972-1974</td>
<td>Blanc-Vernet et al., 1979</td>
<td>PSW/IO</td>
<td>EMED, CMED</td>
<td>EST</td>
<td>COR, TS</td>
</tr>
<tr>
<td>Cycloforina sp.</td>
<td>2008</td>
<td>Langer, 2008</td>
<td>RS</td>
<td>EMED</td>
<td>CAS</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td>Cyclorbiculina compressa (d’Orbigny, 1839)</td>
<td>2002</td>
<td>Meriç et al., 2008a</td>
<td>ATW</td>
<td>EMED</td>
<td>EST</td>
<td>TS, TC/AN, TS/AFS</td>
</tr>
<tr>
<td>Elphidium striatopunctatum (Fichtel &amp; Moll, 1798)</td>
<td>1998</td>
<td>Hyams, 2000</td>
<td>RS</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td>Epistomaroides punctulata (Said, 1949)</td>
<td>2005</td>
<td>Almogi-Labin &amp; Hyams-Kaphzan, 2012</td>
<td>RS</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td>Haddonia sp.</td>
<td>1996</td>
<td>Hyams-Kaphzan, unpubl.</td>
<td>RS</td>
<td>EMED</td>
<td>CAS</td>
<td>COR, TS</td>
</tr>
<tr>
<td>Hauerina diversa Cushman, 1946</td>
<td>1996</td>
<td>Hyams, 2000</td>
<td>PT</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
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<tr>
<td>Heterostegina depressa d’Orbigny, 1826</td>
<td>1965</td>
<td>Moncharmont Zei, 1968</td>
<td>ASE</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
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<tr>
<td>Loxostomina cf. L. africana (Smitter, 1955)</td>
<td>1972-74</td>
<td>Alavi, 1980</td>
<td>IO</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td>Mimosina affinis Millet, 1900</td>
<td>2012</td>
<td>Mouanga, 2017</td>
<td>PTW</td>
<td>ADRIA</td>
<td>CAS</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td>Neoconorbina clara (Cushman, 1934)</td>
<td>1997</td>
<td>Hyams-Kaphzan et al., 2008</td>
<td>PTW</td>
<td>EMED</td>
<td>CAS</td>
<td>COR, TS, TS/AFS</td>
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</tbody>
</table>

continued
<table>
<thead>
<tr>
<th>Species Name</th>
<th>Year</th>
<th>REF</th>
<th>NDR</th>
<th>MSFD subregions</th>
<th>Success</th>
<th>PP</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Nodophilidium antillarum</em> (Cushman, 1922)</td>
<td>1968</td>
<td>Moncharmont, 1968</td>
<td>ATW</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Operculina ammonoides</em> (Gronovius, 1781)</td>
<td>2015</td>
<td>Merkado, 2016</td>
<td>IO</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Parasorites orbitolitoides</em> (Hofker, 1930)</td>
<td>2016</td>
<td>Nadal Nebot, 2017</td>
<td>PTW</td>
<td>WMED</td>
<td>CAS</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Paratrochammina madeirae</em> Brönnimann, 1979</td>
<td>1997</td>
<td>Hyams, 2000</td>
<td>ASW</td>
<td>EMED</td>
<td>CAS</td>
<td>TS, TS/AFS</td>
</tr>
<tr>
<td><em>Planogypsina acervalis</em> (Brady, 1884)</td>
<td>1909</td>
<td>Sidebottom, 1909</td>
<td>PTW</td>
<td>EMED, ADRIA?</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Procerolagena oceanaica</em> (Albiani, 1974)</td>
<td>2003</td>
<td>Hyams, 2006</td>
<td>PW</td>
<td>EMED</td>
<td>CAS</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Pseudomassilina reticulata</em> (Heron-Allen &amp; Earland, 1915)</td>
<td>1998</td>
<td>Hyams, 2000</td>
<td>IO</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Pyrgo denticulata</em> (Brady, 1884)</td>
<td>1994, 1996</td>
<td>Hyams, 2000, Samir <em>et al.</em>, 2003</td>
<td>PTE</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
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<tr>
<td><em>Quinqueloculina cf. Q. mosharafai</em> Said, 1949</td>
<td>2002</td>
<td>Meriç <em>et al.</em>, 2008a</td>
<td>RS</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Schlumbergerina alveoliniformis</em> (Brady, 1879)</td>
<td>2008</td>
<td>Meriç <em>et al.</em>, 2008b</td>
<td>PTW</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS</td>
</tr>
<tr>
<td><em>Sigmanilolinella australis</em> (Parr, 1932)</td>
<td>1977</td>
<td>Alavi, 1980</td>
<td>IO</td>
<td>EMED, CMED, ADRIA</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Siphonaperta distorqueata</em> (Cushman, 1954)</td>
<td>1977</td>
<td>Alavi, 1980</td>
<td>PTW</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Sorites variabilis</em> Lacroix, 1941</td>
<td>1996</td>
<td>Langer (unpublished)</td>
<td>RS</td>
<td>EMED, WMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
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<tr>
<td><em>Spiroloculina angulata</em> Cushman, 1917</td>
<td>1968</td>
<td>Moncharmont Zi, 1968</td>
<td>PN</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
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<tr>
<td><em>Spiroloculina antillarum d’Orbigny, 1826</em></td>
<td>1913</td>
<td>Wiesner, 1913</td>
<td>PN</td>
<td>CMED, ADRIA</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Spiroloculina attenuata</em> Cushman &amp; Todd, 1944</td>
<td>1997</td>
<td>Hyams, 2000</td>
<td>PTW</td>
<td>EMED</td>
<td>CAS</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Spiroloculina aff. S. communis</em> Cushman &amp; Todd, 1944</td>
<td>1996</td>
<td>Hyams-Kaphzan <em>et al.</em>, 2008</td>
<td>PTW</td>
<td>EMED</td>
<td>EST</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Spiroloculina nummiformis</em> Said, 1949</td>
<td>1997</td>
<td>Hyams, 2000</td>
<td>RS</td>
<td>EMED</td>
<td>CAS</td>
<td>COR, TS, TS/AFS</td>
</tr>
<tr>
<td><em>Triloculina cf. T. fichtelian d’Orbigny, 1839</em></td>
<td>2002</td>
<td>Meriç <em>et al.</em>, 2008a</td>
<td>ATW</td>
<td>EMED, CMED</td>
<td>EST</td>
<td>TS, TS/AFS</td>
</tr>
<tr>
<td><em>Varidentella cf. V. neostriatula</em> (Thalmann, 1950)</td>
<td>1996</td>
<td>Hyams, 2000</td>
<td>PTW</td>
<td>EMED</td>
<td>CAS</td>
<td>COR, TS, TS/AFS</td>
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</tbody>
</table>
Table 2. Alphabetical list of currently recognized cryptogenic foraminifera in the Mediterranean Sea (for abbreviations see captions in in Table 1).

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Year</th>
<th>REF (* not illustrated)</th>
<th>NDR</th>
<th>MSFD subregions</th>
<th>Success</th>
<th>PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cymbaloporetta sp. 1</td>
<td>1968</td>
<td>Moncharmont Zei, 1968</td>
<td>PTE</td>
<td>EMED, CMED, ADRIA, WMED</td>
<td>CAS</td>
<td>ST/SH-BAL, ST/AFS, UNAI</td>
</tr>
<tr>
<td>Euthymonacha polita (Chapman, 1900)</td>
<td>2007</td>
<td>Meriç et al., 2010</td>
<td>PW</td>
<td>EMED, ADRIA, CMED</td>
<td>EST</td>
<td>ST/AFS, UNAI</td>
</tr>
</tbody>
</table>

Results

Acervulina inhaerens Schulze, 1854

1854 Acervulina inhaerens Schulze – Schulze, p. 68, pl. 6, fig. 12.

1987 Acervulina inhaerens Schulze – Delliou et al., p. 570, pl. 1, fig. 5.

Acervulina inhaerens was first described by Schulze (1854) from the Adriatic Sea and found to be alive on phytal substrates, on sand and along rocky shores off Ancona (Italy). The species was reported as alien by Delliou et al. (2015) from coastal habitats in the Gulf of Kavala (NE Aegean Sea, Greece). The record by Schulze (1854) shows the species to be present in the Mediterranean prior to the opening of the Suez Canal and the taxon must therefore be considered to be native.

Adelosina carinata-striata (Wiesner, 1912)

1912 Miliolina milletti var. carinata-striata Wiesner – Wiesner, p. 221

1923 Adelosina milletti var. carinata-striata Wiesner – Wiesner, p. 77, figs. 190-191

1970 Quinqueloculina milletti var. carinata-striata (Wiesner) – von Daniels, p. 74, pl. 2, figs. 17a-c, textfig. 49

1987 Quinqueloculina poeyana carinata Albani – Baccaert, p. 97, pl. 47, figs. 5a-c

1991 Adelosina carinata-striata (Wiesner) – Cimerman & Langer, p. 28, pl. 20, figs. 1-4

1993 Cycloforina? carinata (Albani) – Hottinger et al., p. 49, pl. 32, figs. 1-9

2005 Adelosina carinata-striata (Wiesner) – Debenay et al., pl. 1, figs. 14-15

2007 Quinqueloculina carinata-striata (Wiesner) – Bouchet et al., pl. 1

2012 Adelosina carinata-striata (Wiesner) – Koukousioura et al., pl. 10, fig. 18

2013 Adelosina carinata-striata (Wiesner) – Bassler-Veit et al., pl. 5, figs. 1a-b

2014 Adelosina carinata-striata (Wiesner) – Meriç et al., pl. 9, figs. 8-9

2017 Adelosina carinata-striata (Wiesner) – Mouanga, pl. 3, fig. 11

Adelosina carinata-striata was first described by Wiesner (1912) from the Adriatic Sea. The species is present off the European Atlantic coast (Bouchet et al., 2007) and in the Red Sea (Hottinger et al., 1993). Illustrated Mediterranean Sea records include specimens from the Adriatic Sea (Wiesner, 1923; von Daniels, 1970; Cimerman & Langer, 1991; Mouanga, 2017), Greece (Debenay et al., 2005) and Turkey (Bassler-Veit, 2013; Meriç et al., 2014). Subfossil specimens from the Aegean Sea were recorded by Koukousioura et al. (2012). Adelosina carinata-striata is present in the lower part of a borehole from Alykes Kitros, and the illustrated specimen was dated at 7460±40yBP. The species Adelosina carinata-striata is therefore native to the Mediterranean Sea. The specimen recorded by Triantaphyllou et al. (2005) under the name Adelosina milletti var. carinata differs from Adelosina carinata-striata (Wiesner) and belongs to a different species.

Adelosina milletti (Wiesner, 1911)

non 1839 Quinqueloculina boschiana – d’Orbigny, p. 191, pl. 11, figs. 22-24

1898 Miliolina boschiana d’Orbigny – Millett, p. 267, pl. 6, fig. 1

1911b Miliolina milletti Wiesner – Wiesner, p. 506

1912 Miliolina milletti Wiesner – Wiesner, p. 220

1923 Adelosina milletti Wiesner – Wiesner, p. 76

non 1980 Quinqueloculina milletti (Wiesner) – Alavi, p. 20 (appendix), pl. 17, fig. 5, pl. 18, fig. 6

non 1990 Massilina milletti (Wiesner) – Dermitzakis & Triantafillou, pl. 2, fig. 8

non 1993 Quinqueloculina milletti (Wiesner) – Sgarrella & Moncharmont Zei, p. 172, pl. 7, fig. 7

non 2000 Quinqueloculina milletti (Wiesner) – Hyams, pl. 7, fig. 8

non 2006 Edentostomina milletti (Wiesner) – Oflaz, p. 145, pl. 2, figs. 4-6

non 2016 Quinqueloculina milletti (Wiesner) – Hyams-Kaphzan, pl. 2, fig. 10

non 2016a Quinqueloculina milletti (Wiesner) – Dimiza et al., pl. 2, fig. 2

Adelosina milletti was first reported by Wiesner (1911b, as Miliolina milletti) from the Adriatic Sea (not illustrated) and a morphological description was provided by Wiesner in 1912. The author (1923) considered the
species to be identical with *Miliolina bosciana* of Millett (1898) from the Malay Archipelago and to represent the type species. However, Wiesner (1923) pointed out that *Miliolina bosciana* Millett is not present in the Adriatic Sea and that the species is characterized by rounded chambers, a smooth surface, a short, curved neck and therefore differs from *Miliolina bosciana* d’Orbigny (1839). The species was illustrated by Wiesner in his monograph on miliolids from the eastern Adriatic Sea (1923). Mediterranean records by Alavi (1980), Dermitzakis & Triantafillou (1990), Oflaz (2006) and Dimiza et al. (2016a) provide illustrated specimens but they all differ from the original of Millett (1898). The specimens of *Quinqueloculina milletti* (see Sgarrella & Moncharmont Zei, 1993; Hyams, 2000; Hyams-Kaphzan, 2016), a species also considered to be alien to the Mediterranean in EASIN (2020), also differ substantially from Millett’s *Miliolina bosciana* and require further study. To date, there is no reliable record of *Adelosina milletti* in the Mediterranean Sea, and we therefore consider the species to be absent from Mediterranean waters.

*Agglutinella compressa* El-Nakahal, 1983

<table>
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<th>Year</th>
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<tbody>
<tr>
<td>1983</td>
<td><em>Agglutinella compressa</em> El-Nakahal – El-Nakahal, p. 129, pl. 1, figs. 1-3, pl. 2, figs. 10-11</td>
</tr>
<tr>
<td>1993</td>
<td><em>Agglutinella compressa</em> El-Nakahal – Hottinger et al., p. 48, pl. 29, figs. 5-10</td>
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<tr>
<td>2003</td>
<td><em>Agglutinella compressa</em> El-Nakahal – Samir et al., pl. 1, figs. 5, 9-10</td>
</tr>
<tr>
<td>2012</td>
<td><em>Agglutinella compressa</em> El-Nakahal – Aloulou et al., pl. 1, fig. 5</td>
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*Agglutinella compressa* was first described by El-Nakahal (1983) from the Gulf of Suez. The specimens illustrated are identical with the specimens reported by El-Nakhal (1983) from the Red Sea. Only a lateral view is illustrated by El-Nakhal (1983) from modern sediments off Alexandria, Egypt. Present-day Mediterranean occurrences were reported by Meriç et al. (2014) from shallow water sites off Turkey. Living specimens reported as *Agglutinella compressa* by Gruber (2007) from Shikmona (Haifa, Israel) were reexamined by us and belong to *Sorites orbiculus*. Only a lateral view is illustrated by Corsini-Foka et al. (2015) for a specimen from Rhodes Island (Greece), but the species is described to possess two separate layers of chamberlets and a double row of apertures, and as such fulfills the criteria for *Amphisorus*. No living *A. hemprichii* are currently present along the Mediterranean coast off Israel (Merkado et al., 2013; Hyams-Kaphzan, unpublished data). The lower temperature limit for symbiotic-bearing species of *Amphisorus hemprichii* is at around 18°C in the Mediterranean Sea (Langer, unpubl. data). *Amphisorus hemprichii* is widely present in all oceans (Langer & Hottinger, 2000) and shows a circumtropical distribution. The species is native to the Mediterranean Sea.

*Amphistegina lessonii* d’Orbigny, 1826

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<th>Year</th>
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<tr>
<td>1826</td>
<td><em>Amphistegina lessonii</em> – d’Orbigny, p. 304</td>
</tr>
<tr>
<td>1893</td>
<td><em>Amphistegina lessonii</em> d’Orbigny – Hottinger et al., p. 132, pl. 184, fig. 1-11; pl. 185, fig. 1-7</td>
</tr>
<tr>
<td>1997</td>
<td><em>Amphistegina lessonii</em> d’Orbigny – Hollaus &amp; Hottinger, p. 592</td>
</tr>
<tr>
<td>2000</td>
<td><em>Amphistegina lessonii</em> d’Orbigny – Hyams, pl. 28, figs. 1-4</td>
</tr>
<tr>
<td>2002</td>
<td><em>Amphistegina lessonii</em> d’Orbigny – Hyams et al., p. 174, pl. 1, fig. 1</td>
</tr>
<tr>
<td>2006</td>
<td><em>Amphistegina lessonii</em> d’Orbigny – Langer</td>
</tr>
</tbody>
</table>
Amphistegina lessonii has first been described by d’Orbigny (1826) from Mauritius (Indian Ocean). The species has a circumtropical distribution and has also been reported from the Pacific and the Atlantic Ocean, and the Red and the Mediterranean Sea (see Förderer and Langer, 2018 and Fajemila et al., 2020 for biogeographic details). The biogeographic range of A. lessonii is strongly controlled by water temperature and in the Mediterranean Sea (Hollaus & Hottinger, 1997; material collected in 1974) the species has recently reached the coast of Sicily (Guastella et al., 2019). Amphistegina lessonii has established self-maintaining populations, and reaches high abundances in some areas (e.g. Central and eastern Mediterranean; Triantaphyllou et al., 2019), and is present along the coast of Libya (Langer et al., 2019; Tsiamis et al., 2020). The species is currently among the 26 most invasive taxa recorded in the Mediterranean (Servello et al., 2019; Tsiamis et al., 2020). Core material recovered from Haifa Bay (Israel) shows Amphistegina lobifera to be present at a depth of 1.95 m (Avnaim-Katav, 2010) but dating of this core is not clear cut and requires further studies. A sediment core date prior to the opening of the Suez Canal, would support previous hypothesis (Langer & Hottinger, 2000) that Mediterranean populations were restocked from the Atlantic via the Strait of Gibraltar and/or the Red Sea via the Suez Canal.

