D 3.4: Evaluation of the effectiveness of pilot restoration actions under a changing scenario

Marine Ecosystem Restoration in Changing European Seas MERCES

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Contents

Introduction

The main goal of Deliverable 3.4. is to describe the implementation of pilot restoration actions conducted during the MERCES project in the coastal rocky habitats in the the N Atlantic and in different areas of the Mediterranean Sea.

In WP3 we tackled the challenge of scaling up restoration actions implementing 6 pilot studies: 3 in macroalgal habitats from the N Atlantic and the Mediterranean and 3 in the mesophotic Mediterranean coralligenous habitats (Table 1). Two main type of restoration protocols have been implemented: removal of macrograzers and adult transplants. However, in some actions further protocols have been used (Table 1). As indicated the pilot actions involved upscaling the spatial scales concerned by restoration from few m^2 to at least tens m^2 at site level. Besides in some actions, the pilots included several sites separated by large geographic distances (from hundreds of m to few km). The WP3 the pilot restoration actions encompassed wide depth ranges from 5 to 70 m depth. Finally, in some cases the implementation of pilot actions were conducted in collaboration with local diving centers using marine citizen science approaches (several coordination meetings and public presentations on the MERCES project and goals of the pilot restoration action were held with the participants). These collaborations allowed the implementation of restoration actions over the targeted large spatial scales and supported the monitoring activities.

Table 1. Main features of the Pilot Actions carried out in the MERCES project.

	Macroalgal beds habitats			Mesophotic / Coralligenous habitats		
	Pilot 1 (NIVA)	**Pilot 2 (UB)**	**Pilot 3 (CoNISMA)**	**Pilot 4 (UNIVPM/GAIA)**	**Pilot 5 (UNIVPM/GAIA)**	**Pilot 6 (CSIC/UB)**
Species	*L. hyperborea, S. latissima*	*Cystoseira elegans*	*Cystoseira spp.*	*Corallium rubrum*	*Eunicella singularis,*	*Paramuricea clavata*
Location	Vega (Norway)	Medes (Spain)	Porto Cesareo (Italy)	Portofino / Gallinara (Italy)	Gallinara Isl. (Italy)	Medes (Spain)
Depth range (m)		5-10	7-10	35-70	30-35	10-15
Technique	Sea urchin removal, Adult transplants	Sea urchin removal, recruitment enhancement	Sea urchin removal	Adult and juvenile transplants	Adult transplants	Adult transplants
Indicator	% cover macroalgal, survival, sea urchin density	% cover macroalgal, sea urchin density	% cover macroalgal, sea urchin density	Survival	Survival, growth rate	Survival, necrosis
Period (num. months)	>18	>18	>30	>15	>14	>18

The implementation of pilot actions carried out in MERCES WP3 offered a unique opportunity to analyze the effectiveness of upscaling the restoration protocols. The lessons learnt will be key in order to develop marine restoration programs in coastal areas.

The Deliverable 3.4 provides a short description of each of the 6 Pilot actions covering the following main points:

a-Rational for implementing the pilot actions (regarding the local conditions, species, stakeholder’s interests etc...)
b-Short description of the species concerned
c-Methodology implemented and indicators of sucess
d-Main results
e-Conclusions

Macroalgal habitat pilot restoration actions

Pilot action 1. *L. hyperborea*, *S. latissima* forestation at Vega (Norway, NE Atlantic)

a-Rational for implementing the pilot action

Sea urchin grazing poses a significant threat to kelp forest in northern parts of Norway, with negative effect on biodiversity, productivity and the ecosystem services that kelp forests provide (e.g. kelp harvesting, commercial and recreational fishing, tourism, habitat, carbon storage and sequestration, coastline protection and water purification). Restoration efforts may counteract further loss and help regain the valuable functions the kelp forests provide. Pilot kelp transplantation experiment was initiated by NIVA sublittoral to a small skerry in mid-Norway (65°70N). The study area has been overgrazed and barrens maintained by sea urchins (*Strongylocentrotus droebachiensis*) for nearly five decades. Recent years, kelp has gradually recovered at some locations, but mosaic patterns of urchin barrens still remain. At some barrens sea urchins persists in high densities, while at others the sea urchins are heavily reduced, yet without macroalgal recovery.

b- Target species for the pilot action

S. droebachiensis is a widely distributed species, responsible for kelp forest destruction worldwide. *Laminaria hyperborea* and *Saccharina latissima* are the most common kelp species in Norway. At some areas they coexist, but while the slow growing and long-lived *L. hyperborea* are most found in areas with moderate to high wave exposure, the faster growing, shorter lived *S. latissima* are better adapted to protected and moderately exposed areas.

c-Methodology implemented and indicators of success

A pilot experiment for restoration of overgrazed kelp forest was initiated in May 2017. The experimental treatments at the restoration site included transplantation of adult individuals of *L. hyperborea* (n=110) and *S. latissima* (n=42) kelp (according to methods described in D3.2 Protocol M5) in combination with reduction of grazing pressure from sea urchins. Sea urchin removal (n=500) was carried out at the onset of the experiment and during the 4-, 12-, and 24-month survey to promote recruitment of kelp and stimulate to survival of kelp transplants at the restoration site. A subset of kelp was transplanted to the kelp donor sites as procedural controls for the transplant technique in May 2017. Sea urchin removal was conducted at a control site in September 2018. The success of the restoration efforts, indicated as survival of kelp transplants and recruitment of kelp and other macroalgae, has been surveyed during the restoration timeline 4, 12, 16 and 24 months after the transplantation effort. Kelp fronds and floats have been rinsed from fouling organisms at every survey to facilitate survival of transplanted kelp.

d-Main results

Results show that *L. hyperborea* transplants display a higher survival rate compared to *S. latissima* transplants. While only 7% of *S. latissima* transplants were viable 16 months after deployment, 54% of the *L. hyperborea* transplants were still alive and able to produce new fronds (Figure 1a, b). After 24 months only dead remains from the transplanted stipes of *S. latissima* were present while 40% of *L. hyperborea* transplants were still viable. However, a large recruitment event of *S. latissima* took place within the last eight month period of the restoration timeline (month 16-24) resulting in successful recruitment of 110 ± 16 (mean ± SE) individuals of *S. latissima* divided among the seven ropes that each originally hosted 6 transplanted individuals of *S. latissima*. The recruitment event contributed to a large increase of *S. latissima* biomass and population density of small (<10 mm lamina length) to medium sized (<135 mm lamina length) plants at the restoration site (Figure 1c, d). While scattered recruitment of *S. latissima* has been observed at the restoration site (on bedrock, deployed substrate and on transplanted kelp plants, no recruitment of *L. hyperborea* has been observed during the restoration process.

