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SHORT COMMUNICATION

The rhizome layer of *Posidonia oceanica*: an important habitat for Mediterranean brachiopods

Paolo G. Albano[1] · Martina Stockinger[1]

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Abstract

Mediterranean brachiopods are elusive organisms to find alive even if the bathymetric range of some species extends to very shallow waters. We here record an abundant population of *Joania cordata* (Risso, 1826) and *Argyrotheca cuneata* (Risso, 1826) in the rhizome layer of a *Posidonia oceanica* (Linné) Delile, 1813 meadow in Plakias, southwestern Crete from 5 to 20 m depth. Altogether, we collected 963 living individuals and 4309 shells by suction sampling; it is the largest collection of living brachiopods in *Posidonia* meadows ever reported. Although literature records on the occurrence of shallow-water brachiopods in this habitat are few, we claim that *Posidonia* rhizomes are a particularly suitable infralittoral habitat for these organisms due to their sciaphilous conditions. Suction sampling is an effective technique to collect them and can enable the discovery of many more populations in the Mediterranean Sea.

Keywords *Joania cordata* · *Argyrotheca cuneata* · Seagrass · Suction sampling · Crete · Eastern Mediterranean Sea

Introduction

The present-day Mediterranean Sea hosts only 14 species of brachiopods (Logan et al. 2004; Robinson 2017) which prefer habitats with low illumination and are generally reported from coralligenous substrates, coralline algae frameworks typical of the Mediterranean Sea, below 40 m. Some species are known to occur also in shallower waters but only in shaded and protected environments such as caves and beneath boulders (Logan 1979). Shallow-water species are often reported as empty shells from death assemblages whereas findings of living individuals are uncommon and usually limited to a few individuals (e.g. Taddei Ruggiero 1994; Grobe and Lüter 1999; Evangelisti et al. 2011).

We here report an abundant collection of two megathyrid brachiopods, *Joania cordata* (Risso, 1826) and *Argyrotheca cuneata* (Risso, 1826), in the rhizome layer of *Posidonia oceanica* (Linné) Delile, 1813 between 5 and 20 m depth from southwestern Crete. We found hundreds of living individuals and thousands of shells of both species. We claim that direct sampling of this habitat with proper methods, such as suction sampling, can lead to the discovery of similarly abundant populations elsewhere in the Mediterranean Sea.

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✉ Paolo G. Albano
pgalbano@gmail.com

[1] Department of Palaeontology, University of Vienna, Althanstrasse 14, 1090 Vienna, Austria

Material and methods

We sampled a *Posidonia oceanica* meadow in Plakias, southwestern Crete (35.1796°N, 24.3957°E, Fig. 1), from 5 to 20 m depth at 5-m intervals on 8–21 May and 14–27 September 2017. Organisms on the leaves were collected with a net mounted on a metal frame with a 40 × 20-cm opening (Buia et al. 2003). The rhizomes were sampled with air-lift suction sampling (Templado et al. 2010). The sampler consisted of a PVC tube with a length and diameter of 100 cm and 8 cm, respectively. A SCUBA cylinder supplied air and was fitted at 10 cm above the mouth of the tube. At its other end, we attached a removable 0.5-mm mesh nylon bag that could be closed and replaced underwater. Sampling on the rhizomes was carried out on 1-m^2 square areas after defoliation in order to enhance collecting efficacy (Bonfitto et al. 1998). Three replicates per season were sampled at each depth. To assess the *Posidonia* bed structure, the plant shoot density was

