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RESEARCH ARTICLE

Rehabilitation of Mediterranean animal forests using gorgonians from fisheries by-catch

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The assessment of effective and affordable restoration interventions is pivotal to developing new tools to mitigate habitat loss and enhance natural recovery. Gorgonians create important three-dimensional habitats in the Mediterranean Sea providing several ecosystem services associated with coralligenous reefs. Transplantations of the octocorals *Eunicella cavolini*, *Eunicella singularis*, and *Paramuricea clavata* were carried out at the site impacted by the wreck of the Costa Concordia in 2012. A total of 135 by-caught gorgonians, caught in the gears of local artisanal fishermen or found lying on the seabed by SCUBA divers, were transplanted on impacted coralligenous reefs between 20 and 35 m depth and monitored for 2.5 years. A high survival rate (82.1%) was recorded, with main losses attributable to the detachment of the organisms from the substrate rather than death of the colonies. *Eunicella cavolini* transplanted colonies and natural colonies used as controls were monitored and showed similar, and seasonally influenced, growth and healing rates. Epibiosis and necrosis events were reported in both transplanted and natural colonies during summer, highlighting the sensitivity of the species to thermal stress. The present study emphasizes the importance of a management framework as a stepping-stone to achieve effective restoration outcomes, including the removal of pressures that caused changes in natural communities and the participation of local stakeholders. The effectiveness of the methods and procedures proposed in this work allowed the restoration activities to continue at a larger scale during summer and autumn 2020.

Key words: **coralligenous reefs, *Eunicella cavolini*, *Eunicella singularis*, human impacts, Mediterranean Sea, *Paramuricea clavata***

Implications for Practice

- Gorgonians caught in the gears of local artisanal fishermen or naturally detached can be effectively used for transplants.
- The gorgonians *Eunicella cavolini*, *Eunicella singularis*, and *Paramuricea clavata* can be successfully transplanted using epoxy resins, with approximately 80% survival rate after 2.5 years despite high-energy/stormy events.
- Removal of the significant pressures that affected the benthic habitats at the study site and the participation of local stakeholders were crucial aspects of restoration success.

Introduction

Anthropogenic activities play a key role in global environmental change, both driving biodiversity loss and altering ecosystem functioning. In a context of growing pressures, the Mediterranean and Black Seas represent a paradigmatic example of changes occurring in the Anthropocene. Here, environmental and biological features, history, and human activities act synergistically and affect a great number of taxonomic groups hosted in these basins (Coll et al. 2010; Lotze et al. 2011).

Human impacts widely influence the territorial waters of member states of the European Union (EU), and pristine or unaffected areas are very uncommon (Costello et al. 2010; Micheli et al. 2013). A key EU policy is the protection of the marine environment through specific legislation and directives, such as the Habitats Directive (92/43/EEC) and the Marine Strategy Framework Directive (EC 2008), intending to develop management strategies for the sustainable use of natural resources to

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improve the health and good environmental status (GES) of marine ecosystems. Recently, the new EU Biodiversity Strategy for 2030, adopted in May 2020, strengthens the protection of marine ecosystems by expanding or creating new Marine Protected Areas (MPAs) to enhance the effective conservation of regionally important coastal and marine biodiversity features.

In conjunction with the protection measures, the restoration of degraded or damaged habitats will be further developed in the next few years. As stated by the UN Decade on Ecosystem Restoration 2021–2030, protection and restoration represent crucial components of a conservation strategy able to provide both biodiversity conservation and enhancement of services for human well-being (Possingham et al. 2015). The goal of restoration is to improve the recovery of the health and ecological status of damaged populations or communities. Active restoration measures in marine ecosystems are a growing interest of ecologists, who have carried out several experiments transplanting charismatic taxa characteristic of coastal ecosystems (Bayraktarov et al. 2015; Gerovasileiou et al. 2019) with a high potential to provide a wide range of marine ecosystem services. *Posidonia oceanica* (L.) Delile, 1813 meadows and coralligenous reefs represent the two endemic Mediterranean ecosystems where most active restoration actions have been carried out by transplanting habitat-forming species (Montero-Serra et al. 2018; Boudouresque et al. 2021). Coralligenous reefs are bioconstructions primarily built by encrusting red algal thalli growing at low light levels, and secondarily by sessile animal taxa (Ballesteros 2006; Ingrosso et al. 2018). Despite the role of red algae as bioconstructors, sessile invertebrates (e.g. bryozoans and octocorals) have been the primary targets of marine restoration activities carried out on coralligenous reefs (Montero-Serra et al. 2018; Pagès-Escolà et al. 2020). The octocorals *Corallium rubrum* (Linnaeus, 1758), *Eunicella cavolini* (Koch, 1887), *Eunicella singularis* (Esper, 1791), and *Paramuricea clavata* (Risso, 1826) form habitat of conservation interest in the Mediterranean (SPA/RAC-UNEP 2019) and have been reported as species significantly contributing to the aesthetic perception of coralligenous reefs (Tribot et al. 2016). They can be considered as key species providing complex multilayered habitats that increase spatial heterogeneity and support high biodiversity (Bramanti et al. 2017; Ponti et al. 2018; Sini et al. 2019). Furthermore, they play pivotal roles in the functioning of coralligenous reefs, both conveying organic matter from the water column through benthic-pelagic coupling processes and by sequestering and immobilizing carbon (Gili & Coma 1998; Coppari et al. 2019). Gorgonian species are vulnerable to many human pressures (boat anchoring, recreational and commercial fishing, and SCUBA diving) and they are frequently entangled by artisanal trammel net and longline fishing (Angiolillo & Fortibuoni 2020). Due to their sensitivity to human activities and climate change, gorgonians (in particular *E. cavolini*, *E. singularis*, and *P. clavata*) have been included in the formulation of indices able to assess the ecological status and integrity of coralligenous reefs (Montefalcone et al. 2017; Garrabou et al. 2019; Piazzi et al. 2019). In the light of the importance of octocorals in the habitat structure and ecological functions, restoring coralligenous reefs through gorgonian transplantation may prevent the loss of biodiversity and ecosystem complexity (Ponti et al. 2014; Verdura et al. 2019).

