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First Survey of the Sponge Community of a Semi-Submerged Marine Cave along the Adriatic Apulian Coast

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Abstract: Mediterranean marine caves have been categorized as both biodiversity reservoirs and vulnerable habitats. However, only a few studies have focused on Porifera assemblages within marine caves along the Adriatic Apulian coast (southern Italy). In this study, the sponge fauna of the Rondinella cave, a semi-submerged marine cave along the coast of Bari (Southern Adriatic Sea), was investigated for the first time. The use of advanced image analysis in combination with targeted sampling has made it possible to determine the spatial distribution and diversity of Porifera along a transect from the entrance to the end of the cave. Data analysis clustered the stations into two groups, separated according to the distance from the entrance and corresponding to the cave entrance and the semi-dark zone. Sponges were found at all stations covering a considerable part of the substrate, with the highest cover values occurring in the semi-dark zone. A total of 54 sponge taxa were identified: 49 Demospongiae, 3 Homoscleromorpha, and 2 Calcarea. Six species are new records for the Apulian marine caves, one species represents a new record for marine caves, and two species are new findings for the southern Adriatic Sea.

Keywords: marine caves; Porifera; benthic communities; Mediterranean Sea

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1. Introduction

The climatic and geological history of the Mediterranean Sea has given rise to a variety of marine caves along its rocky coasts, each with unique features determined by chemical, physical, topographic, and geomorphological variations [1,2]. Because of their uniqueness, they are known for their role as reservoirs of diversity with high conservation value, where rare or previously undocumented cryptic species with bathyal affinities, relict species, and living fossils are found [1]. To safeguard their fragile and biodiverse environments, marine caves are protected under the EU Habitats Directive (92/43/EEC, Habitat cod. 8330) and the Barcelona Convention (UNEP-MAP-RAC/SPA 2015-2008). Despite being included in conservation directives, marine caves in the Mediterranean Sea are still subject to limited research and comprehensive quantitative analyses of their biodiversity [1]. This data deficiency could hinder conservation efforts, as these ecosystems are vulnerable to anthropogenic pressures and environmental alterations due to their low resilience capacity [3,4].

The sessile communities of caves are highly heterogeneous, generally characterized by decreases in diversity, biomass, and three-dimensionality from the entrance to the end of the cave, reflecting the specific cave's topography, light intensity gradients, and hydrodynamic regime [2,5–9]. Among macrozoobenthic organisms, including Mollusca, Chordata, Bryozoa, Cnidaria, and Annelida, the most represented phylum is that of Porifera, which is dominant in terms of species richness, spatial coverage, and biomass [8,10–12]. They perform various functional roles in marine ecosystems, such as increasing habitat complexity and promoting the abundance and diversity of other organisms [13]. As sponges are predominantly sciaphilic [14], they take advantage of the extinction of light and the consequent decrease in photophilic organisms to occupy the freed space, thus transforming the environment into a "sponge realm" [1]. Sponges with specific growth forms are more common in specific sectors of marine caves, which may indicate an adaptation to local environmental conditions [15]. For instance, encrusting sponges prevail in the darker and innermost regions of caves due to their efficient filtration of the limited organic matter present in the water [6,10,16–18].

In the Mediterranean, a total of 329 sponge species have been identified from at least 185 marine caves, including 279 Demospongiae, 29 Calcarea, 20 Homoscleromorpha, and 1 Hexactinellida, which constitute 48% of the total Mediterranean sponge diversity [1,19,20]. The studied caves represent only a fraction of the estimated 3000 marine caves scattered throughout the Mediterranean, according to a recent census [20]. This, coupled with the challenges of identifying and quantifying sponges in the field [21,22], makes marine cave sponges still poorly studied and not included in monitoring programs, highlighting the ongoing need for comprehensive study and understanding of sponge communities in these unique habitats.

The southern Adriatic coast of Apulia is rich in marine caves, which have been surveyed and listed in the regional registry. However, information about sponge populations inhabiting these caves mainly refers to the Tremiti Islands and the Salento area [18 and references therein], thus leaving a knowledge gap for the remaining coast. This study aims to address this gap by describing the distribution and diversity of sponge fauna within the Rondinella cave, a semi-submerged cave situated in the municipality of Polignano a Mare, along the southern Adriatic coast of the Apulia region (southern Italy).

2. Materials and Methods

2.1. Study Area

The territory of Polignano a Mare (Bari, Italy) lies on the Adriatic side of the Apulian carbonate platform, which represents a portion of the Apulian foreland outcropping [23]. The coastal zone constitutes an area of great interest in terms of coastal karst and is characterized by the presence of karst cavities and numerous marine caves [24,25]. Among the numerous marine caves of the Polignano coast, the Rondinella cave, located within the "Costa Ripagnola" Regional Natural Park, is a natural, semi-submerged cave oriented in the NE direction (coordinates 41°00.010′ N, 17°12.646′ E, Figure 1). The presence of two passages, one of which is vertically open on the plateau from land and corresponds to a collapse doline (or sinkhole) and the other is semi-submerged, makes this cave easily accessible.

