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A Vermetid Bioconstruction at the Adriatic Coast of Apulia (Italy)

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Abstract: This study presents the first comprehensive data on a vermetid formation along the Apulian coast of the Adriatic Sea, representing one of the northernmost records in the Mediterranean. Surveys along the Brindisi coastline employed visual inspection to map the bioconstruction's distribution and extension. Detailed data on the bioconstruction inner and the outer edge length, thickness, width, slope and topographic complexity were collected at three selected sites. Moreover, photographic replicates were used to assess shell aperture density and diameters of *Dendropoma* sp. Associated fauna was studied using two quantitative sampling squares in each transect. The results showed that the vermetid bioconstruction consisted of a thin, encrusted monolayer (thickness < 1.5 cm) that extended for 3.273 linear kilometers, covering 17.23% of the investigated area; it had an average width of 0.5 m, with a mean density of *Dendropoma* sp. at 2.52 ind/cm^2. The associated fauna was composed of 47 taxa dominated by crustaceans, mollusks and annelids. Species richness was correlated with the bioconstruction's thickness and complexity. These findings underline the ecological importance of vermetid bioconstructions as biodiversity hotspots. The lack of massive mortality events along the Apulian coast, in contrast to other Mediterranean vermetid bioconstructions, underscores the necessity for targeted conservation measures.

Keywords: vermetid reef; *Dendropoma* sp.; associated fauna; Adriatic Sea

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1. Introduction

Vermetid bioconstructions are peculiar formations that border rocky shores in the intertidal zone along the southern coast of the Western and especially Eastern Mediterranean Sea [1–5]. The main bioconstructors are represented by sessile and gregarious prosobranch gastropods of the family Vermetidae, genus *Dendropoma.* Phylogenetic studies based on molecular data [6,7] have revealed that the Mediterranean reef-building gastropod formerly known as *Dendropoma petraeum* (Monterosato, 1884) consists of a complex of at least four cryptic species that have non-overlapping distributions. Templado et al. [8] assigned the name *Dendropoma cristatum* (Biondi, 1859) to the species in this complex that is found in the central Mediterranean, while the name *Dendropoma anguliferum* (Monterosato, 1878) was assigned to the Levantine species. The same former authors described the species distributed in the southwestern Mediterranean and neighboring Atlantic coasts, referring to it as *Dendropoma lebeche* [8]; the remaining cryptic species from the Ionian–Aegean areas is taxonomically new to science. Despite the differences in naming, all species within this complex inhabit similar habitats and play the same ecological role [8].

Vermetid formations exhibit a variety of morphologies, ranging from thin crusts to thick platforms that extend towards the sea, as well as mushroom-like pillars, micro-atolls and islands formed through differential erosive processes [3,4,9]. Due to their horizontal extension in the upper infralittoral fringe, these bioconstructions play an important role in enhancing habitat complexity, modulating coastal morphological processes and providing shelter, food resources and nursery areas for many invertebrates and fishes [2,9–17]. The largest formations are located along the coasts of Israel and Lebanon, but also those of Turkey, Crete, Spain and the Balearic Islands, Algeria, Morocco and Malta [1,18–30]. In Italy, the most extensive bioconstructions can found in the Southern Tyrrhenian Sea, particularly along the coast of Sicily between the Cefalù promontory and the coast of Trapani, and in the Egadi islands [3,10,31]. Isolated reefs are found at Milazzo Cape and around Taormina and Syracuse, as well as off the coasts of the islands of Lampedusa and Ustica. In the Central Tyrrhenian Sea, vermetid formations are present in the Gulf of Naples [32] and along the north-eastern coast of Sardinia between Capo Figari and Tavolara island [33]; other minor reefs are known for Licosa Island [34,35].

Vermetid bioconstructions are highly vulnerable biotopes, mainly due to their slow growth rates and the short lifespans of lecithotrophic larvae, which limit their dispersal capacity [36]. For this reason, these bioconstructions are classified under category 'reefs' (code 1170) in Annex I of the European Habitats Directive 92/43/EEC. Additionally, the main builder species, coralline algae and vermetids, are listed in the annexes of the Berne Convention, Annex II of the Barcelona Convention (SPAMI Protocol) and the International Union for Conservation of Nature (IUCN) Red List [9,37]. Despite their important ecological services and observed declines in eastern and central areas of the Mediterranean Sea [5,38,39], vermetid platforms do not receive adequate attention in coastal management activities [40,41]. The presence of a vermetid bioconstruction along the Apulian coast of Brindisi (Italy) is particularly significant, and it marks the first record of such formations in the Adriatic Sea and one of the northernmost reports along the Italian peninsula (excluding the islands).

Therefore, this study aims to (i) describe the main features of vermetid formation in the Southern Adriatic Sea and (ii) investigate the associated benthic fauna. The findings will help establish regional conservation strategies and contribute to a broader understanding of these vulnerable habitats in the Mediterranean Sea.

2. Materials and Methods

2.1. Study Area

The study area (Figure 1) is found in the province of Brindisi along the Adriatic coast of Apulia in southern Italy (western Mediterranean). The coastline in this area is characterized by abrasion terraces modeled on Pleistocene calcarenites and is complex with irregular indentations and protrusions; it shows sandy stretches interrupted by rocky platforms and suggestive coves. A marine terrace consists of a sub-flat surface that gently slopes towards the sea at an angle of a few degrees. Inland, this terrace is bordered by a typically steep cliff, while seaward, it descends towards the open sea with slopes averaging between 5 and 7 degrees. The Apulian Adriatic coast is influenced by the Western Adriatic Current (WAC), which is a surface current that flows southward along the Italian shelf. This current originates south of the Po River and delivers freshwater southwards, as well as suspended and dissolved materials discharged by various rivers along the Italian coast. During winter, water temperatures in this area range from 13 to 14 degrees [42]. The study area extends between two localities named

"Rosa Marina" and "Specchiolla" along approximately 19 km of the coastline (Figure 1). The slope profile of the coast shows values between 5 and 8 degrees.

