Regional Activity Centre for Specially Protected Areas (RAC/SPA)

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PROCEEDINGS OF 2nd MEDITERRANEAN SYMPOSIUM ON THE CONSERVATION OF CORALLIGENOUS AND OTHER CALCAREOUS BIO-CONCRETIONS

Portorož, Slovenia, 29-30 October 2014

ACTES DU 2ème SYMPOSIUM MÉDITERRANÉEN SUR LA CONSERVATION DU CORALLIGÈNE ET AUTRES BIO-CONCRÉTIONS

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INSTITUTE OF THE REPUBLIC OF SLOVENIA FOR NATURE CONSERVATION

May 2015

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With the support of MedKeyhabitats project Financed by the MAVA Foundation

Avec le support du projet MedKeyhabitats Finance par la fondation MAVA

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Citation :

UNEP/MAP – RAC/SPA, 2015. Proceedings of the second Mediterranean Symposium on the conservation of Coralligenous and other Calcareous Bio-Concretions (Portorož, Slovenia, 29-30 October 2014). BOUAFIF C., LANGAR H., OUERGHI A., edits., RAC/SPA publ., Tunis: 260 p.

PNUE/PAM – CAR/ASP, 2015. Actes de deuxième Symposium Méditerranéen sur la Conservation du Coralligène et autres Bio-Concrétions (Portorož, Slovénie, 29-30 octobre 2014). BOUAFIF C., LANGAR H., OUERGHI A., édits., CAR/ASP publ., Tunis: 260 p.

ISBN: 978-9938-9574-2-6

AVANT-PROPOS

Suite aux recommandations du **Plan d'action pour la conservation de la végétation marine en mer Méditerranée** (adopté par les Parties contractantes à la Convention de Barcelone, en 1999), du **Plan d'action pour la conservation du coralligène et des autres bio-constructions de Méditerranée** (adopté par les Parties contractantes à la Convention de Barcelone, en 208)**, du Plan d'Action pour la conservation des habitats et espèces associés aux monts sous-marins, aux grottes et canyons sous-marins, aux fonds durs aphotiques et aux phénomènes chimio-synthétiques en mer Méditerranée (Plan d'action pour les habitats obscurs)** (adopté par les Parties contractantes à la Convention de Barcelone, en 2013) et dans le but du développement des connaissances, une série de symposiums scientifiques, dédiée à ces habitats, a été initiée en 2000 par l'organisation du 1er symposium Méditerranéen sur la végétation marine. Ces initiatives visent essentiellement à faire le point sur les données scientifiques disponibles et à promouvoir la coopération entre les spécialistes qui travaillent en Méditerranée.

Cette année, avec la mise en œuvre du projet de Cartographie des habitats marins clés de la Méditerranée et la promotion de leur conservation par l'établissement d'Aires Spécialement Protégées d'Importance Méditerranéenne (ASPIM) « Projet Medkeyhabitats » financé par la fondation MAVA, l'opportunité s'est présentée pour organiser ensemble les symposiums suivants:

- 5ème Symposium Méditerranéen sur la Végétation Marine
- 2ème Symposium Méditerranéen sur la conservation du Coralligène et autres Bio-concrétions
- 1er Symposium Méditerranéen sur la conservation des Habitats Obscurs

Suite à l'offre de « the institute of the republic of Slovenia for nature conservation » lors du quatrième symposium organisé à Yasmine-Hammamet (Tunisie) du 2 au 4 décembre 2010 d'abriter la 5ème édition du même symposium, il a été convenu de les organiser ensemble back to back à Portorož, Slovenie, du 27 au 31 octobre 2014 comme suit :

- 5ème Symposium Méditerranéen sur la Végétation Marine du 27 au 28 octobre 2014
- 2ème Symposium Méditerranéen sur la conservation du Coralligène et autres Bio-concrétions du 29 au 30 octobre 2014)
- 1er Symposium Méditerranéen sur la conservation des Habitats Obscurs le 31 octobre 2014

Cette édition a vu l'inscription de plus de 140 participants en provenance de 17 pays Méditerranées, ce ne sont pas moins de 126 communications orales et posters qui devraient y être présentés.

Cette édition sera aussi l'occasion d'aborder des sujets d'actualités tels que les invasions biologiques, le réchauffement global, et leurs impacts sur les habitats clés de Méditerranée et de renforcer les liens entre les scientifiques et entre les institutions scientifiques.

Khalil ATTIA
Directeur du CAR/ASP

CONTENTS / SOMMAIRE

PROGRAMME

Wednesday 29 October 2014

8:00-8:30 **Participants welcome and registration**

8:30-8:45 **Opening of the Symposium**

8:45-9:45 Keynote conference: **CIGESMED: Coralligenous based Indicators to evaluate and monitor the "Good Environmental Status" of the MEDiterranean coastal waters, a SEASERA project** by **Pr. Jean Pierre FERAL**

Session 1: **Knowledge of the Coralligenous communities and other calcareous bioconstructions**
Chair: **Joaquim GARRABOU**, Rapporteur: **Boris DANIEL**

9:45-10:00 "**Unexpected artificial-reef-like effect due to a Mediterranean pipeline and the conservation of two circalittoral emblematic species: *Centrostephanus longispinus* and *Cystoseira zosteroides***" by **Patrick BONHOMME,** GOUJARD A., JAVEL A., GRONDIN J., BOUDOURESQUE C.F.

10:00-10:15 "**Coralligenous: insights for a new geomorphological definition**" by **Valentina Alice BRACCHI**, BASSO D., SAVINI A., MARCHESE F., CORSELLI C.

10:15-10:30 "**Environmental factors explaining taxonomic heterogeneity of coralligenous outcrops across France (Northwestern Mediterranean)**" by Florian HOLON, BOISSERY P., **Julie DETER**

10:30-10:45 Discussion

10:45-11:15 ***Coffee break***

Session 1: (Continued) **Knowledge of the Coralligenous communities and other calcareous bioconstructions**
Chair: **Joaquim GARRABOU**, Rapporteur: **Boris DANIEL**

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12:15-12:30	Discussion
13:00-14:00	**Lunch**

14:00-15:30	***Round Table*** **Updating the list of species to be considered as part of the mapping and monitoring of habitats** by **Christine PERGENT-MARTINI,** Rapporteur: **Leonardo TUNESI**

Session 2:	**Impact of climatic changes on Coralligenous community and other calcareous bioconstructions** Chair: **Leonardo TUNESI**, Rapporteur: **Renato CHEMELLO**
15:30-15:45	“**Long-term monitoring of *Cladocora caespitosa* reefs in the Columbretes Islands: from mapping to population dynamics and threats**” by **Diego K. KERSTING,** BALLESTEROS E., BENSOUSSAN N., CASADO C., DE CARALT S., TEIXIDÓ N., LINARES C.
15:45-16:00	“**Response of coralligenous to global change: evidences from field and experimental studies in gorgonian forests**” by **Cristina LINARES**, ARIZMENDI-MEJÍA R., BALLESTEROS E., CEBRIAN E., COMA R., DÍAZ D., HEREU B., KIPSON S., KERSTING D., LEDOUX J.B., TEIXIDO N., THANAPOULOU Z, GARRABOU J.
16:00-16:15	“**Impact of climate changes on coralligenous community in the Adriatic Sea**” by **Petar KRUŽIĆ**, RODIĆ P.
16:15-16:30	“**Long-term demographic traits of red coral populations in the NW Mediterranean: insights into management strategies**” by Ignasi MONTERO-SERRA, **Cristina LINARES**, GARCÍA M., PANCALDI F., FRLETA-VALIĆ M., LEDOUX J.B., ZUBERER F., MERAD D., DRAP P., GARRABOU J.
16:30-16:45	Discussion
16:45-17:15	***Coffee break***
17:15-18:15	**Poster Session**

18:15-19:15	***Side Event*** **“The impacts of acidification on biodiversity and other key Mediterranean ecosystems”** by **Patrizia ZIVERI**

Thursday 30 October 2014

Session 3:	**Mapping and monitoring of the Coralligenous community and other calcareous bioconstructions** Chair: **Giorgio BAVESTRELLO**, Rapporteur: **Giovanni TORCHIA**
8:30-8:45	"**Cartography of main coastal ecosystems (Corallignenous and Rhodolith Beds) along the Corsican Coasts**" by **Marina BONACORSI,** ALAMI S., BREAND N., CLABAUT P., DANIEL B., PERGENT G., PERGENT-MARTINI C.
8:45-9:00	"**Coralligenous reefs in Liguria: distribution and characterization**" by **Almudena CÁNOVAS MOLINA**, MONTEFALCONE M., CANESSA M., COPPO S., DIVIACCO G., MORRI C., FERRARI M., CERRANO C., ARMSTRONG R., BIANCHI C. N., BAVESTRELLO G.
9:00-9:15	"**Assessment of coralligenous assemblages status in the Ligurian sea**" by **Carlo CERRANO,** BERTOLOTTO R., COPPO S., PALMA M., PANTALEO U., VALISANO L., BAVESTRELLO G., PONTI M.
9:15-9:30	"**Croatian coralligenous monitoring protocol: the basic methodological approach**" by **Silvija KIPSON**, KALEB S., KRUZIC P., RAJKOVIC Z., ZULJEVIC A., JAKLIN A., SARTORETTO S., RODIC P., JELIC K., KRSTINIC P., ZUPAN D., GARRABOU J.
9:30-9:45	"**A first insight into the coralligenous assemblages of the Western Sardinia Shelf (Italy)**" by **Simone SIMEONE**, GUALA I., CONFORTI A., INNANGI A., FERRIGNO F., TONIELLI R., DE FALCO G.
9:45-10:00	"**Using MaxEnt to understand and predict the distribution of coralligenous environments**" by **Paula A. ZAPATA-RAMIREZ**, HUETE-STAUFFER C., COPPO S., CERRANO C.
10:00-10:15	"**The resolution in benthic cartography: a detailed mapping technique and a Multiscale GIS approach with applications to coralligenous assemblages**" by Francesco PITITTO, TRAINITO E., MAČIĆ V., RAIS C., **Giovanni TORCHIA**
10:15-10:30	Discussion
10:30-10:45	***Coffee break***
Session 4:	**Population Genetic of the Coralligenous community and other calcareous bioconstructions** Chair: **Stéphane SARTORETTO**, Rapporteur: **Hocein BAZAIRI**
10:45-11:00	"**Genetic connectivity and conservation in the long-lived, harvested species** ***Corallium rubrum***" by **Marco ABBIATI**, COSTANTINI F., RUGIU L., CARLESI L.
11:00-11:15	"**Population genetics of** ***Paramuricea clavata*** **(Risso, 1826) in the Eastern Adriatic Sea: implications for its conservation and management**" by **Maša FRLETA-VALIĆ**, KIPSON S., LINARES C., CEBRIAN E., ANTUNES. A, LEDOUX J.B.

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11:30-11:45 Discussion

Session 5: Management of the Coralligenous community and other calcareous bioconstructions
Chair: **Ricardo AGUILAR**, Rapporteur: **Romain DAVID**

11:45-12:00 "**Remotely operated vehicles (ROVs) as powerful tools for the evaluation of the conservation status of deep red coral banks**" by **Giorgio BAVESTRELLO**, ABBIATI M., ANGIOLILLO M., BETTI F., BO M., CANESE S., CATTANEO-VIETTI R., CAU A., CORRIERO G., COSTANTINI F., GIUSTI M., PRIORI C., SALVATI E., SANDULLI R., SANTANGELO G., TUNESI L.

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13:00-14:00 **Lunch**

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14:30-14:45 Discussion

14:45-16:15 **Poster Session**

16:15-16:45 *Coffee break*

16:45-18:15 *Round-table*

"Protection of the Mediterranean coralligenous reefs: use of existing scientific knowledge & legislative framework to prevent further destruction of coralligenous habitats" by **Anastasia MILIOU**, SENNI D., TSIMPIDIS T., TRAGANOS. D.

18:15-18:45 **Awards for best poster**
Jury: **Joaquim GARRABOU, Leonardo TUNESI, Giorgio BAVESTRELLO, Stéphane SARTORETTO** and **Ricardo AGUILAR**, Secretaries: **Cyrine BOUAFIF** and **Habib LANGAR**

18:45-19:30 **Closure of the Symposium**

20h00 **Social Dinner**

PROGRAMME

<u>Mercredi 29 Octobre 2014</u>

8:00-8:30 **Accueil et Inscription des participants**

8:30-8:45 **Ouverture du Symposium**

8:45-9:45 Conférence Introductive: **CIGESMED: Coralligenous based Indicators to evaluate and monitor the "Good Environmental Status" of the MEDiterranean coastal waters, a SEASERA project** par **Pr. Jean Pierre FERAL**

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12:15-12:30	Discussion
13:00-14:00	**Déjeuner**

14:00-15:30	***Table ronde*** **Actualisation de la liste des espèces à prendre en considération dans le cadre de la cartographie et du suivi des habitats** par **Christine PERGENT-MARTINI, Rapporteur: Leonardo TUNESI**

Session 2 : **Impact des changements climatiques sur les formations coralligènes**
Président: **Leonardo TUNESI**, Rapporteur: **Renato CHEMELLO**

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16:30-16:45	Discussion
16:45-17:15	***Pause-café***
17:15-18:15	**Session Posters**

18:15-19:15	*Evènement parallèle* **"The impacts of acidification on biodiversity and other key Mediterranean ecosystems"** par **Patrizia ZIVERI**

Jeudi 30 Octobre 2014

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11:30-11:45 Discussion

Session 5 : **Gestion des habitats coralligènes et autres bioconcrétions**
Président: **Ricardo AGUILAR**, Rapporteur: **Romain DAVID**

11:45-12:00 "**Remotely operated vehicles (ROVS) as powerful tools for the evaluation of the conservation status of deep red coral banks**" par **Giorgio BAVESTRELLO**, ABBIATI M., ANGIOLILLO M., BETTI F., BO M., CANESE S., CATTANEO-VIETTI R., CAU A., CORRIERO G., COSTANTINI F., GIUSTI M., PRIORI C., SALVATI E., SANDULLI R., SANTANGELO G., TUNESI L.

