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Research Article

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On the presence of the Mediterranean endemic *Microdeutopus sporadhi* Myers, 1969 (Crustacea: Amphipoda: Aoridae) in the Gulf of Naples (Italy) with a review on its distribution and ecology

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Abstract

Microdeutopus sporadhi (Crustacea: Amphipoda: Aoridae), an endemic species of the Mediterranean Sea, was described by Myers in 1969 on material collected from the Aegean Sea in a sheltered environment with high sedimentation rates. A check on the distribution and ecology of *M. sporadhi* showed that: – although not mentioned in the checklist of amphipods of the Italian seas, it was already found in the central Tyrrhenian Sea in 1983-84 and in the northern Adriatic Sea in 2002-03; – it was rarely found in the Mediterranean Sea, one of the most studied basins as concerns amphipod fauna; but notwithstanding the few records available, the wide ecological spectrum of this species was pointed out. This study, conducted off the Island of Ischia (Gulf of Naples, Italy), showed the presence of rich and well established populations through time, but only in a peculiar substratum (artificial collectors) and environment (low pH values). The species seems to be able to withstand harsh environmental conditions and probably to conceal itself through a cryptic behaviour, escaping traditional sampling methods. The role of rare or hidden species in bio-assessment should be re-evaluated.

Keywords: Crustacea Amphipoda, *Microdeutopus sporadhi*, biodiversity, checklists, Mediterranean Sea.

Introduction

Recent studies have focused on the threats for biodiversity in a changing environment (e.g. Coll *et al*., 2010; Beermann & Franke, 2011; Hawkins & Firth, 2011). In this framework, the role of taxonomy and biological collections (e.g. Thomas, 1993; Godfray & Knapp, 2004; Ruffo & Krapp, 2005; Agnarsson & Kuntner, 2007; Costello *et al*., 2010), with the compilation of checklists and their constant updating (Bellan-Santini & Costello, 2001; Ruffo, 2010), were re-evaluated, being at the base of ecological and monitoring studies (Coll *et al*., 2010; Pyke & Ehrlich, 2010; and cited literature).

The crustacean amphipod *Microdeutopus sporadhi* Myers, 1969, an endemic species of the Mediterranean Sea, belonging to the family Aoridae, was described from the Island of Khios in the north-eastern Aegean Sea (Myers, 1969a).

The eleven species of the genus *Microdeutopus* known for the Mediterranean Sea (Ruffo, 1982-1998) are all recorded along the Italian coasts, with the exception of *Microdeutopus sporadhi*, as mentioned in the checklist of amphipod fauna of the Italian seas (Ruffo, 2010). The finding of this species in the coastal waters off the Island of Ischia (Gulf of Naples, Italy), in the framework of a research programme focused on evaluating the impact of low pH values on benthic assemblages (e.g. Hall-Spencer *et al*., 2008), stimulated a review of data available on its distribution and ecology in the Mediterranean Sea.

This study aimed at contributing to the update of available checklists and to knowledge of the ecology of rare or hidden species (Chapman, 1999), taking into account their underestimated role in bio-assessment (Cao *et al*., 1998), in the still open debate about their meaning and importance (Chapman, 1999; Fontana *et al*., 2008).

Materials and Methods

The amphipod material, object of this paper, was obtained from studies conducted at Castello Aragonese (40° 43.84 N, 13° 57.08 E), an area off the Island of Ischia (Gulf of Naples, Italy) characterized by a natural pH gradient which occurs parallel to both sides of the Castello rocky cliff (see Cigliano *et al*., 2010), due to CO_2 volcanic vents.

Invertebrate fauna was sampled at six stations, three on the north side (N1, N2, N3) and three on the south side (S1, S2, S3), adjacent to the rocky wall, along the above mentioned gradient, in April-May 2008, September 2009, March and May 2010, by means of artificial collectors (8 cm diameter scouring pads) settled for one month (three replicates at each station, fixed to buoyed moorings, at about 1 m from the bottom and 2 m depth). Three further replicates were performed at stations N3 and S3 in May 2010. On both sides, st. 1 is characterized by normal pH values (N: 8.09 ± 0.03; S: 8.12 ± 0.01), st. 2 by intermediate values with high temporal fluctuations (N: 7.72 ± 0.12; S: 7.62 ± 0.14), and st. 3 by low values (N: 7.39 ± 0.10; S: 7.33 ± 0.13). For further details about the study site and the sampling design see Cigliano *et al*. (2010) and Ricevuto *et al*. (2012).

