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An updated review of the occurrence of *Bathypolypus sponsalis* (Cephalopoda: Octopodidae) in the Italian seas and notes on its distribution in the Mediterranean

Alessandro Voliani* (✉), Danila Cuccu#, Fabio Fiorentino°, Daniela Giordano§ & Alessandro Mannini◊

* A.R.P.A.T. - R.I.B.M. Risorse Ittiche e Biodiversità Marina, Via Marradi 114, 57126 Livorno, Italy, a.voliani@arpat.toscana.it (✉) Corresponding Author

Dipartimento di Biologia Animale ed Ecologia, Università di Cagliari, Via Tommaso Fiorelli 1, 09126 Cagliari, Italy

° IAMC-CNR, Via Luigi Vaccara 61, 91026, Mazara (TP), Italy

§ IAMC-CNR, Spianata S. Raineri 86, 98122 Messina, Italy

◊ DIP.TE.RIS., Laboratori di Biologia Marina ed Ecologia Animale, Università di Genova, Viale Benedetto XV 3, 16132 Genova, Italy

Abstract

The occurrence and bathymetric distribution of *Bathypolypus sponsalis* in the Italian waters was reviewed on the basis of trawl surveys data routinely collected from 1994 to 2004 within the framework of the Italian GRUND and the International MEDITS research programs. All Italian seas were investigated covering a total area of about 290,000 km^2 within the depth interval 10-800 m. Biomass and abundance indices were computed. *Bathypolypus sponsalis* was caught in the Ligurian Sea, in the Sardinian Sea, in the Sardinian Channel and in the Strait of Sicily, in the depth range 265-704 m. The species was never recorded in the Ionian and the Adriatic Sea and only few records are available for the Tyrrhenian Sea (some specimens caught off northwestern Sicily). Present results, along with information from the literature, indicate the core of occurrence for *B. sponsalis* in the Mediterranean to be located in the western basin. This study addresses the absence of this species in the above mentioned areas on the basis of biogeographical and oceanographical information, paying particular interest to the possibility that the intermediate waters circulation plays a significant part in determining the distribution of the species.

Riassunto

Bathypolypus sponsalis è un ottopode bentonico batofilo di piccole dimensioni. La specie non è distribuita in maniera omogenea nel Mediterraneo ed è segnalata soprattutto nel bacino occidentale. Lo scopo del presente lavoro è quello di aggiornare le conoscenze disponibili sulla sua presenza nei mari circostanti l'Italia e di discutere la distribuzione della specie nel Mediterraneo. Le informazioni sono state raccolte nei campionamenti effettuati in tutti i mari italiani tra il 1994 ed il 2004 nell'ambito di due campagne di ricerca di pesca a strascico condotte in autunno (progetto GRUND) e in primavera (progetto MEDITS). La superficie complessivamente investigata, nell'area compresa tra le batimetriche di 10 e 800 metri, è di circa 290.000 km^2. Il disegno di campionamento adottato in entrambi i programmi di ricerca è di tipo casuale stratificato per profondità, con allocazione delle cale proporzionale all'estensione dei singoli strati batimetrici. Il peso e il numero complessivo degli esemplari di *B. sponsalis* catturati in ogni cala sono stati utilizzati per il calcolo degli indici di biomassa (kg/km^2) e di densità (n/km^2), rappresentati tramite GIS. Delle 17.370 cale complessivamente effettuate, *B. sponsalis* è risultato presente in 424, a profondità comprese tra 265 e 704 m, con abbondanze maggiori tra le batimetriche di 400 e 700 m. La specie è stata catturata solo nella parte occidentale e sudoccidentale dei mari italiani. *Bathypolypus sponsalis* è risultato molto abbondante nel Mar Ligure, meno diffuso lungo la costa occidentale sarda e, infine, scarsamente presente nello Stretto di Sicilia. È stato campionato in una sola cala nel Mar Tirreno (nella parte più occidentale della Sicilia settentrionale) e non è risultato presente nei mari prospicienti la parte orientale e sudorientale della penisola italiana, dove esistono ampie aree con profondità alle quali la specie potrebbe potenzialmente vivere. Sulla base dei presenti risultati e di quanto noto in letteratura, è stata quindi avanzata l'ipotesi che il cuore dell'areale di distribuzione di *B. sponsalis* nel Mediterraneo sia nella parte occidentale, mentre si ipotizza che nel Mediterraneo orientale la specie sia presente come relitto di un areale più ampio raggiunto nelle precedenti fasi glaciali verificatesi nel quaternario. L'attuale assenza della specie nel Mar Tirreno può essere spiegata dai maggiori valori di salinità (S > 38,60 psu) e di temperatura (T > 13,70°C) delle acque intermedie levantine (LIW) di questo mare rispetto a quelli dei corrispondenti livelli batimetrici delle altre parti del bacino occidentale del Mediterraneo.