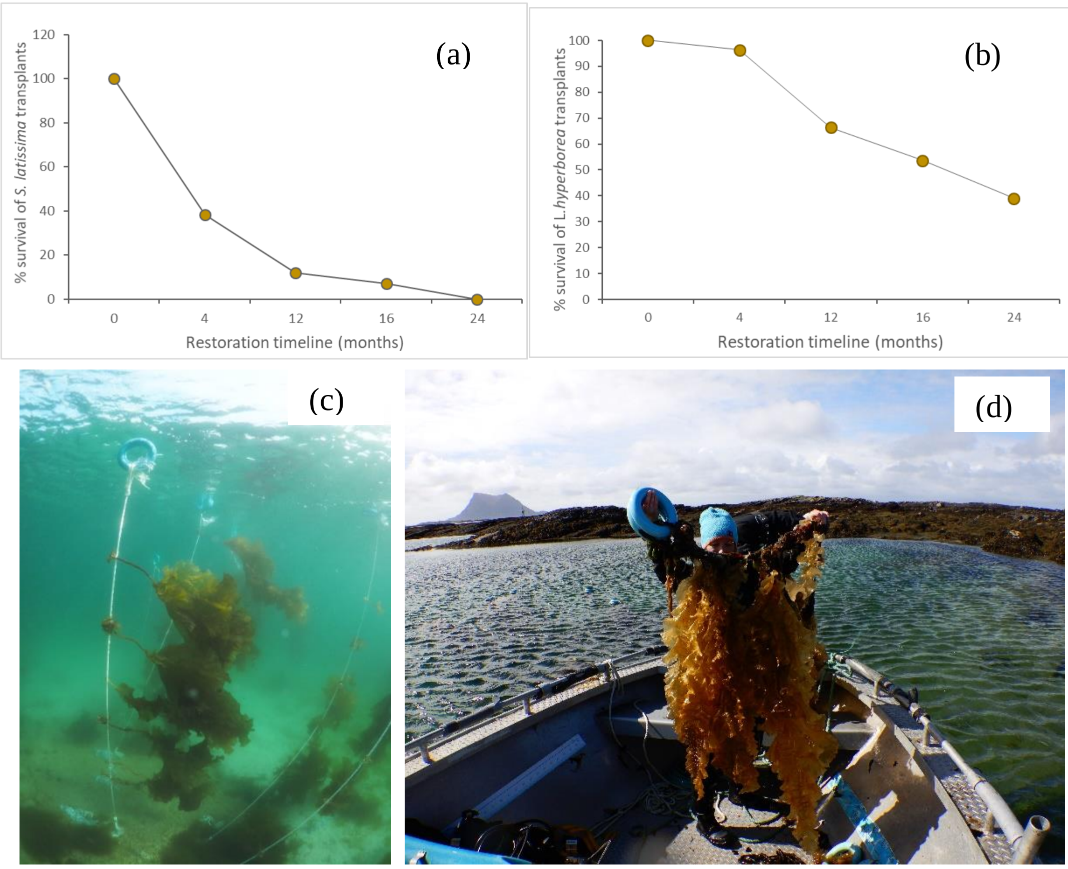

Figure 1. Relative survival rate of the a) *S. latissima* and b) *L. hyperborea* kelp transplants through the restoration timeline of 24 months and density of *S. latissima* on ropes at c) 0 and d) 24 months of the restoration timeline.

Variability of algal cover and sea urchin abundance have been recorded regularly by visual counts (0,25 m2 frames randomly placed between, west and east to the transplanted L. hyperborea kelp) during the 24-month period (May 2017 – 2019) and reveal an increase of more than 40% macroalgal cover at the restoration site since the onset of restoration efforts. The recruitment of S. latissima increased during the first 12 months of the experiment (May 2017 to May 2018). At the last survey in May 2019, the macroalgal cover remained high, but the macroalgal community was dominated by filamentous species, mostly Desmarestia sp., Chordaria flagelliformis and Chorda filum, not kelp. Urchin removal has likely promoted macroalgal recruitment.

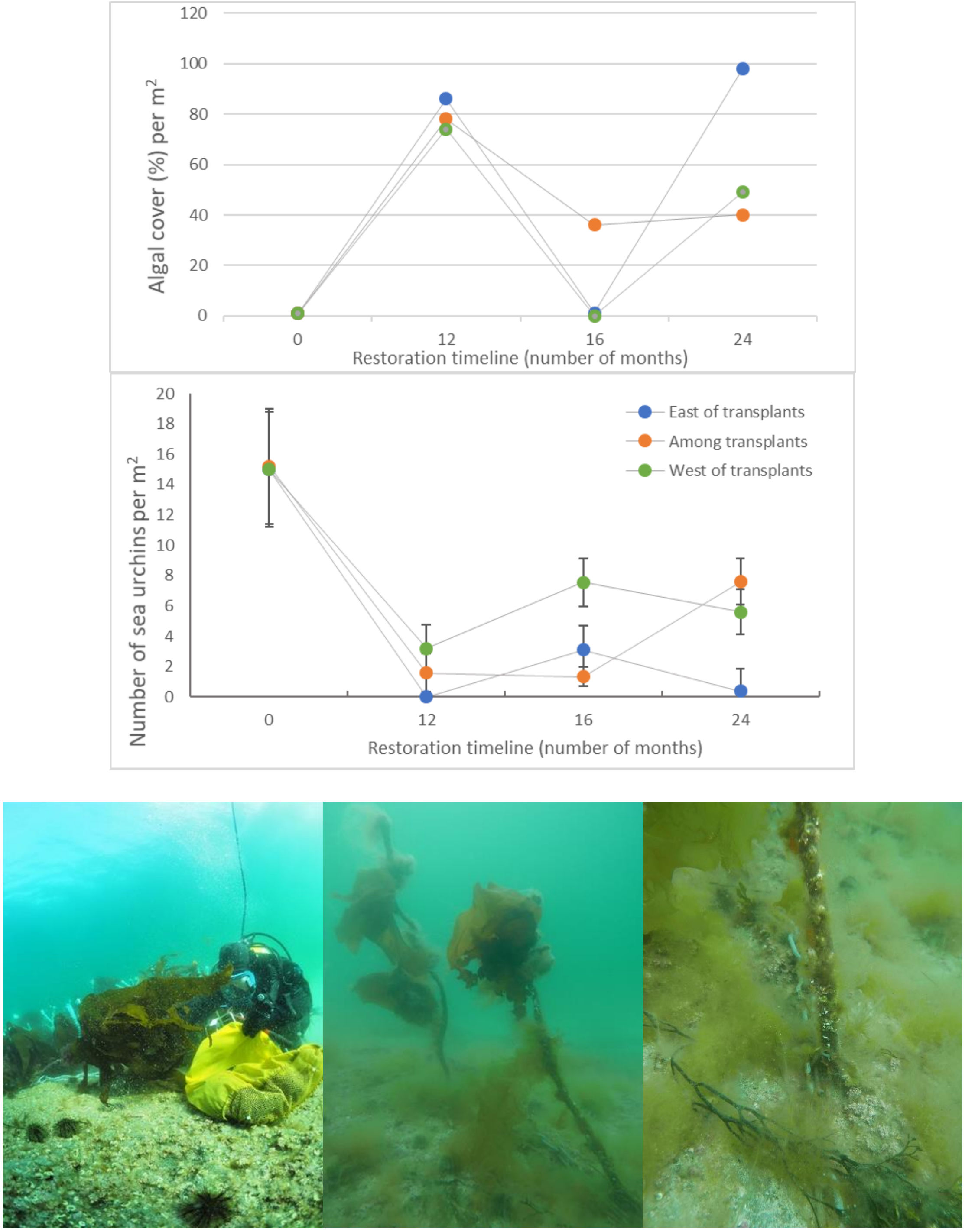

Figure 2. Percentage of algal cover and number of sea urchins during the experimental period considered. Details in the pictures are also shown.

e-Conclusions

Grazing pressure from sea urchins appear as the main obstacle preventing recovery of kelp at the sea floor. At its largest extent, the transplanted kelp patch appeared to form a barrier preventing urchins from entering and thereby reducing grazing pressure on and in between kelp transplants. However, the gradual mortality of *L. hyperborea* transplants resulted in a reduced extent of the transplanted kelp patch and hence a less effective barrier against grazing.