After the sorting of vagile fauna, crustacean amphipods were identified at species level and counted. The specimens of *Microdeutopus sporadhi* were separated into males, ovigerous females, females and juveniles, for each sample.

Results

In order to investigate available information about the presence of *Microdeutopus sporadhi* in the Mediterranean Sea, a check was performed on:

– the checklists available for different geographical areas of the Mediterranean Sea, in particular for the coasts of Italy (Ruffo, 2010), France (Dauvin & Bellan-Santini, 2002), Spain (García & Jaume, 1997-2008; De-la-Ossa-Carretero *et al*., 2010), Algeria (Bakalem & Dauvin, 1995; Grimes *et al*., 2009), Tunisia (Zakhama-Sraieb *et al*., 2009), Libya (Ortiz & Petrescu, 2007), Israel (see Sorbe *et al*., 2002), Turkey (Gözcelioğlu, 2002; Bakir & Çevirgen, 2010), Greece (Stefanidou & Voultsiadou-Koukoura, 1995; Koukouras, 2010), Rovinj (Croatia) and adjacent regions (Krapp-Schickel & Zavodnik, 1993-1996), besides the Sea of Marmara (Bakir, 2012), the Bosphorus (Balkis *et al*., 2002), and the Black Sea (Sezgin & Katağan, 2007).

– papers dealing on ecology, zonation and geographical distribution of amphipods in the Mediterranean Sea, which was extensively studied under this point of view (see Ruffo, 1982-1998; Bellan-Santini & Ruffo, 2003).

The above mentioned research produced the following results, which are summarized, and listed according to time, in Table 1.

Microdeutopus sporadhi ***along the Italian coasts***

Microdeutopus sporadhi, although not mentioned in the checklist of amphipod fauna of the Italian seas (Ruffo, 2010), had already been found along the Italian coasts. Two records are available (Fig. 1), in particular:

– In the central Tyrrhenian Sea, at Torvaldaliga (North of Civitavecchia harbour), an area under the influence of a power station, it was found in samples collected: - from March 1983 to February 1984, at a depth of 0.3 m, on a rocky sub-horizontal bottom colonized by photophylic algae; - in April and July 1983, at a depth of 4 m, on the seagrass *Posidonia oceanica* (L.) Delile, characterized by patchy distribution, among areas of dead ‘matte’ and rocky substratum with algae. No data were presented about the estimated abundances; although in this area *Microdeutopus* spp. (6 species identified on the males) in general were among the dominant taxa, mainly at 0.3 m in September (Taramelli & Venanzangeli, 1989-90).

– In the northern Adriatic Sea, Gulf of Venice, off Chioggia, it was found in 2002-2003 at a depth of about 22-24 m, on rocky outcrops scattered on the sea bottom and emerging 2.5-3 m from the seabed, colonized by complex organogenic structures, like reefs, where the al-