Key words

Bathypolypus sponsalis, trawl surveys, geographical distribution, depth range, Central Mediterranean, biogeography.

Introduction

Bathypolypus sponsalis (P. & H. Fischer, 1892), a small sized bathy-benthic octopod (up to 105 mm mantle length), is the only representative of the sub-family Bathypolypodinae in the Mediterranean Sea (Bello, 1996). The species is also present in the eastern Atlantic Ocean, from the Rockall Trough (northwest of Ireland) to Cape Verde (southwestern Africa) (Nesis, 1987; Collins et al., 2001).

In the Mediterranean Sea the presence of *B. sponsalis* is relatively more abundant at depths between 400 and 700 m (Belcari, 1999), but the species has been recorded at depths of over 1800 m (Villanueva, 1992). A similar bathymetric distribution has been reported for the Atlantic Ocean (Collins et al., 2001).

Mangold and Boletzky (1988) reported a wide distribution of the species throughout the deep waters of the Mediterranean, with the exception of the Adriatic Sea; however, the occurrence of *B. sponsalis* in the Mediterranean basin is not homogeneous (Belcari, 1999). Records of this species refer mainly to the western Mediterranean (Perez-Gandaras & Guerra, 1978), in particular to the Catalan Sea (Wirz, 1955; Morales, 1958), the Alboran Sea, the waters around the Balearic Islands (Quetglas et al., 2001) and those off the Algerian coasts (Wirz, 1954). In the eastern Mediterranean *B. sponsalis* has been recorded in the northern Aegean Sea (D'Onghia et al., 1993, 1995), in the southern Aegean Sea (Lefkaditou et al., 2003) and, more recently, in the south-eastern Ionian Sea (Lefkaditou et al., 2004).

With regard to the Italian waters (central Mediterranean), the occurrence of the species has been reported in the Ligurian Sea (Mannini & Volpi, 1989; Relini et al., 2002; Faldelloni et al., 2005), the Sardinian Sea and Sardinian Channel (Cuccu et al., 2003) and the Strait of Sicily (Jereb & Ragonese, 1990). *Bathypolypus sponsalis* has not been reported among the octopods fauna of both the western Ionian Sea (Tursi & D'Onghia, 1992) or the Adriatic Sea (Bello, 1990). Only a few records exist for the Tyrrhenian southernmost area (Giordano & Carbonara, 1999), while the species has not been recorded in the northern and central parts of this sea. The Mannini and Volpi's records, in fact, refer to an area that was previously classed as the Tyrrhenian Sea but is currently classed as the Ligurian Sea.

Due to their geographical position (central part of the Mediterranean Sea), the Italian waters represent an excellent observatory for studies on the marine fauna distribution and seven out of thirteen of the biogeographycal sectors recognized in the Mediterranean can be identified within the Italian waters (Bianchi, 2007).

The peculiar reproductive biology, with the production of large-sized eggs and the probable lack of a pelagic early juvenile phase (Mangold & Boletzky, 1987), which would cause a reduction in the dispersal capacity of the species (Bello, 2003), makes *B. sponsalis* an interesting candidate for a study of species distribution variations in space and time.

The present study illustrates data collected during the trawl surveys routinely carried out in the Italian seas for stock assessment; although the main aim of the surveys is to monitor abundance and demography of species targeted by fisheries, they also provide standardized data on other demersal species, such as *B. sponsalis*.

