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## Assessment of the *Sabellaria alveolata* reefs' structural features along the Southern coast of Sicily (Strait of Sicily, Mediterranean Sea)

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### Abstract

The honeycomb worm *Sabellaria alveolata* is a gregarious tube-dwelling polychaete that builds remarkable biogenic reefs in marine coastal waters. *Sabellaria alveolata* reefs are considered valuable marine habitats requiring protection measures for their conservation, as they play a key role in the functioning of coastal ecosystems. Sabellarid reefs are extensively developed along the Atlantic coasts of Europe and reported for the Mediterranean Sea and the Italian coasts, where large reefs have been recorded in several localities. Fragmentary information is available on their health status, *Sabellaria* reefs thus being listed as "Data Deficient" in the Red List of Marine Habitats. To fill this knowledge gap, this study focused on the analysis of the structure of three reefs found along the southern coast of Sicily. In particular, we aimed to assess their phases with respect to the natural cycle that characterizes the sabellarid reefs. Reef features were analyzed both on the macroscale, based on the bioconstruction size (diameter and thickness) and degree of fragmentation, and on the microscale, based on the measurement of worm density, opercular length and sand porch presence. This study reveals relevant differences among reefs of the studied locations. These differences we attribute to the temporal shift linked to the natural reef phases, albeit further analyses are needed to understand the possible effect of natural and anthropogenic sources of variation on the Southern Sicilian reefs. In conclusion, *Sabellaria* reefs are a unique and persistent habitat along the Sicilian coast requiring proper management and conservation measures.

**Keywords:** *Sabellaria*; Polychaeta; biogenic reefs; engineer species; habitat heterogeneity; marine conservation; biodiversity; Mediterranean Sea.

### Introduction

Worm reefs are bioconstructions built by polychaetes such as *Phragmatopoma californica* (Fewkes, 1889), *Sabellaria* spp. and *Ficopomatus enigmaticus* (Fauvel, 1923). In the Mediterranean Sea, the latter species constructs remarkable reefs in brackish waters, while the sabellarids *Sabellaria alveolata* (Linnaeus, 1767) and *S. spinulosa* (Leuckart, 1849) are the main reef-forming polychaetes in marine coastal waters (Ingrosso *et al.*, 2018). *Sabellaria alveolata* is a long-living, shallow sub-

tidal to intertidal species, building remarkable structures, which can reach 180 cm in height, on sandy bottoms or adhering to rocks (Sanfilippo *et al.*, 2019). Larval planktonic stages settle on existing reefs or the remains of old ones, contributing to the growth of the reef, meaning that the age and morphology of reefs are not directly related to the age of the individuals (Gruet, 1986; Naylor & Viles, 2000). *Sabellaria alveolata* reefs are extensively developed in the Mediterranean Sea, mostly along the Spanish and Italian coasts (Porras *et al.*, 1996; Ingrosso *et al.*, 2018, Sanfilippo *et al.*, 2020). Along the Italian coast,

large reefs have been recorded and studied in the Ligurian, Tyrrhenian, and Ionian Seas, and the Strait of Sicily (SoS) (Delbono *et al.*, 2003; La Porta & Nicoletti, 2009; Schimmenti *et al.*, 2016; Bertocci *et al.*, 2017; Bonifazi *et al.*, 2019; Sanfilippo *et al.*, 2019; Lisco *et al.*, 2020; Ventura *et al.*, 2021). The other Mediterranean reef-forming *Sabellaria* species, *S. spinulosa*, is a fast-growing species that has recently been found to form a notable subtidal reef in the Mediterranean Sea, along the Apulian coast in the Southern Adriatic Sea (Lezzi *et al.*, 2015; Lisco *et al.*, 2017; Gravina *et al.*, 2018).