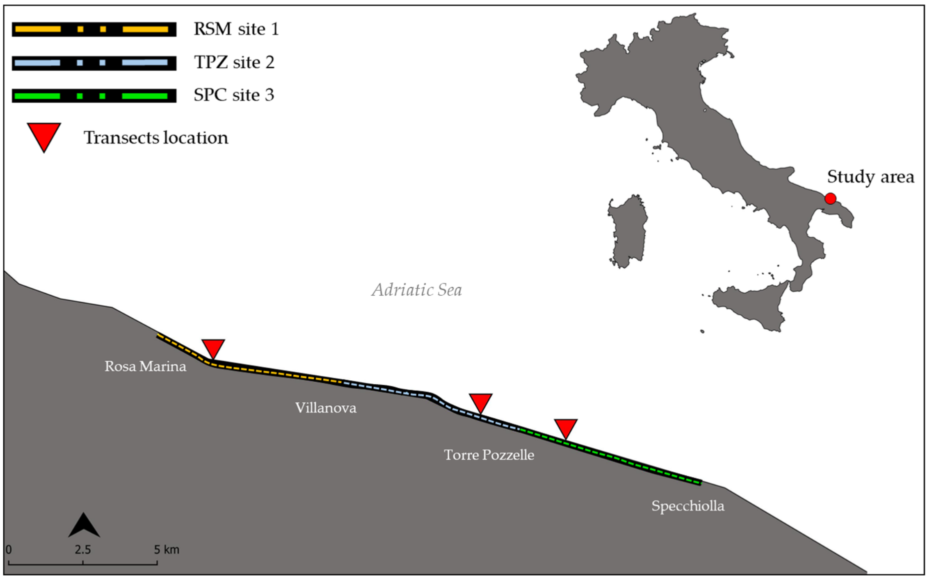

Figure 1. The study area divided in three sites: (i) "RSM site 1" located between Rosa Marina and Villanova; (ii) "TPZ site 2" located between Villanova and Torre Pozzelle; and (iii) "SPC site 3" located between Torre Pozzelle and Specchiolla. The location of the survey transects is highlighted.

2.2. Data Collection

The first part of this research focused on mapping bioconstruction (Figure 2). While Remotely Piloted Aircraft Systems have been employed in recent years for high-resolution mapping of vermetid reefs [43–46], we opted for visual inspection as it was the most suitable method for the investigation of thin crusts built by vermetids, whose edges and width are challenging to assess.

Figure 2. (**a**) Coast's profile in the investigated area; (**b**) detail of the vermetid bioconstruction in the studied area.

To facilitate the mapping operations, the entire study area was divided into 112 sheets at a scale of 1:800. Within each sheet, a grid of numbered quadrants measuring 30 × 30 m on each side was established near the coastline (Figure 3). The mapping of the entire studied area was conducted between May 2022 and March 2023. For each quadrant, we recorded the length of the coastline interested by the presence of the vermetid bioconstruction and measured the width of the bioconstruction (the distance between the outer and inner edges, measured every 5 m using a metered line at resolution of 0.01 m). The area occupied by the vermetid bioconstruction was calculated by approximating each measured section to a rectangle. Since there is no ISPRA protocol specifically allowing for the characterization of vermetid platforms in terms of the number of transects and sampling stations, this study adapted the Marine Strategy protocol for monitoring coralligenous habitats (also included in Annex I of the European Habitats Directive 92/43/EEC under the category 'reefs'—code 1170—(https://groupware.sinanet.isprambiente.it/strategia-marina/library/d1) (access date: 1 December 2024).

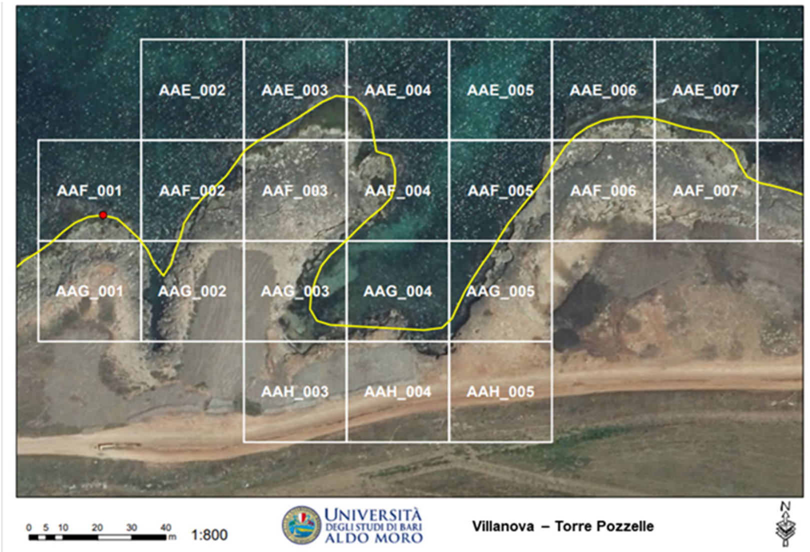

Figure 3. Example of the monitoring sheet at the Villanova–Torre Pozzelle site (TPZ site 2).