The semi-submerged area of the Rondinella cave consists of a single large chamber, which is approximately 40 m long and 20 m wide in its largest section (Figure 2), and then reduces to 12 m at the landing of the small pebbly beach. At the end of the main chamber, there is a narrow tunnel, approximately 50 cm in diameter, semi-submerged at the mouth, of difficult access. The vault is between 6 and 8 m high, gradually decreasing when compact limestones are succeeded by breccia cemented by red and yellow soils. The ceiling has clusters of stubby stalactites and is covered with algae, mosses, and lichens [26].

The depth at the entrance is approximately 4 m, then gradually reduces, reaching 2.5 m in the central part and 0 m in the final part. The bottom consists of the initial and middle parts of scattered rock boulders that are replaced by coarse pebbles in the terminal part.

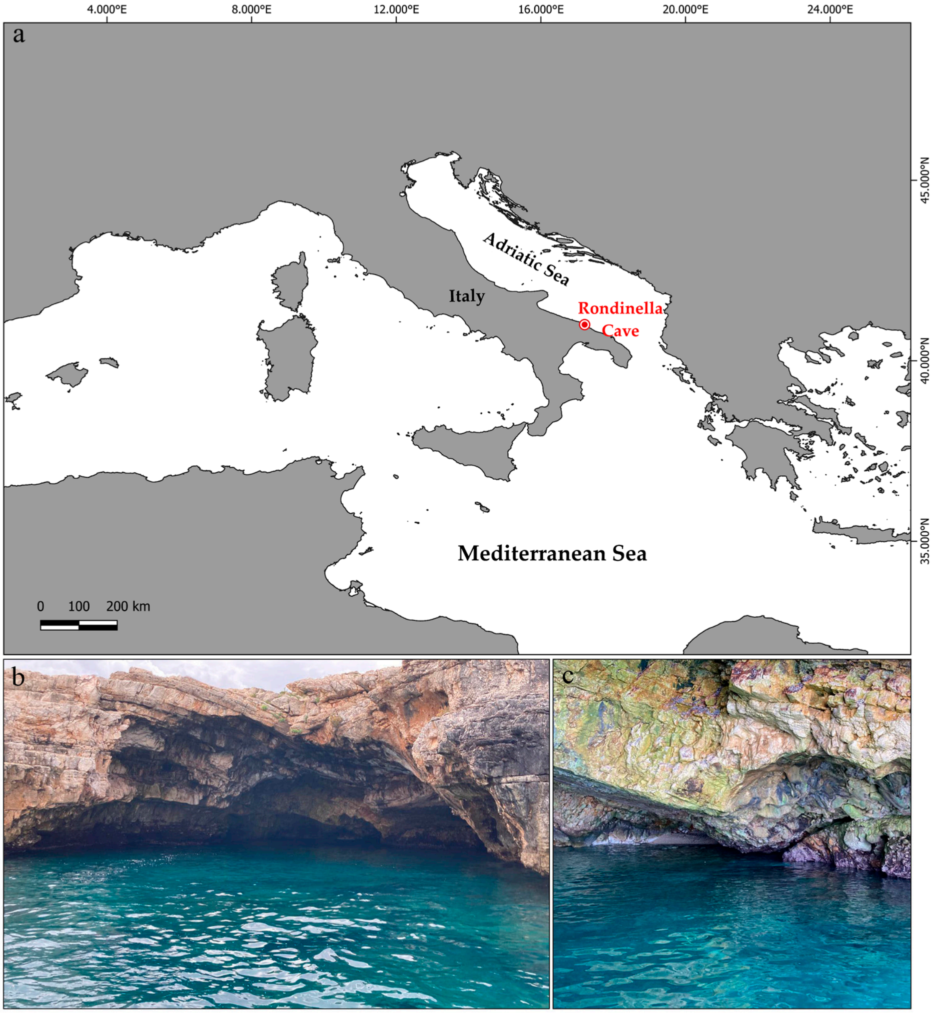

Figure 1. (**a**) Location of the investigated sea cave in the Adriatic Sea; (**b**) semi-submerged entrance of the cave; (**c**) interior of the cave and pebbly beach.

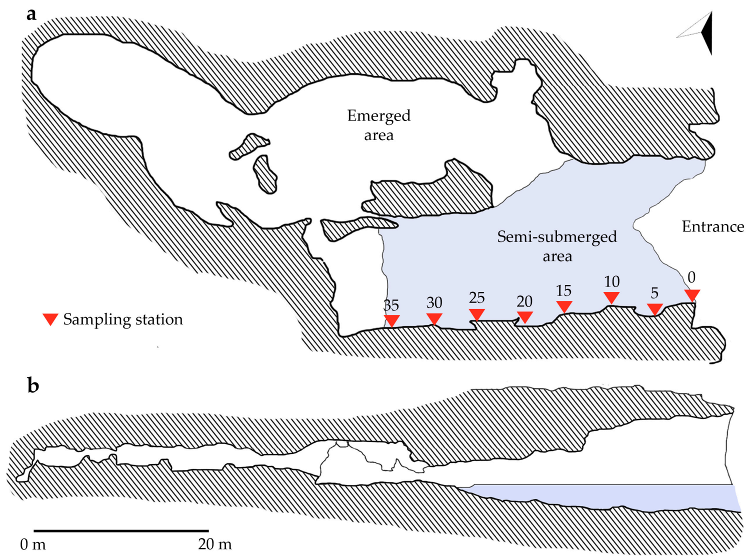

Figure 2. (**a**) Planimetry of Rondinella cave. Triangles indicate the sampling stations along the southern wall and the number the distance from the entrance (meters); (**b**) section of Rondinella cave (modified from http://www.catasto.fspuglia.it/ accessed on 18 March 2024).