*Sabellaria* reefs may persist for many years, although individual clumps may regularly form and disintegrate. Indeed, *Sabellaria* bioconstructions are highly dynamic structures that undergo a natural cycle of development and decay, due to their strict dependence on the proper balance between sediment supply and water movement, providing particles for tube building and growth. Specifically, the variations related to seasonal events are summarized in typical phases, namely *progradation*, including settlement and growth, and *retrogradation*, including stagnation and erosion, (Gruet, 1986; Dubois *et al.*, 2005; Gravina *et al.*, 2018; Bonifazi *et al.*, 2019; Curd *et al.*, 2019). The reef growth phase begins after larval settlement on hard substrates or consolidated sandy bottoms, with the production of sandy tubes that encrust the substrate and determine the enlargement of the reef, both horizontally and perpendicularly to the seabed. Bioconstructions of different geometries and sizes originate from the union of adjacent small formations; thus the shape and orientation of the reef vary according to the type of substrate and hydrodynamic regime (Gruet & Bodeur, 1995). A natural process of physical degradation occurs when the reef has reached a considerable size in relation to the seasonality. Subsequently, a possible stagnation phase can occur due to the rapid and destructive action of storm waves, tides and marine currents (Gravina *et al.*, 2018; Bonifazi *et al.*, 2019). Degradation may also occur due to competition with other gregarious sessile organisms, such as mussel *Mytilus galloprovincialis* Lamarck, 1819 (Ingrosso *et al.*, 2018). Indeed, a destructive phase can be caused by the action of physical factors as well as by the biological disturbance caused by mussels and oysters, which can compete with *Sabellaria* for the same space, or fishes and crabs which are capable of eroding the bioconstruction mechanically (Holt *et al.*, 1998). *Sabellaria* reefs are also highly vulnerable and threatened by direct and indirect anthropogenic disturbances. In summary, the main impacts that the reefs suffer include colonization by mussels and ephemeral green algae, physical impacts from trampling and shellfish farming, or worm harvesting as fish baits (Allen *et al.*, 2002; Gubbay, 2007; Desroy *et al.*, 2011; Gibb *et al.*, 2014; Plicanti *et al.*, 2016).

The status and dynamics of the reefs are the result of both biological and physical factors, whose effects may be detected on both the macroscale and microscale (Lisco *et al.*, 2021). Among biological factors, the proportion of young worms settled on old ones is a major influence on the growth phases of the reef. Consequently, the analysis of the reef architecture is useful for detecting the tube

diameters, indicating the different ages of the worms. At the same time, the analysis of the internal structure makes it possible to distinguish the sandy grains cemented directly by the worms to form tubes from the grains trapped between adjacent tubes to fill the empty gaps, so revealing the growth/erosive stage of the bioconstruction (Lisco *et al.*, 2017; 2020; Sanfilippo *et al.*, 2020). The extension and distribution of the structures also reveal the status and persistence of the bioconstructions, as the structures occurring in an area serve as a potential source of larval supply if effectively connected by alongshore currents (Dubois *et al.*, 2007; Ayata *et al.*, 2009). Other variables revealing the status of *Sabellaria* reefs are the sand porches around the tube opening, the crevices on the reef surface, the portions of eroded edges, and the abundance of epibionts. In particular, good reef conservation status can be gauged from the presence of sand porches, with a few crevices and portions which are only poorly eroded and the low abundance of epibionts (La Porta & Nicoletti, 2009; Curd *et al.*, 2019).

*Sabellaria* reefs play an important role in the functioning of shallow coastal ecosystems, by contributing both to stabilizing the substratum and promoting biodiversity (Jones *et al.*, 2018; Lisco *et al.*, 2020). Thanks to their services to ecosystem *Sabellaria* reefs are included in the Red List of Marine Habitats (Gubbay *et al.*, 2016) and, as such, require assessment measures for their protection, according to the Water Framework Directive (2000/60/EC), Marine Strategy Framework Directive (2008/56/EC) “Sublittoral biogenic reefs” being listed under Annex I within the European Habitats Directive (Council Directive 92/43/EEC) (Firth *et al.*, 2021). The Red List of Marine Habitats defines various parameters of the state of the bioconstructions in different geographical areas, to promote adequate protection measures. Regarding the Mediterranean, information on *Sabellaria* reefs is still fragmentary, and details concerning their extent, occurrence, status, and dynamics are scarce. It is therefore difficult to evaluate their conservation status, as well as the threats that affect these of the Mediterranean Sea. As such to suggest effective management measures and protection for their conservation is still premature. In fact, European *Sabellaria* reefs are listed as “Data Deficient” since it is not possible to assess their status according to the criteria of the IUCN Red List. In this context, it is important to provide estimates of bioconstruction features related to reef dynamics, thus distinguishing the different phases of its natural cycle and correctly assessing *Sabellaria*’s conservation status and potential sources of impact, through monitoring analysis over time.

