SCHACKOINELLA SPINA, A NEW BENTHIC FORAMINIFERAL SPECIES FROM COLD-WATER CORAL ECOSYSTEMS OF THE ALBORAN SEA AND THE GULF OF CADIZ

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ABSTRACT

Schackoinella spina n. sp. has been found in the eastern Alboran Sea at five different stations in water depths ranging from 258–330 m, as well as in one 532 m deep station in the Gulf of Cádiz, north-eastern Atlantic Ocean. Three stations have been sampled with a giant box core (BC) and two stations with a gravity core (GC) system. The sediments of the BCs and the GCs are characterized by cold-water coral (CWC) debris and a high abundance of biogenic components (e.g., bryozoans, echinoderms, bivalves, gastropods, serpulids, foraminifera). The surface samples from the BCs were treated with an ethanol-rose Bengal solution following standardized sampling protocol. In the BC samples the specimens of Schackoinella spina n. sp., were collected from the surface (0–1 cm). In particular, one BC sample (MD13-3456BC) contained six live (stained) specimens and an abundance of non-stained specimens (46 per 50 cm³ sediment). The new species was found at several sediment depth intervals corresponding to a Holocene age.

The occurrence of this small (60–140 μm) species in the Alboran Sea and Gulf of Cádiz has likely been overlooked in this region. Although not straightforward, the presence of this species in association with cold-water coral fragments and its absence in fine-grained pelagic sediments may indicate a relationship with this ecosystem.

INTRODUCTION

The European Atlantic continental margin is characterized by several thriving clusters or provinces of cold-water coral (CWC) reefs and mounds, where the azooxanthellate scleractinian corals Lophelia pertusa and Madrepora oculata proliferate and often build mound-like structures or reefs (Roberts et al., 2006; Henriet et al., 2014). Discoveries of new CWC ecosystems in the last two decades have fueled numerous studies on the various facets of these peculiar ecosystems, in particular, along the Atlantic and Mediterranean margins (e.g., Fink et al., 2007; Williams et al., 2010; Margreth et al., 2009; Fink et al., 2012). Recent studies (e.g., Duineveld et al., 2004, 2007; Kiriakoulakis et al., 2004) demonstrated CWC dependence on an abundant food supply. Cold-water coral ecosystems are unique because they host a highly diverse macrofauna from water depths ranging from 39 m down to several thousand meters (Freiwald et al., 2004).

Micropaleontological studies focusing on benthic foraminifera from CWC ecosystems published so far from the Norwegian shelf (e.g., Joseph et al., 2013; Spezzaferri et al., 2013; Stalder et al., 2014), the Porcupine Seabight and Rockall Trough (e.g., Rüggeberg et al., 2007; Margreth et al., 2009; Schönfeld et al., 2011; Smeulders et al., 2014), and the western Alboran Sea (Margreth et al., 2011) showed that the microfauna (benthic foraminifera) is also more diverse than in the surrounding environments. Based on live (stained) benthic foraminifera assemblages from CWC ecosystems, Margreth et al. (2009) and Spezzaferri et al. (2013) demonstrated that the relatively high diversity of the benthic foraminiferal fauna on reefs or mounds is related to enhanced food supply, to different sedimentary facies, and to increased availability of microhabitats (e.g., on coral branches). A recent comprehensive study of benthic foraminiferal assemblages from the Norwegian shelf, the Porcupine area (Seabight and Rockall Trough), and the Alboran Sea (Spezzaferri et al., in press) showed that benthic foraminiferal assemblages from CWC ecosystems are strongly homogeneous from the north-eastern Atlantic to the western Mediterranean Sea.

