Short Communication

First record of the Central Indo-Pacific reef coral *Oulastrea crispata* in the Mediterranean Sea

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Abstract

A live colony of a non-indigenous zooxanthellate scleractinian coral was found in shallow water on the west coast of Corsica, western Mediterranean. Its diameter of 6 cm suggests that it has already survived for some years. It was identified as *Oulastrea crispata*, a species native on near-shore coral reefs in the central Indo-Pacific with a high tolerance for low water temperatures at high latitudes. Based on its morphology it can be distinguished from other zooxanthellate colonial scleractinians in the Mediterranean. *O. crispata* has a reputation of being a successful colonizer because it is able to settle on a wide variety of substrata and because it utilizes various reproductive strategies as simultaneous hermaphrodite and producer of asexually derived planulae. Owing to its original distribution range in temperate and subtropical waters, it is likely that it will be able to find a suitable temperature regime in the Mediterranean for further range expansion.

Keywords: Colonizer, Corsica, non-indigenous, non-lessepsian, Scleractinia, western Mediterranean, zooxanthellate.

Introduction

The hermatypic scleractinian coral *Oulastrea crispata* (Lamarck, 1816) (family *incertae sedis*; see Budd *et al*., 2012) is reported for the first time as a non-indigenous species in the western Mediterranean. Previously, it had a central Indo-Pacific distribution, ranging longitudinally from Sri Lanka in the central Indian Ocean to the Solomon Islands in the West Pacific and latitudinally from Honshu (Japan) in the north to the Abrolhos-Houtman Islands (West Australia) in the south (Veron, 2000). Owing to its dark skeleton pigmentation (Kawaguti & Sakumoto, 1952; Kawaguti, 1985) and outstanding white septa in retracted polyps, it has been nicknamed "Zebra Coral" (Lam, 2000a; Yamashiro, 2000; Denis *et al*., 2012). However, this colour pattern is variable and is not observed in all specimens (Yamashiro, 2000).

O. crispata is able to live in temperate and subtropical non-reefal conditions, where many other reef coral species cannot survive (Yamashiro, 2000; Chen *et al*., 2003, 2011; Lien *et al*., 2013). It has been reported from near-shore, turbid waters, usually of relatively low salinity (Kawaguti & Sakamotu, 1952; Kawaguti, 1985; Lam, 2000a, b; Cleary *et al*., 2006; Van der Meij *et al*., 2010), from the intertidal zone down to 5-12 m depth (Veron, 1992; Yamashiro, 2000).

Its capacity to occupy a variety of environments over a wide latitudinal range is reflected by its phenotypic variation (Yamashiro, 2000; Chen *et al*., 2011). Furthermore, as a simultaneous hermaphrodite, releasing planulae without zooxanthellae, and as producer of asexually derived planulae with zooxanthellae, it is both a broadcast spawner and a planula brooder (Nakano & Yamazato, 1992; Lam, 2000a). Owing to these life history traits, *O. crispata* appears to be an opportunistic colonizer of various substrates (Lam, 2000b). Although it is not known whether *O. crispata* has specific food requirements, it appears to be capable of ingesting and assimilating seagrass material (Lai *et al*., 2013), which suggests that it does not have a special diet that could limit its survival capacity. It also has been demonstrated that it can survive in darkness for over a year (Denis *et al*., 2012). Because of these qualities and its tolerance to low temperatures, *O. crispata* could potentially become an invasive coral species in the Mediterranean.

Material and Methods

A colony of *Oulastrea crispata* was observed and photographed at 3 m depth on rocky substrate at Punta Palazzu during an underwater survey (SCUBA diving) in the Marine Reserve of Scandola, western Corsica (42°23'N 8°33'E) on 3 October 2012. A part of the colony was sampled and is deposited in the collection of the

Museo del Mar de Ceuta (catalogue number MMC-001). The fragment consists of two complete calices and parts of some others. The coral is compared with specimens of *O. crispata* from the Malaysian peninsula (Strait of Malacca) and Indonesia (Bay of Jakarta and West Papua), and with specimens of *Cladocora caespitosa* (Linnaeus, 1767) (family *incertae sedis*; see Budd *et al.*, 2012), *Oculina* cf. *patagonica* De Angelis, 1908 (Oculinidae), and *Madracis pharensis* (Heller, 1868) (Pocilloporidae), from Mediterranean localities (Spain, France, Italy) deposited in the collection of Naturalis Biodiversity Center in Leiden (RMNH Coel.). The temperature in the vicinity of the coral was recorded at 5 m depth over the years 2005-2011 using an underwater temperature data logger (HOBO Water Temp pro v2).

