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Occurrence of *Paraleucilla magna* (Porifera: Calcarea) in the Mediterranean Sea

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The calcareous sponge *Paraleucilla magna* has been detected at different Mediterranean sites (Taranto, Porto Cesareo, Brindisi and Naples). Its record in well studied areas where several benthic surveys have previously been carried out suggests a recent introduction of the species into the Mediterranean Sea. Until now this sponge has only been recorded from the Brazilian coast. It shows different morphologies, varying from tubular to an irregular massive shape with several folds occurring on its surface. The colour is white-cream. The surface is smooth. The consistency is friable. The oscula are 10–20 mm in diameter and located at the top of tubular protrusions. The skeleton consists of cortical and subatrial triactines and tetractines, together with atrial triactines, differently distributed in the sponge body. *Paraleucilla magna* is abundant in eutrophic environments, where seasonally it may reach very high frequency values and large dimensions. It is resistant to pollution, but it is also able to live in clean waters. The inclusion of this species among Mediterranean alien invasive species is suggested.

INTRODUCTION

The Mediterranean Sea is very susceptible to introductions of alien species due to the many shipping lanes, major ports and innumerable marinas, lagoons and estuaries crowded with fish and mollusc farms, and to the opening of the Suez Canal (Zibrowius, 1983, 1991; Bouderesque et al., 1994; Galil, 2000; Occhipinti-Ambrogi, 2000). Among the benthic fauna, a high number of exotic introduced species is reported in the literature for the most known taxa such as crustaceans and molluscs (Por, 1978; Galil et al., 2002; Zenetos et al., 2004), whereas few data are available for some other benthic groups (Zibrowius, 2002). In particular, among Porifera, only five demosponges (*Chrotella cavernosa* (Lamarck, 1815) = *Cinachyrella tarentina* (Pulitzer-Finali, 1983), *Damiriana schmidti* (Ridley, 1884) = *Lissodendoryx* (*Waldoschmittia*) *schmidti* (Ridley, 1884), *Geodia micropunctata* Row, 1911, *Heteronema erecta* Keller, 1889 = *Hyrtios erecta* (Keller, 1889), *Reniera spinosella* Row, 1911 = *Haliclona* (*Gellius*) *bubastes* (Row, 1911)), are reported as lessepsian species (Por, 1978). As regards the calcareous sponges, the sole record of a possible introduction is referred to an undetermined sponge attributed to the genus *Paraleucilla* Dendy, 1892, collected from the north-western Ionian Sea (Mar Piccolo and Mar Grande of Taranto, southern Italy) (Longo et al., 2004). According to the recent taxonomic revision (Borojevic et al., 2000, 2002) the genus *Paraleucilla* comprises seven valid species with warm-water distribution (Haeckel, 1872; Row, 1909; Dendy, 1913; Row & Hôzawa, 1931; Burton, 1963; Klautau et al., 2004; Clavico et al., 2006; Azevedo & Klautau, 2007).

In the present paper we assign the Mediterranean specimens of *Paraleucilla* to *P. magna* Klautau et al., 2004, a species recently described along the Brazilian coast (Klautau et al., 2004; Clavico et al., 2006). Moreover, we give new information on the ecology of this species as well as describing some features typically distinctive of invasive species.

Figure 1. Distribution of *Paraleucilla magna* in the Mediterranean Sea.