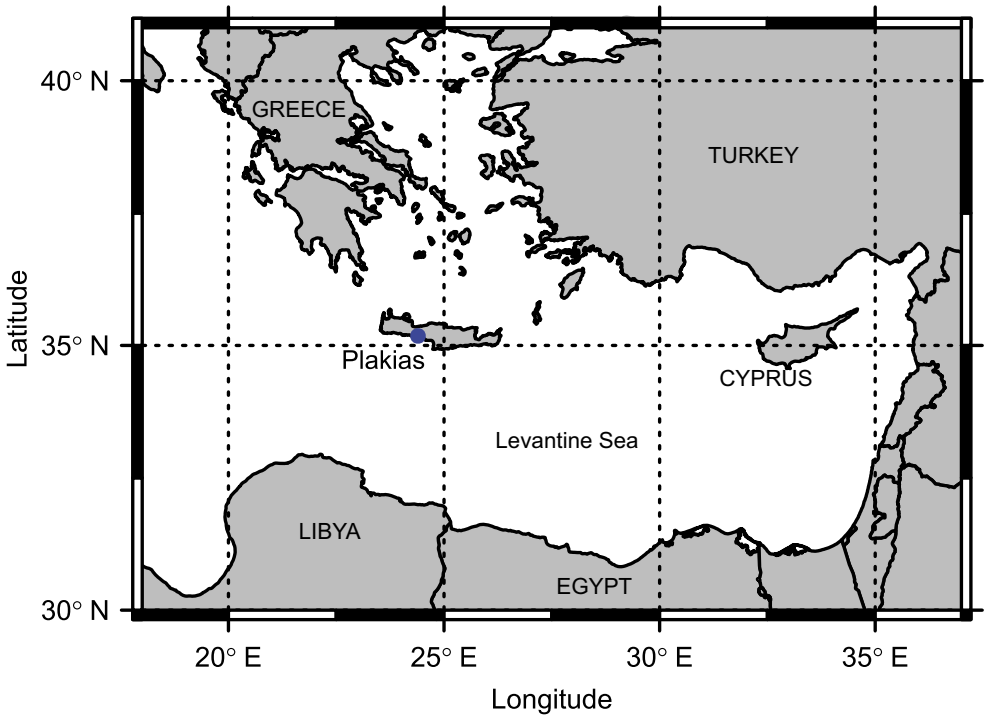

Fig. 1 Geographic location of the study site Plakias, southwestern Crete, in the eastern Mediterranean Sea

quantified by counting on a 40 × 40-cm square area within each 1 m^2 sampled with the air-lift suction sampler.

Samples were sieved with a 1-mm mesh size and sorted under a stereomicroscope in seawater to pick living organisms more easily. The residue was dried and again sorted to pick the empty shells, valves, and overlooked living organisms.

We identified each specimen to the species level on the basis of Logan's review (Logan 1979), counted the individuals, the empty shells, and the valves (as half shell). Photographs were taken using a Zeiss SteREO Discovery.V20 stereomicroscope at multiple focus levels and stacked with Helicon Focus 6 (Helicon Soft Ltd., Roseau Valley, Dominica).

Quantitative data have been deposited in the OBIS database and the samples in the Natural History Museum in Vienna (inventory numbers NHMW 112930/LM/0201 to NHMW 112930/LM/0350 (Mollusca collection)).

Results

We found 963 living brachiopods: 685 *Joania cordata* and 278 *Argyrotheca cuneata*. The great majority was found in the samples from the rhizomes (Fig. 2), but six were also found in the leaf samples. In the rhizomes, both species were abundant at all depths, but we noted a peak in total and mean abundance at 15-m depth (Table 1). We found also 4309 shells: 3231 *Joania cordata*, 1074 *Argyrotheca cuneata*, 3 *Megathiris detruncata* (Gmelin, 1791), and 1 valve of *Novocrania anomala* (Müller, 1776). Although we noted a more abundant living and death assemblage in autumn than in spring, we did not isolate data per season because we suspect that such a pattern could be an artifact of a more intense suction during the autumn fieldwork. The size of both living specimens and empty shells rarely exceeds 4 mm, fully conforming with the size reported for the Mediterranean Sea (Logan 1979).

Most living brachiopods were attached with their pedicle to any hard substrate available such as rhizome fragments, coralline algae, sessile foraminifera, bryozoan colonies, and even inside empty gastropod shells (Fig. 3). The *Posidonia* shoot density declined monotonically with depth (Fig. 4). The meadow hosted a rich community which was dominated by grazers on the leaves, and was more functionally and taxonomically diverse in the rhizomes.