Here, a wide-scale (over an area of approximately 20,000 m^2) gorgonian transplanting action on a human-impacted site—the area of the Costa Concordia wreckage—is presented. The ship sank on 13 January, 2012, and the subsequent wreck removal operations provided a well-defined case study to apply an integrated monitoring approach and to experiment with new methods for marine ecosystem restoration. The largest and arguably the most complex marine salvage operation in history, started in May 2012 and ended in July 2014, causing various impacts on marine organisms (Casoli et al. 2016; Mancini et al. 2019; Pace et al. 2019). Shading, physical disturbances (debris release), and sediment deposition altered marine benthic ecosystems, causing fragmentation and erosion phenomena over 9,952 m^2 of *P. oceanica* meadow and reduction of the integrity and complexity of coralligenous reefs. A “Remediation” phase aiming to eliminate major pressures on the benthic habitat (fine sediment, debris, and man-made structures) started in January 2015, and involved the removal of 25,000 t of grout and 8,935 t of fine sediments and debris that leaked from the wreck over an area of 86,000 m^2. After the “Remediation” phase ended in 2018, heavily impacted bare portions of the seafloor, mainly coralligenous reefs, were identified (Casoli et al. 2020), presenting suitable uncolonized substrate to test and apply restoration methods.

This study aimed to assess the feasibility and effectiveness of transplanting gorgonian populations on a human-impacted site. Depending on the outcome, the technique and materials used in this pilot study might provide valuable insight for conducting marine ecosystems' restoration over large spatial scales.

Methods

Study Area and Transplanting Activities

Transplantation activities were carried out along the east coast of Giglio Island (Tyrrhenian Sea, Italy, 10°55′17.7″E, 42°21′54.1″N; Fig. 1), within the restricted access area defined during the Costa Concordia salvage and affected by the seafloor cleaning operations during the Remediation phase. The restricted area was established in 2012 to avoid any interference related to recreational or professional activities (i.e. diving, boating, fishing) during the salvage operations, and it is still on force. As a result, no human-related disturbances occurred in the restricted area during the transplantation operations. The seabed within the study area is characterized by two monzogranite rocky ridges, developing from a few meters up to 80 m water depth, separated and surrounded by a sandy bottom. Transplantation activities were carried out during the summers of 2018 and 2019; gorgonians were re-attached to impacted coralligenous reefs (Casoli et al. 2017) between 20 and 35 m depth along the southern portion of the aforementioned monzogranite ridges. In these areas only a few natural colonies of *Eunicella cavolini* had survived the wreck removal operations (Fig. 1). By analyzing the positions of natural colonies living in situ, we selected the correct orientation (i.e. according to the main currents characterizing the study site) for the transplanted specimens. Colony density was kept