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13:00-14:00 **Déjeuner**

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14:30-14:45 Discussion

14:45-16:15 **Session Posters**

16:15-16:45 *Pause-café*

16:45-18:15 **Table Ronde**

"Protection of the Mediterranean coralligenous reefs: use of existing scientific knowledge & legislative framework to prevent further destruction of coralligenous habitats" par **Anastasia MILIOU**, SENNI D., TSIMPIDIS T., TRAGANOS. D.

18:15-18:45 **Remise du Prix du Meilleur Poster**

Jury: **Joaquim GARRABOU, Leonardo TUNESI, Giorgio BAVESTRELLO, Stéphane SARTORETTO** et **Ricardo AGUILAR,** Secrétaires: **Cyrine BOUAFIF** et **Habib LANGAR**

18:45-19:30 **Clôture du symposium**

20h00 **Dîner de Gala**

KEYNOTE CONFERENCE

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CONFERENCE INTRODUCTIVE

Jean-Pierre FERAL, ARVANITIDIS C., CHENUIL A., ÇINAR M.E., DAVID R., FREMAUX A., KOUTSOUBAS D., SARTORETTO S.
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CIGESMED: CORALLIGENOUS BASED INDICATORS TO EVALUATE AND MONITOR THE "GOOD ENVIRONMENTAL STATUS" OF THE MEDITERRANEAN COASTAL WATERS, A SEASERA PROJECT (WWW.CIGESMED.EU)

Abstract

Coralligenous is one the main shallow Mediterranean milieu generating structural complexity and biodiversity. It produces goods and services for several sectors. Pollution, anchors and trawling may cause its degradation, whilst traditional fishing as well as angling mainly affect target species. Diver frequentation is another cause of degradation. Coralligenous may also be susceptible to invasive alien species. These habitats, which are of great ecological, socio-economic and patrimonial importance, are also under the pressures caused by the global warming.

CIGESMED's (2013-2016) goal is to understand the links and consequences of natural and anthropogenic pressures to the functioning of these habitats and to define and maintain their Good Environmental Status (GES) in the Mediterranean Sea. Indexes, specific to coralligenous habitat, will be co-constructed and collectively tested by scientists, marine natural parks and reserves, through the implementation of a "citizen science" network. Among other methods, trees of knowledge will be experimented as tools to sort, organize and illustrate very large heterogeneous sets of data. CIGESMED outcome will be an integrative assessment of the GES within the Marine Strategy Framework Directive.

CIGESMED gathers scientists from France, Greece and Turkey, making it possible to access to sites and to work on the same issues in both the northwestern Mediterranean basin and the Aegean-Levantine one. Ten trained (scientific diving and ROV) laboratories of marine ecology are involved. A Committee of External Advisors (scientists, stakeholders and policy-makers), meeting at an annual basis, and aiming at providing advice on all aspects of the execution of the project is helping the scientific steering committee and is ensuring CIGESMED to meet its objectives.

Key-words: citizen science, coralligenous habitat; EraNet; indexes; large ecological data sets; Marine Strategy Framework Directive; monitoring; observable biodiversity; protocol; scientific diving; species list.

Framework

CIGESMED is a SeasEra project (EUFP7ERA-NET) *Towards Integrated Marine Research Strategy and Programmes* supported by the E.C. under Seasera's theme 3: *Development of indicators and science support and management tools for the determination of Good Environmental Status in the Mediterranean Sea*.

CIGESMED is a 3 years project launched on 3 different dates, depending on the national funding agencies: Greece, January 2013, 1st (GSRT), Turkey, February 2013, 1st (TÜBI-TAK), France, March 2013, 1st (ANR).

In spite it was already coined by Lamark (1801), the term "coralligenous", was firstly used [in its ecological meaning] by Marion (1883) to describe the so-called *broundo* along the coasts of Provence. He hypothesized that *Corallium rubrum* was indivisible from these hard biogenic bottoms. Presently, this term sets off debate, because the presence of red coral on this type of bottom is neither inevitable, nor exclusive. Because its physiognomic meaning, Boudouresque (1973) recommended to avoid it. Ballesteros (2006) suggested the use the term "coralligenous habitats" that best describes the different types of habitats covered by this umbrella term. This is the very meaning used in CIGESMED's framework.

In the current European context, coralligenous habitats are considered as habitats of "community interest" (Habitats Directive 92/43/CEE, code: 1170-14) and shortly promised to be promoted as "priority habitat". They are also considered as "high-value ecological zone" since the Barcelona Convention, which proposed, in 2008, a management plan for the coralligenous habitats. However, to-date there is no regulatory instrument for their protection.

In spite of this situation, the EU Marine Strategy Framework Directive (MSFD) requires that each state develops a strategy and an action plan in order to reach and maintain a "Good Environmental Status" [GES] for its marine habitats, assessed and monitored by means of 11 descriptors.

Many studies on coralligenous habitats have been published such as theses or reviews by Laubier (1966), Hong (1980), Ballesteros (2006) or Kružić (2014). The first symposium dedicated to coralligenous habitats took place quite recently (UNEP–MAP–RAC/SPA, 2009), to extend the Action Plan for the Conservation of Marine Vegetation did start (adopted in 1999 by the Barcelona Convention).

Coralligenous habitats are assemblages of complex habitats with very low dynamic of construction that is not well documented. These habitats are not only "hotspots" of biodiversity, but furthermore they represent socio-economic stakes. Activities such as small-scale fishing and scuba diving highly depend on them. Fishermen look for species of high commercial value such as red coral, crustaceans, rock fishes, and other kind of seafood. Divers look for the landscapes beauty, offered by coloured and erect species such as gorgonian corals, algae and bryozoans. Beyond these interests, other services provided by coralligenous habitats are suspected such as CO_2 sequestration (Martins et al., 2013, Noisette, 2013). They are threatened by the global change and anthropogenic pressures. Only a GES may guarantee the maintenance of all the services provided by coralligenous habitats.

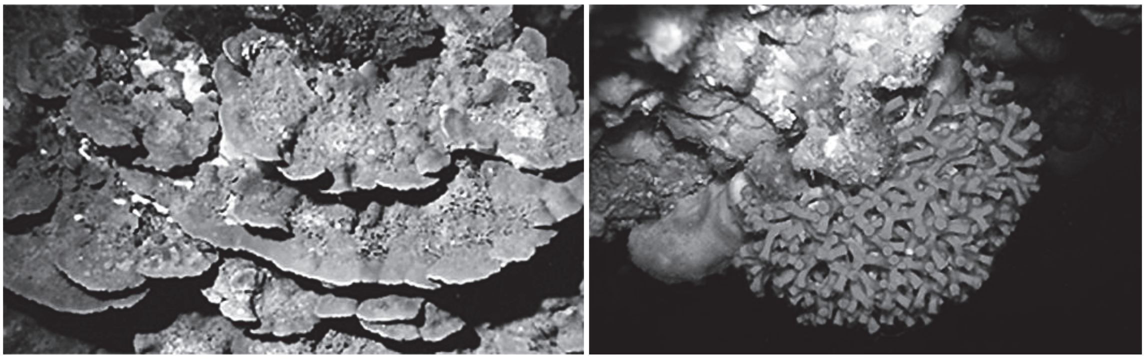
CIGESMED's objectives

There are pretty few programs and networks for the monitoring of coralligenous habitats. CIGESMED is one of them. It implies three countries[1] (France, Greece and Turkey) from 2013 to 2016. CIGESMED objectives are:

(1) to fulfil the key gaps in the current scientific knowledge of the coralligenous habitats that make it difficult to make recommendations for their protection, by developing barcoding to enhance reliable identification for conservation and protection purposes

[1] Only these 3 Mediterranean countries were eligible in the SeasEra's framework. This is the reason why no Italian, Spanish or any other partners were allowed to directly contribute to the project. However, distinguished members of these states do participate to the Committee of External Advisors, established by the project.

(engineer-, invasive- and cryptic- species), and by studying genetic structuring and effective dispersal potential of keystone/habitat species,
The main targets are algal builders (coralline algae and organisms such as bryozoans), eroders (mollusks, sponges …) and erect species (sponges, gorgonians…) [seascape makers]



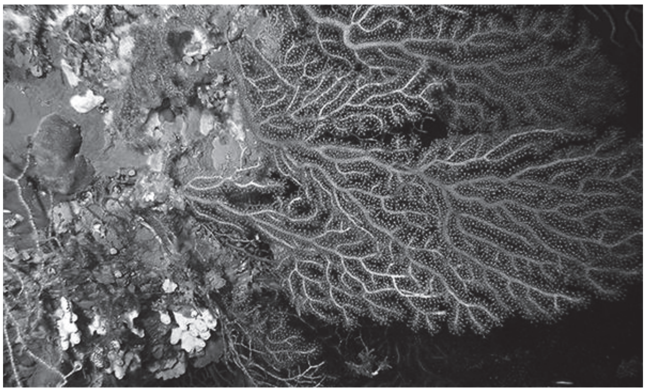
Coralligenous "builders" from Marseilles vicinity: the Rhodophyte* Lithophyllum cabiochae *(left) and the bryozoan* Myriapora truncata *(right)

(2) to enhance the knowledge on coralligenous populations by deciding on reference states, acquiring long temporal sets of observations/data, and setting up a network of Mediterranean experts (long term series).
To do so, CIGESMED was working to establish a list of species relevant to monitor different coralligenous habitat types (*cf. the article by Çinar et al., this volume*). The project also developed a protocol based on photoquadrats which will be validated in the different Mediterranean basins (*cf. the article by David et al., this volume*).

(3) to monitor networks, locally managed and to coordinate them on a regional scale, standardizing protocols that could be applied to the entire Mediterranean and testing indices and indicators, specific to coralligenous.
Assessment of the conservation state is done using IndexCor. It is made of 3 metrics based on (i) the number of sensitive species *vs*. number of indifferent species[2], (ii) the observable species richness, and (iii) a structural complexity index (*cf. article by Sartoretto et al., this volume*).
Other indices will be tested and compared (Checci & Piazzi 2010, Checci *et al*., 2014, Deter *et al*., 2012) as well as rapid visual assessment methods (Gatti *et al.,* 2012, Gatti & Sartoretto 2013, Kipson *et al.,* 2012).

(4) to test population genetic criteria as tools to monitor the GES of the coastal Mediterranean Sea. Target species are chosen among the builder species (coralline algae and the bryozoan *Myriapora*) as well as the seascape makers (*Paramuricea clavata* – see photo on the left).

[2] The terms "sensitive" and "indifferent" refer to a classification of species sensitivity to 4 impact types, assessed by experts: organic matter rate, hyper-sedimentation, physical deterioration and temperatures alteration.



(5) to implement a “citizen science” network to increase the number and frequency of observations, but also to allow observation networks created in the framework of CIGESMED to last and run beyond the end of the project, which is a difficult issue (Arvanitidis *et al.,* 2011).

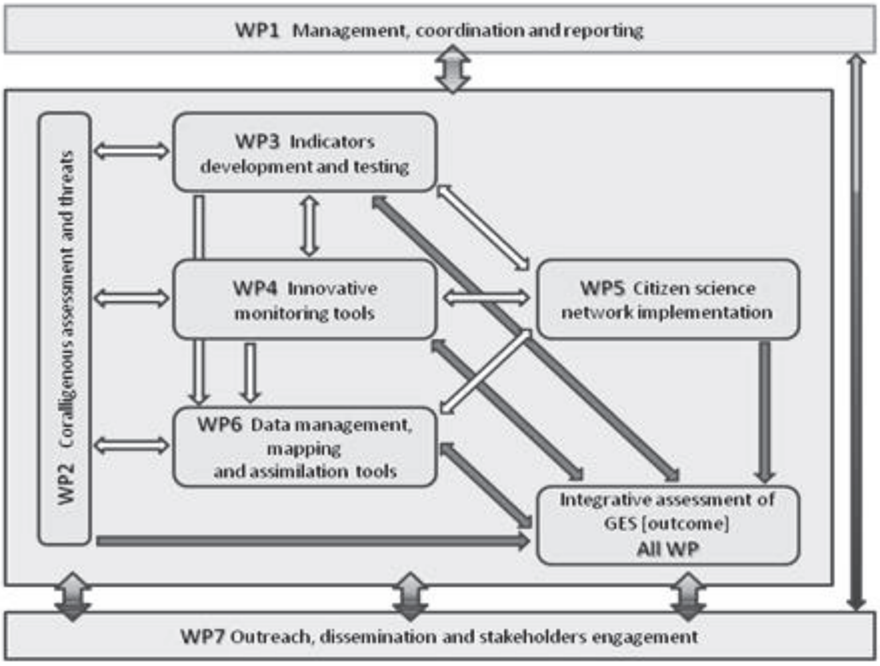
Citizen science will use open source plugin able of self-automatic installation on web site of members. The objective is not only to permit the qualibration of citizen data and include them in the CIGESMED information system, but also to improve methods and tools of implications of citizens allowing long-term observations and analyses. The interfaces are being developed in France (IMBE) and in Greece (HCMR).