The survival rate of transplanted *L. hyperborea* indicates that the transplantation method is suitable for this species. Transplantation was less successful for *S. latissima.* However, it is possible that the transplanted *S. latissima* individuals have contributed with spores for the natural recruitment at the restoration site. No recruitment of *L. hyperborea* was observed during the study. However, this may be explained by the nature of the location which may be less suitable for *L. hyperborea* compared to *S. latissima*. Conversely, the primary recruitment of *S. latissima* and other macroalgal species could also represent an early succession phase dominated by the more opportunistic species, with recruitment of slower growing species occurring at a later stage. However, in order to achieve successful kelp restoration, it appears that a stronger effort for sea urchin reduction and subsequently a lower urchin density, is needed. However, no kelp or macroalgal recovery was observed at the control site where sea urchin removal was tested without transplantation of kelp, indicating that a combination of kelp transplantation and sea urchin removal are the most effective technique for restoration of macroalgae. Although too costly and time-consuming for a pilot experiment, a continuous replacement of dead kelp transplants will likely contribute to restoration success by maintaining negative feedback effects and providing a barrier for sea urchin entrance. Monitoring donor sites showed that harvesting of transplants did not harm donor populations. Understory kelp quickly replaced the harvested canopy kelp at all donor sites and already 12 months after removal the harvested patches were fully recovered.

Pilot action 2. *Cystoseira elegans* forestation at the Montgrí, the Illes Medes and the Baix Ter Natural Park (NW Mediterranean)

a-Rational for implementing the pilot action (regarding the local conditions, species, stakeholders interests etc...)

UB team carried out a pilot action to restore macroalgal forests in degraded shallow-hard bottoms of the Montgrí, the Illes Medes and the Baix Ter Natural Park (NW Mediterranean). Canopy-forming algae as *Cystoseira* species (Fucales) create structurally complex habitats, providing food and shelter to many associated species and harboring a high diversity and productivity. Outbreaks of sea urchins can lead the loss of shallow *Cystoseira* forests pushing them into stable degraded barrens. The main aim of this pilot action is to promote the formation of *Cystoseira* forests in degraded sea urchin barrens to recover its important ecological role.

b- Target species for the pilot action

Cystoseira elegans is an endemic Mediterranean alga. In the study area, some healthy and well preserved *C. elegans* forests inhabit from the infralittoral zone to several meters depth, except in the overgrazed areas dominated by sea urchins. The common sea urchin, *Paracentrotus lividus*, and the black sea urchin *Arbacia lixula*, are the most representative herbivores controlling the macroalgal dynamics in this zone and the main players in the degraded barrens (Medrano et al. 2019).

c-Methodology implemented and indicators of success

To promote the forestation of *Cystoseira elegans* macroalgal forests, two barren areas between 5-10m depth (with high densities of sea-urchins (20-25ind/m^2) and null cover of macroalgal species) were selected as experimental areas and all sea urchins found within the pilot sites (> 100 m^2) were removed in 2017. Two *Cystoseira elegans in-situ* recruitment enhancement techniques were setup after the sea urchin eradication. *Cystoseira elegans* fertile branches were placed inside meshed bags and transplanted within the barren zones. Besides, we scraped some plots to provide an available substrate for the new *C. elegans* recruits in the barren zones. One year later (Spring 2018), the recruitment, survival, and cover of *C. elegans* were assessed.

The two barren areas are located under two management schemes within the Montgrí, the Illes Medes, and the Baix Ter Natural Park allowing testing for the potential differential success under different fishing pressure. Healhy forests and barren zones without intervention were also monitored as reference sites.
In 2018, six more barrens (3 inside the MPA and 3 outside) and four reference sites were restored following the same protocol (Fig. 3).

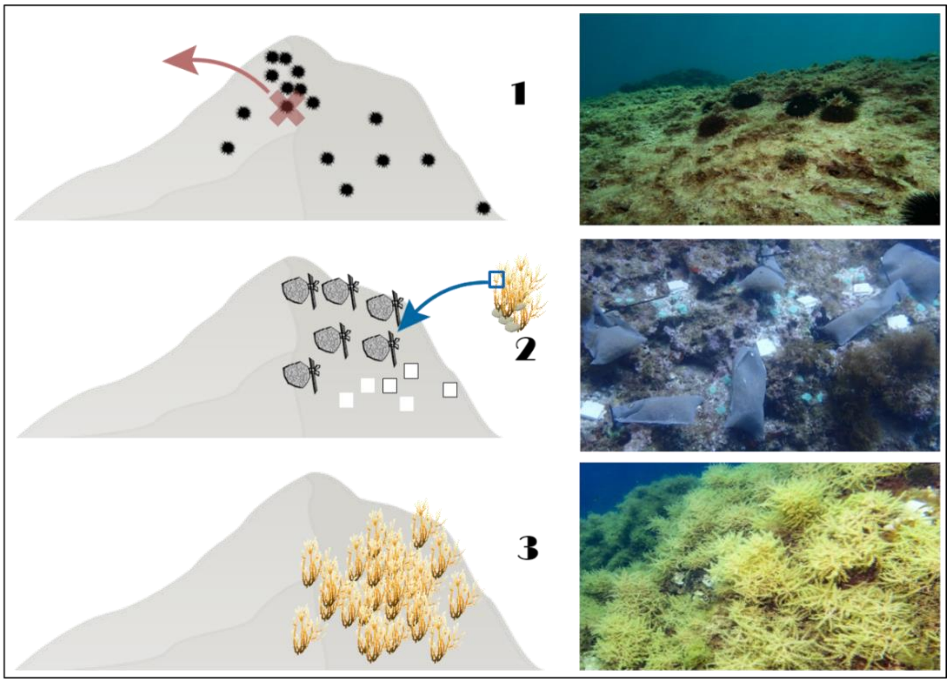

Figure 3. *Cystoseira elegans* forestation diagram. From 1 to 3; 1. Complete sea urchin eradication from degraded barrens, 2. Transplantation of *C. elegans* fertile branches inside meshed bags (grey), and scraped original substrate (white boxes) to enhance the recruiment, 3. Consequent formation of *C. elegans* forest one year later.

d-Main results

Macroalgal forests of *C. elegans* grew up and recovered the degraded sea urchin barrens one year after the pilot action was conducted (Fig. 4). In addition, the abundance of newly arrived *C. elegans* specimens was significant higher (GLM, p<0.001) where active restoration activities were done.

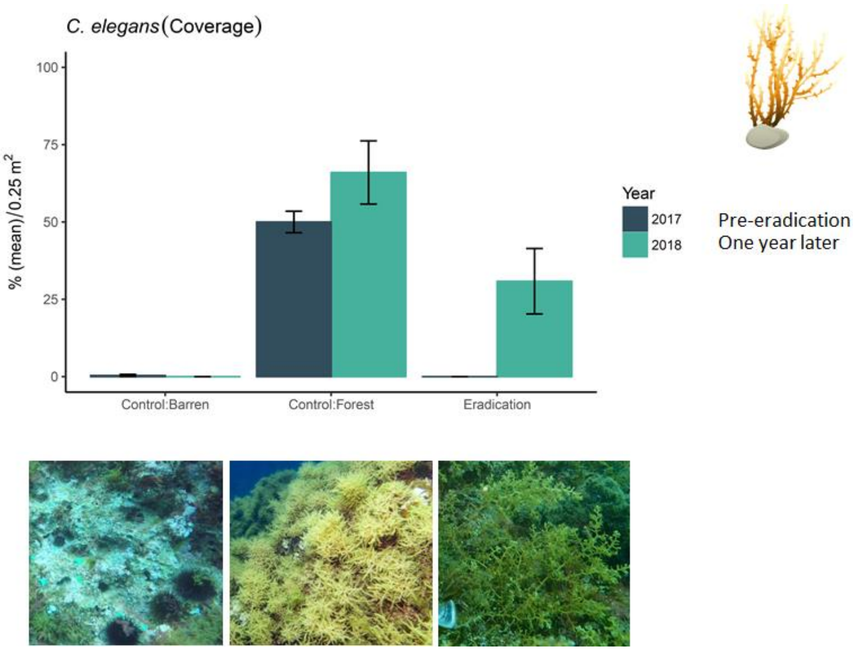

Figure 4. Results of the first pilot action in Medes Islands, where sea urchins were eradicated. One year later, barrens resulted on gorgeous *Cystoseira* forests.

e-Conclusions

The results of this pilot action carried out in 2017 showed the success of combining sea urchin eradication with recruitment enhancement techniques in shallow *Cystoseira* forestation. Results of the six replicate actions will be analyzed in early summer (2019) one year after their implementation. These results will be crucial to elucidate the role of the conservation actions alone (passive restoration through the establishment of protected areas) and their success when combined with active restoration techniques.