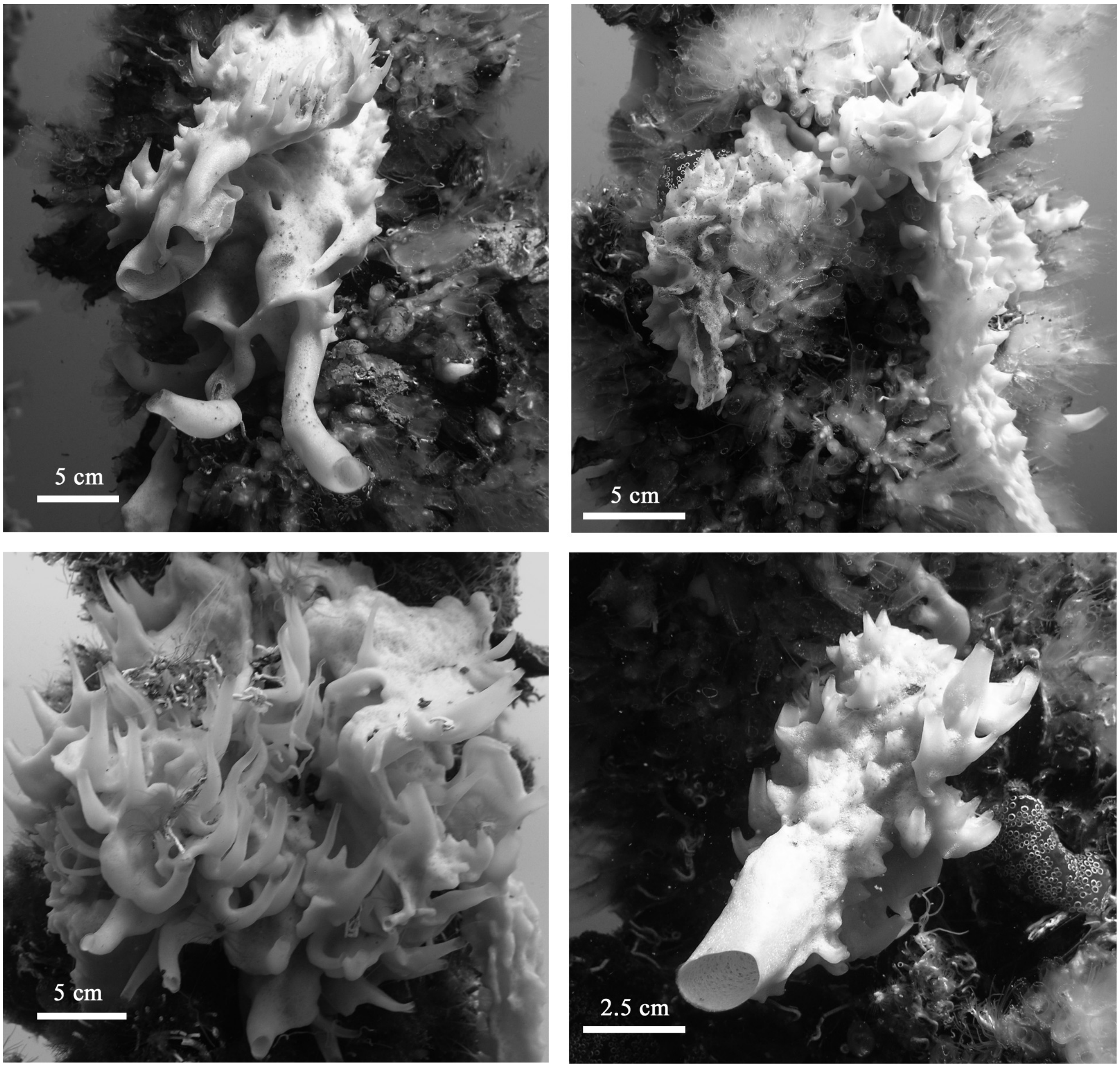

Figure 2. Different morphology of *Paraleucilla magna* in the Mar Piccolo of Taranto (north-western Ionian Sea, southern Italy).

MATERIALS AND METHODS

A total of 816 specimens of *Paraleucilla magna* have been collected since 2001 by SCUBA diving in the Mar Piccolo of Taranto (north-western Ionian Sea, southern Italy) from mussel rows and artificial substrata. Other specimens were collected by SCUBA diving from Porto Cesareo (north-western Ionian Sea), from the port of Brindisi (southern Adriatic Sea) and from the port of Naples (central Tyrrhenian Sea) on different artificial substrata (Figure 1).

The specimens were fixed with 5% formaldehyde in seawater and preserved in 70% ethanol.

Spicule slides were prepared according to the method of Klautau & Valentine (2003), substituting the mounting medium with DPX Fluka. Sections of Araldite® TAAB embedded sponges, made according to the standard protocol and coloured with toluidine blue, were mounted with the same resin.

For each site at least three specimens were selected and processed for spicule measurements. Measurements of 25 spicules of each type were taken using an optical microscope with a micrometric eyepiece. The length from the tip to the base and the thickness at the base of each actine were measured. Numbers are referred to the range of measurement variations of each spicule type, with the mean values and standard deviations in parentheses.