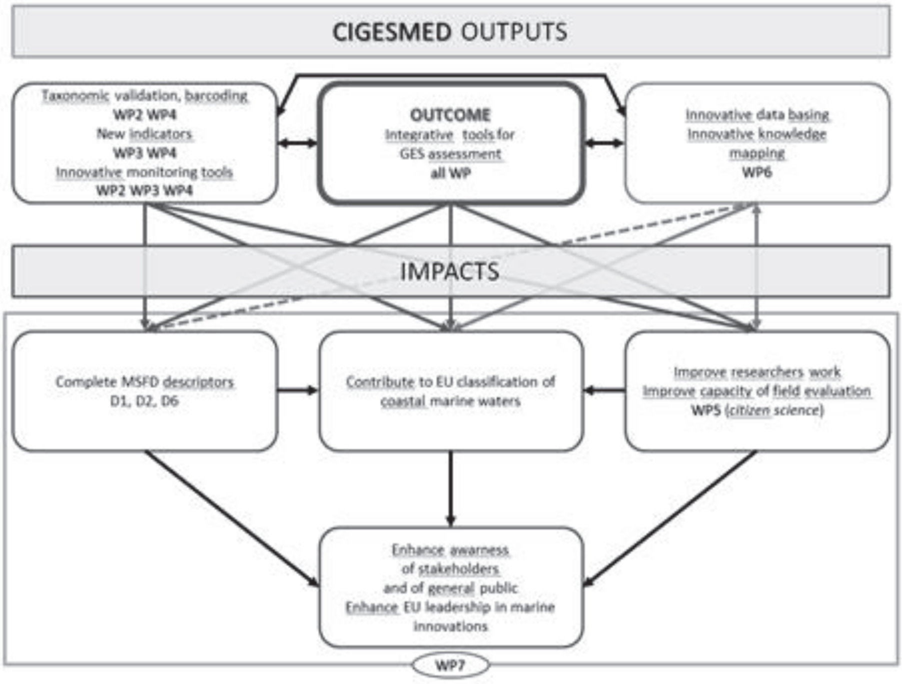
and (6) to create a data systems making data reusable and scalable with other observatory networks. The primary principle of CIGESMED data organisation is to adopt all accessible formats, and requirements (i) to use open access, open data, and open source software, (ii) to increase exchanges between national scientific communities about coralligenous studies, and (iii) to make sure that surveys and protocols are reusable (cost effective, security in dive and analytics methods, knowledge of managers). Indexations servers and programs are responsible to build graphs, and specific ontologies will permit to densify the links between the different objects describing habitats. The objective is to build representations of data, used to find correlation between discrete and non-ordinate values, and not only systems of metrics, usable by every stakeholders to build indicators. Among the different methods of representation CIGESMED is presently in testing the knowledge trees (Authier et Lévi 1992) as tools to sort, organize and illustrate the large heterogeneous sets of produced data and as a tool of dissemination towards scientists, decision makers, environmental managers and general public.

CIGESMED’s structure and organization

CIGESMED outcome will be an integrative assessment of the GES within the Marine Strategy Framework Directive.

To make it possible, CIGESMED gathers scientists from France, Greece and Turkey, making it possible to access to sites and to work on the same issues in both the north-western Mediterranean basin and the Aegean-Levantine one. Ten laboratories of marine ecology are involved.





The Steering Committee consisting of the representatives of the parties (WP leaders) and the coordinator are responsible for all practical decision making, strategic planning and implementation.

A Committee of External Advisors (scientists, stake-holders and policy-makers) will meet at an annual basis, and aims at providing advice on all aspects of the execution of the project to ensure CIGESMED to meet its objectives.

Acknowledgements
We are grateful to the organizers for giving us the opportunity to present the CIGESMED program during one of the plenary sessions of the 2nd Mediterranean symposium on Coralligenous and other calcareous bio-concretions.
This paper also involved the participants to the project: Açik Çinar S., Andral B., Aurelle D., Aysel V., Bakir K., Bellan G., Bellan-Santini D., Bouchoucha M., Bricout R., Celik C., Chatzigeorgiou G., Chatzinikolaou E., Chenesseau S., Daǧli E., Dailianis T., Dimitriadis C., D'Iribarne C., Doǧan A., Dounas C., Dubois S., Egea E., Elguerabi W., Emery E., Erga Z., Evcen A., Faulwetter S., Gatti G., Gerovasileiou V., Güçver S.M., Guillemain D., Issaris Y., Kataǧan T., Keklikoglou K., Kirkim F., Koçak F., Koutsoubas D., Marschal C., Önen M., Önen S., Öztürk B., Panayiotidis P., Panteri E., Pavloudi C., Pergent G., Pergent-Martini C., Poursanidis D., Ravel C., Reizopoulou S., Rocher C., Ruiton S., Sahker S., Salomidi M., Sarropoulou E., Selva M., Sini M., Sourbes L., Simboura N., Taşkin E., Thierry de Ville d'Avray L., Vacelet J., Valavanis V., Vasileiadou A., Verlaque M, Zuberer F.
Works are supported by: France - CNRS - ANR convention n°12-SEAS-0001–01 / LIGAMEN - ANR convention n°12-SEAS-0001-02 / IFREMER - ANR convention n°12-SEAS-0001-03, Greece - GSRT 12SEAS-2-C2, Turkey - Tübitak contract n°112Y393.

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ORAL COMMUNICATIONS

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COMMUNICATIONS ORALES

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GENETIC CONNECTIVITY AND CONSERVATION IN THE LONG-LIVED, HARVESTED SPECIES *CORALLIUM RUBRUM*

Abstract
Corallium rubrum is among the most valuable marine living resources and it has been harvested since thousands of years for the use of its calcareous skeleton in jewelry, traditional medicine, and tribal rituals. Overexploitation of the commercial banks led to depletion of the resource and decline of harvesting yields. In this study knowledge on genetic connectivity in C. rubrum populations is summarized, and application of genetic data to stock delineation, to a sound management policy and conservation strategies are discussed. Strong genetic structuring (including IBD patterns at regional scale) was revealed by microsatellite loci in shallow water populations of C. rubrum at Mediterranean scale; chaotic structuring was detected when downscaling the studies to very small spatial distances and along depth gradients. A boundary in the genetic structure of red coral populations was located across 40-50 m in depth. These results provide a clear evidence of limited connectivity, and suggest that deep coral bank cannot act as refugia for shallow water populations, nor the reverse. Mitochondrial markers revealed unexpected phylogeographic patterns of structuring in deep-water populations, in contrast with shallow water ones. Red coral resources in the Mediterranean Sea consist of an array of metapopulations structured both geographically and in depth, each of which have to be considered as an evolutionary/management units. Therefore, management of the harvesting grounds has to be planned at a local scale, considering each bank as a self-recruiting population. Conservation of the resources requires the implementation of the Mediterranean Regional Management Plan, preservation of deep coral backs accessible only to ROV fishing, creation of networks of no take zones, both in shallow and in the deep sea.

Key-words: Precious corals; Sustainable exploitation; Conservation; Population genetics; Metapopulation

Introduction
Several species belonging to the family Corallidae have been harvested since millennia for the use in jewellery, traditional medicine, and tribal rituals. They are among the most valuable marine living resources (Tsounis *et al.,* 2013). The most intensively harvested Corallidae species are *C. rubrum* (Linneo, 1758), endemic in the Mediterranean Sea and neighbouring Atlantic coasts living at a depth ranging from 10 to 800 m; *C. secundum*, *C. elatius*, *C. konojoi*, *Corallium* sp. and *Paracorallium japonicum*, found at greater depth (400-1500 m) in the Northern Pacific Ocean (Bruckner, 2014).
Red coral fishery in the Mediterranean followed the boom and bust cycles of newly discovered banks, leading to the overexploitation of the resource. In the 1950s SCUBA harvesting was introduced and nowadays is the only legal harvesting method in the Mediterranean Sea. SCUBA/mixed gas diving harvesting is a selective but very effective method and lead to the exhaustion in the first instance of the shallow banks (30-40 m deep), later of the deeper banks (to about 130 m depth). Despite the broadening of the

harvesting depth range, landings declined over the last decades and only rose after the widening of the harvesting geographic area (Fig. 1). Major concern has been expressed about possible extinction or exhaustion of this fragile resource (Santangelo & Abbiati, 2001; Tsounis *et al*., 2013). A debate on conservation strategies, contrasting harvesting management versus trade control (Chang *et al*., 2013), was raised by GFCM and CITES, and involved fishermen, traders, industry, scientists and conservationists.

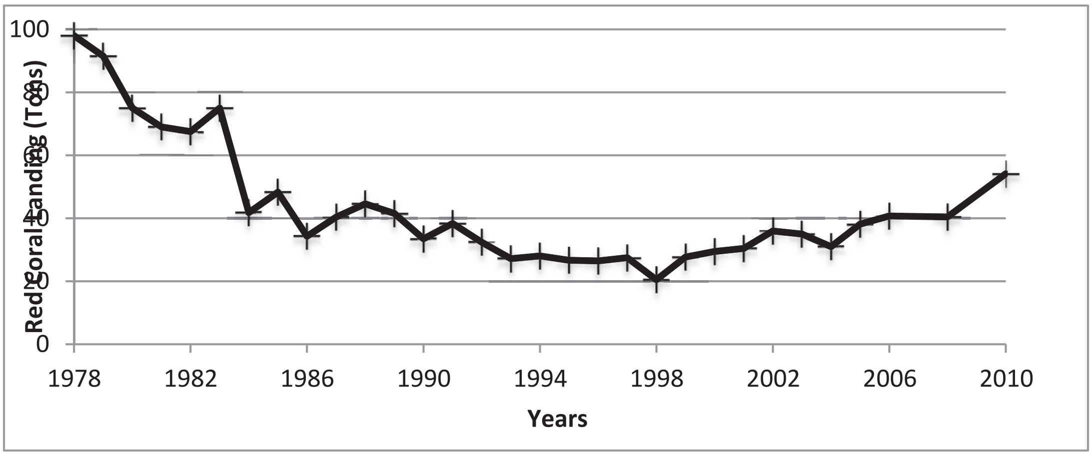

Fig. 1: Mediterranean red coral landing data (Source GFCM- FAO).

Among the major difficulties encountered in defining strategies for the conservation of the species was the lack of knowledge on biology, ecology, connectivity among populations in deep water, and of estimates of the deep stocks. In recent years, the number of scientific publication on Corallidae greatly expanded (Fig. 2), particularly concerning the Mediterranean red coral: the most shallow and accessible species. Studies on reproductive biology, feeding, distribution, population dynamics as well as manipulative experiments on processes driving the ecology of the species in shallow water have been done. A bulk of studies was also addressing the population genetic structure of the species in different habitats, ad different geographical scales, and depth ranges. To be able to estimate recovery capability of the species, however, an accurate estimate of the effective larval dispersal and of the potential for re-colonisation of exhausted areas is needed.

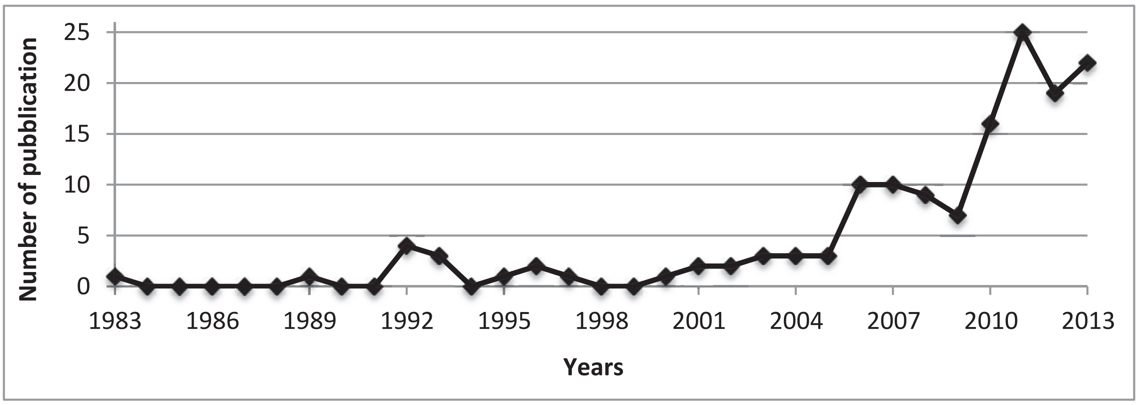

Fig. 2: Number of publication on Corallidae in international scientific journals (Source ISI Web of Science).

In this study knowledge on population genetics of the precious coral *Corallium rubrum* is summarised, with a focus on information relevant to the management of the resource. Indirect estimates of larval dispersal and connectivity useful for the stock delineation, and for the conservation strategy of the species are discussed.