However, considering the scarcity of detailed studies on benthic foraminifera associated with CWC reefs, there is a considerable lack of knowledge regarding their assemblage composition, microhabitat zonation and functioning, biotic interactions, feeding modes, and spatial distributions. Micropaleontological investigations can provide, as in this case, opportunities to find and describe new species. We propose here a new benthic foraminiferal species belonging to the poorly known genus Schackoinella Weinhandl, 1958, which was discovered in sediments from the Alboran Sea (eastern Mediterranean Sea) and the Gulf of Cádiz (Fig. 1A, Table 1).
GEOLOGIC AND OCEANOGRAPHIC SETTINGS

The Alboran Sea is a 1,800 m deep basin located at the western part of the Mediterranean Sea, restricted to the north by the Iberian Peninsula, to its westernmost end by the Strait of Gibraltar, to the south by the African continent and to the east by the Algerian-Balearic Basin (Fig. 1A). The Alboran Sea is further subdivided into three basins, the eastern Alboran Basin (EAB), the western Alboran Basin (WAB) and southern Alboran Basin (SAB; Fig. 1A). The latter two are separated by a large NE-SW trending antiform, the Alboran Ridge (Comas et al., 1999).

Modern oceanographic conditions in the Alboran Sea have been extensively described by La Violette (1984), Parrilla et al. (1986), Heburn & La Violette (1990), and Rohling et al. (1995), among others. The water-mass configuration is strongly related to the water exchange with the Atlantic Ocean through the Strait of Gibraltar and can be subdivided into three main water masses. The uppermost water mass (ca. 0–220 m) consists of Modified Atlantic Water (MAW), which is formed by a jet of Atlantic water passing through the Strait of Gibraltar and spawns two anticyclonic gyres in the Alboran Sea, the eastern Alboran Gyre (EAG) and the western Alboran Gyre (WAG), the Eastern Alboran Basin (EAB), the Western Alboran Basin (WAB), the Southern Alboran Basin (SAB), and the Alboran Ridge (AR). The two dashed areas show the locations of high primary productivity centers.
Although the Mediterranean Sea is usually considered to be oligotrophic, the Alboran Sea can be regarded as an exception with primary productivity of about 215–250 g C m⁻²·yr⁻¹ (Antoine et al., 1995; Bosc et al., 2004). In particular, two high productivity centers have been recognized in the eastern Alboran Sea and flowing towards the west below the MAW at a depth interval between ca. 220–1200 m (La Violette, 1986). The LIW is characterized by temperatures of 12.8–12.9°C and salinity of ~38.42–38.45 in the western Mediterranean sub-basins (van Haren & Millot, 2004).

Although the Mediterranean Sea is usually considered to be oligotrophic, the Alboran Sea can be regarded as an exception with primary productivity of about 215–250 g C m⁻²·yr⁻¹ (Antoine et al., 1995; Bosc et al., 2004). In particular, two high productivity centers have been recognized in the Alboran Sea, the Almeria-Oran Front system in the eastern part of the Alboran and an upwelling system off Malaga (Vergnaud-Grazzini & Pierre, 1991).

**Geographic Distribution of the Genus Schackoinella**

The genus *Schackoinella* Weinhandl, 1958 is poorly known and rarely reported in the literature. Because of its uncommon wall texture, this genus has been placed in different superfamilies (e.g., Orbitoidoidea, Globigerinoidea, Discorboidae) and in different families (e.g., Hantkeninidae, Glabratellidae, Discorbidae). As originally described, this genus includes forms characterized by spines on the spiral side. However, specimens showing this character have also been placed in genera such as *Rosalina* d’Orbigny, 1826, *Glabratella* Dorrean, 1948, and *Cororbella* Hofker, 1951. Figure 1B displays the geographic distribution of *Schackoinella* spp. (and morphologically similar forms) and includes their ecological and environmental preferences, if available (Table 2).

