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The Red Coral Community in the Messina Strait: New Findings from the 1700s Lazzaro Spallanzani Collection

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Abstract: The precious red coral (*Corallium rubrum* L.) represents one of the most fascinating marine species of the Mediterranean Sea. Several samples, including red coral together with its accompanying species, were found in the zoological collection of the Italian pioneer biologist Lazzaro Spallanzani (1729–1799), collected in the Messina Strait during his voyage in Sicily (1788). The study of these samples allowed the inclusion of numerous additional species in the traditional red coral facies as the large oyster *Neopycnodonte cochlear*, the giant barnacle *Pachylasma giganteum*, the mesophotic scleractinian *Caryophyllia* (*Caryophyllia*) *cyathus*. These specimens proved to be very useful in describing the diversity of the paleo-community including red coral, shedding light on its formation processes. In particular, some specimens are composed of red coral rubble consolidated and cemented with other carbonatic remains Probably, these peculiar specimens have a similar origin to those of the Sciacca Banks already known from the Sicily Channel. In fact, the two areas are prone to intense seismic activity that periodically causes mass mortalities of red coral from nearby rocky reliefs and the formation of biogenic detritus, while the resulting chemical environment of the water and the sediments allows the consolidation of the carbonatic remains.

Keywords: *Corallium rubrum*; subfossil facies; Messina Strait; historical collections

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1. Introduction

The Italian scientist Lazzaro Spallanzani (1729–1799) was a pioneer of biological research in the XVIII century [1]. A large part of his work was dedicated to marine organisms and in 1783, he established the first marine laboratory in the world in the village of Portovenere, on the eastern coast of the Ligurian Riviera [2].

In 1788, during his trip to Sicily, he visited Messina and the Aeolian Archipelagos [3] and collected several information about the red coral *Corallium rubrum* (Linnaeus, 1758) and its harvesting. Through a series of observations of living colonies, Spallanzani confirmed the animal nature of this organism as stated by Peyssonnell, Jussieu, Guettard, Donati and Cavolini, confuting the opinion of Marsigli who mistook the coral polyps for flowers.

Spallanzani provided a detailed description of the fishing area in the Messina Strait "This fishing is done from the mouth of the Faro River until off the church of Santa Maria della Grotta, three miles from the city of Messina" (Figure 1). He also provided information on the exploited depth "Coral-producing reefs lie almost in the middle of the Strait at varying depths, ranging from 350 to 650 feet (=100–190 m)", and the employed gear. This area, corresponding to the northern sector of the Strait, is characterized by a wide valley (named Valley of Scilla) located at about 200 m, rising abruptly with steep flanks, and giving a U-shape to the cross-section of the valley [4].

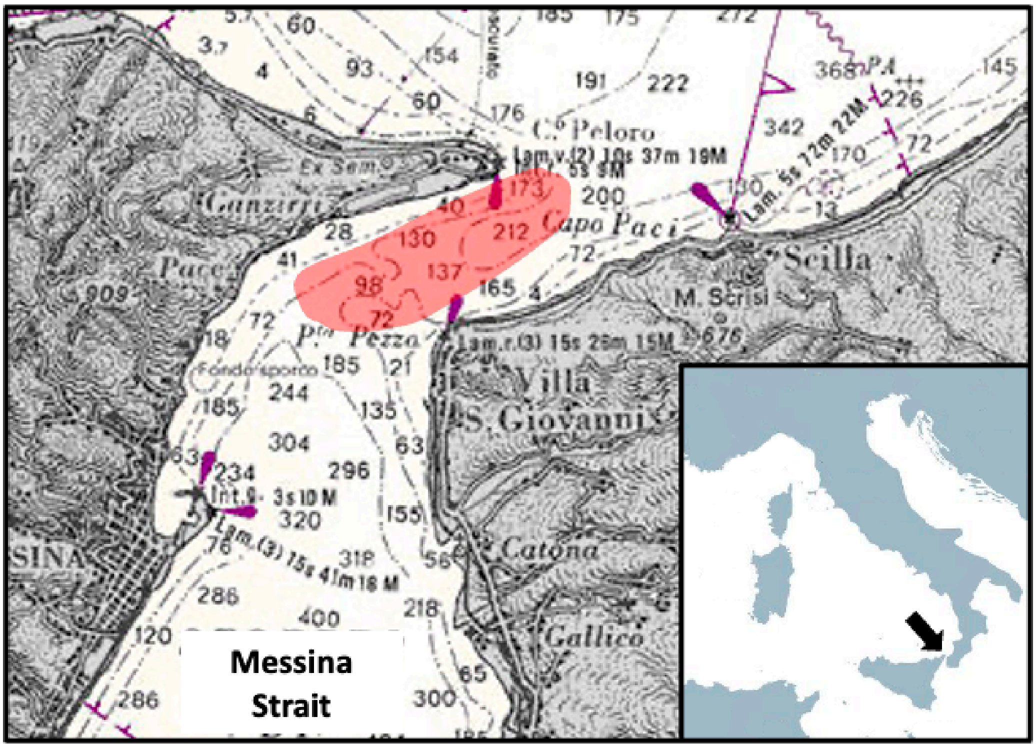


Figure 1. Geographic location of the red coral fishing area (in red) in the Messina Strait reconstructed by the detailed description of Lazzaro Spallanzani.