Genetic structure of *Corallium rubrum*

The first studies on the genetic structure of *Corallium rubrum* have been dealing with phylogeographic patterns in populations down to 50 m depth in N-W Mediterranean (Abbiati *et al*., 1993; Costantini *et al.,* 2007a; Ledoux *et al*., 2010b; Aurelle *et al*., 2011). Nuclear DNA dispersal in red coral is limited, suggesting that overexploitation may lead to local extinction of the population, and recovery may be unlikely.

Subsequent studies have been downscaling the investigated scales to identify the genetic patch size in red coral shallow water populations. Costantini *et al*., (2007b) used a structured sampling design to test local scale differentiation and found strong genetic structuring at the smallest investigated scale: 10m (Fig. 3B). A fine- scale study, analysing genetic structure between patches at 1 m distance, was done in San Fruttuoso (Genova, Italy) and strong genetic structuring was found. Spatial autocorrelation indicated that neighbouring colonies are the most genetically similar and that the larvae tend to settle within a patch of about one meter (Fig. 3C; Costantini *et al.,* unpub. data).

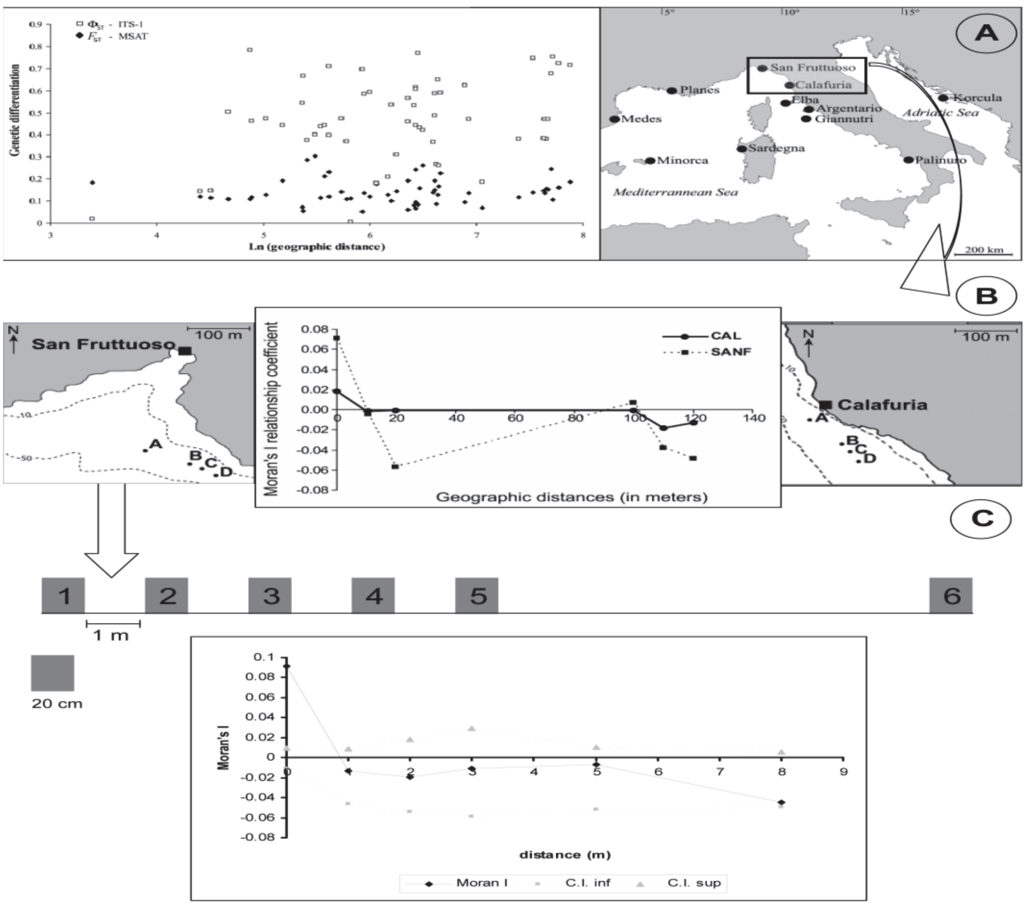

Fig. 3: Summary of the major findings on spatial genetic structuring in *Corallium rubrum* Sources (Costantini *et al.,* 2007a, 2007b; Ledoux *et al.,* 2010a; Costantini *et al.,* unpub. data).

Similar fine-scale patterns were also found analyzing populations in the Gulf of Lion (Ledoux *et al.,* 2010a ; Aurelle & Ledoux 2013).
Empirical evidence of small size of genetic patches along geographic gradients raised the question about vertical patterns of genetic structuring in red coral. Would red coral show a patch size of meters also along vertical gradients? This question has been addressed by Costantini *et al.,* (2011), were genetic structuring from 20 to 70 m depth was investigated in 2 locations in the Western Mediterranean. In both locations, strong patterns of genetic structuring among samples were found. Consistent reduction in genetic variability along the depth gradient was also observed, with a threshold across 40–50 m depth, supporting the hypothesis of isolation between shallow- and deep-water red coral populations. Knowledge on genetic structuring in deep water red coral populations (below the critical threshold of 50m depth) could provide evidence of the occurrence of isolated shallow- and deep-water red coral stocks. The analyses of the red coral colonies collected below 600m depth (Costantini *et al.,* 2010) supports this hypothesis. ITS-1 and mtMSH sequences found, differed from those of shallow water colonies, supporting the occurrence of genetic isolation between shallow- and deep-water populations. Furthermore, Costantini *et al.,* (2013) investigated genetic spatial structuring of *Corallium rubrum* populations between 58 and 118 m depth in the Tyrrhenian Sea. High spatial genetic structuring was observed, suggesting that populations are likely to be isolated. Moreover, mitochondrial markers revealed significant genetic structuring at spatial scales greater than 100 km, suggesting the occurrence in deep-water populations of a geographic structuring that was not found in shallow-water populations (Fig. 4).

Discussion and conclusions

The analysis of the genetic patterns of red coral populations in the North-Western Mediterranean Sea revealed: 1) strong genetic structuring at Mediterranean scale with IBD patterns in the North Western regions; 2) strong genetic divergence at fine (meters) geographic and bathymetric scales; 3) genetic isolation and differences in evolutionary patterns between shallow- and deep-water populations.
Genetic data support the assumption that population are ‘closed’ (relevant to the population dynamic studies), and that the effective larval dispersal in this species is limited to very short distances. This information shades a new light on the management needs, and on the limited resilience of despoiled red coral banks. Several workshops have been held on management of red coral, aiming to define a sustainable exploitation of the resource. GFCM (2014) successfully promoted the definition of a Regional Management Plan for the Mediterranean Sea. However, experimental data show that *Corallium rubrum* is a slow growing species, with a patchy distribution, low recruitment rates and limited larval dispersal. These biological and ecological features suggest that red coral cannot be managed sustainably. Red coral is not a species at risk of biological extinction thanks to the abundance of small sized, crowded shallow water populations (Santangelo & Abbiati, 2001), but the history of Mediterranean red coral fishery show that economic extinction is likely. Since ever harvesting has been booming at the discovery of new banks and collapsed as soon as the bank was exhausted.
There are evidences that banks that have been exhausted in the ’50 by the first SCUBA harvesters to date did not recover. Recently, red coral harvesting has been mainly supported by the discovery of new banks (nowadays mainly along the coast of North Africa), and by broadening the harvesting depth to the limits of the human physiology (about 130m) using mixed gas diving.

Currently a major pressure is made by the harvesters and traders to adopt the use Remotely Operated Vehicles to access pristine banks below 130 m depth. Genetic data already provided a strong scientific basis for the recommendation made by GFCM (2011) to ban *Corallium rubrum* harvesting down to 50 m depth.

Recent data showed that genetic diversity of red coral over its actual range of depth distribution is shaped by complex interactions among geological, historical, biological and ecological processes, and mitochondrial and rDNA haplotypes of deep populations.

Currently a major pressure is made by the harvesters and traders to adopt the use Remotely Operated Vehicles to access pristine banks below 130m depth. Genetic data already provided a strong scientific basis for the recommendation made by GFCM (2011) to ban *Corallium rubrum* harvesting down to 50 m depth.

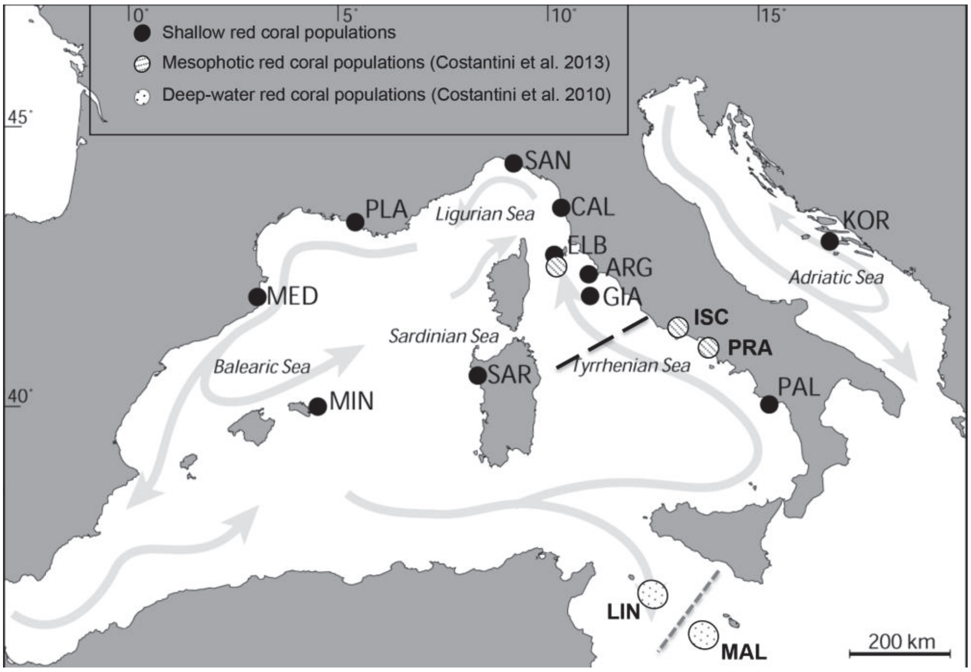

Fig. 4: Patterns of spatial genetic structuring in *Corallium rubrum* populations at different depth. The dashed lines indicate the main genetic boundaries in mesophotic and deep-populations

Recent data showed that genetic diversity of red coral over its actual range of depth distribution is shaped by complex interactions among geological, historical, biological and ecological processes, and mitochondrial and rDNA haplotypes of deep populations contribute to the genetic diversity of the species. These findings provide a scientific support for the conservation of the pristine deep red coral banks, and against the use of ROV for the harvesting, unless strict roles on fishing efforts will be effectively enforced. Moreover, to preserve the diversity of the species, establishment of networks of marine protected areas in the deep sea and on off-shore reefs is needed. Creation of MPA in deep red coral banks is recommended as a precautionary conservation tool. The use of red coral as a "flag species" could be also beneficial to promote the conservation of coralligenous reefs: a reservoir of Mediterranean Marine Biodiversity.

Acknowledgments

This study has been funded by grants from the Italian Ministry of Environment; Italian Ministry of Agriculture, Food and Forestry; Italian Ministry of Education, Universities and Research.

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REMOTELY OPERATED VEHICLES (ROVS) AS POWERFUL TOOLS FOR THE EVALUATION OF THE CONSERVATION STATUS OF DEEP RED CORAL BANKS

Abstract
The management of the red coral, Corallium rubrum (L.), is an international issue still lacking of an effective solution in the Mediterranean Sea. The main goal of this research was the evaluation of the ROV efficiency as a monitoring non-destructive tool in studies concerning the conservation status of the deep red coral populations (living under 50 m depth). Both Ligurian Sea and Tuscan Archipelago are considered among the most important Italian historical sites of the red coral professional harvesting. Fishing effort in these areas is now decreased (in Liguria is virtually ceased) due to the drastic reduction of colonies of commercial size and thanks to conservation laws. Today, the protection of this natural resource has been directed mainly to coastal, shallow-water populations (living between 20 and 40 m depth), while the deeper banks, the main target of professional harvesting by technical scuba divers, still need dedicated management plans. ROV explorations allowed the identification of several deep red coral banks: in the Ligurian Sea, 6 out of 12 explored sites (50%) and in the Tuscan Archipelago, 7 out of 13 explored sites (50%). The banks may be considered almost "pristine" only around Montecristo Island. In the Ligurian Sea, the only deep population in a good conservation status is that of the Maledetti Shoal, off the Bergeggi Island MPA.

Key-words: Mediterranean red coral; ROV-Imaging; management; conservation.

Introduction

The management of the red coral, *Corallium rubrum* (L.), a valuable and endangered Mediterranean resource, is an international unsolved issue, despite this species has been listed in the annexes of the EU Habitat Directive and in Bern and Barcelona Conventions. In 2010, the CITES (Convention on International Trade in Endangered Species) rejected the US proposal of including red coral in the list of species subjected to a controlled trade (Bussoletti *et al.,* 2010). One of the main reasons leading to this decision was the lack of knowledge on the real state of conservation of the deep coral banks affected by fishing. In fact, despite available sound data on the Mediterranean coastal populations (Cicogna & Cattaneo-Vietti, 1993; Santangelo & Abbiati, 2001; Santangelo & Bramanti 2010; Tsounis *et al*., 2010; Cattaneo-Vietti & Bavestrello, 2010; Bramanti *et al*., 2014; Bavestrello *et al*., 2014), very little knowledge is available on the deep banks (Rossi *et al*., 2008; Priori *et al.* 2013). Moreover, it is virtually impossible to define the structure of pristine populations, in terms of density and biomass of the colonies, due to the fact that the only few studied banks have been exploited for decades (Tsounis *et al*., 2010).
Remotely Operated Vehicles (ROVs) could be a good scientific tool to explore new banks and to evaluate the state of conservation of the exploited ones in the Mediterranean Sea; however, their efficiency has never been tested before in this basin.