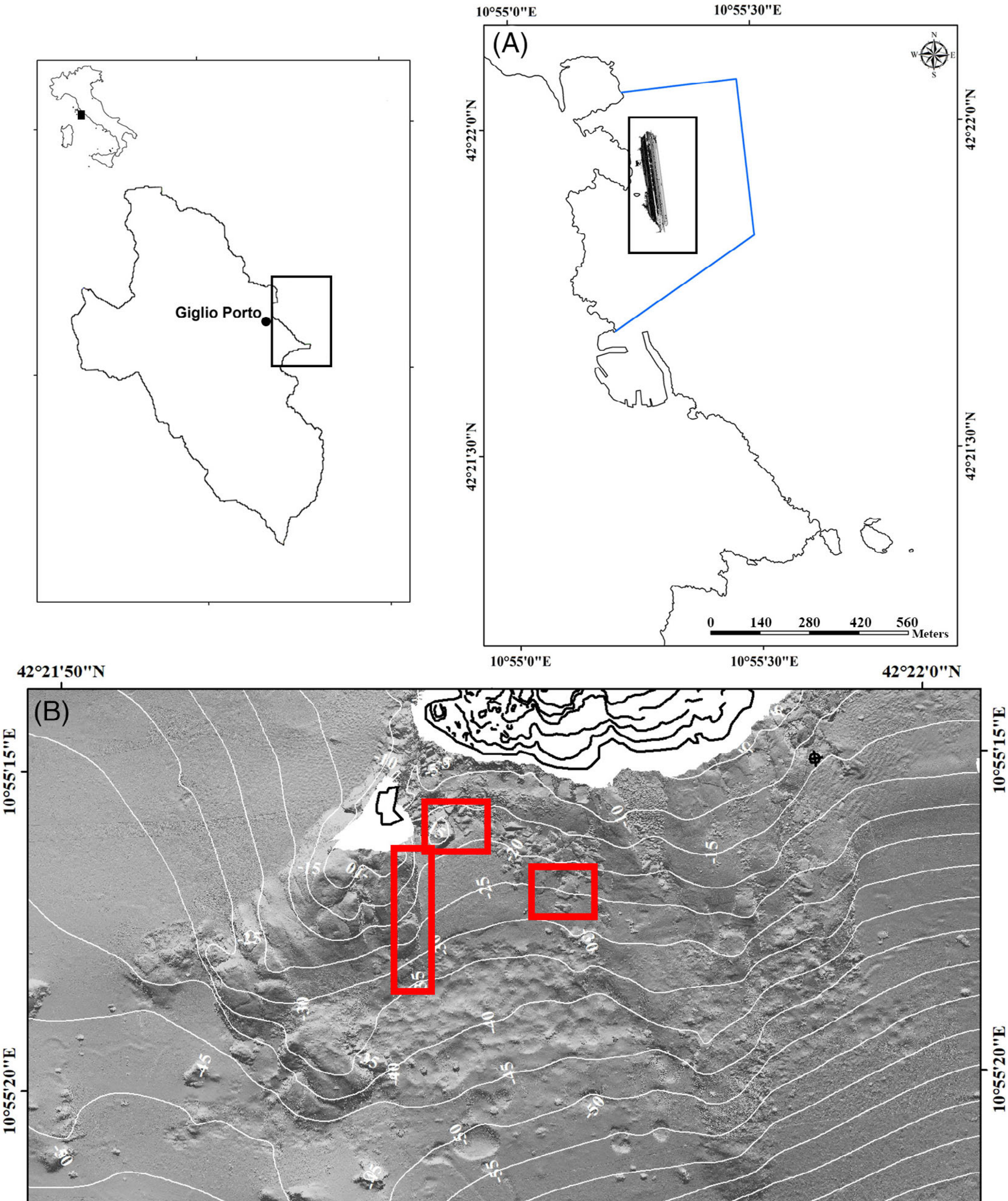

Figure 1. Location and map of the study area. Costa Concordia wreck along Giglio Island eastern coast and restricted area established in 2012 highlighted in blue (A). Vertical biogenic walls between 20 and 35 m where transplants were carried out indicated in red (B).

lower than natural values reported in the literature (Sini et al. 2015; Betti et al. 2020a) due to the limited availability of transplant material and to cover as much surface as possible.

Colonies belonging to the species *E. cavolini*, *Eunicella singularis*, and *Paramuricea clavata* were collected with the collaboration of local artisanal fishermen from among the gorgonian by-catch of fishing gears, or found naturally detached by scuba divers at the base of coralligenous walls around the island (between 20 and 40 m depth, Fig. 2). Only colonies detached from the substrate by these anthropogenic activities were used

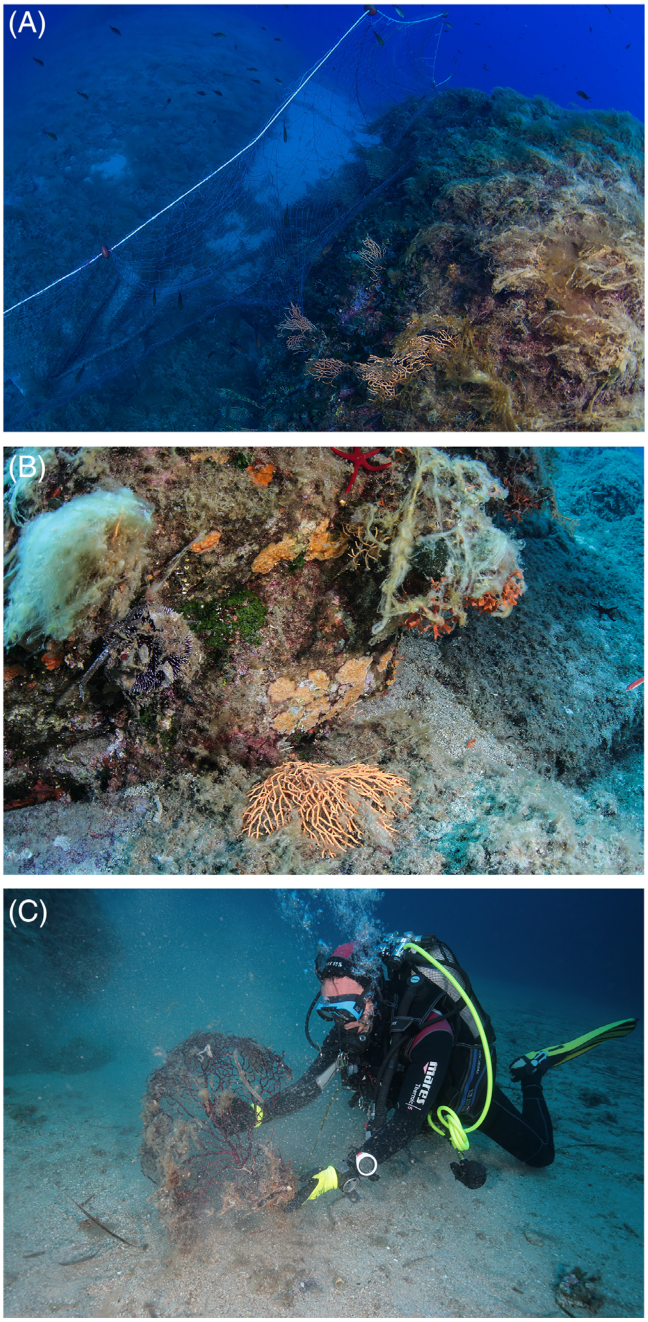

Figure 2. (A) Active fishnet entangled on *Eunicella cavolini* and *Paramuricea clavata* forest; (B) *E. cavolini* colony found detached at the base of coralligenous reefs; (C) scientific SCUBA diver collects *P. clavata* colony found detached on a sandy seafloor.

for transplantation. No living colonies attached to the reef were intentionally detached and used as part of the transplantation.

