

## Article

# The Diversity, Structure, and Development of the Epibiont Community of *Paramuricea clavata* (Risso, 1826) (Cnidaria, Anthozoa)

Martina Canessa <sup>1,2,\*</sup> , Ilaria Amedeo <sup>3</sup>, Giorgio Bavestrello <sup>1,2</sup> , Pier Panzalis <sup>4</sup> and Egidio Trainito <sup>5</sup> 

- <sup>1</sup> Dipartimento di Scienze della Terra dell'Ambiente e della Vita (DISTAV), Università di Genova, Corso Europa 26, 16132 Genoa, Italy; giorgio.bavestrello@unige.it
- <sup>2</sup> National Biodiversity Future Center (NBFC), Piazza Marina 61, 90133 Palermo, Italy
- <sup>3</sup> Via Santa Chiara 11, 07026 Olbia, Italy; ilaria.amedeo1@gmail.com
- <sup>4</sup> Tavolara Punta Coda Cavallo MPA, Via S. Giovanni 14, 07026 Olbia, Italy; ambiente@amptavolara.it
- <sup>5</sup> Genoa Marine Centre-Stazione Zoologica Anton Dohrn Istituto Nazionale di Biologia, Ecologia e Biotecnologie Marine, Villa del Principe, Piazza del Principe 4, 16126 Genoa, Italy; et@egidiotrainito.it
- \* Correspondence: marti.canessa@gmail.com; Tel.: +39-3425601343

**Abstract:** Mass mortality events and anthropogenic impacts affecting *Paramuricea clavata* (Risso, 1826) have been increasingly documented during the last decades. These impacts have enhanced the settling of epibiont organisms on injured colonies. This epibiosis was studied using photographic sampling carried out on the granitic outcrops of the Tavolara Channel within the Tavolara–Punta Coda Cavallo marine-protected area (NE Sardinia) between 2017 and 2023 at 35–55 m. The number of colonies and percentage of surface involved in the epibiosis, the specific richness of the epibiont community, and the temporal evolution of the phenomenon were studied. Almost all the investigated gorgonians (93%) showed parts involved in epibiosis, with high percentages of surface covering (one-third of the surface). Out of the 37 epibiont species recorded, the most recurrent ones demonstrated an ecological succession dominated by Hydrozoa, Porifera, Bryozoa, Serpulidae, and the parasitic soft coral *Alcyoniun coralloides*. Nevertheless, single colonies studied over time revealed the unpredictability of the colonization process. The peculiar habitat of the granitic outcrops hosting the *P. clavata* forests is of a high naturalistic value and demonstrates a widespread condition of suffering, supported by both environmental and anthropogenic sources of stress. Such considerations make it necessary to review the current zonation of the area, where the actual vulnerability and usability evaluations are based on incomplete information.

**Keywords:** gorgonians; benthic assemblages; fishing impact; global change; conservation; Mediterranean Sea



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## 1. Introduction

The purple gorgonian *Paramuricea clavata* (Risso, 1826) is an endemic Mediterranean species [1] considered “vulnerable” in the Red List of the International Union for Conservation of Nature [2] because of its large size, branched shape, and limited flexibility that render it highly susceptible to a wide range of natural and human impacts [3–6]. A pool of evidence regarding the reduction in some Mediterranean populations in the last three decades has addressed a mix of consequences due to the increase in positive thermal anomalies with summer diseases and the development of filamentous algae, mucilage, and invertebrate epibionts [7–22].

Moreover, it has been recognized that *P. clavata* forests are highly sensitive to direct and indirect anthropogenic impacts (boat anchoring, recreational and commercial fishing, and SCUBA diving) [19]. In 1997, Bavestrello et al. [4] described the multiple damages inflicted on these gorgonians by fishing activity: lost lines in contact with colonies scrape

the coenenchyme, and these abrasions create suitable conditions for the settlement of numerous epibiont organisms that weigh down the branches until the total or partial breaking of the colony occurs under the action of the currents. This issue has been reported by several authors who suggest that the number of colonies involved in epibiosis is an index of the stress of the population due to fishing [2,5,6,23,24]. In fact, Linares et al. [25] stated that, without extraordinary events, the extent of colony injury and the proportions of affected gorgonian colonies have remained low over time; therefore, any substantial increase in these parameters may serve as a good indicator of recent disturbances.

The Tavolara–Punta Coda Cavallo Marine Protected Area (40.8830 N, 9.7020 E, Sardinia, Italy) hosts a large population of *P. clavata* settled on both Tavolara Island's limestones and the Tavolara Channel's granitic outcrops [26,27]. This *P. clavata* population has been widely studied in recent years, with several surveys conducted since the 2000s to evaluate its health status after the occurrence of diseases/mortality events [14,16,21,28]. Unfortunately, this pool of data covers only shallow sites (up to 35 m in depth) under the medium–high protection regime (A–B Zones) and does not include gorgonians settled on deeper granitic shoals at depths ranging from 35 to 55 m [27], characterized by low protection levels (C Zone) and prone to intense fishing activity [29,30].

This paper aims to obtain data about the levels of epibiosis in the gorgonians present in this charismatic MPA and also concerning different regimes of protection. Moreover, a particular focus is provided on the diversity, structure, and development of the epibiont community. In fact, despite the wide use of epibiosis as an index of injuries, few data are available regarding descriptions of the community.

