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Dictyota ciliolata Sonder *ex* Kützing (Phaeophyceae, Dictyotales) in the Mediterranean Sea

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Abstract – The presence of *Dictyota ciliolata* (Dictyotales, Phaeophyceae) on the coasts of the Iberian Peninsula is reported. *D. ciliolata* is a tropical to subtropical species mainly distributed along the coasts of the Atlantic and Indian oceans. Although it occurs in areas next to the Mediterranean, like the Red Sea and the Atlantic coasts of Morocco, Canary Islands and Madeira, *D. ciliolata* had not been previously reported from the Mediterranean Sea. A morphological and anatomical comparison of the Iberian specimens of this species with those of other geographical areas, as well as with other similar species of *Dictyota* occurring in the Mediterranean Sea, is provided.

***Dictyota ciliolata* / Dictyotales / marine algae / Mediterranean Sea / Phaeophyceae**

Résumé – ***Dictyota ciliolata* Sonder *ex* Kützing (Phaeophyceae, Dictyotales) en Mer Méditerranée.** *Dictyota ciliolata* est une espèce tropicale-subtropicale qui se trouve principalement sur les côtes des océans Atlantique et Indien. Bien que déjà signalée des zones proches de la Méditerranée, telles la Mer Rouge et les côtes Atlantiques du Maroc, des Canaries et de Madère, *D. ciliolata* n'avait pas été rapportée en Méditerranée ; elle est, ici, signalée sur les côtes de la Péninsule Ibérique. La morphologie et l'anatomie des individus de *D. ciliolata* de la Péninsule Ibérique sont comparées avec celles de spécimens d'autres zones géographiques, ainsi qu'avec d'autres espèces de *Dictyota* de la Méditerranée.

***Dictyota ciliolata* / Dictyotales / algues marines / Mer Méditerranée / Phaeophyceae**

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INTRODUCTION

Lamouroux (1809) erected the genus *Dictyota* that included, among others, all the known representatives of the order Dictyotales. Agardh (1882) created the genus *Dilophus* to accommodate those specimens of *Dictyota* showing a multilayered medulla at least in the basal parts. More recently and after a thorough study on the morphology, anatomy and karyology of the north Atlantic species of *Dictyota* and *Dilophus*, Hörnig *et al*. (1992) were unable to find any characters that would reliably separate both genera. Therefore, they considered *Dilophus* as a synonym of *Dictyota* and transferred the species belonging to the first genus to *Dictyota*. Such a taxonomic treatment is currently followed (Wynne *et al*., 1998; Abbott & Huisman, 2004; Furnari *et al*., 2003; Guiry *et al*., 2005). Hörnig & Schnetter (1988) studied the *Dictyota dichotoma* complex in the eastern coasts of the North Atlantic concluding that two varieties can be distinguished in *D. dichotoma*: *D. dichotoma* (Hudson) J.V. Lamouroux var. *dichotoma* with rounded thallus apices and *D. dichotoma* var. *intricata* (C. Agardh) Greville [including *D. linearis* (C. Agardh) Greville and *D. pusilla* J.V. Lamouroux] with narrow thalli all over or broad at the base, and with rounded to acute tips. Hörnig *et al*. (1992), with a synthetic criterion, considered that in the European and Mediterranean area the only taxa of *Dictyota* occurring were *D. dichotoma* var. *dichotoma*, *D. dichotoma* var. *intricata*, *D. fasciola* (Roth) J.V. Lamouroux and *D. spiralis* Montagne. Ribera *et al*. (1992), with an analytic criterion, pointed out that the genus *Dictyota* was represented in the Mediterranean Sea by the following taxa: *D. dichotoma* var. *dichotoma*, *D. dichotoma* var. *intricata*, *D. fasciola* var. *fasciola* [as *Dilophus fasciola* (Roth) Howe], *D. fasciola* var. *repens* (J. Agardh) Ardissone [as *Dilophus repens* (J. Agardh) J. Agardh], *D. linearis*, *D. mediterranea* (Schiffner) G. Furnari (as *Dilophus mediterraneus* Schiffner) and *D. spiralis* Montagne [as *Dilophus spiralis* (Montagne) Hamel].