Discussion

Joania cordata and *Argyrotheca cuneata* are two common brachiopods in the Mediterranean Sea and were reported in shallow water also from Greece (Gerovasileiou and Bailly 2016), including Crete (Logan 1979; Brunton 1988; Logan et al. 2002). Their presence in *Posidonia oceanica* meadows was first reported from death assemblages in southern Italy (Taddei Ruggiero 1985). *Joania cordata* was then reported alive in *Posidonia oceanica* rhizomes for the first time on an off-shore reef in the Tyrrhenian Sea: 7 living individuals, along with 97 shells, were collected by suction sampling (Evangelisti et al. 2011). This reef hosted small seagrass

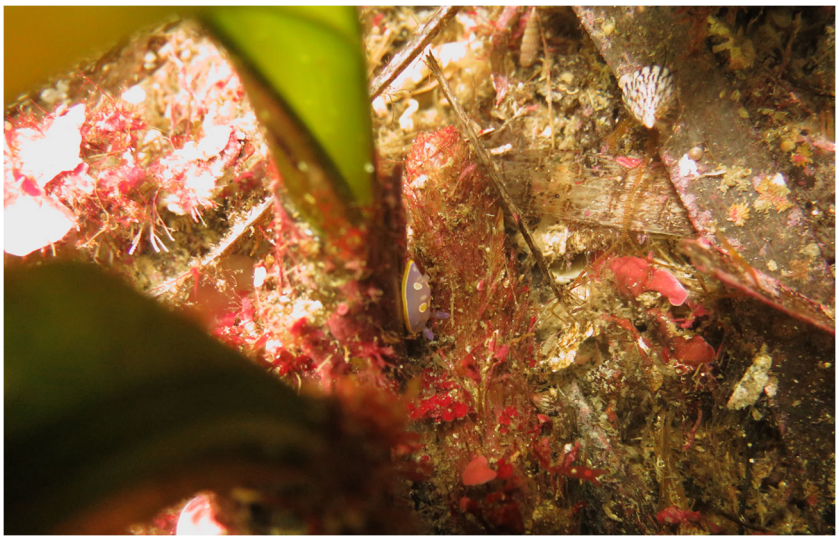

Fig. 2 The rhizome layer of the *Posidonia oceanica* meadow in Plakias, southwestern Crete. The rhizomes host one of the most diverse invertebrate assemblages in the Mediterranean Sea

patches on a hard substrate covered by extensive coralligenous concretions with similar but distinct molluscan assemblages characterized by the presence of several species typical of deeper sciaphilous environments (Albano and Sabelli 2011, 2012). Although we found a few specimens also in the leaf samples, in the Crete meadow, these brachiopods definitely prefer the rhizomes and their low hydrodynamism and dim light. Moreover, this layer has plenty of small and large objects for the brachiopods to attach such as the rhizome themselves and other plant debris, shells, foraminiferal tests, and bryozoan colonies (Fig. 3). Nonetheless, because the shoot density declined monotonically with depth, the abundance peak at 15-m depth, which is particularly remarkable for *Joania cordata*, cannot be easily explained by a calmer or darker environment. Megathyrid brachiopods were found in similar sciaphilic and cryptic habitats also in other regions such as the Caribbean (Asgaard and Stentoft 1984), the Red Sea (Zuschin and Mayrhofer 2009), and the Bay of Fundy, eastern Canada (Noble et al. 1976). The habit of most brachiopods to settle in such habitats may have evolved as a response to the increasing occurrence of grazing invertebrates (e.g. gastropods) during the Mesozoic (Witman and Cooper 1983; Tomašových 2008a, b; Radley 2010).

Megathiris detruncata and *Novocrania anomala* were not found alive. *M. detruncata* is rare in so shallow waters, its optimum range being 20–160 m (Logan 1979). Still, the presence of shells suggests that also this species can be encountered alive, albeit rarely, in *Posidonia* meadows. *Novocrania anomala* does occur in very shallow waters but lives cemented to boulder and shell substrates (Logan 1979). Suitable hard substrates may be rare among the rhizomes and in any case difficult to intercept with our sampling gear.