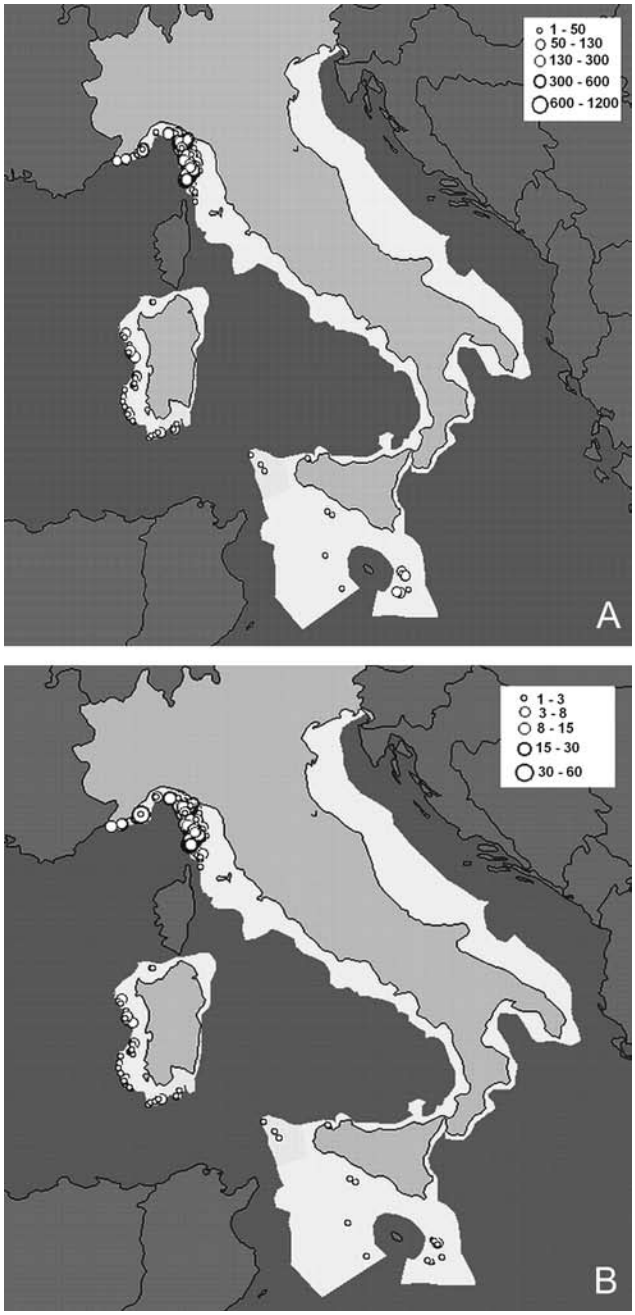

Fig. 1. Maps showing the studied area (light coloured) and the position of tows where *Bathypolypus sponsalis* was caught. **A.** Densities, n/km^2, observed in each tow; the circle sizes are proportional to the density. **B.** Biomass, kg/km^2, observed in each tow; the circle sizes are proportional to the biomass.

Fig. 1. Mappe con l'area indagata (parte più chiara) e posizione delle cale dove *Bathypolypus sponsalis* è stato catturato. **A.** Densità, n/km^2, osservate in ciascuna cala; le dimensioni dei cerchi sono proporzionali alla densità. **B.** Biomassa, kg/km^2, osservata in ciascuna cala; le dimensioni dei cerchi sono proporzionali alla biomassa.

Material and methods

Information was collected by trawl surveys carried out seasonally (in autumn and spring-summer) from 1994 to 2004 in the framework of two research programmes, GRUND (Relini, 2000) and MEDITS (Bertrand et al., 2002). The adopted sampling design was random within preestablished strata, with an allocation of tows proportional to the surface of the bathymetric strata. Each survey covered all Italian seas in an area of about 290,000 km^2, exploring the depth range 10 to 800 m.

The total number and weight of the specimen for each tow were used to estimate the biomass (kg/km^2) and density (n/km^2) indices. Geo-referenced information was represented with the software ArcView (ESRI, 1996); this enabled us to highlight the tows in which the species was found, after defining a quantitative scale for the representation of both indices.

Finally, for the areas where the species was more fre-

quently found, the mean biomass indices by depth intervals of 100 m were also calculated.