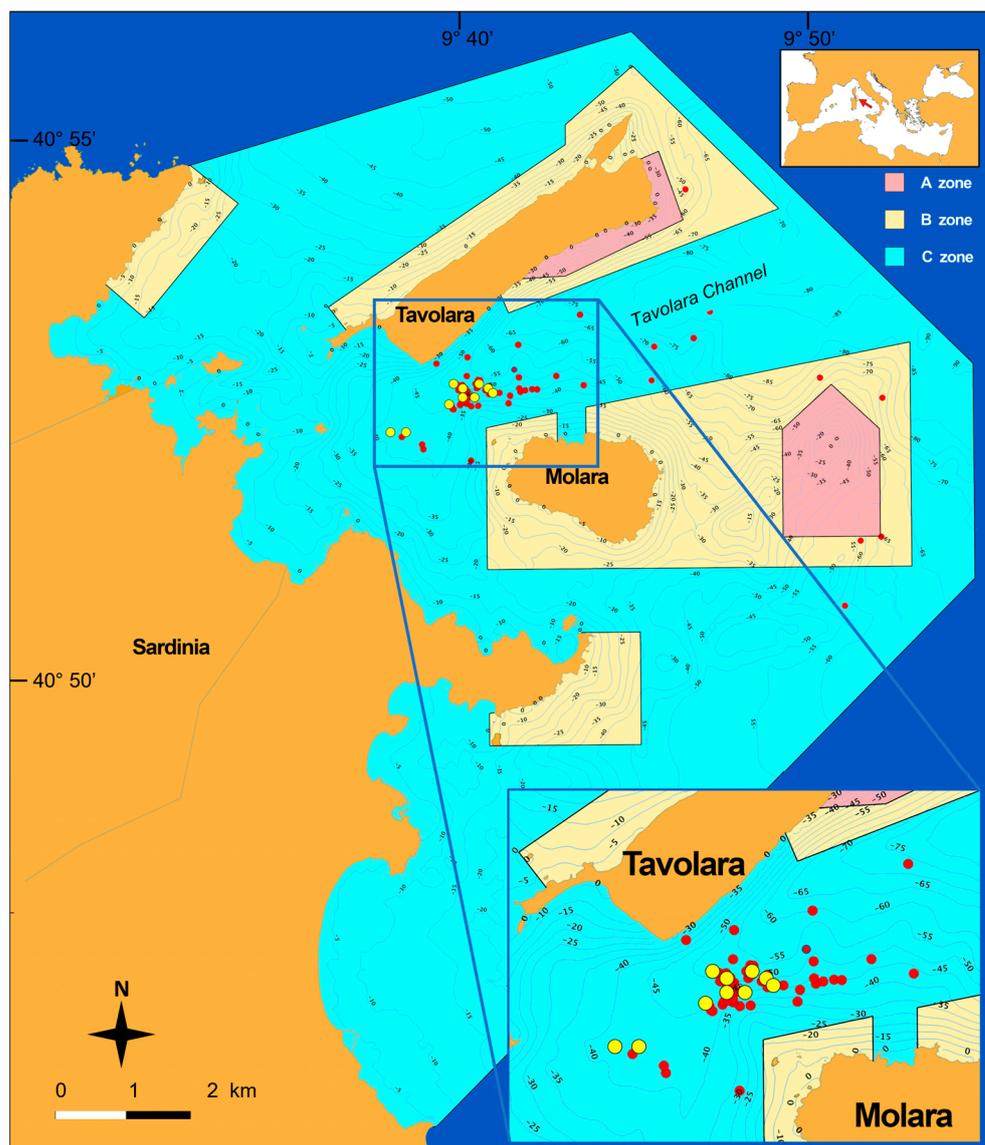
## 2. Materials and Methods

The Tavolara MPA was established in 1997, and the zoning definition, based on various campaigns documented by Bianchi et al. [31], has not subsequently changed. This MPA provides three levels of protection with definitive regulations (decree n°299, issued by the Ministero dell'Ambiente e della Tutela del Territorio del Mare on 30 December 2014): the A Zone, the no-entry/no-take reserve; the B Zone, the general protection reserve; and the C Zone, the partial protection reserve. Artisanal fishing performed only with selective gears that preserve the seafloor integrity is allowed in the B and C Zones. In the latter, recreational fishing is also allowed, though with some restrictions.

Our study area involved granitic outcrops that emerge from a detrital plain located in the middle of the Tavolara Channel (C Zone) between the Tavolara and Molara Islands, in the depth range of 35–55 m (Figure 1).

During scuba dives performed from 2017 to 2023, 10 granitic sites (out of 57 where *Paramuricea clavata* is present) were selected on the basis of gorgonian abundance ( $>5$  col.  $m^{-2}$ ). For each shoal, on average, 40 photos were obtained, applying the multi-zoom photographic approach [32] to evaluate the occurrence of damages to and epibionts on gorgonians. Images were taken using a Sony A6000 camera (24 megapixels, two Inon Z330 flashes, color temperature of 5000 K) with a Sony 16–50 lens (focal length of 19 mm), a Nauticam WW1 wet wide lens (130° rectilinear field angle) and a Sea & Sea MDX-A6000 underwater case with a flat porthole. Photos were post-processed with Adobe Photoshop©, while formal analysis was performed with ImageJ Software [33].

Out of 410 photographs, 582 colonies of *P. clavata* with frontal perspectives were examined to evaluate the recurrence percentage of single epibionts, the diversity of the epibiont assemblage, and the relative surface of the gorgonian involved in epibiosis. The epibiont coverage was estimated as a percentage of the planar colony surface to avoid problems due to the angular distortion of the images. The three-dimensional development of the epibionts was not considered, as our focus was the relative area of each colony involved in epibiosis. Only colonies with more than 5% of the surface area subjected to epibiont coverage were considered in our study. Finally, we recorded the presence of entangled and abandoned fishing gear.



**Figure 1.** The investigated area within the Tavolara–Punta Coda Cavallo MPA. Red spots indicate granitic shoals with the presence of *Paramuricea clavata*; yellow spots indicate the shoals considered in this study.

Epibiont organisms were identified and classified at the lower taxonomic level; when specific or generic identification was not possible, other taxonomic and morphological units (OTUs) were adopted. Only taxa with a recurrence higher than 10% of the whole photographic dataset were employed in the formal analysis.

Moreover, owing to the wide photographic archive (1986–2023) (ET), we had the opportunity to analyze images of the same colonies (easily recognizable by the overlapping of the main ramifications) taken over a long period. These data allowed us to reconstruct the temporal evolution of the epibiosis process. All images present in the archive and selected for this study were obtained with the same technique.

### 3. Results

#### 3.1. *Paramuricea Clavata* of the Tavolara Channel Granitic Shoals

The granitic outcrops emerging from the detritic bottom of the Tavolara Channel are characterized by a modest development of the basal coralline algal layer that only occasionally forms the typical coralligenous bioherms. The density of the *Paramuricea clavata* varied from 5 to 25 colonies  $m^{-2}$ . Moreover, the macrobenthic community is mainly represented

by other gorgonians (*Eunicella cavolini* (Koch, 1887), *E. singularis* (Esper, 1791), *E. verrucosa* (Pallas, 1776), erected sponges (*Axinella polypoides* Schmidt, 1862, *Spongia* (*Spongia*) *officinalis* Linnaeus, 1759, *Sarcotragus foetidus* Schmidt, 1862) and branched bryozoans (*Adeonella calveti* Canu and Bassler, 1930, and *Turbicellepora avicularis* (Hincks, 1860)) (Figure 2a,b).