2.2. Sampling

2.2.1. Sponge Cover

For the quantitative analysis of the sponge community, video surveys were conducted following a transect from the entrance to the end of the cave along the southern wall, according to the morphology of the cave. Sampling stations were established every five meters along the transect, resulting in a total of 8 stations (Figure 2). Videos were recorded using a GoPro Hero 10 camera, uncapped and equipped with two EasyDive illuminators (with an LED power of up to 15,000 lumens) and two LED pointers placed at a distance of 20 cm. To capture information that was as representative as possible of the entire cave, at least ten frames per station were extracted.

The percentage of biotic cover for Porifera was calculated by analyzing a sub-area of 400 cm^2 at the center of each image (quadrats with a length of 20 cm $\times$ 20 cm) [27]. To obtain more concise and explicative bio-ecological information, sponges were identified at the lowest possible taxonomic level. Taxa with very similar external morphology were grouped into operational taxonomic units (OTUs) [28]. The identified OTUs were orange encrusting sponges (OES), white encrusting sponges (WES), and black horny sponges (BHS). The percent of cover of the identified taxa for every quadrat was calculated using PhotoQuad software (v. 1_4) [29].

2.2.2. Taxonomic Analysis

Sampling was carried out in 2022 by SCUBA divers through a targeted collection of sponge specimens, and was performed at each defined station. Collected samples were stored in 70% ethanol. For species identification, slides of dissociated spicules and transversal sections were prepared following the methods proposed by Rutzler [30]. For each type of spicule, 20 measures were taken using a Nikon ECLIPSE 80i microscope. Histological sections were made for the identification of mineral skeleton-less species. Light microscopy images were made using a Nikon Eclipse Ni microscope with a DS-Fi3 camera and NIS D 5.30.00 acquisition software. Taxonomic identification was conducted using "Systema Porifera" [31], "Fauna d'Italia" [32], and all available literature. The systematics followed Morrow and Cárdenas [33], and the updated nomenclature was checked using the World Porifera Database [34]. A comparison with the previous literature on the Apulian marine caves [20] was carried out to highlight new reports on Apulian marine caves. Additionally, through the World Register of Marine Cave Species [35] (a database that refers only to marine cave species), we checked whether the species were newly found in marine cave environments. The geographic distribution of sponges was initially compared with that reported by Pansini and Longo [36], and then complemented with an updated bibliography. Finally, sponge species were categorized according to their morphology to evaluate morphological dominance in the cave [37]. The chosen morphological categories were boring, insinuating, encrusting, massive, and erect [38].

2.2.3. Statistical Analysis

Canonical correspondence analysis (CCA), based on the Bray–Curtis similarity matrix of square-root-transformed percentage cover data, was performed to explore the relationships between the percentage cover of sponges and the distance from the entrance. The taxa responsible for multivariate patterns were overlaid on the plot as vectors. Two-way PERMANOVA was performed for two factors: distance from the entrance (Dist), fixed with eight levels (0, 5, 10, 15, 20, 25, 30 and 35 m), and light, fixed with two levels (H: high intensity, L: low intensity). A non-parametric Kruskal–Wallis test (KW) was applied to test for significant differences in the total percentage of sponge cover in each station. To illustrate this, the cover in each station was plotted with a boxplot.

Finally, regarding the taxonomic analysis, a cluster analysis based on the Jaccard similarity matrix (the paired group average method) of qualitative (presence–absence) data was applied to evaluate the sponge distribution at all examined stations. The clustering verification was performed with one-way ANOSIM.

CCA was conducted using Primer-E v6 [39] with the PERMANOVA extension [40], while two-way PERMANOVA, the Kruskal–Wallis test, and one-way ANOSIM were conducted using Past (Paleontological Statistical) software (v_4.03) [41].

3. Results

3.1. Sponge Cover

The video analysis, coupled with the targeted sampling of specimens, allowed for the identification of 18 sponge taxa: *Oscarella lobularis* (Schmidt, 1862), *Penares helleri* (Schmidt, 1864), *Erylus discophorus* (Schmidt, 1862), *Geodia cydonium* (Linnaeus, 1767), *Cliona rhodensis* Rützler and Bromley, 1981, *Cliona schmidtii* (Ridley, 1881), *Cliona viridis* (Schmidt, 1862), Suberitidae, *Terpios gelatinosus* (Bowerbank, 1866), *Tethya aurantium* (Pallas, 1766), *Phorbas fictitius* (Bowerbank, 1866), *P. tenacior* (Topsent, 1925), *Bubaris vermiculata* (Bowerbank, 1866), *Dendroxea lenis* (Topsent, 1892), *Petrosia* spp., *Ircinia variabilis* (Schmidt, 1862), *Chondrosia reniformis* Nardo, 1847, and *Aplysina aerophoba* (Nardo, 1833) (Figures S1–S3, Supplementary Materials).