Pilot action 3. Removal of sea urchins *Arbacia lixula* and *Paracentrotus lividus* Marine Protected Area (MPA) of Porto Cesareo (Apulia, SE Italy)

a-Rational for implementing the pilot action (regarding the local conditions, species, stakeholders' interests etc...)

Increasing anthropogenic pressures are causing long-lasting regime shifts from high-diversity ecosystems to low-diversity ones. In the Mediterranean Sea, large extensions of rocky subtidal habitats characterized by high diversity have been completely degraded to barren grounds, featured by the dominance of sea urchins whose grazing combines with the impact of overfishing. Some studies shown a positive effect of sea urchin removal on the recovery of overexploited subtidal rocky habitats. To date, the practice of extensive sea urchins culling has been already applied in some areas of the world, but never in the Mediterranean Sea. During the project MERCES we had the opportunity to carried out a long-term experiment aimed to the test the effectiveness of this approach over a scale of hundreds of meters. The study was conducted within the Marine Protected Area (MPA) of Porto Cesareo (Apulia, SE Italy) where oligotrophic waters, overexploitation of fish stocks, dramatically high sea urchins (i.e. *Arbacia lixula* and *Paracentrotus lividus*) densities and the large expansion of barren grounds caused by date mussel fishery hampered the natural recovery of shallow subtidal reefs even several years after the MPA was established. For these reasons, the identification of specific actions aimed to reverse this degraded condition is fundamental for the development and implementation of large-scale management strategies in order to meet the conservation purposes that lead to the establishment of the MPA in 1997.

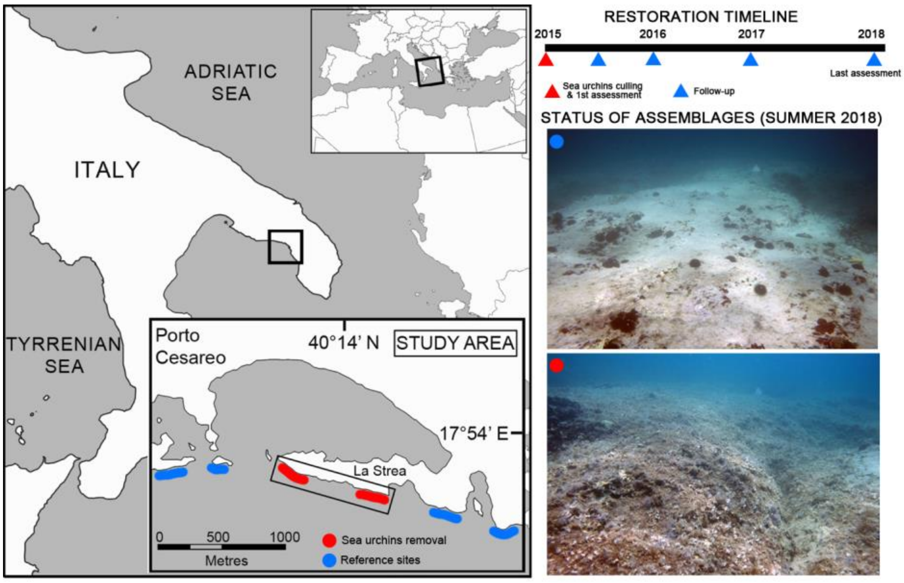

Figure 5. Summary of the large-scale removal experiment carried out by CoNISMa.

b-Material and methods

The restoration intervention (i.e. sea urchins culling) was carried out in two area of the no-take zone of the MPA covering a total area of 1.2 hectares. The consequences of sea urchin removal, carried out in spring 2015, were monitored at regular intervals (by mean of video transects and photographic surveys), covering a time span of 3 years, and compared with two controls adjacent to the area interested by the intervention (Fig. 1). The effectiveness of the intervention was assessed by mean of the following indicators of success: i) % coverage of macroalgal species; ii) reduction of barren ground; iii) sea urchin rates of recruitment. Multivariate analyses (i.e. PERMANOVA) have been carried out to explore likely changes in the structure of assemblages under manipulated and reference conditions.

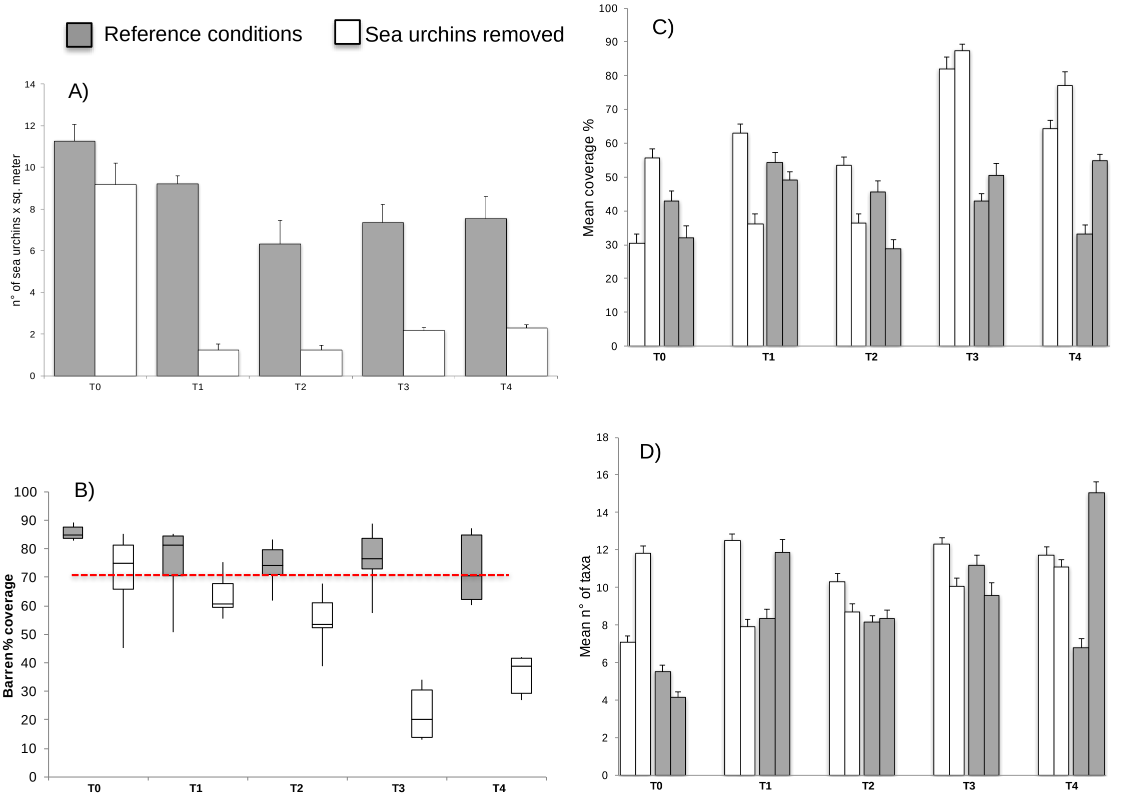

Figure 6. Summary of ANOVAs carried out to test differences between treatments in time (From T0 = 2015 to T4 = 2018) across locations on (A) sea urchins density, (C) total % coverage and (D) mean number of taxa. In the box plot (B) the % reduction of barren area across experimental factors is reported.

c-Main results

Very low recolonization of sea urchins was observed in the time frame covered by the experiment (Fig. 2a), so that any additional culling was necessary. Results show a high recovery after the beginning of the experiment, with a progressive reduction of the barren grounds in the area affected by the intervention (Fig. 2b,c). By contrast, no difference has been detected in terms of species richness (Fig. 2d).