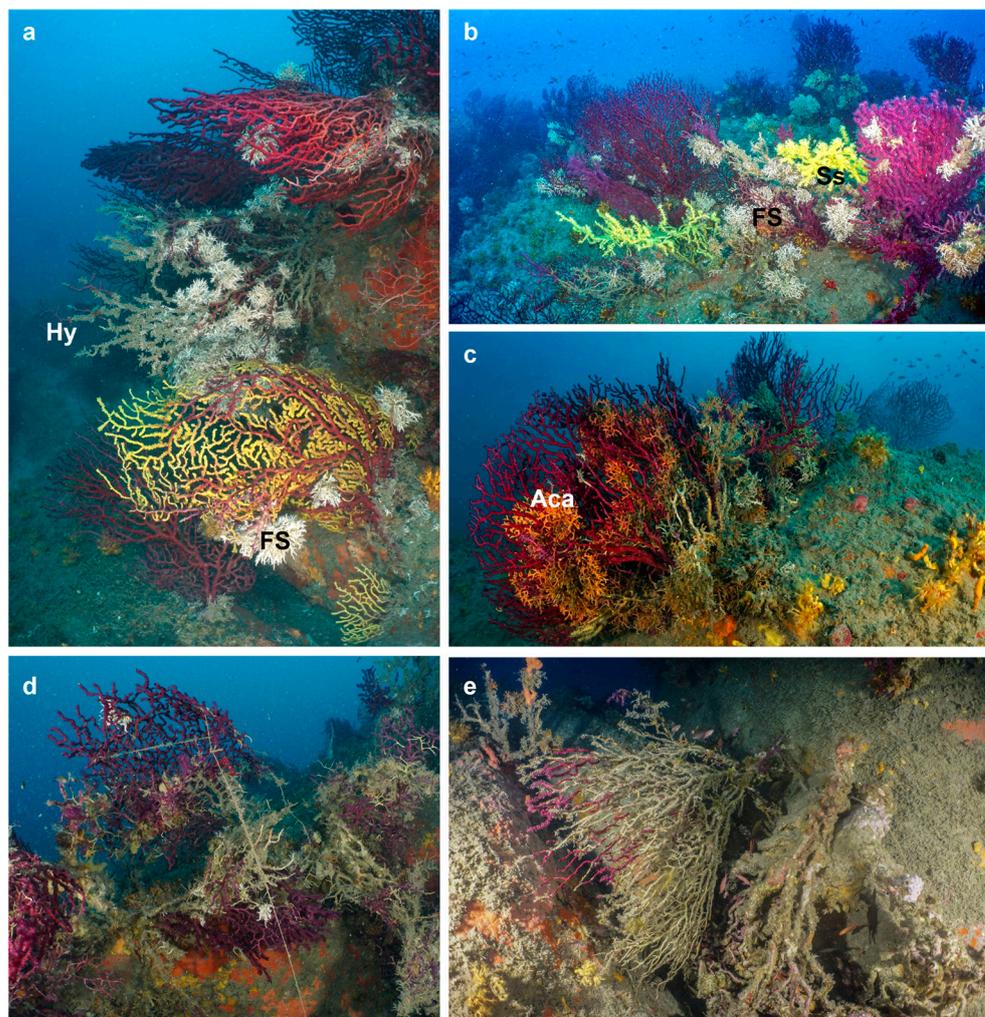


**Figure 2.** (a,b) The benthic community settled on the granitic shoals of the Tavolara Channel is mainly characterized by large sponges (*Sarcotragus foetidus*, *Axinella* species) and gorgonians (*Eunicella verrucosa*, *Paramuricea clavata*). (c,d) Diseased colonies showed a massive coenenchyme loss during the mass mortality of 2018. (e) Spawning and (f) recruits of *P. clavata*; (g) spawning of the parasitic soft coral *Alcyonium coralloides*.

During the period of observations, serious damages to colonies resulting from heat waves, with necrosis and loss of coenenchyme, were documented in 2018 (Figure 2c,d); other less intense episodes were recorded in 2017, 2019, and 2020. The *P. clavata* spawning (Figure 2e) was recorded between 2009 and 2022 (ET personal observations), with the exceptions of 2010, 2018, and 2019. Recruits, as small unbranched colonies composed of less than ten polyps (Figure 2f), were observed in 2017, 2018, and 2020.

### 3.2. Epibiosis

Of the 582 studied colonies of *P. clavata*, 541 presented some degree of epibiosis (93.0%), and only 41 (7.0%) were intact (Figure 3a–c); 455 (78.2%) showed epibiosis on more than 5% of the colony’s surface, 15 (2.6%) were recorded completely dead in standing position, 31 (4.6%) were found entangled in lost fishing gear (Figure 3d), and 58 (8.8%) were uprooted (Figure 3e). On average, epibiosis affected  $27.3 \pm 1.2\%$  of the colony surface.



**Figure 3.** (a–c) *Paramuricea clavata* forests showing a high level of epibiosis due to Hydrozoa carpet (Hy), false black coral *Savalia savaglia* (Bertoloni, 1819) (Ss), *Filograna/Salmacina* spp. (FS), and calcified branched Bryozoa *Adeonella calveti* (Aca). (d) Colonies recorded entangled in lost fishing gear and (e) totally uprooted.

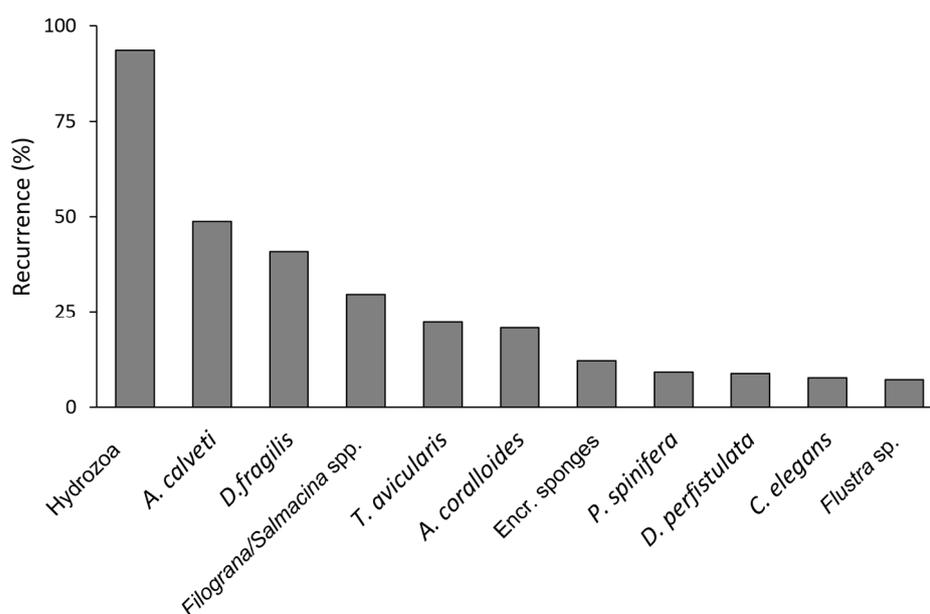
From the diversity point of view, the epibiont assemblages on the gorgonians of the Tavolara MPA accounted for 37 species (or OTUs), of which 5 were vagile (Table 1).