Since the publication of the Red List of habitats, however, some studies have been filling the information gap on the reefs occurring along the Italian coast (Gravina *et al.*, 2018; Bonifazi *et al.*, 2019; Sanfilippo *et al.*, 2020; Ventura *et al.*, 2021). Particularly, Lisco *et al.* (2021) revised the development process, from growth to destructive stage, of different Mediterranean reefs and proposed a new methodological approach, based on sedimentological and ecological analysis both on the macro and micro scale, to compare different growth models of the *Sabel-*

*laria* reefs from the central Tyrrhenian and the Adriatic coasts. This method appeared effective for determining the developmental trends of sabellarian bioconstructions and deserves to be tested in other case studies.

Along the south Sicilian coast, in the Strait of Sicily (SoS), three *S. alveolata* reefs were reported and analyzed from the faunal point of view, revealing unique faunal assemblages, including the polychaete *Eulalia ornata* Saint-Joseph, 1888, recorded for the first time in the Mediterranean Sea during the above-mentioned surveys (Schimmenti *et al.*, 2016; Bertocci *et al.*, 2017). However, no structural analyses of the reefs able to reveal their status have been undertaken till now. This study aims to assess the status of the *S. alveolata* reefs along the Sicilian coast in the SoS by distinguishing their different stages of development, under the criteria proposed by Lisco *et al.* (2021). Our further objectives are to contribute to increasing knowledge on the Mediterranean reefs and to test the effectiveness of the aforementioned method to discriminate the progradation/retrogradation phases of sabellarid reefs.

## Materials and Methods

### Study area and sampling activities

The SoS is located between the southern coast of Sicily (Italy) and the north-eastern coast of Tunisia, connecting the Western and Eastern Mediterranean sub-basins. Water circulation and physico-chemical features of the area are greatly influenced by two water masses: the Atlantic Ionian Stream, derived from Atlantic waters (cooler and less saline) entering through the Gibraltar Strait and moving eastward in the surface layers, and the Levantine

Intermediate Water (warmer and saltier), flowing westward in the deeper layers (Gasparini *et al.*, 2005; Poulain & Zambianchi, 2007). Therefore, the average salinity in the channel is about 38 ‰ at the surface, reaching 38.4 ‰ at depth. The stretch of the Sicilian coast facing the channel is characterized by shallow sandy shores, locally interspersed with *Posidonia oceanica* meadows and rocky shores, and several river outlets. The tidal amplitude of the area is a few centimeters, but the coast is steadily exposed to strong waves and winds.

*Sabellaria alveolata* reefs were sampled by SCUBA divers in June 2013 at two random sites (1, 2) in three different locations along the Sicilian coast: Triscina (TRI; 37.58° N, 12.80° E), Eraclea Minoa (EM; 37.39° N, 13.28° E) and Donnalucata (DL; 36.75° N, 14.64° E) (Fig. 1).

The main physiographic and environmental features along the study area are similar in terms of climatological, hydrological, coastal and sedimentary dynamics. At the three locations, mean annual temperature ranged from 18.8 ± 3.1 °C (TR) to 19.8 ± 4.2 °C (DL) based on records from 1999 to 2019 (<https://it.climate-data.org/>). Wind and wave directions reveal dominant western components (<https://it.windfinder.com/>). Beach width at the three locations was measured using the Google Earth software and it varied from 10.2 ± 0.5 m (ER) to 34.4 ± 1.9 m (DL). The substrate was mainly composed of sand throughout the study area.

At each location, within each site, two replicate portions of a reef (10 x 10 x 10 cm; R1-R2) were collected using a hammer and a putty knife at a depth ranging from 1.5 m to 3 m depending on the location. Then, each reef portion was separately stored in 70% ethanol for the laboratory analysis.



**Fig. 1:** Map of the study area with the locations where *Sabellaria* reefs were analysed, Triscina, Eraclea Minoa and Donnalucata, along the Southern coast of Sicily. The sampling design is also reported: per each location, the numbers 1 and 2 indicate the sampling sites, and R1-R2 indicate the replicates collected at each site.