In addition, some specimens were dehydrated in ethanol and embedded in Paraplast for routine histological examination with the aim of describing the shape and size of the choanocyte chambers. Sections 7 μm thick were then stained with toluidine blue.

The *in vivo* photographs were made by using an Olympus Camedia 8080 wz digital camera fitted with an Olympus PT-023 underwater case and a Nikonos SB 105 strobe. Spicule and skeletal photographs were made using a Nikon digital sight DS-5M connected to a Leica DMLS optical microscope and a personal computer.

The sponges collected from the Mar Piccolo of Taranto were also processed to obtain monthly estimations of biomass (wet weight, measured by using an electronic balance), and seasonal measures of frequency (expressed as the number of sponge specimens per 100 randomly selected specimens of mussels).

SYSTEMATICS

Class CALCAREA Bowerbank, 1864
Subclass CALCARONEA Bidder, 1898
Order LEUCOSOLENIDA Hartman, 1958
Family AMPHORISCIDAE Dendy, 1892
Genus *Paraleucilla* Dendy, 1892
Paraleucilla magna Klautau et al., 2004
(Figures 2–6)

Material examined

The most representative samples and their slide preparations are deposited in the Zoology Museum of Bari University (MUZAC).

MUZAC 1187 Mar Piccolo of Taranto, southern Italy, north-western Ionian Sea, 20 December 2005, 3–4 m depth.

MUZAC 1188, MUZAC 1189 Porto Cesareo, southern Italy, north-western Ionian Sea, 5 May 2006, 10 m depth.

MUZAC 1193, MUZAC 1194 tourist port of Brindisi, southern Italy, southern Adriatic Sea, 3 March 2007, 0.5–2 m depth.

MUZAC 1191, MUZAC 1192 port of Naples, southern Italy, central Tyrrhenian Sea, 12 October 2004, shallow water.

Description

The sponge shows different morphologies, varying from tubular to irregular massive shapes. Generally, the tubular shape is most frequent in small specimens, whereas several folds occur on the surface of large massive specimens, reaching a height of 10–15 mm (Figure 2). Tubes are not isodiametric and exhibit a right or bent behaviour. Main oscules, 10–20 mm in diameter, are at the top of tubes, whilst smaller ones are distributed over the folded sponge surface. These different morphologies occur in all the studied populations (Taranto, Porto Cesareo, Brindisi and Naples) and may also coexist in the same sampling site. The colour in life and after preservation is white-cream. The consistency is friable. If handled with bare hands the sponge feels prickly. The surface is smooth.

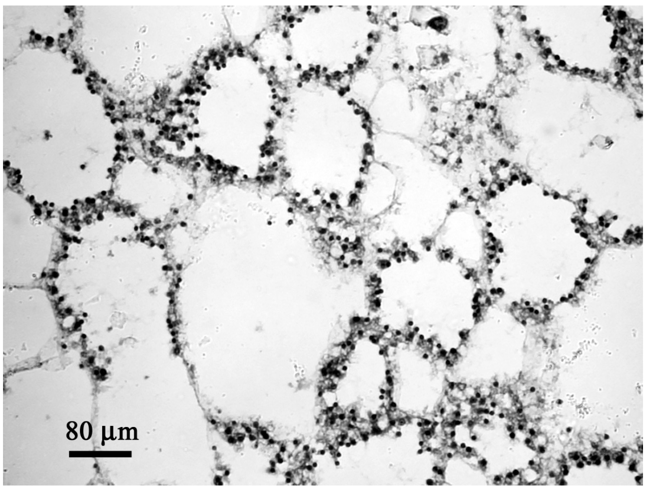

Figure 3. *Paraleucilla magna*: spherical and sub-spherical choanocyte chambers with apinucleate choanocytes.