**MATERIALS AND METHODS**

This study was performed on samples from two gravity cores (GCs) recovered during the cruise TTR-17 in 2008, and on six box cores (BCs, 50 x 50 cm; Fig. 2, Table 1) recovered during the Eurofleets MD194 cruise in June 2013. One of these BCs was collected in the Gulf of Cádiz and five in the eastern Alboran Sea (Fig. 1A, Table 1). Three surface-sample replicates were collected from each BC. Additionally, three to four sub-cores (10 cm in diameter, up to 1 m long) were collected for each BC. The protocol for micropaleontological studies of Schönfeld et al. (2012) was applied to surface sediments. After description, the surface samples were collected with a graduated cylinder (8 cm in diameter and 1 cm high; total volume = 50 cm³), preserved in plastic containers with an ethanol-rose Bengal solution (2 g/L), and stored at 4°C for at least 3 weeks. Samples were then washed through a 63 μm mesh sieve and live (stained) and fossil (not stained) benthic foraminifera were analyzed from this fraction. The split size was defined by a target value of 300 specimens. Splits were picked and counted entirely. The gravity cores (Fig. 3) were sampled at 20 cm intervals for geochemical and micropaleontological investigations. Samples were processed following standard procedures for foraminiferal preparation. Approximately 10 g of dry bulk sediment sample was washed through three sieves (63, 125 and 250 μm) and at least 200 specimens per fraction were counted and glued on plummer cells for archiving. All samples were quantitatively investigated for their benthic foraminiferal content. In the samples containing the new species, all residues were systematically investigated to collect a maximum of specimens.

Scanning electron microscope (SEM) images were taken with a FEI Sirion XL30 FEG SEM and all specimens were coated with a 20 nm gold layer. Images for the holotype were performed using a SEM Phenom ProX. The holotype was not coated to avoid damaging the specimen. Figure 1 shows the location of the stations/cores where *Schackoinella* were found. The number of tests gives the abundance of dead (not stained) and live (stained) specimens in the BC (per ~50 cm³ sediment) and GC samples (per ~10 g of sediment). MMF = Melilla Mounds Field; BC = Box core; GC = Gravity core; BSF = Below Sea-Floor.

<table>
<thead>
<tr>
<th>Station</th>
<th>Region</th>
<th>Lat. (° N)</th>
<th>Long. (° W)</th>
<th>Depth (m)</th>
<th>no of tests</th>
<th>Sed. Facies</th>
<th>Gear</th>
<th>BSF (cm)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD13-3441BC</td>
<td>Gulf of Cádiz</td>
<td>35’17.765’</td>
<td>06’47.276’</td>
<td>532</td>
<td>36</td>
<td>Biogenic sand</td>
<td>BC</td>
<td>0 – 1</td>
<td>Recent</td>
</tr>
<tr>
<td>MD13-3456BC</td>
<td>Alboran Sea (MMF)</td>
<td>35’26.170’</td>
<td>02’30.824’</td>
<td>330</td>
<td>6*46</td>
<td>Biogenic sand</td>
<td>BC</td>
<td>0 – 1</td>
<td>Recent</td>
</tr>
<tr>
<td>MD13-3461BC</td>
<td>Alboran Sea (MMF)</td>
<td>35’26.528’</td>
<td>02’31.065’</td>
<td>320</td>
<td>3</td>
<td>Biogenic sand</td>
<td>BC</td>
<td>0 – 1</td>
<td>Recent</td>
</tr>
<tr>
<td>MD13-3465BC</td>
<td>Alboran Sea (MMF)</td>
<td>35’26.035’</td>
<td>02’30.848’</td>
<td>346</td>
<td>0</td>
<td>Biogenic sand</td>
<td>BC</td>
<td>0 – 1</td>
<td>Recent</td>
</tr>
<tr>
<td>MD13-3466BC</td>
<td>Alboran Sea (MMF)</td>
<td>35’25.915’</td>
<td>02’30.877’</td>
<td>474</td>
<td>0</td>
<td>Biogenic sand</td>
<td>BC</td>
<td>0 – 1</td>
<td>Recent</td>
</tr>
<tr>
<td>MD13-3471BC</td>
<td>Alboran Sea (Cabierns)</td>
<td>35’47.750’</td>
<td>02’15.152’</td>
<td>341</td>
<td>2</td>
<td>Biogenic sand</td>
<td>BC</td>
<td>0 – 1</td>
<td>Recent</td>
</tr>
<tr>
<td>TTR17-399G</td>
<td>Alboran Sea (MMF)</td>
<td>35’20.904’</td>
<td>02’32.178’</td>
<td>258</td>
<td>4</td>
<td>Biogenic sand</td>
<td>GC</td>
<td>40</td>
<td>Sub-recent</td>
</tr>
<tr>
<td>TTR17-396G</td>
<td>Alboran Sea (MMF)</td>
<td>35’20.421’</td>
<td>02’31.077’</td>
<td>300</td>
<td>3</td>
<td>Biogenic sand</td>
<td>GC</td>
<td>20</td>
<td>Sub-recent</td>
</tr>
<tr>
<td>TTR17-396G</td>
<td>Alboran Sea (MMF)</td>
<td>35’20.421’</td>
<td>02’31.077’</td>
<td>300</td>
<td>6</td>
<td>Biogenic sand</td>
<td>GC</td>
<td>60</td>
<td>Sub-recent</td>
</tr>
<tr>
<td>TTR17-396G</td>
<td>Alboran Sea (MMF)</td>
<td>35’20.421’</td>
<td>02’31.077’</td>
<td>300</td>
<td>5</td>
<td>Biogenic sand</td>
<td>GC</td>
<td>100</td>
<td>Sub-recent</td>
</tr>
<tr>
<td>TTR17-396G</td>
<td>Alboran Sea (MMF)</td>
<td>35’20.421’</td>
<td>02’31.077’</td>
<td>300</td>
<td>2</td>
<td>Biogenic sand</td>
<td>GC</td>
<td>120</td>
<td>Sub-recent</td>
</tr>
<tr>
<td>TTR17-396G</td>
<td>Alboran Sea (MMF)</td>
<td>35’20.421’</td>
<td>02’31.077’</td>
<td>300</td>
<td>4</td>
<td>Biogenic sand</td>
<td>GC</td>
<td>160</td>
<td>Sub-recent</td>
</tr>
</tbody>
</table>