According to the Author [4], the Messina fleet was composed by 18–20 boats and "The quantity of coral that is fished can amount to about twelve Sicilian quintals (951 kg; 1 Sicilian q = 79 kg) *each year*". It is interesting to note that the Messina fishermen operate a sort of management *ante litteram* of their precious resource. "Those coral fishermen have divided the entire fishing field of the Strait into ten portions. Each year, they fish only in one of these portions, nor do they return to fish until the decade has passed. They believe this ten-year interval is necessary for the coral to acquire its entire growth in height and full consistency. When in fact they neglect this rule, they find the coral smaller and less consistent. After the decade they believe that the coral no longer grows in height, but only in thickness, which, however, has its limit. Indeed, they observed that the coral fished in a place where it had never been fished was not greater in height than ordinary".

Spallanzani gave also other details about the relationships between the coral banks and the water movement of the area, and the position of the colonies on the seafloor. Additionally, the morphometric features of the colonies were provided "The greatest height never reaches the foot, the ordinary thickness is that of a little finger".

Spallanzani's data about red coral biology and fishing in the Messina Strait were further cited in other more popular books [5]. During his trip, Spallanzani collected an important series of zoological, paleontological, lithological, botanical specimens, today available at the Reggio Emilia Museum (Musei Civici di Reggio Emilia), Italy. In this personal collection both red coral colonies as well as coral branches consolidated and cemented with many remains of carbonatic benthic organisms are present.

Due to the particularly strong tidal currents determining an erosive regime until 300–350 m depth, the benthic communities of the Messina Strait are very peculiar [4,6]. These communities include kelp forests [7], facies dominated by the stylasterid hydrozoan *Errina aspera* (Linnaeus, 1767) [6,8,9], and by the giant barnacle *Pachylasma giganteum* (Philippi, 1836) [9,10]. Despite the high biodiversity, there are no scientific papers indicating the presence of *Corallium rubrum* in the area of the Strait [11]. In particular, in a recent large-scale survey conducted along the Italian coast, red coral was recorded immediately northern (Scilla) and southern (Pellaro Cape) of the Strait, but it was absent in the area described by Spallanzani [12]. On the other hand, the existence of coral harvesting activity in the Messina Strait was known in the past century but surely ended after the XX century [13].

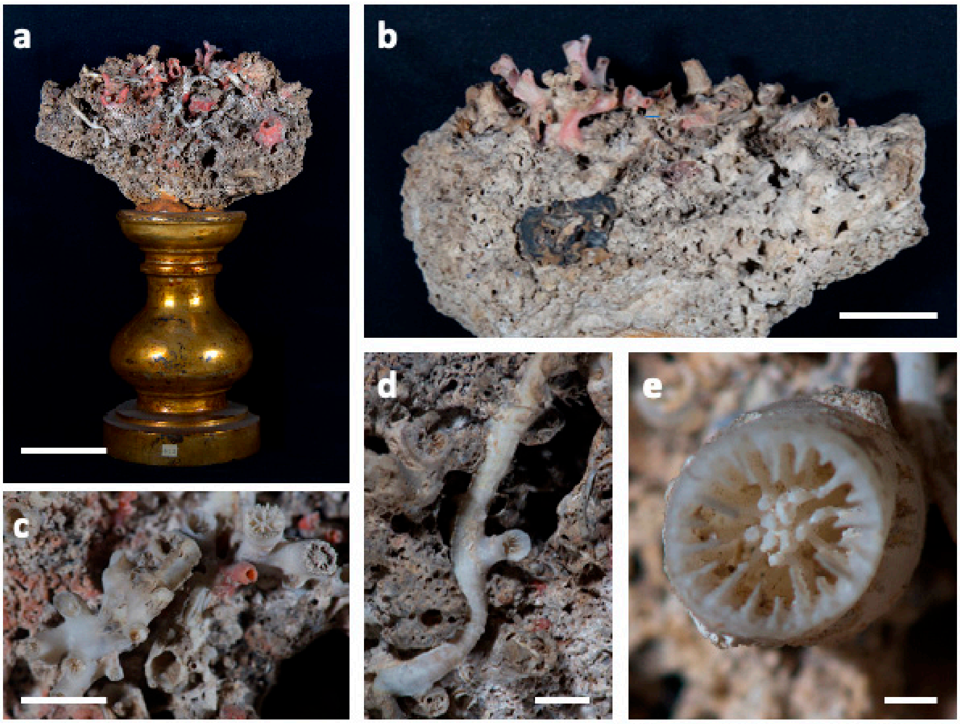
This current putative absence of red coral in the Strait makes the Spallanzani's data particularly intriguing: the aim of this study was the description of the specimens of the Reggio Emilia Museum to shed light on the benthic assemblage of the Strait inclusive of red coral, a community which, during the last two hundred years, has probably undergone significant changes.