Recently, during the studies carried out in order to realize the *Flora phycologica iberica*, several specimens of *Dictyota ciliolata* Sonder *ex* Kützing were found at some localities of the Iberian Peninsula, most of them in the Catalan coast (north-western Mediterranean), but also in an Atlantic locality next to the Gibraltar strait (Fig. 1).

Dictyota ciliolata was described by Kützing (1859) on the basis of specimens collected at La Guaira, Venezuela, and its current distribution mainly includes the tropical coasts of the Atlantic and Indian oceans, as well as the western tropical coasts of the Pacific Ocean (Guiry *et al.,* 2005). Although this species is reported from the Red Sea (Silva *et al*., 1996) and the Atlantic coasts of Western Sahara (John *et al*., 2004), Canary Islands (Haroun *et al*., 2002) and Madeira (Neto *et al*., 2001) it has not been previously recorded from the Mediterranean.

MATERIAL AND METHODS

The specimens of *D. ciliolata* were collected in three localities of the Mediterranean north-eastern Iberian Peninsula [Palamós (41º 51' N, 3º 08' E), Barcelona (41º 24' N, 2º 10' E) and Sitges (41º 14' N, 1º 48' E)] and in Sancti Petri (36º 22' N, 6º 13' W), Atlantic locality next to the Gibraltar strait (Fig. 1). The

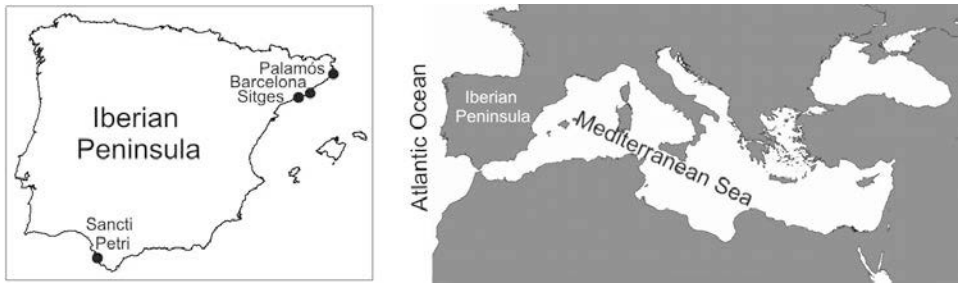


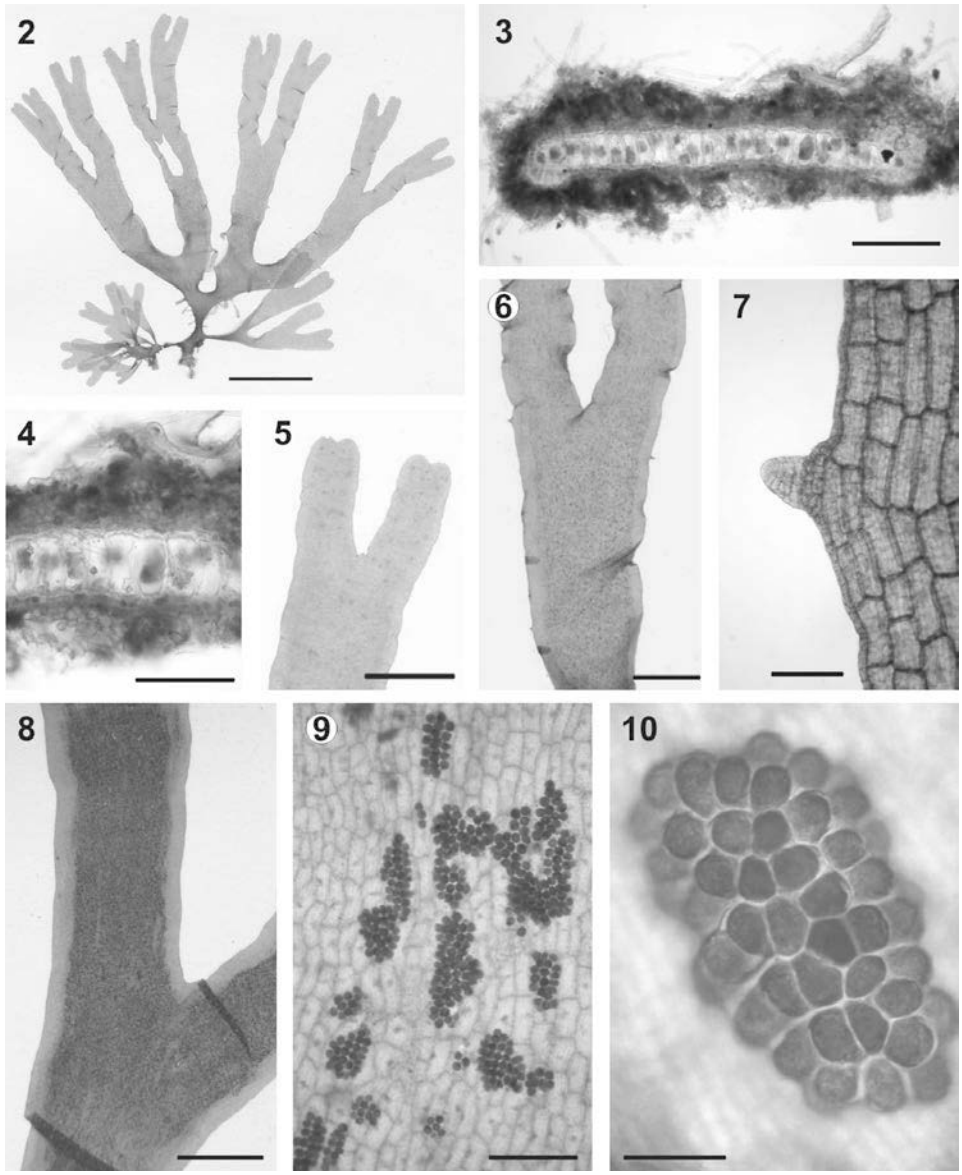
Fig. 1. Distribution of *Dictyota ciliolata* in the Iberian Peninsula.