The most diversified group was Porifera, with 11 species (or OTUs), followed by Bryozoa and Ascidiacea, respectively, with 7 and 5 species (or OTUs). About 13% of the observed colonies showed only one epibiont species (OTUs), about 45% hosted two to three species, while 23% were found with four to five species (OTUs). The highest value of species (OTUs) per colony was 16, which was recorded in one colony. The most common species/OTUs (Figure 4) resulted in the ubiquitous Hydrozoa recorded in 91.9% of the epibiont colonies, four Porifera (*Dysidea fragilis* (Montagu, 1814) (43.8%), *Crella* (*Crella*) *elegans* Schmidt, 1862) (10.4%), *D. perfistulata* Pulitzer-Finali and Pronzato, 1980 (10.2%), (*Pleraplysilla spinifera* (Schulze, 1879) (9.9%)), three Bryozoa (*Adeonella calveti*

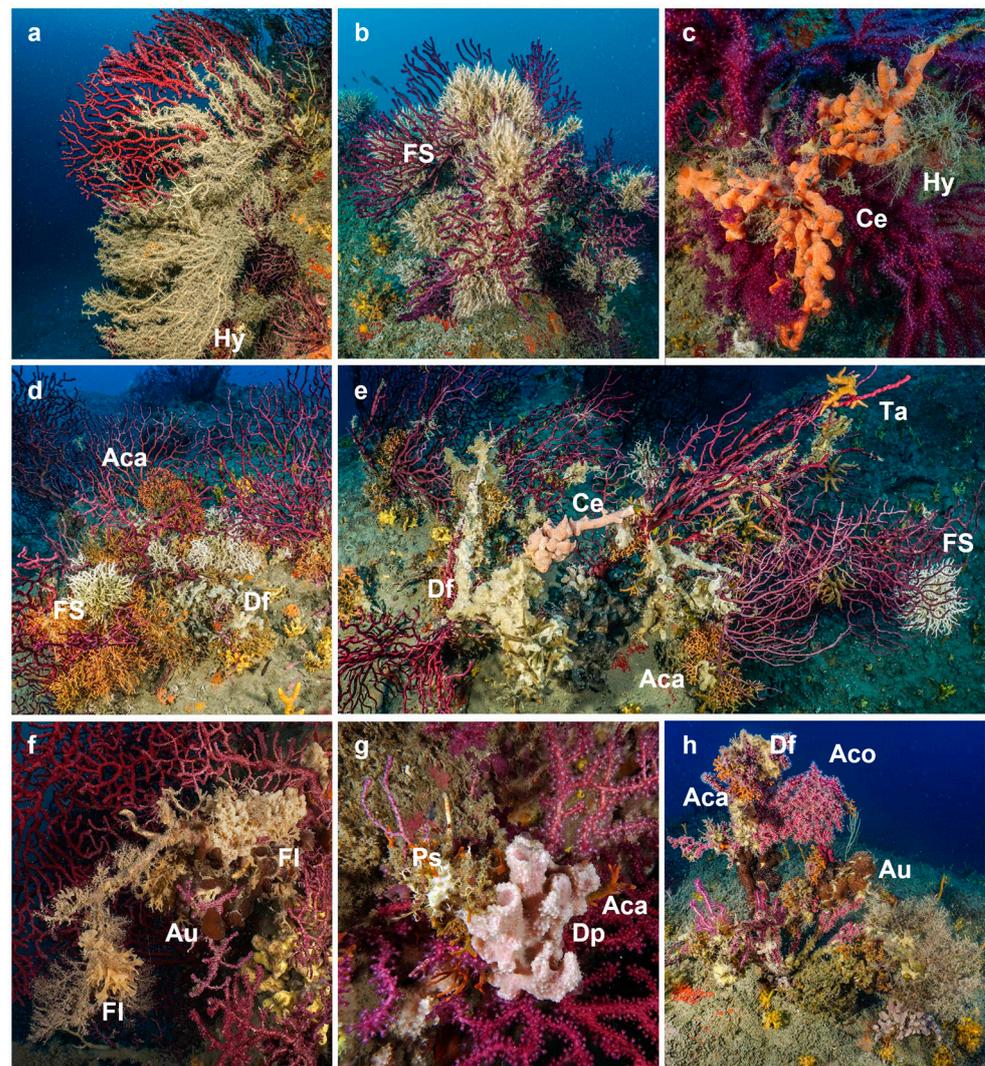
(52.3%), *Turbicellepora avicularis* (26.9%), *Flustra* sp. (9.6%)), parasitic Alcyonacea *Alcyonium coralloides* (Pallas, 1766) (22.9%), and Serpulidae *Filograna/Salmacina* spp. (33.3%) (Figure 5).

**Table 1.** Species/OTUs found on *Paramuricea clavata* and their percent of recurrence, calculated based on the whole photographic dataset. (\*) Vagile species and taxa with a recurrence of <10% were not taken into account for the formal analysis.

Species/OTUs	Recurrence (%)	Species/OTUs	Recurrence (%)
Algae		Anellida	
Crustose Corallinales	2.5	<i>Filograna/Salmacina</i> spp.	33.3
<i>Flabellia petiolata</i>	0.2	Serpulidae	5.6
<i>Valonia</i> sp.	0.2	Bryozoa	
Porifera		<i>Adeonella calveti</i>	52.3
<i>Anchinoe tenacior</i>	0.2	<i>Beania magellanica</i>	0.9
<i>Crella elegans</i>	10.4	<i>Cellaria salicornioides</i>	0.5
<i>Dysidea avara</i>	0.2	<i>Flustra</i> sp.	9.6
<i>Dysidea fragilis</i>	43.8	<i>Pentapora fascialis</i>	1.6
<i>Dysidea perfistulata</i>	10.2	<i>Turbicellepora avicularis</i>	26.9
<i>Haliclona mediterranea</i>	1.4	Encrusting Bryozoans	1.4
<i>Ircinia variabilis</i>	0.2	Crustacea	
<i>Oscarella lobularis</i>	2.5	<i>Periclimenes scriptum</i> *	0.5
<i>Pleraplysilla spinifera</i>	9.9	Echinodermata	
<i>Terpios fugax</i>	2.8	<i>Antedon mediterranea</i> *	0.2
Encrusting Sponges	14.4	<i>Astrospartus mediterraneus</i> *	0.2
Cnidaria		Chordata	
Hydrozoa	91.9	<i>Aplidium undulatum</i>	7.9
<i>Alcyonium coralloides</i>	22.9	<i>Clavelina dellavallei</i>	1.6
<i>Epizoanthus</i> species	0.2	<i>Clavelina oblonga</i>	0.9
Mollusca		Didemnidae	0.9
<i>Pteria hirundo</i>	0.7	<i>Pycnoclavella communis</i>	0.7
<i>Calliostoma conulus</i> *	0.2		
<i>Flabellina ischitana</i> *	0.5		