2. Materials and Methods

The study of the Spallanzani's red coral collection at the Reggio Emilia Museum offered the opportunity to describe 12 red coral specimens (numbers 746/512, 747/513, 870/636, 871/637, 872/638, 873/639, 876/642, 878/644, 880/646, 881/647, 885/651, 886/652. The first number corresponds to the catalogue of the Spallanzani's collection compiled by Alfredo Jona in 1888; the second is a progressive number inside the old Linnean classes: class VI, Vermes, Order V, Zoophyta). Five samples were composed of red coral branches consolidated and cemented with several other calcareous organisms, while seven samples represented red coral colonies grown on other calcareous organisms. All the specimens were photographed thanks to the courtesy of the curator of the Museum, and the biodiversity of the community present in the consolidated coral rubbles was assessed. For the species determination we have mainly used the following taxonomic guides: scleractinians [14,15], bryozoans [16], serpulids [17], barnacles [18]; brachiopods [19,20]; bivalves [21,22].

3. Results

The first specimen analyzed in Spallanzani's collection is a large piece of coralligenous substratum (16 $\times$ 9 cm) (n° 886/652) (Figure 2a,b): it is mainly composed by the accretion of coralline algae (Figure 2b), and several bases of red coral colonies in their original position (Figure 2a,b), with a basal diameter ranging from 5 mm to 18 mm. Additionally, several scleractinians (including *Coenocyathus cylindricus* Milne Edwards and Haime, 1848) (Figure 2c–e), serpulids tubes (Figure 2f–g) and the bryozoan *Copidozoum* sp. (Figure 2h) were observed.



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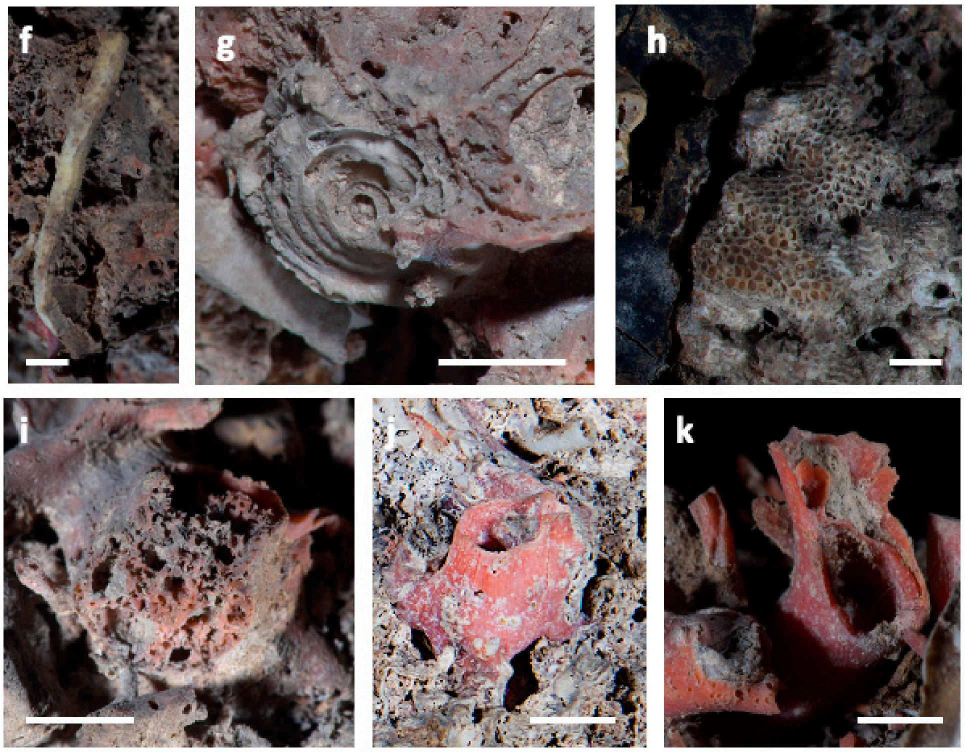


Figure 2. Front (**a**) and back (**b**) of a piece of a coralligenous substratum found in the Spallanzani's collection (n° 886/652). Red coral colonies occurred with other calcareous organisms such as scleractinians (**c**–**e**), serpulids tubes (**f**–**g**), and the bryozoan *Copidozoum* sp. (**h**). The bored coral scleraxis resulted in small chambers producing a typical spongious pattern (**i**) or converged to occupy the entire scleraxis (**j**–**k**). Scale bars: (**a**) 5 cm; (**b**) 3 cm; (**c**,**d**) 1 cm; (**e**) 0.1 cm; (**f**,**g**) 0.5 cm; (**h**) 0.2 cm; (**i**–**k**) 1 cm.

In three samples (Figure 3a–c), colonies of red coral settled on the wall plates of the giant barnacle *Pachylasma giganteum* (Philippi, 1836) about 3 cm in diameter (n° n° 870/636, 871/637, 872/638). The coral coenenchyma entirely covered the plates, laying on them a thin sheet of red scleraxis from which some coral branches (up to 3 cm long and 5 mm wide) arose (Figure 3a–c). A similar situation was observed on the corallites of the mesophotic scleractinian *Caryophyllia (Caryophyllia) cyathus* (Ellis and Solander, 1786) (Figure 3d,e). When red coral settled on the scleractinian, the coenenchyme covered the external side of the corallites without reaching the opening, probably due to the presence of the living coenenchyme of the scleractinian.