## Collection and analysis of data

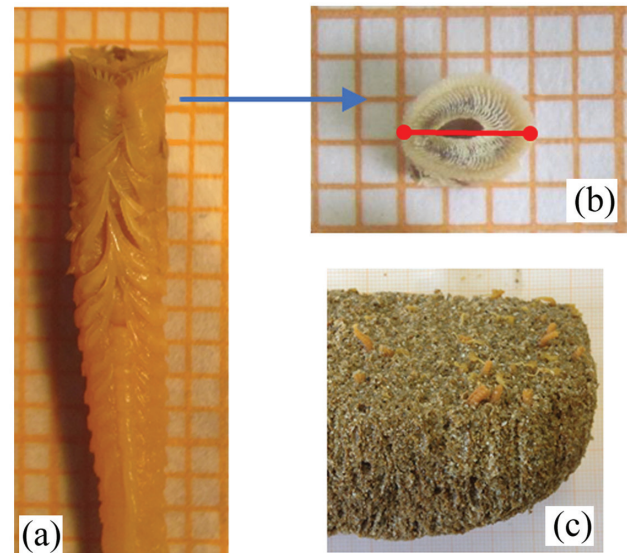
Reef features were captured at both the macroscale and microscale (Table 1). The size (bioconstruction diameter and thickness) and degree of fragmentation of sampled reefs were evaluated as macroscale data and acquired in the field. The fragmentation degree was assessed according to Lisco *et al.* (2021) by assigning: (i) a low fragmentation value (L) in the absence of interruptions, (ii) a moderate fragmentation value (M) if the discontinuities were equal to 30%, (iii) a high fragmentation value (H) in the presence of continuous structure interruptions higher than 50%.

At the microscale the following data were assessed in the laboratory: (i) opercular length, defined as the maximum width of the operculum following Bertocci *et al.* (2017), (ii) coefficient of variability (ratio of standard deviation to mean), (iii) sand porch presence. The opercular length of 480 *S. alveolata* specimens, (40 per replicate) randomly chosen, was measured. The latter analysis was used to define the number of individuals per opercular size class, per each site at the 3 locations. Ten size classes were a-posteriori set based on the largest individual measured (opercular length 5 mm) and subjectively considering 0.5 mm intervals, with the first class including the specimens having an opercular length  $\leq 0.5$  mm and the last one including individuals with opercular length  $> 4.5$  mm. Opercular length is considered as a proxy of body size and, therefore, of home-tube diameter as the operculum seals the end of the tube. The opercular length was measured after cutting the prostomial portion of the specimen and then placed vertically on millimeter paper (Fig. 2). The terms opercular length and tube diameter are used as synonyms throughout the text.

Table 1 reports the main macro- and microscale features proposed by Lisco *et al.* (2021) and the indicators

of the reef status as defined by La Porta and Nicoletti (2009), herein used to compare the reef conditions along the Sicilian coast.

For the analysis of the variation in the number of individuals per size class at each location and site, the experimental design included 2 factors; Location, (random, 3 levels) and Site (random, nested in Location, 2 levels), making it possible to describe multivariate spatial variation of the distribution of worms in size classes along the study area at different spatial scales. Significant differences in tube opening diameters among locations and sites were tested by means of permutational analysis of



**Fig. 2:** *Sabellaria alveolata* (a): Dorsal view of one specimen with the anterior part highlighted; (b): operculum, the red line indicates how the opercular length was measured; (c): portion of the reef showing the first segments of the worms out of the tubes.

**Table 1.** Features associated with the growth cycle of *Sabellaria* reef proposed by Lisco *et al.* (2021) and the status indicators defined by La Porta and Nicoletti (2009) used to describe the development phases defined by Curd *et al.* (2019) of *Sabellaria* reefs in the Mediterranean Sea.

|                          | Features                    | Progradation phase                  | Retrograding phase                     |
|--------------------------|-----------------------------|-------------------------------------|--|
| <b>Macroscale</b>        | Structure size/extension    | Large dimension/ wide area occupied | Small dimension/ reduced area occupied |
|                          | Fragmentation degree        | Low                                 | Moderate/High                          |
|                          | Thickness                   | Increased                           | Reduced                                |
| <b>Microscale</b>        | Tube diameter               | Large                               | Small                                  |
|                          | Coeff. of variability       | Low                                 | High                                   |
|                          | N° of tubes/ind.            | Low                                 | High                                   |
| <b>Status indicators</b> | Sand porch                  | Present                             | Absent                                 |
|                          | Erosion                     | Absent                              | Present                                |
|                          | Number of openings/crevices | Few/absent                          | Numerous                               |
|                          | Epibionts/assoc. fauna      | Present/abundant                    | Absent/reduced                         |

variance (PERMANOVA) and permutational analysis of dispersion (PERMDISP) using the Bray Curtis similarity on the matrix of the number of individuals per size class per replicate. For the PERMANOVA the p values were approximated using Monte Carlo simulations when the number of unique permutations appeared unsuitable. Tube diameter data were also visualized by non-metric multidimensional scaling (nMDS), based on the Bray Curtis similarity. The analyses were carried out using the software PRIMER 7.0.20 with the add-on PERMANOVA+ (Anderson *et al.*, 2008).