Results and Discussion

A more or less circular encrusting colony of nearly one hundred polyps and a diameter of approximately 6 cm (Fig. 1) of an unusual scleractinian coral was found at 3 m depth on a vertical wall in the Scandola Marine Reserve in Corsica (Fig. 2). Based on its brown tissue colouration and shallow depth, it is assumed to be zooxanthellate. It does not fit the description of any azooxanthellate coral (Cairns & Kitahara, 2012).

It was found living in a 2-5 m deep zone (Fig. 1) amidst macro-algae (*Sargassum vulgare* C. Agardh, 1820, *Cystoseira* spp., *Padina pavonica* (Linnaeus) Thivy, 1960), encrusting calcareous algae, some sponges (*Crambe crambe* (Schmidt, 1862), *Sarcotragus spinosulus* Schmidt, 1862), and herbivorous invertebrates, such as the sea urchin *Arbacia lixula* (Linnaeus, 1758). The latter (Fig. 1) is able to clear algae from rocky substrates, which facilitates the settlement of corals (Coma *et al.*, 2011). The measured mean monthly seawater temperatures at this site (2005-2011) varied between 13°C (s.d. 0.6) in February and 25°C (s.d. 0.8) in August.

Based on its morphology, the specimen is identified as *Oulastrea crispata*, a species native to the Central Indo-Pacific (Veron, 2000; Hoeksema & Van Ofwegen, 2004). The extended tentacles are dark brown to olive green with white acrospheres (Fig. 1A), which are tentacle tips containing batteries of nematocysts. The general morphology of the Corsican specimen matches that of *O. crispata* morphotypes reported from Asian waters (Chen *et al.*, 2011). Calices are round to elliptical in outline with a diameter of approximately 5 mm (Figs. 1, 3). The calices contain up to 36 full-grown septa with a poor development of the pali and collumella; the first-order septa and costae are more prominent (higher and thicker) than those of higher orders. They are densely arranged and show intra- and extra-calicular budding. The diameter (6 cm) of the coral colony suggests that it has already survived for about 5 years based on a growth rate of 12-13 mm a^{-1} (Lam, 2000b). The sampled coral fragment is white (Fig. 3) as observed in specimens from Japan (Yamashiro, 2000: Fig. 3D), and Indonesia (Fig. 4C). No trace of black skeleton pigment was detected, which otherwise is common in *O. crispata* (Kawaguti & Sakumoto, 1952; Yamashiro, 2000; Fig. 4).

In comparison to the holotype at the Museum national d'Histoire naturelle in Paris (MNHN 15), the specimen from Corsica has some characters in common and some that differ. The shape of the septa, the columella and the narrow coenosteum of the Mediterranean specimen (Fig. 2) resemble those of the holotype, but the latter has a darker colouration and a lower number of septa. The holotype has 24 septa per calice (consisting of two cycles), whereas the Corsican specimen has 36 septa (three cycles). The number of septa in other *O. crispata* specimens appears to vary, mostly around 24 and but also around 36, or even up to 45 (e.g. for examples of 36 septa or more, see Fig. 4E; Nemenzo, 1955; Veron, 2000). The septa in the Corsican specimen are thin, although the first order septa are relatively thick and long (Fig. 2B), but thickness of the septa is another variable character in *O. crispata* (Chen *et al.*, 2011).
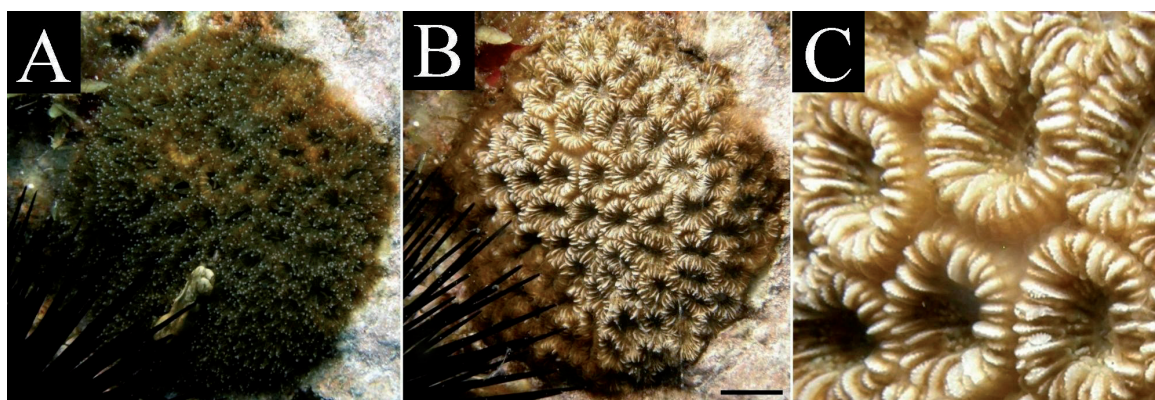