In another specimen, a coral colony grew on the oyster *Neopycnodonte cochlear* (Poli, 1795) in its turn overgrown by a small specimen of the bivalve (n° 885/651) (Figure 3f,g). Several juvenile red coral colonies developed on the shell of *N. cochlear* (Figure 3h). The shell, about 12 cm in diameter, was severely eroded by boring sponges, and was partially colonized by serpulids and scleractinians. The coral colonies appeared as small branches (1–2 cm high) arising from a common plate (Figure 3i1) or as red dots 2–3 mm in diameter (Figure 3i2,3).

In two cases (Figure 4a–c), dead colonies of red coral (10–12 cm high with a base diameter of 8–9 mm, respectively) were enveloped by coralline algae, probably *Pseudolithophyllum expansum* (Philippi) Me. Lemoine, 1924 together with some tubes of serpulids (n°871/639, 878/644).

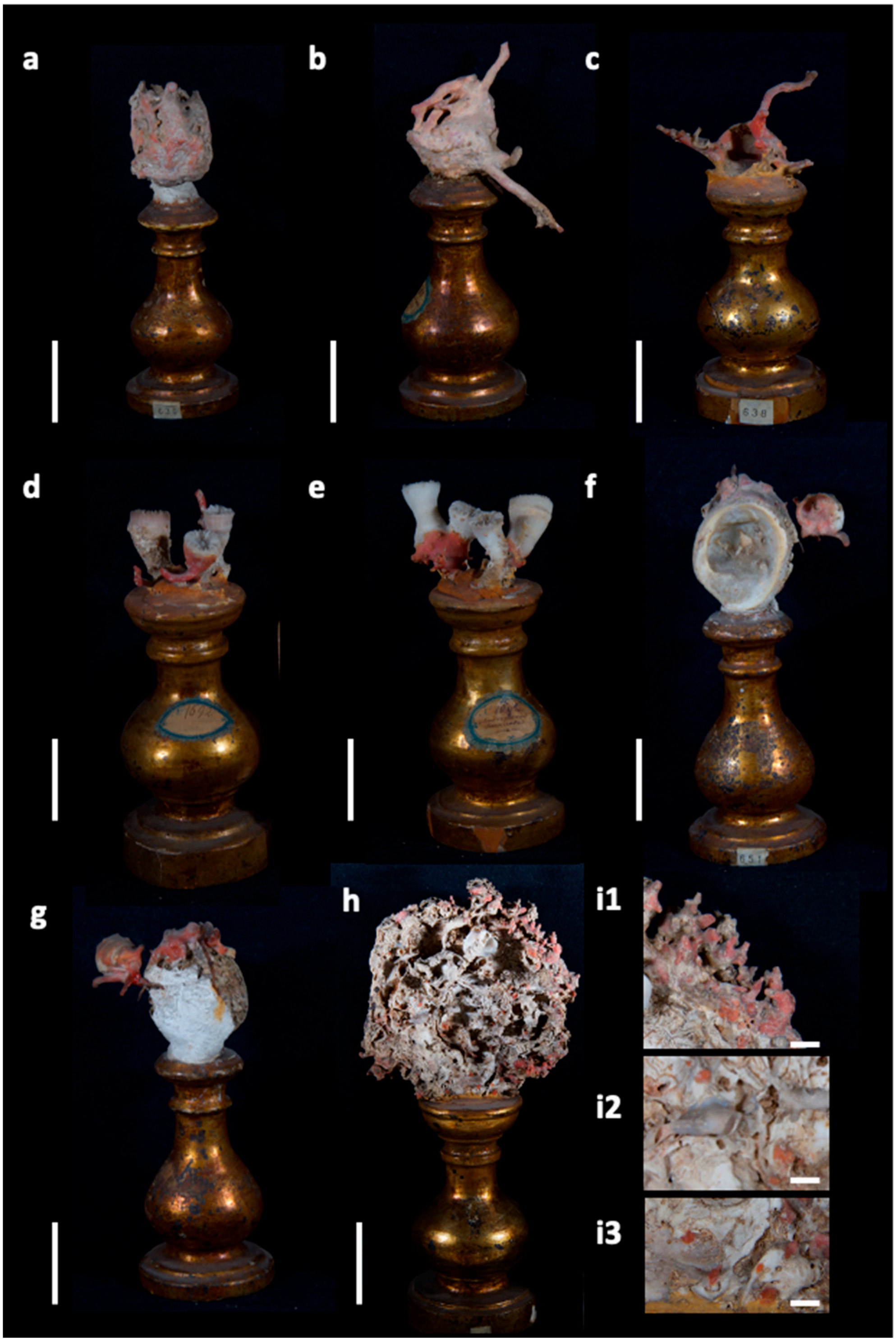


Figure 3. Examples of red coral and epibiosis: (**a**–**c**) colonies of red coral settled on the plates of dead specimens of the giant barnacle *Pachylasma giganteum* (n° 870/636, 871/637, 872/638) (**d**,**e**) corallites of *Caryophyllia (Caryophyllia) cyathus* above *Corallium rubrum.* (n° 746/512, 747/513) (**f**,**g**) A coral colony growing on a specimen of *Neopycnodonte cochlear* in its turn overgrown by a small specimen of the bivalve (n° 885/651). (**h**) Young coral colonies developed on the shell of the oyster *Neopycnodonte cochlear* (n° 876/642). The coral colonies appeared as small branches arising from a common plate (**i1**) or as red dots (**i2,3**). Scale bars, (**a**–**g**,**i**) 3 cm; (**i1**–**i3**) 1 cm.