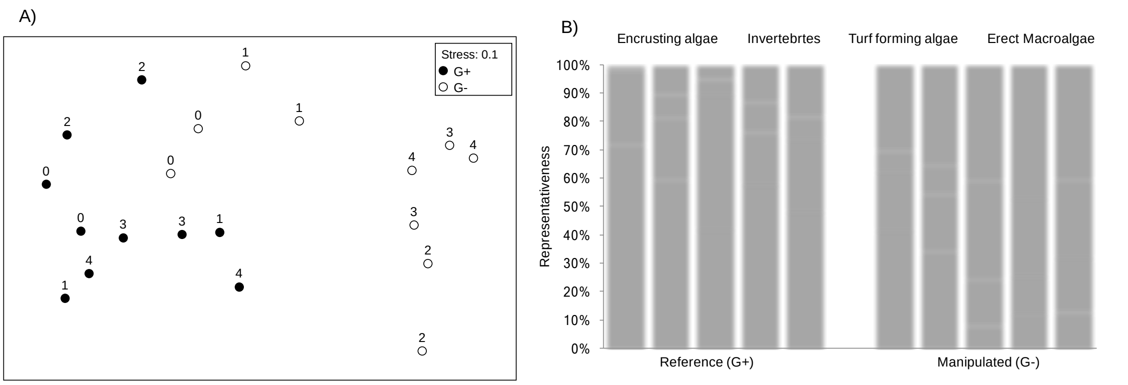

Figure 7. (A) Non-metric multidimensional scaling (nMDS) on the basis of Bray-Curtis dissimilarities of locations x treatment centroids across the five sampling dates (T0:T4). (B) Temporal change in % contribution of morphofunctional groups to the overall structure of assemblages subjected to different experimental conditions. G+ = controls; G- = culled areas.

Multivariate analyses (i.e. PERMANOVA) detected significant differences in the structure of assemblages mostly driven by an increase in % coverage of erect and turf forming algae (Fig. 3) instead the contribution of invertebrates is still not relevant after 3 years from the intervention.

d-Conclusions

Our results show a critical change from an extensive barren to an assemblage featured by erect and turf forming algae. However, for the moment, habitat forming algae have not recovered yet and the contribution of the invertebrate component is still very limited. Long term monitoring including sea urchin density is needed to understand the trajectories of the manipulated assemblages. Further interventions (e.g. transplanting of species showing a greatest ecological role) might be required to further increase the structural and functional complexity of target assemblages.

Since in reference areas a significant but slightly reduction of sea urchin densities was also observed during the time span of the experiment, further investigation in other areas historically characterized by the presence of barren grounds are necessary. This will allow to frame the recovery intervention in a wider context, taking into account also other factors possibly related to climate change which could have had a crucial role in affecting the outcomes of the intervention.

Mesophotic coralligenous habitat pilot restoration actions

Pilot action 4. Red coral *Corallium rubrum* transplants at Portofino MPA Island (Italy, Ligurian Sea, NW Mediterranean)

1-Rational for implementing the pilot action (regarding the local conditions, species, stakeholders' interests etcc...)

One of the most important charismatic species of the Portofino MPA is *Corallium rubrum*. Its presence is common along the Portofino Promontory but colonies are generally small or, in any case, without any commercial value. In the past, during the sixties, colonies were generally attained large sizes and for this reason collected by fishermen using scuba diving. In the same area, a mesophotic population, at 70 m depth has been found still with large colonies but very scattered and no juvenile colonies have been detected.

b- Target species for the pilot action
The red coral *Corallium rubrum* is a long living species (up to 200 years) with a very slow groth rate (about 1 mm / year in height) and display low natural mortaliy rates. The red coral has been commercially exploited since thousands of years but in the last two centuries its presence dramatically decreased in all the shallow and in many deep areas of its known geographic distribution.
The loss of important habitat forming species may trigger negative cascade effects on many other species but our knowledge is too poor to adequately understand these effects. It is gonochoric and it reproduces yearly during summer season.

c-Methodology implemented and indicators of success

At 70 m depth a small area with around 30 big colonies of commercial value has been recently found. To test the possibility to increase the density and the extension of this small population a transplant has been performed adopting two different approaches.

1. Transfer of 50 adult colonies from 35 m depth to 70 m depth
2. Transfer of artificial panels with around 30 newly settled larvae (two cohorts) from 35 m depth to 70 m depth

Survival of colonies will be considered as indicator of success.

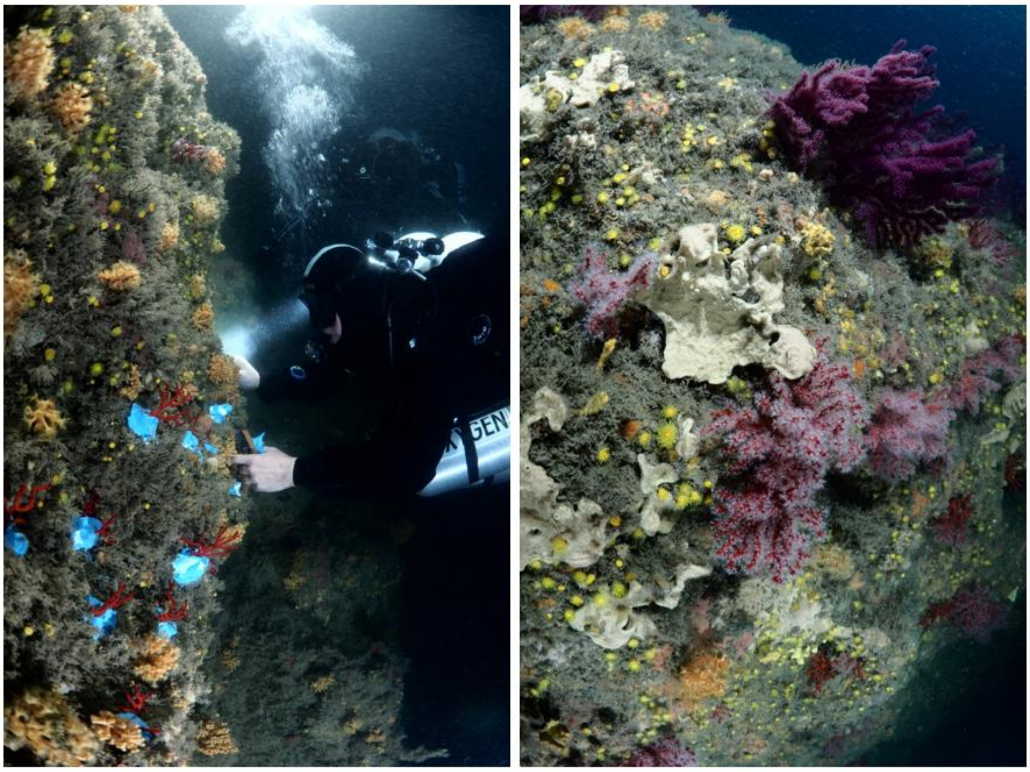

Figure 8. Red coral *Corallium rubrum* transplants fro 35 to 70 m and large sized colonies population discovered at 70 m in the Portofino MPA.

d-Main results

At the moment of the reporting all the transplanted colonies and the newly settled specimens are still *in situ* and alive. For the moment, the growth of the transplanted colonies is detectable only in few colonies and based on the number of polyps more than on linear growth.

e-Conclusion

The good results coming from this experience will allow the comparison between the dynamics of the wild colonies from the donor population and the transplanted colonies. In turn, this will enable checking whether environmental variables of the mesophotic zone can affect colonies' growth, and which variables - in case. Results are supporting the study of the feasibility of actual restoration of deep populations.