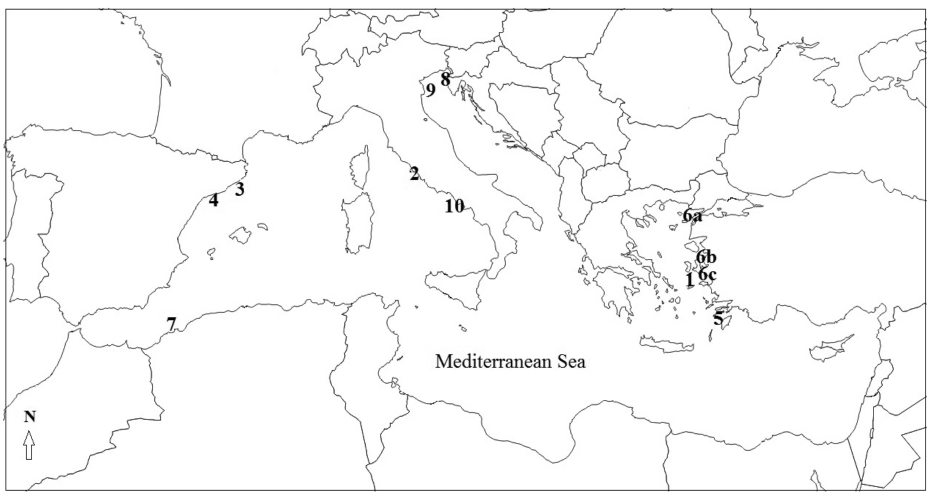


Fig. 1: Records of *Microdeutopus sporadhi* Myers, 1969 in the Mediterranean Sea (see Table 1). 1: Type locality: Emborios Bay, Island of Khios (Greece). 2: Torvaldaliga (Italy). 3: Blanes (Spain). 4: Creixell beach (Spain). 5: Datça (Turkey). 6a: Saros Körfezi (Turkey). 6b: Karaburun (Turkey). 6c: Çeşme (Ildir) (Turkey). 7: Gulf of Oran (Algeria). 8: Fiesa (Slovene). 9: Gulf of Venice (Italy). 10: Present study: Castello Aragonese, Island of Ischia (Italy).

Table 1. Records of *Microdeutopus sporadhi* in the Mediterranean Sea, listed according to time.

	Geographical Area	Locality	Date	Depth	Substratum	Reference
1.	North-eastern Aegean Sea	Type locality: Emborios Bay, Island of Khios, Greece	August 8-11th 1967	0-2 m	very high detritus accumulation on *Cystoseira* spp.	Myers, 1969a, b
2.	Central Tyrrhenian Sea	Torvaldaliga, North of Civitavecchia harbour, Italy	1983-1984	0.3 m; 4 m	algae and *Posidonia oceanica*	Taramelli & Venanzangeli, 1989-90
3.	Catalan-Balearic Sea	Blanes, north-eastern Spain	1984-1988	6-15 m	rocky bottoms with *Mesophyllum lichenoides*	Jimeno & Turon, 1995
4.	Catalan-Balearic Sea	Creixell beach, north-eastern Spain	1991-1992	0.5-3.5 m	sandy sediments of the surf zone	San Vicente & Sorbe, 1999
5.	South-eastern Aegean Sea	Datça, Turkey	June-July 1995	2-5 m	rocky bottoms with *Padina pavonia*	Kirkim *et al.,* 2005a
6.	North-eastern Aegean Sea	Saros Körfezi, Karaburun, Çeşme (Ildir), Turkey	July-June 1995-1996	Upper infralitt.	rocky bottoms	Kirkim *et al.*, 2005b; Bakir & Çevirgen, 2010
7.	Western Mediterranean	Gulf of Oran, Algeria	August 5th 1997	56 m	fine sand	Grimes *et al.*, 2009
8.	Northern Adriatic Sea	Fiesa near Piran, Gulf of Trieste, Slovene	January 20th 2002	few cms	fine and coarse gravel, mainly boulders and some algae, in mediolittoral rocky pool	Fišer, 2002
9.	Northern Adriatic Sea	Off Chioggia, Gulf of Venice, Italy	August 2002-June 2003	20 m	rocky outcrops scattered on sea bottom, colonized by complex organogenic structures, like reefs	Casellato *et al.*, 2006 Casellato & Stefanon, 2008
10.	Central Tyrrhenian Sea	Castello Aragonese, Island of Ischia, Gulf of Naples, Italy	April 2008-June 2011	1.5-2 m	artificial substratum	Present investigation

gal component plays a minor role in comparison to other coralligenous habitats. These formations, called *tegnùe*, are a unique environment, a *'true oasis of biodiversity'* for the northern Adriatic Sea, compared to the surrounding soft bottoms, and '*act as a trap for the rich content of dissolved and particulate organic matter, and suspended plankton*' (Casellato *et al*., 2007). Among the several species found and not yet listed for Italian seas, *M. sporadhi* is the only Aoridae present in the few amphipod species (10) identified. No abundance data are available (Casellato *et al*., 2007; Casellato & Stefanon, 2008).

Microdeutopus sporadhi *in the Mediterranean Sea*

Microdeutopus sporadhi was described from material collected in the north-eastern Aegean Sea, at Emborios Bay (Island of Khios, Greece) (Fig. 1), on August 8th 1967 at a depth of about 0-2 m from among *Cystoseira* spp. with very high detritus accumulation (Myers, 1969a, b; Ruffo, 1982-1998). Six males were studied; the length reported for the holotype is 3.0 mm, for paratypes 2.8 - 3.2 mm (Myers, 1969a), and for female 3.2 mm (Ruffo, 1982-1998).