The percentage of cover of the taxa observed in each analyzed frame ranged from 13.45% (10 m station) to 77.87% (35 m station). The highest median reported was 57.1 ± 2.2% at the 25 m station, followed by 47.3 ± 6% at the 35 m station. The lowest median (30.8 ± 5.4%), instead, was reported at the 15 m station (Figure 3). The observed differences were, however, significant (Kruskal–Wallis test: $p < 0.05$). *C. reniformis* was the species that presented the highest cover values throughout the entire cave, with a maximum value of 18.77 ± 4.98% at 25 m. OES, which included *Crambe crambe* (Schmidt, 1862). *Spirastrella cunctatrix* Schmidt, 1868 also showed high values, mainly at the station at 15 m, where it reached 15.95 ± 7.4%. This species group was also the most common, as it was found in 93% of the analyzed frames. Species belonging to the Suberitidae family were also commonly found (88.9% of the frames). They presented, however, relatively lower values of average percentage cover, with the highest value of 8.17 ± 3.42% at the 20 m station and a lower value of 0.63 ± 0.21% at the 30 m station. Finally, even if highly represented in the cave, the perforating species of the genus *Cliona* presented low cover values, as only their papilla counted for the cover (Table S1, Supplementary Materials).

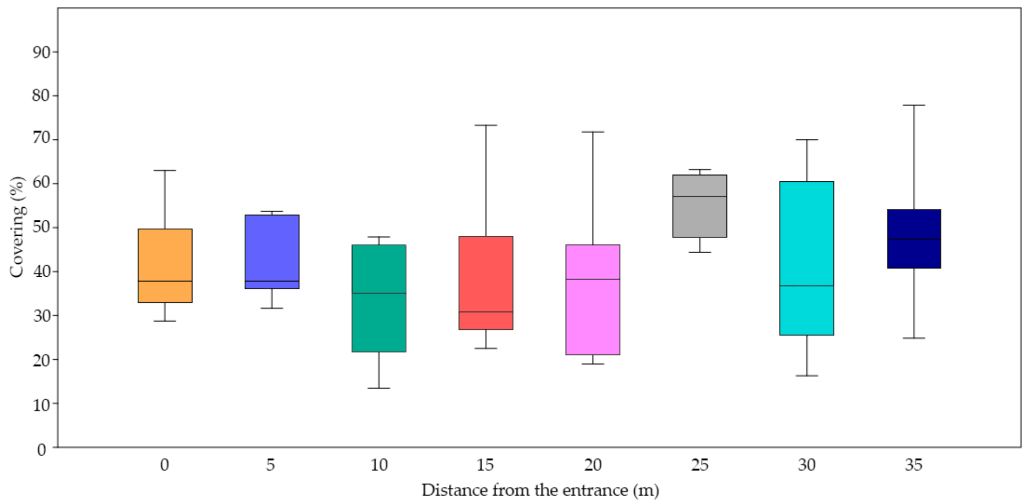

Figure 3. Box plots representing the percent values of sponge cover in each station of the Rondinella semi-submerged marine cave. Central lines in boxplots correspond to medians; the tops and bottoms of the boxes represent the 1st and 3rd quartiles.

Multivariate resemblance analysis (CCA) of cover values at each station revealed two major groups (Figure 4): one corresponding to the cave entrance (CE, in the graphic represented by the symbols on the left), from the entrance to 20 m, and the other corresponding to those of the internal cave stations in the semi-dark zone (SD), corresponding to the symbols on the right, from 25 m to the end of the cave. The factors "Distance" and "Light" resulted as significant for the sponge community (PERMANOVA: $p < 0.05$).

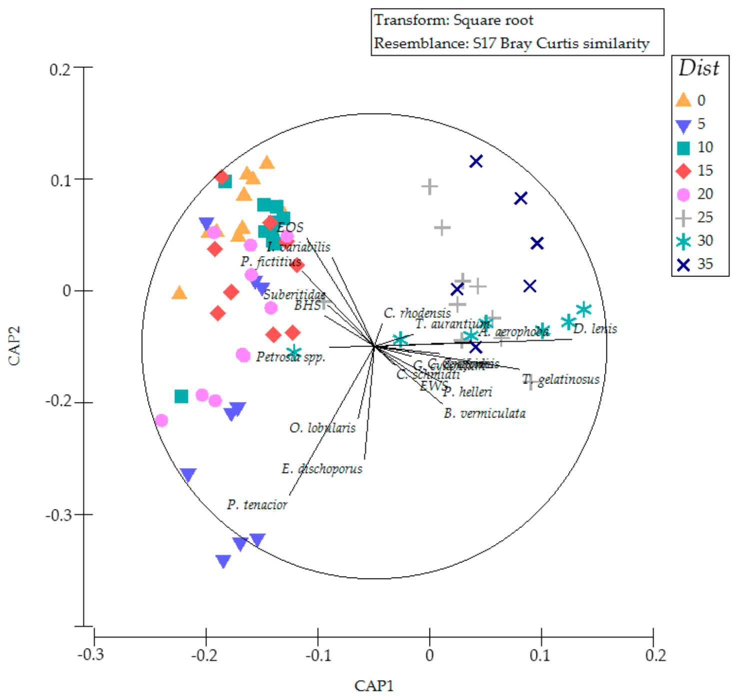

Figure 4. Canonical correspondence analysis (CCA) showing the composition of the sponge community and its correlation with distance from entrance. Taxa overlaid on the plot as vectors.