Pilot action 5. White gorgonian *Eunicella singularis* transplants at Gallinara Island (Italy, Ligurian Sea, NW Mediterranean)

a-Rational for implementing the pilot action (regarding the local conditions, species, stakeholders interests etcc...)

The Gallinara Island is a private island in the Ligurian sea located in the municipality of Albenga (SV) one nautical mile off the coast comprised between Santa Croce Cape and Vadino Point. It has a surface of 10 ha and a maximum altitude of 87 m (Figure 9). The coast of the island is characterized by high cliffs that can continue in the water until 20-30 m of depth. It is the main hard bottom area present in the western Ligurian coast and it is subject to different stressors as fishing activities and seasonal tourism. There is an historical documentation (fishermen and divers memories, old photos, skeletons of *Savalia savalia*) and scientific papers that clearly indicate that in the past the coralligenous of the island hosted gorgonians including the white and yellow gorgonians *Eunicella singularis* and *E. cavolini*.
The pilot action has the scope to restore that condition and recreate the past habitat complexity.

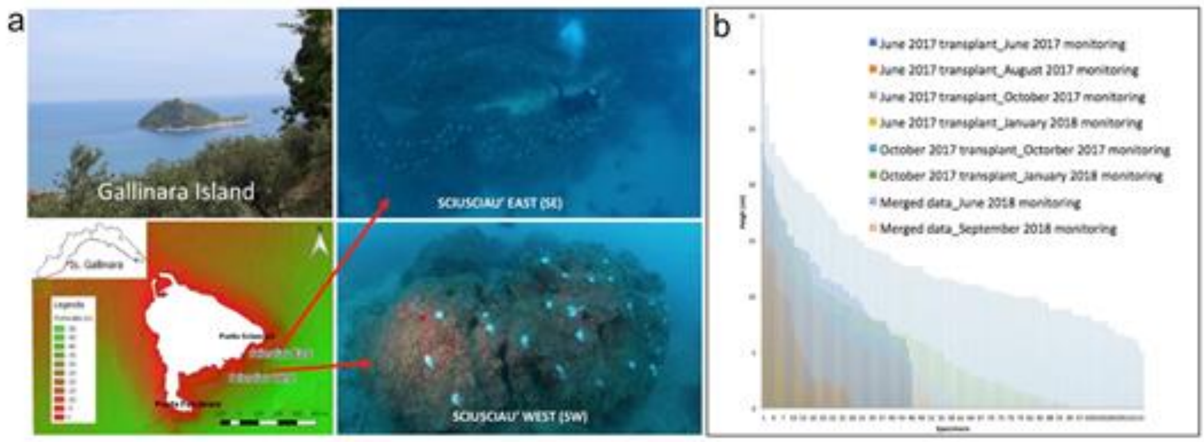

Figure 9. a) Location of the restoration area at Gallinara Island, and photo taken immediately after the transplanting of the latest batch of *E. singularis*. b) The trend of transplanted colonies showing a continuous decrease in the number and size during the monitoring periods

b-Short description of the species concerned

E. singularis (Cnidaria: Anthozoa: Octocorallia) is a Mediterranean Sea fan belonging to the family Gorgoniidae. Colonies are generally composed of long, straight and parallel branches with few ramifications; in most cases the colony grows on one plan, but in turbulent water it can assume a bush-like form. Polyps can live in symbiosis with photosynthetic algae, called zooxanthellae; for this reason, the color of the colony may vary from white when has no zooxanthellae to a brown, greyish white when they are present. The symbiotic algae belong to the *Symbionidium* clade and their diversity is not correlated with the depth at which the colony is located.
The recorded growth rate is in the order of a few centimeters every year (2.24 cm year^{-1} – 4.52 cm year^{-1}), although it has been recently recorded a faster growth rate of 7.71 cm year^{-1} in a young colony in Spain. The longevity of this species can be inferred, presuming constant the growth. *E. singularis*, as other octocorals, is a gonochoric iteroparous

species, with internal fecundation: the spermatozoid, released into seawater by male polyps, enter the female body cavity through the oral aperture.

c-Methodology implemented and indicators of success

The method implemented for the pilot action was selected from previous tests using different transplant techniques. Out of the various tested (Figure 10), the double branch technique showed the highest percentage of survival and for this reason the transplant at a large scale has been implemented with this technique. As indicators of success of the restoration action, we considered survival and growth rate.

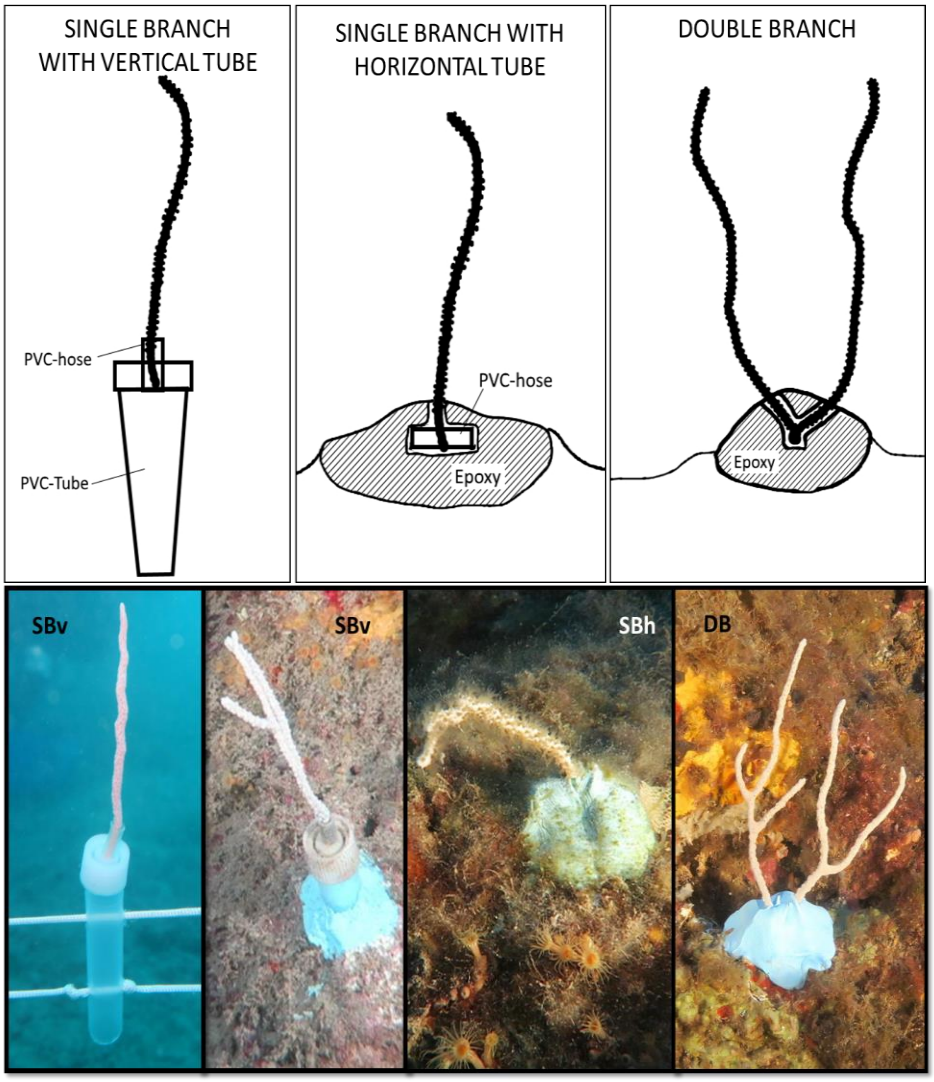

Figure 10 - Transplant techniques. "*Single branch with vertical tube*" (SBv): a single branch is inserted in a hole drilled in a 14ml PVC-tube plug with the aid of a piece of PVC-hose and hot glue. "*Single* b*ranch with horizontal tube"* (SBh): a single branch is dovetailed in a piece of PVC-hose and then glued directly with the epoxy. "*Double branch"* (DB): a V-shaped colony is directly attached to the substratum with epoxy resin, the epoxy covers the branching point. The two photos of the SBv technique show two branches before and after moving the colonies from the camp to SW. (The second SBv photo, the SBh photo and the DB photo are curtesy of Fabio Rossetto and Susanna Manuele from "InforRmare ASD")