* = living specimens (stained).

(WAG; La Violette, 1986). The MAW is characterized by relatively lower salinities (<36.5) at its entrance into the Alboran Sea and becomes gradually saltier with residence time and mixing with Mediterranean water (Font et al., 1998). The intermediate water mass is composed of Levantine Intermediate Water (LIW), originally generated in the eastern Mediterranean Sea and flowing towards the west below the MAW at a depth interval between ca. 220–1100 m (La Violette, 1986). The LIW is characterized by temperatures of ~13.1–13.2°C and salinities of ~38.5 (Millot et al., 2006, and references therein). The Western Mediterranean Deep-Water (WMDW) fills the lowest part of the Alboran Basin and represents, together with the LIW, the main source of Mediterranean Outflow Water (MOW) flowing towards the Rockall Channel (Iorga & Lozier, 1999). Deep-water formation occurs in the Gulf of Lion and is a tributary of the regional circulation pattern, the initial density of the MAW and the LIW and wind strength (Cacho et al., 2000). The Western Mediterranean Deep Water has a temperature of ~12.8–12.9°C and salinity of ~38.42–38.45 in the western Mediterranean sub-basins (van Haren & Millot, 2004).

### Table 1. Station list of the BC and GC samples where *S. spinos* Stalder & Spezzaferri n. sp. have been found. The number of tests gives the abundance of dead (not stained) and live (stained) specimens in the BC (per ~50 cm³ sediment) and GC samples (per ~10 g of sediment). MMF = Melilla Mounds Field; BC = Box core; GC = Gravity core; BSF = Below Sea-Floor.
Spina n. sp. occurred and Table 1 summarizes the number of live (stained) and fossil specimens counted for each station.

To document the size range of the new species, we applied basic morphometric analyses on a selection of specimens (n = 37) with relatively well-preserved chambers. From these 37 specimens, 3 were rose Bengal stained (i.e., live). As the spines of most specimens were damaged, possibly during sample preparation, we measured the maximum (length) and the minimum (width) diameters of the tests (Fig. 4). The 37 specimens were first documented with SEM images from the dorsal view and the morphometric parameters were then measured with the "Olympus measureIT" software.