Amphistegina lobifera Larsen, 1976

1968 Amphistegina madagascariensis d’Orbigny – Moncharmont Zei, p. 29, pl. 5, figs. 2a-b
1969 Amphistegina madagascariensis d’Orbigny – Blanc-Vernet, p. 214, pl. 10, 2, nr. 30
1976 Amphistegina lobifera Larsen – Larsen, p. 4, pl. 3, figs. 1-5, pl. 7, fig. 3, pl. 8, fig. 3
1980 Amphistegina lobifera Larsen – Alavi, p. 67 (appendix), pl. 34, fig. 3, pl. 35, figs. 1, 3
1993 Amphistegina lobifera Larsen – Hottinger et al., p. 133, pl. 186, figs. 1-11, pl. 187, figs. 1-7, pl. 188, figs. 1-6
1998 Amphistegina lobifera Larsen – Yanko et al., p. 193, pl. 3, figs. 14-16
2000 Amphistegina lobifera Larsen – Langer & Hottinger, p. 112
2000 Amphistegina lobifera Larsen – Hyams, pl. 28, figs. 5-6
2002 Amphistegina lobifera Larsen – Hyams et al., p. 174, pl. 1, figs. 2-4

Amphistegina lobifera has first been described by Larsen (1976) from the Red Sea. Its biogeographic range is strongly controlled by water temperature and the distributional range is currently delimited by the 13.7°C winter isotherm (Zmiri et al., 1974; Hollaus & Hottinger, 1997; Langer & Hottinger, 2000). The species is widely present in the eastern Mediterranean and the Ionian Sea (Blanc-Vernet, 1969; Langer, 2008; Guy-Haim et al., 2017; Manda et al., 2020; Triantaphyllou et al., 2005; Triantaphyllou & Dimiza in Siokou et al., 2013), and is present along the coast of Libya (Langer et al., 2019; Tsiamis et al., 2020). Core material recovered from Haifa Bay (Israel) shows Amphistegina lobifera to be present at a depth of 1.95 m (Avnaim-Katav, 2010) but dating of this core is not clear cut and requires further studies. A sediment core date prior to the opening of the Suez Canal, would support previous hypothesis (Langer & Hottinger, 2000) that Mediterranean populations were restocked from the Atlantic via the Strait of Gibraltar and/or the Red Sea via the Suez Canal.

Amphistegina cf. A. papillosa Said, 1949

2014 Amphistegina cf. A. papillosa Said – Caruso & Cosentino fig. 5, 8

Amphistegina cf. A. papillosa, an ecomorphotype of Amphistegina papillosa Said, was recently reported by Caruso & Cosentino (2014) from shallow waters off the Pelagian Islands, Central Mediterranean Sea. The ecomorphotype is similar to A. papillosa, which is commonly found attached to green algae in the Red Sea at water depth of 112 and 135 m (Hottinger et al., 1993), and is one of the Amphisteginids that occupies the deepest waters (Murray, 2006 and reference therein). The ecomorphotype has not been formally described but was considered to be a putative exotic form (Caruso & Cosentino,
2014) and was listed as an alien species by Servello et al. (2019). The holotype of *A. papillosa* was described by Said (1949) from the Red Sea, but neither *A. papillosa* nor a related “eco”-morphotype has been reported prior the finding of Caruso & Cosentino (2014) from the Mediterranean Sea. *Amphistegina cf. A. papillosa* and *Amphistegina papillosa* Said are not known from the Mediterranean coast of Israel, and the occurrence at the Pelagian Islands is puzzling. For the time being, *Amphistegina cf. A. papillosa* is here considered to be alien to the Mediterranean Sea, but molecular genetic studies are needed to confirm that the species is identical with the Red Sea species.

**Archaias angulatus** (Fichtel & Moll, 1798)

1798 *Nautilus angulatus* Fichtel & Moll – Fichtel & Moll, p. 113, pl. 22, figs. a-e
1928 *Archaias angulatus* Fichtel & Moll – Cushman, p. 220, pl. 31, fig. 9

The holotype of *Archaias angulatus* has been described by Fichtel & Moll (1798) from the Red Sea but was not found in present-day assemblages recorded by Said (1949) and Hottinger et al. (1993). *Archaias angulatus* has been recorded from the Cape Verde Islands (Rocha & Mateu, 1971). An obscure finding of a single, small, megalospheric test of *A. angulatus* was reported from around the Korati Islands, Adriatic Sea (Langer & Mojtahid, 1980). To date, this represents the only record in the Mediterranean Sea. Cushman (1931) and Smout & Eames (1958) consider the species to be absent from the Mediterranean Sea. Other Mediterranean occurrences of *A. angulatus* have never been reported and we therefore consider the species to be absent from the Mediterranean Sea.

**Articulina alticostata** Cushman, 1944

1944 *Articulina alticostata* Cushman – Cushman, p. 16, pl. 4, figs. 10-13
non 2004 *Articulina alticostata* Cushman – Meriç et al., p. 109, pl. 16, fig. 10
non 2006 *Articulina alticostata* Cushman – Oflaz, p. 180, pl. 4, fig. 6
non 2009 *Articulina alticostata* Cushman – Yokeş & Meriç, pl. 2, figs. 10-11

Meriç et al. (2004) consider *Articulina alticostata* to be present in the Mediterranean Sea but the initial part of the specimen illustrated is lacking. Therefore, the species can not be assigned with certainty to the genus *Articulina*. Specimens illustrated by Yokeş & Meriç (2009) show chambers that are less inflated than in the holotype and are similar to *Nodophthalmidium antillarum*. The specimen identified by Oflaz (2006) as *Articulina alticostata* is an aberrant juvenile variety of *Articulina pacifica* (for further information see remarks on *Articulina pacifica*). To date, convincing evidence for the presence of *Articulina alticostata* in the Mediterranean Sea is lacking and we therefore consider the species to be absent.

**Articulina mayori** Cushman, 1922

1922 *Articulina mayori* Cushman – Cushman, p. 71, pl. 13, fig. 5
non 2006 *Articulina mayori* Cushman – Oflaz, pl. 4, fig. 9

*Articulina mayori* is a tropical species that was first described from the Tortugas (Florida) by Cushman (1922). The illustration provided by Oflaz (2006) has a very faint striation pattern and is not identical with the distinctly ornamented specimen described and illustrated by Cushman (1922). The specimen depicted by Oflaz (2006) may belong to the genus *Nodophthalmidium* but its true identification requires further study. For the time being, we consider *Articulina mayori* to be absent from the Mediterranean Sea.

**Articulina pacifica** Cushman, 1944

1944 *Articulina sulcata* Reuss – Sidebottom, p. 16, pl. 4, figs. 16-17
1993 *Articulina pacifica* Cushman – Cushman, p. 17, pl. 4, figs. 14-18
2006 *Articulina alticostata* Cushman – Oflaz, p. 180, pl. 4, fig. 6

The holotype of *Articulina pacifica* was described by Cushman (1944) from Fiji. The species is present in the Red Sea (Hottinger et al., 1993). Mediterranean records include the specimens illustrated by Sidebottom (1904, as *Articulina sulcata* Reuss), Oflaz (2006) and Hyams-Kaphzan et al. (2008). As the oldest record of *Articulina pacifica* was provided by Sidebottom (1904) from the island of Delos (Greece), and the species is considered to be native to the Mediterranean Sea.

**Astacolus insolitus** (Schwager, 1866)

1866 *Cristellaria insolita* Schwager – Schwager, p. 242, pl. 6, fig. 85
1980 *Astacolus insolitus* (Schwager) – Srinivasan & Sharma, p. 28, pl. 5, figs. 12-13
non 2009 *Astacolus insolitus* (Schwager) – Yokeş & Meriç, pl. 4, fig. 1
non 2009 *Astacolus insolitus* (Schwager) – Mojtahid et al., pl. 2, fig. 26
non 2014 *Astacolus insolitus* (Schwager) – Meriç et al., pl. 46, figs. 11a-b

*Astacolus insolitus* has been described from fossil deposits of Car Nicobar, north-eastern Indian Ocean (Schwager, 1866). A neotype has been illustrated by Srinivasan & Sharma (1980). Records from the Mediterranean Sea were illustrated by Yokeş & Meriç (2009), Mojtahid et al. (2009) and Meriç et al. (2014) but differ substantially from Schwager’s illustrations and the neotype and belong to a different species, most probably to *Astacolus*.
crepidulus (Fichtel & Moll, 1798). To date, there is no record for *Astacolus insolitus* in the Mediterranean Sea and we therefore consider the species to be absent.

**Brizalina simpsoni** (Heron-Allen & Earland, 1915)

1915 *Bolivina simpsoni* Heron-Allen & Earland – Heron-Allen & Earland, p. 648, pl. 49, figs. 18-35

1997 *Brizalina simpsoni* (Heron-Allen & Earland) – Hottinger et al., p. 92, pl. 111, figs. 8-13, pl. 112, figs. 1-2

2014 *Brizalina simpsoni* (Heron-Allen & Earland) – Merić et al., pl. 50 fig. 1

2017 *Brizalina simpsoni* (Heron-Allen & Earland) – Thissen & Langer, pl. 13, figs. 6-8

The holotype of *Brizalina simpsoni* has been described by Heron-Allen & Earland (1915) from the Quirimba Islands off northeastern Mozambique. The species has also been reported from the Red Sea (Hottinger et al., 1993; Haunold et al., 1997) and Zanzibar (Thissen & Langer, 2017). The first Mediterranean record was given by Merić et al. (2010) from the Pamuçak Cove (northwest Kuşadası, Turkey). The species has later been illustrated by Merić et al. (2014) from the Gulf of Kuşadası, Aegean Sea. For the generic assignment, we follow the concept of Merić et al. (2014) from the Gulf of Kuşadası, Aegean Sea. The available records show that the species is alien to the Mediterranean Sea.

**Borelis schlumbergeri** (Reichel, 1937)

1973 *Neoalveolina pygmaea schlumbergeri* Reichel – Reichel, p. 110, pl. 10, figs. 1-3, pl. 11, fig. 6b

1993 *Borelis schlumbergeri* (Reichel) – Hottinger et al., p. 68, pl. 75, figs. 1-17

? 2000 *Borelis sp.* – Hyams, pl. 14, figs. 9-10

? 2002 *Borelis sp.* – Hyams et al., pl. 1, figs. 5-6

2008 *Borelis sp.* – Langer, fig. 5

? 2017 *Borelis sp.* – Makled et al., pl. 13, figs. 19-20

2019 *Borelis schlumbergeri* (Reichel) – Bassi et al., pl. 14, figs. 12-13

The genus *Borelis* has a circumtropical distribution and is represented by two extant species (Langer & Hottinger, 2000): an elongate *Borelis schlumbergeri* and a spherical *Borelis pulchra*. Fossil occurrences of other species of *Borelis* spp. from the Mediterranean region were reported by Reiss & Gvitzman (1966), Adams (1976), Jones et al. (2006), Makled et al. (2017) and Bassi et al. (2019). Unpublished records of modern *B. schlumbergeri* from northern Israel (Hyams-Kaphzan) show the species to be present in the year 1999 at Akhziv. Later, more *Borelis* were found at Akhziv by Lazar (2007), showing the typical elongate test shape (see also Langer, 2008). Specimens reported by Hyams (2000) and Hyams et al. (2002) represent subspherical forms that may represent juvenile stages of *Borelis schlumbergeri* or *Borelis pulchra*. Subspherical forms were also reported from fossil sediments in the Nile Delta (Makled et al., 2017). For the time being, we consider the elongate *Borelis schlumbergeri* to be alien to the Mediterranean Sea.

**Cibicides mabahethi** Said, 1949

1949 *Cibicides mabahethi* Said – Said, p. 42, pl. 4, figs. 20a-c

1993 *Cibicides mabahethi* Said – Hottinger et al., p. 115, pl. 151, figs. 6-12

2000 *Cibicides mabahethi* Said – Hyams, pl. 22, figs. 1-2

*Cibicides mabahethi* was first described from the Red Sea by Said (1949). Recent material from the eastern Mediterranean Sea has been recorded by Hyams (2000), Hyams et al. (2002) and Hyams-Kaphzan et al. (2008). This species is considered to be alien to the Mediterranean Sea.

**Clavulina angularis** d’Orbigny, 1826

1826 *Clavulina angularis* d’Orbigny – d’Orbigny, p. 268, pl. 12, fig. 7

non 1979 *Clavulina angularis* d’Orbigny – Blanc-Vernet et al., pl. 21, fig. 3

non 1980 *Clavulina angularis* d’Orbigny – Alavi, p. 11 (appendix), pl. 5, fig. 12, pl. 7, fig. 1

1993 *Clavulina angularis* d’Orbigny – Hottinger et al., p. 41, pl. 21, figs. 1-13

non 2000 *Clavulina angularis* d’Orbigny – Hyams, pl. 2, fig. 8

non 2008a *Clavulina angularis* d’Orbigny – Merić et al., pl. 1, figs. 7a-b

non 2009 *Clavulina angularis* d’Orbigny – Yokeş & Merić, pl. 1, figs. 6-7

non 2014 *Clavulina angularis* d’Orbigny – Merić et al., pl. 7, figs. 3-4

non 2016 *Clavulina angularis* d’Orbigny – Ayadi et al., pl. 2, fig. 6

*Clavulina angularis* has first been reported by d’Orbigny (1826) from Corsica in the western Mediterranean Sea. Jones and Parker (1860) reported it from the Gulf of La Spezia (Italy) and Crete (as *Valvulina angu laris*, not illustrated). The specimens reported by Alavi (1980), Hyams (2000), Yokeş & Merić (2009), Merić et al. (2008a; 2014) and Ayadi et al. (2016) show rounded last chambers that are absent in the holotype and belong to *Clavulina* cf. *C. multicamerata*. The first record of *Clavulina angularis* shows the species to be present before the opening of the Suez Canal and therefore native to the Mediterranean Sea.

**Clavulina cf. C. multicamerata** Chapman, 1907

1907 cf. *Clavulina parisien sis* d’Orbigny var.
multicamerata Chapman – Chapman, p. 127, pl. 9, fig. 5

1979 Clavulina angularis d’Orbigny – Blanc-Vernet et al., pl. 21, fig. 3

1980 Clavulina angularis d’Orbigny – Alavi, p. 11 (appendix), pl. 5, fig. 12, pl. 7, fig. 1

1993 Clavulina cf. C. multicamerata Chapman – Hottinger et al., p. 42, pl. 22, figs. 1-6

2000 Clavulina angularis d’Orbigny – Hyams, pl. 2, fig. 8

2008a Clavulina angularis d’Orbigny – Meriç et al., pl. 1, fig. 7

2008a Clavulina cf. C. multicamerata Chapman – Meriç et al., pl. 1, fig. 8

2009 Clavulina angularis d’Orbigny – Yokeş & Meriç, pl. 1, figs. 6-7

2009 Clavulina cf. C. multicamerata Chapman – Yokeş & Meriç, pl. 1, figs. 8-9

2014 Clavulina angularis d’Orbigny – Meriç et al., pl. 7, figs. 3-4

2014 Clavulina angularis d’Orbigny – Meriç et al., pl. 7, figs. 5-6

2014b Clavulina cf. C. multicamerata Chapman – Katsanevakis et al., p. 688, fig. 20

The holotype of Clavulina multicamerata has been described from Victoria (Australia) by Chapman (1907). A similar but subtriangular to rounded form was reported by Hottinger et al. (1993) from the Red Sea and represents a separate species (Clavulina cf. C. multicamerata). For morphological details on this variety, see the remarks in Hottinger et al. (1993). Specimens of the latter species were also reported from Tunisia (Blanc-Vernet, 1979), Turkey (Alavi, 1980; Meriç et al., 2008a; 2014; Yokeş & Meriç, 2009), Israel (Hyams, 2000; collected in 1996) and Greece (Katsanevakis et al., 2014b). The available illustrated records indicate that this species is alien to the Mediterranean.