The study area was divided into three sites, each approximately 6.3 km long. The first site was located between Rosa Marina and Villanova (RSM Site 1), the second between Villanova and Torre Pozzelle (TPZ site 2), and the third between Torre Pozzelle and Specchiolla (SPC site 3) (Figure 1). To characterize the vermetid bioconstruction distributed in patches along the study sites, three 20 m long survey transects (nominated T1, T2 and T3), distant from each other at least 50 m, were fixed at each site. Several coast features, such as exposure and settlement substrate type, were recorded along these transects. Moreover, we collected data on several morphological characteristics of vermetid bioconstruction: (1) the lengths of the inner and the outer edges, (2) the width measured every 2 m, (3) the slope of the bioconstruction (measured using a goniometer) and the depth (measured with a plastic ruler every 2 m in the central part of the bioconstruction), and (4) the thickness, which was measured every 2 m using a caliper at a resolution of 0.01 m only at the outer margin, since the inner margin was often too thin to measure accurately. Additionally, within each transect, two sampling squares (20 cm × 20 cm) were employed 5 m apart to calculate topographic complexity: accurately following the substrate morphology form, four sides and two diagonals of each square were measured using a measuring tape with a resolution of 0.01 m. Topographic complexity was calculated using the ratio Xi/Xn, where Xi represents collected measures and Xn is the known measure of the used square [47]. A ratio of 1 indicates a lack of complexity; the further the ratio is from 1, the more complex the substrate is [48].

To study the density of *Dendropoma* sp., we conducted ten photographic replicates within a 10 × 10 cm frame for each transect in May and June 2023. For each photo, we calculated the surface area of the vermetid bioconstruction using ImageJ software (version 1.54g) [49]. The density ($D = N_{ind}./cm^2$) was determined by counting the number of shell apertures of *Dendropoma* sp., where N_{ind} represents the number of individuals and

cm^2 refers to the unit area in square centimeters. The same photographic replicates were also used to measure the diameters of the shell apertures using ImageJ software [50].

Associated fauna was studied in May and June 2023 using two quantitative samplings squares (10 × 10 cm, nominated A and B) in each transect by scraping off thin vermetid encrustation. In the laboratory, the samples were fixed in 4% formalin–seawater solution and, after 48 h, they were transferred into 70% ethanol for species identification and counting. Since *Dendropoma* species are protected under the SPA/BIO Protocol (Barcelona Convention) and the Habitats Directive 92/43/EEC, the sampling effort was reduced to 18 replicates [51]. Samples were carefully sorted, and most macrobenthic invertebrates were identified at the species level.

Biotic parameters computed for each sampling site included the number of taxa (S, taxon richness), abundance (N), Shannon diversity (H', diversity) and Pielou equitability (J, evenness) [52]. A non-parametric permutational analysis of variance (one-way PERMANOVA), based on Bray–Curtis (dis)similarity measures, was conducted to test for significant differences between biotic parameters and between characteristics of vermetid bioconstructions, i.e., length of the outer and inner edge, topographic complexity, width and thickness and vermetid density among sites. To calculate the one-way PERMANOVA, the AREA factor with three random levels (sites) was considered. Pairwise comparisons between all site pairs were performed using post hoc Bonferroni correction. Cluster analysis, based on abundance data and Bray–Curtis similarity, was carried out to assess dis/similarity in terms of species composition among sampling sites. The data used were previously processed by logarithmic transformation [log10 (n + 1)] and subjected to Shapiro–Wilk and Kolmogorov–Smirnov normality tests ($p < 0.05$). Finally, Spearman's rank correlation analysis was performed to investigate the influence of collected variables, i.e., bioconstruction thickness, *Dendropoma* sp. density and topographic complexity, on taxonomic richness (S) in each sampling station. All data analyses were performed using Past 4.03, Biodiversity Pro 2.0 and Biostat 7.6.5.

3. Results

3.1. Mapping of Vermetid Bioconstruction

At RSM site 1, vermetid bioconstruction was irregularly present along 1.49 km, which accounts for 24% of the entire site. It covered a surface area of 791 m^2, with widths varying from 0.1 to 2.5 m and an average of 0.53 (±0.36 SD). At TPZ site 2, vermetid bioconstruction was present over 173 m, representing 3% of the investigated site, and covered a limited surface of 80 m^2. Its width ranged from 0.1 to 2 m, with an average width of 0.47 (±0.39 SD). At SPC site 3, bioconstruction was irregularly found along 1.65 km (26% of the investigated site), covering a surface area of 951 m^2, with widths ranging from 0.1 to 5.0 m and an average value of 0.52 (±0.42 SD). The surface occupied by vermetid bioconstruction for each quadrant is illustrated in Figure 4.

3.2. Features of Vermetid Bioconstruction

All investigated sites shared the same substrate type, similar coastal exposure and comparable values of the slope profile (average ± SD of 7.3 ± 1.5°) as well as the depth at which bioconstruction occurred (average ± SD of 21.5 ± 5.7 cm) (Table S1). In terms of morphological features, the outer reef edge was longer than the inner edge (Figure 5) at each transect; however, bioconstruction was more patchily distributed in transect 1T3. The bioconstruction thickness varied between the lowest measurement of 5.1 mm at 1T1 (RSM site 1) and the highest measurement of 12.5 mm at 3T1 (SPC site 3) (Figure 5); the overall average thickness was 8 mm (±0.7 SD). The greatest topographic complexity was observed at sites 2 and 3 (Figure 6). Analysis of ten images collected from each transect indicated that the average density of *Dendropoma* sp. ranged from 1.6 ± 0.4 ind/cm^2 in 1T3 to 4.2 ind/cm^2 in 3T2 (Figure 6). The frequency distribution of shell diameters is shown in Figure 7. Most individuals had similar shell diameters, ranging from 1 to 2 mm, with averages of 1.7 mm (±0.37 SD) at RSM site 1, 1.5 mm (±0.27 SD) at TPZ site 2, and 1.5 mm (±0.2 SD) at SPC site 3. The PERMANOVA test revealed no significant differences among sites in terms of the length of the outer and inner edges, topographic complexity, width and thickness of the bioconstruction and vermetid density (pseudo F = 2.75; p = 0.13).