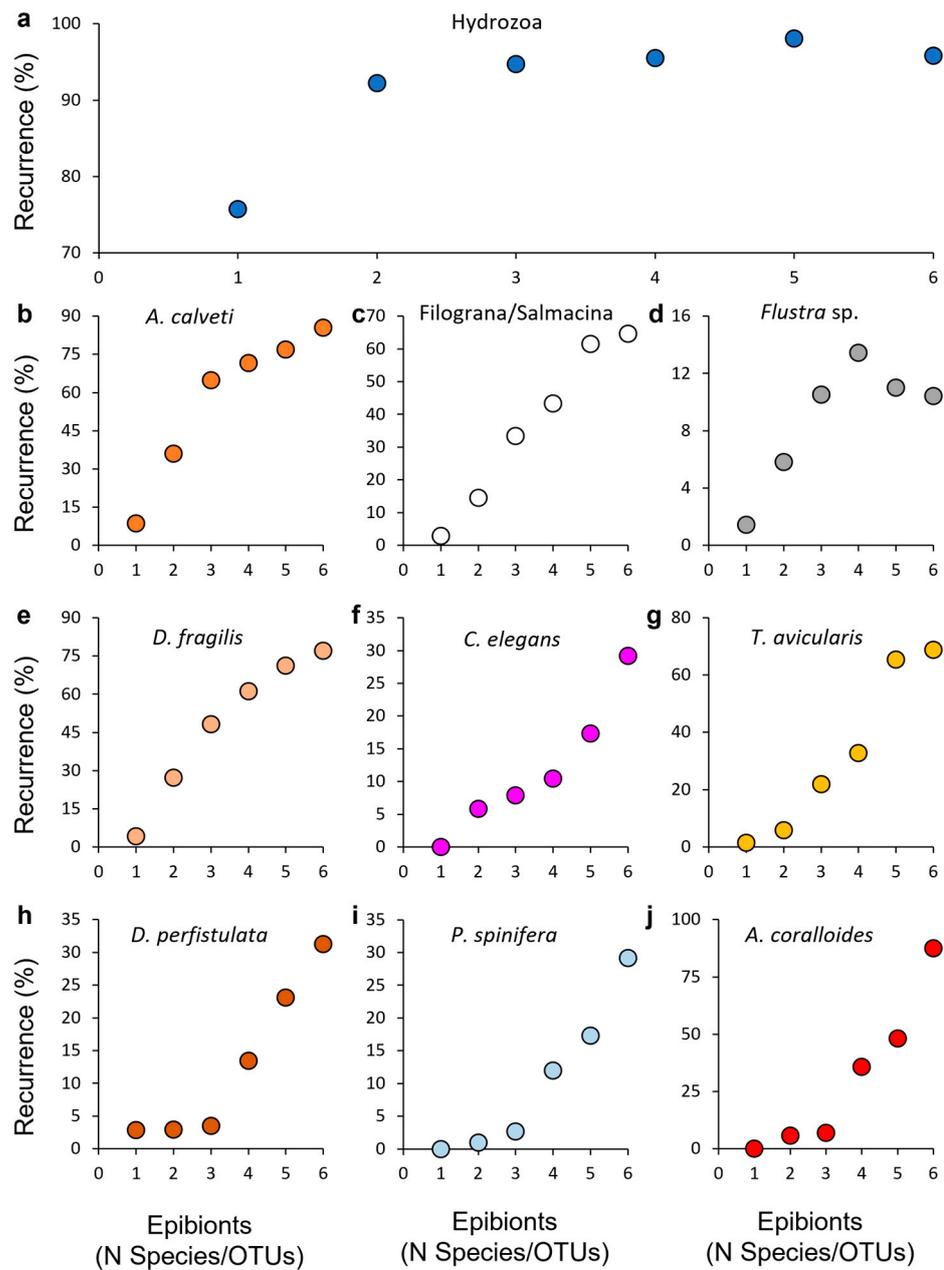
**Figure 4.** Percent of recurrence of the recorded species/OTUs with values greater than 10%, calculated based on the whole photographic dataset.



**Figure 5.** The main epibionts recorded on *Paramuricea clavata*: (a) Hydrozoa turf (Hy), (b) large masses of Serpulidae *Filograna/Salmacina* spp. (FS), (c) Porifera *Crella elegans* (Ce), (d–h) complex epibiont communities composed of Porifera *Dysidea fragilis* (Df), *D. perfistulata* (Dp), and *Pleraplysilla spinifera* (Ps), parasitic Alcyonacea *Alcyonium coralloides* (Aco), Serpulidae *Filograna/Salmacina* spp., Bryozoa *Adeonella calveti* (Aca), *Flustra* sp. ((FI) and *Turbicellepora avicularis* Ta), and Tunicata *Aplidium undulatum* (Au).

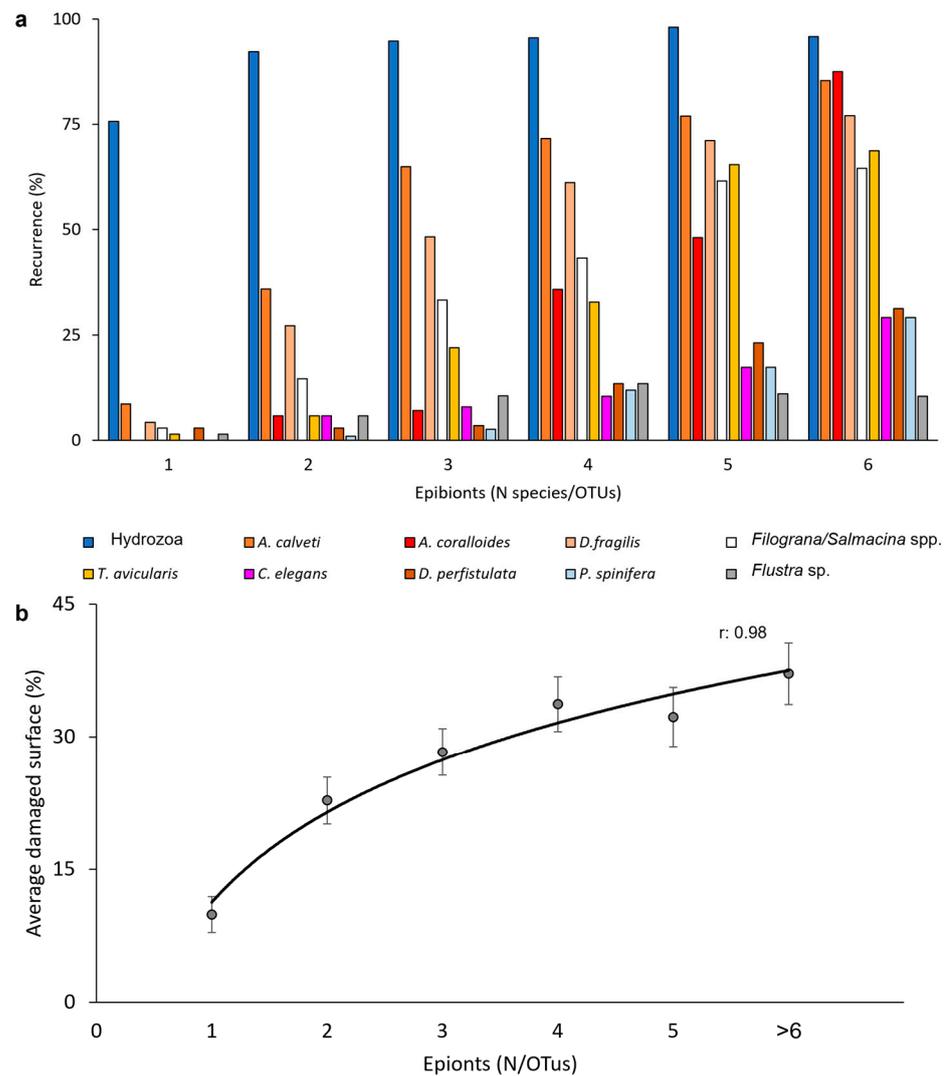
These species produced different growth patterns on the gorgonian branches (Figure 5). The observed Hydrozoa generally did not make large colonies but a carpet of small creeping colonies involving the entire naked skeleton. *A. calveti*, *T. avicularis*, and *Filograna/Salmacina* spp. were able to produce large subspherical colonies that develop starting from a small portion of the free skeleton. Finally, Porifera and *A. coralloides* grew, covering entire branches of the gorgonians.