Sancti Petri specimens were found among drift material, whereas the rest grew on hard substrate between 0.5 and 6 metres deep, mainly in harbour areas like quay walls or breakwaters. Specimens were either pressed or preserved in 4% formalin-seawater. Sections were made with a razor blade and studied under a light microscope. The size of different types of vegetative cells, reproductive structures and other anatomical features were measured with an ocular micrometric; in each case ten measures were taken and the final result was expressed as a variation interval. Some morphological and anatomical features were drawn with a *camera lucida* or photographed. All collected specimens were deposited in BCN-Phyc (the Herbarium of the Plant Biodiversity Documentation Centre of the University of Barcelona). Specimens of *Dictyota dichotoma* held in several Iberian Herbaria, as well as a specimen of *D. ciliolata* from the Canary Islands (Punta Hidalgo, Tenerife, 3-XI-2004, TFC-Phyc 13052) were also studied with comparison purposes.

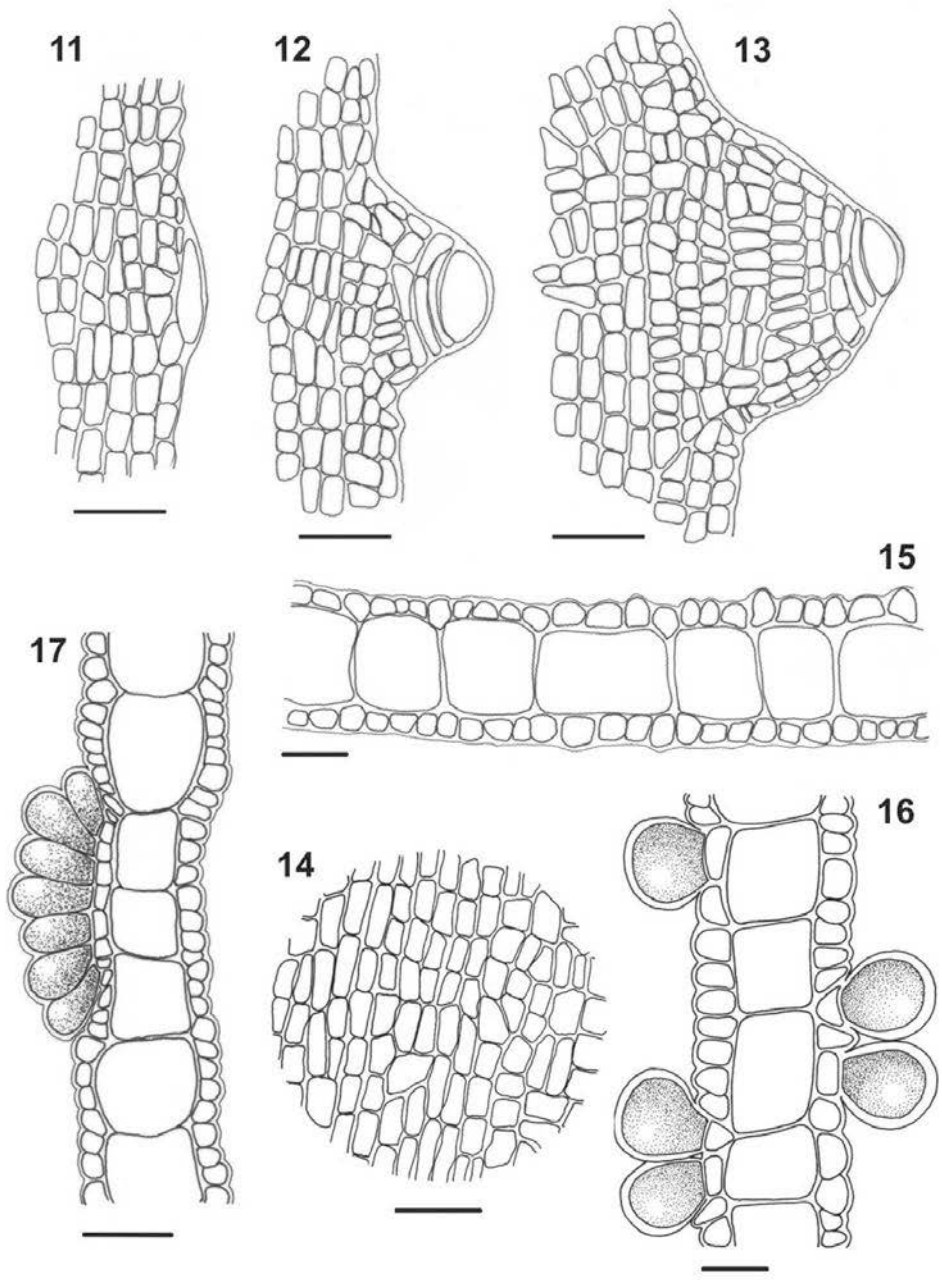
Selected specimens: Barcelona, harbour breakwater, 0.2 - 0.5 m deep, 24-III-2005, BCN-Phyc 1596, with sporangia; *ibidem*, 16-IV-2005, BCN-Phyc 1600, with sporangia; Sitges (Barcelona), 3 - 6 m deep, VI-2004, BCN-Phyc 1601, with sporangia; *ibidem*, VI-2004, BCN-Phyc 1607, with oogonia; Palamós (Girona), Nautical Club, 0.2 - 0.5 m deep, 03-IV-2005, BCN-Phyc 1602, with sporangia; *ibidem*, 10-V-1987, HGI-A 2039, with sporangia (as *D. dichotoma*); Sancti Petri (Cádiz), drift material, 11-VI-1995, BCN-Phyc 1606. Herbarium abbreviations follow Holmgren *et al.* (1990).