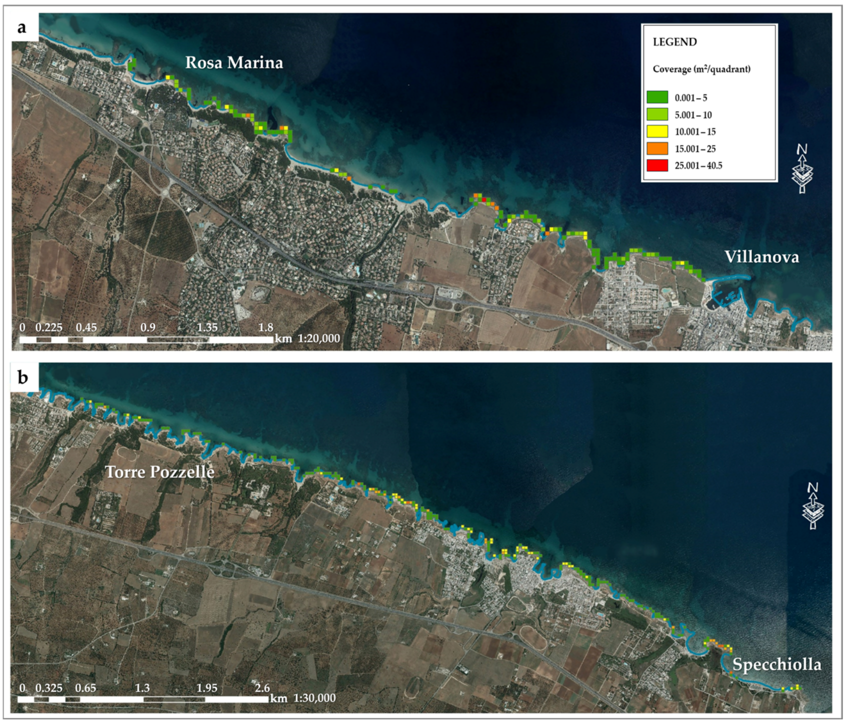

Figure 4. Surface area occupied by the vermetid bioconstruction in each quadrant, in both the first (**a**) and second (**b**) parts of the investigated area. The colors represent different ranges of coverage values as indicated in the legend.

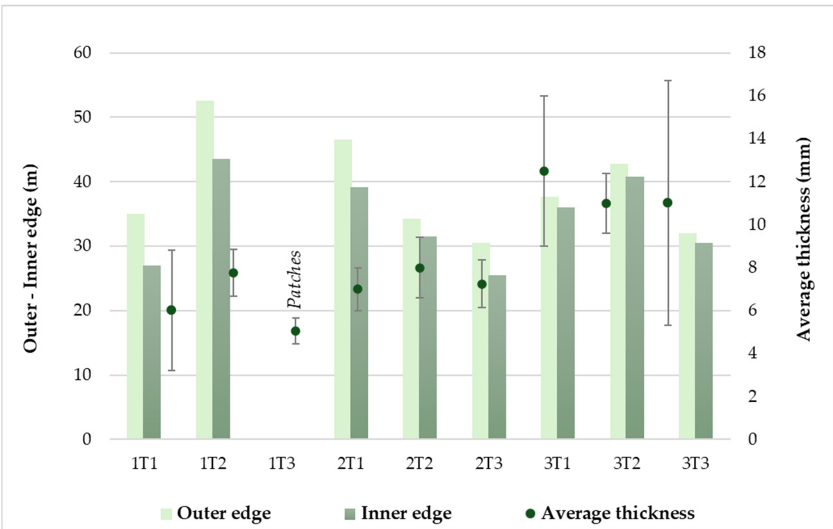

Figure 5. Length of the inner and outer edge (m) and average thickness (mm ± SD) of the vermetid bioconstruction in each transect.

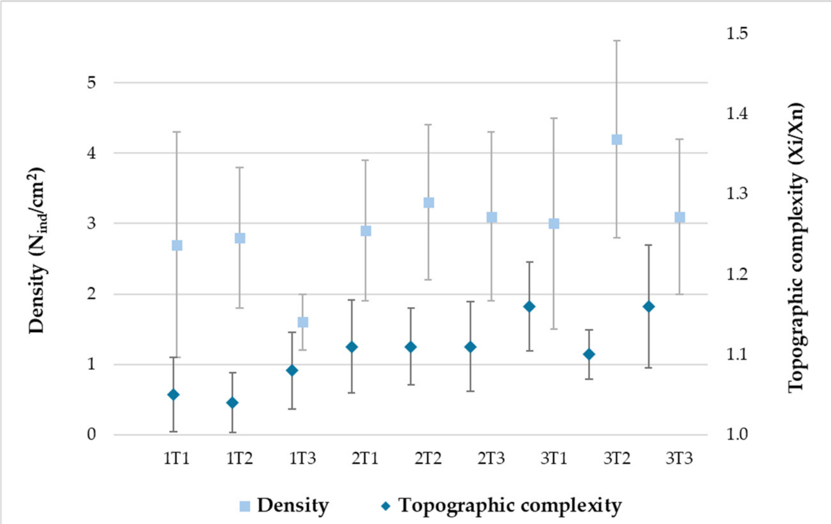

Figure 6. Average density values (±SD) of *Dendropoma* sp. (N_{ind}/cm^2) and topographic complexity (Xn/Xi) of the vermetid bioconstruction in each transect.

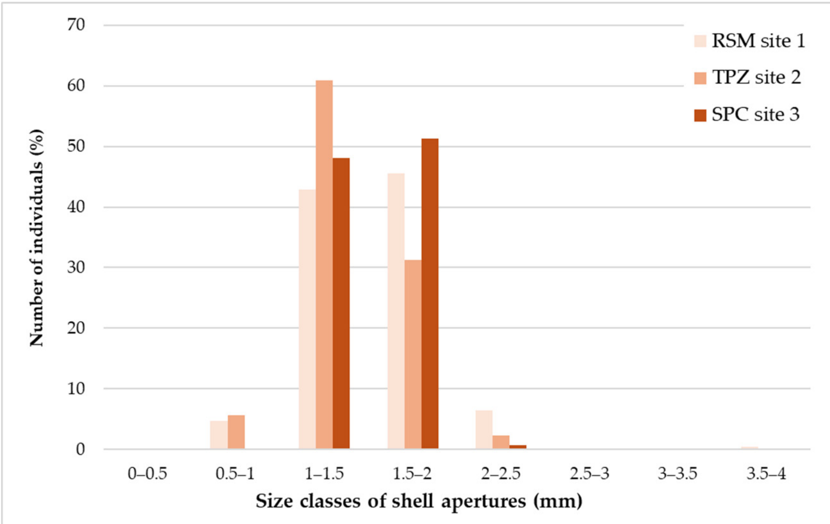

Figure 7. Frequency distribution (%) of *Dendropoma* sp. shell diameters.