Fig. 1: Colony of *Oulastrea crispata* at Punta Palazzu, western Corsica, with polyps expanded (A) and retracted (B). Foreground: a specimen of the Mediterranean-Atlantic sea urchin *Arbacia lixula*; scale bar: 1 cm. C. Close-up showing calices and narrow coenosteum (Photo: O. Ocaña Vicente).

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Fig. 2: The rocky environment in the vicinity of the recorded *Oulastrea crispata* colony at Punta Palazzu, Marine Reserve of Scandola, western Corsica (Photo: O. Ocaña Vicente).
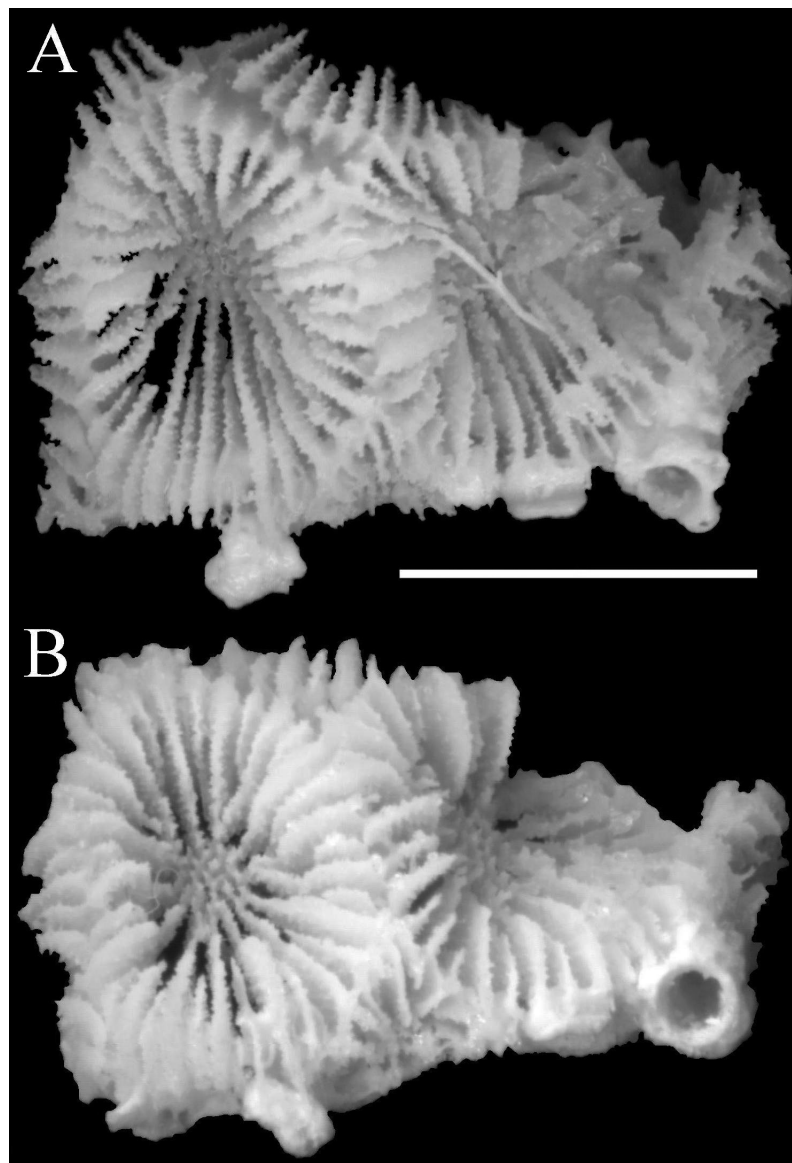