## Results

*Sabellaria* reefs were characterised by variation in the structural features at both the macroscale and the microscale (Table 2). Considering the macroscale, the results revealed that the reef reached the maximum values of thickness and diameter at Eraclea Minoa and the minimum values at Triscina. In this latter location the level of fragmentation was the highest, while it was the lowest at Donnalucata, while it showed variable values at Eraclea Minoa. The comparison at microscale among the reefs revealed that the sand porches were present only in the reefs of Donnalucata, where the opercular length was the greatest, and of Eraclea Minoa, with the minimum and intermediate coefficients of variation respectively. By contrast, the lowest opercular length values and maximum coefficients of variation were measured for the Triscina reef where the sand porches were not observed.

The PERMANOVA carried out on the opercular length data demonstrated significant differences among the three localities in terms of worm abundance among

the range classes of diameters of the tube openings, but no differences between replicate sites in locations (Table 3). The PERMDISP for the location factor was non-significant ( $F_{2,9}$  1.546; P(perm) 0.507).

The nMDS graphically confirmed the separation among the three reefs based on worm size classes, estimated on the opercular length at each location (Fig. 3).

The histograms of opercular length frequency distribution (Fig. 4) confirmed the largest length-class range with the highest number of individuals combined in the 0.5-2.0 mm classes for the Triscina reef; consistently, the length-classes 2.0-3.0 mm showed the highest frequencies in the other two localities.

## Discussion

Although the SoS is a complex marine district where the water surface circulation exhibits relevant spatial and temporal variation (Ciani *et al.*, 2019), the herein analysed locations are rather regarding their physical and environmental features. Nonetheless, a remarkable difference in the morphological structure, size and tube openings features was evident among the *Sabellaria* reefs.

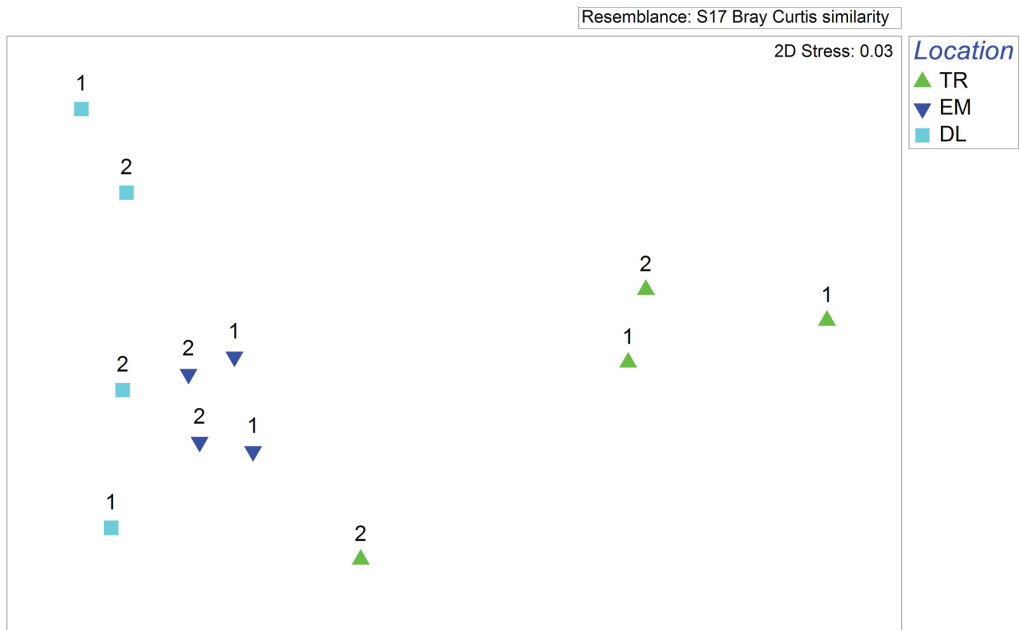
At macroscale, the reefs ranged from small veneers with a moderate degree of fragmentation at Triscina to large, brain-shaped hummock formations at Eraclea Minoa. An intermediate situation was found at Donnalucata, where the reefs formed hummocks of intermediate diameter and thickness with a very low degree of fragmentation. Differences were also observed on the microscale, i.e., opercular length, used as a proxy for tube opening. The Triscina reefs had on average the smallest tube size and the greatest coefficient of variability, while the other

**Table 3.** Results of the permutational multivariate analysis of variance (two-way PERMANOVA) based on opercular length data of the *Sabellaria* reefs revealing the difference in worm abundance among the range classes of tube diameter in the SoS. Bray Curtis similarity measure. Permutation = 9999. Lo = location, Si = site. P(MC) = significance calculated using Monte Carlo simulations. Significant p-values are given in italics.