The absence of previous records of abundant living brachiopods in the rhizome layer may be due to the difficulties in sampling this habitat. Brachiopods are too small to be seen and picked individually. Grabs and other indirect methods do not easily penetrate the *matte,* and, in any case, they would be extremely damaging for the seagrass meadow. For similar reasons, the collection of pieces of rhizomes to be inspected in the laboratory, similar to the direct or indirect collecting of rocks and coralligenous concretions, is not advisable; moreover, cutting into the dense *matte* would be extremely

Table 1 Total and mean abundance per square meter of living brachiopods and empty shells in the rhizome layer of the *Posidonia oceanica* meadow in Plakias, southwestern Crete

	Joania cordata				*Argyrotheca cuneata*			
	Living		Shells		Living		Shells	
Depth (m)	Total abundance	Mean abundance	Total abundance	Mean abundance	Total abundance	Mean abundance	Total abundance	Mean abundance
5	168	28 ± 33	324	54 ± 62	64	11 ± 11	165	28 ± 32
10	177	30 ± 16	762	127 ± 88	57	10 ± 8	200	33 ± 19
15	243	41 ± 23	1210	202 ± 156	83	14 ± 12	344	57 ± 45
20	92	15 ± 5	936	156 ± 66	73	12 ± 3	366	61 ± 21

