

First documented record of a living solemyid bivalve in a pockmark of the Nile Deep-sea Fan (eastern Mediterranean Sea)

CLARA F. RODRIGUES^{1,2}, SÉBASTIEN DUPERRON¹ AND SYLVIE M. GAUDRON¹

¹Université Pierre-et-Marie-Curie, UMR 7138 (UPMC CNRS IRD MNHN), Systématique Adaptation, Evolution, Paris, 75052, France, ²CESAM & Department of Biology, Universidade de Aveiro, Aveiro, 3810-193, Portugal

A living specimen of a solemyid bivalve was collected at bathyal depths near a pockmark in the Nile Deep-sea Fan (eastern Mediterranean) and is here presented. Both taxonomic and molecular results suggest a Solemya species but due to the small size of the animal and the lack of molecular data for other solemyid species the species cannot be determined. This is the first record of a living solemyid from deep-sea cold seeps in the Mediterranean Basin.

Keywords: Solemyidae, cold seeps, eastern Mediterranean

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INTRODUCTION

With a fossil record extending back into the Lower Palaeozoic, Solemyidae are the oldest chemosymbiotic bivalves (Taviani, 2010). Solemyids live in 'U'- or 'Y'-shaped burrows; shells display an elongate, near cylindrical shape and are covered with glossy, thick, brown periostracum extended as a broad, pleated, flexible fringe (Reid, 1998; Taylor & Glover, 2010).

Solemyids are geographically widespread at depths ranging from the intertidal to 5350 m (Fujiwara, 2003), and often associate with organically enriched habitats (reviewed in Taylor & Glover, 2010). The family Solemyidae is well documented at cold seeps in the Pacific, where mainly empty shells have been observed in low numbers (Sibuet & Olu, 1998; Sahling *et al.*, 2002; Neulinger *et al.*, 2006; Kamenev, 2009). Only recently they have been found in cold seeps from the North Atlantic, (Oliver *et al.*, submitted). To date, more than 30 species are known but continuous progress in deep sea investigation could rapidly increase this number (Neulinger *et al.*, 2006; Kamenev, 2009).

In the Mediterranean Sea a single species (*Solemya togata*) has been reported from shallow coastal waters' settings such as seagrass beds. On the other hand, large size solemyids ('*Acharax doderleini*') are known from Neogene deposits of this basin interpreted as deep-sea reducing habitats (Taviani *et al.*, 2008; Taviani, 2010).

This paper reports on the first solemyid recorded from bathyal depths in the Mediterranean Sea, based on a single living specimen found at 1697 m depth in the central province of the Nile Deep-sea Fan (eastern Mediterranean), where fluid seepage was reported in several locations (Dupré *et al.*, 2007; Bayon *et al.*, 2009).

MATERIALS AND METHODS

A single specimen of a solemyid bivalve was cored in soft sediment next to an active pockmark area of the Nile Deep-sea Fan (eastern Mediterranean Sea) (Station TVMUC1059; 32°32.05'N 30°21.13'E, 1697 m depth) using a TVMUC onboard the RV 'Maria S Merian' (Germany) (chief scientist: F. Wenzhöfer) during the MSM13/4 (HOMER) cruise (Figure 1). All metadata are stored in the PANGAEA database (<http://www.pangaea.de>).

After collection the only available specimen (shell partly broken during sampling) was fixed in ethanol. Due to the single broken specimen available and its small size (7.5 mm shell length), detailed morphological identification was not possible and molecular tools were employed to help clarify its taxonomic position. DNA was extracted from gill tissue using the DNeasy Blood and Tissue Kit (QIAGEN, CA). Multiple marker genes (18S rRNA, 28S rRNA and cytochrome *c* oxidase subunit (COI)) were PCR amplified using primers and conditions described previously (Folmer *et al.*, 1994; Taylor *et al.*, 2007) and sequenced (GATC Biotech, Germany). The presence of bacterial symbionts was also tested using PCR amplification of bacterial 16S rRNA genes (Duperron *et al.*, 2007).

Sequences were compared with the GenBank database using BLAST to identify sequences with highest similarities. Gene sequences were deposited in the EMBL database (<http://www.ebi.ac.uk/embl>) under Accession numbers FR715296 (18S), FR715297 (28S), and FR715326 (COI).

RESULTS AND DISCUSSION

The solemyid shell presented the features reported for the genus *Solemya*. For instance, the shell was thin, flexible, poorly mineralized, elongate-oval, inflated to compressed, and its surface displayed widely spaced weak radial ribs. The

Corresponding author:
C.F. Rodrigues
Email: clfrodriques@gmail.com



Fig. 1. Map of the study area (© Google Earth).

ligament was opisthodontic, internal, and attached to chondrophore (Figure 2). A reduced digestive tract was also visible.