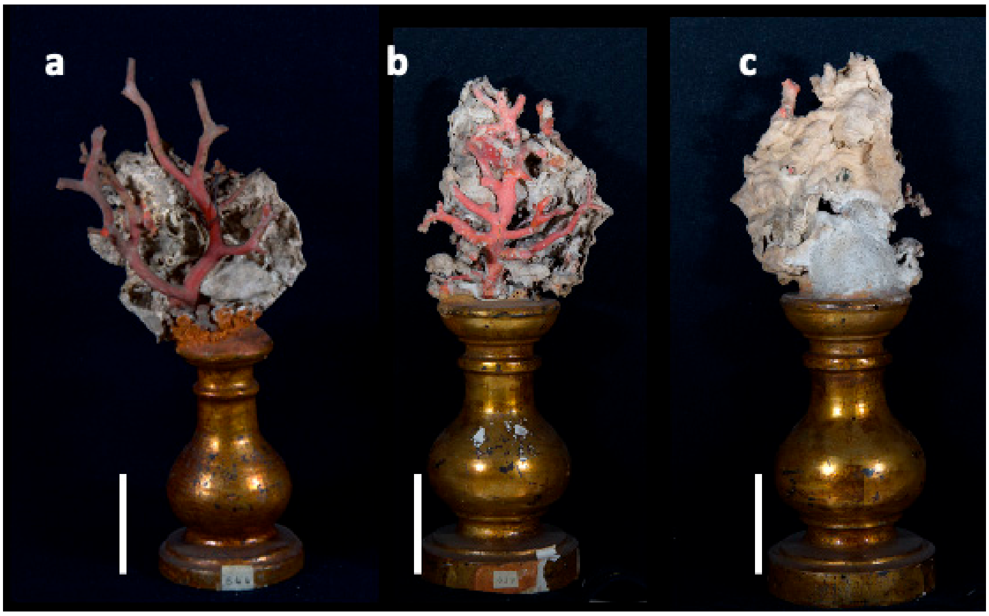
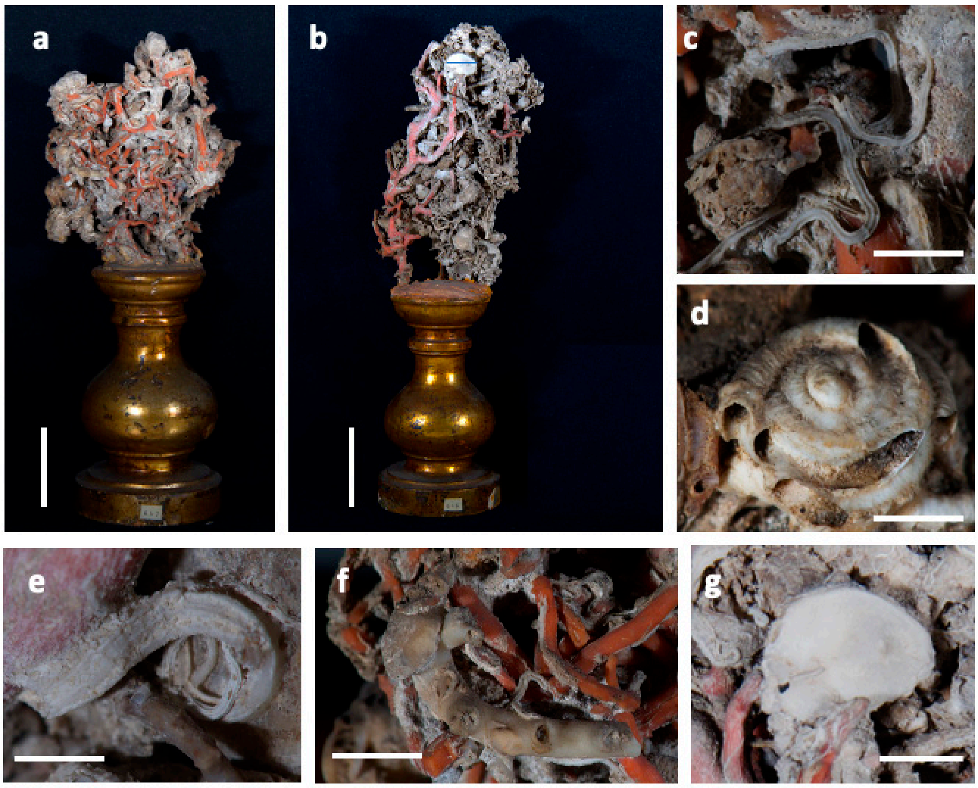


Figure 4. Front (**a**,**b**) and back (**c**) of dead red coral colonies enveloped by a sheet of the coralline alga *Pseudolithophyllum expansum* (n°871/639, 878/644). Scale bars, (**a**–**c**) 3 cm.