Results

Bathypolypus sponsalis was present in 424 tows out of the 17,370 carried out in the investigated area, revealing a distribution as shown in **Fig. 1**.
As can be seen, the most striking feature is the absence of records in the Tyrrhenian Sea (with the exception of a few specimen caught off the northwestern Sicilian coasts). The species is well represented in the Ligurian Sea and it is almost continuously distributed along the western Sardinian coasts and in the Strait of Sicily. The species abundance is also variable: *B. sponsalis* is relatively abundant in the Ligurian Sea, especially in its eastern side, but it is characterised by very low indices of biomass along the western Sardinian coasts and it is notably rather scattered and poorly represented in the Strait of Sicily, with the exception of a small area off the eastern coast of Malta.
The species has been captured within the depth range of 265 to 704 m, although the mean values of biomass and density indices obtained for the Ligurian Sea, the Sea and Channel of Sardinia and the Strait of Sicily, indicated 400 to 700 m as a preferential bathymetric range (see **Tab. 1**). A graphic representation of the biomass indices by depth in the Ligurian Sea is given in **Fig. 2**. Data from other areas are too scarce to be graphically elaborated.

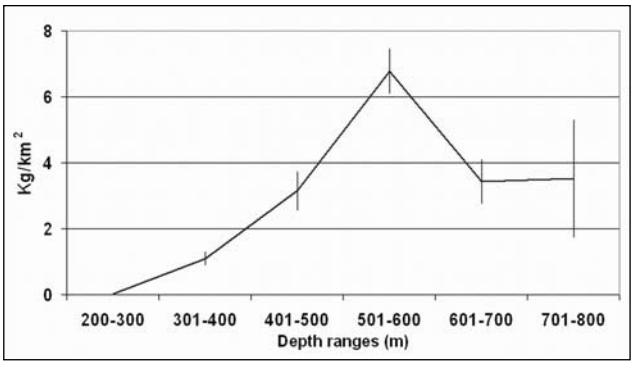

Fig. 2. Mean biomass indices (kg/km^2) of *Bathypolypus sponsalis* and associated standard error (vertical bars), by depth range, in the Ligurian Sea.

Fig. 2. Indici medi di biomassa (kg/km^2) di *Bathypolypus sponsalis* ed errore standard relativo (barrette verticali), per intervalli di profondità, nel Mar Ligure.

Discussion and conclusions

The results of this study confirm the non-homogeneous distribution of the species in the Italian waters, as was previously shown by a review of the available information compiled by Belcari (1999).
It is worth noting that the presence of *Bathypolypus sponsalis* in other Mediterranean areas that were not investigated within the GRUND and MEDITS scientific cruises, such as, for example, the waters off the west coast of Corsica, cannot be excluded.
It is difficult to find a satisfactory explanation for the absence of *B. sponsalis* from the Tyrrhenian, the Ionian (with the exception of sporadic occurrences in its southeastern-most portion reported in Lefkaditou et al., 2004), and the Adriatic Sea, although there is the possibility that the species is present at depths deeper than those investigated, considering that *B. sponsalis* has been found at depths of over 1,800 m (Villanueva, 1992) in the western Mediterranean.
The Tyrrhenian and Ionian Seas, caused particular surprise, as there are wide areas including the depth interval from 400 to 700 m, that are mostly inhabited by the species (Jereb et al., 1989; Mannini & Volpi, 1989; Belcari, 1999).
As with most of the other representatives of the cephalopod fauna, *B. sponsalis* came to the Mediterranean through a colonization process from the Atlantic, after the Messinian crisis (Mangold & Boleztky, 1988).
It seems reasonable that this deep water species, or the species originating it, spread all over the Mediterranean during the glacial periods (Quaternary glaciation cycle), favoured by the flow of the deep bottom current from the Atlantic to the Mediterranean (Emig & Geistdoerfer, 2004). When the waters became warmer and saltier along the slope of the eastern Mediterranean, they very likely also became "unfavourable" for this species. The species' affinity for relatively fresh and cold deep waters can

Depth (m)	Ligurian Sea			Sea and Channel of Sardinia			Strait of Sicily		
	Occurrence (%)	kg/km^2	n/km^2	Occurrence (%)	kg/km^2	n/km^2	Occurrence (%)	kg/km^2	n/km^2
200-300	1/82 (1%)	0.02	0.41	1/48 (2%)	0.01	0.20	1/82 (1%)	0.03	1.51
301-400	65/204 (32%)	1.10	21.85	4/77 (5%)	0.05	0.84	8/100 (8%)	0.09	3.91
401-500	70/122 (57%)	3.15	67.87	14/97 (14%)	0.23	5.50	4/55 (7%)	0.14	4.93
501-600	142/166 (86%)	6.78	123.31	26/125 (21%)	0.27	5.75	3/106 (3%)	0.05	0.53
601-700	72/101 (71%)	3.44	47.13	4/35 (11%)	0.21	4.15	3/145 (2%)	0.01	0.36
701-800	2/3 (67%)	3.52	62.60	–	–	–	0/10 (0%)	0	0

Tab. 1. Frequency of occurrence, biomass and density indices of *Bathypolypus sponsalis* by depth range.