RESULTS

The Iberian specimens of *Dictyota ciliolata* consist of a single, erect and fairly regular dichotomously divided blade, sometimes spirally twisted (Fig. 2); they can reach up to 17 cm high and are attached to the substratum by a stupose basal holdfast formed by simple or branched multicellular rhizoids measuring 16-24 µm in diameter (Figs 3, 4). The angle of the dichotomies is quite variable, measuring (15)25-78(90)º. The straps measure 4-9(13) mm broad and 112-152(198) µm thick at the middle part of the plant and (2)3-4 mm broad at the apical segments; the length of the interdichotomies at the middle part of the plant is (7)10-38(45) mm. The straps have a rounded apex (Fig. 5), a smooth surface without superficial proliferations and disperse hair tufts on both surfaces. The strap margins are commonly entire and somewhat undulate, though usually bear



Figs 2-10. *Dictyota ciliolata*. **2.** Habit of the plant [Sitges (Barcelona), June 2004, BCN-Phyc 1601]; scale bar = 2 cm. **3.** Cross section of a stupose base; scale bar = 300 µm. **4.** Detail of a stupose base cross section; scale bar = 200 µm. **5.** Rounded apices; scale bar = 5 mm. **6.** Strap with some marginal teeth; scale bar = 5 mm. **7.** Detail of a marginal tooth; scale bar = 200 µm. **8.** Arrangement of the sporangia leaving a sterile margin; scale bar = 5 mm. **9.** Sori of oogonia in surface view; scale bar = 500 µm. **10.** Detail of an oogonia sorus in surface view; scale bar = 100 µm.