SEDIMENTOLOGY

The sediments from the surface of the BCs and the sediments from the GCs in which S. spina were found were all characterized by CWC fragments up to 20 cm in diameter (Figs. 2, 3) and by abundant biogenic components such as bryozoans, gastropods, bivalves, serpulids, and planktonic and benthic foraminifera. The surface samples of box cores MD13-3465BC and MD13-3468BC (Fig. 2, Table 1) recovered from the same study area did not contain any S. spina and were both characterized by fine grained sediment with few or no CWC fragments (Van Rooij et al., 2013).

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**FIGURE 2.** A, B Sedimentary characteristics of the surface of box cores MD13-3456BC and MD13-3468BC; C Picture showing two rose Bengal stained specimens of Schackoinella spina Stalder & Spezzaferri n. sp.

**FIGURE 3.** Lithology and log of sediment cores TTR17-396G and TTR17-399G including the distribution of the main macrofaunal components. The figure displays the distribution of the dominant planktonic foraminiferal assemblages and the samples where S. spina Stalder & Spezzaferri n. sp. were found.
**Table 2.** List of benthic foraminifera sharing similar morphological characteristics with *S. spina* Stalder & Spezzaferri n. sp., and their ecological information. nd = not described.

<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>Water depth</th>
<th>Facies</th>
<th>Age</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <em>Conorbella imperatoria</em></td>
<td>South of Grande Terre, New Caledonia</td>
<td>30 m</td>
<td>nd</td>
<td>Recent</td>
<td>Debenay, 2012</td>
</tr>
<tr>
<td>2. <em>Rosalina imperatoria</em></td>
<td>Poland</td>
<td>outcrop</td>
<td>shelly, muddy, pebbly sand</td>
<td>Sarmatian (Miocene)</td>
<td>d'Orbigny, 1846</td>
</tr>
<tr>
<td>4. <em>Schackoinella dissensa</em></td>
<td>Honshu, Japan</td>
<td>shallow</td>
<td>Recent–Holocene</td>
<td>Hoelocene</td>
<td>Clark, 1994</td>
</tr>
<tr>
<td>5. <em>Schackoinella favoculcita</em></td>
<td>SW Pacific Ocean</td>
<td>2031–4290 m</td>
<td>Recent–Holocene</td>
<td>Holocene</td>
<td>Culver et al., 2012</td>
</tr>
<tr>
<td>6. <em>Schackoinella globosa</em></td>
<td>South China Sea</td>
<td>1.3 m</td>
<td>Recent</td>
<td>Gulf of Thailand</td>
<td>Culver et al., 2012</td>
</tr>
<tr>
<td>7. <em>Schackoinella globosa</em></td>
<td>Gulf of Thailand</td>
<td>9 m</td>
<td>Recent–Holocene</td>
<td>clayey silt</td>
<td>Melis &amp; Violanti, 2006</td>
</tr>
<tr>
<td>9. <em>Schackoinella gordonbankensis</em></td>
<td>Gorda Bank, USA</td>
<td>56 m</td>
<td>Recent–Holocene</td>
<td>Holocene</td>
<td>McIlweth, 1977</td>
</tr>
<tr>
<td>11. <em>Schackoinella imperatoria</em></td>
<td>Tarnopol (Poland)</td>
<td>outcrop</td>
<td>Recent</td>
<td>Tarnopol</td>
<td>Papp &amp; Schmid, 1985</td>
</tr>
<tr>
<td>12. <em>Schackoinella imperatoria</em></td>
<td>Gulf of Naples, Italy</td>
<td>160–460 m</td>
<td>Recent</td>
<td>Tarnopol</td>
<td>Sgarella &amp; Monchamant Zei, 1993</td>
</tr>
<tr>
<td>15. <em>Schackoinella sarmatica</em></td>
<td>Austria</td>
<td>outcrop</td>
<td>Recent–Holocene</td>
<td>Tarnopol</td>
<td>Blanc–Vernet et al., 1979</td>
</tr>
<tr>
<td>17. <em>Schackoinella wadea</em></td>
<td>SW Australia</td>
<td>outcrop</td>
<td>Recent</td>
<td>Tarnopol</td>
<td>Quilty, 1975</td>
</tr>
</tbody>
</table>
**Dimension.** Average diameter 0.11 mm, range 0.06–0.14 mm (Fig. 4).