The 18S rRNA-encoding gene displayed 93% similarity with a sequence from *Solemya velum* 18S ribosomal RNA gene (AF120524) (Giribet *et al.*, 2000); the 28S rRNA-encoding gene displayed 99% similarity with a sequence from *S. velum* 28S ribosomal RNA gene (AY45421) (Passmaneck *et al.*, 2004); the COI sequence yielded 83% sequence similarity with *S. velum* cytochrome *c* oxidase subunit I (U56852) (Hoeh *et al.*, 1998). Molecular results thus relate the present specimen with *S. velum*, a species from the north-west Atlantic that lives in sulphide-rich coastal sediments. Unfortunately, few 18S and 28S, and no COI sequences are available for the two genera of the family (*Solemya* and *Acharax*), so molecular data cannot yet be invoked as support for the generic affiliation with *Solemya*.

At this point, and in the absence of appropriate data on other species for comparison, it also seems impossible to

determine the species or to postulate for a new species. Nevertheless several hypotheses may be suggested. First, the specimen here studied could be related to the shallow species *Solemya togata* (no available sequence) and could be the result of an evolutionary process from shallow to deep waters as already documented in other bivalve species (e.g. mytilids; Jones *et al.*, 2006). An alternative hypothesis would be that the specimen is a living relative of the recorded fossil '*Acharax*' *doderleini*.

The majority of *Solemya* species have been found in shallow depths, but Kamenev (2009) reported the occurrence of *Solemya pervernica* in Sagami Bay cold seeps at 1510 m; thus the occurrence of a *Solemya* species in the eastern Mediterranean at 1697 m would be not surprising.

Large size solemyids ascribed to the genus *Acharax* are known to have inhabited the Mediterranean in the past (Taviani, 2010). Solemyids were widely distributed in

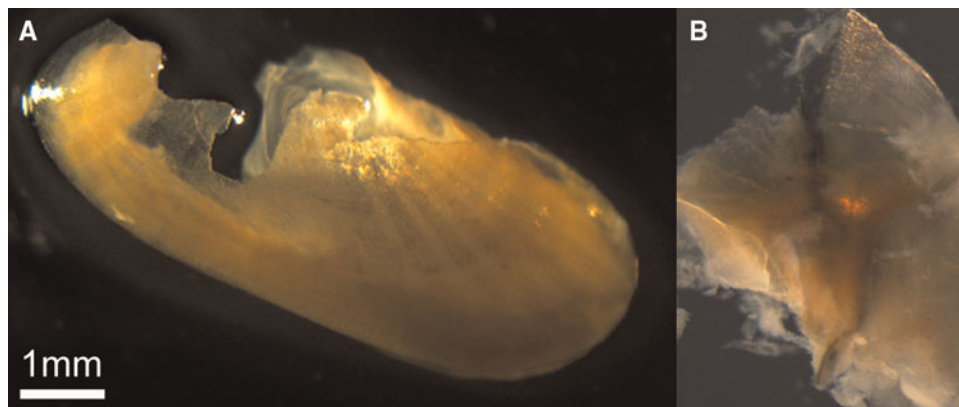


Fig. 2. Solemyidae found in the central province of the Nile Deep-sea Fan: (A) broken shell; (B) ligament detail.

Miocene deep-sea reducing habitats and, after the Messinian salinity crisis (MSC), re-colonized suitable reducing environments up to the Middle Pliocene (Taviani *et al.*, 2008). The putative absence of deep-sea solemyids in the present Mediterranean was puzzling and it was tentatively suggested to be possibly related to temperature (Taviani *et al.*, 2008), although it was anticipated that this absence was only apparent (Taviani, 2010).

Until further molecular data becomes available on other species, these hypotheses cannot be tested.

Despite repeated attempts, no bacterial 16S rRNA gene sequence was amplified. In all previous studies Solemyidae are presented as 'symbiont dependent', with some species having small, reduced, or even absent alimentary tracts (reviewed in Taylor & Glover, 2010). A weak suspension feeding capability is retained in *S. velum* (Krueger *et al.*, 1992). This capability could occur in other species and explain the absence of symbionts, but the most likely hypothesis remains that the protocols employed here actually failed to amplify symbiont DNA.

With the discovery of the first living solemyid at a depth of 1697 m in a cold seep in the eastern Mediterranean, this work extends the known distribution of this bivalve family. More research is needed to explore the deep richness of the Mediterranean Sea where a number of potentially suitable habitats for solemyids are present (Taviani, 2010). Nevertheless we expect to sample more specimens in the future to confidently assess the taxonomic position of Mediterranean deep-water solemyids and to unravel their evolutionary and biogeographical connections.

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Correspondence should be addressed to:

C.F. Rodrigues
Université Pierre-et-Marie-Curie
UMR 7138 (UPMC CNRS IRD MNHN)
Systématique Adaptation, Evolution
Paris, 75052, France
email: clfrodrigues@gmail.com