After its first finding, no other records of *M. sporadhi* are available (Myers, 1973; Ruffo, 1982-1998) until 1983 for the central Tyrrhenian Sea, as mentioned above. After that, the species was found in the whole Mediterranean Sea (Fig. 1) as follows:

– In the Catalan-Balearic Sea, at Blanes, along the north-eastern coasts of Spain, it was identified, from 1984 to 1988, among the various substratum types studied on rocky bottoms, only, at a depth of 6-15 m, on *Mesophyllum lichenoides* (J. Ellis) Me. Lemoine, a red alga belonging to the family Corallinaceae, which is one of the main bio-constructors of coralligenous habitats. It was not mentioned among dominant species (Jimeno & Turon, 1995).

– In the Catalan-Balearic Sea, at Creixell beach, along the north-eastern coast of Spain, it was found in samples from January 1991 to January 1992, among the suprabenthos on sandy (fine sand) sediments of the surf zone, at a depth of 0.5-3.5 m, showing low densities and a low frequency throughout the year. The suprabenthic community of the site has the features of an exposed and dissipative beach due to strong wave action. The environment is characterized by high instability and a great amount of plant detritus deposited on the bottom (San Vicente & Sorbe, 1999; Munilla & San Vicente, 2005).

– In the south-eastern Aegean Sea, at Datça, along the coasts of Turkey, it was found in June-July 1995 on rocky bottoms colonized by the photophylic alga *Padina pavonia* (L.) J.V. Lamouroux, at a depth of 2-5 m, with only two specimens. Notwithstanding that the study covered almost all the Turkish Aegean Sea coastline, including many sampling localities from North to South, it was found only at this site, which is characterized by the lowest species richness according to substratum heterogeneity and low algal covering (Kirkim *et al*., 2005a).

– In the north-eastern Aegean Sea, at Saros Körfezi, Karaburun and Çeşme (Ildir), along the coasts of Turkey, it was found in July and June 1995-96, on rocky bottoms of the upper infralittoral (0-5 m depth). No abundance data are available (Kirkim *et al*., 2005b; Bakir & Çevirgen, 2010).

– In the western Mediterranean, along the coasts of Algeria, in the Gulf of Oran, the species, not previously reported for this area (Bakalem & Dauvin, 1995), was found on August 5th 1997 on fine sand, at a depth of 56 m, with only one specimen (Grimes *et al*., 2009).

– In the northern Adriatic Sea, at Fiesa near Piran (Gulf of Trieste, Slovene) it was found on January 20th 2002, in a mediolittoral rocky pool, generated at low tides, on very fine and coarse gravel, with mainly cobbles and boulders, and some algae, among which some *Cystoseira* thrown by waves. No abundance data are available (Fišer, 2002).

Present study

On the whole, *Microdeutopus sporadhi* was present in 19 of the 77 samples examined, collected from 2008 to 2010, with a total of 197 individuals (57 males, 38 ovigerous females, 35 females, 67 juveniles), which accounted for 6.0 % of the whole amphipod assemblages studied and 32.1 % of the family Aoridae. It was present only at stations S2 (27 ind.) and S3 (170 ind.), on the south side. In particular, at station S3, it was among the dominant species, accounting for 28.6 % of amphipods and 85.9 % of Aoridae, and showed the highest abundances of males and ovigerous females, and juveniles, in May and September, respectively (Fig. 2). The adult specimens reached the length of 4.0 mm (males) - 4.2 mm (ovigerous females).

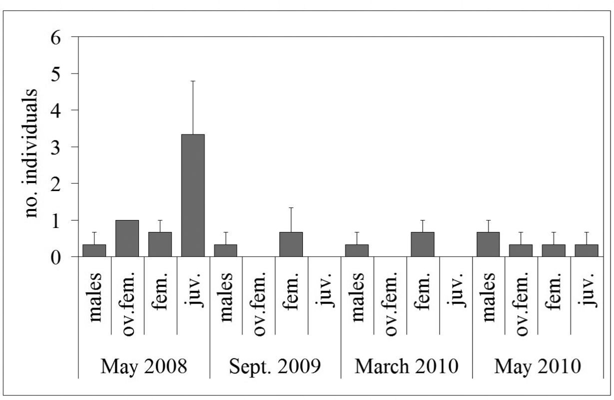
The family Aoridae, which accounted, on the whole, for 18.8 % of the individuals of the studied amphipod assemblages, was also represented by the congeneric species *Microdeutopus chelifer* (Bate, 1862) (82 indiv.) and *M. obtusatus* Myers, 1973 (90 indiv.), as well as *Lembos websteri* Bate, 1857 (189 indiv.), and few individuals (8) of *Leptocheirus guttatus* (Grube, 1864), *L. pectinatus* (Norman, 1869), *L. pilosus* Zaddach, 1844 (Table 2).