3.3. Associated Fauna

A complete list of the 47 identified taxa is presented in Table 1. A total of 1817 individuals from 4 phyla were identified: Cnidaria, represented by Anthozoa (1 sp.); Annelida, represented by Polychaeta (10 spp.) and Sipuncula (1 sp.); Mollusca, represented by Bivalvia (7 spp.), Gastropoda (3 spp.) and Polyplacophora (2 spp.); and Arthropoda, represented by Crustacea, and, in particular, by Balanomorpha (1 sp.), Amphipoda (6 spp.), Tanaidacea (2 spp.) and Isopoda (2 spp.). Moreover, nine taxa of Porifera were also identified, mainly from the class Demospongiae, with only one taxon belonging to Calcarea. The abundance percentages of Polychaetes remained relatively constant at approximately 20% across all sites. Peracarid crustaceans were dominant at TPZ site 2 (39%) and at SPC site 3 (56,9%) (Figure 8). Polyplacophora, Balanomorpha and Demospongiae were almost exclusively found at RSM site 1.

Several species were found exclusively at site 2, including the polychaetes *Exogone dispar*, *Syllis pectinans* and *Syllis pulvinata*, as well as the mollusks *Pisania striata*, *Cardita calyculata*, *Lasea rubra*, *Musculus custulatus* and *Mytilus galloprovincialis*. Species *Syllis gerlachi*, *Syllis gracilis*, *Phascolosoma stephensoni* (Annelida), *Caprella rapax*, *Quadrimaera inaequipes* (Crustacea), *Striarca lactea*, *Acanthochitona crinita* and *Lithophaga lithophaga* (Mollusca) were exclusive of site 3. Common species across all three sites included the polychaetes *Perinereis macropus*, *Syllis amica* and *Syllis rosea*, the crustaceans *Chthamalus stellatus* and *Protohyale camptonyx* and the mollusks *Patella ulyssiponensis*, *Mytilaster minimus* and *Lepidochitona caprearum*. Additionally, among the polychaetes, four species from the Syllidae family were reported for the first time in association with the Italian vermetid bioconstruction: *E. dispar*, *S. gerlachi*, *S. gracilis* and *S. pectinans.* The latter species is an alien species newly reported in the Adriatic Sea and only the second instance in Italian waters [53]. The most abundant crustacean species recorded include *Ampithoe riedli*, *Caprella grandimana*, *Synapseudes shiinoi* and *Dynamene bidentata,* all of which are new records for these environments. Moreover, the isopod *Mesanthura* sp. is an alien species that has recently been documented in cryptic environments on the Italian rocky bottom of the Gulf of Taranto (Ionian Sea) and the harbor of Salerno (Tyrrhenian Sea) [54]. Conversely, *M. minimus*, *L. caprearum* and *P. ulyssiponensis* are considered some of the most representative species of Mediterranean vermetid bioconstructions [4,11].

Table 1. List of species associated with vermetid bioconstruction, with indication on the number of individuals. Taxa presence is indicated by "•" (exclusively for Porifera). The total number of taxa (Taxa tot) in each transect is also reported.

	RSM Site 1			**TPZ Site 2**			**SPC Site 3**		
Taxa	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
CNIDARIA									
ANTHOZOA									
Actiniaria ind.	1								
ANNELIDA									
POLYCHAETA									
Perinereis macropus	3	6	9	3	7	3	26	13	1
Nereididae ind.				10	32	41	12	114	67
Palola valida		1						1	1
Exogone dispar					2				
Syllis amica		3	2		2	10	1	5	
Syllis gerlachi									1
Syllig gracilis									1
Syllis pectinans				2					
Syllis pulvinata					1				
Syllis rosea		2		3	2	9	6	3	
Syllis westheidei					11	4		11	
SIPUNCULA									
Phascolosoma stephensoni									1
MOLLUSCA									
GASTROPODA									
Patella ulyssiponensis	6	11	4	5	17	15	25	12	24
Patella pellucida			1						
Patella sp.				29	7	20	7	2	17
Pisania striata				2					
BIVALVIA									
Cardita calyculata					2	1			
Lasaea rubra				1					
Lithophaga lithophaga								2	
Musculus costulatus					1				
Mytilaster minimus		9	27	11	40	35	41	48	39
Mytilus galloprovincialis						1			
Striarca lactea									1
POLYPLACOPHORA									
Acanthochitona crinita								1	3

Table 1. *Cont.*

Taxa	RSM Site 1			TPZ Site 2			SPC Site 3		
	T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
Lepidochitona caprearum		11	7		3	3	1	1	1
ARTHROPODA									
CRUSTACEA									
BALANOMORPHA									
Chthamalus stellatus	7	9	2		3			1	
AMPHIPODA									
Ampithoe riedli	1			2	14	6	10	38	23
Caprella grandimana				7	19	2	18	47	38
Caprella rapax								2	
Elasmopus pocillimanus					1		1	18	29
Protohyale camptonyx		2	1	13	47	4	4	36	30
Quadrimaera inaequipes								1	6
Amphipoda sp.				1	15	3	9	49	32
TANAIDACEA									
Synapseudes shiinoi				1	31	4	13	84	53
Tanais dulongii					1			4	1
ISOPODA									
Dynamene bidentata				4	33	6	62	16	24
Mesanthura sp.								1	1
PORIFERA									
DEMOSPONGIAE									
Protosuberites rugosus			•						
Suberitidae gen. sp.		•							
Halichondriidae gen. spp.	•		•						
Bubaris vermiculata	•								
Rhabderemia pusilla		•							
Rhabderemidae gen. sp.							•		
Cliona rhodensis		•							
Clionidae gen. spp.		•		•		•			
CALCAREA							•		•
Taxa tot	7	13	10	16	22	18	17	24	23