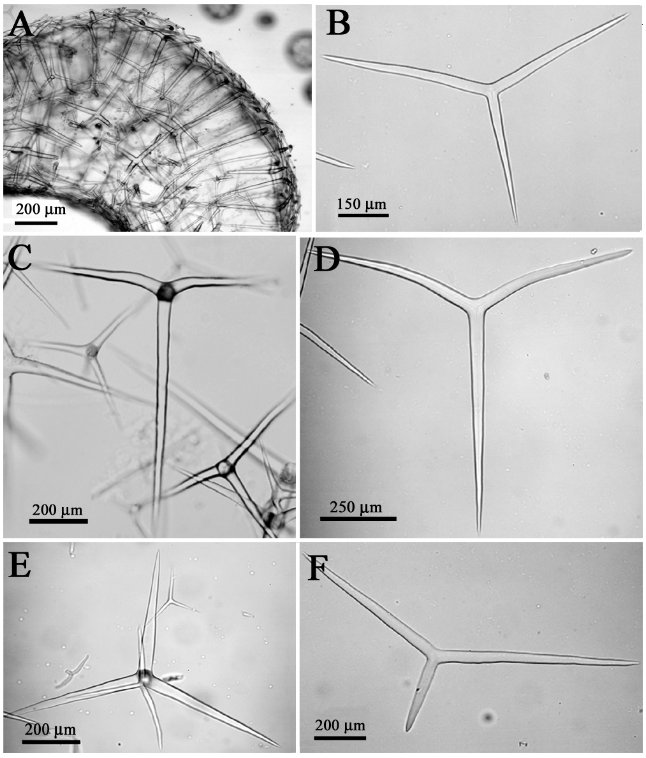

Figure 4. *Paraleucilla magna*: (A) skeletal cross section; (B) cortical triactine; (C) cortical tetractine; (D) subatrial triactine; (E) subatrial tetractine; (F) atrial triactine.

The aquiferous system is leuconoid with spherical or sub-spherical choanocyte chambers 87 ±28.8 µm (mean value) in diameter and apinucleate choanocytes (Figure 3).

The sponge may reach up to ~40 cm in diameter and 500 ml in volume.

Skeleton

The skeleton is typically inarticulate, and can be divided into two regions. The external one consists of cortical triactines, usually sagittal but sometimes equiangular. These spicules are tangentially disposed. There are also cortical tetractines with their apical actines, usually longer than the basal ones, pointed inward. This layer is followed by a primary subatrial skeleton made of a different kind of triactines and tetractines: the subatrial triactines usually have an unpaired actine longer than the paired ones and the subatrial tetractines have their apical actines shorter than the basal ones. The internal region consists of a secondary subatrial skeleton with scattered triactines and tetractines, similar to the primary subatrial ones, followed by an atrial skeleton consisting of sagittal triactines with the unpaired actines, shorter than the paired ones (Figure 4A).

Spicules

- Cortical triactines (Figure 4B): length of the paired actines 210–560 µm (374.9 ±81.2 µm) and unpaired ones 270–640 µm (427.9 ±27.9 µm), thickness of the actine at its base 10–40 µm (27.9 ±8.4 µm);
- cortical tetractines (Figure 4C): length of the apical actine 315–823 µm (572.1 ±125.6 µm) and basal ones 192–616 µm (388.9 ±100.8 µm), thickness of the actine at its base 16–45 µm (36.6 ±6.5 µm);

Figure 5. Numerous specimens of *Paraleucilla magna* (arrows) on mussel rows in the Mar Piccolo of Taranto.

- subatrial triactines (Figure 4D): length of the paired actines 200–640 μm (399.6 ±83.6 μm) and unpaired ones 336–730 μm (584.1 ±138.3 μm), thickness of the actine at its base 10–45 μm (35.9 ±7.4 μm);
- subatrial tetractines (Figure 4E): length of the unpaired actine 197–640 μm (383.6 ±101.4 μm) and paired actines 160–576 μm (344.4 ±96.9 μm), thickness of the actine at its base 16–45 μm (30.6 ±6.5 μm);
- atrial triactines (Figure 4F): length of the paired actines 96–440 μm (236.5 ±88.6 μm) and unpaired ones 24–144 μm (64.2 ±23.5 μm), thickness of the actine at its base 4–12 μm (7.4 ±1.5 μm).

