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Supplementary Data

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

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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 Rhodophyta (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% |