Finally, the last two specimens were constituted by branches of red coral intermixed with numerous other calcareous organisms and joined together by a micritic cement (Figure 5a,b) (n° 880/646, 881/647). In addition to the coral branches, several serpulids (*Serpula* sp., *Spirobranchus* sp.) (Figure 5c,e), a colonial scleractinian (probably *Madrepora oculata* Linnaeus, 1758) (Figure 5f), the bivalve *Spondylus gussonii* O. G. Costa, 1830 (Figure 5g), numerous bryozoans (*Cellaria* sp., *Reteporella* sp., *Copidozoum* sp.) (Figure 5h,i), and the brachiopod *Megerlia truncata* (Linnaeus, 1767) (Figure 5j) were recorded.



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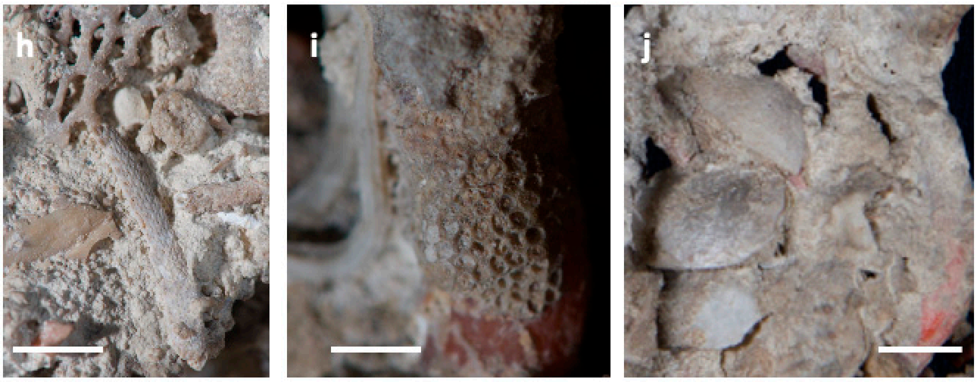

Figure 5. Two samples (**a**,**b**) composed of red coral fragments intermixed with other calcareous organisms and joined together by a micritic cement (n° 880/646, 881/647). (**c**–**e**) Serpulids (*Serpula* sp., *Spirobranchus* sp.); (**f**) a colonial scleractinian (probably *Madrepora oculata*); (**g**) the bivalve *Spondylus gussonii;* (**h**,**i**) bryozoans (*Cellaria* sp., *Reteporella* sp., *Copidozoum* sp.); (**j**) the brachiopod *Megerlia truncata*. Scale bars: (**a**,**b**) 5 cm; (**c**) 1 cm; (**d**,**e**) 0.5 cm; (**f**–**h**) 1 cm; (**i**) 1 cm; (**j**) 0.5 cm.

In all the studied specimens, red coral branches were widely bored by sponges. In particular, two types of erosions were evident. In one case, the coral scleraxis was bored by numerous very small (<1 mm) chambers producing a typical spongy aspect (Figure 2i). In the other cases, the boring chambers converged to occupy the entire scleraxis leaving only a thin sheet of carbonate (Figure 2j–k).

4. Discussion

Despite the scarcity of specimens, Spallanzani's historical collection gives interesting new information about the occurrence of red coral in the Messina Strait at the end of the XVIII century. These data are particularly important because, although the existence of coral harvesting activity in the Messina Strait was historically known, it was no longer reported by the end of the past century [13]. According to several authors [23–26], Cattaneo-Vietti et al. [11] stated that in the XIX century, the southernmost most-productive fishing ground along the Calabrian coast was Scilla. Additionally, recent ROV surveys conducted in the area of the Strait described by Spallanzani (e.g., Peloro Cape) never found colonies of the species [9,12]. This fact suggests that a local extinction or strong reduction in the red coral stocks occurred in this area.

The study of different specimens of the collection, compared with Spallanzani's descriptions, gave information about the substratum where red coral lived and the depth of the banks. Particularly interesting is the aptitude of *Corallium rubrum* in the Messina Strait to colonize other carbonatic organisms. Finally, the study of the conglomerates allowed describing the detritic community where the coral branches accumulated after the death and consequent detachment of the colonies.

Although red coral is able to settle on a large variety of substrata (Spallanzani describes colonies settled on broken potteries or, in the Aeolian archipelago, on a piece of "volcanic lacquer" = obsidian), as in most Mediterranean sites, also in the Messina Strait it settled preferentially on coralligenous rocks [12]. The presence of this organogenic substratum together with living *Pseudolithophyllum* spp. algae enveloping dead coral branches supported the hypothesis that the coral community was settled at a depth reached by enough light intensity to allow the algal growth. This evidence agrees with the bathymetric range described by Spallanzani (100–190 m depth) and with the preferential depth range of the species at the Mediterranean level [12]. A synthetic description of the coralligenous is present in a letter of the Abbot Gaetano Grano to Spallanzani [27] "The pieces of rock on which the coral colonies are attached are clusters of encrusting marine products. The fishermen . . . say they have never seen other rocks attached to the collected coral colonies. It is probable that the sandstone rock, typical of the area, is covered by marine productions on which, in their turn, coral colonies grow". The term coralligenous (coralligène) was created by A.F. Marion [28] to describe the hard bottoms that fishermen from Marseilles called "broundo", which range between 30 and 70 m depth, between seagrass meadows of *Posidonia oceanica* and coastal muddy bottoms. "Coralligène" means "producer of coral" and is related to the abundance of the red coral in this type of substratum. Grano's letter anticipates one century the more formal description of this peculiar biogenic structure.

