

Supplementary Data

Impact assessment of fish cages on coralligenous reefs through the use of the STAR sampling procedure

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Mediterranean Marine Science, 2019, 20 (3)

Table S1. The main steps used to apply STAR procedure.

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| 1. vertical substrate (85-90°) at around 35 m depth was selected in each sampling site; |
| 2. the sampling design expected to characterize a site consisted of 3 areas about 4 m ² in size, 10 m apart; |
| 3. 10 photographic samples (0.2 m ² in surface) were collected in each area as replicates; |
| 4. thickness of the calcareous layer was measured through a hand-held penetrometer with 6 replicated measures per each area; |
| 5. size (mean height), necrosis and epibiosis (percentage) of erect anthozoans were assessed through an RVA approach; |
| 6. percent cover of the conspicuous taxa/morphological groups and sediment was evaluated for each sample through ImageJ software; |
| 7. the overall Sensitivity Level (SL) was calculated by multiplying the value of the SL of each taxon/group for its class of abundance and then summing up all the final values. The cover value of each taxon/morphological group was divided in eight classes of abundance: 1) 0<%<0.01; 2) 0.01<%<0.1; 3) 0.1<%<1; 4) 1<%<5; 5) 5<%<25; 6) 25<%<50; 7) 50<%<75; 8) 75<%<100); |
| 8. richness (α -diversity), i.e. the mean number of the taxa/groups per photographic sample, was calculated; |
| 9. β -diversity was evaluated through PERMDISP analysis as the mean distance of all photographic samples from centroids; |
| 10. ESCA, ISLA and COARSE indices were calculated. |

Table S2. Sensitivity Level (SL) of the main taxa/morphological groups in the coralligenous assemblages for ESCA index (from Piazzì *et al.*, 2017a).

Taxa/Groups	SL
Algal turf	1
Hydrozoans (e.g. <i>Eudendrium</i> spp.)	2
<i>Pseudochlorodesmis furcellata</i>	2
Perforating sponges (e.g. <i>Cliona</i> spp.)	2
Dictyotales	3
Encrusting sponges	3
Encrusting bryozoans	3
Encrusting ascidians (also epibiotic)	3
Encrusting Corallinales, articulated Corallinales	4
<i>Peyssonnelia</i> spp.	4
<i>Valonia</i> spp., <i>Codium</i> spp.	4
Sponges prostrate (e.g. <i>Chondrosia reniformis</i> , <i>Petrosia ficiformis</i>)	5
Large serpulids (e.g. <i>Protula tubularia</i> , <i>Serpula vermicularis</i>)	5
<i>Parazoanthus axinellae</i>	5
<i>Leptogorgia sarmentosa</i>	5
<i>Flabellia petiolata</i>	6
Erect corticated terete Ochrophyta (e.g. <i>Sporochnus pedunculatus</i>)	6
Encrusting Ochrophyta (e.g. <i>Zanardinia typus</i>)	6
Azooxantellate individual scleractinians (e.g. <i>Leptopsammia pruvoti</i>)	6
Ramified bryozoans (e.g. <i>Caberea boryi</i> , <i>Cellaria fistulosa</i>)	6
<i>Palmophyllum crassum</i>	7
Arborescent and massive sponges (e.g. <i>Axinella polypoides</i>)	7
<i>Salmacina-Filograna</i> complex	7
<i>Myriapora truncata</i>	7
Erect corticated terete Rodophyta (e.g. <i>Osmundea pelagosae</i>)	8
Bushy sponges (e.g. <i>Axinella damicornis</i> , <i>Acanthella acuta</i>)	8
<i>Eunicella verrucosa</i> , <i>Alcyonium acaule</i>	8
Erect ascidians	8
<i>Corallium rubrum</i> , <i>Paramuricea clavata</i> , <i>Alcyonium coralloides</i>	9
Zooxantellate scleractinians (e.g. <i>Cladocora caespitosa</i>)	9
<i>Pentapora fascialis</i>	9
Flattened Rhodophyta with cortication (e.g. <i>Kallymenia</i> spp.)	10
<i>Halimeda tuna</i>	10
Fucales (e.g. <i>Cystoseira</i> spp., <i>Sargassum</i> spp.), <i>Phyllariopsis brevipes</i>	10
<i>Eunicella singularis</i> , <i>Eunicella cavolini</i> , <i>Savalia savaglia</i>	10
<i>Aedonella calveti</i> , <i>Reteporella grimaldii</i> , <i>Smittina cervicornis</i>	10

Table S3. Descriptors used to calculate ESCA index $EQR = ((EQR_{SL} + EQR_{\alpha} + EQR_{\beta}) \times 3^{-1})$. Individual EQRs were calculated as the ratios of the values of the three descriptors to the values of the same descriptors of the reference location for the north-western Mediterranean Sea.

Descriptor	Calculation method
α -diversity	The α -diversity of the assemblages was evaluated as the number of taxa/morphological group per sample
β -diversity	The β -diversity was evaluated based on the spatial heterogeneity of assemblages as calculated by PERMDISP analysis (Primer 6+ PERMANOVA)
Sensitivity Level	The total Sensitivity Level of photographic sample (SL_{sa}) was calculated as the mean of values of all the samples. The Sensitivity Level of each sample was obtained by multiplying the sensitivity value of each taxa/groups (see Table S2) for its class of abundance (from 1 to 8), and finally adding values of all taxa/groups present in the sample

Table S4. Scores of the Integrated Sensitivity Level (ISL) for the main taxa/morphological groups in the coralligenous assemblages, as obtained combining the values of sensitivity to disturbance (DSL) and of sensitivity to stress (SSL) (Montefalcone *et al.*, 2017). In the case of alien species, the ISL score is put to -1 *a priori*.