Tab. 1. Frequenza di rinvenimento, indici di biomassa e densità di *Bathypolypus sponsalis* per intervalli di profondità.

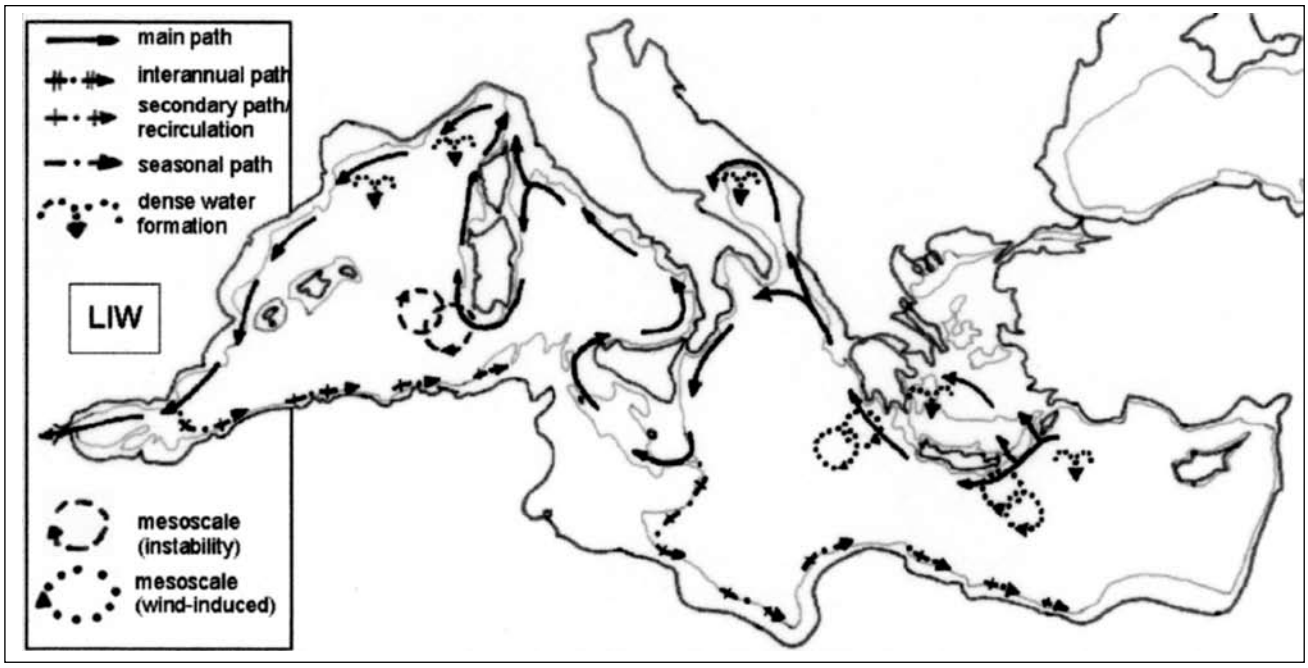

Fig. 3. Circulation of Levantine Intermediate Waters (LIW) in the Mediterranean Sea. The formation areas of dense water and the isobath 500 m are shown (after Millot & Taupier-Letage, 2005).

Fig. 3. Circolazione delle acque intermedie levantine (LIW) nel Mediterraneo. Sono riportate le principali aree di formazione di acque dense e l'isobata dei 500 m (da Millot & Taupier-Letage, 2005).

be assumed considering that four out of the five existing species of the genus *Bathypolypus* live in the Atlantic Ocean, mainly at artic, boreal and temperate latitudes (Cephbase, 2005).