Fig. 3: Skeleton fragment of *Oulastrea crispata* from Corsica, photographed from two angles for a better view of various parts of the skeleton. A. Showing the narrow coenosteum. B. Showing variable thickness of septa of three cycles and the columellas. Scale bar: 0.5 cm (Photo: O. Ocaña Vicente).
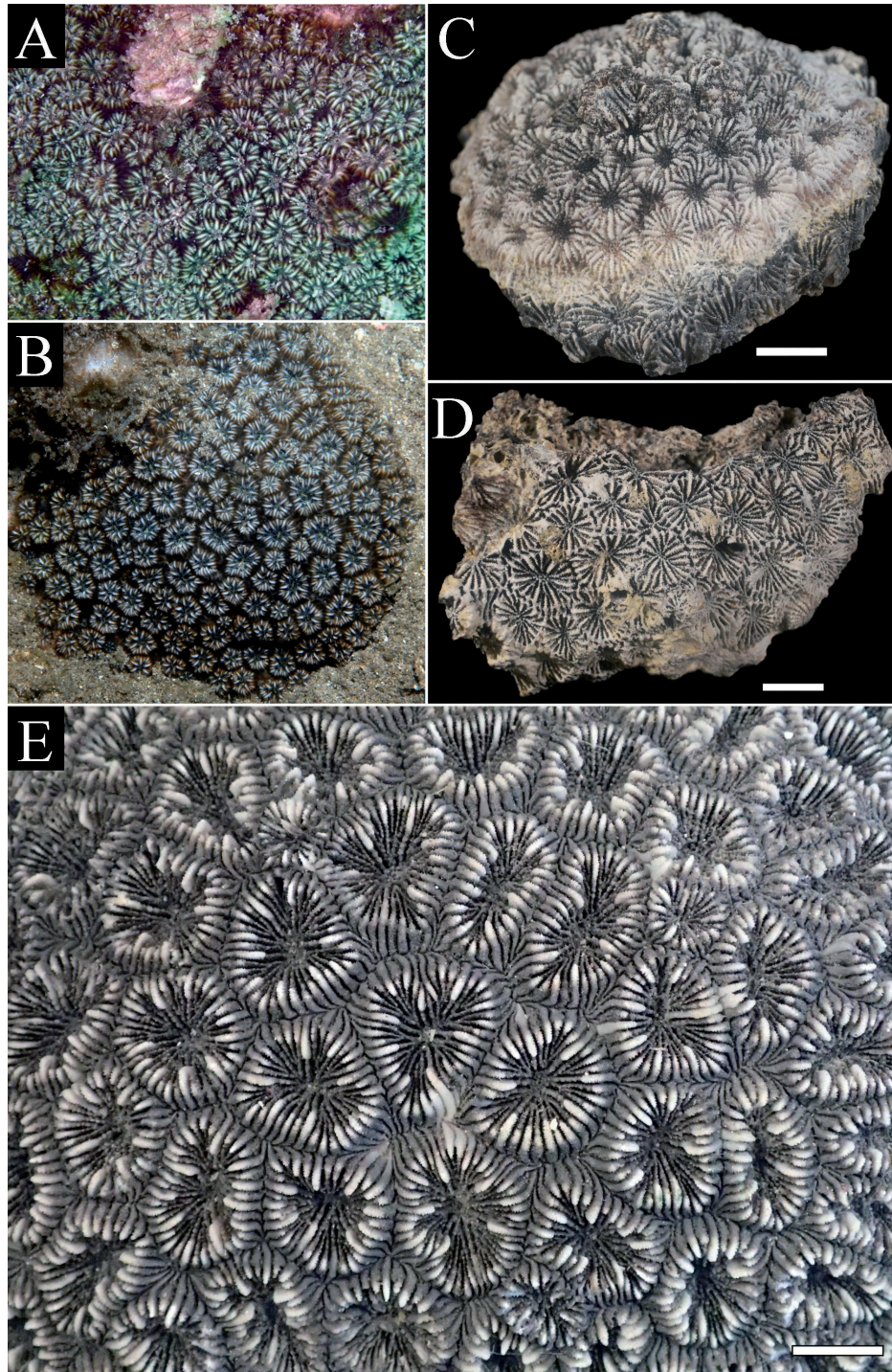
Fig. 4: Life specimens (A, B) and coral skeletons of *Oulastrea crispata* (C, D). A. West coast Peninsular Malaysia, Strait of Malacca, Pulau Kaca Bay (06°04.31'N 100°03.08'E) 5 June 2013. B. Indonesia, West Papua, Raja Ampat, Waigeo (00°25.75'S 130°33.95'E) 3 December 2007. C, D. RMNH Coel. 33635, Indonesia, Moluccas, Ambon, north coast, Manuala Beach (03°35'S 128°05'E) 7 November 1996, coll. B.W. Hoeksema. E. RMNH Coel. 9300, Indonesia, Bay of Jakarta, east side of Onrust Island (06°02'S 106°44'E), 11 February 1931, coll. J. Verweij. Scale bars: 0.5 cm (Photos: B.W. Hoeksema).