Collaboration with local diving centers helped us to identify sites where gorgonians were detached. Upon their collection, the gorgonians were temporarily kept on board in a bucket filled with seawater and then transferred, within 1 hour, to a PVC structure adjacent to the transplantation reefs. The sea fans were hung upside-down on the PVC support frame (1.5 m above the seabed), using monofilament nylon wrapped around their basal discs to ensure good water flow over the polyps and prevent sedimentation issues. Gorgonians were stored on the PVC rack for as short a time possible; sometimes only a few hours and never more than a week before transplantation. Colonies sometimes showed necrosis due to the fishing gear or abrasion after natural detachment; only material showing less than 50% of the surface affected by necrosis was transplanted. Scientific SCUBA divers carried out all the activities.

Two different epoxy putties were used to transplant the colonies: Milliput Standard Yellow-Grey type and ALL FIX two-part epoxy. Previous tests carried out in the same study area had established the effectiveness of these epoxy putties underwater. The adopted transplantation technique reflected the "raw technique" defined by Linares et al. (2008) and consisting of attaching the colony directly to the substrate with epoxy without using sticks or tubes for support. From an operational point of view, the time required for resins hardening was an issue. Epoxy putties were mixed onboard the vessel: 30 minutes were required to ensure suitable hardening of the material.

All the transplanted gorgonians, and the natural colonies used as controls, were tagged underwater and distinguished by an ID code to allow easy and quick identification during the sampling events. Tags were placed close to the colonies on the coralligenous reefs.

Monitoring of Transplants

Underwater visual census surveys and photographic samplings were carried out to evaluate the effectiveness of the transplantation. A digital camera (Sony α7-III, 24Mpixel CMOS image sensor) in a SeaFrog housing, equipped with two lights (Scubalamp PV52T), was used with a scaled PVC sheet (accuracy 0.1 cm) placed behind the colony (Fig. 3). The PVC sheet helped maintain the monitored gorgonians in the center of the images, take every time pictures of the same side of the colony, and reduce parallax error, keeping the camera lens as parallel as possible to the sheet and to the subsequent image scaling operation. Data were collected during 14 surveys over 2.5 years, in September 2018, February 2019, May 2019, July 2019, September 2019, October 2019, November 2019, February 2020, May 2020, June 2020, July 2020, September 2020, November 2020, and February 2021. Activities were interrupted in March 2020 due to the Covid-19 emergency; no natural colonies were photographed in February 2019.

Survival rate at a given sampling time for the three transplanted species (*E. cavolini*, *E. singularis*, and *P. clavata*) was defined as the ratio between the number of living and attached colonies and the total number of colonies transplanted. The detachment or death of colonies was recorded separately to identify if loss was related to the attachment methodology or to natural mortality.

A finer analysis, involving the estimation of the following descriptors was applied to a representative number of transplanted ($n = 43$) and natural ($n = 17$) *E. cavolini* gorgonians to better depict seasonal dynamics. These comprised:

- Monthly growth rate (MGR), defined as the average of each colony's living part (i.e. the coenenchyme) maximum