The two defined groups, CE and SD, were characterized by distinctive taxa: the stations from the entrance to 20 m were characterized by the presence of *Petrosia* spp., Suberitidae, BHS, *P. fictitius*, *I. variabilis*, and the species included in the out "Encrusting Orange Sponge"; the stations from 25 m to the end of the cave were, instead, distinguished by *T. aurantium*, *A. aerophoba*, *D. lenis*, *C. reniformis*, *Cliona* spp., *G. cydonium*, *P. helleri*, *T. gelatinosus*, and *B. vermiculata* (Figure 4).

3.2. Taxonomic Composition

The sponge species recorded from the Rondinella cave are listed in Table 1. A total of 54 taxa were recorded, 50 of which were identified at the species level, 3 at the genus level, and 1 at the family level. Most species (49) appertained to the class of Demospongiae (3 subclasses, 12 orders, 25 families, 37 genera), followed by 3 species of Homoscleromorpha (1 order, 2 families, 3 genera) and 2 Calcarea (2 subclasses, 2 orders, 2 families, 2 genera). The order Poecilosclerida was the most represented, with five families, seven genera, and nine taxa. Tetractinellida and Clionaida, with eight and seven taxa, respectively, were other representative orders. The endemic Mediterranean species found numbered seven, corresponding to almost 11% of the total. Considering the list of species surveyed in Apulian marine caves [20], *Sycon raphanus* Schmidt, 1862 (Figure 5a), *Stelletta lactea* (Carter, 1871), *Siphonodictyon infestum* (Johnson, 1899), *Hamigera hamigera* (Schmidt, 1862), *Clathria* (*Microciona*) *strepsitoxa* (Hope, 1889), and *Timea crassa* (Topsent, 1900) were new records; of these, *S. infestum* was a new record for caves (WoRCS). Two species *S. lacteai* and *T. crassa* were new findings for the Southern Adriatic Sea (Figures S4–S9, Supplementary Materials). Three of the species found, *C. reniformis*, *A. aerophoba*, and *C. schmidtii* (Figure 5b,e,f, respectively), were present at all stations. *I. variabilis*, *P.* (*Petrosia*) *ficiformis* (Figure 5c), *B. vermiculata*, *G. cydonium*, *P. fictitius*, *P. tenacior*, and *T. gelatinosus* were found in at least four of the stations (Table 1).

Table 1. List of Porifera taxa identified in each station of the Rondinella cave (southern Adriatic Sea). New records and growth forms are also represented. Underlined species indicate Mediterranean endemism. New records for: "#" = Apulian cave; "§" = cave; "Ø" = southern Adriatic. "*" = indicates the presence of the taxa in the corresponding stations. Growth form (GF): M = massive; Er = erect; En = encrusting; Ex = excavating; In = insinuating.

	Distance from Entrance (m)								GF
	0	5	10	15	20	25	30	35	
Calcarea									
Subclass: **Calcinea**									
Order: **Clathrinidae**									
Leucetta solida (Schmidt, 1862)		*							M
Subclass: **Calcaronea**									
Order: **Leucosolenida**									
Sycon raphanus Schmidt, 1862 [#]					*				Er
Homoscleromorpha									
Order: **Homosclerophorida**									
Oscarella lobularis (Schmidt, 1862)		*							M
Plakina trilopha Schulze, 1880					*				En
Plakortis simplex Schulze, 1880	*			*					En
Demospongiae									
Subclass: **Verongimorpha**									
Order: **Chondrosida**									
Chondrosia reniformis Nardo, 1847	*	*	*	*	*	*	*	*	M
Order: **Verongida**									
Aplysina aerophoba (Nardo, 1833)	*	*	*	*	*	*	*	*	Er
Subclass: **Keratosa**									
Order: **Dictyoceratida**									
Ircinia oros (Schmidt, 1864)	*								M
Ircinia variabilis (Schmidt, 1862)	*		*	*	*	*		*	M
Sarcotragus spinosulus Schmidt, 1862	*			*					M
Dysidea fragilis (Montagu, 1814)	*								En
Subclass: **Heteroscleromorpha**									
Order: **Haplosclerida**									
Dendroxea lenis (Topsent, 1892)					*	*	*	*	En
Haliclona (*Rhizoniera*) *rosea* (Bowebank, 1866)	*								M
Petrosia (*Petrosia*) *ficiformis* (Poiret, 1789)	*	*	*	*	*				M
Petrosia (*Strongylophora*) cf. *vansoesti* Boury-Esnault, Pansini, and Uriz, 1994								*	M
Siphonodictyon infestum (Johnson, 1899) [#,§]	*					*			Ex
Order: **Axinellida**									
Eurypon sp.					*				En
Order: **Bubarida**									
Bubaris vermiculata (Bowerbank, 1866)		*	*		*	*	*		En
Dictyonella marsillii (Topsent, 1893)			*						M
Order: **Biemnida**									
*Rhabderemia topsenti*van Soest and Hooper, 1993				*			*		En