Coscinospira hemprichii Ehrenberg, 1839

? 1791 Nautilus (Lituus) arietinus Batsch – Batsch, p. 15, figs. 15d-f

1839 Coscinospira hemprichii Ehrenberg – Ehrenberg, p. 143, pl. 2, fig. 2

? 1875 Peneroplis pertusus (Forskål) arietinus (Batsch) – Baccaert, p. 60, pl. 19, figs. 3a-b, pl. 20, figs. 1-2

1991 Coscinospira hemprichii Ehrenberg – Cimerman & Langer, p. 49, pl. 47, figs. 8-11

1993 Coscinospira hemprichii Ehrenberg – Hottinger et al., p. 69, pl. 76, figs. 1-12, pl. 77, figs. 1-8

1997 Coscinospira hemprichii Ehrenberg – Hollaus & Hottinger, p. 593

2002 Coscinospira hemprichii Ehrenberg – Hyams et al., pl. 1, figs. 7-8

2008 Coscinospira hemprichii Ehrenberg – Langer, fig. 4

2008b Peneroplis arietinus (Batsch) – Meriç et al., pl. 4, figs. 17-19, pl. 5, figs. 1-3, 5-6

2010 Coscinospira hemprichii Ehrenberg – Koukousioura et al., p. 171, pl. 1, fig. 3

Coscinospira hemprichii was originally described from the Red Sea by Ehrenberg (1839). The specimens illustrated by Batsch (1791) are believed to originate from recent sediments in the Adriatic Sea (Cushman, 1931) and were assigned to Spiroolina hemprichii (Ehrenberg) or Spiroolina cylindracea (see Cushman, 1931, p. 72). Modern Mediterranean records include material from the Adriatic Sea, Greece, Israel and Turkey (Cimerman & Langer, 1991; Hollaus & Hottinger, 1997; Hyams et al., 2002; Langer, 2008; Meriç et al., 2008b; Koukousioura et al., 2010). Fossil material of Coscinospira hemprichii from the Mediterranean was recently reported by Melis et al. (2015). Yümün et al. (2016) and Hyams-Kaphzan (unpublished) from the Adriatic Sea, Turkey and Israel, respectively. Both the fossil record and the material from Batsch show that Coscinospira hemprichii was present in the Mediterranean prior to the opening of the Suez Canal and the species must therefore be considered to be native.

Cribromiliolinella milletti (Cushman, 1954)

1954 Hauerina milletti Cushman – Cushman et al., p. 337, pl. 84, fig. 23

Cribromiliolinella milletti has been reported as a possible species of Cribromiliolinella milletti. However, the illustrated specimen (see also Meriç et al., 2014) differs significantly from the original by Parker & Jones (1865, number of costae and ornamental pattern on the neck) and belongs to a different species. The specimens reported as Lagena striatopunctata by Sidebottom

1865 Lagena sulcata Walker and Jacob, var. striatopunctata Parker & Jones – Parker & Jones, p. 350, pl. 13, figs. 25-27

non 1910 Lagena striatopunctata Parker & Jones – Sidebottom, p. 17, pl. 2, figs. 5a-b

non 1940 Lagena striatopunctata Parker & Jones – Buchner, p. 444, pl. 7, fig. 100

1987 Cushmanina striatopunctata (Parker & Jones) – Patterson & Richardson, p. 217, pl. 1, figs. 2-6

non 2009 Cushmanina striatopunctata (Parker & Jones) – Yokeş & Meriç, pl. 4, fig. 5

non 2014 Cushmanina striatopunctata (Parker & Jones) – Meriç et al., pl. 48, fig. 7

Yokeş & Meriç (2009) consider C. striatopunctata (Parker & Jones) to be alien to the Mediterranean Sea. However, the illustrated specimen (see also Meriç et al., 2014) differs significantly from the original by Parker & Jones (1865, number of costae and ornamental pattern on the neck) and belongs to a different species. The specimens reported as Lagena striatopunctata by Sidebottom
(1910) and Buchner (1940) also differ from the type specimen. To date, there is no reliable record for Cushmanina striatopunctata in the Mediterranean Sea and the species is therefore not alien to the Mediterranean Sea. The status and the taxonomic identification of the species illustrated by Yokeş & Meriç (2009) and Meriç et al. (2014) require further study.

**Cycloforina quinquecarinata** (Collins, 1958)

1958 *Quinquiloculina quinquecarinata* Collins – Collins, p. 360, pl. 2, figs. 8a-c
1993 *Cycloforina quinquecarinata* (Collins, 1958) – Hottinger et al., p. 49, pl. 33, figs. 7-15
2016 *Cycloforina quinquecarinata* (Collins, 1958) – Hyams-Kaphzan, pl. 2, figs. 6-7

*Cycloforina quinquecarinata* has an Indopacific origin (Collins, 1958) and is also present in the Red Sea (Hottinger et al., 1993). The species has been recorded along the Mediterranean coast of Israel by Hyams-Kaphzan et al. (2008; 2009) and Hyams-Kaphzan (2016). Martins et al. (2016) reported the species from off Bizerte (Tunisia) but their specimen lacks the typical short neck, has somewhat inflated chambers and the surface shows microstriae that are not present in the original material. New findings from core records along the coast of Israel (Hyams-Kaphzan, unpublished) show that the species has been present in the Mediterranean Sea for at least 250 years (core depth: 80 cm). The species is therefore native to the Mediterranean Sea.

**Cycloforina sp.**

1993 *Cycloforina sp.* – Hottinger et al., p. 50, pl. 35, figs. 7-13
2008 *Cycloforina sp.* – Langer, p. 407, fig. 8

*Cycloforina sp.* has been reported by Hottinger et al. (1993) from the Red Sea (as *Cycloforina sp. C*). The species is characterized by its reticulated test surface ornamentation, produced by intersecting costae (Langer, 2008). It resembles *Quinquiloculina pseudoreticulata* but is provided with a neck and a rounded aperture. Rare specimens were found off Haifa, Israel (Langer, 2008). *Cycloforina sp.* is here considered to be alien to the Mediterranean Sea.

**Cyclobalporella compressa** (d’Orbigny, 1839)

1839 *Orculicina compressa* d’Orbigny – d’Orbigny, p. 66, pl. 8, figs. 4-6
1884 *Cyclobalporella compressa* (d’Orbigny) – Brady, pl. 14, figs. 7-9
2008a *Cyclobalporella compressa* (d’Orbigny) – Meriç et al., pl. 11, fig. 12 (non fig. 11)
2008b *Cyclobalporella compressa* (d’Orbigny) – Meriç et al., p. 314, pl. 5, fig. 10 (non figs.

The holotype of *Cyclobalporella compressa* has been described by d’Orbigny from Cuba (1839). Smout & Eames (1958) consider the biogeographic range of *Cyclobalporella compressa* to be restricted to the Caribbean, the Gulf of Mexico and other parts of the tropical western Atlantic. The species has not yet been recorded from the Red Sea (Said, 1949; Hottinger et al., 1993). Some specimens illustrated by Meriç et al. (2008a; 2008b; 2014) and Yokeş & Meriç (2009) from Turkey show similarity to the holotype of d’Orbigny, although no profile views were shown; other specimens closely resemble Sorites. For the time being, we consider *Cyclobalporella compressa* to be alien to the Mediterranean Sea. The species was probably introduced into the Mediterranean Sea via passage through the Strait of Gibraltar. Records by Brady (1884) from the Cape Verde Islands support this conclusion.

**Cymbaloporetta sp. 1**

? 1924 *Tretomphalus bulloides var. plana* Cushman – Cushman, p. 36, pl. 10, fig. 8
? 1968 *Tretomphalus planus* (Cushman) – Moncharmont Zei, pl. 4, figs. 8a-b
? 1979 *Pseudotretomphalus planus* (Cushman) – Hofker, p. 23, figs. 12-13
? 1987 *Cymbaloporetta plana* (Cushman) – Loeblich & Tappan, pl. 649, figs. 1-3
? 1991 *Cymbaloporetta sp.* 1 – Cimerman & Langer, pl. 80, figs. 1-5
? 1993 *Cymbaloporetta sp.* A – Hottinger et al., p. 120, pl. 160, figs. 1-8
? 1994 *Cymbaloporetta plana* (Cushman) – Jones, pl. 102, figs. 7-8, 12
? 2000 *Cymbaloporetta sp.* 1 – Hyams, pl. 23, figs. 6-8
? 2008b *Cymbaloporetta plana* (Cushman) – Meriç et al., pl. 8, figs. 2-7
2010 *Cymbaloporetta plana* (Cushman) – Koukousioura et al., pl. 2, figs. 1-2
2014 *Cymbaloporetta plana* (Cushman) – Meriç et al., pl. 62, figs. 12-13
? 2014 *Cymbaloporetta plana* (Cushman) – Meriç et al., pl. 62, figs. 14-16

The holotype of *Cymbaloporetta plana* Cushman (1924) was described from Samoa (Pacific Ocean). Although the quality of the original illustration is poor, photographs of the holotype provided by the Smithsonian Museum of Natural History (2020) appear to be identical with most specimens illustrated from the Mediterranean Sea. *Cymbaloporetta sp.* 1 has been frequently reported from the Mediterranean Sea (as C. sp. 1 and *C. plana*; see synonymic list). The species has been recorded by Hottinger et al. (1993) from the Red Sea (as C. sp. A). Hofker (1979) recorded the species (as *Pseudotretomphalus planus*) from the Caribbean. Some authors (Rückert-Hilbig,
1983) consider C. plana to be a synonym of C. bulloides (d’Orbigny, 1839). The complex taxonomic status of the species (e.g. C. plana, C. bulloides, C. sp.) has not yet been resolved and requires further studies. The species is widespread and present in most oceans (Pacific, Atlantic, Red Sea, Mediterranean Sea). Until molecular genetic data are available for the specimens from the type locality and other regions, and because of its complex taxonomic status, we consider the status of Cymbaloporetta sp. 1 from the Mediterranean Sea as cryptogenic.

**Edentostomina cultrata** (Brady, 1881)

1881 *Milolima cultrata* Brady – Brady, p. 45
1884 *Milolina cultrata* Brady – Brady, p. 161, pl. 5, figs. 1-2
1987 *Edentostomina cultrata* (Brady) – Loeblich & Tappan, pl. 334, figs. 6-8
1980 *Edentostomina cultrata* (Brady) – Alavi, p. 14 (appendix), pl. 10, fig. 11
non 2004 *Edentostomina cultrata* (Brady) – Merič et al., pl. 5, fig. 1
2006 *Edentostomina cultrata* (Brady) – Oflaz, pl. 2, fig. 3
2006 *Edentostomina milletti* (Wiesner) – Oflaz, pl. 2, figs. 4-6
non 2008b *Edentostomina cultrata* (Brady) – Merič et al., pl. 2, figs. 1-5

*Edentostomina cultrata* was first described by Brady (1884) from Papua New Guinea. Mediterranean records from Turkey were given by Alavi (1980) and Oflaz (2006). The specimens identified as *E. cultrata* by Merič et al. (2004; 2008b) do not show the typical thick, everted apertural rim, lack a pronounced neck and therefore belong to a different species of *Edentostomina*. The species *Edentostomina milletti*, originally described by Cushman (1917, as *Biloculina milletti*), looks similar but has a short bifid tooth. Records of *Edentostomina cultrata* in recent surface samples along the Mediterranean coast of Israel as well as findings of this species in core material deposited prior to the opening of the Suez Canal (Hyams-Kaphzan, unpublished) indicate that this species is native to the Mediterranean Sea.

**Elphidium charlottense** (Vella, 1957)

1957 *Elphidionion charlottensis* Vella – Vella, p. 38, pl. 9, figs. 187-188
1958 *Elphidium advenum* (Cushman) – Parker, pl. 4, figs. 3-4
1980 *Elphidium advenum* (Cushman) – Alavi, pl. 32, fig. 12
1991 *Elphidium* sp. 1 – Cimerman & Langer, p. 79, pl. 89, fig. 8
1997 *Elphidium charlottense* (Vella) – Hayward et al., p. 72, pl. 6, figs. 15-16
2004 *Elphidium advenum* (Cushman) – Merič et al., pl. 32, figs. 9-10
2006 *Elphidium* sp. 1 – Langer & Schmidt-Sinnes, pl. 15, fig. 5
2008a *Elphidium charlottense* (Vella) – Merič et al., pl. 16, figs. 1-3
2012 *Elphidium advenum* (Cushman) – Debenay, p. 218
2017 *Elphidium namibium/advenum* – Mouanga, pl. 16, fig. 17

The holotype of *Elphidium charlottense* has been described by Vella (1957) from Rellings Bay, Queen Charlotte Sound, Marlborough (New Zealand). The species is characterized by its rounded keel, translucent wall and non-inflated chambers resulting in a comparatively smooth test surface. The species differs from *Elphidium advenum* (Cushman), a species that has more inflated chambers and deeper interlocular septae and spaces. *Elphidium charlottense* has not been recorded from the Red Sea (Hottinger et al., 1993) but is present in shallow waters off the coast of Namibia (Langer, unpublished). *Elphidium charlottense* has been found in core material collected off Greece (Parker, 1958, as *Elphidium advenum*) and is therefore considered to be native to the Mediterranean Sea.

**Elphidium striatopunctatum** (Fichtel & Moll, 1798)

1798 *Nautilus striatopunctatus* Fichtel & Moll – Fichtel & Moll, p. 61, figs. a-c
non 1909 *Polystomella striatopunctata* (Fichtel & Moll) – Sidebottom, pl. 4, fig. 10, pl. 5, figs. 1-2
1993 *Elphidium striatopunctatum* (Fichtel & Moll) – Hottinger et al., p. 149, pl. 213, figs. 1-8, pl. 214, figs. 1-6
2000 *Elphidium striatopunctatum* (Fichtel & Moll) – Hyams, pl. 27, figs. 7-8
2001 *Elphidium striato-punctatum* (Fichtel & Moll) – Aşvar et al., pl. 4, figs. 8-11
2009 *Elphidium striatopunctatum* (Fichtel & Moll) – Yokeş & Merič, pl. 5, figs. 8-10
2014 *Elphidium striatopunctatum* (Fichtel & Moll) – Merič et al., pl. 83, figs. 16-17

*Elphidium striatopunctatum* has been described from the Red Sea by Fichtel & Moll (1798). Modern Mediterranean records include specimens from Israel (Hyams, 2000) and Turkey (Aşvar et al., 2001; Yokeş & Merič, 2009; Merič et al., 2014). Not illustrated records include Jones and Parker (1860), Schaudinn (1911) and Wiesner (1911a; 1911b). The illustrations given by Sidebottom (1909) show a different species. *Elphidium striatopunctatum* is therefore considered to be alien to the Mediterranean Sea.

**Epistomaroides punctulata** (Said, 1949)

1949 *Epistomaria punctata* Said – Said, p. 37, pl. 4, figs. 23a-c
1980 *Anomalina punctulata* d’Orbigny – Hansen & Rögl, pl. 1, figs. 4-8
The holotype of *Epistomaroides punctulata* was described by Said (1949) from the Red Sea. According to Hottinger *et al.* (1993), the specimens recorded by d’Orbigny (1826) as *Anomalina punctulata* are identical to the specimens described by Hansen & Rögl (1980). The material of d’Orbigny (1826) was collected around the Island of Mauritius, Indian Ocean. The first Mediterranean record of this species along the northern coast of Israel was provided by Almogi-Labin & Hyams-Kaphzan (2012). Today, the species is very abundant and widely distributed along the Mediterranean rocky coast of northern Israel (Hyams-Kaphzan, unpublished). We consider this species to be alien to the Mediterranean Sea.

**Euthymonacha polita** (Chapman, 1900)

1900 *Peneroplis (Monalysidium) polita* Chapman – Chapman, p. 4, pl. 1, fig. 5  
1994 *Monalysidium politum* (Chapman) – Jones, p. 29, pl. 13, figs. 24-25  
2010 *Euthymonacha polita* (Chapman) – Meriç *et al.*, p. 192, fig. 2  
2013a *Euthymonacha polita* (Chapman) – Langer *et al.*, fig. 7, 23-24  
2014 *Euthymonacha polita* (Chapman) – Meriç *et al.*, pl. 35, figs. 8-15  
2015 *Euthymonacha polita* (Chapman) – Delliou *et al.*, pl. 1, fig. 3  
2016 *Euthymonacha polita* (Chapman) – Huth, p. 31, pl. 1, figs. 10-12  
2017 *Euthymonacha polita* (Chapman) – Mouanga, pl. 1, figs. 1a-d  
2018 *Euthymonacha polita* (Chapman) – Emter, pl. 21, fig. 6

*Euthymonacha polita* was first described by Chapman (1900) from Funafuti (Pacific Ocean). Mediterranean records include findings from the Gulf of Kuşadası, Ilica Bay and the Karaburun Peninsula in Turkey (Meriç *et al.*, 2010; 2011), from the Kavala Gulf in Greece (Delliou *et al.*, 2015), from off Otranto, Italy (Huth, 2016), Libya (Emter, 2018) and the Balearic Islands off Spain (Alvira Romero, 2019). Brady (1884) recorded it from the Cape Verde Islands (Atlantic Ocean) as *Peneroplis pertusus* var. *e* (see Jones, 1994), and Langer *et al.* (2013a) recorded it from the Bazaruto Archipelago (Mozambique). So far, the species has not been recorded from the Red Sea or the Mediterranean coast of Israel (Said, 1949; Hottinger *et al.*, 1993; Hyams-Kaphzan *et al.*, 2008). The circum-tropical distribution and the widespread occurrence in the Mediterranean Sea suggest that this species may possibly be native to the Mediterranean. However, no record prior to the opening of the Suez Canal exists to date. For the time being we consider the species to be cryptogenic and further evidence is needed to resolve its status.