Figs 11-17. *Dictyota ciliolata*. **11-13.** Marginal teeth in different growth phases. **14.** Cortical cells in surface view. **15.** Cross section of the strap in the middle of the plant. **16.** Cross section of the strap with sporangia. **17.** Cross section of an oogonia sorus. Scale bar = 50 μm.

scattered teeth in different growth phases, from a few cells (microscopic teeth) to small triangular teeth (Figs 6, 7, 11-13). Marginal teeth occur along the whole plant, but in general they are more frequent in the upper and basal parts. Although marginal proliferations are usually absent, they can be common in the broken zones of the straps and also near the base, where they are narrow, simple or more or less dichotomously divided and usually dentate. In surface view, the cortical cells are rectangular, square or irregularly polygonal, 16-44(62) × 10-28 μm, and more or less arranged in longitudinal rows (Fig. 14). Medullary cells are hyaline, square or elongated, 0.9-2.5(2.9) times longer than broad, and measure 79-196(258) × (36)53-80(134) μm; the ratio length of medullary cells / length of cortical cells is 4.3. The apical cell is lenticular and 44-64 × 12-20 μm. In cross section, both cortex and medulla are unistratose, with cells square or elongated, anticlinally or periclinally arranged (Fig. 15); exceptionally, some cortical cells can divide once in a plane parallel to the strap surface. Cortical cells measure 16-29(44) × 10-29(36) μm and medullary cells 52-103(152) × 36-103(201) μm.

Fertile sporophytes and female gametophytes were observed. The sporangia are isolated and densely placed on both surfaces of the straps, leaving a conspicuous sterile zone near the margins which appear iridescent underwater (Fig. 8). The sporangia are rounded in surface view, 72-118 × 60-103 μm, and appear rounded or more or less pyriform, 60-90 × 46-92 μm in cross section. They are supported by a pedicel consisting of a single cell, usually triangular in shape, measuring 15-40 × 8-24 μm (Fig. 16); divided sporangia were sometimes observed. Oogonia arise in more or less elongated sori scattered on both surfaces of the straps (Figs 9, 10); they are rounded or ovoid in surface view, 53-68 × 40-64 μm, and they appear more or less pyriform, 70-99 × 40-59 μm, in cross section. Oogonia arise on a pedicel consisting of a single cell measuring 22-29 × 11-15 μm (Fig. 17). Male gametophytes were not observed.

DISCUSSION

In general, the Iberian specimens of *Dictyota ciliolata* agree with the illustrations and descriptions of this species provided by other authors (Taylor, 1960; Earle, 1969; Jaasund, 1970, 1976; Richardson, 1975; Lawson & John, 1987; Schneider & Searles, 1991; Littler & Littler, 2000; De Clerck *et al*., 2002; De Clerck, 2003; Abbott & Huisman, 2004). In particular, our specimens show a habit similar to that described and illustrated by most authors, except that illustrated by Jaasund (1976) and Abbott & Huisman (2004), characterized by very short interdichotomies. Moreover, some authors comment that the straps show a transverse banding pattern of iridescence, in contrast to the Iberian specimens. On the other hand, specimens illustrated by Taylor (1960) and Littler & Littler (2000), as well as the studied material from the Canary Islands, show a regularly dentate margin, while in both our specimens and those described by the rest of authors the strap margins bear some scattered teeth. However, it should noted most authors regard the presence and density of teeth in this species as very variable and in some specimens they are lacking.

Anatomically, the Iberian specimens also are consistent with available bibliographical data, although they present medullary cells smaller than both those of the specimens described by De Clerck (2003) from the Indian Ocean [(103)216-242(525) × (67)118-132(224) μm in surface view and (115)180-205(235) μm

high in cross section] and those from the Canary Islands here studied [180-412 × (64)88-128(160) μm in surface view].

