Serpula cavernicola Fassari & Mòllica, 1991
(Annelida Polychaeta): diagnostic features of the tube and new Mediterranean records

Serpula cavernicola Fassari & Mòllica, 1991 (Annelida Polychaeta) :
caractères diagnostiques du tube et nouvelles signalisations en Méditerranée

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ABSTRACT
Tube analysis of the recently described Serpula cavernicola (Fassari & Mòllica, 1991) is given, based on holotype and additional material. The re-description of the species focuses on the morphology and structure of its tube. It is very large-sized with a thick wall. Three or five longitudinal ridges, the central one being more prominent, frequently occur on the distal end of the tube. The outer surface, especially of the oldest most calcified parts, is scaly and spongy. SEM magnification reveals the microstructure of the tube wall, consisting of two calcareous layers: an outer thick layer (ca. 600 µm), with crystals arranged in desorder in a criss-cross pattern, and an inner one (ca. 200 µm) very thin, with parallel crystals, more closely patched. This analysis of tube features has proved to be a useful basis for taxonomic distinction. New records of the species from shallow-water caves in the Southern Mediterranean are also given.

RÉSUMÉ
Les analyses du tube de Serpula cavernicola (Fassari & Mòllica, 1991) récemment décrit, ont été effectuées à partir de l’holotype et avec d’autres matériaux. La redescription de l’espèce s’appuie sur la morphologie et la structure du tube. Il est de très grande taille avec une paroi épaisse. Trois ou cinq crêtes longitudinales, dont une plus grosse que les autres, situées au centre, ornent fréquemment la partie distale du tube. La surface externe, dans les parties les plus calciﬁées des tubes âgés, est écailleuse et spongieuse. La microstructure des parois du tube, analysée au SEM, montre deux couches calcaires : l’une externe (600 µm), faite de cristaux désordonnés assemblés en croix ; et l’autre interne (200 µm), très fine avec des cristaux parallèles très resserrés. Cet examen de l’organisation du tube s’est révélé utile d’un point de vue taxonomique. De nouvelles signalisations de cette espèce dans des grottes sous-marines peu profondes du sud de la Méditerranée sont aussi données.

INTRODUCTION
Owing to its rarity, Serpula cavernicola (Fassari & Mòllica, 1991) has been only recently described, records being scant, despite its large size.
New records of this species (living individuals, tubes and fragments), are here reported from some shallow-water caves in Sicily and the Southern Tyrrhenian Sea.

The original description of the species (Fassari, Mòllica, 1991) was performed using the classical taxonomy, based on the morphological features of the worm’s body. In the present work, the tube morphology and structure of S. cavernicola have been re-described and it has been noted that they are univocal diagnostic features for taxonomy. The value of this approach is evident especially when only empty or fossil tubes are available (thanatocoenosis or taphocoenosis).
MATERIAL AND METHODS

New specimens of *S. cavernicola* were sampled in four infillral caves from the Ionian coast of Sicily and the Southern Tyrrenhenian Sea (Campanian coast).

Maraviglia Cave (Mazzarò, Eastern Sicily)
Small semi-submerged cave, with a 13 m wide entrance at a depth of 12 m. It consists of a wide central chamber and two submerged channels separate centrally by a big rocky spur. The left channel is shorter and still well lit. The right channel, entirely submerged, is about twenty meters long and totally dark in its distal portion. Inside the cave, there are three different zones: a photophilic zone near the entrance where algae, typical of the bottom outside the cave, still occur; a moderately scaphiphic zone characterising the central chamber and the left channel; and a completely dark zone, present only in the right channel.

Material

Five living specimens with their tubes (holotype and paratypes) (Fassari, Mòlica, 1991). Living specimens colonised the vault of the dark portion of the cave together with scaphiphic species related to the cave biotope such as the serpuloids *Filograna annulata* (Costa), *Spiralina massiliensis* (Zibrowius), *Josephella marenzelleri* Caullery & Mesnil, *Semivermilia crenata* (Costa), *Spirobranchus lima* (Grube), *Vinearia koehleri* (Caullery & Mesnil), *Paraleucoma striata* (Quèvrière); the bryozoans *Puellina radiata* (Moll), *Crassimarginatella solidula* (Hincks), *Onychocella marioni* Jullien; the brachiopods *Neocrania anomala* Müller and *Argyrotheca cordata* Riso; the cidarians *Leptosamonia pruvoti* Lac.-Duth. and *Hoplantia durotrix* Gose; the sponges *Petrobionia massiliana* Vacelet, *Sycon* sp.; and the foraminifer *Miniaicina miniacea* (Linnaeus).

Gymnasium Cave (Maddalena Peninsula, Eastern Sicily)
Karstic submerged cave at 20 m depth, with an entrance 8 m wide and 3 m high. It consists of four sub-horizontal chambers following each other, altogether about 50 m long (Leonardi, 1994). The third chamber, in its distal portion, and the fourth chamber are totally dark.