**Euuvigerina sp.**

1982 *Uvigerina peregrina* Cushman – Foraminiferi Padani, pl. 34, figs. 1-1bis  
2004 *Euuvigerina* sp. – Meriç *et al.*, pl. 22, figs. 2-3

*Euuvigerina* sp. was reported by Meriç *et al.* (2004) from Turkey and claimed to be alien to the Mediterranean Sea. The illustration provided is identical to specimens of *Uvigerina peregrina* reported in Foraminiferi Padani (1982), which, according to the authors, has been present in the Mediterranean Sea since the Pliocene. However, the holotype of *Uvigerina peregrina* Cushman differs from *Euuvigerina* sp. of Meriç *et al.* (2004). The taxonomic status of *Euuvigerina* sp. requires further study, but the species is certainly present in fossil material and therefore native to the Mediterranean Sea.

**Guttulina? sp.**

2008a *Entosigmomorphina* sp. – Meriç *et al.*, pl. 13, figs. 8a-b  
2014 *Entosigmomorphina* sp. – Meriç *et al.*, pl. 49, figs. 8a-b  
2014 *non* *Euuvigerina* sp. – Caruso & Cosentino, pl. 4, fig. 12

Meriç *et al.* (2008a) provide the first illustrated record of this species from the Mediterranean Sea. The chambers of the illustrated specimen are rapidly increasing in size and height and successive chambers appear to be 144° apart. The sutures are strongly depressed and the aperture is radiate. This would place the specimen in the genus *Guttulina* d’Orbigny, 1839. As this represents the first record of this taxon, it is considered to be native to the Mediterranean Sea. The specimen illustrated by Caruso & Cosentino (2014) does not belong to the genus *Entosigmomorphina*, differs from Meriç *et al.* (2008a, 2014), and requires further study.

**Haddonia sp.**

1993 *Haddonia?* sp. C – Hottinger *et al.*, p. 31, pl. 4, figs. 5-9  
2008a *Haddonia* sp. – Meriç *et al.*, pl. 1, figs. 1-4  
2008b *Haddonia* sp. – Meriç *et al.*, pl. 1, figs. 1-14  
2009 *Haddonia* sp. – Yokeş & Meriç, pl. 1, figs. 1-3  
2014 *Haddonia* sp. – Meriç *et al.*, pl. 2, figs. 7-17

*Haddonia* is a genus described from coral reefs from the Torres Strait (off northern Australia) by Chapman (1898). Hottinger *et al.* (1993) recorded a total of four different species in the Red Sea. *Haddonia* sp. was reported from Turkey by Meriç *et al.* (2007, see also Meriç *et al.*, 2008b; Yokeş & Meriç, 2009; and Meriç *et al.*, 2009).
Hauerina diversa Cushman, 1946

1932 Hauerina bradyi Cushman – Cushman, p. 44, pl. 10, figs. 12-15
1946 Hauerina diversa Cushman – Cushman, p. 11, pl. 2, figs. 16-19
1993 Hauerina diversa Cushman – Hottinger et al., p. 50, pl. 36, figs. 1-7
1998 Hauerina diversa Cushman – Yanko et al., p. 195, pl. 5, figs. 1-3
2000 Hauerina diversa Cushman – Hyams, pl. 6, figs. 6-7
2006 Sigmoidhauerina bradyi (Cushman) – Ofizl, p. 170, pl. 3, fig. 9
2008a Hauerina diversa Cushman – Merić et al., pl. 4, figs. 9-12
2008b Hauerina diversa Cushman – Merić et al., pl. 3, figs. 12-14
2010 Hauerina diversa Cushman – Avnaim-Katav, pl. 2, fig. 12
2014 Hauerina diversa Cushman – Merić et al., pl. 16, figs. 11-15
2017 Hauerina diversa Cushman – Guy-Haim et al., pl. 4 fig. 16, pl. 5, figs. 10-11

Hauerina diversa was first described by Cushman (1946) from Hereheretue, French Polynesia. Mediterranean records of Hauerina diversa include material from the Turkish Aegean coast (Meric et al., 2008a; 2008b) and from Israel (Yanko et al., 1998; Hyams, 2000; Hyams-Kaphzan et al., 2008; Avnaim-Katav, 2010 core-top). Non-illustrated records from Turkey also include Avşar (1997) and Avşar et al. (2001). The species has recently been found in large numbers along the rocky coast of northern Israel (Hyams-Kaphzan, unpublished). The Mediterranean and Red Sea forms do not show internal septulae and are placed into the genus Hauerina. We consider Hauerina diversa to be alien to the Mediterranean Sea. The species has been recovered from fish guts collected in the the Suez Canal and the Mediterranean Sea (Guy-Haim et al., 2017), indicating that ichthyochory is a potential vector for long-distance transport and species introduction.

Heterocyclina tuberculata (Möbius, 1880)

1880 Heterostegina tuberculata Möbius – Möbius, p. 107, pl. 12, figs. 3-7
1977 Heterocyclina tuberculata (Möbius) – Reiss et al., p. 104, figs. 35 A-C, 36 A
1993 Heterocyclina tuberculata (Möbius) – Hottinger et al., p. 156, pl. 226, figs. 1-7, pl. 227, figs. 1-8, pl. 230, fig. 10

Heterocyclina tuberculata has been described by Möbius (1880) from the western Indian Ocean. It has been recorded from the Turkish Mediterranean coast by Avşar et al. (2001; 2008) and from Greece (Debenay et al., 2005) but the specimens are not illustrated. Langer & Hottinger (2000) consider Heterocyclina tuberculata to be “restricted to the Indian Ocean and the Red Sea”. Illustrations of this species from the Mediterranean Sea were not published and we therefore consider the species to be absent from the Mediterranean Sea.

Heterostegina depressa d’Orbigny, 1826

1826 Heterostegina depressa d’Orbigny – d’Orbigny, p. 305, pl. 17, figs. 5-7
non 1865 Heterostegina depressa d’Orbigny – Parker et al., p. 34, pl. 3, fig. 100
non 1907 Heterostegina depressa d’Orbigny – Silvestri, p. 43, pl. 2, fig. 5
1968 Heterostegina antillarum d’Orbigny – Moncharmont Zei, p. 27, pl. 5, figs. 3-7
1980 Heterostegina antillarum d’Orbigny – Alavi, p. 27, pl. 35, figs. 3-7
1993 Heterostegina depressa d’Orbigny – Hottinger et al., p. 157, pl. 228, figs. 1-11, pl. 229, figs. 1-8, pl. 230, fig. 9
2000 Heterostegina depressa d’Orbigny – Langer & Hottinger, p. 110, text-fig. 4A
2002 Heterostegina depressa d’Orbigny – Hyams et al., pl. 1, fig. 9
2008 Heterostegina depressa d’Orbigny – Langer, p. 403, fig. 2
2008b Heterostegina depressa d’Orbigny – Merić et al., p. 323, pl. 10, figs. 1-12
2010 Heterostegina depressa d’Orbigny – Avnaim-Katav, p. 236, pl. 10, fig. 20

Heterostegina depressa has been described by d’Orbigny (1826) from the island of Saint Helena in the South Atlantic. The species is a true circumtropical foraminifer and its distribution encompasses the Caribbean, the North and South Atlantic, the entire Indian and Pacific Oceans and the Red and Arabian Sea (Langer & Hottinger, 2000; Langer, 2008 and references therein). Mediterranean records include specimens from Lebanon (Moncharmont Zei, 1968, as H. antillarum), Israel (Yanko et al., 1998, not illustrated; Hyams et al., 2002; Avnaim-Katav, 2010 core-top) and Turkey (Alavi, 1980; Merić et al., 2008b). Fossil occurrences of this species were reported by Parker et al. (1865) from “Middle Tertiary limestones of Malta and Vienna” and by Silvestri (1907) from a cave near Turin, Italy. However, the quality of the illustrations is too poor to assign the species to H. depressa and the specimens probably belong to a different species (Hottinger, pers. comm.). Heterostegina depressa is therefore considered to be alien to the Mediterranean Sea.

Loxostomina cf. L. africana (Smittmer, 1955)

1955 cf. Loxostomum africanum Smittmer –
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Smitter, p. 118, fig. 40 (o)

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Smitter, p. 118, fig. 40 (o)

1975 Brizalina (Parabrizalina) cf. B. (P .) africana (Smitter) – Zweig-Strykowski & Reiss, p. 100, pl. 3, figs. 1-8

1980 Bolivina africana (Smitter) – Alavi, p. 42 (appendix), pl. 26, figs. 5, 9-10

1993 Loxostomina cf. L. africana (Smitter) – Hottinger et al., p. 97, pl. 119, figs. 10-15

2000 Loxostomina cf. L. africana (Smitter) – Hyams, pl. 18, fig. 1

non 2017 Brizalina africana (Smitter) – Makled et al., p. 479, pl. 16, fig. 18

Loxostomina africana has been described by Smitter (1955). The material was collected from sediments off Mozambique and are “probably Upper Miocene” in age. The holotype has a smooth surface texture. Hottinger et al. (1993) illustrated a similar species. However, the Red Sea specimens have distinct longitudinal striae across the entire test surface and were therefore referred to as Loxostomina cf. L. africana. Striated representatives of this species were also recorded from Turkey by Alavi (1980) and from Israel by Hyams (2000), Hyams (2006), and Hyams-Kaphzan et al. (2008). So far, the species has not been recorded in fossil material. The first record of Loxostomina cf. L. africana from the Mediterranean Sea was provided by Alavi (1980). As the oldest record for this species originates from the Red Sea (Zweig-Strykowski & Reiss, 1975) the species is considered to be alien to the Mediterranean Sea.

Loxostomina costulata (Cushman, 1922)

1922 Bolivina limbata var. costulata Cushman – Cushman, p. 26, pl. 3, fig. 8

1993 Loxostomina? limbata (Brady) costulata (Cushman) – Hottinger et al., p. 97, pl. 120, figs. 8-13

? 2000 Loxostomina? limbata (Brady) costulata (Cushman) – Hyams, pl. 18, fig. 2

2016 Loxostomina limbata (Brady) costulata (Cushman) – Huth, p. 32, pl. 2, figs. 1-2

2017 Loxostomina limbata (Brady) costulata (Cushman) – Mouanga, pl. 12, figs. 10a-b

Loxostomina costulata has been described by Cushman (1922) from the Tortugas (Florida). Hottinger et al. (1993) recorded specimens from the Gulf of Aqaba, Red Sea. The species was also found in the Adriatic Sea off Otranto, Italy (Huth, 2016). Specimens from the coast of Israel provided by Hyams (2000) do not show the strong costate surface as illustrated by Hottinger et al. (1993) but may represent a morphological variety of this species. Fossil specimens of Loxostomina costulata with faint costate surfaces, were also found in core material from Israel (Hyams-Kaphzan, unpublished). The species is therefore considered to be native to the Mediterranean Sea.

Mimosina affinis (Cushman, 1934)

1934 Tretomphalus clarus Cushman – Cushman, p. 99, pl. 11, figs. 6 a-c, pl. 12, figs. 16-17

1993 Tretomphaloides clara (Cushman) – Hottinger et al., p. 112, pl. 145, figs. 6-11

2008 Tretomphaloides clara (Cushman) – Hyams-Kaphzan et al., p. 344

The holotype of Neoconorbina clara has been described by Cushman (1934) from Guam Anchorage, Ladrones Islands (western Pacific Ocean). Hottinger et al. (1993) recorded this species from the Gulf of Aqaba, Red Sea. The species was reported from the Mediterranean coast of Israel (Hyams-Kaphzan et al., 2008; Hyams-Kaphzan, unpublished). Neoconorbina clara is here considered to be alien to the Mediterranean Sea.
Nodophthalmidium antillarum (Cushman, 1922)

1922 Articulina antillarum Cushman – Cushman, p. 71, pl. 12, fig. 5
1929 Nodophthalmidium antillarum (Cushman) – Cushman, p. 52, pl. 12, fig. 4
1949 Nodophthalmidium antillarum (Cushman) – Said, p. 20, pl. 2, fig. 3
1968 Nodophthalmidium antillarum (Cushman) – Moncharmont Zei, pl. 3, fig. 3
1980 Nodophthalmidium antillarum (Cushman) – Alavi, pl. 20, fig. 9
1993 Nodophthalmidium antillarum (Cushman) – Hottinger et al., p. 44, textfig. 2, pl. 23, figs. 4-7
2000 Nodophthalmidium antillarum (Cushman) – Hyams, pl. 3, fig. 4

Non 2008b Nodophthalmidium antillarum (Cushman) – Meriç et al., pl. 2, fig. 10 (non figs. 11-14)
Non 2009 Nodophthalmidium antillarum (Cushman) – Yokeş & Meriç, pl. 1, figs. 10-11
2013a Articulina antillarum Cushman – Langer et al., pl. 7, figs. 6-7
2014 Nodophthalmidium antillarum (Cushman) – Meriç et al., pl. 8, figs. 11-12
Non 2017 Nodophthalmidium antillarum (Cushman) – Mouanga, pl. 3, fig. 6

Nodophthalmidium antillarum was first described by Cushman (1922) from Tortugas, Florida (Cushman, 1922). The species was also recorded from the Red Sea (Said, 1949; Hottinger et al., 1993) and the Bazaruto Archipelago, Mozambique (Langer et al., 2013a). The first Mediterranean record was provided by Moncharmont Zei (1968) from material collected at Ras Muker Ben and Ras Minet el Hosn (Lebanon) at depth between 75 m and 246 m. Other Mediterranean records include specimens from Turkey (Alavi, 1980; Meriç et al., 2008b) and Israel (Hyams, 2000; Yanko et al., 1998, not illustrated). Specimens illustrated by Meriç et al. (2008b) and Yokeş & Meriç (2009) differ substantially from the holotype (chamber shape and striation pattern) and belong to a different species. The juvenile specimen illustrated and recorded by Mouanga (2017) from the coast of Albania is also a different species. Nodophthalmidium antillarum is considered to be alien to the Mediterranean Sea.

Operculina ammonoides (Gronovius, 1781)

1781 Nautilus ammonoides Gronovius – Gronovius, p. 282 (no. 1220), pl. 19, figs. 5-6
1993 Assilina ammonoides (Gronovius) – Hottinger et al., p. 154, pl. 222, figs. 1-8, pl. 223, figs. 1-14, pl. 224, figs. 1-8, pl. 225, figs. 1-9
2016 Operculina ammonoides (Gronovius) – Merkado, fig. 2 A, fig. 21, fig. 24, fig. 26

The holotype of Operculina ammonoides has been described by Gronovius (1781) from the Bay of Bengal (Indian Ocean). Hottinger et al. (1993) recorded this species from the Gulf of Aqaba, Red Sea. The species also has been reported from the Adriatic Sea by Wiesner (1913) and Silvestri (1950) and by Yokeş & Meriç (2009) from Turkey. The latter records, however, lack illustrations. Operculina ammonoides was recently reported from the Mediterranean coast of Israel (Merkado, 2016). It is currently also present in rocky reefs of Shikmona, Haifa (Hyams-Kaphzan, unpublished). Populations along the coast of Israel are genetically closely related to specimens from the Red Sea and Japan (Merkado, 2016). The data currently available indicate that Operculina ammonoides is alien to the Mediterranean Sea.