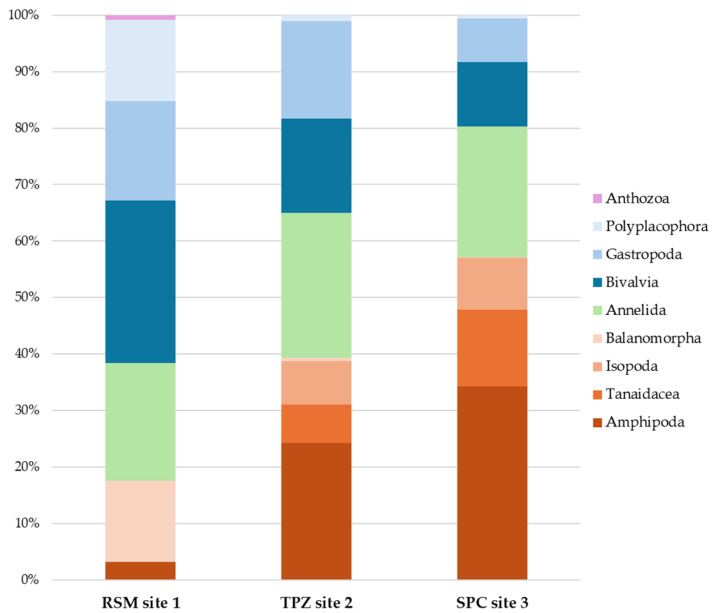

Figure 8. Percentage composition of taxa (number of individuals) at the three sampling sites.

Cluster analysis, based on species composition, highlighted the highest similarity between TPZ site 2 and SPC site 3 (69% similarity) compared to RSM site 1 (Figure 9). Abundance, species richness and diversity were highest at SPC site 3, while Pielou's index (J′) showed the largest value at site 1 (Figure 10). The PERMANOVA test revealed overall significant differences in these biotic parameters (pseudo F = 13.4; $p < 0.001$), and in the pairwise comparisons, significant differences were noted between RSM site 1, TPZ site 2 ($p < 0.05$) and SPC site 3 ($p < 0.005$) (Table S2).

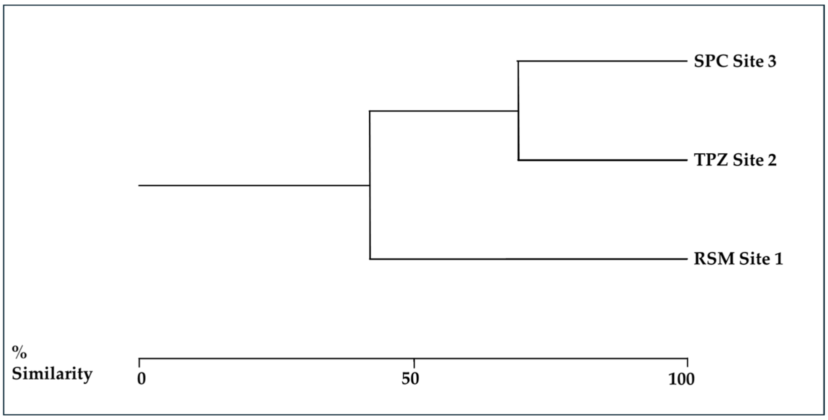

Figure 9. Dendrogram from hierarchical cluster analysis based on abundance data (Bray–Curtis similarity index).