The alien *O. crispata* is an addition to 33 other species that already constitute part of the Mediterranean scleractinian fauna (Zibrowius, 1980; Vertino *et al.*, 2014). It is also the second non-indigenous scleractinian here. Its predecessor, *Oculina patagonica* (*sensu* Zibrowius 1974), was first reported from the Gulf of Genova (Fig. 5A), where it may have arrived by shipping although its

original range is unknown (Zibrowius, 1974). During the last decades it has spread throughout the Mediterranean (Fine *et al.*, 2001; Shenkar *et al.*, 2006; Sartoretto *et al.*, 2008; Bitar & Zibrowius, 1997; Serrano *et al.*, 2013). *Oculina* cf. *patagonica* is so far the only Mediterranean scleractinian considered invasive (Zenetos *et al.*, 2010).

Among other Mediterranean scleractinians, *O.*

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crispata can most easily be confused with *O.* cf. *patagonica*, but it shows a combination of characters not observed in the latter: (1) When retracted, the polyps of *O. crispata* show a distinctive pattern of radiating stripes consisting of white septa and dark brown tissue in between (Fig. 1B; compare with Fig. 4A, B); (2) New calices are produced by extra-tentacular budding in addition to intra-tentacular budding (Lim, 2000b; Denis *et al.*, 2012), whereas *Oculina* only shows intra-tentacular budding (Veron, 2000); (3) Both budding mechanisms acting together result in a dense calice arrangement (Figs. 1B, 3), whereas calices in *O.* cf. *patagonica* are separated by a smoothly ribbed or finely granulated coenosteum (Fig. 5); (4) The calices of *O. crispata* (Fig. 4) are about twice as large as those of *O.* cf. *patagonica* (Fig. 5); (5) The dark brown to olive green of the Corsican specimen in expanded condition (Fig. 1A) resembles exactly that of an *O. crispata* specimen from Japan (Veron, 2000, vol. 3, p. 229, Fig. 4) and another one in Bali (Hoeksema & Van Ofwegen, 2004), while the brown in *Oculina* is generally lighter (Veron, 2000).

On the other hand, *O. crispata* usually shows a dark-taupe to black coloured pigment in the skeleton (Fig. 4), which is lacking in the collected coral (Fig. 3), but also in other specimens from high latitudes (Yamashiro, 2000) and partially in a specimen from Indonesia (Fig. 4C). This pigment is also lacking in the upper layer of a skeleton from Singapore (Lai *et al.*, 2013: Fig.1A). Ya-mashiro (2000) demonstrated that the skeletal colour is changeable in both directions, rather than being a genetically fixed trait.

Oulastrea crispata corals can be overlooked and perhaps be confused with juvenile *Oculina* cf. *patagonica*, which eventually can form large colonies (Serrano *et al.*, 2012). Since *O.* cf. *patagonica* material is not well represented in museum collections (but see Fig 5), it was not possible to search for misidentified *O. crispata* specimens among them in order to retrieve earlier records (see Hoeksema *et al.*, 2011).