Pararotalia calcariformata McCulloch, 1977

1977 Pararotalia calcariformata McCulloch – McCulloch, p. 428, pl. 177, figs. 10-11
1980 Pararotalia aff. P. bisaculeata (d’Orbigny) – Alavi, pl. 30, fig. 8
1994 Eponides repandus (Fichtel & Moll) – Yanko et al., pl. 2, figs. 1-9
1994 Pararotalia spinigera (Le Calvez) – Reinhardt et al., pl. 2, figs. 11-12
1998 Pararotalia spinigera (Le Calvez) – Yanko et al., pl. 1, figs. 6-9
2000 Pararotalia spinigera Le Calvez – Hyams, pl. 24, figs. 5-7
2010 Pararotalia spinigera Le Calvez – Avnaim-Katav, pl. 9, figs. 7-10
2013 Pararotalia calcariformata McCulloch – Meriç et al., figs. 2-3
2015 Pararotalia calcariformata McCulloch – Schmidt et al., fig. 1
2016 Pararotalia calcariformata McCulloch – Titelboim et al., fig. 5, 3-4
2020 Pararotalia calcariformata McCulloch – Avnaim-Katav et al., fig. 4, 18a, b
2020 Pararotalia calcariformata McCulloch – Manda et al., fig. 3C

The holotype of Pararotalia calcariformata was collected at Colombo Bay, Ceylon, Indian Ocean (McCulloch, 1977). This species has been considered to be alien to the Mediterranean Sea by Meriç et al. (2013) and Schmidt et al. (2015). Pararotalia calcariformata has been frequently reported as Pararotalia spinigera (Reinhardt et al., 1994; Yanko et al., 1998; Hyams, 2000; Hyams-Kaphzan et al., 2008). It is currently widely present and increasing in abundance off the coast of Israel from very shallow water depths down to 40 m (Hyams-Kaphzan et al., 2014; Titelboim et al., 2016; Avnaim-Katav et al., 2020; Manda et al., 2020). It has not yet been found in the Red Sea but is present around Bazaruto (Mozambique; Langer et al., 2013a). However, fossil evidence shows P. calcariformata (reported as P. spinigera) to be present at Caesarea Marina (Israel, Mediterranean Sea) by 171BC-78AD (Reinhardt et al., 1994) as well as in Haifa Bay (HB30, 5 m), Israel (Avnaim-Katav, 2010). We therefore consider the species to be native to the Mediterranean Sea.
**Pararotalia cf. P. socorroensis** (McCulloch, 1977)

1977 cf. *Praeglobotruncana? socorroensis*
McCulloch – McCulloch, p. 424, pl. 178, fig. 4, pl. 179, figs. 1, 3

1993 *Pararotalia cf. P. socorroensis* (McCulloch)
– Hottinger *et al.*, p. 141, pl. 200, figs. 1-11

2008 *Pararotalia cf. P. socorroensis* (McCulloch)
– Hyams-Kaphzan *et al.*, p. 344

The holotype of *Pararotalia socorroensis* is from Socorro Island, eastern Pacific Ocean (McCulloch, 1977). The species has been recorded in the Red Sea by Hottinger *et al.* (1993) and from the eastern Mediterranean Sea by Hyams-Kaphzan *et al.* (2008) and Hyams-Kaphzan (unpublished). *Pararotalia cf. P. socorroensis* is considered to be alien to the Mediterranean Sea.

**Pararotalia spinigera** Loeblich & Tappan, 1957 (ex. Le Calvez, 1949)

1987 *Pararotalia spinigera* (Le Calvez) –
Loeblich & Tappan, p. 18, pl. 4, figs. 1a-3

non 1994 *Pararotalia spinigera* (Le Calvez) –
Reinhardt *et al.*, pl. 2, figs. 11-12

non 2000 *Pararotalia spinigera* Le Calvez – Hyams, pl. 24, figs. 5-7

*Pararotalia spinigera* was considered to be alien to the Mediterranean Sea (Zenetos *et al.*, 2012). All illustrated Mediterranean records are now considered to be identical with *Pararotalia calcariformata*, a species that is native to the Mediterranean Sea (for further details, see *Pararotalia calcariformata*).

**Parasorites orbitolitoides** (Hofker, 1930)

1930 *Praesorites orbitolitoides* Hofker – Hofker, p. 149, pl. 55, figs. 8, 10, 11, pl. 58, figs. 1-5, pl. 59, figs. 3, 14

non 1977 *Sorites orbitolitoides* (Hofker) – Hottinger *et al.*, figs. 11B, 13, 30A-C, 32A

1994 *Sorites orbitolitoides* (Hofker) –
Gudmundsson, figs. 55-58, pl. 7, figs. 1-3

2017 *Parasorites/Broeckina orbitolitoides* (Hofker) –
Nadal Nebot, pl. 1, fig. *

2018 *Parasorites sp.* – Mateu-Vicens *et al.*, 2018

2018 *Parasorites orbitolitoides* (Hofker) –
Ferragut Perelló, pl. 1, fig. 6, textfig. 6

2019 *Parasorites orbitolitoides* (Hofker) –
Alvira Romero, pl. 1

*Parasorites orbitolitoides* has been first described by Hofker (1930) from Indonesia. The species has not been recorded in the Red Sea (Hottinger *et al.*, 1993). Reliable records for *Parasorites orbitolitoides* from the Mediterranean Sea are known from the Balearic Islands, Spain (Nadal Nebot, 2017; Ferragut Perelló, 2018; Mateu-Vicens *et al.*, 2018 (not illustrated, but re-examined); Alvira Romero, 2019). Populations of Mediterranean *P. orbitolitoides* show a genetic similarity of 98% with the Indo-Pacific population analyzed from Guam (Alvira Romero, 2019). For the time being, we consider this species to represent a true alien in the Mediterranean Sea.

**Paratrochammina madeirae** Brönnimann, 1979

1979 *Paratrochammina madeirae* Brönnimann –
Brönnimann, p. 7, pl. 7, figs. a-c, f, h, pl. 10, figs. b, e

1993 *Paratrochammina madeirae* Brönnimann –
Hottinger *et al.*, p. 32, pl. 7, figs. 11-15

2000 *Paratrochammina* sp. 1 – Hyams, pl. 1, figs. 9-10

non 2004 *Paratrochammina madeirae* Brönnimann –
Diz *et al.*, pl. 1, figs. 4a-b

2008 *Paratrochammina madeirae* Brönnimann –
Hyams-Kaphzan *et al.*, p. 336 (not illustrated)

*Paratrochammina madeirae* has first been recorded from Brazil (Brönnimann, 1979) and later from the Red Sea (Hottinger *et al.*, 1993). The species has also been found along the coast of Israel (Hyams, 2000; Hyams-Kaphzan *et al.*, 2008) and is considered to be alien to the Mediterranean Sea.

**Pegidia lacunata** McCulloch, 1977

1977 *Pegidia lacunata* McCulloch –
McCulloch, p. 347, pl. 154, fig. 2

1993 *Pegidia lacunata* McCulloch –
Hottinger *et al.*, p. 108, pl. 139, figs. 7-9, pl. 140, figs. 1-5

2008 *Pegidia lacunata* McCulloch –
Langer, p. 407, fig. 9

*Pegidia lacunata* has been described by McCulloch (1977) from the Philippine Islands, western Pacific. Hottinger *et al.* (1993) have reported the species from the Gulf of Aqaba at depths between 20 and 190 meters. The species has been rarely observed at a single sample site off Haifa, Israel (Langer, 2008, material collected in 1994) and is here considered to be alien to the Mediterranean Sea.

**Peneroplis cf. P. antillarum** (d’Orbigny, 1839)

1826 cf. *Dendritina antillarum* d’Orbigny –
d’Orbigny, p. 285

non 1839 *Dendritina antillarum* d’Orbigny –
d’Orbigny, p. 58, pl. 7, figs. 3-6

non 1994 *Peneroplis antillarum* (d’Orbigny) –
Gudmundsson, p. 111, textfigs. 19, 20, pl. 3, fig. 4, pl. 4, fig. 4

non 2000 *Peneroplis antillarum* (d’Orbigny) –
Hohenegger *et al.*, text-fig. 6

2002 *Peneroplis antillarum* (d’Orbigny) –
Hyams *et al.*, pl. 1, figs. 10-11

non 2019 *Peneroplis antillarum* (d’Orbigny) –
Förderer and Langer, pl. 2, figs. 16-18
Peneroplis antillarum has been described from the Antilles, Caribbean Sea (d’Orbigny, 1826). Specimens recorded by Hyams et al. (2002) from the Mediterranean coast off Israel differ from the specimens illustrated by d’Orbigny (1826, 1839) and Hohenegger et al. (2000). The test surface of the Mediterranean specimen is ornamented by costae, has curved sutures and is more rounded in outline. The aperture is characterized by irregular, bilobate, rimmed openings. We consider the Mediterranean species to be a separate taxon, that is tentatively regarded as P. cf. P. antillarum. As this represents the first record of this species, it is considered to be native to the Mediterranean Sea.

Peneroplis arietinus (Batsch, 1791)

1791  
Nautilus arietinus Batsch – Batsch, pl. 6, fig. 15c

1979  
Spirolina arietinus (Batsch) – Blanc-Vernet et al., pl. 24, fig. Sp a

1994  
Peneroplis arietinus (Batsch) – Gudmundsson, pl. 2, fig. 3, pl. 3, fig. 2

2008a  
Peneroplis arietinus (Batsch) – Merci et al., pl. 9, figs. 14-16, pl. 10, figs. 1-5

2017  
Spirolina arietina (Batsch) – Lamourou et al., fig. 7g

2019  
Peneroplis arietinus (Batsch) – Förderer & Langer, p. 13, pl. 2, figs. 6-12

The first description of Planispirinella exigua was provided by Brady (1879) from the Admiralty Islands and New Guinea. Not illustrated records from the Adriatic Sea include Wiesner (1911a) and Cosović et al. (2011). Oflaz (2006) illustrates P. exigua from Turkey. This species is also present off the coast of Israel (Hyams-Kaphzan, unpublished, material collected in 1997). We therefore consider P. exigua to be alien to the Mediterranean Sea.

Planispirinella exigua (Brady, 1879)

1884  
Hauerina exigua Brady – Brady, p. 196, pl. 12, figs. 1-4

1954  
Planispirinella exigua (Brady) – Cushman et al., p. 341, pl. 85, fig. 28

1994  
Planispirinella exigua (Brady) – Loeblich & Tappan, p. 38, pl. 57, figs. 7-8

2006  
Planispirinella exigua (Brady) – Oflaz, p. 141, pl. 1, figs. 10-11, pl. 11, fig. 3

The first description of Planispirinella exigua was published, material collected in 1997). We therefore consider P. exigua to be alien to the Mediterranean Sea.

Planogypsina acervalis (Brady, 1884)

1884  
Planorbulina acervalis Brady – Brady, p. 657, pl. 92, fig. 4

1909  
Planorbulina acervalis Brady – Sidebottom, p. 2, pl. 1, fig. 4

1949  
Planorbulina mediterranensis d’Orbigny – Said, p. 44, pl. 4, fig. 25

1994  
Planogypsina acervalis (Brady) – Hottinger et al., p. 125, pl. 169, figs. 1-9, 170, figs. 1-8

2006  
Planorbulina acervalis (Brady) – Oflaz, pl. 8, fig. 16

2008b  
Planogypsina acervalis (Brady) – Merci et al., pl. 8, fig. 9 (non figs. 4-5, 10-11)

2010  
Planogypsina acervalis (Brady) – Koukousiouara et al., p. 163, pl. 2, figs. 4-5

2014  
Planogypsina acervalis (Brady) – Merci et al., pl. 63, figs. 4a-b (non figs. 5-6)

Planogypsina acervalis has first been described by Brady (1884) from Booby Island, located in the Pacific Ocean (~ 14 m water depth). Said (1949) and Hottinger et al. (1993) reported the species from the northern Red
Sea. The first record from the Mediterranean Sea was provided by Sidebottom (1909, Island of Delos, Greece). Records of *P. acervalis* were given by Wiesner (1923) from Rimini (Adria) and by Moncharmont Zei (1968) from off Lebanon, but they all lack illustrations. Other Mediterranean records include Meriç *et al.* (2008b; 2014) and Hyams-Kaphzan (unpublished, material collected in 1998). The currently available evidence indicates that this species is alien to the Mediterranean Sea.

**Planogypsina squamiformis** (Chapman, 1901)

1901 *Gypsina vesicularis* (Parker & Jones) var. *squamiformis* Chapman – Chapman, p. 200, pl. 19, fig. 15
1901 *Gypsina vesicularis* (Parker & Jones) var. *monticulus* Chapman – Chapman, p. 200, pl. 19, fig. 14
1949 *Planorbulina acervalis* Brady – Said p. 43, pl. 4, fig. 28
1979 *Planorbulina aff. P. acervalis* Brady – Pereira, p. 288, pl. 41, figs. N-Q
1993 *Planogypsina squamiformis* (Chapman) – Hottinger *et al.*, p. 126, pl. 171, figs. 1-9
non 2008a *Planogypsina squamiformis* (Chapman) – Merić *et al.*, pl. 15, figs. 1-4
non 2008b *Planogypsina squamiformis* (Chapman) – Merić *et al.*, pl. 8, figs. 12-15
non 2009 *Planogypsina squamiformis* (Chapman) – Yokşe & Merić pl. 4, figs. 14-15
non 2014 *Planogypsina squamiformis* (Chapman) – Merić *et al.*, pl. 63, figs. 7-10

*Planogypsina squamiformis* was described by Chapman (1901) from Funafuti, Pacific Ocean. The species has also been recorded by Said (1949, Red Sea), Pereira (1979, Kenya) and Hottinger *et al.* (1993, Red Sea). The specimens illustrated by Merić *et al.* (2008a; 2008b; 2014) and Yokşe & Merić (2009) differ from the specimens recorded from the Pacific and the Indian Oceans and belong to *Planorbulina mediterranensis*. To date, there is no reliable record for *Planogypsina squamiformis* in the Mediterranean Sea, and we therefore consider the species to be absent.

**Procerolagena oceanica** (Albani, 1974)

1974 *Lagena oceanica* Albani – Albani, p. 37, pl. 1, figs. 7, 10-11
1993 *Lagena oceanica* Albani – Hottinger *et al.*, p. 78, pl. 90, figs. 9-11

*Procerolagena oceanica* has first been described from Australia by Albani (1974). Mediterranean records are limited to specimens from the Mediterranean coast off Israel (*Lagena oceanica*: Hyams, 2006; Hyams-Kaphzan, 2016; not illustrated but reexamined). We consider *Procerolagena oceanica* to represent a species that is alien to the Mediterranean Sea.

**Pseudohauerinella dissidens** (McCulloch, 1977)

1977 *Pseudohauerinella dissidens* McCulloch – McCulloch, p. 237, pl. 102, fig. 7
1993 *Pseudohauerinella dissidens* (McCulloch) – Hottinger *et al.*, p. 67, pl. 74, figs. 1-8
1998 *Pseudohauerinella dissidens* (McCulloch) – Piller & Haunold, pl. 6, fig. 15
2000 *Pseudohauerinella dissidens* (McCulloch) – Hyams, pl. 14, fig. 8
2017 *Pseudohauerinella dissidens* (McCulloch) – Thissen & Langer, pl. 9, figs. 15-18

The type locality of *Pseudohauerinella dissidens* is Sulphur Bay, Clarion Island (eastern Pacific, 31 m depth; McCulloch, 1977). *Pseudohauerinella dissidens* has been recorded from the Red Sea by Hottinger *et al.* (1993) and Piller & Haunold (1998) and from Zanzibar by Thissen & Langer (2017). The first Mediterranean record was provided by Hyams (2000) from the coast off Israel. The Mediterranean representatives of *P. dissidens* are not as strongly plicated as their tropical counterparts. A reduction of test ornamental features is typical for several alien foraminifera that have migrated from warm tropical waters to the colder waters of the Mediterranean Sea. We consider this species to be alien to the Mediterranean Sea.

**Pseudolachlanella slitella** Langer, 1992

1980 *Quinqueloculina “laevigata”* d’Orbigny – Alavi, p. 19 (appendix), pl. 10, fig. 5, pl. 11, fig. 5
1992 *Pseudolachlanella slitella* Langer – Langer, p. 90, pl. 2, figs. 4-6
1993 “*Quinqueloculina* eburnea” d’Orbigny – Hottinger *et al.*, p. 59, pl. 53, figs. 9-11, pl. 54, figs. 1-5
2003 *Pseudolachlanella slitella* Langer – Samir *et al.*, pl. 3, figs. 3-5
2008 *Pseudolachlanella slitella* Langer – Langer, p. 406, fig. 7

*Pseudolachlanella slitella* has first been described by Langer (1992) from the Lagoon at Madang, Papua New Guinea. The species has also been recorded by Loeblich & Tappan (1994) from the Timor Sea, by Debenay (2012) from New Caledonia, and Hottinger *et al.* (1993) from the Red Sea (as “*Quinqueloculina* eburnea”). Mediterranean records include the studies by Alavi (1980, Turkey, as *Quinqueloculina “laevigata”*), Samir *et al.* (2003, Egypt) and Langer (2008, Gulf of Gabes). The species is rarely found along the coast off Israel (Hyams-Kaphzan, unpublished). *Pseudolachlanella slitella* was considered to be alien to the Mediterranean Sea by Langer (2008), but the first documented occurrence by Alavi (1980) shows that it was present in the Mediterranean Sea before its first record from Papua New Guinea, New Caledonia, and the Timor Sea. *Pseudolachlanella slitella* is therefore considered to be native to the Mediterranean Sea.
**Pseudomassilina australis** (Cushman, 1932)

1932 *Massilina australis* Cushman – Cushman, p. 32, pl. 8, figs. 2 a-b

non 1980 *Pseudomassilina* cf. *P. australis* (Cushman) – Alavi, pl. 19 (appendix), fig. 8

1993 *Pseudomassilina australis* (Cushman) – Hottinger et al., p. 53, pl. 41, figs. 3-11

non 2000 *Pseudomassilina* cf. *P. australis* (Cushman) – Hyams, pl. 11, fig. 1

2006 *Pseudomassilina australis* (Cushman) – Oflaz, p. 171, pl. 3, fig. 10

The holotype of *Pseudomassilina australis* was described by Cushman (1932) from Raratonga, Cook Islands. Hottinger *et al.* (1993) recorded *P. australis* from the Gulf of Aqaba, Red Sea. The specimen illustrated by Oflaz (2006) from Turkey shares all morphological features with the holotype but appears to be a semi-adult individual. Similar specimens were recorded by Alavi (1980) from the Cilicia Basin, Turkey, and Hyams (2000) from the coast off Israel, but they show strong transverse ribs and were therefore assigned to *Pseudomassilina* cf. *P. australis*. For the time being we consider the specimen illustrated by Oflaz (2006) to be identical with the holotype and *Pseudomassilina australis* to be alien to the Mediterranean Sea.