d-Main results

Survival of transplants varied from 55 to 25 % at the end of the monitoring of this pilot action with "Sciusciaù East" location displaying the highest rates of survival (Table 2). Growth rate was negative in all sites at the end of the pilot with a loss in mean size ranging from 1.2 up to 5.8 cm (Figure 9, Table 2).

Table 2 - Mean values considering all the gorgonians. SE = "Sciusciaù East" **-** June 2017 Transplant, SEnew = "Sciusciaù East" **-** October 2017 transplant, SW = "Sciusciaù West", SD = Standard Deviation of individual results, SE = Standard Deviation of the mean, CI = 95 % Confidence Interval

Station	Monitoring Period	Variable	Mean	SD	SE	CI
SE	August 2017	Height (cm)	6.1	5.1	0.8	1.7
SE	August 2017	Necrosis	34.86%	43.56%	7.16%	14.52%
SE	August 2017	% Survival	100.00%	NA	NA	NA
SE	October 2017	Height (cm)	8.4	4.4	0.7	1.5
SE	October 2017	% Necrosis	12.08%	29.48%	4.85%	9.83%
SE	October 2017	% Survival	59.00%	NA	NA	NA
SE	January 2018	Height (cm)	4.7	4.0	0.7	1.3
SE	January 2018	% Necrosis	10.16%	24.56%	4.04%	8.19%
SE	January 2018	% Survival	55.00%	NA	NA	NA
SEnew	October 2017	Height (cm)	12.6	4.9	0.5	0.9
SEnew	October 2017	% Necrosis	0.50%	2.70%	0.30%	0.50%
SEnew	October 2017	% Survival	100.00%	NA	NA	NA
SEnew	January 2018	Height (cm)	6.8	5.2	0.5	1
SEnew	January 2018	% Necrosis	7.40%	20.60%	1.90%	3.80%
SEnew	January 2018	% Survival	80.00%	NA	NA	NA
SW	August 2017	Height (cm)	7.3	3.3	0.5	1.1
SW	August 2017	% Necrosis	0.90%	4.10%	0.70%	1.40%
SW	August 2017	% Survival	100.00%	NA	NA	NA
SW	October 2017	Height (cm)	6.3	4.1	0.7	1.4
SW	October 2017	% Necrosis	8.60%	13.30%	2.20%	4.40%
SW	October 2017	% Survival	53.00%	NA	NA	NA
SW	January 2018	Height (cm)	7.2	3.4	0.6	1.1
SW	January 2018	% Necrosis	6.20%	13.90%	2.30%	4.60%
SW	January 2018	% Survival	26.00%	NA	NA	NA
SW	May 2019	Height (cm)	6.1	NA	NA	NA
SW	May 2019	% Necrosis	5.40%	NA	NA	NA
SW	May 2019	% Survival	25.00%	NA	NA	NA

e-Conclusions

At the moment the pilot is still in progress and a new transplant has been performed on the 29th of May 2019. Around 100 new colonies have been transplanted and the 50 colonies coming from the previous transplants are still *in situ* suggesting the site is suitable and that the first phase of the pilot action (short-medium term) can be considered successful.

From now on, the implementation of this action will be focused on local authorities, showing the results and asking for specific long-term conservation measures of the area where transplants are present. A series of communication events are scheduled during the summer.

Pilot action 6. Red gorgonian *Paramuricea clavata* transplants at Medes Islands MPA (Spain, Catalan Sea, NW Mediterranean)

a-Rational for implementing the pilot action (regarding the local conditions, species, stakeholders' interests etc...).

Since the early 90' some red gorgonian populations *Paramuricea clavata* in some areas of the Medes Islands MPA displayed clear signs of degradation. In order to enhance the recovery of these populations, we suggested to the management body of the Medes Islands MPA to conduct a restoration pilot action within the MPA. The director of the MPA proposed the involvement of diving centers operating within the MPA in the pilot action. We organized a series of meetings to explain the rational of the restoration action and organize the involvement of diving instructors in the restoration activities.

b-Short description of the species concerned

The Mediterranean red gorgonian *Paramuricea clavata* is a key habitat forming species for the coralligenous coralligenous assemblages, one of the richest and most threatened Mediterranean communities. This species has been recurrently impacted by large-scale mass mortality events, putatively linked to climate change, as well as the impacts of fishing gears and recreational divers. In general, this species display slow population dynamics (low growth, mortality and recruitment rates) and low dispersal capacity. These features result in low resilience to disturbances.

c-Methodology implemented and indicators of success

Fragments (5-10 cm) from healthy colonies (>30 cm in height) were collected from a Medes Islands population the same day of the action. The fragments were kept in coolers at 16-18 ºC prior to transplants. The selected site (El Guix) is located in the NW area of the main Medes Island. This site harbors a degraded population of red gorgonian in a vertical wall between 12-18 m depth.

Following the proposed restoration method for red gorgonian (Deliverable 3.2), the fragments were transplanted in natural holes with the help of the putty arranged in groups of 6-8 fragments were transplanted within 20 x 20 cm areas (Figure 11). Permanent marks were placed to identify the transplant areas to support the monitoring of the survival of the transplants. The diving instructors participating in the restoration action attended a trainining on the methods to be implemented. During the underwater operations they were always assited by scientists.

The transplants were carried out the 31st May 2017. In this video https://www.youtube.com/watch?v=Kgar7860Lic&feature=youtu.be we reported the key steps and the participation of diving instructors in the pilot action.

For the monitoring we used 20 x 20 cm quadrats placed randomly in the transplant areas. For each fragment found within the quadrat its status (healthy or with necrosis) was assessed. In case of necrosis, the % was estimated. We look as well for patches with putty still attached to the substrate but without any fragment to estimate the transplant failure.

d-Main results

Setting-up the pilot action. In the pilot action more than 400 fragments were transplanted. More than 20 diving instructors participated in the action.

Few days after the transplantation, most of transplant displayed healthy conditions without any necrosis confirming that the chosen restoration technique was reliable for scaling up (Figure 11a,b).

Evolution of transplants. During the 2017 summer the Catalan coast suffered a severe bloom of filamentouse algae (*Acinetospora crinita*) that covered the substratum and adult gorgoninans. Thus preventing to monitor the restoration action till October 2017. when the filamentouse algae cover decreased. By then about 60% of transplants survived (Figure 11a) although more than 50% of transplants prestend necrosis (Figure 11b). In October 2018 the bad weather conditions prevented us to conduct the planned annual monitoring. After two years (May 2019), the survival rate was very low less than 20% (Figure 11) and most of transplants died despite that the putty was still in the substratum (Figures 11b).