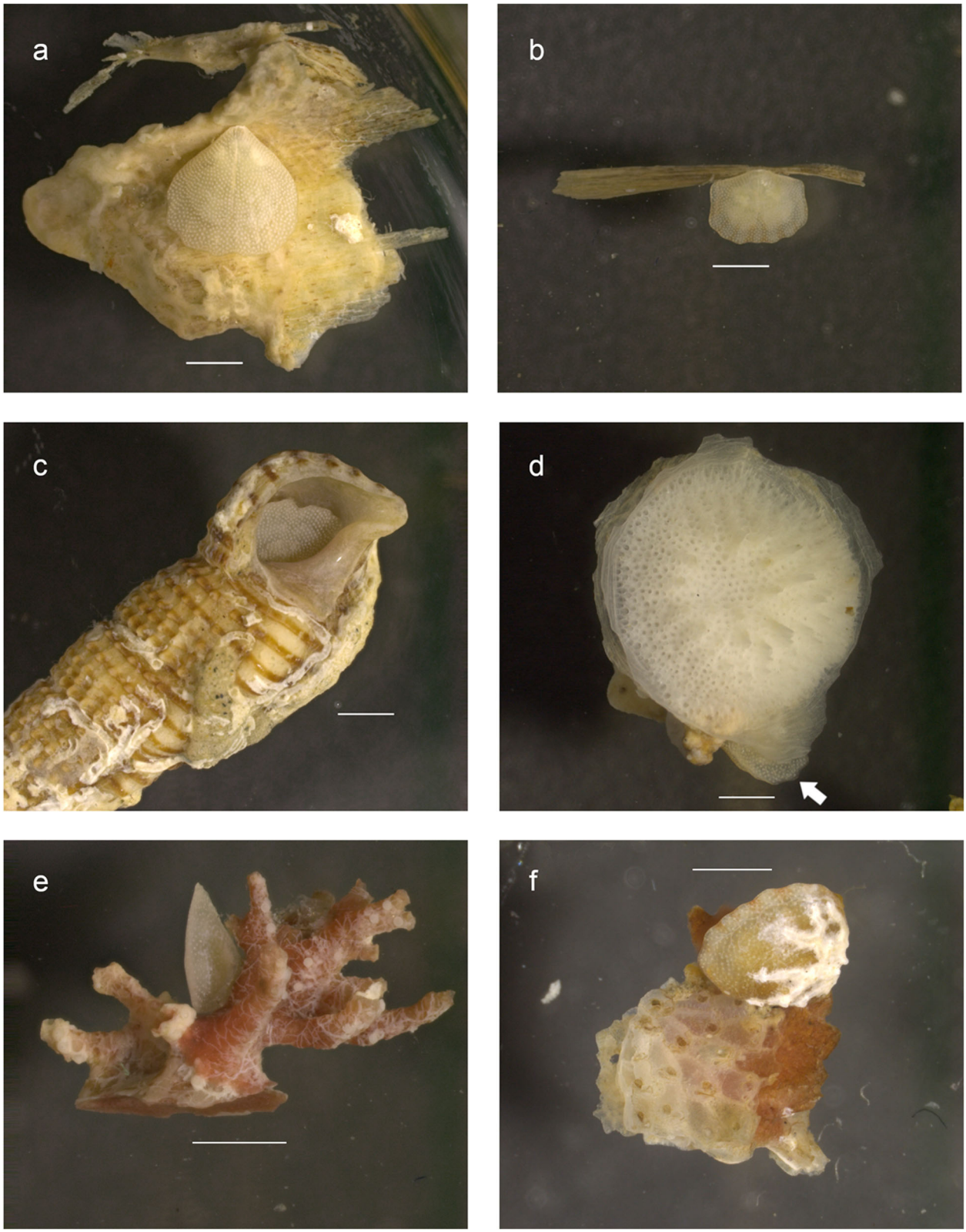

Fig. 3 Living brachiopods from the rhizome layer of the *Posidonia oceanica* meadow in Plakias, southwestern Crete Greece. **a** *Joania cordata* on plant debris, − 20 m; **b** *Argyrotheca cuneata* on plant debris, − 20 m; **c** *Joania cordata* inside the aperture of an empty shell of the gastropod *Bittium latreillii* (Payraudeau, 1826), − 10 m; **d** *Joania cordata* beneath the bryozoan *Patinella radiata* (Audouin, 1826), − 10 m; **e** *Joania cordata* attached to the foraminiferan *Miniacina miniacea* (Pallas, 1766), − 20 m; **f** *Argyrotheca cuneata* attached to the foraminiferan *Miniacina miniacea* (Pallas, 1766) covered by a bryozoan colony of *Hippaliosina depressa* (Busk, 1854). Scale bar 1 mm

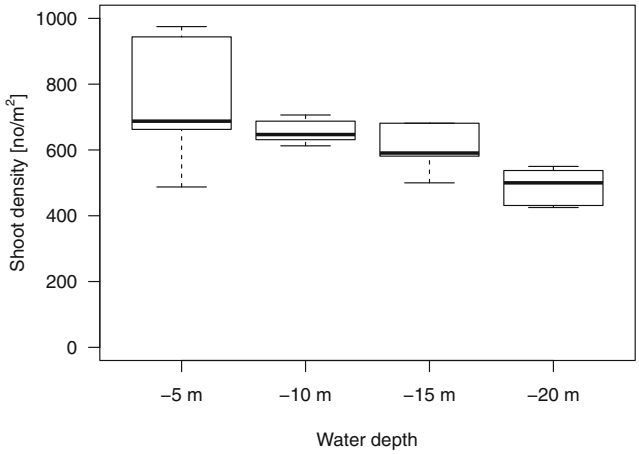

Fig. 4 Shoot density per square meter of the *Posidonia oceanica* meadow in Plakias, southwestern Crete

laborious and strenuous. Suction sampling offers a practical alternative that enables collecting small organisms effectively with minimal harm to the substrate. It can be operated with a diver tank or a motorized pump (Templado et al. 2010) and enables the collection of large amounts of organisms and species perfectly suiting biodiversity inventory needs (Bouchet et al. 2002; Linnane et al. 2003; Albano et al. 2011; Ringvold et al. 2015; Evans et al. 2018). We think that the lack of appropriate sampling approaches has prevented the discovery of shallow-water brachiopod populations in other *Posidonia* meadows so far. This habitat is easily accessible and can offer large sample sizes of living individuals and shells for biological and ecological studies (e.g. Grobe and Lüter 1999; Lüter 2001; Evangelisti et al. 2012, 2014).

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Compliance with ethical standards

Conflict interest The authors declare that they have no conflict of interest.

Ethical approval No animal testing was performed during this study.

Sampling and field studies No permits were required to conduct our fieldwork. The study is compliant with CBD and Nagoya protocols.

Data availability Quantitative data have been deposited in the OBIS database and the samples in the Natural History Museum in Vienna (inventory numbers NHMW 112930/LM/0201 to NHMW 112930/LM/0350 Mollusca collection).

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