Another Mediterranean zooxanthellate colonial coral is the endemic *Cladocora caespitosa*, which has small, phaseloid corallites (Kersting *et al.*, 2013; Vertino *et al.*, 2014; Fig. 6). Its corallum is much thicker and higher in appearance than the two alien species. Therefore, the *O. crispata* coral from Corsica differs clearly from *C. caespitosa* collected from the same island (Fig. 6B, C). *Madracis pharensis* is an apozooxanthellate scleractinian, which differs from *O. crispata* by its knobby, nodular growth form and its much smaller calices (1-2 mm), each containing only ten primary septa, which are fused with the centrally located solid columella (Zibrowius, 1980; Morri *et al.*, 2000; RMNH Coel. 24272 from Marseille, France). Other shallow-water colonial scleractinians in the Mediterranean are brightly coloured azooxanthellate corals, such as *Astroides calycularis* (Pallas, 1766) (Goffredo *et al.*, 2011; Casado-Amezua *et al.*, 2013), which
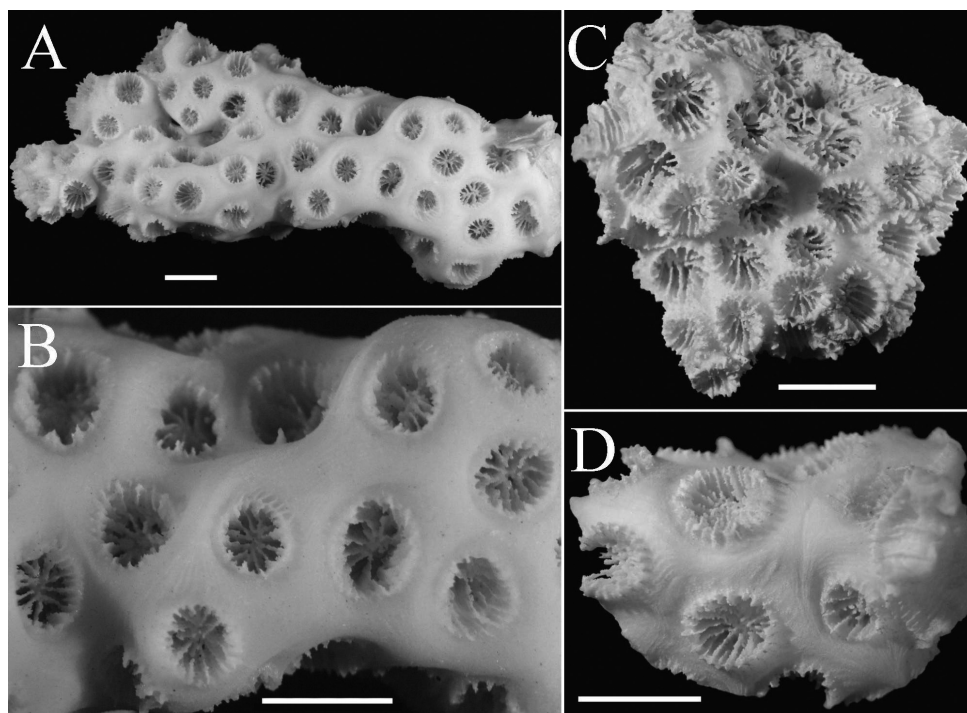

Fig. 5: Coral skeletons of *Oculina* cf. *patagonica*, showing coenosteum between calices. A, B. RMNH Coel. 13759, Italy, Gulf of Genova, between Albiscola and Marina Savona, coll. H. Zibrowius, 4 November 1979. C. RMNH Coel. 38566, Spain, Portmann, Aboret, 20 km east from Cartagena, coll. H. Zibrowius, 10 April 1981. D. RMNH Coel. 16912, France, Marseille, Ile Riou, coll. E. Verheij, 12 December 1983. Scale bars: 0.5 cm (Photos: B.W. Hoeksema).
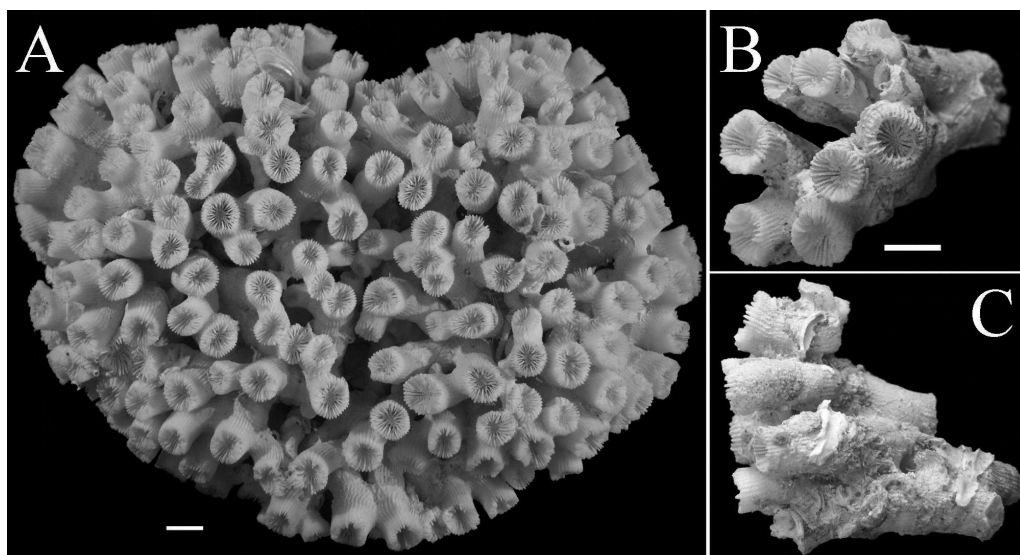
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Fig. 6: Coral skeletons of *Cladocora caespitosa*, showing phaseloid growth form. A. RMNH Coel. 16257, France, Ile Bagaud, south of Hyères, coll. E. Verheij, 1 August 1983. B, C. View from above and the side of RMNH Coel. 16259, France, Corsica, Staresco, coll. M.B. Best, June 1982. Scale bars: 0.5 cm (Photos: B.W. Hoeksema).