**Type Level.** Eastern Alboran Sea and Gulf of Cádiz (Table 1). The holotype is from the surface sample of box core MD13-3441BC, recovered at 35°17.765’N, 06°47.276’W at 532 m water depth. The sedimentary facies consists of cold-water coral fragments and abundant coarse biogenic components in a muddy-sand matrix.

**Type Material.** A paratype series of three specimens was selected. Other material examined consists of more than 80 specimens. Additional bulk sediment from the same sub-samples is stored at the University of Fribourg.

**Geographic Distribution.** This species has been observed in Holocene sediments from the Alboran Sea. A few live specimens (6) were also found on BC tops from the same regions. These specimens are stored at the Department of Earth Sciences of the University of Fribourg in plummer cells.

**Repository.** The holotype MHNF32031 from MD13-3441BC and 3 selected paratypes (Fig. 5.2–4) MHNF32032 from MD13-3461BC, MHNF32033 from TTR17-396G-160 cm, MHNF32034 from MD13-3456BC are on an SEM stub in the collection of the Natural History Museum of Fribourg, Switzerland. Additionally, 44 specimens of the
new species are stored at the Natural History Museum of Fribourg under the reference number MHNF32035.

**Distinguishing Features.** *Schackoinella spina* differs from *Murrayinella globosa* (Millet, 1903) by having rectangular/subrectangular to triangular chambers on the spiral side instead of globular, two spines on the second chamber instead of none, a slightly conical spiral side instead of a flat side, and a wide aperture instead of small and indistinct.

This species differs from *Conoribella imperatoria* (d’Orbigny, 1846) by having radial U-shaped incisions extending from the aperture to the base of the chambers in correspondence with the spines, a rounded peripheral margin instead of subacute, and the second chambers with two spines instead of one. Additionally, *C. imperatoria* has more regular chambers increasing moderately in size as added and separated by backward sutures, characters that are not present in *S. spina*.

*Schackoinella spina* differs from *Schackoinella sarmatica* Weinhandl, 1958 by its rectangular/subrectangular chambers on the spiral side and by the two spines on the second chamber after the proloculus.

*Schackoinella spina* is different in several aspects from the *Schackoinella wadeae* described by Quilty (1975) from the Nanarup Limestone Member of the Werillup Formation (Western Australia): the spines of the new species are longer and well demarcated from the chambers. The wall texture of *S. wadeae* is finely perforated, but not reticulated. The aperture of this latter species is narrower and its margin is ornamented with a series of fine striae that are not present in *S. spina*.

Clark (1994) reported the species *Schackoinella favoculcita* Clark, 1994 from the deep (2031–4290 m) tropical SW Pacific Ocean. This species differs from *S. spina* by its strongly reticulate dorsal ornament, well-rounded periphery, and nearly circular outline.

McCulloch (1977) described two species from the Pacific Ocean attributed to the genus *Schackoinella*: *S. dissensa* McCulloch, 1977 and *S. gordabankensis* McCulloch, 1977. *Schackoinella dissensa* shows important similarities to *M. globosa*, with globular chambers and dense hispid wall ornaments characteristic of the genus *Murrayinella*. This species is different from *S. spina* because of its relatively high trochospiral test, its semiglobose chambers and the granular wall texture. The second species described by McCulloch (1977), *S. gordabankensis*, is larger (200 µm in the maximum diameter of the test) than *S. spina*; it also has eight chambers in the last whorl, while *S. spina* has only five. *Schackoinella gordabankensis* lacks the typical morphological characteristics of *S. spina*, which are the prominent grooves at the periphery of the test, two spines on the second chamber of the test and the coarsely perforate proloculus. Furthermore, the specimen of *S. gordabankensis*, as illustrated in McCulloch (1977), is characterized by ten spines on the dorsal side. None of our *S. spina* specimens has more than nine spines (Fig. 4).