According to direct observations of Spallanzani, confirmed by the study of the specimens present in his collection, in the Messina Strait red coral grew also on carbonatic organisms or on their remains (*Pachylasma giganteum*, *Neopycnodonte cochlear*, *Caryophyllia (Caryophyllia) cyathus*), sharing the same mesophotic distribution. Regarding bivalves, Spallanzani described at least one of the samples present in the collection "*In several fishing activities that those fishermen made when I was present, more than once they collected dead oyster shells to which small coral colonies were settled*". Relevant is the evidence that, on this substratum, several post-larval colonies of coral were present. These very small colonies were already described in a letter that the abbot Grano wrote to Spallanzani: "Fishermen have often observed on matters drawn from the bottom of the sea the principles of nascent coral which they describe as red spots with a button, or shoot consisting of a bone sometimes tender and fragile sometimes hard and of the colour and of the nature of ordinary coral" [27]. The growth of red coral colonies on *N. cochlear* reefs was recently reported at mesophotic depth along the Apulian coasts. In this situation, the colonies showed a patchy distribution, with aggregates of several specimens concentrated below the pinnacles of the structure [29].

Although Spallanzani was less specific about this topic, very relevant is the evidence that the colonies of red coral settled on dead shells of *P. giganteum* "[red coral] grows on the abundant shells or on any solid body". *P. giganteum* is an important component of highly diverse deep cold-water coral communities south of Malta including also red coral. In any case, on this site, the epibiosis of *C. rubrum* on the giant barnacles was never documented [30].

Regarding *C.* (*Caryophyllia) cyathus*, an assemblage dominated by this scleractinian and together with *C. rubrum* was already described on the circalittoral rock with a low degree of slope at Seco de los Olivos Seamount (SW Mediterranean Sea) [31].

Generally, red coral does not have shown exclusive preferences for the substratum, occupying both natural hard surfaces, as coralligenous and rocks, as well as plastic debris [32], but a specific epibiotic habitus was never reported in literature. The specimens of Spallanzani's collection are particularly interesting because red coral not only grew on the *P. giganteum* plates forming small unbranched colonies but completely overlayed these shells with a thin sheet of coenenchyme and scleraxis. A similar aptitude was shown by black corals that cover the stalked barnacles settled on their skeleton with a sheet of their spiny chitinous skeleton [33]. Obviously, we have also to take in consideration the possibility that red coral settled on these barnacle plates when the organisms was already dead and, in this case, it is not possible to consider this behavior as a true epibiosis.

Jackson [34] demonstrated that some colonial organisms can shift from encrusting to erect forms in relation to the level of competition in the community. In highly diversified coralligenous habitats, red coral produces erect colonies escaping competition, but, on the giant barnacles, this species is able to produce large encrusting colonies without the energetic costs associated with the bio-deposition of an erect carbonatic scleraxis. A similar situation was observed when the species grows on abandoned plastic lines [32]. Encrusting colonies of red coral were rarely described, although in some localities of the Aegean Sea they seem quite frequent [35].

Data on species diversity and structure in coralligenous outcrops dominated by *C. rubrum* are until now lacking. A survey conducted in several Mediterranean localities allowed the description of the diversity of perennial species inhabiting coralligenous outcrops [36]. This study listed about 120 species without including any of the species found associated with red coral in the Messina Strait. This evidence highlights once more the peculiarity of this area, together with the high ecological plasticity shown by red coral.

The occurrence of red coral branches consolidated and cemented with other carbonatic remains allowed describing the detritic community present at the base of rocks occupied by the coral populations. The study of detritic bottoms implies the problem of bioturbation that overturn the original position of different layers [37]. Hence, the study of cemented coral rubble samples represented an advantage to work on the undisturbed original community composition. These samples are of the same type as those recently described from the Sciacca Banks in the Sicily Channel and share with them some species as the shells of the brachiopod *Megerlia truncata* (Linnaeus, 1767), the bivalve *Spondylus gussonii*, and large serpulids [38]. A remarkable difference comparing the Messina specimens with those from Sciacca is the scarcity of the white coral *Madrepora oculata*.

In his book about the trip in Sicily, Spallanzani discussed the issue of the coral color "In the Messina Strait, in addition to red coral colonies, white ones were collected by fishermen. When I was present at the fishing, the caught corals were always red, but my friend Abbot Grano supplied me with some colonies shading from gray to completely white" [3]. Today, it is clear that colonies of *C. rubrum* are always red due to the presence of a polyenic or carotenoid pigment [39]. Probably, Spallanzani interpreted as white *C. rubrum* the colonial scleractinian *M. oculata*. A fragment of this last species occurred in one of the analyzed samples (n° 881/647), while large colonies are present in the Spallanzani's collection at the Reggio Emilia Museum. This finding is interesting because nowadays the common presence of red coral and *M. oculata* is very rare and generally happen at higher depth. A close association of the two species in the Sicily Channel has been described near Malta [40] and Linosa [41] around 800 to 650 m depth. Moreover, the two species have been recorded together in the Sciacca Banks [37] and the Cassidaigne Canyon along the French Mediterranean coast [42], at the same depth range of the Messina Strait populations.