Material

One living specimen within its tube from the inner part of the third chamber. Scaphiphic species related to the cave biotope are associated: the serpulid *Spiralina massiliensis* (Zibrowius), the mollusc *Asperarea magdalena* (Zibrowius), the bryozoan *Puellina radiata* (Moll) and the brachiopod *Tetrahyndichia mediterranea* Logan.

Betsabea Cave (Capo Passero Island, South Eastern Sicily)
Karstic semi-submerged cave. The entrance, at a depth of 6 m, is about 2 m wide. There is another entrance at 3 m depth. Both openings lead into a wide chamber (4x9 m) with sandy bottom sediments. Both entrances are totally submerged while the vault locally emerges about one meter above sea level. The cave narrows in its terminal portion (1 m in height) and there are many collapsed blocks on the bottom. In the inner totally dark portion of the cave there are fibres and leaves of *Posidonia oceanica* (Linnaeus) Delile, testifying to moderate hydrodynamism.

Material

One living specimen with its tube from the wall of the main chamber where light was weak and the covering of benthic organisms was notably reduced (<40%). The Bryozoans *Puellina radiata* (Moll), *Crassimarginatella solidula* (Hincks), the Brachiopods *Megathiris detruncata* (Gmelin), *Argyrotheca sp.* and the serpuloids *Semivermilia crenata* (Costa), *Josephella marenzelleri* Caullery & Mesnil, *Pomatoceros triqueter* (Linnaeus) and *Jania pagenstecheri* (Quatrefages) are associated.

Isca Cave (Sorrento Peninsula, Southern Tyrrenhenian Sea)
Wide chamber (25x30 m) with a narrow (2 m) vertical entrance 6 to 14 m deep. A weak hydrodynamic circuit laps the walls of the cave. Biotopes with major rheophila are present in restricted parts of the cave. The light sharply decreases inward, where floristic elements disappear and the environment becomes completely dark (Taddei Ruggieri et al., 1996).

Material

Two fragments of the tube distal end from bottom sediment in the inner part of the cave. Scaphiphic species related to the cave biotope are associated (serpuloids: *Semivermilia pomatostegoides* (Zibrowius), *Jania limbriata* (Delle Chiaje), *Vermilopsis monodiscus* Zibrowius, *Vermilopsis labiata* (Costa); bryozoans: *Euryistrotos occulta* Harmelin, *Puellina hincksii* (Friedl), *Puella venusta* (Canu & Basler) and *Escharina vulgaris* (Moll); brachiopods: *Neocrania anomala* (Müller)). A subordinate group of allochthonous species, typical of infrillral biocoenoses (*Posidonia* and algal grasses), also occurs.

Sampling of tubes was done by scuba diving and scraping the cave wall. A small pneumatic hammer connected to the diving tanks was used to detach the part of the substratum encrusted by the serpulid tubes. The tube fragments from the Isca Cave were collected by hand-sampling from the bottom sediment.

Tubes were cleaned with H₂O₂ before coating with gold palladium for SEM observations. Some tubes were broken to investigate the wall structure.

TUBE MORPHOLOGY AND STRUCTURE

Whereas the original description of *S. cavernicola* was based on the anatomy of the soft body (Fassari, Mòlica, 1991), the present description focuses on tube morphology and structure, which prove to be a good tool for taxonomic distinction.
Figure 1 - Serpula cavernicola (Fassari & Möllica, 1991). A: Tube with longitudinal ridges, encrusted by epifauna (Betsabea Cave). B: Tube lacking in its posterior part; ventral side showing small areas attached to the substrate. In the middle part of the tube the inner layer (arrowed) is visible under the outer one (Maraviglia Cave). C: Tube of the holotype Maraviglia Cave, Mazzaro. D: Distal end of the tube with five dorsal ridges, the median of which is more evident (Maraviglia Cave). E: Microstructure of the smoother posterior part, showing transverse clearly distinct growth lines, rounded and symmetrical in section (Maraviglia Cave).

Figure 2 - *Serpula cavernicola* (Fassari & Möllica, 1991). A: Distal calcified part of the tube showing a scaly and spongy structure on the outer surface (Betsabea Cave). B: Microstructure of the two calcareous layers: thicker opaque layer with crystals arranged in a criss-cross pattern (a); inner strong layer with disoriented crystals (b) (Betsabea Cave). C: Transverse section of the two-layered tube wall. Marked bio-erosion is visible inside the outer white layer (Betsabea Cave).

Description

The tube is white opaque and large-sized, up to 15 cm in length. It is more or less coiled folding on itself in the attached part, distally rising from the substrate (figure 1: A, B and C). The cross section is circular, the tube lightly encrusting the substrate. The outer diameter is relatively constant along the tube (ca. 8 mm). The wall is about 800 μm thick but randomly reaches 1.4 mm (figure 2: C).

The posterior part is smooth. Here, only transverse clearly distinct growth lines, rounded and symmetric in section, are apparent (figure 1: E).

The distal more calcified part of the tube shows a scaly and spongy structure on the outer wall and possesses at least one dorsal ridge (figure 2: A). Most often, three or five longitudinal ridges are apparent, the median of which is most prominent, undulated and extending to the mouth with a small tooth (figure 1: A and D). Careful illumination reveals that a pair of very thin lateral, barely visible grooves may occur (figure 2: A).