Ecology

Paraleucilla magna is very common in the Mar Piccolo of Taranto, a semi-enclosed basin seasonally subjected to strong dystrophic events (Caroppo et al., 1994). It occurs at depths ranging between 2 and 7 m, on mussel rows (Figure 5) and on artificial hard substrata (floats). The highest number of recorded specimens (759 out of a total of 816

Table 1. *Worldwide distribution of* Paraleucilla *species.*

Species	Distribution	References
Paraleucilla cucumis (Haeckel, 1872)	Indo-pacific region	Haeckel, 1872
Paraleucilla saccharata (Haeckel, 1872)	Indo-pacific region; Red Sea	Haeckel, 1872; Burton, 1963
Paraleucilla crosslandi (Row, 1909)	Red Sea	Row, 1909
Paraleucilla proteus (Dendy, 1913)	Indian Ocean	Dendy, 1913
Paraleucilla princeps (Row & Hôzawa, 1931)	Indo-pacific region	Row & Hôzawa, 1931
Paraleucilla magna Klautau et al., 2004	Atlantic Ocean	Klautau et al., 2004; Clavico et al., 2006
Paraleucilla perlucida Azevedo & Klautau, 2007	Atlantic Ocean	Azevedo & Klautau, 2007

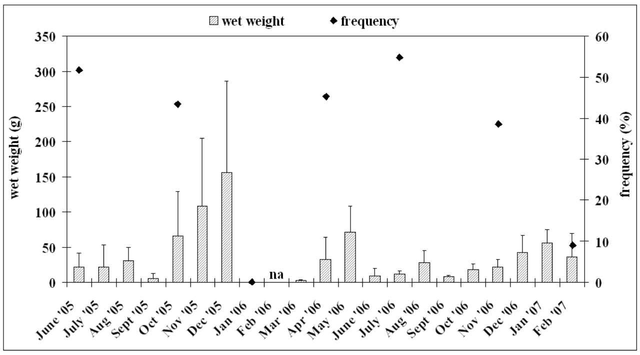

Figure 6. *Paraleucilla magna*: wet weight (mean value and standard deviation of at least ten specimens collected each month) and seasonal frequency of the samples collected from the Mar Piccolo. (na, no available data).

specimens collected) overgrow the mussel shells, where the sponge coexisted with a rich filter feeder community, mainly characterized by ascidians and polychaetes (Matarrese et al., 1980; Gherardi et al., 1993). Where this fouling community is richer, the sponge shows low abundance values, probably due to competition phenomena.

Paraleucilla magna is well known to local mussel farmers who have observed it for at least 20–30 years calling it 'pane' (bread). They have to clean the mussel rows frequently to control sponge growth. The sponge, in fact, has a high colonization ability, since it appears in 15–20 days on newly submerged mussel rows.

The sponge shows wide temporal variations in biomass with peaks during the autumn and early winter (the highest biomass values were recorded in December 2005), whereas it declines or disappears in winter and summer (Figure 6). However, inter-annual differences affect this distributional pattern, probably related to high hydrological variability (Caroppo et al., 1994). The sponge frequency, expressed as number of specimens collected from 100 mussel specimens, is remarkable (mean value 34.5%), with highest values (more than 50%, measured in June 2005 and July 2006) recorded after disease or decline events. This latter phenomenon, regarding both sponges and all the benthic community, occurs during summer due to seawater warming (Caroppo et al., 1994) (Figure 6).

At Porto Cesareo the sponge occurs 1.5 miles off the coast, overgrowing the mussel shells and as fouling on the surface of submerged floats, around 10 m in depth. In the ports of Brindisi and Naples the sponge was collected from fouling communities on artificial panels and submerged ropes in shallow eutrophic waters. No further information is available on the samples collected from these sites.

Distribution

The complete distribution of the species belonging to the genus *Paraleucilla* is reported in Table 1. It encompasses the Indo-pacific region, the Red Sea and the Atlantic south-eastern coasts of Brazil (Haeckel, 1872; Row, 1909; Dendy, 1913; Row & Hôzawa, 1931; Burton, 1963; Klautau et al., 2004; Clavico et al., 2006; Azevedo & Klautau, 2007).

Remarks

Paraleucilla magna, characterized by its peculiar large dimensions, is easy to recognize among the other co-generic species thanks to the atrial skeleton consisting exclusively of triactines and lacking diactines.