Regarding the reproductive structures, the Iberian specimens also agree with the descriptions of most authors. Only Schneider & Searles (1991) and Littler & Littler (2000) report that the sporangia are disposed in sori or clusters, contrary to what observed by other authors and in our specimens. Moreover, the sporangia of the Iberian specimens are somewhat smaller than those described by De Clerck (2003).

Besides *Dictyota ciliolata* there are other species of *Dictyota* bearing marginal teeth: *D. crenulata* J. Agardh, *D. grossedentata* De Clerck & Coppejans, *D. hauckiana* Nizamuddin and *D. spinulosa* Harvey. However, *D. crenulata*, a species described from the Mexican Pacific coasts and cited from the Canary Islands [as *Dilophus crenulatus* (J. Agardh) Nizamudim & Gerloff] by Nizamuddin & Gerloff (1979), differs from *D. ciliolata* in having spathulate apical segments and a multilayered medulla at the base (Nizamuddin & Gerloff, 1979; Hörnig *et al.*, 1992). *D. grossedentata* is a small prostrate species (De Clerck & Coppejans, 1999) in comparison with *D. ciliolata*, which shows an erect habit and can reach a height up to 20(25) cm. *D. hauckiana* is a large species (up to 50 cm high) that bears the sporangia grouped in sori (De Clerck, 2003), whereas *D. ciliolata* is not so large and bears isolated sporangia. And finally, *D. spinulosa* bear superficial spinose proliferations (De Clerck, 2003), absent in *D. ciliolata*. On the other hand, *D. ciliolata* also can be similar to *D. menstrualis* (Hoyt) Schnetter, Hörnig & Weber-Peukert, since this species occasionally can bear marginal teeth. However, unlike *D. ciliolata*, *D. menstrualis* often have a multilayered medulla at the base (Hörnig *et al.*, 1992; Littler & Littler, 2000).

As mentioned above, *Dictyota ciliolata* had not been previously recorded from the Mediterranean Sea, where the genus *Dictyota* was represented until now, according to Ribera *et al.* (1992), by the following five species: *D. dichotoma*, *D. linearis*, *D. fasciola*, *D. mediterranea* and *D. spiralis*. The three latter species have a multilayered medulla, at least at the basal parts of the straps (a medulla consisting of a single layer of cells in *D. ciliolata*). *D. linearis* has a medulla unistratose throughout, but it can be easily distinguished from *D. ciliolata* by the width of the straps [up to 1 mm according to Hamel (1939) in comparison with 3-12(15) mm in *D. ciliolata*]. Concerning *D. dichotoma*, also a species with a unistratose medulla throughout, the differences are not so clear. Most authors (Taylor, 1960; Earle, 1969; Jaasund, 1970; Lawson & John, 1987; Adams, 1994) commented that *D. dichotoma* is a very polymorphic species that usually bears marginal proliferations, particularly near the base, which grow into new straps and obscure the original division pattern. In particular, Taylor (1942) and Earle (1969) suggest that some proliferous specimens of *D. dichotoma* can be reminiscent of *D. ciliolata*. Moreover, the exceptional occurrence of slightly dentate margins in *D. dichotoma* was described only by Hörnig & Schnetter (1988) and Hörnig *et al.* (1992). In our opinion, even though proliferations may be confused with teeth, we agree with De Clerck (2003) that *D. dichotoma* lacks conspicuous dentation. It should be noted that no dentate margins were found in all Iberian specimens of *D. dichotoma* examined. Moreover, others diacritic characters that distinguishes *D. ciliolata* from *D. dichotoma,* are the presence of several fronds arising from a basal tuft of rhizoids in the latter species and the relation between the length of medullary cells and the length of cortical ones; according to Hörnig *et al.* (1992), this relation varies between 2.7 and 3.0 in *D. dichotoma*, whereas it is equivalent to 4.1 (Hörnig *et al.*, 1992) or (3.0)5.0-5.7(8.6) (De Clerck, 2003) in *D. ciliolata*, in agreement with the values observed in Iberian specimens of these species.

As noted earlier, *D. ciliolata* had not been previously recorded in the Mediterranean Sea, even in well sampled localities, so it is probable that this species had been recently introduced to this Sea. This hypothesis is also supported by the occurrence of the species usually near or in harbour areas that are considered risk spots for the alien species introduction (Ribera Siguan, 2002).

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