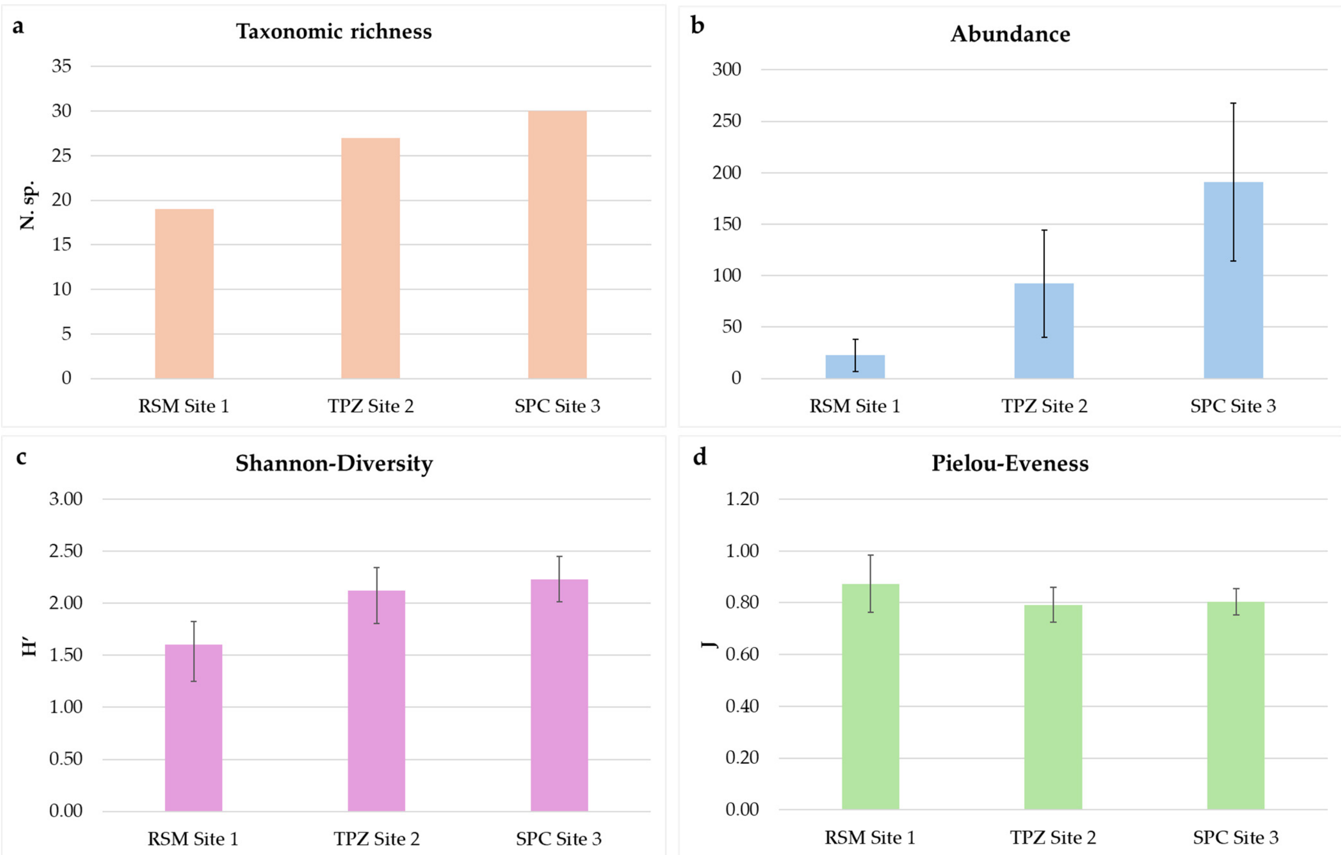

Figure 10. Taxonomic richness (N.sp. = number of spieces) (**a**) and abundance (**b**), Shannon diversity (**c**) and Pielou evenness (**d**) (mean values ± standard deviation, SD) and at each sampling site.

4. Discussion

The present study characterized, for the first time, the vermetid bioconstruction located along 19 km of the Apulian coast in the province of Brindisi, Italy. It provides detailed data regarding its extension, morphological and structural features as well as the associated biodiversity. This report is significant for two main reasons: first, it marks the northernmost vermetid formation documented on the Italian peninsula (excluding islands); second, unlike massive mortality events reported in other areas, such as the Eastern Mediterranean Sea and the northern Sicilian coast, where extensive die-offs of *Dendropoma* bioconstructions occurred over the past decade due to climate changes [5,39,55], this study observed no signs of mortality events. Even if vermetids are more commonly found along the southern coasts of the Mediterranean [3,4], the investigated vermetid bioconstruction has persisted since the 1970s, when its presence was first recorded (Corriero, pers. observation).

Important differences and similarities were observed among the analyzed sites, both in terms of bioconstruction features and the associated fauna. The vermetid bioconstruction described here consists of a monolayered encrustation that is patchily distributed along the Apulian coastline, extending for 3.273 linear kilometers (17.23% of the investigated area) between Rosa Marina and Specchiolla (BR) and covering an area of 1822 m^2. The distribution of *Dendropoma* aggregations varied across sites. At RSM site 1 and SPC site 3, the distribution was almost regular, measuring 1.5 and 1.6 km in length, respectively, and occupying the largest recorded areas. In contrast, at TPZ site 2, the bioconstruction was distributed more patchily and covered the smallest area, measuring just 80 m^2. The discontinuous reef distribution at TPZ site 2 is attributable to the presence of sandy beaches and anthropogenic structures, such as harbors and bathing facilities, which are more abundant at this site.

The vermetid bioconstruction exhibited similar lengths for both outer and inner margins, with low average width values (52 cm $\pm$ 0.4 SD) across the investigated area. These width values align with those reported for the vermetid formations along the north-eastern coasts of Sardinia [33] and Malta [30], as well as those described on the exposed side of the rocky coast at Licosa Islet [35,45]. Otherwise, the most impressive structures have been described at lower latitudes along the coasts of Israel and Lebanon, where they are notable for their extensive linear development and coast-to-coast width [5]. The same holds for vermetid reefs found in the eastern Mediterranean and Sicily [10], particularly in the north-western part facing the southern Tyrrhenian Sea [31]. In this area, vermetid reefs are characterized by a well-developed outer margin, cuvettes and inner margin. In the Gulf of Cofano (Capo San Vito, Sicily), several platforms have also been described with a maximum width extending from 5 to 6 m, starting from a rugged step approximately 1 m high, and developing above the mean sea level [56].

The observed encrusting morphology, consisting of a layer of *Dendropoma* shells up to 1.5 cm thick, differs from those described in most other localities within the Mediterranean [2]. Despite the fact that the studied coast is an abrasion platform favorable for the development of vermetid platforms [4], the observed low values of thickness can be attributed to different factors. Latitude, for instance, is known to impact platform development. The literature indicates that the most developed and impressive bioconstructions are present in the southwestern and eastern sectors of the Mediterranean basin, particularly at latitudes below 38° N [4,10,13]. Brindisi is located at 40° N, and as stated by Milazzo et al. [4], *Dendropoma* concretions have seen a gradual expansion of in the northernmost regions of the Mediterranean basin over the past few decades, while typically exhibiting crust or ledge morphology. Additionally, the coastal conformation of the studied sites, characterized by a slope of approximately 8 degrees, may have strongly influenced the reduction in thickness, while producing crusty morphology [4]. Similar morphology has been reported in the Maltese islands [30,57] and along the Mediterranean coast of Spain [58]. Several small reefs shaped as ledges and encrustations have also been observed around Taormina and Syracuse on the eastern coast of Sicily, as well as the islands of Lampedusa and Ustica [3].