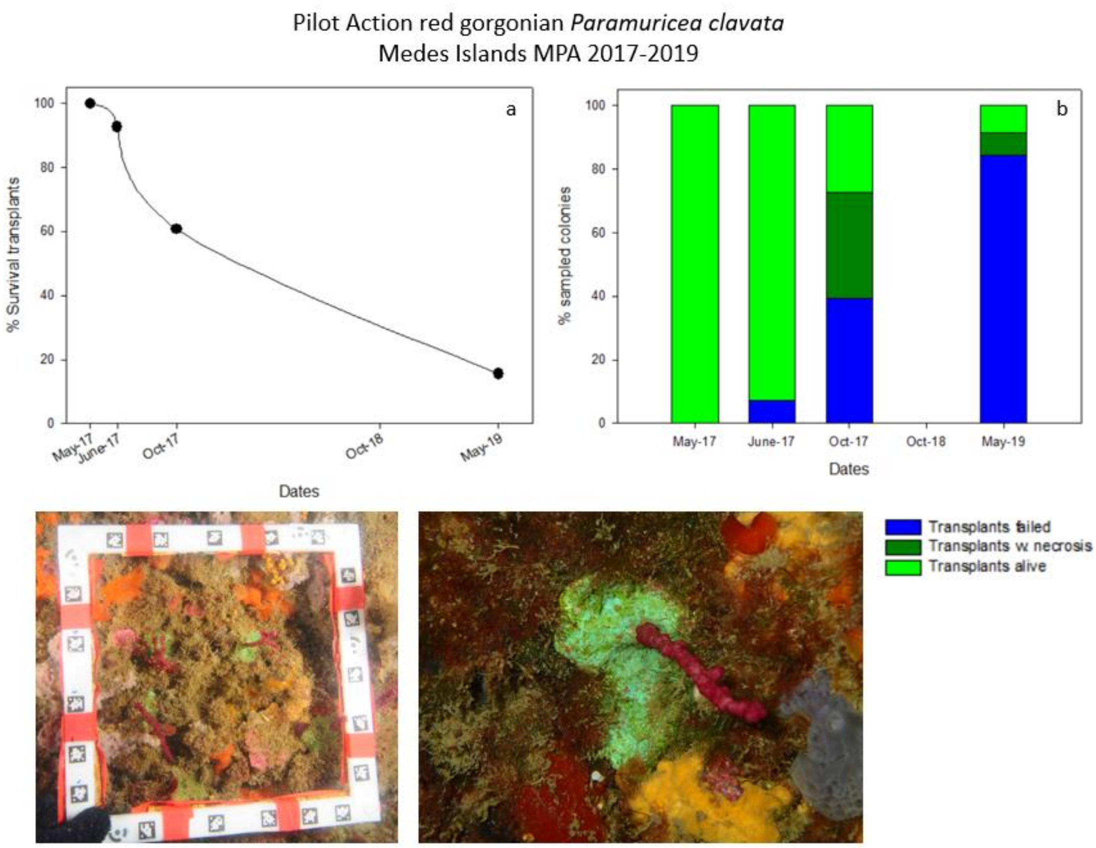

Figure 11. a) survival of transplants of *Paramuricea clavata* of the Medes Islands MPA started in May 2017 till May 2019; b) status of transplants sampled during the period May 2018 till May 2019 (no data for Oct 2018 because bad weather conditions). Below images of the transplants in 2017, the green colour corresponds to the putty used to attach the gorgoninan fragments to the rock.

Despite that the survival rate of transplants after two years from the starting of the action was low, it is worth mentioning that the putty was covered mainly by encrusting coralline algal species (e.g. *Mesolphyllum alternans*) (Figure 12). This indicates that the colonization of the putty guarantees the consolidation of the attachment of the fragments to the substrate after only 2 years.

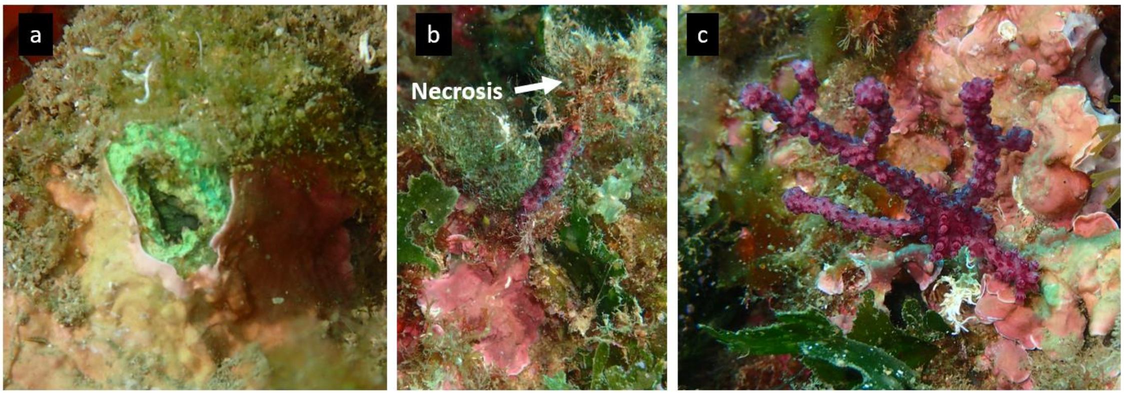

Figure 12. Transplants from the Medes Islands MPA Pilot Action in May 2019. a) detail of failed transplant, the fragment was dead and then detached from the putty mass (center of the image); b) a transplants displaying necrosis, and c) and healthy transplant. Note that note that the putty is covered by encrusting algae in all cases.

e-Conclusions

The low survival rates of transplants the red gorgonians (*P. clavata*), cannot be attributed to technical failure or misuse by volunteers involved, since monitoring just after the implementation indicated a high survival. Instead, we contend that the filamentous algal bloom and the high temperatures observed during summer 2017 and the high temperatures recorded again in 2018 that specially affected the suprathermoclinal waters are the most likely cause of mortality of transplants.

Main conclusions

The main goal of the Pilot actions was to scale-up the implementation of restoration actions targeting benthic habitat forming species developed within WP3 using the fined tuned restoration protocols defined during the WP3 activities (Deliverable 3.2). The pilot actions proved the robustness of the proposed restoration protocols since they could be implemented at larger scales, i.e. from few m^2 to tens-hundred of m^2. Furthremore, the experience acquired during the implementation and monitoring provided crucial lessons learnt that can be capitalized in future restoration plans.

Regarding the success of the pilot actions, for both habitats the period of implementation was in general too short to provide conclusive results on the effectiveness of the restoration actions. However, in the covered period we obtained contrasted outcomes. As expected macroalgal habitats responded faster than coralligenous habitats. In macroalgal beds, combining removal of sea-urchins along with transplants and recruitment enhacement protocols showed the better results in terms of recovery of target species than single actions. For coralligenous habitats, transplants of the different gorgonian species were sucesful. However, the prevalence of drivers of habitat degradation in the restoration areas, mainly abrasion by fishing gears, the occurrence of marine heat waves and the development of bloom of filamentouse algal severely impacted the survival and growth rates of transplants. These species display slow growth rates, thus ensuring the survival of transplants is key towards the success of restoration actions. Regulating the uses in view to reduce the mortality of transpants over the restoration actions should be a priority to enhance their effectiveness. Besides, the ongoing works (within WP3 and beyond) to identifiy the basis to the resistance to thermal stress could support transplantations resistant to the future thermal conditions.

Despite the restoration protocols proved the feasibility for restoration purposes, however scaling up their implementation still remains a real challenge. Only if we will promote the effectiveness of scaling up process, marine restoration will have a significant ecological impact recovering degraded marine habitats. WP3 activities clearly contribute in this direction. The capitalization of theses experiences and lessons learn with stakeholders and appropriate funding opportunites will make the difference.