**Pseudomassilina reticulata** (Heron-Allen & Earland, 1915)

1915 *Milolinia* (*Massilina*) secans, var. *reticulata* Heron-Allen & Earland – Heron-Allen & Earland, p. 582, pl. 45, figs. 1-4

1987 *Pseudomassilina australis* (Cushman) subsp. *reticulata* (Heron-Allen & Earland) – Baccaert, p. 111, pl. 51, fig. 2

1993 *Pseudomassilina reticulata* (Heron-Allen & Earland) – Hottinger *et al.*, p. 54, pl. 42, figs. 5-8, pl. 43, figs. 1-8

2000 *Pseudomassilina reticulata* (Heron-Allen & Earland) – Hyams, pl. 11, figs. 2-3

2008a *Pseudomassilina reticulata* (Heron-Allen & Earland) – Merič *et al.*, pl. 7, fig. 4

2008b *Pseudomassilina reticulata* (Heron-Allen & Earland) – Merič *et al.*, pl. 4, fig. 6

2009 *Pseudomassilina reticulata* (Heron-Allen & Earland) – Yokeş & Merič, pl. 2, fig. 6

2014 *Pseudomassilina reticulata* (Heron-Allen & Earland) – Merič *et al.*, pl. 27, fig. 16

Heron-Allen & Earland (1915) first described *Pseudomassilina reticulata* from several localities in the Quirimbas Archipelago off northern Mozambique. Their illustrations (figs. 1-2) show a distinct reticulate surface pattern as a characteristic feature of this taxon. The species has been reported from Zanzibar (Thissen & Langer, 2017) and the Red Sea by Hottinger *et al.* (1993). Mediterranean records include Hyams (2000), Avsar et al., 2001 (not illustrated), Merič *et al.* (2008a; 2008b), Yokeş & Merič (2009) and Merič *et al.* (2014). In the Mediterranean Sea, the test reticulation appears to be less pronounced, a morphological feature that is typical for species that have migrated from warm tropical waters to the colder Mediterranean. Hottinger *et al.* (1993) consider test reticulation to be variable. We therefore consider the specimens illustrated by Hyams (2000) and Merič (2008a) to be identical with the holotype of *Pseudomassilina reticulata* and the species to be alien to the Mediterranean Sea.

**Pseudoschlumbergerina ovata** (Sidebottom, 1904)

1904 *Sigmoilina ovata* Sidebottom – Sidebottom, p. 6, fig. 1

1968 *Sigmoilina ovata* Sidebottom – Monchamont Zei, p. 27, pl. 2, fig. 11

1980 “*Sigmoilina*” ovata Sidebottom – Alavi, p. 25 (appendix), pl. 11, fig. 12, pl. 17, fig. 11

1990 *Septloculina rotunda* El-Nakhal – El-Nakhal, p. 91, pl. 1, figs. 8-11, pl. 2, fig. 13

1993 *Pseudoschlumbergerina ovata* (Sidebottom) – Hottinger *et al.*, p. 55, pl. 46, figs. 1-6

2000 *Pseudoschlumbergerina ovata* (Sidebottom) – Hyams, pl. 11, figs. 5-6

2006 *Septloculina rotunda* El-Nakhal – Oflaz, p. 164, pl. 3, fig. 5

2012 *Pseudoschlumbergerina ovata* (Sidebottom) – Milker & Schmiedl, p. 68, pl. 17, figs. 29-30

2017 *Pseudoschlumbergerina ovata* (Sidebottom) – Guy-Haim *et al.*, pl. 4, fig. 19, pl. 2, fig. 15

*Septloculina rotunda* is listed as alien to the Mediterranean in EASIN (2020). The species was described by El-Nakhal (1990) from the Red Sea but is a junior synonym of *Pseudoschlumbergerina ovata* (Sidebottom, 1904), a species that was first recorded from the Mediterranean. *Septloculina rotunda* has been considered to be alien to the Mediterranean Sea by Oflaz (2006). It has been recorded by Hyams-Kaphzan *et al.* (2008, 2014) as *Pseudoschlumbergerina ovata*. Marriner *et al.* (2005), Milker & Schmiedl (2012) and Hyams-Kaphzan (unpublished) recorded fossil occurrences from the Mediterranean. *Pseudoschlumbergerina ovata* is therefore native to the Mediterranean Sea. Guy-Haim *et al.* (2017) found living specimens of *Pseudoschlumbergerina ovata* in feral pellets of herbivorous rabbitfish collected in the Suez Canal, indicating that present-day species introductions via ichthyochory vectors are ongoing.

**Pseudotriloculina subgranulata** (Cushman, 1918)

1918 *Triloculina subgranulata* Cushman – Cushman, p. 290, pl. 96, figs. 4a-c

1993 *Pseudotriloculina subgranulata* (Cushman) – Hottinger *et al.*, p. 56, pl. 47, figs. 8-13, pl. 48, figs. 1-8


1998 *Pseudotriloculina subgranulata* (Cushman)
Pseudotriloculina subgranulata has been described by Cushman (1918, as Triloculina subgranulata) from the Tortugas (Florida). The species is characterized by its rough test surface, resulting from distinct microstriae. Pseudotriloculina subgranulata was also reported from the coast of Israel by Yanko et al. (1998) and Hyams (2000). Other records from the Mediterranean Sea include Moncharmont Zéi (1968) and Hyams-Kaphzan et al. (2008), but lack illustrations. The fossil specimen reported by Reinhardt et al. (1994) requires further study. The species was recently recorded in core material from the Mediterranean coast off Israel (Hyams-Kaphzan, unpublished). Pseudotriloculina subgranulata is therefore native to the Mediterranean Sea.

**Pyrgo denticulata** (Brady, 1884)

1884 *Biloculina ringens var. denticulata* Brady – Brady, p. 143, pl. 3, figs. 4-5
1950 *Pyrgo denticulata* (Brady) – Said, p. 7, pl. 1, fig. 15
1993 *Pyrgo denticulata* (Brady) – Hottinger et al., p. 56, pl. 49, figs. 8-12
2000 *Pyrgo denticulata* (Brady) – Hyams, pl. 12, fig. 2
2008a *Pyrgo denticulata* (Brady) – Merić et al., p. 7, fig. 10
2010 *Pyrgo denticulata* (Brady) – Avnaim-Katav, p. 224, pl. 4, fig. 7

*Pyrgo denticulata* has been reported from Honolulu and Tongatapu (Tonga) by Brady (1884), from the Malay Archipelago (Millett, 1898), Funafuti (Chapman, 1901), the Kerimba Archipelago (Heron-Allen & Earlaid, 1915), Jamaica (Cushman, 1929) and the Red Sea (Said, 1950; Hottinger et al., 1993). The first occurrence in the Mediterranean Sea was provided by Hyams (2000) from off Israel. A single figure is provided by Merić et al. (2007; 2008a; 2008b; 2014) and Yokeş & Merić (2009), a figure that is identical in all four publications. Avnaim-Katav (2010) recorded fossil occurrences from the Mediterranean Sea, Haifa Bay, Israel (HB30, 1.95 m, Israel). However, dating of the core material is not clear-cut and requires further study. For the time being we consider *Pyrgo denticulata* to be alien to the Mediterranean Sea.

**Quinqueloculina cf. Q. mosharrafai** Said, 1949

1949 cf. *Quinqueloculina mosharrafai* Said – Said, p. 10, pl. 1, fig. 23
1993 *Quinqueloculina cf. Q. mosharrafai* Said – Hottinger et al., p. 59, pl. 54, figs. 6-9, pl. 55, figs. 1-6
2008a *Quinqueloculina cf. Q. mosharrafai* Said – Merić et al., pl. 6, fig. 12
2009 *Quinqueloculina cf. Q. mosharrafai* Said – Yokeş & Merić, pl. 2, fig. 4
2014 *Quinqueloculina cf. Q. mosharrafai* Said – Merić et al., pl. 24, fig. 8
2014 *Quinqueloculina cf. Q. mosharrafai* Said – Hyams-Kaphzan et al., p. 13

*Quinqueloculina mosharrafai* was first described from the Red Sea by Said (1949). Hottinger et al. (1993) illustrate a similar species (*Quinqueloculina cf. Q. mosharrafai*) from the Red Sea that differs from the holotype in having a bifid tooth and a partially agglutinated test surface. The holotype illustrated by the Smithsonian National Museum of Natural History (2020) shows agglutinated particles on the test surface but lacks the bifid tooth. The specimen described by Merić et al. (2008a; 2014) and Yokeş & Merić (2009) from Turkey is identical to *Quinqueloculina cf. Q. mosharrafai* from the Red Sea (Hottinger et al., 1993). *Quinqueloculina cf. Q. mosharrafai* has also been reported from the coast of Israel (Hyams-Kaphzan et al., 2014, material collected in 2013) and is here considered to be alien to the Mediterranean Sea.

**Quinqueloculina cf. Q. multimarginata** Said, 1949

1949 cf. *Quinqueloculina multimarginata* Said – Said, p. 10, pl. 1, fig. 34
1993 *Quinqueloculina cf. Q. multimarginata* Said – Hottinger et al., p. 59, pl. 55, figs. 7-10
2000 *Quinqueloculina cf. Q. multimarginata* Said – Hyams, pl. 7, fig. 9
2018 *Quinqueloculina cf. Q. multimarginata* Said – Förderer & Langer, pl. 23, figs. 28-30

The holotype of *Quinqueloculina multimarginata* described by Said (1949) from the Red Sea has thin keels and irregular costae on parts of the test surface. *Quinqueloculina cf. Q. multimarginata* described by Hottinger et al. (1993) differs from Said’s illustration by having an angular periphery and a rounded carina. In addition, the test surface is covered with distinct anastomosing microstriae. The Mediterranean specimen illustrated by Hyams (2000) represents a morphological variety of *Q. cf. Q. multimarginata* and has a slightly smoother surface than the specimens illustrated by Hottinger et al. (1993, Gulf of Aqaba) and Förderer & Langer (2018, Indonesia). For the time being, we consider *Quinqueloculina cf. Q. multimarginata* to be alien to the Mediterranean Sea.

**Schlumbergerina alveoliniformis** (Brady, 1879)

1879 *Miliolina alveoliniformis* Brady – Brady, p. 268
1884 *Miliolina alveoliniformis* Brady – Brady, p. 181, pl. 8, figs. 15-20
1987 *Schlumbergerina alveoliniformis* (Brady) – Baccaert, p. 150, pl. 65, figs. 4-5, pl. 66, figs. 1a-c
1993 Schlumbergerina alveoliniformis (Brady) – Hottinger et al., p. 61, pl. 58, figs. 11-14, pl. 59, figs. 1-9
2008b Schlumbergerina alveoliniformis (Brady) – Meriç et al., p. 331, pl. 3, figs. 8-11
2009 Schlumbergerina alveoliniformis (Brady) – Yokeş & Meriç, pl. 1, figs. 16-17
2014 Schlumbergerina alveoliniformis (Brady) – Meriç et al., pl. 24, fig. 8

Schlumbergerina alveoliniformis has been described by Brady (1879) from the Admiralty Islands in the Pacific Ocean with occurrences in Honolulu and Tongatabu. Mediterranean specimens illustrated by Meriç et al. (2008b; 2014) and Yokeş & Meriç (2009) represent the only Mediterranean records. We consider the species to be alien to the Mediterranean Sea.

Septloculina angulata El-Nakhal, 1990

1904 Sigmoilina ovata Sidebottom – Sidebottom, p. 6 (pars), text-fig. 1 (non pl. 2, figs. 12-13)
1990 Septloculina angulata El-Nakhal – El-Nakhal, p. 91, pl. 1, figs. 1-7
2006 Septloculina angulata El-Nakhal – Oflaz, p. 164, pl. 3, fig. 4

The species Septloculina angulata was described by El-Nakhal (1990) from the littoral zone off Tartus Town, Syria (Mediterranean Sea). Septloculina angulata is a species with seven, externally visible chambers, a subangular thickened periphery, a rough surface, and a semicircular terminal aperture provided with a bifid tooth. The species illustrated by Oflaz has less chambers, lacks the thickened chamber periphery and probably belongs to a different genus. The species was first described from the eastern Mediterranean is therefore native to the Mediterranean Sea.

Septloculina tortuosa El-Nakhal, 1990

1990 Septloculina tortuosa El-Nakhal – El-Nakhal, p. 91, pl. 2, fig. 4-9
2006 Septloculina tortuosa El-Nakhal – Oflaz, p. 165, pl. 3, fig. 6

The species Septloculina tortuosa has been described by El-Nakhal from Alexandria (1990, Egypt, Mediterranean Sea) and is therefore native to the Mediterranean Sea. The specimen reported by Oflaz (2006) from Iskenderun Bay, Turkey shows a quinqueloculine chamber arrangement and belongs to a different genus.

Sigmamiliolinella australis (Parr, 1932)

1932 Quinqueloculina australis Parr – Parr, pl. 1, figs. 8a-c
1987 Miliolinella australis (Parr) – Baccaert, p. 138, pl. 60, figs. 6-8

Sigmamiliolinella australis was described by Parr (1932) from the Admiralty Islands. Mediterranean specimens illustrated by Oflaz has less chambers, lacks the typical thickened apertural rim. To date, the species has not yet been found in core material. Sigmamiliolinella australis is currently abundant on macroalgae at sites off Haifa (Hyams-Kaphzan, unpublished) and appears to be a recent arrival in the southeastern Mediterranean Sea. We consider Sigmamiliolinella australis to be alien to the Mediterranean Sea.

The type locality for Sigmamiliolinella australis is east of Cape Pillar, Tasmania (Parr, 1932). Baccaert (1987) noted that the species is typical for tropical and temperate waters of “Indopacific shallow-water localities exclusively”. Sigmamiliolinella australis is not known from the northern Red Sea (Said, 1949; Hottinger et al., 1993; Piller & Haunold, 1998). A typical feature of S. australis is the partially coarse test surface at the proximal part of the shell. Some specimens of S. australis from the Mediterranean have been assigned to Miliolinella subrotunda. The first Mediterranean reference of Miliolinella subrotunda was provided by Alavi (1980), p. 90. The first illustrated record of Sigmamiliolinella australis in the Mediterranean was given by Triantaphyllou et al. (2005, identified as Miliolinella subrotunda). Other records include material from Greece (Koukousioura et al., 2011), Elba Island, Italy (Langer & Schmidt-Sinns, 2006), Dhermi, Albania (Mouanga, 2017), Corfu (Langer, unpublished; material collected in 2014) and Israel (Avnaim-Katav, 2010 core-top, material collected in 2005; Hyams-Kaphzan et al., 2014, material collected in 2013). The specimen illustrated in Dermitzakis & Triantafillou (1990) has inflated chambers, a smooth surface, lacks the typical thickened apertural rim and thus differs from Sigmamiliolinella australis (Parr). Recently re-illustrated material from the same material (Triantaphyllou, unpublished) has a similar test surface but shows a specimen with an oblique middle chamber and small aperture that also lacks the typical thickened apertural rim. To date, the species has not yet been found in core material. Sigmamiliolinella australis is currently abundant on macroalgae at sites off Haifa (Hyams-Kaphzan, unpublished) and appears to be a recent arrival in the southeastern Mediterranean Sea.
**Sigmoihauerina bradyi** (Cushman, 1917)

1884 *Hauerina compressa* d’Orbigny – Brady, pl. 11, figs. 12-13 (non *H. compressa* d’Orbigny)

1904 *Hauerina compressa* – Sidebottom, p. 19, no. 20

1917 *Hauerina bradyi* Cushman – Cushman, p. 62, pl. 23, figs. 2-a-b

1949 *Hauerina bradyi* – Said, p. 17, pl. 2, fig. 5

1968 *Hauerina bradyi* – Monchコメント mont Zei, p. 14, pl. 3, fig. 7

1993 *Hauerina bradyi* – Hottinger et al., p. 62, pl. 60, figs. 1-12

2006 *Sigmoihauerina bradyi* (Cushman) – Ofzlaz, p. 170, pl. 3, fig. 9

Brady (1884) provided the original illustrations for *Sigmoihauerina bradyi* (Cushman) from material collected in the Torres Strait and at Booby Island (Pacific Ocean). The species is characterized by its compressed test and thus differs from the more inflated species *Hauerina compressa* (d’Orbigny 1846) from Miocene deposits of the Vienna Basin. The Mediterranean records provided by Sidebottom (1904, as *Hauerina compressa*), Monchament Zei (1968), and Ofzlaz (2006) show the inflated form and that does not match the holotype or the specimens illustrated by Hottinger et al. (1993). Specimens with the typical large and compressed test are not yet known from the Mediterranean Sea and we therefore consider *Sigmoihauerina bradyi* to be absent from this region.