Taxa/Groups	DSL	SSL	ISL
Alien species (e.g. <i>Caulerpa cylindracea</i> , <i>Womersleyella setacea</i>)	na	na	-1
Algal turf	6	0	0
Small hydroids	7	1	0
<i>Pseudochlorodesmis furcellata</i>	8	1	1
Siphonous with vesicle-like thallus (<i>Valonia</i> spp., <i>Codium</i> spp.)	8	2	1
Encrusting sponges	8	3	1
Dictyotales	8	3	2
Encrusting Corallinales	8	4	2
Encrusting Ochrophyta (e.g. <i>Zanardinia typus</i>)	6	6	2
<i>Peyssonnelia</i> spp.	8	4	2
Perforating sponges (e.g. <i>Cliona</i> spp.)	9	2	2
Large hydroids (e.g. <i>Eudendrium</i> spp.)	11	1	2
Encrusting bryozoans	11	2	2
Encrusting ascidians (also epibiotic)	10	2	2
Erect corticated Ochrophyta (e.g. <i>Nereia filiformis</i> , <i>Sporochnus</i>	9	6	3
<i>Flabellia petiolata</i>	8	6	3
<i>Palmophyllum crassum</i>	7	8	3
Erect corticated Rhodophyta (e.g. <i>Botryocladia</i> spp., <i>Osmundea pelagosa</i>)	9	9	4
Macroforaminifera (e.g. <i>Miniacina miniacea</i>)	11	6	4
Sponges prostrate (e.g. <i>Chondrosia reniformis</i> , <i>Petrosia ficiformis</i>)	12	4	4
<i>Parazoanthus axinellae</i>	12	4	4
Stolonifera (e.g. <i>Cornularia cornucopiae</i>)	12	6	4
Flattened Rhodophyta with cortication (<i>Kallymenia</i> spp., <i>Acrodiscus vidovichii</i>)	9	10	5
<i>Halimeda tuna</i>	9	10	5
Laminariales (e.g. <i>Phyllariopsis brevipes</i>)	10	10	5
Bushy sponges (e.g. <i>Axinella damicornis</i> , <i>Acanthella acuta</i>)	13	7	5
<i>Leptogorgia sarmentosa</i>	16	4	5
Azooxantellate solitary scleractinians (e.g. <i>Leptopsammia pruvoti</i>)	15	4	5
Bivalve molluscs	15	5	5
Large serpulids (e.g. <i>Protula tubularia</i> , <i>Serpula vermicularis</i>)	14	5	5
<i>Salmacina-Filograna</i> complex	13	6	5
Ramified bryozoans (e.g. <i>Caberea boryi</i> , <i>Cellaria fistulosa</i>)	14	5	5
Fucales (e.g. <i>Sargassum</i> spp., <i>Cystoseira</i> spp.)	10	11	6
Arborescent and massive sponges (e.g. <i>Axinella polypoides</i> , <i>Sarcotragus</i>	16	6	6
Actinians	15	7	6
<i>Eunicella cavolini</i>	16	7	6
Azooxantellate colonial scleractinians (e.g. <i>Phyllangia americana</i>)	16	5	6
Vermetids	16	5	6
Erect ascidians	15	7	6

<i>Alcyonium acaule</i>	16	8	7
<i>Alcyonium coralloides</i>	16	9	7
<i>Corallium rubrum</i>	17	8	7
<i>Eunicella verrucosa</i>	16	7	7
<i>Paramuricea clavata</i>	16	8	7
Zooxantellate individual scleractinians (e.g. <i>Balanophyllia europea</i>)	15	9	7
<i>Myriapora truncata</i>	17	6	7
<i>Pentapora fascialis</i>	17	8	7
<i>Savalia savaglia</i>	16	11	8
Zooxantellate colonial scleractinians (e.g. <i>Cladocora caespitosa</i>)	17	9	8
<i>Eunicella singularis</i>	16	12	9
<i>Aedonella calveti</i> , <i>Reteporella grimaldii</i> , <i>Smittina cervicornis</i>	17	12	9

Table S5. Criteria for the assignment of quality scores to each descriptor for each replicate in COARSE index. ECR= encrusting coralline algae, NCEA= non calcified encrusting algae, EA= encrusting animals. L = the maximum height found in literature for each species. The necrosis is evaluated as the mean percentage of necrosis of each individual colony.

Layer	Descriptor	score 3	score 2	score 1
BASAL	% cover (cover x score / 100)	ECR	NCEA, EA	Turf, sediment
	Penetration	<1	>1	0
	Borer marks	absent	occasional	common
INTERMEDIATE	Species Richness (SR)	SR >8	8 > SR > 5	SR < 5
	Erect calcified organisms	ECO > 3	1 < ECO ≤ 3	ECO ≤ 1 2
	Sensitivity of bryozoans	<i>S. cervicornis</i> , <i>R. grimaldii</i>	<i>P. fascialis</i> , <i>calveti</i> A.	<i>M. truncata</i>
ERECT	% cover	% > 25	25 > % > 5	% < 5
	Maximum height(MH)	MH > 0.6xL	0.6xL > MH > 0.3xL	MH < 0.3xL
	Necrosis (N)	N < 10%	75% > N > 10%	N > 75%