cannot be confused with the zooxanthellate *O. crispata*, or corals such as *Hoplangia durotrix* Gosse, 1860, *Phyllangia mouchezii* (Lacaze-Duthiers, 1897), and *Polycyathus muellerae* (Abel, 1959), which have calices that are much higher and more phaseloid, with a large coenosteum in between them (Zibrowius, 1980).

The record of *O. crispata* from the western Mediterranean (42°23'N) represents a northward range expansion from its northernmost location in the western Pacific at 38°04'N (Yamashiro, 2000). This scleractinian is reputed to survive well in low temperatures and turbid water (Chen *et al*., 2011). Its lowest recorded survival temperature is 7°C (Yamashiro, 2000), whereas the winter temperature in the western Mediterranean is usually 12-16°C (Bianchi, 2007), which is within the temperature tolerance range of this species. The Mediterranean Sea is well known for being invaded by Indo-Pacific alien species, many of which entered through the Suez Canal as so-called lessepsian species (Bianchi, 2007; Zenetos *et al*., 2010). The introduction of *O. crispata* is non-lessepsian because its original distribution range does not include the Red Sea.

Several non-indigenous species in the western Mediterranean Sea are of tropical origin and may have been introduced via shipping (Galil, 2009, 2012; Zenetos *et al*., 2010). Since *O. crispata* is considered the most coldtolerant zooxanthellate reef coral (Veron & Minchin, 1992), it may survive transport through cold water over long distances. *O. crispata* corals can settle on various artificial shallow-water substrates (Lam, 2000b, 2003). Therefore, they may also be able to attach themselves to metal substrates, as demonstrated by the amphi-Atlantic reef coral *Favia fragum* (Esper, 1793) (Hoeksema *et al*., 2012). The Indo-Pacific coral species *Tubastraea micran-*

thus (Ehrenberg, 1834), was first observed on an oil rig in the Gulf of Mexico, western Atlantic (Sammarco *et al*., 2010). It has been suggested that the Indo-Pacific *Tubastraea coccinea* Lesson, 1829, which has been recorded in the western Atlantic since 1943, was also introduced by maritime traffic or an imported oil platform (Cairns, 2000; Ferreira, 2003; Fenner & Banks, 2004; Creed & de Paula, 2007). Oil and gas platforms are suitable artificial substrates for this species (Sammarco *et al*., 2012), which is also able to colonize natural rocky substrates at the expense of other benthic fauna (Creed, 2006; Mantellato *et al*., 2011; Riul *et al*., 2013).

The octocoral *Acabaria erythraea* (Ehrenberg, 1834), presently classified as *Melithaea erythraea* (see Reijnen *et al*., 2014), has been recorded from the harbour of the Hadera powerplant (Israel) since 1999 and is another example of an anthozoan species that may have reached the Mediterranean by ship, either as a fouling organism or in larval stage in ballast water (Fine *et al*., 2005). One way or the other, shipping can be considered a plausible vector for benthic animals to enter new territories (Farrapeira *et al*., 2011; Zenetos *et al.,* 2012), which may also be the case for *O. crispata* in the Mediterranean Sea. Its range expansion may be a matter of time, as recently observed for other stony corals in the Eastern Atlantic and the Mediterranean (Clemente *et al*., 2010; López-González *et al*., 2010; Ocaña *et al*., 2011; Serrano *et al*., 2013).

Aknowledgements

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