In Japan, ROVs are used to harvest several coral species (e.g. *Corallium elatius* and *Paracorallium japonicum*) (Iwasaki *et al*., 2012), while in the Mediterranean Sea, the use of ROV is allowed only for prospection, as the harvesting is permitted only through professional SCUBA diving.
The main goal of this work was to evaluate the ROV efficiency as a monitoring tool to study, in a non-destructive way, the demography and conservation status of deep red coral populations in two critical Mediterranean areas (Ligurian Sea and Tuscan Archipelago in the northern Tyrrhenian Sea).
Moreover, a general descriptive survey of the biocoenoses associated to the red coral inside the deep circalittoral zone, a largely unknown habitat, has been carried out. An exhaustive picture of this habitat would in fact represent a crucial element to define the real health status of these deep ecosystems and their natural resources, and would help defining the best management strategies.

Materials and Methods

The explorations were performed in 2012 on board the R/V *Astrea* (ISPRA). The ROV "Pollux II" was equipped with a digital camera (Nikon D80, 10 megapixels), a strobe (Nikon SB 400), a high definition video camera (Sony HDR-HC7), and 3 jaw grabbers. The ROV hosted also a depth sensor, a compass, and three parallel laser beams providing a 10-cm scale for the measurement of the frames area and size of organisms. The ROV was also equipped with a USBL (Ultra Short Base Line) underwater acoustic positioning system, providing every second the ROV geographic position.
A total of 12 Ligurian and 13 Tuscan localities were explored between 40 and 230 m depth (Tab. 1). For each ROV track, randomly subdivided in frames, coral occupancy (% occurrence of coral colonies in the frames), the average colony density (number of colonies for m^2) and the size range of the colonies (height and basal diameter) were obtained. Moreover, the fishing impact on the deep assemblages was assessed in terms of occurrence of lost gears in the frames.

Results

<u>Red coral populations</u>

In the Ligurian Sea, the deep banks, all living on rocky walls, appeared severely fragmented, with low average densities. .
In the eastern Ligurian Sea, along the Portofino Promontory, an area hosting well-known shallow red coral populations (Cattaneo-Vietti & Bavestrello, 2010; Bramanti *et al*., 2014; Bavestrello *et al*., 2014), only two deep banks (Punta del Faro and Isuela Shoals) were found. The red coral density at Isuela is 97 ± 34 m^{-2}, with basal diameters ranging between 0.5-0.7 cm.
In the western Ligurian Sea, red coral colonies were found in the deepest recorded for the whole Ligurian Sea (90-100 m depth) and the largest population was found close to Bergeggi Island (the Maledetti Shoal), at about 70 m depth, with patches reached reaching a density of 200-300 colonies m^{-2} and 0.8±0.5 cm of basal diameter.
In the westernmost part of the Ligurian coast (Canyons of Lua and Arma di Taggia), coral populations were characterised by very low densities (less than 0.1 colonies m^{-2}) and small size (average basal diameter 0.3±0.1 cm), with the only significant exception of the Bordighera Canyon bank where densities reached around 35±16 colonies m^{-2}.

Tab. 1: List of the Ligurian and Tuscan shoals explored between 40 and 230 m depth by ROV. For each shoal, data on coral occupancy, average density, size of the colonies are reported as well as the fishing impact, measured in terms of percentage occurrence of lost gears in the evaluated frames.

Locality	Depth range (m)	Occupancy (%)	Density (col m^{-2})	Height (cm)	Basal diameter (cm)	Fishing impact (%)
Liguria						
St. Lucia Bank	140-200	0	-	-	-	18
Punta del Faro	50-100	5.6	41 ± 12	5.8 ± 2.5	0.5 ± 0.3	24
St. Giorgio Sh.	85-95	0	-	-	-	29
Isuela Shoal	40-60	15.2	97 ± 34	7.5 ± 5	0.7 ± 0.2	20
Mantice Sh.	80-150	0	-	-	-	38
Corallone Sh.	60-110	0				53
Maledetti Sh.	60-90		278 ± 12	7 ± 2.1	0.8 ± 0.5	28
Canyon Lua	90-140	3.4	0.1	2.5 ± 1.8		49
Vedove Shoal	100-230	0	-	-	-	65
Taggia Arma	90-160	0.2	0.03	3.2 ± 1.5	0.3 ± 0.1	51
Bordighera	60-80	21.0	35 ± 16	5.1 ± 2.2	0.6 ± 0.3	57
Besughi Sh.	120-200	0	-	-	-	46
Tuscany						
Capo Bianco	80-105	0.0	-	-	-	18.6
North Pianosa Is.	70-80	36.8	48 ± 23	3.9 ± 1.6	0.6 ± 0.1	3.9
Pomonte Sh.	70-110	16.9	-	-	-	3.0
Filone Sh.	85-95	0.0	-	-	-	1.5
Punta Fetovaia	65-80	0.0	-	-	-	11.7
Coniglio Sh.	100-120	0.0	-	-	-	0.0
Sante Shoal	75-95	31.2	21 ± 16	4.8 ± 2.2	0.7 ± 0.2	3.1
Montecristo Sh.	60-100	60.7	72 ± 47	7.3 ± 4.0	0.8 ± 0.3	0.0
Bancotto	110-120	0.0	-	-	-	2.3
Panozzo	145-200	0.0	-	-	-	4.4
Tuna Paradise	80-100	24.3	41 ± 30	4.0 ± 2.0	0.7 ± 0.3	7.9
Montecristo W	100-190	19.8	-	-	-	1.3
Cassaforte Sh.	130-170	1.1	-	-	-	1.1

In the Tuscan Archipelago, red coral banks were found at a depth ranging between 60 and 120 m. The richest population was found at Montecristo Island, an area subjected to a long lasting protection (about 30 years); it survived to the "ingegno" fishing, operating in the area until the 70's. Here, red coral colonies showed the largest heights (on average 7.3±4.0 cm; maximum value: 18.4 cm; average basal diameter 0.8±0.3 maximum value 1.9 cm) and a medium density (72±47 colonies m^{-2}, maximum value: 228 colonies m^{-2}). In this area, only in other two localities (Sante and Tuna Paradise Shoals) red coral was present showing low density values (21±16 colonies m^{-2} and 41.0±30.0 colonies m^{-2}, respectively), and morphometric values of 4.8±2.2 cm in height and 0.7 cm in basal diameter. In the other explored banks, red coral was present, but colonies showed a smaller size and lower densities.

Around Elba and Pianosa no red coral populations were found during the surveys carried out during this research, however several red coral patches have been recently found in other sites of this area (Santangelo *et al.*, 2012; Priori *et al.*, 2013). The small population at the North of Pianosa, with densities of 48±23 colonies m^{-2}, represents the only red coral population found in the northernmost part of the Tuscan Archipelago during this survey. Here, red coral colonies are located on the edge of boulders placed on a plateau formed by sand and sediments at 70-75 m depth. The colonies showed a small size, reaching 7.1 cm in height (on average, 3.9 ± 1.6 cm) and 0.6 cm of basal diameter.

Deep communities and fishing impact

The Ligurian deep coralligenous communities (40 -230 m depth) accounted for 14 structuring anthozoan species. The gorgonians *Eunicella cavolinii* and *Paramuricea clavata* were dominant from the Portofino Promontory to the sites around Savona. In the westernmost areas of the Ligurian basin, the dominant species recorded were black corals (mainly *Antipathella subpinnata* and *Parantipathes larix)*, the gorgonian *Eunicella verrucosa* and the scleractinian *Dendrophyllia cornigera*. This latter species was particularly abundant in relatively shallow waters (about 80 m depth) only in the western Ligurian basin (Mantice Shoal). This species here is found at the northernmost range known for the Mediterranean Sea.

On the whole, all the visited sites showed a huge impact due to lost fishing gears, with a higher occurrence of lines and trammel nets, often entangling directly in the coral colonies: the 39,8% of the evaluated frames, in fact, showed traces of impact.

On the contrary, the Tuscan shoals appeared much less impacted (only the 4.5% of the frames showed lost fishing gears) and the deep circalittoral communities associated to the red coral showed a good conservation status and a high specific richness of some structuring anthozoans for a total of 17 species (*D. cornigera, Leptogorgia sarmentosa, P. clavata, P. macrospina, E. cavolinii, E. verrucosa, Acanthogorgia hirsuta, Callogorgia verticillata, Villogorgia bebrycoides, Bebryce mollis, Viminella flagellum, Savalia savaglia, A. subpinnata, P. larix, Leiopathes glaberrima, Antipathes dichotoma*).

Conclusion

The ROV investigations carried out in this study revealed different situations concerning deep red coral populations among the explored sites.

In Liguria, red coral banks suffered a heavy pluri-centennial harvesting and today it is hard to quantify the original structure of pristine populations. However, thanks to a long-term comparative analysis over 50 years, it was possible to state that, while shallow water populations protected for over two decades show initial signs of recovery (Bavestrello *et al*., 2014), the deeper ones appear close to extinction. In the western Ligurian banks, down to 230 m depth, red coral was not found or was very rare, and all banks were strongly impacted by fishing gears (Bo *et al*., 2014). Red coral paucity is particularly relevant as this area was an historical fishing ground since the XVII century. Today, red coral almost disappeared, likely due to an increasing of the silting levels that could prevent larval settlement in a species characterised by a limited larval dispersal (Costantini *et al*., 2011; 2013), and to the continuous fishing activities (not necessarily linked to the coral harvesting). Only the coastal populations along the Portofino Promontory and the deep bank of Maledetti, close Bergeggi Island, showed high population densities.

On the contrary, in the Tuscan Archipelago, the deep red coral populations seem to be subjected to a lower human impact, with a reduced damage to the coral colonies. These deep banks represent well-preserved habitat, sometimes characterized by a high density and a large colony size.

Today, the survived banks in the two studied areas are partially protected within MPAs (Portofino and Bergeggi in the Ligurian Sea, Pianosa and Montecristo in the Tuscan Archipelago). The importance of the Maledetti Shoal recently induced the Bergeggi

Municipality (managing the Bergeggi Island Site of Community Interest - SCI) propose the enlargement of the existing SCI to include this bank as “rocky reef” habitat.
So far, this represents a unique example for the Italian territory.
This large-scale survey represents the first Italian effort in the characterisation of deep red coral banks. ROV proved to be a very effective tool to study, with a non-destructive approach, their conservation status. In particular, through the analysis of the video footages, it is possible to gather a fair amount of data on coral occupancy, density, size of the colonies, and environmental characteristics as well as the damages caused by anthropogenic activities. ROV sampling revealed also some limits: as far it allows obtaining good data on occupancy and density of the colonies, on the other hand, the data regarding the colony diameter measurements results to be less reliable (Priori *et al.*, 2013). Such a limit may potentially have practical consequences for the conservation of the species. In fact, recently, coral fishermen asked the permission to use ROV to evaluate colony size in view of a direct harvesting. The potential overestimation of diameter might allow the collection of undersized colonies.
Finally, this survey has also highlighted the extraordinary and unexpected richness of several mesophotic communities, mainly dominated by anthozoans, which need to be protected. The institution, also in deeper environments, of managed areas (MPAs, SCIs) to preserve these biocoenoses is, therefore, highly recommended as well as the monitoring of these structural, but fragile habitats, also considering the standards required by the Marine Strategy Framework Directive for the near future (Tunesi *et al.,* 2013).

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CARTOGRAPHY OF MAIN COASTAL ECOSYSTEMS (CORALLIGNENOUS AND RHODOLITH BEDS) ALONG THE CORSICAN COASTS

Abstract
In the Mediterranean Sea, the improvement of knowledge on bio-concretion (bioconstructing) assemblages (coralligenous and rhodoliths beds) and particularly their distribution, is one of the priority actions identified in the Action Plan for the conservation of coralligenous and other bioconstructions in the Mediterranean. The various studies available show relatively recent and uneven knowledge across the basin regarding the distribution of coralligenous bioconstructions and very specific information about the distribution of rhodolith beds. In addition, while the methods for mapping infralittoral communities are now well mastered and standardized, methods and tools of investigation on settlements located at greater depths still require further development.
A mapping program of the main assemblages and bottom types between 0 and 100 m depth has been carried out since 2010 on part of the coast of Corsica (e.g. Cap Corse, Bouches de Bonifacio). The mapped areas cover a 780 km^2 area of Cap Corse and 387 km^2 area of Bouches de Bonifacio. The available results show the significant distribution of rhodolith beds and the frequency of hard substrates, hosting coralligenous bioconstructions in the area of Cap Corse. On the contrary the area of Bonifacio would appear to be characterized by great richness in coralligenous bioconstructions but over a smaller area with regard to the rhodolith beds surface area. These results represent a significant contribution to the knowledge of the distribution of these assemblages in relation to the extent of the area occupied by the rhodolith beds in particular, and showed the importance of these two areas for conservation.