Single epibiont species adopted a different pattern of colonization in relation to the richness of the assemblage. Hydrozoa were always recorded as pioneers and occurred in the epibiont community independently of their richness. The group of bushy species (Bryozoa and Serpulidea) followed Hydrozoa, and their occurrence quickly increased according to the number of species present in the community. A similar trend was shown by a pair of Porifera (*D. fragilis* and *C. elegans*) that grew, covering a wide portion of the gorgonian's branches. Finally, other species such as *D. perfistulata*, *P. spinifera*, and *A. coralloides*, needed more than four species or OTUs of the assemblage for their settling (Figure 6).



**Figure 6.** Percent of recurrence of the main species/OTUs showing different colonization strategies in relation to the diversity of the assemblage. (a) Hydrozoa is the main pioneer species and remains dominant at all the colonization phases; (b–i) branched Bryozoa (*Adeonella calveti*, *Flustra* sp., and *Turbicellepora avicularis*), Serpulidae *Filograna/Salmacina* spp., and Porifera *Dysidea fragilis* and *Crella elegans* settled immediately after Hydrozoa and quickly increased according to the community richness. (j) *D. perfistulata*, *Pleraplysilla spinifera*, and *Alcyonium coralloides* need a certain degree of diversity of the assemblage for their settling (>4 species/OTUs); after that, their growth is continuous.

During the colonization process, new species were added to the community that became more and more complex without substitution (Figure 7a): in fact, the average percentage of the gorgonian surface involved in epibiosis colonies increased according to the diversity of the epibiont community (Figure 7b).

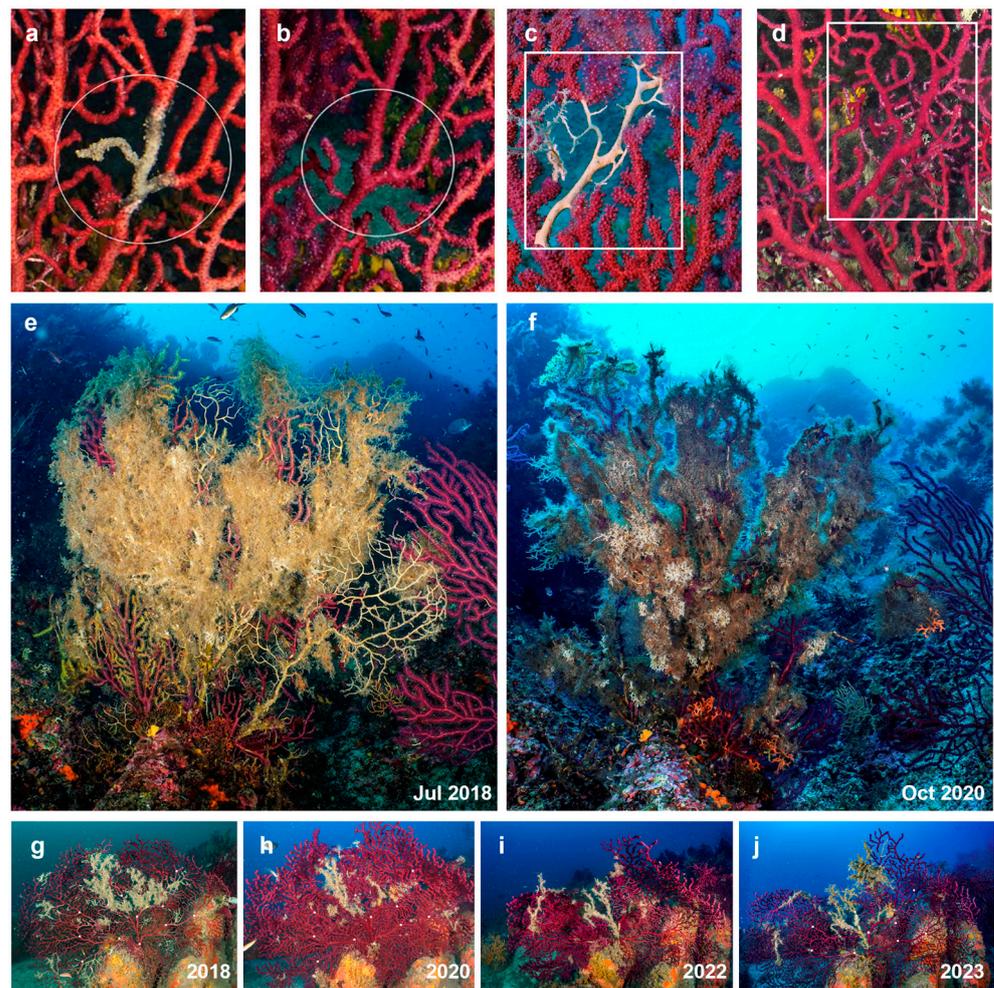


**Figure 7.** (a) Percent of recurrence of the main species/OTUs according to the diversity of the epibiont community. (b) The average percentage of the gorgonian surface involved in epibiosis shows a progressive increase according to the diversity of the epibiont community, as shown by the correlation line ( $r: 0.98$ ).

### 3.3. Observations on Single Gorgonians through Time

By observing single colonies through time (months, seasons, and years), it was possible to describe the development of epibiosis on *P. clavata*, which showed great variability in mode and time, even if some general patterns can be described.

When the lesions of the coenenchyme originate from thermal stress, the fate of the epibiosis depends on the extension of the denuded scleraxis. In fact, if the involved surface was not too extended, the coenenchyme was able to re-grow on the naked skeleton, even if already covered by the hydrozoan carpet. Two colonies photographed in 2020 showed a complete recovery in two years (Figure 8a–d). When the lesions were too wide, recovery was not possible, and epibiosis developed very quickly, involving the entire colony (Figure 8e,f).