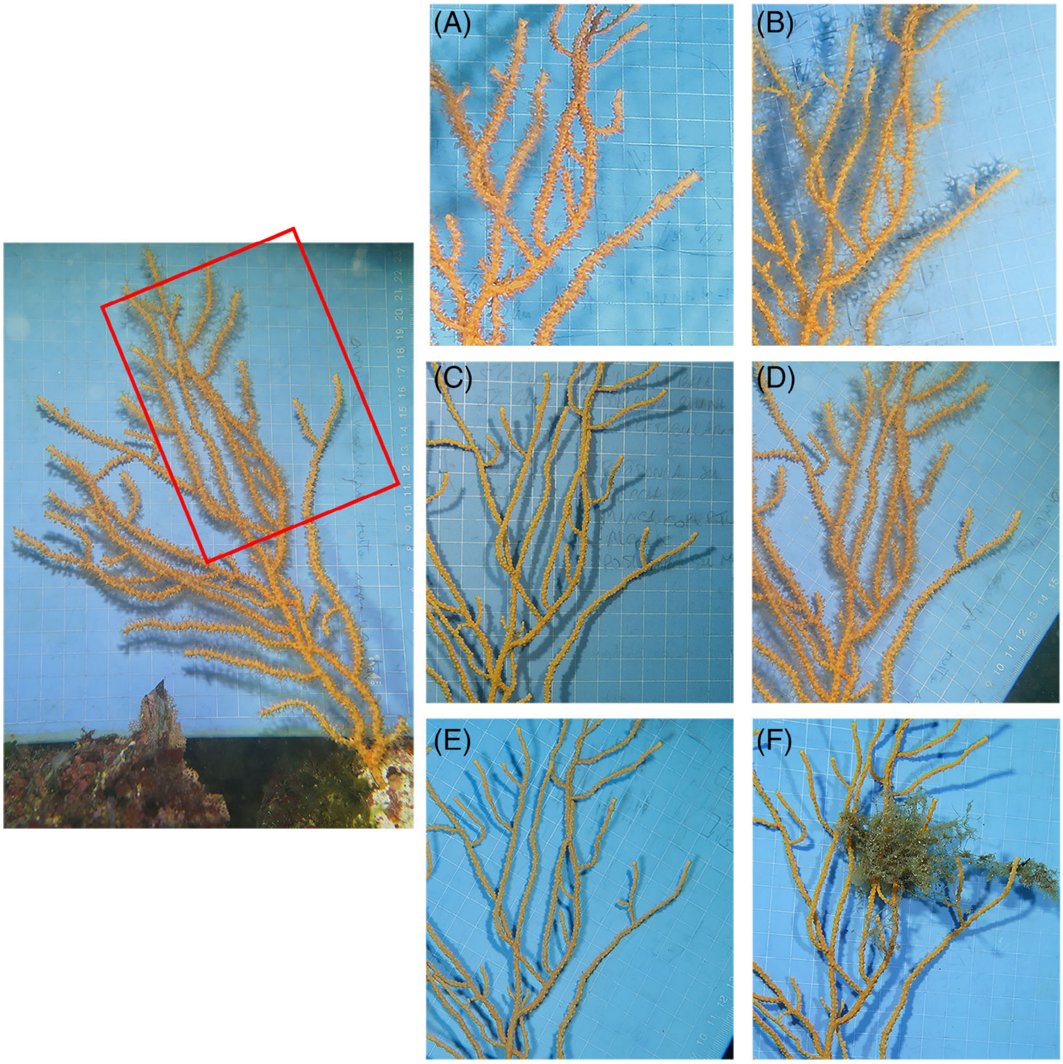

Figure 3. Detail of *Eunicella cavolini* colony transplanted in September 2018 and monitored throughout the study. Crops (highlighted by red polygon) of the pictures acquired in February 2019 (A), May 2019 (B), November 2019 (C), February 2020 (D), May 2020 (E), and July 2020 (F) are displayed.

increment in length (cm) divided by the number of months passed between two subsequent measures;

- Monthly new branches (MNB), that is, the number of new branches counted per colony between two subsequent measures divided by the number of months passed;
- Monthly recovery from necrosis (MRN), calculated as the average of each colony's coenenchyme maximum length (cm) colonization of branches previously affected by necrosis (i.e. healing rate), divided by the number of months passed between two subsequent measures;
- Percentage of colonies with epibiosis and maximum portion of colony covered by epibionts;
- Percentage of colonies affected by necrosis and maximum percentage of colony affected by necrosis.

Target colonies were randomly chosen among those transplanted and natural survivors in the area, unequivocally identified, and photographed. Digital images were analyzed by the software ImageJ to calculate the following parameters for each colony at every sampling time, according to Fava et al. (2010). Monitored colonies were classified in three size classes: small (≤15 cm, $n = 15$), medium (16–30 cm, $n = 35$), and large (≥31 cm, $n = 10$). The size classes were based on the maximum height value available in the literature, according to Gatti et al. (2015).

It should be noted that the evaluations based on these five descriptors were not carried out for the other two species (*E. singularis* and *P. clavata*) due to the absence within the study area of natural colonies to be used as procedural controls.

Statistical Analyses

Using Linear Mixed Effect Models (MEMs), three parameters were analyzed: average values of monthly growth rate (MGR), mean count of new branches (MNB), and monthly recovery from necrosis (MRN). As these descriptors did not respect the assumptions of normality and homoscedasticity even after log-

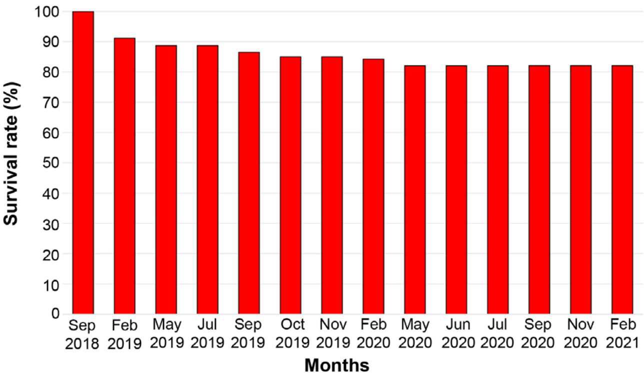

Figure 4. Survival (expressed as a percentage) of the transplanted gorgonians from September 2018 to February 2021.

transformation, the ID code of each monitored colony was set as random effect to solve the issue of heteroscedasticity. The model consisted of one random (Month) and two fixed factors: Treatment (2 levels: transplanted and natural), Month (12 levels), and Size (3 levels). Analysis of variance (ANOVA) was used to test the significance of the MEMs. For both MEMs and ANOVA, a significance level of 0.05 (p-value <0.05) was chosen.

All the statistical analyses were performed in the R platform using "lme" function for MEMEs included in the "nlme" library.

Results

Transplanting Effectiveness

A total of 135 gorgonians was transplanted in the Costa Concordia wreckage site between September 2018 and October 2019. The number of colonies was not balanced among species, resulting from by-catch events: 85% were *Eunicella cavolini*, 10% were *Paramuricea clavata*, and 5% belonged to *Eunicella singularis*, respectively. Colonies' density ranged from 2 to 8 colonies/m^2.

The survival rate 2.5 years after transplantation (January 2021) was 82.1% (Fig. 4), with major declines in the first 2 months after the two transplanting events, that is, February 2018 and October 2019. The survival rate remained stable after May 2020. Detachment from the epoxy resin base was the leading cause (85%) of colony loss, while necrosis accounted for the remaining 15%. No mortality events were reported among natural colonies from September 2018 to February 2021.

Within 1.5 years of transplantation, the epoxy resin base was entirely colonized by encrusting benthic organisms and indistinguishable from the natural bottom: such evidence, together with its grip effectiveness (only approximately 15% of transplants were lost due to detachment), encourages the use of this material for reattachment of gorgonian colonies.