Key-words: Mediterranean Sea, Cartography, Side scan sonar, Multibeam echosounder, Coralligenous, Rhodolith.

Introduction
In the Mediterranean, localization and mapping of the coralligenous and other calcareous bio-concretions are priority actions, identified in the Action Plan for the conservation of the coralligenous and other calcareous bio-concretions (bioconstructing) in the Mediterranean sea, (UNEP-MAP-RAC/SPA, 2008), adopted by the Contracting Parties of the Barcelona Convention.
These assemblages form the basis of the Mediterranean specific richness (Bellan-Santini *et al*., 1994; Relini, 2009) and are particularly important because of their extensive distribution, structural complexity, species diversity, role in energy flux and carbon cycle, and economic value (Bianchi & Morri, 2000; Ballesteros, 2006; Martin *et al.,* 2013b). The coralligenous assemblages create typical Mediterranean underwater seascapes, based on algal frameworks (Corallinaceae) that grow in dimly lit, relatively calm waters (Ballesteros, 2006). Mediterranean rhodoliths beds are constituted by free-living calcareous algae (Corallinaceae or Peyssonneliaceae), living on sedimentary bottoms (infralittoral and circalittoral); they are developed under dim light conditions and high level of current (UNEP-MAP-RAC/SPA, 2008).

Recent studies provide uneven information concerning the distribution of coralligenous and rhodolith beds. A preliminary study (UNEP-MAP-RAC/SPA, 2009) shows a substantial lack of relevant geospatial data with only fifty maps identified across the western basin. Most available data are based on a limited number of studies with scattered quantitative data, limited spatial range, on presence/absence data at a very low spatial resolution (Giakoumi *et al.,* 2013). Currently, there is only information on approximately 30 % of the Mediterranean coast. Data are unevenly distributed, essentially because the majority of systematic studies have taken place in the western Mediterranean (Martin *et al.,* 2014).
A mapping program of the main assemblages and bottom types, between 0 and 100 m depth and incursions to 150 m depth, has been carried out since 2010 on parts of the coast of Corsica (*e.g*. Cap Corse, Bouches de Bonifacio).

Materials and methods

Cap Corse, located in the north of Corsica (France, Mediterranean), corresponds to a relatively well-preserved coastline; Bouches de Bonifacio located in the south of Corsica corresponds to the area of the French-Italian Parc Marin International des Bouches de Bonifacio (International Marine Park). A small area called "Asinara" located to the southwest of the Marine Park has also been mapped.
The mapping of the main benthic assemblages and bottom-types between 0 and 150 m depth was carried out between July 2010 and May 2014.
In the Cap Corse area, the shallow waters (from 0 to -15 m) were mapped using complete photographic coverage (146 color aerial photographs at 1/5 000th, from the BD ORTHO® 2007 of National Geographic Institute) and with a resolution of 0.5 m. Image processing was applied to each photograph using Envi 4.4® software following the method of Pasqualini *et al.* (1998).
The deeper zone (-15 to -150 m) was mapped using exhaustive acoustic coverage (coupling a multibeam echosounder EM 1000™ and a side-scan sonar Klein 3000™). These data were acquired during three oceanographic cruises (Capcoral 1, Capcoral 2 and Coralcorse) during the summers of 2010, 2011 and 2013 and were processed with the Caraibes 3.8® software program. A digital Terrain Model (DTM) and a mosaic (resolution of 0.5 m) were developed.
More than 800 field data (bathyscope and scuba-diving observations, Remote Operated Vehicle images, grabs) provided a basis for validating the interpretation of aerial photographs and the mosaic of the sonograms.
All the data were gathered into a Geographic Information System (GIS; ArcGis 10®; projection Mercator-WGS84).
The identification of the main assemblages and bottom-types is based on work at Mediterranean level, on the basis of the classification of Péres & Picard (1964) and their description (Bellan-Santini *et al.,* 2002), following the typology of Michez *et al.* (2011).
If the treatment of aerial photographs and sonograms allows to obtain the production of a map of biocoenoses and associations, it is necessary to evaluate the reliability of these maps. It was assessed using different scales (Pasqualini, 1997; Pasqualini *et al.,* 1998; MESH, 2008).

Results

The mapped areas cover a 780 km^2 area of Cap Corse between 0 and 150 m depth (Fig.1) and a 387 km^2 area of Bouches de Bonifacio between 20 and 100 m depth (Fig. 2 and 3). The map of the main biocoenoses and associations of Cap Corse shows the importance of the association of rhodoliths (Fig. 1), which forms accumulations in the sandy depressions (9328 ha) or constitutes “carpets” (1660 ha), down to 90 m depth. The frequency of hard substrates, hosting coralligenous assemblages, is also observed (26 ha). In contrast, the area of Bouches de Bonifacio would appear to be characterized by great richness in hard substrates, hosting of coralligenous assemblages (Fig. 2 and 3; 181 ha) but over a smaller area with regard to the rhodolith beds surfaces areas (2013 ha). These rhodoliths are only observed down to maximum depths of 75 m and form accumulations in the sandy depressions.

It should be noted that, for both sites, the coralligenous areas are underestimated due to the method used (side scan sonar) which only takes into account horizontal or subhorizontal surfaces (3D assemblage).

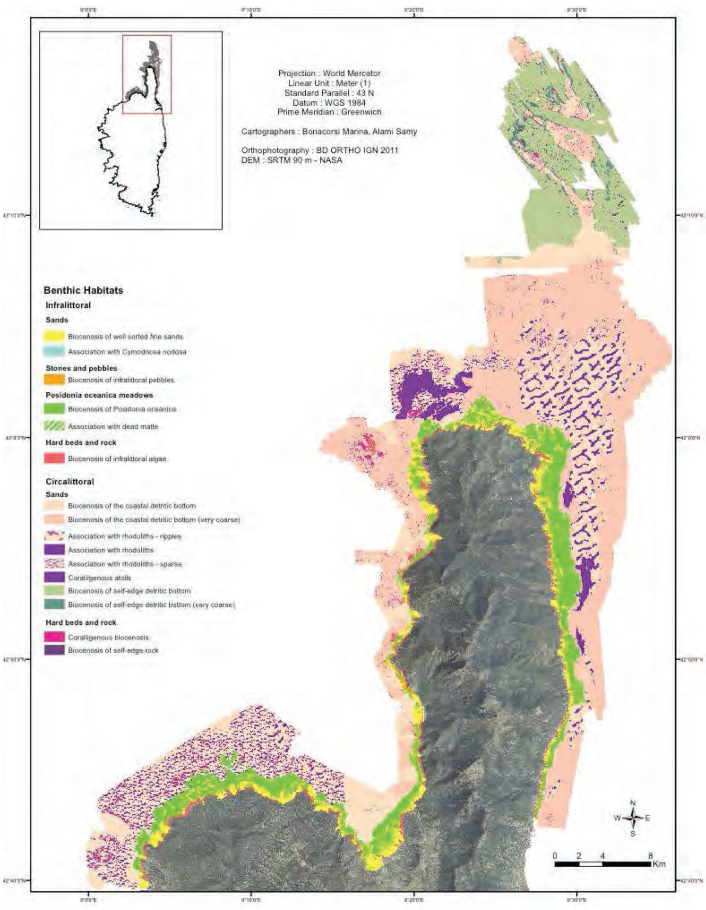

Fig. 1: Map of the main biocoenoses and associations of Cap Corse.

In addition in the northern part, new structures have been discovered. These structures, never previously identified in the Mediterranean Sea, are named "coralligenous atolls" because of their circular shape. They are formed of a massive central core constituted by a massive coralligenous structure, a halo of detritic bottom and a peripheral crown of free rhodoliths. The absence of coralligenous atolls must be emphasized, at the area of Bouches de Bonifacio, a site otherwise closely comparable to Cap Corse, despite the presence of coralligenous assemblages. The reliability of the three maps is high. It is between 88% and 90% for Cap Corse and 91% and 90% for Bouches de Bonifacio according to the scale of Pasqualini *et al.*, (1998) and MESH (2008).

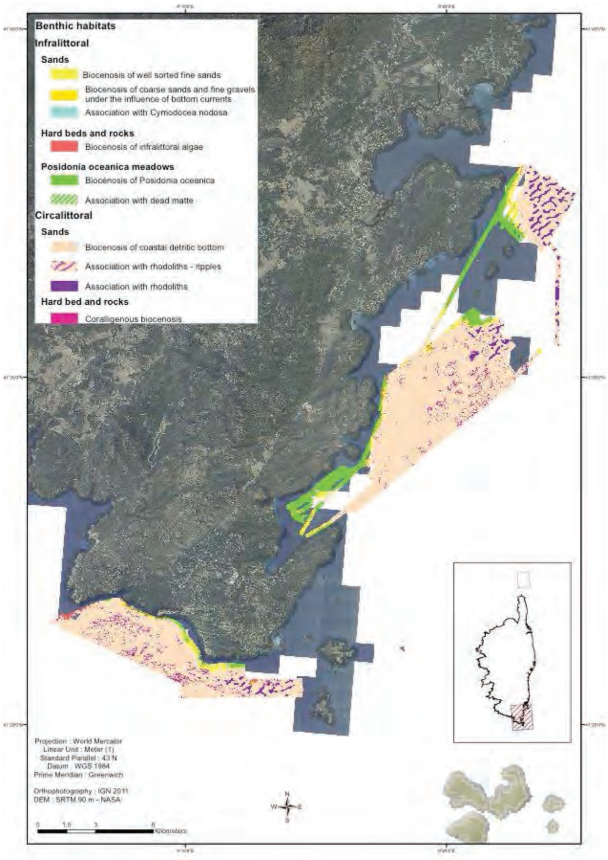

Fig. 2: Map of main biocoenoses and associations of Bouches de Bonifacio.

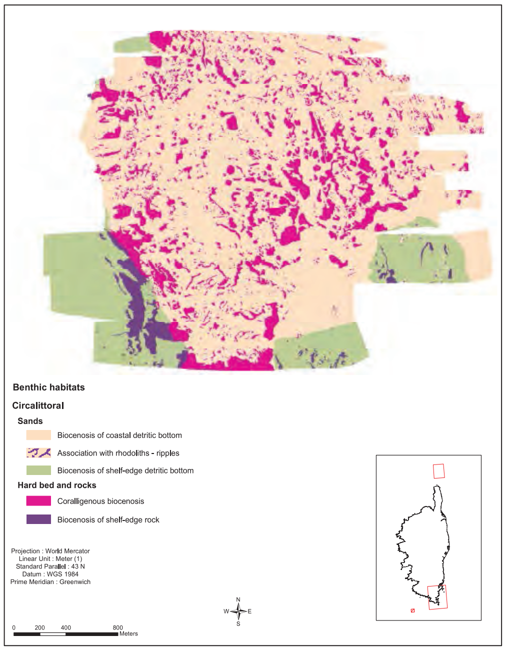

Fig.3: Map of main biocoenoses and associations of Asinara.

Discussion and conclusion

The maps produced constitute a significant contribution to knowledge of the distribution of the rhodolith beds and coralligenous assemblages, according to the existing data (UNEP-MAP-RAC/SPA 2009; Martin *et al.*, 2014) especially on rhodolith beds whose knowledge was limited, compared to what was available for coralligenous outcrops (Martin *et al.*, 2014). This study demonstrates the extent of the surface area occupied by the rhodolith beds in these Natura 2000 sites (8 % of the total mapped surface of the western Mediterranean basin (Martin *et al.*, 2014)).

Our results are in accordance with the existing data concerning the bathymetric distribution of coralligenous (Ballesteros, 2006) and rhodolith associations (Barbera *et al.*, 2003; Georgiadis *et al.*, 2009) even if our observations are among the deepest recorded for the coralligenous in the western basin (down to -120 m; Bonacorsi *et al.*, 2012).

In addition to a heritage interest, these calcareous bio-concretions probably play a major role in the production of calcium carbonate and more generally in the biogeochemical cycles of carbon at regional level, but their role is still insufficiently studied (Martin *et al.*, 2013a). Calcimetric analysis showed particularly high content in calcium carbonate of the biocoenosis of coastal detritic bottoms (90 %) as already reported for Balearic Islands (between -40 and -90 m; Fornos & Ahr, 1997), in the Gulf of Cagliari (-50 to -5 m;

Lecca *et al.*, 2005) and at the Pontine Islands (between -60 and -80 m; Brandano & Civitelli, 2007). It seems that these high levels are probably related not only to the nature and the topography of the bottom and/or bathymetry but also to the present benthic communities (Canals & Ballesteros, 1997). The values of calcium carbonate production of calcareous bio-concretions measured by Canals and Ballesteros (1997) and Martin *et al.* (2007) were applied to our surfaces. This production is then estimated respectively between 27 302 100 kg.an-1 and 63 275 867 kg.an^{-1} for rhodolith beds. Concerning coralligenous assemblages the values proposed by Canals & Ballesteros (1997) correspond to a production of 961 722 kg.an^{-1} for coralligenous assemblages. It confirms that coralligenous communities play a major role as carbon and carbonate producer in the Mediterranean Sea (Martin *et al.*, 2013a).

Acknowledgments
This research is a part of the University of Corsica and the « Collectivité Territoriale de Corse » CHANGE programme (FRES 3041). This work would not have been possible without the support of the N/O L'Europe (Ifremer-Genavir-Insu), the efficiency of the crew of the Oceanographic vessel, and the financial support of the 'Agence des Aires Marines Protégées'. The authors wish to thank Mr Michel Marengo and Mr Adrien Pangrani for their assistance in the field.