DISCUSSION

Paraleucilla magna may be considered a moderately sciaphilous species, since it occurs at shallow depths in very turbid waters, and at 10 m depth in more transparent waters. The sponge is restricted to environments with low water movement conditions, such as ports, semi-enclosed basins and calm open waters, probably due to the high fragility of its skeletal structure. *Paraleucilla magna* is abundant in eutrophic environments, where, seasonally, it may reach very high abundance values. These observations agree with Klautau et al. (2004), who indicate *P. magna* as an abundant species ('the most abundant calcareous sponge in Rio de Janeiro State'), with a strong seasonality, resistant to pollution, but also able to live in clean water.

The presence of *P. magna* in well studied areas, where several benthic surveys have previously been carried out, suggests the recent introduction of this species into the Mediterranean Sea. Indeed, the species was not mentioned in the exhaustive sponge lists drawn up by Michele Sarà for the Gulf of Naples (Sarà, 1959a,b, 1960a,b, 1961; Sarà & Siribelli, 1960, 1962). Similarly, the faunistic lists of the zoo-benthic community of the Mar Piccolo of Taranto, some of which were drawn up by sponge taxonomists, did not report the occurrence of this sponge before about 30 years ago (Gherardi, 1973; Gherardi & Lepore, 1974; Scalera-Liaci et al., 1976; Pulitzer-Finali, 1983; Tursi et al., 1983–1984; Scalera-Liaci & Corriero, 1993).

The Mar Piccolo of Taranto is historically affected by heavy intercontinental shipping traffic (both military and civilian) and by the presence of several mussel and oyster farms that, together with industrial emissions and sewage, have determined a drastic decrease in the seawater quality (Cardellicchio et al., 1991), and a significant increase in dystrophic events (Caroppo et al., 1994). According to Mastrototaro et al. (2004) the above mentioned activities have determined not only the decay of the local benthic community but also the introduction of several exotic species. The first non-native species recorded in this environment was an opistobranch mollusc (Tortoricci & Panetta, 1977). The subsequent introductions were numerous, with a dramatic increase in the last five years (see Mastrototaro et al., 2003, 2004; Brunetti & Mastrototaro, 2004; Mastrototaro & Brunetti, 2006). As regards *P. magna*, it has certainly persisted in the Mar Piccolo of Taranto since 2001 (Longo et al., 2004). However, according to the local mussel farmers it could have colonized this environment 20–30 years earlier.

In the Mar Piccolo of Taranto *P. magna* shows seasonal high abundance values and high capacity to colonize hard substrata. The species markedly selects mussel shells among the available hard substrata, probably affecting the mussel growth. Indeed, in spite of the lack of scientific data, this hypothesis is supported by the evidence of the high and repeated effort carried out by local farmers to control the sponge growth.

The record of *P. magna* at different sites of the Italian coast (Taranto, Porto Cesareo, Brindisi, Naples) outlines the high spread of the sponge in the Mediterranean Sea. The ability of *P. magna* to colonize different environments with a high number of specimens, rapidly extending its range, allows us to consider it as a Mediterranean alien invasive species (Occhipinti-Ambrogi & Galil, 2004). The occurrence of invasive taxa is relatively unusual among Porifera. Two species only, out of more than 30 records of alien introduced sponge species throughout the world are indicated as invasive: they are the demosponges *Celtodoryx girardae* Perez et al., 2006 and *Mycale armata* Thiele, 1900 = *Mycale* (*Mycale*) *grandis* Thiele, 1867 (DeFelice et al., 2001; Coles et al., 2002; Perez et al., 2006). Apart from *Heteropia glomerosa* (Bowerbank, 1873), a cryptogenic calcareous sponge reported by Coles et al. (1999) in Pearl Harbor Bay (central Pacific Ocean, Oahu, Hawaii), no records of allochthonous calcareous sponges are available in the literature. Therefore, *P. magna* may be considered the first true record of alien and invasive species among calcareous sponges. In addition, this is the first record of an invasion due to Porifera for the Mediterranean Sea.

The almost simultaneous finding of *P. magna* in different areas of the Mediterranean Sea (north-western Ionian Sea, southern Adriatic Sea, central Tyrrhenian Sea) and along the Atlantic coast of Brazil (Klautau et al., 2004), makes it difficult to suppose a scenario able to describe the possible transfer of this species. However, bivalve farming together with shipping traffic may be considered as the most probable vectors responsible for the recent expansion of this sponge along the west Mediterranean coasts.

We would like to dedicate this paper to the memory of our sponge teacher Professor Michele Sarà who recently died.

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