Furthermore, qualitative samples collected using the same method, showed the presence of the species (5 males and 3 ovigerous females) in June 2011 also.

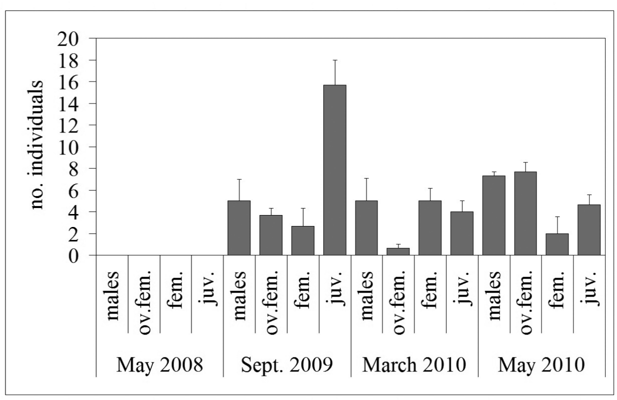
M. sporadhi was absent on the adjacent natural substrata, in quantitative samples collected at the same stations, using an airlift suction sampler, in 2008 on the rocky wall (pers. obs.; Kroeker *et al*., 2011) and in 2011 in *Posidonia oceanica* meadows (pers. obs.; Scipione & Garrard, 2013).

Discussion

The review of *Microdeutopus sporadhi* distribution in the Mediterranean Sea, a widely studied basin as regards its biodiversity (Coll *et al*., 2010) and amphipod fauna in particular (see e.g. Ruffo, 1982-1998), showed its rarity. But, notwithstanding the scanty reports available, these pointed out the wide ecological spectrum of this species. In fact, although *M. sporadhi* was considered well adapt-



S2



S3

Fig. 2: Mean values (± SE) of number of individuals, belonging to males, ovigerous females, females, juveniles, of *Microdeutopus sporadhi*, identified in April-May 2008, September 2009, March and May 2010, at stations S2 and S3, off Castello Aragonese (Ischia, Italy).

Table 2. Amphipod species belonging to the family Aoridae found at the studied stations (N1, N2, N3, S1, S2, S3) off Castello Aragonese (Ischia, Italy). The total number of individuals is given for each taxon, and for Aoridae and Amphipoda. n = number of samples. At stations N3 and S3, due to the presence of further replicates collected in May 2010, the total number of samples (n) and individuals are given in brackets.

	N1	**N2**	**N3**	**S1**	**S2**	**S3**	**Total**
	n = 12	n = 12	n = 12 (15)	n = 12	n = 12	n = 11 (14)	n = 71 (77)
Lembos websteri	2	18	7 (9)	82	70	7 (8)	186 (189)
Leptocheirus guttatus					1	(1)	1 (2)
Leptocheirus pectinatus		2	(1)				2 (3)
Leptocheirus pilosus	1		2				3
Microdeutopus chelifer	23	9	9 (25)	2	8	5 (15)	56 (82)
Microdeutopus obtusatus	6	40	33		7	4	90
Microdeutopus sporadhi					27	165 (170)	192 (197)
Microdeutopus ind.			(1)	23	7		30 (31)
Aoridae ind.	1	3			13		17
Aoridae	33	72	51 (71)	107	133	181 (198)	577 (614)
Amphipoda	582	379	357 (475)	647	585	538 (595)	3088 (3263)

ed to shallow waters with low hydrodynamics and high sedimentation rates only (Ruffo, 1982-1998), mainly due to its first finding in such an environment (Myers, 1969a, b), it is able to live in habitats subjected to different, and sometimes peculiar environmental conditions; for example, from the suprabenthos of exposed sandy sediments with high hydrodynamics and rocky pools of meso- and upper infra-littoral up to coralligenous habitats characterized by a sciaphylic environment, and to deeper sediments (see results). On the other hand, in the above mentioned so different environments, this species might find similar cryptic micro-habitats suitable for its ecological requirements (Chapman, 1999).