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UNEXPECTED ARTIFICIAL-REEF-LIKE EFFECT DUE TO A MEDITERRANEAN PIPELINE AND THE CONSERVATION OF TWO CIRCALITTORAL EMBLEMATIC SPECIES: *CENTROSTEPHANUS LONGISPINUS* AND *CYSTOSEIRA ZOSTEROIDES*

Abstract
The Gardanne alumina plant (western Provence, France) has since 1967 been discharging at sea bauxite residues through a pipeline with its outlet in the Cassidaigne Canyon (320 m deep), located in the Calanques National Park. Within the framework of the Barcelona Convention, discharging will end in December 2015. The question that arises is therefore: should these pipes be removed at the end of their exploitation? The two pipes were explored in May 2013 by means of a Remotely Operated Vehicle (ROV) equipped with a video camera. Outstanding species were identified and located. 344 individuals of the diadem sea urchin Centrostephanus longispinus were observed between 45 and 96 m depth along the pipelines. Such a high density has never been observed in the NW-Mediterranean. The brown alga Cystoseira zosteroides was common from the lower limit of the Posidonia oceanica seagrass meadow (30 m) down to 52 m depth, which represents one of the two most extensive populations within the Calanques National Park. The presence of significant populations of species of high heritage value (C. longispinus and C. zosteroides) in artificial habitats (subsea-pipelines), populations that may be more extensive than those located in natural habitats, raises questions with regard to the interest of these artificial habitats for conservation purposes, the justification for dismantling the unused pipes and the concepts of management and restoration of the marine environment.

Key-words: Artificial reef, *Centrostephanus longispinus*, Conservation, *Cystoseira zosteroides*, Pipeline.

Introduction

The alumina plant at Gardanne (western Provence, France) has since 1967 be discharging at sea solid, but diluted in freshwater, residues (0.2-1.4 Mt a^{-1}), of bauxite through a 25 cm diameter pipeline (Gardanne pipeline) with its outlet at 320 m depth in the submarine Canyon of Cassidaigne (Picard, 1978; Mioche, 2010). The path and the outlet of the pipeline are located within the recently established (April 2012) *Parc national des Calanques* (Calanques National Park). Another pipeline (La Barasse pipeline), now unused (since 1990), is located close to the Gardanne pipeline (Fig. 1).

In 1996, within the framework of the Barcelona Convention for the Protection of the Mediterranean Sea, the company Aluminium Pechiney (then owner of the site) made a commitment to reduce waste and to stop these discharges on December 31, 2015. Within this framework, the possible dismantling of the pipelines, after the end of their use, was studied by

Alteo, current operator of the plant. The question is: should we remove these pipelines? Or is it better to leave them in place in order to minimize the environmental impact?
Here, we report the results of the exploration of the 2 underwater pipelines (Gardanne and La Barasse), with special attention paid to the species of natural heritage value.

Materials and methods
The underwater stretch of the pipelines studied, between Port-Miou Cove and their outlets at the head of the Cassidaigne Canyon, at 320 m depth, is 7.5-km long (Fig. 1). With the exception of their initial landward part, the pipes cross soft bottom habitats. Pipelines were explored in May 2013 by means of a ROV (Remotely Operated Vehicle) equipped with a video camera, between 30 m (lower limit of the *Posidonia oceanica* (Linnaeus) Delile seagrass meadow) and 320 m depth.
The videos were analysed to identify and locate outstanding species, species with natural heritage value and/or species with a protection status established on the pipeline and in its close vicinity (~1 m). Species of this kind that were encountered included the diadem sea urchin *Centrostephanus longispinus* (Philippi, 1945) (Echinodermata, Metazoa) and the seaweed *Cystoseira zosteroides* C. Agardh (Phaeophyceae, Stramenopiles). Other species of *Cystoseira* were possibly present. Whenever an individual or group of individuals was observed, the coordinates were identified, on the basis of the navigation files established by the ROV. Between two geographical points recorded by the ROV, the intermediate positions of individuals were calculated (assuming that the speed of the ROV was regular). In addition, a scuba dive was performed (30-32 m depth) in order to collect specimens and check their identification.
The analysis of videos was made by means of the ZOODEX tool (ZOOlogical Data EXploitation system Zoological operating system; Goujard & Fourt, 2013). This tool enables transcription of the data in the form of logbook listing all the events corresponding to the observation of species, waste, substrates, etc. These events are pinpointed (longitude, latitude and depth) from the navigation files of the ROV.

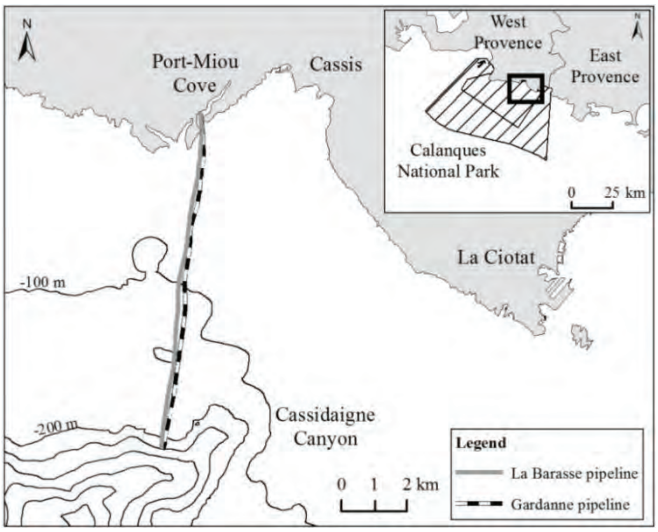

Fig. 1: Location of the study site and of the 2 pipelines. West Provence and East Provence correspond to the French administrative divisions 'Bouches-du-Rhône' and 'Var', respectively. Lines: depth contours.

Results

Along the path of the two pipelines, 344 individuals of *Centrostephanus longispinus* (Fig. 2) were counted, 176 and 168 on the La Barasse and Gardanne pipes, respectively. The depth ranged from 45 to 96 m and the distance from the shore from 730 to 3 950 m. However, most individuals (85%) were located between 60 and 75 m depth (Fig. 3). The mean density, in the stretch where sea urchins were present, was 0.6 individuals/10 m, and up to 4.6 individuals/10 m in densely occupied zones. The density peaks slightly differ between the two pipelines: 1 300-1 800 m from the shore and 65-75 m depth along the La Barasse pipe, versus 1 050-1 300 m from the shore and 60-65 m depth along the Gardanne pipe (Fig. 3).

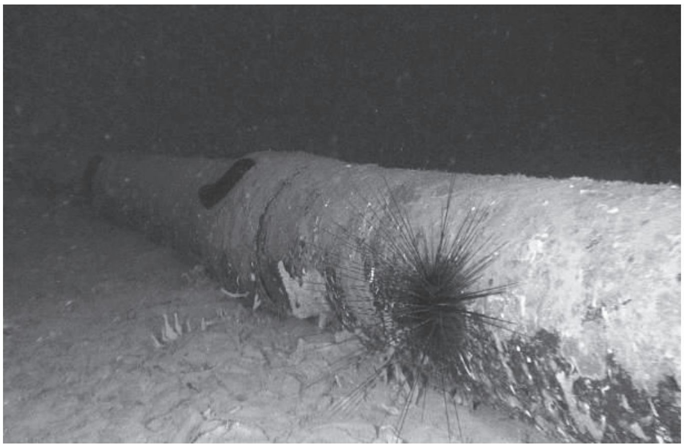

Fig. 2: A sea urchin *Centrostephanus longispinus* on the La Barasse pipeline, 68 m depth. Photo: ©ROV, COMEX.

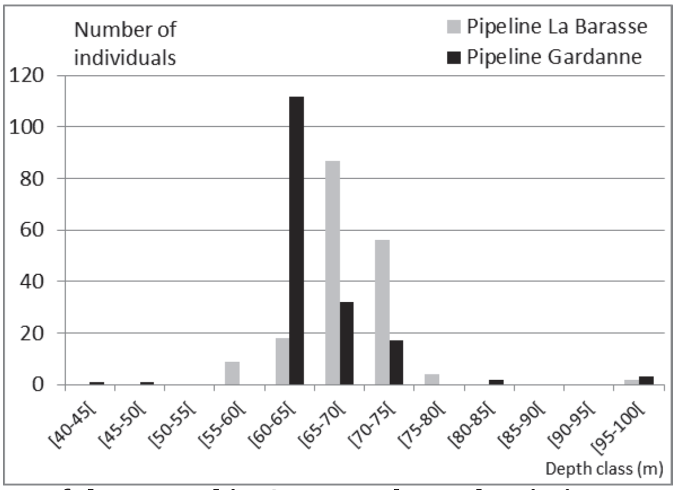

Fig. 3: Abundance of the sea urchin *Centrostephanus longispinus*, as a function of the depth, along the La Barasse and Gardanne pipelines, in May 2013.

On the 2 pipes, stands of the seaweed genus *Cystoseira* were observed, between the lower limit of the *P. oceanica* seagrass meadow (30 m) and 52 m depth (Fig. 4, 5). Between 30 and 32 m, scuba diving and collection of specimens enabled their identification as *C. zosteroides*. The presence of other species on the deepest parts of the pipes cannot be excluded, since these species cannot be distinguished from *C. zosteroides* on the basis of videos alone. Hereafter, '*Cystoseira zosteroides*' therefore means '*C. zosteroides* and (perhaps) other species of the genus *Cystoseira*'. *C. zosteroides* was more common (63%

of all records) on the Gardanne than on the La Barasse pipe; its depth range was 30 to 52 m and 32 to 40 m on the Gardanne and La Barasse pipes, respectively.

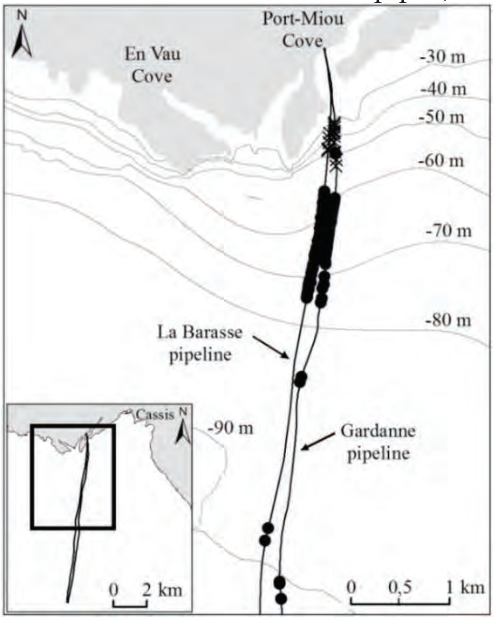

Fig. 4: Distribution of the sea urchin *Centrostephanus longispinus* (X) and the seaweed *Cystoseira zosteroides* (●) along the La Barasse and Gardanne pipelines. Each item (X or ●) means the presence of the species, either as an isolated individual or a more or less dense population.

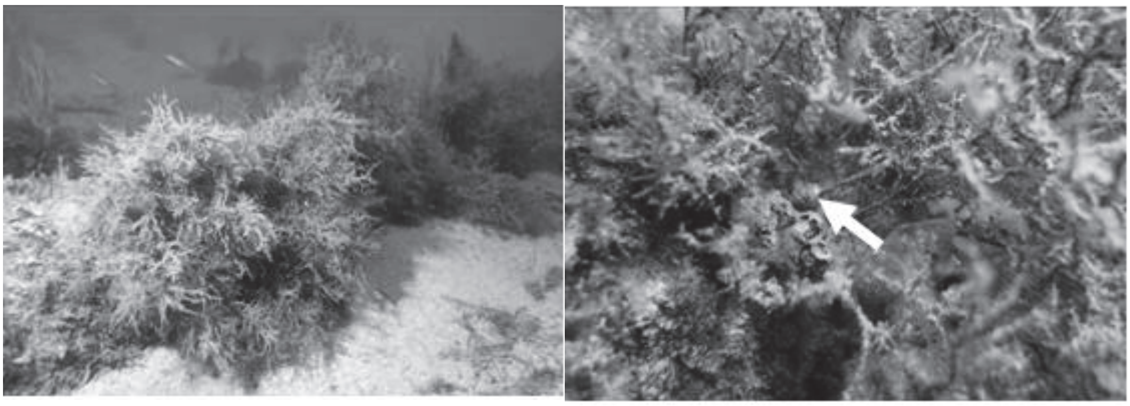

Fig. 5. Left: *Cystoseira zosteroides*, Gardanne pipeline, 32 m depth. Right: the arrow shows smooth 'tophules', storage organs playing the same role as the bulbs of terrestrial plants, a characteristic feature of the species. Photos: ©Patrick Bonhomme, GIS Posidonie.