The new species shows certain morphological similarities with *Schackoinella antarctica* Ward, 1987, found in the McMurdo Sound (Ross Sea) and on outcrops from the Ross Island (Fig. 1B). Both have a slightly reticulate wall texture, the apertures of all chambers are arranged to form an open and centered umbilicus, and both species have radial grooves or striae on the umbilical side. However, *S. spina* clearly differs from *S. antarctica* by its rectangular to subrectangular chambers on the spiral side and by the total number of chambers, which are up to five in the last whorl for *S. spina* and four for *S. antarctica*. Furthermore, *S. spina* usually has one long spine per chamber except for the second chamber, which is characterized by the presence of two long spines instead of numerous shorter spines all over the test, as in *S. antarctica*. One of the most characteristic features of this new species is the differentially coarser, perforate proloculus, which is smooth in *S. antarctica*. The sutures of *S. spina* are less depressed than those of *S. antarctica* and the grooves are more marked, especially at the periphery of the test.

**DISCUSSION**

The new species described has been attributed to the genus *Schackoinella* (type species *Schackoinella sarmatica* Weinhandl, 1958) because it possesses all the typical characteristics of the genus (see also Loeblich & Tappan, 1987), such as a trochospiral test, consisting of very few whorls, spines in the midpoint of each chamber, and a smooth to reticulate wall texture. Presently accepted as belonging to the Schackoinella genus are *S. sarmatica* Weinhandl, 1958, *S. wadeae* Quilty, 1975, *S. dissensa* McCulloch, 1977, *S. gordabankensis* McCulloch, 1977, *S. antarctica* Ward, 1987, and *S. favoculcita* Clark, 1994.

To provide a global overview of ecological preferences and distribution of different species that have been attributed to the genus *Schackoinella* in the literature, we here discuss similarities and differences with species displaying evident morphological characters of the genus *Schackoinella*. These species are *C. imperatoria* (d’Orbigny, 1846), which Quilty (1975) and Ward (1987) both agree should be referred to the genus *Schackoinella*, and *M. globosa* (Millet, 1903; Table 2).

**DISTRIBUTION AND ECOPHYLOS OF SCHACKOINELLA SPINA**

The relatively low number of samples, which were recovered during the mentioned cruises and available for micropaleontological, makes it problematic to clearly attribute the new species to the Eastern Alboran Sea–Gulf of Cádiz seaway or clearly associate it to CWC ecosystems. This species was not reported in previous studies from this region (Table 3; e.g., Margreth et al., 2011) and was not previously observed associated with other CWC ecosystems along the northern European margin, such as the Norwegian Shelf, the Porcupine Seabight and Rockall Trough (Fig. 1A).

However, this study shows that the new species is, indeed, present in the eastern Alboran Sea and in the Gulf of Cádiz (Table 1) where CWC ecosystems occur. Its presence may have been overlooked due to its small size (Fig. 4). Milker & Schmiedl (2012) reported the occurrence of the larger species, *Conoribella imperatoria*, from the Alboran Sea and the Mallorca Shelf in their 125 µm sieve fraction (Tables 2, 3). We found our specimens of *S. spina* (Fig. 4) exclusively in the smallest sieve fraction (63 µm), thus providing additional evidence that these two species found in the Alboran Sea are clearly different.
Furthermore, *C. imperatoria* has not been found on CWC settings so far.