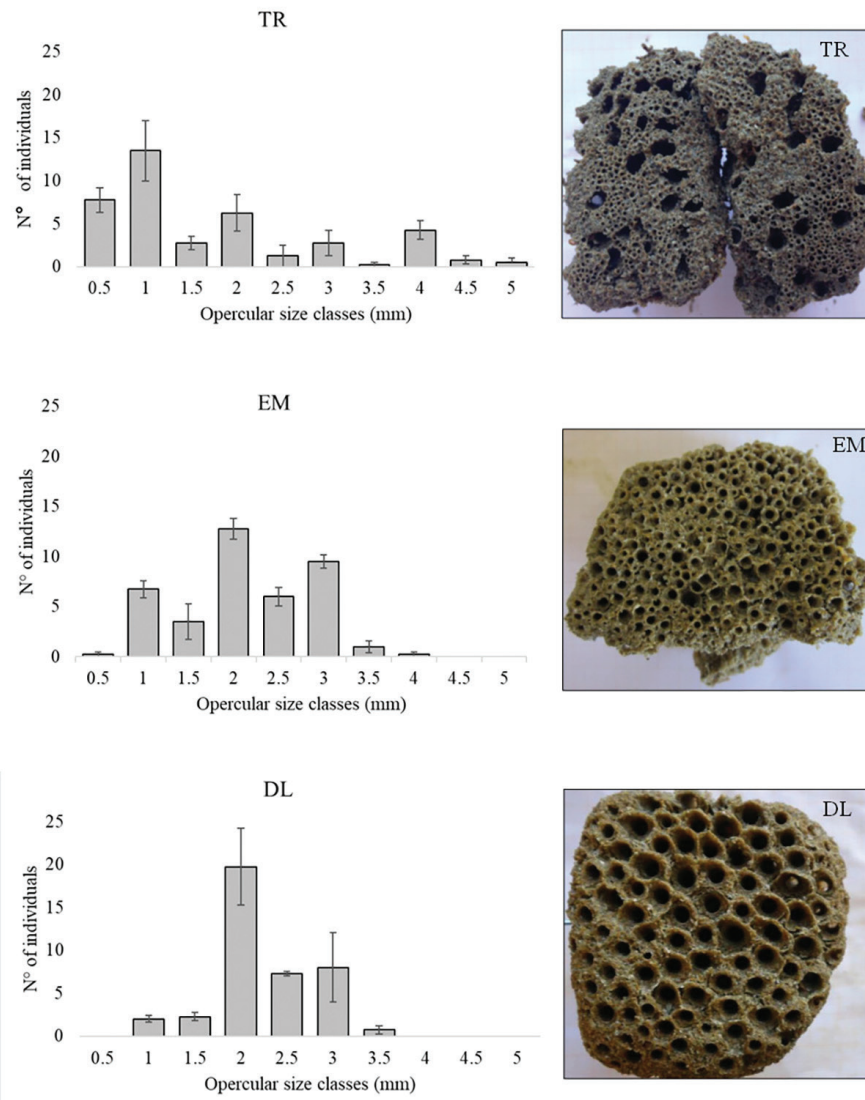
| Source  | df | MS      | Pseudo-F | P (perm) | Unique perms | P (MC)        |
|---------|----|---------|----------|----------|--------------|---------------|
| Lo      | 2  | 4362.00 | 11.197   | 0.0658   | 15           | <i>0.0039</i> |
| Si (Lo) | 3  | 389.58  | 0.60962  | 0.8192   | 9631         | 0.7478        |
| Res     | 6  | 639.06  |          |          |              |               |
| Total   | 11 |         |          |          |              |               |

**Table 2.** Macroscale (mean thickness and diameter of the bioconstruction) and microscale (mean  $\pm$  SE of opercular length) features of the studied *Sabellaria alveolata* reefs at the three locations along the Southern Sicily coast. \* According to Lisco *et al.* (2021): Low (L) absence of interruption; Moderate (M) fragmentations <30%; High (H) fragmentations >50%.