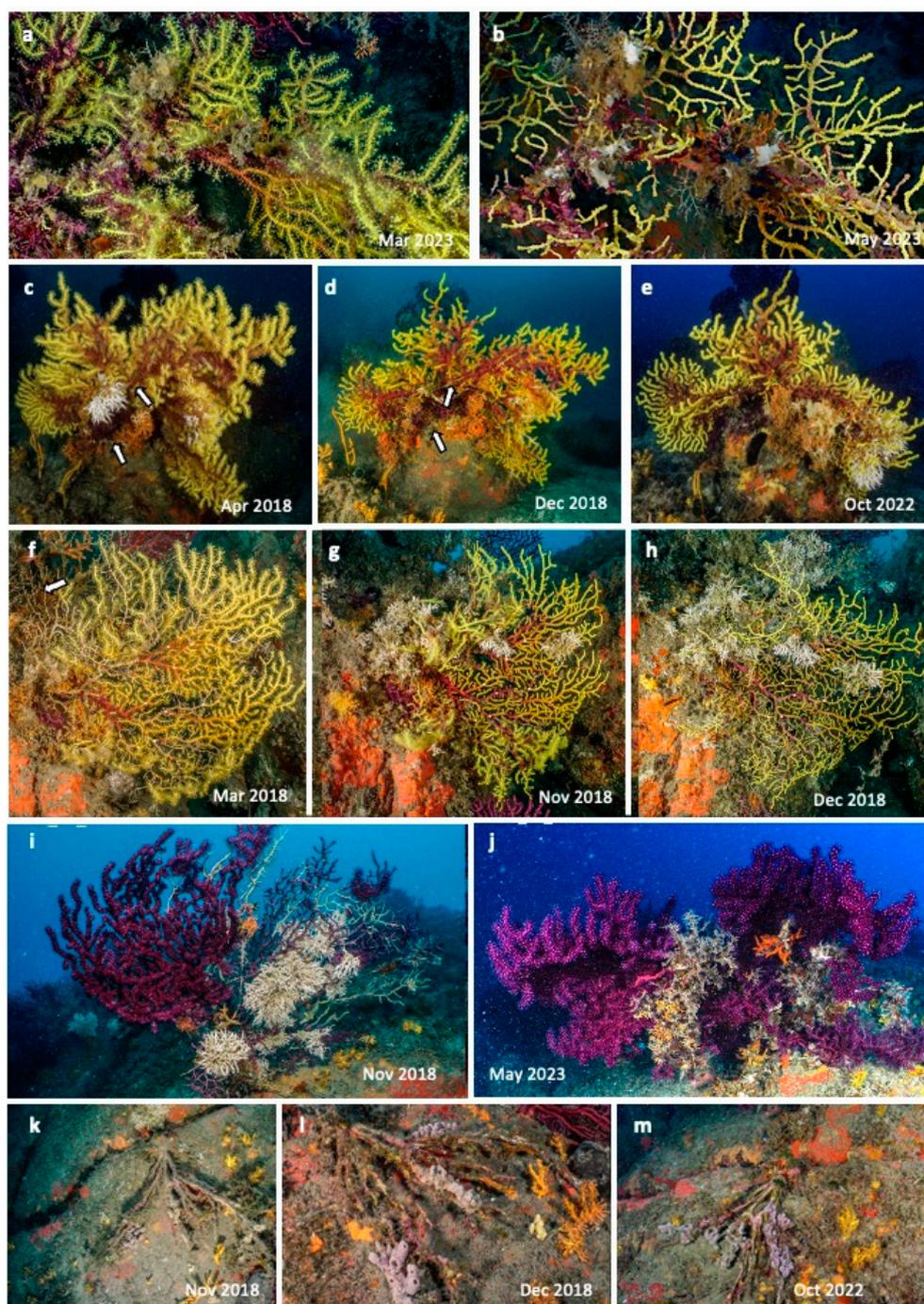


**Figure 8.** Examples of different evolutions of the coenenchyme lesions and consequent epibiosis due to thermal stress. (a–d) Two cases of damage on small portions of branches were recovered after two years. (e,f) Extensive lesions were not recovered by the gorgonian, and epibiosis developed very quickly, involving the entire colony. (g–j) A colony involved in the thermal disease of 2018 showed minor damage severity changes across four years.

In some rare cases, the epibiont community did not increase its complexity, and branches remained covered by Hydrozoa for several years. A colony in 2018 showed several naked portions of the skeleton partially covered by Hydrozoa (18.9% of the colony surface); two years after (2020), the epibionted surface decreased to 9.1% owing to a re-growth of coenenchyme on the involved branches. After four years (2023), the colony surface again showed a modest increase in epibiosis (19.3%) (Figure 8g–j).

Quick colonization was also observed when epibiosis was due to the scraping of entangled lines. A colony photographed in March 2023 entangled by a lost line, already colonized by Hydrozoa and *A. calveti*, showed a very fast development of the epibiont community: in 47 days (May 2023), it also included *D. fragilis*, *Terpios fugax* Duchassaing and Michelotti, 1864, Serpulidea, and *Beania magellanica* (Busk, 1852) with a covered surface shifting from 15.7% to 24.4% (Figure 9a,b).

Another colony recorded entangled in April 2018 by a line showed an epibiont community composed of *A. calveti*, *T. avicularis*, and *Filograna/Salmacina* spp. In the following December, the epibiotic community progressively developed in size without increasing the number of species or OTUs. In this period, the *Filograna/Salmacina* spp. appeared drastically reduced. The comparison with an image obtained four years after (October 2022) showed the settlement of the sponge *D. fragilis* and a shift in the involved surface from 22.73% to 50.74% (Figure 9c–e).



**Figure 9.** Development of epibiosis linked to lost fishing line entanglement. (a,b) Quick colonization (47 days) by Porifera and Bryozoa. (c–e) Increasing complexity of the epibiont community on a gorgonian entangled in a line (arrows) for 54 months; note that the sponge *Dysidea fragilis* appears later. (f–h) The settlement of *Filigrana/Salamacina* spp. covered almost the entire naked parts (arrows) of a colony after the summertime of 2018. (i,j) The settling of calcified organisms stops the movement of the entangled lines, thus preventing further damage. (k–m) A dead colony totally covered by sponges and encrusting coralline algae after five years.

In March 2018, a colony was recorded with some nude branches partially covered by Hydrozoa and *A. calveti*; at the end of the year (November/December 2018), naked parts were covered by a massive development of *Filigrana/Salamacina* spp. (Figure 9f–h). In some cases, when the scraping of the lost line is blocked by the growth of the carbonatic epibionts, the colonies are able, after several years, to recover damaged portions (Figure 9i,j).

The observation of one dead extirpated colony (line still in situ) showed a long persistence of the gorgonian skeleton (five years) that became heavily colonized by sponges and encrusting coralline algae (Figure 9k–m).

#### 4. Discussion

In natural assemblages, epibiosis increases biodiversity by improving the coexistence of different species [34]. In general, gorgonians are particularly involved in this phenomenon [35]. Nevertheless, in the Mediterranean Sea, it is clear that epibiosis on *Paramuricea clavata* is enhanced by disturbances due to thermal stress or anthropogenic injuries such as fishing activity; therefore, it has to be considered as a sentinel of environmental degradation [8,19].

The first impressive evidence emerging from the study of epibionts on the *P. clavata* forests in Tavolara MPA was the high percentage of involved colonies: more than 70% of the studied specimens showed, on average, one-third of the surface covered by epibionts. For comparison, a study conducted in the Medes Islands MPA (Catalan Sea) indicated that between 10% and 33% of the colonies of unprotected populations were partially colonized by epibionts, whereas only 4% to 10% of the populations in the MPA were affected [36]. Inside the Portofino MPA (Ligurian Sea), 51% of colonies showed epibionts [19]; along the eastern Adriatic coasts, less than 10% of the observed colonies presented denuded branches or epibiosis [37]. Very probably, the present data indicate that the Tavolara MPA is the Mediterranean area with the highest recorded values. This high presence of injured colonies induced, in 2008, an experiment in restoration by pruning the forest [38].