Furthermore, its rarity could be discussed, and should probably be considered as a hidden species or with a cryptic behaviour, not easily collected by traditional sampling methods (Lowman *et al*., 1996; Smith-Vaniz *et al*., 2006; Thomas & Krapp-Schickel, 2011). The present results contribute to supporting this hypothesis. In fact, at the study site, Castello Aragonese, *M. sporadhi* was represented by several specimens of males, mature females and juveniles, through time, showing the presence of rich and well established populations, with specimens reaching a greater body length compared to the holotype and paratypes (Myers, 1969a; Ruffo, 1982-1998), but these were found only in a peculiar substratum and environment. In fact, the species was present only on artificial collectors and not, for example, on the adjacent rocky bottoms and *Posidonia oceanica* meadows (pers. obs.), and the highest abundances were reached in correspondence with the lowest pH values recorded along the studied natural gradient.

Cryptic lifestyle, which may be expressed morphologically and behaviourally (e.g. Hoeksema *et al*., 2009), is considered in a wide sense usual in amphipods, which are able to hide in different ways in substratum. A cryptic behaviour was observed and studied in habitats such as seagrasses (e.g. Stoner, 1980) and algae (Hay *et al*., 1990 and cited literature), and in a more specialized way in endobiotic and/or commensal forms (e.g. Thiel, 1999; Enochs & Hockensmith, 2008) and in various tube-dwellers (Carter, 1982); sometimes it may generate co-evolutionary processes (Conran & Bradbury, 2007). In this study, the roughness and the large number of small cavities of the artificial collectors, which also act as a trap for suspended particulate organic matter, represent a good refuge and the ideal habitat for *Microdeutopus sporadhi* to conceal itself.

Recently, the impact of ocean acidification on marine flora and fauna, biodiversity and ecosystem processes represented the focus of many studies worldwide (e.g. Doney *et al*., 2009) and in the Mediterranean Sea (CIESM, 2008). Coastal areas, which are under the influence of natural CO_2 volcanic vents, represent natural laboratories that are perfect for improving the knowledge and giving new insight in this framework (e.g. Hall-Spencer *et al*., 2008). According to studies carried out at Castello Aragonese (Ischia), different responses were observed in benthic invertebrate assemblages and taxa, and amphipods appear to be among the more tolerant to variable and low pH conditions (Cigliano *et al*., 2010; Kroeker *et al*., 2011; Ricevuto *et al*., 2012). However, previous studies suggest that the impact on amphipods may vary according to many factors, such as the degree of water acidification, size and developmental stage (Conlan, 1994), time of exposure with possible changes in organism physiology (Hauton *et al*., 2009). *Microdeutopus sporadhi*, in the studied environment, was not affected by CO_2 volcanic vents, and appeared to be tolerant, well adapted or even favour the lowest pH values recorded, coupled with lower hydrodynamics (pers. obs.) at the south side of the Castello.

In the Mediterranean Sea, *Microdeutopus sporadhi* apparently shows a patchy distribution (Chapman, 1999), with the highest number of records in the eastern Aegean Sea, possibly in relation to its first finding in that geographical area. Probably, due to a possible cryptic behaviour, its ability to spread is less efficient (Thomas, 1993; Chapman, 1999), also in comparison to species characterized by the same life habits (epifaunal tube building). For example, the congeneric species *Microdeutopus obtusatus*, described only a few years later and at a close locality (Gulf of Izmir, Turkey, Myers, 1973), if compared to *M. sporadhi*, is more frequently recorded showing a wider distribution area (e.g. Ruffo, 1982-1998; Bellan-Santini & Ruffo, 2003; Ruffo, 2010).

However, amphipods are very sensitive to external disturbance (Conlan, 1994) and thus good bioindicators (Thomas, 1993); this species seems to be well adapted to harsh environmental conditions (good resilience) showing a behaviour pattern that probably maximizes its ability to conceal itself in micro-habitats (cryptic behaviour). 'Rare' species and organisms with a cryptic behaviour tend to be overlooked in biodiversity and ecological risk assessment studies (Smith-Vaniz *et al*., 2006). Moreover, according to the results, their role should be re-evaluated (Cao *et al*., 1998).

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