The density of *Dendropoma* sp. in this study ranged from a minimum 1.25 ind/cm^2 to a maximum of 6.3 ind/cm^2, with a mean density of 2.52 ind/cm^2. This is consistent with the literature data regarding impressive vermetid bioconstructions. Indeed, studies carried out along the Sicilian coast reported average densities ranging from 0.65 to 6.17 ind/cm^2 [59], from 1.22 to 4.80 ind/cm^2 [60] and equal to 2.06 ind/cm^2 [3]; an average density of 4.94 ind/cm^2 was also found along the Licosa coast. Contrarily, other bioconstructions with an encrusting morphology, such as those found in Malta, exhibited lower density values of 0.2105 ind/cm^2 [30]. The distribution of shell aperture diameters, ranging from a minimum of 0.63 mm to a maximum of 3.85 mm (mean size 1.7 mm), indicated an almost bell-shaped distribution, thus highlighting the presence of a relatively stable population.

The present study reports a rich and diverse fauna associated with vermetid bioconstruction in the studied area, comprising nearly 2000 individuals across 47 different taxa. High numbers and abundance of polychaetes, crustaceans and mollusks were observed, consistent with findings from previous studies [58]. Polychaetes were predominantly represented by the Nereididae family, including *Perinereis macropus*, which typically inhabits shallow rocky bottoms, as well as the Syllidae family. Notably, the Syllidae family accounted for 80% of the recorded polychaete species.

While several *Syllis* species with large bathymetric distribution can be components of both animal (e.g., vermetid reef) and algal concretions (*S. amica*, *S. gerlachi*, *S. gracilis*, *S. rosea*), several other species (*S. pulvinata*, *S. pectinans*, *S. westheidei*) are typical inhabitants of shallow bioconcretions built by *Dendropoma cristatum* and calcareous alga *Lithophyllum tortuosum* [61]. Among mollusks, the bivalve *Mytilaster minimus* was the most abundant, in accordance with what has already been observed for the Sicilian vermetid reefs. Polyplacophorans were common, particularly *Lepidochitona caprearum*, a species characteristic of the mesolittoral component of the Sicilian reefs, where it colonizes more exposed sides of the external and internal edges [11]. Gastropods such as *Patella ulyssiponensis* and *Lasea rubra* are typical mesolittoral components, and their presence could suggest suitable ecological conditions for vermetid bioconstruction along the studied coast. Furthermore, a significant diversity of crustaceans was observed, addressing the previous data gap for this group. Notably, the Tanaid *Synapseudes shiinoi* was recorded for the second time since its initial description fifty years ago [62,63], where it was associated with a vermetid reef in Addaura Bay, Palermo (Tyrrhenian coast north-west of Sicily). This species has since been reported on the Spanish Mediterranean coast, where it was associated with the alga *Corallina elongata* [64]. In the Apulian vermetid formation, *S. shiinoi* was one of the most abundant species. Other distinctive and abundant crustaceans included the isopod *Dynamene bidentata*, which is usually found within calcareous wall plates of barnacles [65], and various amphipods such as *Ampithoe riedly*, *Caprella grandimana*, *Protohyale camptonyx* and *Elasmopus pocillimanus*, all of which are common in wave-exposed algal biotopes [66]. The ecological affinities of these species for infralittoral, rather than mesolittoral, bottoms proved their abundance in sites 2 TPZ and 3 SPC, where the thickness, topographic complexity and depth of bioconcretion were the highest. It is likely that vagile crustaceans find suitable conditions for settlement among the interstices and crevices of the substrate that provide shelter from fluctuations in water levels.

From the faunal perspective, the cluster analysis revealed the greatest differences in site 1 compared to sites 2 and 3, based on species composition. Moreover, the PERMANOVA test indicated significant differences in biotic parameters in site 1 compared to sites 2 and 3.

At TPZ site 2 and SPC site 3, peracarid crustaceans and polychaetes were highly abundant, whereas at RSM site 1, mollusks predominated alongside Demospongiae. The differences observed in the benthic fauna may also be associated with biogenic formation features. TPZ site 2 and SPC site 3 consistently exhibited slightly higher values of thickness and topographic complexity compared to RSM site 1; furthermore, Spearman's rank correlation coefficient indicated a significant positive correlation between taxonomic richness and both bioconstruction thickness and topographic complexity. Therefore, the differences in the associated fauna are likely due to limited differences in substrate heterogeneity, which can promote the colonization of diverse benthic taxa. RSM site 1 was characterized by a high abundance of sessile organisms, such as sponges and barnacles, which occupied much of the substratum. These colonial and gregarious organisms may have filled most of the interstices and crevices, thereby hindering the settlement of other motile fauna [4,60].

The list of species reported in this study significantly contributes to our understanding of the fauna associated with this neglected habitat [17,51,67]. Many taxa were identified during the research, highlighting the rich diversity of species associated with these formations. Despite the encrusting morphology of the vermetid bioconstruction, the presence of a rich and diversified 'hidden' biodiversity indicates that these biogenic formations are an essential part of the upper infralittoral landscape along the Apulian coast of Brindisi. Furthermore, the lack of significant mortality events along the Apulian coast points to the resilience of these bioconstructions at this latitude. This resilience indicates their ability to withstand environmental stressors and maintain biodiversity, further underscoring the importance of conserving these unique habitats. The findings of this study are particularly significant in light of the EU Habitats Directive, as vermetid species are now part of this initiative. Given their ecological importance, these bioconstructions require greater attention in conservation policies. The results strongly advocate for targeted conservation measures to protect these vital habitats, including the expansion of the boundaries of the Site of Community Importance "Litorale Brindisino" to encompass the area studied here, which is characterized by the presence of vermetid bioconstruction. Protecting this habitat will not only preserve the vermetid bioconstruction but will also safeguard the biodiversity it supports, ensuring the ongoing health and resilience of coastal ecosystems.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/d17010049/s1: Table S1: Geographic coordinates, coastal features (exposure and substrate composition), slope (degrees) and depth (centimers) of the vermetid bioconstruction at the three investigated sites; Table S2: One-Way PERMANOVA results with Pairwise Site Comparisons.

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