**Siphonaperta cf. S. pittensis** (Albani, 1974)

1957 *Quinqueloculina parvaggluta* Vella – Vella, p. 27, pl. 4, figs. 71-73

1974 *Siphonaperta pittensis* Albani – Albani, p. 33, pl. 1, figs. 1-3

1993 *Siphonaperta pittensis* (Albani) – Hottinger et al., p. 63, pl. 64, figs. 1-6

2000 *Siphonaperta* cf. *S. pittensis* (Albani) – Hyams, pl. 9, fig. 6

2010 *Quinqueloculina parvaggluta* Vella – Hayward et al., p. 154, pl. 5, figs. 1-2

2012 *Quinqueloculina parvaggluta* Vella – Debenay, p.125

2012 *Quinqueloculina pittensis* (Albani) – Debenay, p.125

2013a *Siphonaperta pittensis* (Albani) – Langer et al., pl. 4, figs. 33-34

*Siphonaperta pittensis* was considered to be a Lessepsian invader by Hyams-Kaphzan et al. (2008). The Mediterranean records are now considered to constitute a separate species. *Siphonaperta cf. S. pittensis* is more elongated than *S. pittensis* and its chambers are less inflated (see also Hyams, 2000). *Siphonaperta cf. S. pittensis* also resembles *Quinqueloculina parvaggluta* as described by Vella (1957). The relationship between

*Siphonaperta distorqueata* (Cushman, 1954)

1954 *Quinqueloculina distorqueata* Cushman – Cushman et al., p. 333, pl. 83, fig. 27

1980 *Quinqueloculina berthelotiana* d’Orbigny – Alavi, pl. 15, fig. 2

1993 *Siphonaperta distorqueata* (Cushman) – Hottinger et al., p. 63, pl. 62, figs. 4-9, pl. 63, figs. 1-6

2000 *Siphonaperta distorqueata* (Cushman) – Hyams, pl. 9, figs. 2-3

2009 *Quinqueloculina distorqueata* Cushman – Parker, p. 195, figs. 138-139

2011 *Siphonaperta distorqueata* (Cushman) – Makled & Langer, fig. 7, 7-9

2017 *Siphonaperta distorqueata* (Cushman) – Thissen & Langer, pl. 7, figs. 24-26

2017 *Quinqueloculina distorqueata* Cushman – Fajemila & Langer, fig. 4, 30-32

*Siphonaperta distorqueata* has been described from the Marshall Islands by Cushman et al. (1954). The species has been recorded from the Red Sea by Hottinger et al. (1993), from around Australia by Parker (2009, and references therein), from the Chukat Atoll (western Pacific) by Makled & Langer (2011), from the Atlantic Ocean (Fajemila & Langer, 2017) and from Zanzibar by Thissen & Langer (2017). Mediterranean records include specimens from Turkey (Alavi, 1980, as *Quinqueloculina berthelotiana*) and from shallow waters off Israel (Hyams, 2000; Hyams-Kaphzan et al., 2008; 2014). The species is here considered to be alien to the Mediterranean Sea.

**Sorites variabilis** Lacroix, 1941

1941 *Sorites variabilis* Lacroix – Lacroix, (pars), p. 14

1941 *Sorites variabilis* Lacroix – Lacroix., p. 11 (pars), figs. 12, 18

? 1979 *Sorites variabilis* Lacroix – Blanc-Vernet et al., pl. 21, fig. 14, pl. 24, fig. S

? 1993 *Sorites variabilis* Lacroix – Hottinger et al., p. 73, pl. 84, figs. 1-15

? 2008a *Sorites variabilis* Lacroix – Meriç et al., pl. 12, figs. 12-15, pl. 13, figs. 1-4

? 2008b *Sorites variabilis* Lacroix – Meriç et al., pl. 7, figs. 1-8

2013 *Sorites variabilis* Lacroix – Merkado et al., pl. 7, figs. 1-2

? 2016 *Sorites variabilis* Lacroix – Ayadi et al., pl. 1, fig. 9, pl. 3, figs. 2-3

2017 *Sorites variabilis* Lacroix – Lamourou et al., fig. 7(h)
Sorites variabilis has been first described by Lacroix (1941) from the Gulf of Aqaba, Red Sea. Lacroix described three types of soritid foraminifera. Only type II has been designated to represent S. variabilis (see also Hottinger et al., 1993). The Mediterranean records from Turkey (Meriç et al., 2008a; 2008b) do not provide illustrations of the apertural features and their true identity requires further study. The specimens from Israel (Hyams-Kaphzan et al., 2008, not illustrated) and from Villefranche (Langer, unpublished; material collected in 1996) were reexamined by us, show the typical morphological features of Sorites variabilis (particularly thin-shelled, single row of apertures). All Sorites specimens described or illustrated from Naxos (Greece, Cherif, 1970) of from along the coast of Tunisia (Glacon, 1962; Blanc-Vernet et al., 1979; Langer, unpublished) are thick-shelled, show the typical features of Sorites orbiculus, and do not belong to Sorites variabilis (see also Baccaert, 1987). For the time being, this species is considered to be alien to the Mediterranean, but further molecular studies are required.

Spiroloculina angulata Cushman, 1917

1917 Spiroloculina grata Terquem var. angulata
Cushman – Cushman, p. 36, pl. 7, fig. 5;
1968 Spiroloculina grata Terquem var. angulata
Cushman – Moncharmont Zei, pl. 3, fig. 10
non 2008 Spiroloculina angulata Cushman – Yağmurlu et al., pl. 1, fig. 8
non 2013 Spiroloculina angulata Cushman – Cosentino et al., p. 8786, pl. 1, fig. 18

The type species of Spiroloculina angulata has been described by Cushman (1917) from the northern Pacific. The species is characterized by its truncated periphery and a characteristic median carina. A single illustrated record of this species exists from the coast of Lebanon (Moncharmont Zei, 1968). Other records of Spiroloculina angulata include Alavi (1980), Morehange et al. (2000), Basso & Spezzaferri (2000), Samir & El-Din (2001), Ayşar et al. (2001), Meriç et al. (2004), Zaibet et al. (2016), Altnasçı et al. (2017, Sea of Marmara), but they all lack illustrations. For the time being, Spiroloculina angulata is considered to be alien to the Mediterranean Sea.

Spiroloculina antillarum d’Orbigny, 1839

1839 Spiroloculina antillarum d’Orbigny – d’Orbigny, p. 166, pl. 9, figs. 3-4
1920 Spiroloculina antillarum d’Orbigny – Martinotti, p. 261, figs. 16-17
1923 Spiroloculina antillarum d’Orbigny – Wiesner, p. 33, pl. 4, fig. 20
non 1970 Spiroloculina antillarum d’Orbigny – Cherif, p. 37, pl. 3, fig. 3
1977 Spiroloculina antillarum d’Orbigny – Le Calvez, p. 91, pl. 17, figs. 1-6
non 1979 Spiroloculina antillarum d’Orbigny –

This species was first recorded from Cuba by d’Orbigny (1839), is elongate fusiform in lateral view and possess a densely costate test surface and long neck (see Le Calvez, 1977). The first record from the Mediterranean was provided by Wiesner (1913, not illustrated). The specimen was later illustrated by Martinotti (1920, Libya), Wiesner (1923, Adriatic Sea). Records without illustrations include Moncharmont-Zei (1968, Lebanon), Samir et al. (2003, Egypt), Mkawar et al. (2007, Tunisia), and Serandrei-Barbero et al. (2011, Adriatic Sea). We consider Spiroloculina antillarum to be alien to the Mediterranean Sea. The specimens illustrated by Hottinger et al. (1993), Meriç et al. (2008 a,b), Avnaim-Katav (2010), Mouanga (2017), Thissen & Langer (2017) and Emter (2018) are coarsely costate, broadly fusiform, and have a short neck and thus differ from the original of d’Orbigny and represent a separate species. The Red Sea/Indian Ocean type (e.g. Hottinger et al., 1993) was also reported from fossil sediments by Mateu (1972), Avnaim-Katav (2010), Melis et al. (2015), Yümün et al. (2016) and Hyams-Kaphzan (unpublished) and is native to the Mediterranean Sea.

Spiroloculina attenuata Cushman & Todd, 1944

1944 Spiroloculina attenuata Cushman & Todd – Cushman & Todd, p. 54, pl. 9, figs. 23-25
1987 Spiroloculina communis Cushman & Todd subsp. attenuata – Baccaert, p. 118, pl. 53, figs. 4-5
1993 Spiroloculina attenuata Cushman & Todd – Hottinger et al., p. 45, pl. 25, figs. 3-9
2000 Spiroloculina attenuata Cushman & Todd – Hyams, p. 4, fig. 2

This species was described by Cushman and Todd (1944) with the type locality near Pago Pago Harbor, Samoa (Pacific Ocean). The WoRMS Editorial Board (2020) has recently placed the taxon into Naxotia (Al-Zamel & Cherif, 1997), a new genus that was introduced for evolute quinqueloculine forms, with five chambers visible externally, tests with a greasy luster and a necked
circular aperture with two teeth. *Spiroloculina attenuata* does not fulfill the range of features required to be placed in *Naxobia*. Hyams (2000) recorded this species from the Mediterranean coast of Israel. We consider *Spiroloculina attenuata* to be alien to the Mediterranean Sea.

**Spiroloculina aff. S. communis** Cushman & Todd, 1944

1944 *Spiroloculina communis* Cushman & Todd – Cushman & Todd, p. 63, pl. 9, figs. 4-5, 7-8

? 1949 *Spiroloculina communis* Cushman & Todd – Said, p. 14, pl. 1, fig. 37

1993 *Spiroloculina aff. S. communis* Cushman & Todd – Hottinger et al., p. 45, pl. 25, figs. 10-15

The holotype of *Spiroloculina communis* recorded by Cushman & Todd (1944) originates from the San Andres Island in the Philippines. *Spiroloculina communis* was later illustrated by Said (1949) from the Red Sea. However, the quality of the illustration is poor. *Spiroloculina aff. S. communis* was described from the Red Sea by Hottinger et al. (1993). This species resembles *S. communis* but possesses only one bifid tooth. Recent material from the Mediterranean Sea for *Spiroloculina aff. S. communis* has been recorded by Hyams-Kaphzan et al. (2008). We therefore consider the species to be alien to the Mediterranean Sea.

**Spiroloculina nummiformis** Said, 1949

1949 *Spiroloculina nummiformis* Said – Said, p. 16, pl. 1, fig. 39

1993 *Spiroloculina nummiformis* Said – Hottinger et al., p. 46, pl. 27, figs. 1-9

2000 *Spiroloculina nummiformis* Said – Hyams, pl. 4, fig. 6

non 2011 *Spiroloculina nummiformis* Said – Elshanawany et al., pl. 7, fig. 8

*Spiroloculina nummiformis* has been described from the Red Sea by Said (1949). Mediterranean occurrences include two records from the Levantine coast off Israel (Hyams, 2000; Hyams-Kaphzan et al., 2008). The specimen illustrated by Elshanawany et al. (2011) from Abu-Qir Bay off Alexandria (Egypt) differs substantially from the holotype and the specimens illustrated by Hottinger et al. (1993) from the Red Sea. *Spiroloculina nummiformis* is considered to be alien to the Mediterranean Sea.

**Textularia agglutinans** d’Orbigny, 1839

1839 *Textularia agglutinans* d’Orbigny – d’Orbigny, pl. 1, figs. 17, 18, 32-34

1884 *Textularia agglutinans* d’Orbigny – Brady, pl. 43 figs. 1–2

1977 *Textularia agglutinans* d’Orbigny – Le Calvez, p. 13–14, fig. 1

1981 *Textularia agglutinans* d’Orbigny – Banner & Pereira, pl. 1, figs. 6–7, pl 2, fig. 1

1990 *Textularia agglutinans* d’Orbigny – Dermitzakis & Triantafillou, p. 161, pl. 3, fig. 6

1991 *Textularia agglutinans* d’Orbigny – Cimerman & Langer, pl. 10, figs. 1–2

1993 *Textularia agglutinans* d’Orbigny – Hottinger et al., pl. 13, figs. 1-9

2012 *Textularia agglutinans* d’Orbigny – Milker & Schmiedl, fig. 10, 15-16

2015 *Textularia agglutinans* d’Orbigny – Merkado et al., fig. 4, 1-4; fig. 5, 1-9

2020 *Textularia agglutinans* d’Orbigny – Manda et al., fig. 3c

*Textularia agglutinans* d’Orbigny is a cosmopolitan agglutinated foraminiferal species, with an elongated biseri al test in its adult stage and a low arched aperture. It was first described by d’Orbigny in 1839 from sandy beaches around Cuba and has been reported from numerous locations worldwide: Atlantic Ocean (Culver & Buzas, 1980), Red Sea (Hottinger et al., 1993), Timor Sea (Loeblich & Tappan, 1994), Pacific Ocean (Debenay, 2012), Indian Ocean (Langer et al., 2013a), western and eastern Mediterranean (Cimerman & Langer, 1991; Hyams-Kaphzan et al., 2008, p. 336; Milker & Schmiedl, 2012), Adriatic Sea (Jorissen, 1987), Tyrrenhian Sea (Sgarrella & Moncharmont Zei, 1993) and Marmara Sea (Army–not du Châtelet et al., 2013). Recent molecular analyses (Merkado et al., 2015) indicate that the northern Red Sea and the eastern Mediterranean hard-bottom populations of *T. agglutinans* off Israel belong to the same genetic population, regardless of their large morphological variability. Further molecular studies are required to validate if the Mediterranean species are indeed genetically identical to the material from the Caribbean type locality. Fossil *T. agglutinans* material was recorded from Holocene deposits by Milker & Schmiedl (2012) from the western Mediterranean Sea (off Mallorca, Alboran Platform and Oran Bight) and from the Gulf of Corinth (Dermitzakis & Triantafillou, 1990). The species is also abundant in core material (Hyams-Kaphzan, unpublished) collected off Israel. Fossil evidence and the global biogeographic distribution makes it difficult to consider *T. agglutinans* as alien to the Mediterranean Sea. The species is therefore considered to be native.

**Triloculina asymmetrica** Said, 1949

1949 *Triloculina asymmetrica* Said – Said, p. 18, pl. 2, fig. 11

1993 *Triloculina asymmetrica* Said – Hottinger et al., p. 64, pl. 66, figs. 4-9

non 2017 *Triloculina asymmetrica* Said – Mouanga, pl. 9, figs. 14-15

The holotype of *Triloculina asymmetrica* was described by Said (1949) from the Red Sea. Hottinger et al. (1993) recorded it from the Gulf of Aqaba, Red Sea. The record by Oflaz (2006) lacks an illustration. The pho-
Triloculina cf. T. fichteliana d’Orbigny, 1839
non 1839 Triloculina fichteliana d’Orbigny – d’Orbigny, p. 171, pl. 9, figs. 8, 10
non 1929 Triloculina fichteliana d’Orbigny – Cushman, p. 63, pl. 17, figs. 1a-c
non 1977 Triloculina fichteliana d’Orbigny – Le Calvez, p. 106, fig. 1
1993 Triloculina fichteliana d’Orbigny – Hottinger et al., p. 65, pl. 66, figs. 10-15
2008a Triloculina cf. T. fichteliana d’Orbigny – Meriç et al., pl. 7, figs. 14-16, pl. 8, figs. 1-2
2008b Triloculina cf. T. fichteliana d’Orbigny – Meriç et al., pl. 4, figs. 9-12
2010 Triloculina fichteliana d’Orbigny – Koukousioura et al., p. 164, pl. 2, fig. 3
2015 Miliolinella fichteliana (d’Orbigny) – Delliou et al., pl. 1, fig. 1
2017 Triloculina fichteliana d’Orbigny – Thissen & Langer, pl. 8, figs. 10-12

Triloculina fichteliana was originally described by d’Orbigny (1839) from Cuba (see also Le Calvez, 1977). The specimens recorded from the Mediterranean and the Red Sea share a common morphology, that differs from the material described from Caribbean localities (Cushman, 1929). The main differences concern the test ornamentation and the shape of the tooth. We therefore consider specimens from the Red Sea, the Mediterranean Sea (Hottinger et al., 1993; Meriç et al., 2008a; 2008b) and the Indian Ocean (Thissen & Langer, 2017) to represent a species that differs slightly from d’Orbigny (1839), herein referred to as Triloculina cf. T. fichteliana. As such, we consider it to represent a species alien to the Mediterranean Sea. The specimen illustrated by Cushman (1929) differs from the holotype of d’Orbigny in having a lip instead of a tooth (see also Le Calvez, 1977), belongs to a different genus, but does not have taxonomic priority over Triloculina fichteliana of d’Orbigny (1839).