Growth and Recovery of the Gorgonians

Seasonal patterns in Monthly Growth Rate (MGR), Monthly New Branches (MNB), and Mean Recovery from Necrosis (MRN) emerged for both *E. cavolini* transplanted and natural colonies, with higher values from September to May (Fig. 5). The maximum MGR increments in length were measured in February 2019 for the transplanted colonies (mean $\pm$ SD $=$ 0.25 ± 0.28 cm) and in February 2020 for the natural ones (0.31 ± 0.27 cm). The broad SD bars reflect the heterogeneous increase in size during the whole sampling period (Fig. 5A).

An average MNB of 1.0 ± 0.6 between September 2018 and February 2019, and 1.3 ± 1.2 between November 2019 and February 2020 was computed for transplanted and natural colonies, respectively (Fig. 5B). The appearance of new branches was reported for more of the 90% of both transplanted and natural colonies in February 2019 and 2020 respectively, supporting the same patterns previously highlighted by MGR (Fig. 5C).

Null growth values (both MGR and MNB) were quantified from June to September 2020. Transplanted colonies, however, showed recovery from necrosis (MRN) throughout the whole sampling period, particularly during winter and spring (November—May; Fig. 5D). The maximum MRN values (up to 2.46 cm/month) reflected a different recovery speed from necrosis compared to the growth.

Results of the ANOVA on the MEMs three descriptors (MGR, MNB, and MRN) are reported as Table S1, Supporting Information. Significant variations emerged for the MEMs intercepts and the descriptor Month (ANOVA, p-value <0.001 for all tests). By contrast, no significant variations occurred according to the factors Treatment and Size.

Epibiosis and Necrosis Phenomena

Both transplanted and natural colonies showed epibiosis exceeding 45% during late spring and summer (May, June, July, and September; Fig. 6A). The maximum percentage surface with epibiosis varied among months, ranging from 25% to 50% in transplanted gorgonians and from 5% to 45% in natural ones (Fig. 6B). Epibionts were mainly represented by seasonal organisms, such as turf algae and hydrozoans. The percentage of colonies affected by necrosis was generally 2 months shifted if compared to epibiosis (Fig. 6C), showing higher values at the end of summer (July and September 2019 and September and November 2020) in both transplanted and natural gorgonians. As for maximum injuries diffusion, transplanted colonies were mostly affected (Fig. 6D); the maximum portion of colony interested by necrosis decreased during the winter and spring months from 40% to 10% due to the recovery/healing processes rate highlighted by the MRN descriptor. On the contrary, natural gorgonians increased the maximum necrosis in the summer months exclusively, never exceeding 10% of the colony surface.

Discussion

This study presents an effective transplanting operation to rehabilitate gorgonian populations impacted by human-related disturbances. The restoration followed the removal of the Costa Concordia wreck and the Remediation phase, which aimed to remove the stressors and establish suitable conditions for habitat

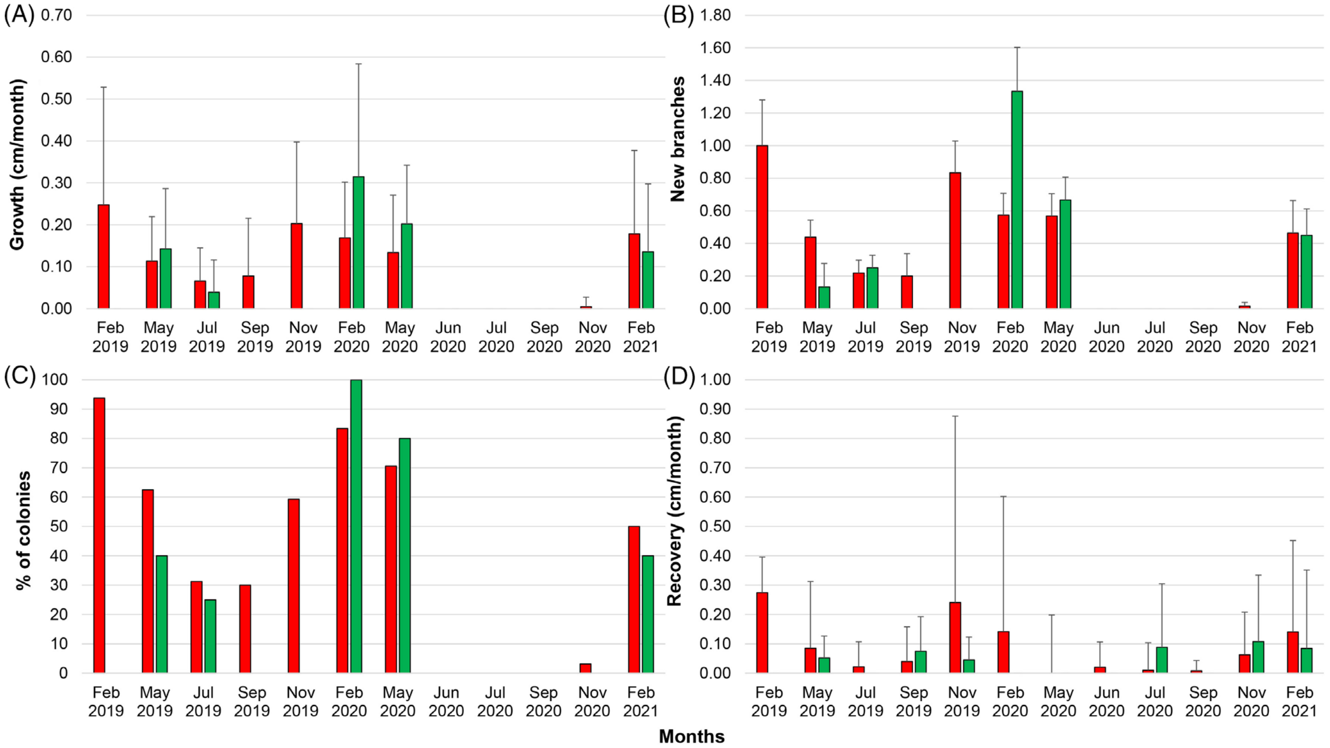

Figure 5. Growth and recovery from necrosis (mean ± SD) measured in transplanted (red) and natural (green) colonies throughout the study period: (A) MGR; (B) MNB; (C) percentage of gorgonians showing new branches; (D) MRN.