The higher abundance of dead (46) and living tests (6) of *S. spina* in surface samples (MD13-3456BC) from the Alboran Sea and from the Gulf of Cádiz (36 dead) compared to the lower abundances at other stations (1 dead) may be interpreted as due to different local environmental conditions. In particular, since *S. spina* is absent in typical fine-grained pelagic facies that are also devoid of cold-water coral fragments (e.g., box core MD13-3468BC; Fig. 2), we suggest that hard-bottom substratum represented by coral framework and the sediment grain size may be the limiting factors for the distribution of this new species. Schönfeld (2011) and Spezzaferri et al. (2013) have demonstrated that, in CWC ecosystems, epibenthic foraminifera such as *Cibicides lobatulus* (Walker & Jacob), *Cibicides refugiens de Montfort*, and *Discanomalina coronata* (Parker & Jones) colonize preferentially elevated hard substrates like coral branches or other biogenic fragments where bottom currents are stronger and the availability of food particles is higher. The preferred, permanently attached, living strategy of species with the availability of food particles is higher. The preferred, permanently attached, living strategy also for the genus *Schackoinella*. Regarding the few specimens and sampling sites, it is, however, not possible to clearly define the ecological preferences that control the distribution of *S. spina*.

Specimens of *S. spina* were found at water depths ranging from 258–532 m. *Schackoinella antarctica* was found at a corresponding depth in the Ross Sea (Ward, 1987). *Schackoinella favoculcita* was recovered from the deep Pacific Ocean in water depths from 2031–4290 m (Clark, 1994). McCulloch (1977) found the species *S. dissensa* and *S. gordabankensis* in shallow waters not exceeding 56 m water depth. Milker & Schmiedl (2012) reported *C. imperatoria* from the Mallorca shelf between 67–235 m and the species *M. globosa* (= *S. globosa*) was reported from shallow (1.3–9 m) sites in the South China Sea (Culver et al., 2012), the Gulf of Thailand (Melis & Violanti, 2006), and western Australia (Wang & Chappell, 2001), demonstrating that these species have diverse habitats ranging from tidal flats down to deep-sea environments. In particular, the depth range of *S. spina* corresponds to the depth of occurrence of CWC in the Alboran-Cádiz gateway, suggesting a possible causal link between their occurrences.

Finally, this study reveals that the occurrence of this species is constrained to the upper part of the investigated cores (Fig. 3, Table 1). Based on the planktonic foraminiferal turnover reported in the Alboran Sea at ca. 8 ka BP by Rohling et al. (1995), from an interval dominated by *Neogloboquadrina incompta* (Cifelli) to an interval dominated by *Globorotalia inflata* (d’Orbigny), we infer that *S. spina* has been present in the eastern Alboran Sea at least since the early Holocene.

**CONCLUSIONS**

We describe here *Schackoinella spina*, a new species occurring in sediment surface and core samples from the eastern Alboran Sea and the Gulf of Cádiz. Live (stained) specimens from surface samples indicate that this new species is extant in the eastern Alboran Sea. Fossil specimens from gravity cores indicate that *S. spina* has been present in the eastern Alboran since at least the early Holocene. No specimens have been found in older sediments (core) or from surface sediments characterized by fine-grained sediments, indicating preference for hard substrata represented by the cold-water coral framework and coarser grain-size.

**ACKNOWLEDGMENTS**

We thank the captains and crews of R/V Professor Logatchev and R/V Marion Dufresne for their valuable help onboard. The authors also thank the reviewers, Dr. Gerhard Schmiedl and Dr. Fabrizio Frantalini, for their help and their useful comments on the manuscript. The MD194 EUROFLEETS cruise was carried out under Grant Agreement n°228344, with full and duly acknowledged support of IPEV. We are especially grateful to Agostina Vertino from the University of Milano–Bicocca for the descriptions of the box cores. Many thanks to the Swiss National Foundation projects 200020_131829 and 200020.153125, which provided financial support. The lead author (CS) warmly acknowledges the Cushman Foundation for Foraminiferal Research for the Johanna M Resig Fellowship 2014. This research frames also under the ESF COCARDE European Research Network.

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