Table 1. *Cont.*

	Distance from Entrance (m)								GF
	0	**5**	**10**	**15**	**20**	**25**	**30**	**35**	
Order: **Tetractinellida**									
Dercitus (*Stoeba*) *plicatus* (Schmidt, 1868)		*	*						In
Jaspis johnstonii (Schmidt, 1862)		*							Ex, In
Stelletta lactea Carter, 1871 [#,Ø]							*	*	En
Erylus discophorus (Schmidt, 1862)		*	*	*	*	*	*		En
Geodia cydonium (Linnaeus, 1767)	*	*	*	*		*		*	M
Penares helleri (Schmidt, 1864)		*		*		*			M
Alectona millari Carter, 1879						*	*	*	Ex
Thoosa mollis Volz, 1939	*			*		*	*		Ex
Order: **Poecilosclerida**									
Crambe crambe (Schmidt, 1862)		*							En
Hamigera hamigera (Schmidt, 1862) [#,Ø]	*								En
Hymedesmia (*Hymedesmia*) *peachii* Bowerbank, 1882		*							En
Hymedesmia sp.	*			*		*			En
Phorbas fictitius (Bowerbank, 1866)	*	*	*	*	*	*			En
Phorbas tenacior (Topsent, 1925)	*	*	*	*	*				En
Clathria (*Microciona*) *strepsitoxa* (Hope, 1889) [#]		*							En
Mycale (*Mycale*) *lingua* (Bowerbank, 1866)	*								En
Tedania (*Tedania*) *anhelans* (Vio in Olivi, 1792)	*	*							En
Order: **Clionaida**									
Cliona celata Grant, 1826	*				*			*	Ex
Cliona rhodensis Rützler and Bromley, 1981	*		*	*		*	*	*	Ex
Cliona schmidtii (Ridley, 1881)	*	*	*	*	*	*	*	*	Ex
Cliona vermifera Hancock, 1867						*	*	*	Ex
Cliona viridis (Schmidt, 1862)	*					*	*	*	Ex
Cliona sp.			*						Ex
Spirastrella cunctatrix Schmidt, 1868		*		*	*	*	*		En
Order: **Tethyida**									
Tethya aurantium (Pallas, 1766)	*			*				*	M
Timea crassa (Topsent, 1900) [#,Ø]			*						En
Timea fasciata Topsent, 1934		*							En
Timea stellata (Bowerbank,1866)	*			*					En
Order: **Suberitida**									
Aaptos aaptos (Schmidt, 1864)		*		*	*		*	*	En
Pseudosuberites sulphureus (Bowerbank, 1866)		*							En
Terpios gelatinosus (Bowerbank, 1866)		*	*	*	*	*	*	*	En
Halichondria (*Halichondria*) *contorta* (Sarà, 1961)				*					En
Halichondriidae						*			En
Topsentia cf. *lacazei* (Schmidt, 1868)						*			En

Figure 5. (**a**) *Sycon raphanus*; (**b**) *Chondrosia reniformis* and *Tethya aurantium*; (**c**) *Petrosia* (*Petrosia*) *ficiformis* with vertical irregular digitiform processes; (**d**) *Erylus discophorus*; (**e**) *Geodia cydonium* (down) and miniaturized growth form of *Aplysina aerophoba* (top); (**f**) *Cliona schmidtii*.

The cluster analysis of sponge species from the presence–absence matrix distinguished two groups of stations: the first one, corresponding to the cave entrance (CE), included stations from 0 to 20 m; the second one, corresponding to the semi-dark zone (SD), included stations from 25 to 35 m. These differences were confirmed with one-way ANOVA: $p < 0.05$ (Figure 6).