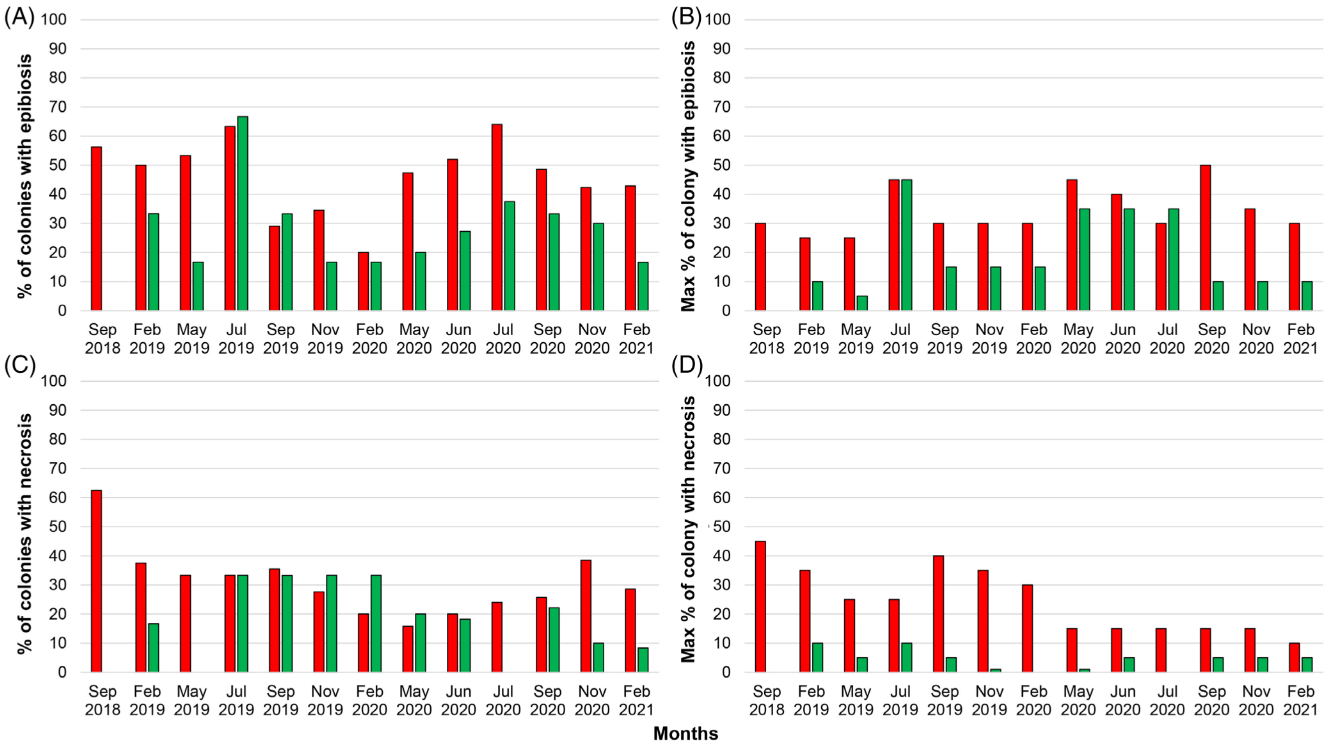

Figure 6. Percentage of gorgonians showing epibiosis (A), maximum percentage of surface affected by epibiosis (B), percentage of gorgonians affected by necrosis (C), and maximum percentage of the whole colony surface with injuries/necrosis (D), in both transplanted (red) and natural (green) colonies.

recovery. Elliott et al. (2007) offered the conceptual and management framework for this approach, emphasizing the need to remove all the stressors or disturbances that caused changes in natural communities to reach effective restoration outcomes.

The gorgonian colonies survival (82.1% after 2.5 years) here observed was higher than similar restoration actions carried out using Anthozoa: a mean annual survival of 60% was reported for hexacorals (Montero-Serra et al. 2018), while transplantation experiments carried out with Mediterranean gorgonian species reported 30%–98% survival (Linares et al. 2008; Fava et al. 2010; Montseny et al. 2019). Even though we used gorgonians obtained in by-catch (i.e. disturbed organisms) for transplants, only 3% of the transplants were lost due to total necrosis of the colonies. Breakage of the epoxy/substratum bond, or failure in resin hardening, were the main causes of the loss of colonies, with significant losses after the dramatic storm event in the Tyrrhenian Sea during fall 2018 (Oprandi et al. 2020; Betti et al. 2020a). However, this study definitively demonstrates that epoxy resin may represent an easy and repeatable method to transplant and attach gorgonian colonies on coralligenous reefs.