It was already stated that epibiosis originates from the loss of coenenchyme integrity, which creates exposed portions on the gorgonian skeleton on which epibionts can settle. Gorgonian diseases and fishing impact are considered the main causes of this phenomenon involving *P. clavata* [3,10,25,39]. In the area of Tavolara MPA, diseases/mass mortalities have occurred at least since 2001 [28], and other episodes followed in 2008 [16], 2018 [14], and 2019–2020 [21]. Recent mortality events have been shown to be increasingly damaging, as previous anomalies did not hit populations at 35–40 m depth [25,40,41]. These phenomena had a wide impact on the populations: for example, during the 2008 event, about 100% of the colonies living between 20 and 30 m depth were damaged, and this value decreased between 40 and 60% under a 35 m depth [16]. Currently, 15 years after the 2008 event, no colony of *P. clavata* can be found at depths of less than 29 m.

Regarding the fishing impact, demersal fishing activities represent one of the major causes of gorgonian mortality, causing entanglements, partial breakages, and detachment [19,24,42]. The persistent abrasion of the lost lines may cause wounds and infections and lead to extended epibiosis and/or necrosis [4,5,43–46]. Artisanal fishing activity is particularly intense within the Tavolara Channel, an area under a low protection regime, as demonstrated by the presence of lost fishing gear in 81 of the 82 visited sites [30] and the high percentage of impacted erect organisms [27,29].

Previous evaluation of the environmental quality of the Tavolara MPA [47] assigned low values to the Tavolara Channel because of the absence of a biogenic secondary substrate due to the lithological nature of the bedrock [26]. Considering the data presented here, the same priority habitat value of typical coralligenous reefs should be assigned to this area.

Although it is not easy to determine the causative event through the observation of epibiont colonization, some hints can be obtained. Generally, diseases caused by heat waves occur in short periods of time, causing acute stress, while damages related to entangled lines work over a long time period, producing chronic stress. In the first case, the fate of the epibiosis process depends on the percent of involved gorgonian surface [48]: when the affected portions are small, the coenenchyme is able to re-grow on the naked skeleton, plausibly quickly, despite the presence of pioneer epibionts (hydroids) [25,48–51]. Fast tissue regeneration in about one month was observed after the mass mortality event in the Portofino MPA in 2008 in the case of minor injuries [52]. Studies on soft corals [53] demonstrated that they could activate recovery mechanisms to quickly heal minor and mo-

mentary injuries and prevent the settlement of pioneer epibiont species, such as hydroids, on lesioned surfaces [54]. Recolonization of necrotic tissue might be faster and less expensive in terms of energy consumption than the production of new colony branches or tissue and is, therefore, influenced mainly by competition for space with epibionts. If the lesions involve a large portion of the denuded skeleton, the recovery is not sufficient to contrast the settling and development of calcified organisms that make epibiosis permanent.

On the other hand, for the entangled colonies, the continuous stress produced by the friction of lines, as well as friction applied to a small coenenchyme surface, completely prevents tissue recovery, favoring the development of complex epibiotic assemblages characterized by several calcified organisms (Bryozoa, Serpulidea), Porifera, and *Alcyonium coralloides*. In fact, a chronic injury enables a permanent colonization phase of a diversified epibiont community [4,55,56].

Although several authors have recorded the epibiosis process involving *P. clavata*, less attention has been dedicated to the diversity of the epibiont community: during this study, the 37 species (OTUs) found demonstrated a flourishing situation. Although we identified numerous species, some groups, virtually unidentifiable through photos, were considered as higher taxa (e.g., Hydrozoa) or as OTUs (e.g., encrusting sponges); this fact clearly indicates that the described diversity is underestimated. The recorded assemblage is similar to that previously observed in the Ligurian Sea [4].

No species are strictly related to gorgonians, although the Porifera *Pleraplysilla spinifera* and the bivalve *Pteria hirundo* (Linnaeus, 1758) were frequently recorded as acrophilic on *P. clavata* [57–60]. The Alcyonacea *A. coralloides*, a typical parasite of many gorgonians, grows by fouling (“runner” type) the apical axis of colonies [61,62]. *A. coralloides* exploit the stressed conditions of its host due to the reproductive window and oligotrophy of the water column during summertime, synchronizing its reproduction cycle with those of *P. clavata* [63]. Indeed, the emission of sexual products by *A. coralloides* has been documented in the Tavolara MPA area in the middle of May (Figure 2g), with the settling of recruits a couple of weeks after (ET, unpublished), occurring simultaneously with the spawning of *P. clavata*. The study conducted in the Medes MPA suggested that epibiosis of this species was caused by the intense diving activity and not directly by fishing impact; this is not the situation in the Tavolara Channel, where diving activity is negligible and sporadically limited to two sites, while, on the contrary, fishing is widely performed [30]. Other frequent epibionts are the opportunistic tube-dwelling polychaetes *Filograna/Salmacina* spp., particularly recorded after summertime [64,65].

Lacking the possibility to observe a temporal pattern of colonization, we related the presence of each epibiont with the total diversity of the epibiont community. Our observations clearly indicate that when the assemblage consists of only one species, it was generally represented by pioneer Hydrozoa turf (72%) and more rarely by Bryozoa (9%) and Porifera (4%). At this stage, the parasitic Alcyonacea *A. coralloides* was never found. When the assemblage increased in complexity, the species already present continued to be recorded with the progressive addition of other taxa following this order: Hydrozoa, Bryozoa, Serpulidea, Porifera, and *A. coralloides*. Considering the gorgonians with more than seven epibiont species/OTUs, this anthozoan was present in more than 90% of them. In general, in a hypothetical model of community development, new species are added without substitution of the previous ones. The general scenario recalls a facilitative model of succession. It has been well documented that a tolerance model, based upon recruitment dynamics and life history characteristics without later species requiring earlier ones to become established, can lead to a predictable sequence [66,67].

Another problem concerns the age estimation of epibiont assemblages. Some data are available in the literature for the first phases after mass mortality. Perez et al. [9] recorded microorganism colonization after a few days, while Hydrozoa, followed by Bryozoa and Serpulidea, were observed some weeks later. This evolution was confirmed by other authors [4,13,16,68]. Our data, obtained on single colonies photographed in different years, indicate that the epibiont assemblage persists for several years. According to Wahl [69],

epibiont species commonly grow fast. This is certainly true for pioneer species (filamentous green and/or red algae and/or Hydrozoa) that colonize wide stripped portions of the colonies in a few weeks [4,13,16]. Enrichetti et al. [42] studied the evolution of epibiosis on lost nylon lines: after four years, the diversity of the recorded community was very similar to that of those found on *P. clavata*, but only after a couple of years when large colonies of calcified Bryozoa were found. These data suggest the possibility of obtaining a rough age of epibionts of gorgonians, as indicated by the temporal sequence of images of single colonies.

These results highlight how the development of epibiosis appears as a partially stochastic phenomenon. The understanding of the dynamics of the processes requires continuous monitoring techniques on a consistent number of colonies. The possibility of obtaining images over long periods of time requires a high effort in terms of resources, but on the other hand, it can allow the acquisition of fundamental information for the conservation of important and fragile habitats.

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