Vaginulinopsis sublegumen Parr, 1950
1950 Vaginulinopsis sublegumen Parr – Parr, p. 325, pl. 11, figs. 18a-b
non 2004 Astacolus sublegumen (Parr) – Meriç et al., p. 126, pl. 19, fig. 9

Astacolus sublegumen was reported to be present in Turkey by Meriç et al. (2004). The holotype of this species originates from the Antarctic Ocean and is currently referred to as Vaginulinopsis sublegumen (see Jones, 1994; and WoRMS Editorial Board, 2020). The specimens illustrated by Meriç et al. (2004) significantly differ from the holotype. The same illustration was used in Yokeş & Meriç (2009) and Meriç et al. (2014). To date, there is no valid record of Vaginulinopsis sublegumen in the Mediterranean Sea and the species is therefore absent and not alien.

Varidentella cf. V. neostriatula (Thalmann, 1950)
1932 cf. Quinqueloculina striatula Cushman – Cushman, p. 27, pl. 7, figs. 3-4
1950 Quinqueloculina striatula Thalmann – Said, p. 5, pl. 1, fig. 9
1987 Quinqueloculina neostriatula Thalmann – Baccarot, p. 91, pl. 43, figs. 1-6
1993 Varidentella cf. V. neostriatula (Thalmann) – Hottinger et al., p. 66, pl. 70, figs. 5-11, pl. 71, figs. 1-7
1998 Varidentella neostriatula (Thalmann) – Piller & Haunold, pl. 6, fig. 9
2000 Varidentella cf. V. neostriatula (Thalmann) – Hyams, pl. 14, fig. 4

Quinqueloculina striatula was described by Cushman (1932) from Mojaukar Anchorage, Fiji (Melanesia). The holotype is characterized by five chambers, a subacute chamber periphery and a test wall that is well ornamented by numerous costae. Quinqueloculina neostriatula recorded by Said (1950) and Piller & Haunold (1998) from the northern Red Sea resembles the specimens illustrated by Hottinger et al. (1993). However, Said (1950) provides only a single side view illustration. Baccarot (1987) illustrated specimens from Australia with variable morphologies, some of which resemble specimens from the northern Red Sea. A single record of Varidentella cf. V. neostriatula from the Mediterranean Sea was illustrated by Hyams (2000). It is identical to some of the specimens illustrated by Hottinger et al. (1993). The morphotypes of this species are highly variable and further studies are required. For the time being, we consider Varidentella cf. V. neostriatula to be alien to the Mediterranean Sea.

Discussion

Our survey and reexamination of alien benthic foraminifera currently present in the Mediterranean Sea yielded a total of 44 validly recognized species and two cryptogenic taxa (Table 1). This reduces the number of previous recordings of alien foraminifera (Hyams-Kaphzan et al., 2008, Zenetos et al., 2012; EASIN, 2020), and is mainly due to new occurrence records, new findings in the fossil record, erroneous identifications, and evidence predating the presence of alien species prior to the opening of the Suez Canal. The revised list of accepted alien species includes both larger symbiont-bearing and smaller benthic foraminifera, including 16 hyaline-perforate, 3 agglutinated and 25 porcelaneous taxa.

The vast majority of alien foraminifera reported so far have become established in the Eastern Mediterranean Sea (41 species = 93.1%; Tbl. 1, Fig. 1), primarily along the Levantine coasts (Langer & Hottinger, 2000; Hyams et al., 2002; Hyams-Kaphzan et al., 2008; Langer, 2008;
Almogi-Labin & Hyams-Kaphzan, 2012; Langer et al., 2012; Mouanga & Langer, 2014; Langer & Mouanga, 2016; Guastella et al., 2019; Servello et al., 2019; Katsanevakis et al., 2020). The number of alien species decreases rapidly from east to west. Eleven species of alien benthic foraminifera were recorded in the central Mediterranean (27.2%), 8 species in the Adriatic (20.4%), and only 5 (11.6 %) in the western Mediterranean Sea. The preferential establishment of NIS of benthic foraminifera within the warmer eastern Mediterranean is indicative for a point source from a tropical location, in particular the Red Sea/Indian Ocean with a pathway through the Suez Canal. In fact, recent molecular phylogenetic analyses have provided evidence that modern populations of a few selected species belong to the same genetic population and were therefore considered Lessepsian migrants (Merkado et al., 2013; 2015; Schmidt et al., 2015). However, the fossil record provides evidence that all of them (Textularia agglutinans, Sertoria orbiculus, Pararotalia calcariiformata) were present in the Mediterranean prior to the opening of the Suez Canal (see Results). They are therefore native to the Mediterranean Sea and, per definition, can neither be considered alien nor invasive aliens. In addition, fully conclusive evidence to trace the origin of an alien species can only be provided when molecular data are available from the type locality. To trace the origin of a putative alien species via molecular genetic analysis of Mediterranean and Red Sea/Indian/Pacific Ocean material remains therefore inconclusive, if the type locality is located in a different geographic zone (e.g. the Caribbean Sea for Textularia agglutinans).

Being located at the crossroads between the Atlantic and the Indo-Pacific Oceans, alien species enter the Mediterranean Sea mainly via the Suez Canal but also via the Strait of Gibraltar and the Dardanelles. Foraminifera entering the Mediterranean via the Suez Canal pathway, generally follow the counterclockwise current pattern and first settle along the eastern shores of the Levantine coast (Langer, 2008). Biological invasions through the Suez Canal have been facilitated as a consequence of extended connectivity including the extension, broadening and enlargement of the Suez Canal (Galil et al., 2017; Zenetos, 2017). This has raised concern over rising propagule pressure and introductions of new NIS with potential consequences on native biotas (Galil et al., 2017). The Red-to-Med invasion of tropical taxa has also been promoted by rising sea surface temperatures (Raitsos et al., 2010; Manda et al., 2020) and the Nile damming (Skliris & Lascaratos, 2004). While rising sea surface temperatures increase thermal habitat suitability (Marras et al., 2015), damming of the Nile has caused drastic modifications in sedimentation patterns, circulation and salinity, diminished pre-existing environmental barriers and provided an additional stimulus for the invasion and establishment of alien species.

The distribution of tropical larger benthic foraminifera (LBF) is strongly constrained by water temperature (Langer & Hottinger, 2000). As they invade the temperate waters of the eastern Mediterranean, they meet a physical border that limits their rapid distribution. The temperature requirements of tropical foraminifera restrict their distributional capacity and migration towards the colder western Mediterranean, which is influenced by cold water currents from the Atlantic Ocean. Some of the larger symbiont-bearing foraminifera have reached Sicily and Tunisia (Langer & Hottinger, 2000; Langet al., 2012; El Kateb et al., 2018; Damak et al., 2019; Guastella et al., 2019), entered the Adriatic Sea (Langer & Mouanga, 2016), and continue to their range expansion towards the northwestern Mediterranean with more than 10 km/yr (Langer et al., 2012; Guastella et al., 2019).

To project future species distributions, species distribution modelling based on ecological niche constraints of current distributions were applied to foraminifera by Langer et al. (2012; 2013b) and Weinnmann et al. (2013). The projection onto the RCP4.5 scenario (Collins et al., 2013) suggests that the overall habitat suitability will increase with potential range expansions into the western area of the Mediterranean along the coast of northern Africa, into the Alboran and Balearic Sea, along the Tyrrhenian coast in Italy, and deep into the Adriatic Sea, following a continuous northwestern dispersal. The range expansions are fueled in response to temperature increases and the extension of climate belts (Tittensor et al., 2010, Langer et al., 2012; Guastella et al., 2019). Minimum winter sea surface temperatures (SST) has previously been invoked to be among the main agents controlling the latitudinal distribution of LBF (Zmiri et al., 1974; Langer & Hottinger, 2000) and the observed range extension of thermophilic LBF and endosymbiotic foraminifera were shown to track contemporary SST increase (Langer et al., 2012; Weinnmann et al., 2013; Langer & Mouanga, 2016; Schmidt et al., 2015; 2018; Guastella et al., 2019; Manda et al., 2020). In addition, the proliferation and recent range expansion rates of LBF (Langer & Mouanga, 2016; Guastella et al., 2019; Damak et al., 2019) provide strong support for previous species distribution models projecting the northward migration and range shifts and corroborate findings that rising water temperatures and warm currents are the most likely agents controlling the latitudinal extension of larger symbiont-bearing foraminifera. Compared to alien LBF, hardly anything is known about range expansions rates of smaller benthic foraminifera. Previous studies have documented that populations of putative Lessepsian migrants (Textularia agglutinans and Pararotalia calcariiformata) became very dominant along the Israeli Mediterranean coast (Hyams-Kaphzan et al., 2014; Merkado et al., 2015; Schmidt et al., 2015) possibly as a result of rising water temperatures (e.g. Manda et al., 2020).

Almost all alien foraminifera present in the Mediterranean Sea appear to be innocuous and only one fulfills the criteria to be considered as an invasive alien: Amphistegina lobifera (Langer et al., 2012; Guastella et al., 2019; Servello et al., 2019). This species is a prolific carbonate producer (Hallock, 1981; Langer et al., 1997; Langer, 2008) and displays extreme forms of ecosystem invasibility (Langer et al., 2012; Mouanga & Langer, 2014; Langer & Mouanga, 2016). This includes mass occurrences, hyperabundances and the appearance in mono-
cultures, with capabilities to reduce native diversity and species richness (Mouanga & Langer, 2014), to transform the composition, grain size and chemistry of sediments from predominantly siliceous to carbonate deposits (Hyams et al., 2002; Samir et al., 2003; Gruber, 2007; Yokoș & Merić, 2009; Abu Tair & Langer, 2010; Langer et al., 2012; Weimann et al., 2013; Caruso & Cosentino, 2014; Mouanga & Langer, 2014; Guastella et al., 2019; Merić et al., 2020), and to trigger changes in ecosystem functioning (Langer et al., 2012). Triantaphyllou et al. (2005), Koukouziou et al. (2011), and Dimiza et al. (2016b) have suggested that their presence and numerical abundance may be used as proxy to assess the degree of environmental disturbance. At some sites extreme abundances of amphisteginid invaders were shown to result in the formation of large amounts of “living sands” (Meric, 2008; Meric et al., 2008a; Yokoș & Merić 2009; Abu Tair & Langer 2010; Langer et al., 2012). The invasion and prolific occurrences indicate that the amphisteginid invaders successfully fill an open niche that is obviously providing ideal conditions. While the immediate impact of Amphistegina lobifera appears to be obvious, the resilience of native biotas to key invaders remains yet to be determined.

Amphisteginid invasions selectively affect taxa that share the same microhabitat and suggests that competitive exclusion is a major driving force regulating species richness in invaded communities. The displacement of native species may be of local nature and natives may persist in nearby uninvaded areas. Whether Amphistegina lobifera displaces any other organisms than foraminifera and what role they play in the food web of metacommunities, is currently not known. Mouanga & Langer (2014) have demonstrated that massive invasions of amphisteginids locally result in the homogenization of the foraminiferal faunas with a clear correlation between the diversity of foraminiferal biotas and percent abundances of amphisteginid invaders (Langer & Mouanga, 2016). Amphistegina lobifera was recently included in the list of the top 26 high-priority species that display invasive traits and for which the performance of risk assessments is encouraged (Tsiamis et al., 2019) under Descriptor 2 of the European Union Marine Strategy Framework Directive (EU, 2008) and the Biodiversity Strategy (EU, 2014b).

Means of dispersal of benthic foraminifera are multifold and involve natural and human-mediated sources. Natural means involve transportation by ocean currents, attachment to bodies of birds and fish, the incidental consumption and translocation by macroorganisms, and rafting on algae and other objects (Lipps, 1983; Langer, 1993; Langer et al., 1998; Goldbeck et al., 2005; Guy-Haim et al., 2017; Finger, 2017), where the ranges of native species are broadly constrained by limitations on their capacity for dispersal. Knowledge of the processes and mechanisms that govern dispersal and colonization in benthic organisms is crucial for understanding biodiversity patterns and historical development of biogeography. However, the rate at which humans translocate species has substantially intensified with increasing globalization and does not show any signs of saturation (Seebens et al., 2017). Human-mediated introductions of NIS include ballast water, hull fouling and sea chests (water-intake recesses in the hull), intentional and accidental releases of aquaculture species, aquarium discards and aquarium trade.

Ballast water is generally invoked to be among of the major pathways for the introduction of nonindigenous marine species (Ruiz et al., 1997; Carlton et al., 1999; Molnar et al., 2008; Seebens et al., 2016), but hardly anything is known about the potential role of transoceanic ship deballasting as a vector for the introduction of alien foraminifera in the Mediterranean Sea (Galil & Hülsmann 1997; McGann et al., 2020). The release of ballast water and the transport stowaway pathway related to shipping traffic (biofoulers and hitchhikers) have been widely suspected as vectors for the introduction of non-native foraminifera (Hayward, 1997; Hayward et al., 1999, 2004; McGann et al., 2000; Calvo-Marcilese & Langer, 2010; Polovodova Asteman & Schönfeld, 2016; Eichler et al., 2018; Deldicq et al., 2019), has led to a breakdown of classical biogeographic regions and is considered a major vector for Red-to-Med alien species invasions (Zenetos et al., 2012).

Cargo ships and tankers take up and release large volumes of ballast water. The ballast water is used for stability and maneuverability and may also be added to add weight to pass under bridges and other structures. Ballasting and deballasting most frequently occurs in shallow water, in ports and in estuaries. Ballast water was shown to contain abundant and diverse biotas, is moved across oceans and constitutes “a conveyor belt of marine organisms wrapping around the world”. Together with the ballast water, ships also pump substantial amount of sediment (including foraminifera) into their ballast tanks (Carlton & Geller 1993; Chu et al., 1997; Galil & Hülsmann 1997; Gollasch et al., 1998; Macdonald, 1998; Lavoie et al., 1999; Smith et al., 1999; McGann et al., 2000, 2020; Drake et al., 2005; Johengen et al., 2005). Ballast water may contain both benthic and planktic foraminifera, including all life stages ranging from propagules to adult life-stages. The invasion success of ballast water aliens is highly probabilistic and a game of ecological roulette, where the outcome depends on a myriad of dynamic factors (Ricciardi, 2016), including species traits, available nich space, interactions with native biotas, trade routes, climate change and water temperature (among many others).

Predicting foraminiferal invasions is a challenging task and there is general international consensus that multi-vector pathways-based management is a priority in minimizing marine alien species (Ojaveer et al., 2018). To date, there is no evidence that foraminifera are toxic (Langer & Bell, 1995), they are of no concern to human health, and by virtue of their substantial carbonate production, they may be even beneficial to coastal protection (Hallock, 2002; Hohenegger, 2006; Langer, 2008, Langer et al., 2013b; Doo et al., 2014). Management of invasive alien species has been among the main priorities of the IAS Regulation (Article 4, EU, 2014a), but measures to mitigate the impact of alien foraminifera, or to efficiently control or even eradicate are neither feasible...
nor costeffective (Tsiamis et al., 2020), and may be even counterproductive. Because of their abundance, high reproduction rates, and ubiquity in virtually all marine environments, however, foraminifera are excellent predictors of rates of global change.

The revision and revised list of alien foraminifera presented here is a dynamic resource and will continue to evolve as the number of alien species is likely to increase. Regular updates, more accurate information and the application of molecular techniques will assist our understanding of climate driven range shifts and the magnitude of alien species impacts in the Mediterranean Sea and in global oceans. In addition, recent molecular genetic studies provide accumulating evidence that traditional morphospecies taxonomy vastly underestimates true diversity in foraminifera and routinely report a higher number of previously unrecognized species (e.g. Pawlowski et al., 2014; Prazeres et al., 2020). On a molecular level, alien foraminifera present in the Mediterranean Sea are currently underresearched and require intensified efforts to trace their source. Rigorous morpho- and molecular species identifications, studies on ballast water, species distribution modeling and new evidence from the fossil record will thus continue to shed new light on the status (native/alien/cryptogenic), pathway, vector and origin of species (Atlantic/Red Sea).

Summary

A large-scale survey on alien benthic foraminifera in the Mediterranean Sea has been conducted and resulted in a revised list of 44 validly recognized alien and two cryptogenic species, including both larger symbiont-bearing and smaller benthic taxa. The reexamination of previous alien species records is based on a critical and careful revision of the current taxonomic status of each species, new findings in the fossil record, and recently published data obtained through molecular genetic analysis. The vast majority of alien foraminifera recorded so far have established self-sustaining populations in the Eastern and Central Mediterranean Sea. It is anticipated that rising sea surface temperatures and the expansion of climate belts will convey the range expansion and northwestern migration of alien species. To date, only Amphistegina lobifera meets the full set of criteria to be considered as an invasive alien. Measures to mitigate its impact on ecosystems and native biota, to efficiently control, manage or even eradicate are neither feasible nor costeffective and may even be counterproductive. The number of alien foraminifera is likely to evolve as travel, shipping trade, rising temperatures and increasing globalization promote the spread of alien taxa in the Mediterranean Sea. Because of their abundance, ubiquity, and high reproduction rates, foraminifera are excellent proxies for rates of global climate change. Monitoring future range expansions of key alien taxa (e.g. Amphistegina spp.) will thus provide a baseline to assess the magnitude, rate and impact of predicted global change.

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