To increase habitat three-dimensionality and speed up processes that would take many years to occur (Bavestrello et al. 1997; Cerrano et al. 2010), and avoid further stresses to colonies obtained in fishing by-catch, we did not split the transplanted colonies into more fragments, as done in similar studies (Linares et al. 2008; Fava et al. 2010). The approach we used drastically reduced the number of organisms transplanted: in fact, every large colony could have been divided into many small healthy fragments. This would have increased the density but at the expense of deploying larger colonies to enhance habitat structure. Both aforementioned approaches can be considered satisfactory in the evaluation of the intervention as a management tool to mitigate local disturbances leading to the loss of long-lived species at a human-impacted site.

Results have shown that the gorgonians obtained from by-catch of artisanal fishers can be effectively used as transplant material; this is consistent with a previous pilot study carried out in Mediterranean continental shelf (Montseny et al. 2019) and opens new perspectives in terms of sustainability and opportunities of the interventions in the field of the restoration of coastal ecosystems.

The engagement of local stakeholders (i.e. artisanal fishers and diving centers) in this project was a key factor of success, producing a twofold result: from one side, it increased the possibility of material collection, especially at depths not reachable by scientific divers, and from the other side it enhanced local people's environmental perception and support, both pivotal for the longevity of conservation initiatives (Bennett et al. 2019). Nevertheless, demersal fishing represents one of the major causes of gorgonian mortality (Sini et al. 2015; Betti et al. 2020b). Local restoration activities, such as those described in the present study, must not be interpreted as the sole response to the urgent need for drastic management measures to safeguard these three-dimensional benthic ecosystems from human disturbances.

All descriptors used in this study (MGR, MNB, and MRN) to monitor *Eunicella cavolini* colonies showed peaks during winter and spring seasons and slowest rates during summer and early autumn. Growth and recovery rates differed greatly among colonies, as shown by the large data variance. The higher values measured in transplanted gorgonians may be caused by the unbalanced number of colonies for each treatment (transplanted—natural); although number of organisms was not balanced, we preferred to collect data from the same site in order to reduce, as much as possible, variation due to site features.

The annual planktonic production cycle, as well as hydrodynamic phenomena (i.e. current speed), characterize winter and spring seasons in the north-western Mediterranean Sea, thus influencing the availability of food sources (i.e. zooplankton) and the metabolism of the gorgonian species (Ribes et al. 1999; Previati et al. 2010; Cocito et al. 2013; Fullgrabe et al. 2020). Recovery from necrosis was observed over the entire monitoring period, showing the same variability discussed for growth. Recolonization of necrotic tissue through coenenchyma might be faster and less expensive in terms of energy consumption than the production of new colony branches or tissue, and therefore influenced mainly by competition for space with epibionts. Octocorals can rapidly heal their lesions through the fast growth of a new coenenchyma and inhibit settlement of epibionts (Riegl & Riegl 1996; Bavestrello et al. 1997). Although the capacity to recover from injuries is reported as size-dependent in modular organisms (Henry & Hart 2005), that is, the bigger the colony the faster the regeneration, the monitored colonies did not reflect differences in MRN according to size. Growth and appearance of new branches (MGR and NB) showed no significant variations according to size as well; such pattern is not consistent with previous studies carried out on Mediterranean gorgonians (Coma et al. 1998) and might be affected by the unbalanced number of colonies for each of the three size classes considered. Therefore, further research is needed to address the question "does the size of the transplanted colonies affect the transplant success?" The absence of significant differences between transplanted *E. cavolini* and natural colonies for the three descriptors may be considered an indicator of the success of transplanting activities. Transplanted colonies showed a good health status as well, quickly recovering their biological functions.

Transplanted and natural colonies shared intra-year fluctuation of epibiosis and necrosis phenomena. It is well-known that *E. cavolini* is particularly sensitive to temperature increases in the warm months, showing a critical thermal threshold around 25°C which leads to mortality events (Cerrano et al. 2000; Garrabou et al. 2009). Likely, the physical disturbances causing colony detachment had a crucial role in the spread of epibiosis and injuries on transplanted gorgonians. Although we expected such patterns based on previous research (Sini et al. 2015; Betti et al. 2020b), we did not hold colonies in tanks for a given time interval in order to test their ability to recover from injuries directly in situ, reducing as much as possible time spent by colonies ex situ. Healing rates and gradual reduction in surface affected by injuries from September 2018 to February 2021 represent a relevant outcome supporting the proposed procedure's feasibility.

Overall, this study demonstrates the success of an active restoration project following several steps, which encompass (1) the removal of the disturbances causing the habitat loss, (2) the management of the intervention site, (3) the active monitoring procedures, and (4) the participation of local stakeholders. Gorgonians obtained as by-catch are a practical restoration resource, as demonstrated by several authors (Montseny et al. 2019, 2020), but protection measures are needed to reduce the anthropic disturbances acting on these ecosystem engineer species. Thus, reducing sources of disturbance should be the first and mandatory management action to achieve restoration and to allow recovery through time (Hawkins et al. 1999). Although the success of ecological restoration should be reasonably assessed over longer monitoring times (Suding 2011; Bayraktarov et al. 2015), >80% survival 2.5 years after transplantation is very encouraging, and will hopefully instigate further initiatives at larger spatial scales.

In conclusion, together with protection measures, the effectiveness of restoration actions on large benthic suspension feeders represents a considerable benefit for the conservation strategy of coralligenous reefs structure and functioning, restoring the services that this ecosystem provides as well (Zunino et al. 2020).

Acknowledgments

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Supporting Information

The following information may be found in the online version of this article:

Table S1. Result of analysis of variance (ANOVA) performed on the MEMs on three descriptors (MGR, MNB, and MRN) assessed on *Eunicella cavolini* colonies according to treatment, month, and size.

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