| Localities    | Macroscale            |                |                         | Microscale   |                       |                       |
|---------------|-----------------------|----------------|-------------------------|--------------|-----------------------|-----------------------|
|               | Fragmentation degree* | Thickness (cm) | Structure diameter (cm) | Sand porches | Opercular length (mm) | Coeff. of variability |
| Triscina      | M                     | 30             | 50                      | Absent       | 1.7 $\pm$ 0.5         | 0.38                  |
| Eraclea Minoa | M/L                   | 150            | 200                     | Present      | 2.1 $\pm$ 0.1         | 0.29                  |
| Donnalucata   | L                     | 50             | 100                     | Present      | 2.2 $\pm$ 0.2         | 0.15                  |



**Fig. 3:** nMDS ordination plot comparing opercular length data between sites sampled at the three locations (TR = Triscina; EM = Eraclea Minoa; DL = Donnalucata).



**Fig. 4:** Average abundance of *Sabellaria alveolata* individuals ( $\pm$  standard error) per size class of the opercular length at the three locations (left). Per each location the picture of a randomly selected reef sample is also shown (right). TR = Triscina; EM = Eraclea Minoa; DL = Donnalucata.

two locations had larger tube openings, with a greater coefficient of variability in *Eraclea Minoa* than in *Donnalucata*. We hypothesize that the observed differences may be related to a different phase of the growth cycle of the considered reefs, as a consequence of the one-off sampling that captured a “snap-shot” of the reef cycle, as evident from the *Triscina* reef where massive recruitment in respect to the other locations was observed. A detailed study of the local currents and the identification of source/sink areas would shed light on the herein observed variability in the reefs’ life cycles. According to *Curd et al.* (2019), the size and morphology of the mound formations, the tube diameters and features, including the absence of sand porches, and the high worm abundance observed at *Triscina*, all represent the end of the reef retrograding phase and the beginning of the prograding phase. Indeed, in this location the reef was partially divided into separated mounds of varying size with moderate fragmentation and with tubes characterized by small openings and a high coefficient of variability. Such features indicate high *Sabellaria* density and a recent larval recruitment event, characteristic of the initial progradation phase, together with the presence of few adult individuals, who survived the retrogradation phase. Indeed, the coexistence of old and new generations is crucial to ensure the subsequent growth of the reef (*Lisco et al.*, 2021). In addition, a high level of fragmentation and crevices enhance microhabitat heterogeneity, which, in turn, facilitates the settlement of *Sabellaria* juveniles, as expected at the beginning of the progradation phase (*Bonifazi et al.*, 2019; *Curd et al.*, 2019). Accordingly, other indicators of reef condition, such as the absence of sand porches, crevices on the reef surface and the abundance of epibiont/associated fauna, were likely to be a consequence of the retrogradation phase. By contrast, at *Donnalucata* and *Eraclea Minoa* the reefs appeared at the end of the progradation phase towards the beginning of the retrograding phase. The larger dimension of the hummocks recorded in these locations, along with their low fragmentation, are coherent with reefs at a peak of intense growth. The larger mean tube diameter composing the reefs, coinciding with the remarkably low coefficient of variation in *Donnalucata*, reveals the dominance of adult individuals in both the *Donnalucata* and *Eraclea Minoa* reefs. On the other hand, the few juveniles coexisting with the adults at *Eraclea Minoa* revealed that in this last location the progradation phase was not fully reached. In addition, the aggregation of large tubes near to each other resulted in the compactness of the structures in these last two locations, with few crevices and interstices available for colonization by epibionts and associated fauna, which were less abundant and diverse compared to *Triscina* (*Schimmenti et al.*, 2016; *Bertocci et al.*, 2017). At the same time, the openings of the tubes equipped with the characteristic sand porches demonstrated that *Eraclea Minoa* and *Donnalucata* reefs reached an advanced stage of the progradation phase, without showing evidence of an imminent retrograding phase.