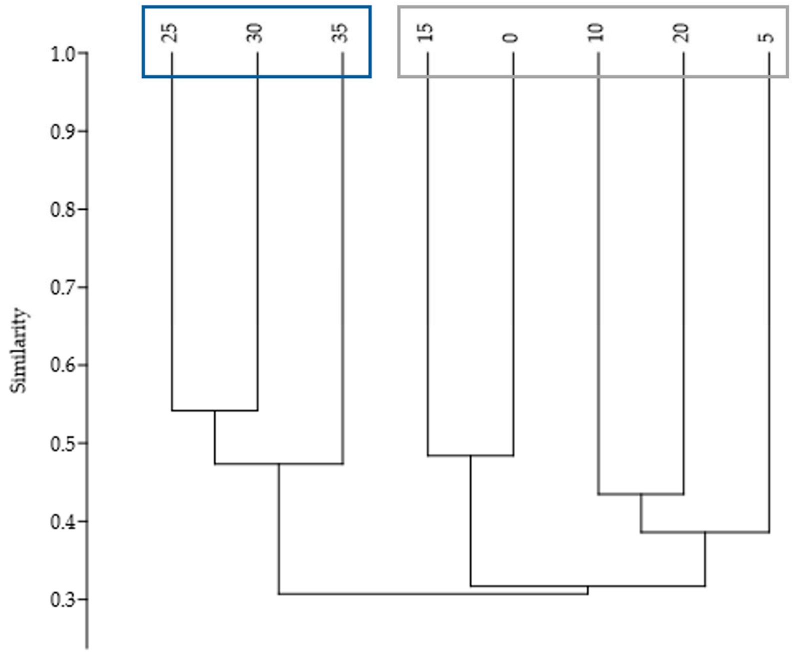

Figure 6. Cluster analysis based on the Jaccard coefficient of similarity (paired group average method). Blue frame corresponds to the semi-dark zone (SD), gray frame corresponds to the cave entrance (CE).

The number of sponge taxa surveyed in the eight stations investigated varied from 16 to 24, as recorded at the end (35 m) and the entrance (0 m) of the cave, respectively. Considering the growth forms of the identified taxa, sponges with an encrusting habitus dominated, reaching 52% of the total species (Figure 7a). Sponges with a boring or insinuating growth form reached a maximum value in the station at 25 m from the entrance, with seven taxa; contrarily, massive and erect growth forms were represented by only two species at 30 m (Figure 7b).

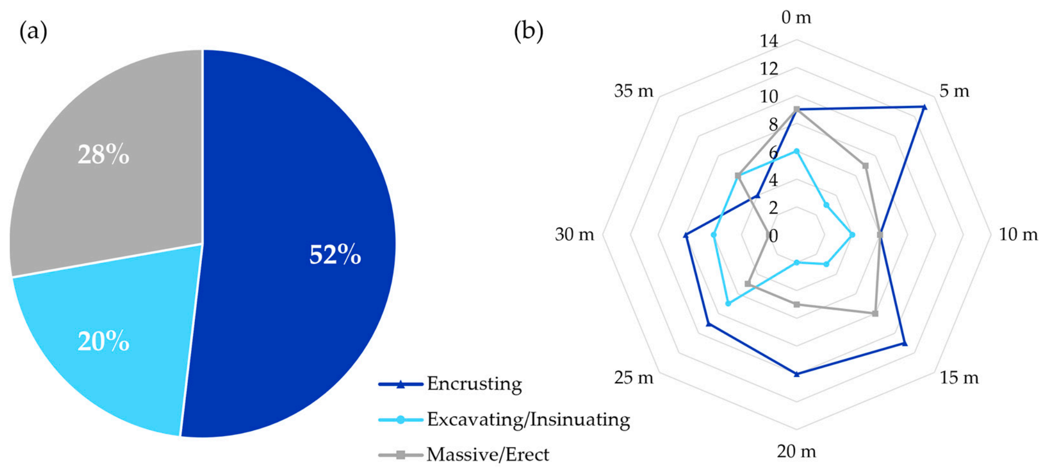

Figure 7. (**a**) Pie chart showing the percentage of sponge taxa surveyed in Rondinella cave considering different growth forms; (**b**) distribution of the sponge taxa among stations according to their growing forms.

4. Discussion

Marine caves are the perfect habitat for the study of sponge communities: to date, 48% of Mediterranean Porifera have been found in marine caves [19]. In this habitat, especially in the darker zone, sponges can be considered habitat-forming species, as they can support rich associated macrofauna assemblages and increase habitat complexity [5]. So far, however, few studies have focused on the sponge communities of marine caves along the Apulian Adriatic coast. This study provides a first description of the diversity and spatial distribution of sponge assemblages in a marine cave of the southern Adriatic: the semi-submerged Rondinella cave located in the municipality of Polignano a Mare (BA).

A total of 54 taxa have been identified, with demosponges comprising the majority of the reported sponge species and Poecilosclerida being the most represented order. Similar species richness values have been reported for other Mediterranean Sea caves [1,10,42–45]. Among the species commonly found in Mediterranean caves [1,22], we have found *O. lobularis*, *Jaspis johnstonii* (Schmidt, 1862), *P. helleri*, *E. discophorus*, *C. viridis*, *C. schmidtii*, *C. celata* Grant, 1826, *S. cunctatrix*, *Aaptos aaptos* (Schmidt, 1864), *T. gelatinosus*, *C. reniformis*, *C. crambe*, *P. tenacior*, *P. ficiformis*, *I. variabilis*, *I. oros* (Schmidt, 1864), and *D. fragilis* (Montagu, 1814). In contrast, three species have been found until now in a single Mediterranean marine cave: *C. vermifera* in the Bue Marino cave (Tremiti Archipelago) [10], *M. lingua* in the Viole cave (Tremiti Archipelago) [42] and *T. crassa* in the Endoume cave (Marseille) [46].