Circular peristomes can be present near the opening, testifying former mouths (figure 1: B).

The tube wall comprises two distinct layers: an outer white opaque layer (600 μm thick), and an inner thinner one (200 μm thick) very strong, white to brownish in colour (figure 2: B and C).

Both layers consist of small calcium carbonate crystals with a prismatic very squat habitus ca. 3 μm long. In the outer layer they are arranged criss-cross in a homogeneous microcrystalline structure (figure 2: B-a); in the inner layer similar crystals are more closely patched, arranged along a common crystallographic axis (figure 2: B-b). This structure confers a high degree of hardness to the layer around the lumen of the tube.

Remarks

*Serpula cavernicola* is an easily-recognisable species, remarkable for its large size (more than 35 mm with a tube length of up to 100-150 mm) especially as compared with other serpulids from cave environments.

In comparison with the original description of the species, on the basis of new records and observations of individuals in their natural environment, it is possible to give new information on the coloration of this species. The branchial tuft has a white basal part and a red distal end; the collar is white with small red spots; the thoracic membranes are red; most of the opercular rays are dark-violet, but irregularly one or two white rays are visible. The opercular peduncle is yellow-whitish; the body is flesh-coloured.

The tube may be similar to that of *Serpula vermicularis* in sometimes having three or five longitudinal ridges in the distal end, but it is markedly bigger and possesses a two-layered tube wall. Moreover, *S. vermicularis* tube is not coiled proximally and is not scaly in the distal end. Owing to this similar ornamentation of the distal end, *S. cavernicola* has been probably included by some authors under forms of *Serpula vermicularis* s.l. (e.g. Ben-Eliahu, Fieg, 1996). Thus, some nominal species described for the Mediterranean have been synonymised with *Serpula vermicularis*, which should be regarded as a species complex (ten Hove, pers. com.).

*S. cavernicola* has been included in the checklist of Italian serpulids by Castelli et al. (1995).

Ecology

The species is rare and occurs within caves, where it seems to prefer dark parts with still intense water movements. Owing to its rarity and still scarce sightings, a wider distribution in deep-sea environments (similar to those of the cave for some ecological factors) cannot be excluded.

New Mediterranean sightings of *S. cavernicola* have been added to those of the original description: Ionian Sea (Eastern coast of Sicily) and Southern Tyrrenian Sea (Campanian coast). Further findings are also from shaded caves in the western Mediterranean (National Park of Port-Cros, Marseille) and from near Atlantic areas (Straits of Gibraltar, Southern Portugal) (Zibrowius, unpublished data).

**DISCUSSION**

The ecological study of the submarine caves make it possible to observe in a restricted area the reaction of benthic communities to environmental gradients. Water movements within a cave strongly influence a variety of physical-chemical factors which, in turn, affect biological aspects. Light availability and hydrological confinement are therefore essential in determining the structure and composition of cave communities (Harmelin, 1980; Bianchi, Morri, 1994). Since cave communities show high sensitivity even to slight ecological changes, ecolphenotypic variations and community composition changes may occur within different parts of the same cave. This being so, is not surprising if *S. cavernicola* has been observed only in a few specific parts of the studied caves, mainly depending on local stream water exposure.

Owing to their large size, tubes are easily found in a diving recconnoitre of a cave. Nevertheless, they are rare and isolated, thus the species can be underestimated or ignored when traditional sampling methods are used (scrapping on a surface of the cave wall, sampling of bottom sediment).

**CONCLUSION**

The tube features of *Serpula cavernicola* have been investigated, offering a useful tool to identify the species when soft parts are lacking.

The role of the tube characters as taxonomic tools has been stressed in some recent works dealing other serpuloideans, where tube morphology and
structure are investigated using modern techniques (ten Hove, Zibrowius, 1986; Pillai, ten Hove, 1994; Aliani et al., 1995; Sanfilippo, 1996, 1998a, 1998b).

The importance of this method for serpuuloidae is evident when only empty or fossil tubes are present. Living records of S. cavernicola being quite rare, it is thus only possible to individuate the species only by means of empty tubes (encrusting cave walls) or fragmented tubes (within bottom cave sediments). These fragments would be attributed to undetermined serpuuloidae using the traditional zoological approach for taxonomic identification.

In the fossil record, tube characters are the only diagnostic features for specific identification. The use of this method could throw light upon palaeosystematics and palaeoecology of serpuuloidae, both scarcely dealt with in the palaeontological literature.

The observations above stress the importance of the re-description of the tube to show the following character:
- White opaque tube very large-sized circular in cross section;
- Posterior part irregularly coiled, smooth, with regular distinct growth lines;
- Distal end scaly and spongy with one, three or five longitudinal ridges; two very thin lateral grooves can be also present;
- Circular mouth sometimes bearing a small tooth. Rare peristomes near the opening testify previous growth stages;
- Tube wall consisting of two calcareous layers: an outer one, thicker and an inner one very thin and hard, with crystals more closely packed.

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