An intriguing aspect is the process of consolidation of red coral rubbles only known for the Sicily Channel and now for the Messina Strait, with the only exception of a large specimen coming from Sardinian waters [38]. The progressive lithification of coral rubble was explored in tropical waters, where is considered related to the microbial biofilm promoting cementation and consolidation [43]. The formation of the Sciacca deposits is considered linked with the recurrent earthquakes occurring in the area that destroy the coral populations settled on the nearby volcanic tuffaceous rocks and lead to the accumulation of broken colonies at the base of the rocks [44,45]. Plausibly, the same conditions occur in the Messina Strait due to the seismically active tectonic context also characterizing this area [46]. It is also probable that the volcanism of the zone produces a chemical environment that favors the detritus cementation. Very likely, Spallanzani was the first marine biologist to handle portion of consolidated detritus including subfossil red coral branches almost 100 years before the Sciacca Banks' discovery.

The red coral branches of the Messina Strait are widely bored by bio-erosive sponges as already remarked by Spallanzani "The fishermen often fished coral branches pierced by lithophagous worms also observed by Donati and Marsigli". Unfortunately, it was not possible to remove fragments of etched material for an accurate microscopical analysis. Nevertheless, the large excavations extending to the entire scleraxis leaving free only a thin sheet of carbonate are very similar to those recorded in dead red coral from the Alboran Sea and attributed to *Delectona ciconiae* Bavestrello, Calcinai and Sarà, 1996 [47], while the spongiosus micro-excavation are very similar to those of *Siphonodictyon corallirubri* (Calcinai, Cerrano and Bavestrello, 2007) [48].

Finally, it is relevant the idea, at the end of the XVIII century, of a management of the red coral fishing obtained through a rotation of the banks on a decennial base. Caddy [49] identify this strategy as an 'ideal' management for sedentary species: the stock is divided into sub-areas, whose harvesting is staggered over a period of years, thus allowing depleted stocks to recover before restarting harvesting. Several Mediterranean countries and regions already had closures of coral fisheries in their legislation and nowadays, harvesting based on rotating areas is used in Morocco and Greece [50,51].

It is now clear that a decennial span of time is inconsistent with the slow growth rate of red coral colonies ([51] for a review). Probably, in a restricted area such as the Messina Strait, the rotation of the banks actuated by the fishermen proved to be too quick, resulting in overfishing that could have influenced, together with other unknown causes, the disappearance of the red coral from the area.

An aspect of red coral biology that could be related to its management regards its putative asexual reproduction. Spallanzani reported Vitaliano Donati's assumption about the ability of broken coral branches to live on the seafloor stating that "it is necessary that broken apexes found a stable, hard substratum where settle thanks to their mucous secretion". This idea was shared one century later by the famous French zoologist Henry Lacaze-Duthiers in his monumental Histoire naturelle du corail [52]. This last author suggested scattering in the sea the broken apexes of the collected colonies with the idea to enhance the reconstitution of the stocks. More recently, it was demonstrated through laboratory experiments the ability of red coral to reproduce via branch bailout [53]. Nowadays, the possible ability of branch fragments to produce a new colony is incorporated in the regional legislation of Sardinia that recommends to the fishermen to, after harvesting, immediately release, possibly in the fishing sites, the tips of the coral that are accidentally broken that cannot be marketed [54].

5. Conclusions

The study of the material collected by Lazzaro Spallanzani and held in the collection at the Reggio Emilia Museum allowed the description of a peculiar assemblage, including the precious red coral, occurring in the Messina Strait at the end of the XVIII century. Additionally, thanks to his accurate observations, both directly collected during fishing activities and obtained by interviews with local fishermen, we can make a sketch of this coral population that today is probably disappeared or strongly reduced. In this area, red coral settled as usual on coralligenous rocks, but also on the carbonatic structures of living organisms and their remains. Particularly interesting is a possible association between red coral and *Madrepora oculata,* two species that, nowadays, generally show a different bathymetric range. Although some of these associations are known in different areas of the Mediterranean Sea, they are present together in the Strait confirming the peculiarity of the assemblages occurring in this area.

Moreover, it is interesting that some recent findings about the biology, ecology and conservation of this charismatic species were described in nuce in Spallanzani's book.

For example, the evidence that red coral has strong preferences for the biogenic substrata produced by the accumulation of the talli of coralline algae, anticipates one century the formal description of the coralligenous bioherms [28]. Additionally, the idea that marine resources and, in particular, red coral, are not infinite but need accurate managemental strategies seems particularly modern.

In conclusion, the XVIII century represented a turning point in the study of red coral biology. Marsigli, Peyssonnell, Jussieu, Guettard, and Donati Cavolini have provided essential contributions to the nature, ecology, and fishing of this charismatic organism and Spallanzani's work provides a milestone in clarifying numerous aspects related to the ecology, fisheries, and management of this species with an essential focus on a peculiar area of the Mediterranean Sea.

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