Regarding the Apulian coast, to date, a total of 145 Porifera species have been reported in marine caves on this coast [20]. Of these species, 44 have also been found in Rondinella cave, while 6 species (*S. raphanus*, *S. infestum*, *S. lactea*, *H. hamigera*, *C.* (*Microciona*) *strepsitoxa*, and *T. crassa*) represent new records for the Apulian marine caves. The presence of *Halichondria* (*Halichondria*) *contorta* (Sarà, 1961), which has only been reported in cave environments along the Apulian coast, is also noteworthy [10,18,47]. On the other hand, *S. lactea* and *H. hamigera*, reported only in the north Adriatic [36,48], were surveyed in the southern Adriatic for the first time. In addition, *C.* (*Microciona*) *strepsitoxa* represents the second report for the Adriatic Sea [49].

Considering the growth forms of sponges, half of the sponges identified by video analysis showed an encrusting habitus. The remaining 50% were massive, insinuating, or boring forms. These data may be useful for monitoring purposes, as previous observations in other marine caves over a 50-year monitoring period have revealed a shift from three-dimensional to two-dimensional growth forms, which are more resilient to thermal anomalies [47,50–52]. Related to this, it is also important to note the presence of a miniaturized growth form of *A. aerophoba*, already reported in the Ligurian, Ionian, and Northern Adriatic seas [52,53]. It is likely that the development of this variant over the last few years has been linked to climatic anomalies that have affected the Mediterranean Sea [54]. Finally, within the boring forms category, 12 taxa with this growth form were surveyed in Rondinella cave. Here, the presence of rhodophyte algae and crustaceans from the Cirripedia subclass has created an endolithic layer that is easily perforable by boring or insinuating species [5,10].

The analysis of photographic images made it possible to obtain information on the distributional patterns of the sponge population, which were widespread at all the stations within the cave. The substrate cover reached maximum values in the semi-dark zone of the cave, with the highest value (77.8%) obtained at the 35 m station. In this cave, the large opening of the entrance vault (74 m^2) could have caused algae to grow up to 20 m away (in the CE zone), making competition an important factor that does not allow for the maximum development of sponges. They, instead, found ideal conditions in the semi-dark zone, as they are mainly sciaphilous [14], and with decreasing light, they overcome competition against macroalgae and dominate semi-dark communities [55].

The distance from the entrance also played a key role in explaining the differences in sponge distribution, as highlighted by CCA and cluster analysis. Considering both the sponge distribution data, obtained from video analysis, and the species surveyed during sampling, two groups were defined: one corresponding to the cave entrance zone (CE) and the other corresponding to the semi-dark zone (SD). Some Porifera species have been confirmed to have a preferential zone in which they develop [10,42,56–59]. In the case of the Rondinella cave, *C. vermifera*, *Topsentia* cf *lacazei*, and *D. lenis* were found in areas farthest from the entrance, while two species belonging to the order Poecilosclerida (*Tedania anhelans* and *Mycale lingua*) could only be found in the cave entrance zone [1]. Nonetheless, considering the literature, the distance from the entrance to the cave end is not the only factor determining the distribution of sponges [60]. Apart from the light gradient and entrance area, the key roles of water movement and water renewal should also be considered [9,10,61–63]. In the Rondinella cave, water movement and renewal, both useful for nutrient supplies, removal of catabolites, and transport of larvae [64], may be elevated throughout the entire cave, as it is a semi-submerged cave with a relatively small extent. Due to the combination of all these factors, the Rondinella cave does not show a decrease in diversity or percent cover toward the innermost part, as occurs in completely submerged caves. In these caves, the constant decreasing trend [10] and zonation patterns are more apparent than those of semi-submerged caves [61].

The superficial marine cave environments harbor highly diverse sponge fauna, comparable in terms of population richness and number of species to that of the pre-coralligenous and coralligenous communities of the circalittoral zone [42,65]. Moreover, through water circulation, biological interactions, and species connectivity, marine caves are ecologically connected with coralligenous assemblages, but also with mesophotic communities [20,66]. Despite being separated by hundreds of kilometers, these ecosystems also share several habitat similarities, such as low light intensity and limited food resources [67,68]. Indeed, 77% of the surveyed species in Rondinella cave were also reported in association with coralligenous biocenoses, while 50% were found in mesophotic environments. Understanding and protecting these habitats is essential for conserving biodiversity and maintaining ecosystem health in coastal regions.

5. Conclusions

The results of this study: (i) reveal the different distributions of Porifera along the transect and species richness confirms that caves are suitable for sponge communities; (ii) increase the existing data on sponges in Apulian marine caves, emphasizing the need for further research to enhance scientific knowledge of marine caves along the Adriatic coast; and (iii) highlight the need for establishing a baseline of sponge fauna composition that will serve as a basis for effective management, conservation, and restoration efforts. This is particularly crucial given the presence of protected species in the Rondinella cave, such as *A. aerophoba*, *G. cydonium*, and *T. aurantium*, falling under the protocol SPA/BIO [69].

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/jmse12040682/s1, Figures S1–S9: Images of the Rondinella cave and main sponge spicule complements. The images report the species belonging to the genus *Cliona*, *Phorbas*, and the new records from Apulian marine caves. Table S1: Average percent cover (±SE) of Porifera in each station along the left wall of the Rondinella cave.

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