Structural variations in *Sabellaria* reefs may not only depend on the different phases of their natural seasonal

cycle, as the bioconstructions also suffer from the impact of human activities, which may cause their erosion and retreat. Along the Italian coast of the Middle Tyrrhenian Sea, the main damage to sabellarid reefs is caused by human trampling and worm collection used as bait for recreational fishing (*Bonifazi et al.*, 2019), while along the European Atlantic coasts, *Sabellaria* reefs are impacted by trawling for shrimps, dredging activities for oyster and mussel collection and human trampling (*Riesen & Reise*, 1982; *Dubois et al.*, 2002; *Plicanti et al.*, 2016). Impacts on hydrological and sediment regimes resulting from coastal engineering (*Vorberg*, 2000), as well as water eutrophication (*Dubois et al.*, 2006) also affect the reef condition. On the other hand, some anthropogenic activities, such as the deployment of artificial coastal defense structures, may support the formation of *Sabellaria* reef (*Firth et al.*, 2015). Although the present study did not aim at assessing anthropogenic impact affecting the reefs of the studied area, we found no clear evidence suggesting the presence of forms of acute or chronic anthropogenic pressures causing the heterogeneity observed among reefs. Further studies are needed to evaluate the anthropic pressure in the area and its eventual impact on the local reefs. We hypothesize that the micro and macroscale variations observed may be partially due to biotic factors, such as the intraspecific heterogeneity in the growth cycle of *S. alveolata*, possibly including asynchrony in larval recruitment among locations, something undetectable by a single sampling event such as ours. Consequently, the status of the *Triscina* reef may be attributable to a shift in the early progradation phase, when many young individuals of *S. alveolata* are present. Furthermore, other biological factors should be considered to explain the structural differences among the studied reefs, including the differences in faunal composition (*Bertocci et al.*, 2017).

Other environmental factors acting at local scale may be responsible for the differences observed among the studied reefs. A high degree of differentiation has been reported for other *Sabellaria* reefs occurring along the Sicilian coast. In *Portopalo di Capo Passero*, on the southern point of the Sicilian coast, *Sabellaria* formed crustose bioconstructions (vaneer) on sandy bottom near algal assemblages (*Sanfilippo et al.*, 2020), while along the Sicilian eastern coast off the *Simeto* river mouth, reefs occurred on sandy-muddy sediment and showed differences in the structure of tubes (*Sanfilippo et al.*, 2019). In our study, the nature of the sea bottom possibly contributed to differentiating *Triscina* from the other locations. Here, the sandy bottom is mixed with pebbles and patches of *P. oceanica*, in comparison with the more homogeneous sandy bottom of *Eraclea Minoa* and *Donnalucata*. We hypothesize that the presence of *P. oceanica* may favor *Sabellaria* larval recruitment and possibly promote sediment capture by the worms. A positive effect of the presence of macroalgae, especially *Ericaria giacconeii* D. Serio & G. Furnari, 2021, on *Sabellaria* bioconstructions has been shown by *Sanfilippo et al.* (2021) in *Portopalo di Capo Passero*. The coexistence of *Posidonia* and *Sabellaria* and their interaction are worth analyzing and are currently being studied along the Apulian coast in Southern Italy.



In addition to the current conservation status of the reefs, we should mention that among the Mediterranean locations hosting sabellarid reefs, the study area considered here is almost unique in that historical data have documented the presence of ancient reefs (Ingrosso *et al.*, 2018), facilitating speculation on reef persistence. The first record of *Sabellaria* reef in Sicily dates back to seventy years ago, when Molinier & Picard (1953) described a remarkable reef, that extended for about 50 m at a depth between 1 and 2.5 meters, along the coast near Agrigento close to Eraclea Minoa. Despite the brief description of the reef, we can reasonably consider it as valid historical evidence that the reef persisted in the area for well over half a century. This is a noteworthy feature, since *Sabellaria* reefs are listed as valuable habitats requiring protection, according to the European Habitat Directive. Therefore, their persistence in time is one of the most important requirements for assessing conservation strategies (Hendrick & Foster-Smith, 2006), as well as for management planning or counteracting the effect of anthropogenic impact with restoration actions (Franzitta *et al.*, 2022). We might also note mentioning that *S. spinulosa* reefs of the North Sea, which were found to be persistent over a two-year period, were recommended for protection, despite their patchy and dynamic distribution (Van der Reijden *et al.*, 2021).

In conclusion, our results contribute to improve the knowledge of the *Sabellaria* reefs along the southern Sicilian coast. Specifically, based on macro and microscale analyses, this study reveals the status and phase of these biogenic reefs and depicts their high level of heterogeneity in this sector of the Mediterranean Sea. Furthermore, we show that *Sabellaria* reefs are unique, ecologically valuable and persistent along the southern Sicilian coast: as such their preservation should be guaranteed. Finally, the novelties herein reported for the Sicilian coast contribute to filling the “Data Deficient” gap regarding *Sabellaria* reefs, thus improving the information required by the European Red List of Habitats for the assessment of the status of the European coastal environments.

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