It is well known that the depth range where the species lives in the Mediterranean is characterised by the occurrence of intermediate waters (200-700 m), the Levantine Intermediate Waters (LIW) being the most important component of the layer. The LIW, originating in the northern part of the Levantine Sea, flow, counter-clockwise and along-slope, in most of the Mediterranean, and constitute the bulk of the Mediterranean waters outflowing from Gibraltar to the Atlantic Ocean (**Fig. 3**) (Millot & Taupier-Letage, 2005). LIW have maximum salinity ($S > 39.1$ psu) and temperature ($T = 16\text{-}17°C$) in the Levantine Sea itself (Roether et al., 1998). Moving to the West, the LIW gradually become fresher and colder, reaching $38.60 < S < 38.68$ psu and $13.45 < T < 13.90°C$ in the Strait of Sicily, before flowing into the western basin (Astraldi et al., 2002).

A review of available literature has clearly shown that *B. sponsalis* is not present in most of the eastern basin (Salman et al., 2002; Goren et al., 2006). Bearing in mind the species' affinity for relatively cold and less salty waters, the occurrence of *B. sponsalis* in the Aegean Sea (D'Onghia et al., 1995; Salman et al., 2002; Lefkaditou et al., 2003) and the south-eastern portion of the Ionian Sea (Lefkaditou et al., 2004), could be considered as a "relict" of a once more widely distributed population in the Eastern Mediterranean, now confined to an area where the hydrological conditions are less unfavourable than in adjacent seas. In the Aegean Sea, the Black Sea Waters (BSW) flow to the west and reach the Mirtoan Sea (southwestern Aegean), where the Mirtoan Intermediate Waters (MIW), colder ($14.5 < T < 14.7°C$) and less saline ($39.02 < S < 39.06$ psu) than the LIW, are formed (Theocharis et al., 1999).

Conversely, the situation in the western Mediterranean is quite different, where *B. sponsalis* is well represented with the main exception of the Tyrrhenian sea.

The LIW flow from the eastern towards the western basin through the Strait of Sicily (**Fig. 3**). Subsequently, most of them enter the southern Tyrrhenian Sea and flow, above and along with the Tyrrhenian Deep Waters (TDW), in a cyclonic and along-slope circulation around the whole Tyrrhenian Sea (Millot, 1999). Then, the LIW + TDW cross the Sardinian Channel and enter the Algerian basin where they mix up with the so called "old LIW", i.e. the Intermediate Waters modified by the influence of the Western Mediterranean Intermediate Waters (WIW). The "new" Intermediate Waters, also affected by the large eddies produced by the Algerian current (Millot, 2005), flow along-slope off the western coast of Sardinia and Corsica, eventually entering the Ligurian Sea and continuing towards Gibraltar.

The result of this complex circulation is that the characteristics of the Tyrrhenian Sea waters, within the bathymetric range colonized by the species, are very similar to those of an eastern Mediterranean body of waters, as illustrated by the climatological atlas of the western Mediterranean by Picco (1990). At 400 m depth, which is representative of the intermediate water layer, the annual mean isolines of temperature (13.7°C) and salinity (38.60 psu) clearly separate the salty and warm waters of the Tyrrhenian Sea from those of the other areas of the western Mediterranean. This observation suggests that the absence of the species in the Tyrrhenian slope is likely due to unfavourable hydrological conditions.

A possible confirmation of this hypothesis is given by the very peculiar distribution of *B. sponsalis* at the north-

ern limits of the Tyrrhenian Sea: it is absent south-east of Cape Corse, while being particularly abundant only a few miles north, in the Ligurian basin (Faldelloni et al., 2005).

The role of sea water temperature in explaining the spatial distribution of the neritic marine organisms in the Mediterranean was recently discussed by Bianchi (2007). He stated that the Aegean Sea biota is more similar to that of the western basin than to that of the Levant Sea and that the Tyrrhenian Sea has biogeographic features different from the Balearic-Sardinian area.

Although information on Mediterranean deep water biota is still too scarce (Emig & Geistdoerfer, 2004; Bianchi, 2007) for appropriate consideration, the function of the intermediate waters in affecting the composition of the deep sea fauna of the Mediterranean Sea was previously hypothesized by Ghidalia & Bourgois (1961) and Bombace (1972) to explain the distribution of the deep water shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus*. Cau et al. (2002) have confirmed the existence of a longitudinal gradient in the deep water red shrimps occurrence, with *A. foliacea* more abundant in the Tyrrhenian Sea and the eastern Mediterranean, whereas *A. antennatus* prevailing in the western Mediterranean. In our opinion, the observed distribution of the deep water octopus *B. sponsalis* strongly supports the thesis of the determinant role of intermediate waters circulation in the spatial pattern of the deep water biota in the Mediterranean.

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