Discussion and conclusions

The distribution range of the sea urchin *Centrostephanus longispinus* encompasses the Mediterranean Sea and the eastern Atlantic Ocean. It is a stenothermal species of warm water affinities, relatively rare in the north-western Mediterranean, but common in the western Atlantic (Francour, 1986, 1989, 1991; Le Loeuff, 1993; Templado & Moreno, 1996). In the Mediterranean, it dwells between 15 and 130 (up to 200) m depth, but is uncommon below 100 m (Tortonese, 1965; Francour, 1986; Agence des Aires Marines Protégées *et al.*, 2013). It grazes on benthic animals and primary producers, but can perhaps also utilize dissolved organic carbon (DOC) and particulate organic matter

(POM) carbon *via* the porous external surface of the spines (Régis, 1981; Paul *et al.,* 1983). Once settled at a location, *C. longispinus* seems to be relatively sedentary, but movement at a speed of 5-16 m h^{-1} has been observed (Paul *et al.,* 1983; Francour, 1986, 1991). *C. longispinus* is a protected species in France that is cited in several international conventions. Such a high density of *C. longispinus* has never before been recorded in the NW Mediterranean, or even perhaps at the scale of the entire Mediterranean Sea. Considering the proximity of the populations of the 2 pipes (~400 m) and the moving speed of the species, individuals thriving on the 2 pipes can be regarded as belonging to the same population.

Spawning aggregation is known in many sea urchin species, e.g. *Paracentrotus lividus* (Lamarck, 1816) (Boudouresque & Verlaque, 2013). The observed populations probably do not correspond to spawning aggregation, although the density probably enhances their reproductive efficiency. A possible difference in temperature at the surface of the pipe, due to the effluent, cannot be the driving parameter, as the 2 pipes, both active and non-used, are similarly colonized. Rather, colonization may result from the conjunction of a suitable hard substrate and the supply of feeding resource (DOC, POM) *via* currents, including the neighbouring Cassidaigne Canyon upwelling. In addition, the prohibition of trawling in the area, in order to avoid damaging the pipelines, may mimic a 'reserve effect' (Boudouresque *et al.,* 2005).

Cystoseira zosteroides is a perennial long-lived species, endemic to the Mediterranean Sea (Ballesteros *et al.,* 2009). Due to direct and indirect human impact, it has suffered dramatic loss and locally has become nearly extinct (Thibaut *et al.,* 2005). The species is regarded as a threatened species and is cited in several international conventions. The population of *C. zosteroides* established on the pipes constitutes one of the 2 largest stands known within the Calanques National Park, with the other located at Tiboulen de Maïre. Another stand is present at 63 m depth, at the mouth of Contrebandiers Cove, to the south of Riou Island (Bonhomme *et al.,* 2004; Rouanet *et al.,* 2012). Its thriving on the pipes may be related to the absence of trawling and the release from most macroherbivores, on an unusual hard substrate surrounded by vast areas of soft bottoms.

The presence of significant populations of species of high heritage value in artificial habitats (subsea-pipelines) does not challenge the value and protection status of these species. Rather, it draws attention to the possible interest of some man-made structures in the conservation of rare and threatened species. The study pipelines have obviously mimicked artificial reefs. This 'positive' result should be considered with caution: whatever the interest of some artificial habitats, as in the case of zoos, they cannot be seen as a substitute for species conservation in natural habitats. As regards the question of the dismantling and removing of the non-used pipes, this may seem justified from the standpoint of the 'naturalness' of the habitats of the Calanques National Park. However, in the context of the worrying decline of *C. zosteroides*, reduced to near extinction in extensive Mediterranean areas, including Marine Protected Areas, the alternative non-removal choice may also appear to present certain advantages.

Acknowledgments

The authors acknowledge with thanks Alteo, the owner of the pipelines, for permission to publish these data, Marc Verlaque, who checked the *Cystoseira* identification and Michael Paul, a native English speaker, for improving the English text.

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CORALLIGENOUS: INSIGHTS FOR A NEW GEOMORPHOLOGICAL DEFINITION

Abstract

Mediterranean marine benthic bionomists refer to Coralligenous (C) de plateau as a circalittoral biocoenosis consisting of a biogenic framework forming a solid substrate settled on an originally mobile substrate. Pérès & Picard (1951) indicated that the true C de plateau develops from the coalescence of rhodoliths, although they already underlined the problem of the identification of its substrate. C de plateau falls into the "bank" category sensu Ballesteros (2006): flat frameworks mainly built over more or less horizontal substrate with lateral continuity. Actually few examples of C de plateau have been documented in literature, and present-day examples of C de plateau are much rarer than originally thought. Large areas along the Apulian coast have been investigated from the coastline down to 100 m water depth in the framework of BIOMAP project aimed at mapping the C habitat. Collected remote data have been ground-truthed by ROV and camera inspections. This large data set allowed the categorization of several morphologic types of C, all falling into the bank category: from smallest type forming isolated columns, to large platforms. Through a systematic analysis carried out on the acoustic data and thanks to the detailed scale of observation (i.e.: from 0.5 m up to tens of meters), a new morphological categorization to describe C frameworks found along the shelf is proposed.

Key-words: Coralligenous, Mediterranean Sea, remote sensing, geomorphology, category

Introduction

In the framework of Mediterranean marine benthic zonation Coralligenous (C) is indicative of a circalittoral biocoenosis consisting of a three dimensional biogenic build up that forms a new solid substrate primarily dominated by coralline algae (Laborel, 1961; Pérès & Picard, 1964; Bellan-Santini *et al.,* 1994; Bressan *et al*., 2001).
Marine bionomists consider the substrate to be a key factor in distinguishing C typologies, although it represents a difficult aspect to investigate. Only recent acoustic-sismic techniques have been applied to determine the type of substrate were the coralligenous develops (Georgiadis *et al*., 2009; Bracchi *et al*., *in press*).
Pérès & Picard (1951) firstly specified C *de plateau*-type as a biogenic framework developed from the coalescence of rhodoliths, even if they underlined the problem of the substrate identification. C *de plateau* was hereafter indicated as the biogenic build-up forming a solid substrate settled on a general originally mobile substrate (Pérès & Picard, 1964). Hard substrate is instead reported for C *d'horizon inférieur de la roche littoral* type. However some authors suggest that C *de plateau* frameworks have probably grown on rocky outcrops (Got & Laubier, 1968; Laborel, 1987).
Moreover C build-ups vary in shape and dimension and their morphological expression have not been exhaustively categorized. From this point of view, two main morphologies have been indicated (Pérès & Picard, 1964; Laborel, 1987; Ballesteros, 2006): 1) banks – flat frameworks with thickness ranging from 0.5 to 4 m mainly built over more or less horizontal substrata, and 2) rims – structures on submarine vertical cliffs or surrounding

the opening of submarine caves, generally located in shallower waters than banks. Nevertheless various definitions, reflecting different building morphologies, are found in the scientific literature: columnar crustose coralline algal build-ups described as heads, blocks patches, or banks (Sarà, 1968), vertical pillar (Di Geronimo *et al*., 2002), horizontal pillar (Sartoretto, 1994), algal reefs (Bosence, 1983), and minute reef aggregation (Georgiadis *et al*., 2009). These definitions all fall into bank category *sensu* Ballesteros (2006), although these terms better express the real geomorphological aspect of C build-ups.

If we try to relate marine bionomists C definitions and morphological definitions, C *de plateau* falls into the bank category, although the horizontal substrate must be represented by mobile substrate to have the C *de plateau* in its genetic definition. C *d'horizon inférieur de la roche littoral* type falls into rim category. Bank growing on hard substrate does not correspond with any bionomic definition.

Apulian coralligenous is known in literature since decades (Sarà 1966; 1968; Parenzan, 1983). Large areas along the Apulian coast have been investigated from the coastline down to 100 m water depth in the framework of BIOMAP project aimed at mapping the C distribution. C is well developed all along the Apulian coasts (BIOMAP Final Report, 2014).

Through a systematic analysis carried out on the acoustic remote data, ground-truthed by video inspections, we documented the highest variability of C morphologies and distribution (preliminary results in Bracchi *et al*., *in press*). All the peculiar morphologic types of Apulian C fall into the bank category. Probably due to the different type of substrate Apulian C build-ups occupy, rarely they can be identified as C *de plateau* in its original definition, but because of the sub-horizontal substrate, they do not correspond with the other definition of marine bionomists (*i.e.*: C *d'horizon inférieur de la roche littoral*). We spotted that present-day available categorizations, both the bionomic one than the morphological one, even though they totally work, should be revised, properly thank to the availability of new data obtained from new acoustic sampling.

Consequently the result of this work is to indicate some examples of the peculiarity of C build-ups in terms of different geomorphological expression they present and associated settled substrate. The aim of this study is to give some indications of which is the best strategy to follow to study these aspects, and to open a discussion about the possibility to develop a more detailed categorization, starting from the known and overall accepted categories.

Materials and methods

We analyzed acoustic data obtained from ship-based research surveys, performed between March 2012 and October 2012 under the framework of the BIOMAP project. Data spanned areas located offshore Puglia coasts, ranging from 5 and 100 m in water depth. The R/V Minerva 1 (property of Sopromar SPA) was used to explore the deepest areas, whereas the boat Calafuria ISSEL (property of CoNISMa) was used to investigate the shallowest ones.

Positional data were provided by a Hemisphere Crescent R-Series dGPS. The BIOMAP project's datum was WGS84 and the projection chosen for navigation and display was UTM fuse 33.

The remote technical devices we used included two models of dual frequency Side Scan Sonar (SSS) (the 100/500 kHz Klein3000 system and the 100-400 kHz EdgeTech 4- 2000), two different Multi-Beam (MB) Echosounders (the 50kHz Reson Seabat 8160

for the deepest areas, and the 455 kHz Reson Seabat 8125 for the shallowest ones) and, only during the BIOMAP II cruise (May 2012), the GeoAcoustic (3/7 kHz) chirp sonar to collect seismic-stratigraphic data.
Water sound velocity was obtained using the Seabird SBE 21 device.
SSS operated at 200 m range setting and we reached 50% of overlap between adjacent lines. SSS data processing, performed using Triton ISIS (Triton Elics Information-TEI) suite software packages, produced geo-referenced gray-tone acoustic images of the seafloor at 0.5 m resolution. Only for SSS data acquired during the survey on the R/V Minerva 1, the track of the *fish* was computed using the position of the ship, the length of the tow cable, and the elevation of the fish above the sea floor. On the Issel boat the SSS *fish* was anchored on a vertical pole, consequently a simple fixed offset (from the dGPS antenna position) was used to obtain georeferenced SSS images.
Acquired MB data did not cover all the investigated areas with 100% of coverage, but provided high-resolution bathymetry of the surveyed seafloor (*i.e.* a 2 m cell size at 100 m in wd). The digital terrain model (DTM), provided by the MB survey, was used for the final georectification of the processed SSS mosaic obtained from the R/V Minerva 1 surveys.
Seismic-stratigraphic data have been processed using Triton SB Interpreter (TEI).
To ground-truth the acoustic remote data, video inspections have been collected during all the oceanographic cruises, using a ROV system (Prometeo) and a subaqueous trawled camera (Quasi-Stellar © Elettronica Enne – this latter was used only during the Issel surveys).
All data were integrated and analyzed using GIS-based procedures (ArcGIS TM software).
In our present work, two sectors along the Apulian coast (one in the Adriatic Sea, between Otranto and Santa Maria di Leuca and one in the Ionian Sea, in the area of Ugento coast) have been selected to illustrate the high geomorphological variability of the Apulian C build-ups.

Results

The collected video data allowed identifying different morphologies of C build-ups as positive relief on the seafloor, and verify which type of acoustic response we obtained in correspondence of such frameworks.
On SSS mosaic C build-ups generally show a pattern of intermediate to very high backscatter. Two typical textures have been identified: 1) continuous spotted/spackled intermediate to high backscatter, or 2) distinct circular features characterized by high backscatter. These textures are strongly different from adjacent ones, characterized by intermediate to low backscatter.
MB data allowed us to sketch the most relevant morphometric features of C outcrops. C provided seafloor relief varying between 0.5 and 4 m. The elevated structures show steep flanks and are often sub-vertical with sharp boundaries. The lateral continuity of C structures marks a very variable morphological feature.
Texture 1 is generally associated to C build ups with metrical lateral continuity, whereas texture 2 shows C build ups that are generally characterized by constrained lateral continuity, from 0.5 to 4 m.
On MB data the surface of C structures are not homogeneous and show a high level of roughness. From a geomorphological point of view we can distinguish two end-members within the variety of the investigated C outcrops: from 1) isolated squat columns

randomly scattered to 2) large ridges with metric lateral continuity and variable geometry (from circular to ellipsoidal or elongated structures alternated to channels yielding a sort of ridge/channel pattern). However, several intermediate expressions have been reported where blocks begin to coalesce although their distinct shape is still identifiable.
Chirp profiles crossing the identified C build-ups have been selected to investigate the substrate. Echo types associated to C build-ups are 1A or IIB-2 of Damuth and Hayes (1977). This is due to the nature of C build-ups that are hard frameworks of biogenic origin able to create a rugged morphology, producing an irregular physiography on the seafloor profile. These echo-types have no apparent sub-bottom reflector, and no internal stratigraphic structures are traceable. Consequently it is not possible to distinctly identify/outline any type of substrate. In addition C build-ups often depicted a topographic relief, from 3 to 12 ms (i.e.: from 1 up to 4 m) in height. Where C build-ups are not reported and where a flat seafloor characterized by mobile sediment (as identified on other remote acoustic data or video data) occur, the seismic profiles show a weaker signal, sometimes with the occurrence of a layering pattern.

Discussion and conclusions

According to our results Apulian C build-ups generally grew on more or less sub-horizontal substrate. Consequently they do not correspond with the definition reported by marine bionomists (*i.e.*: C *d'horizon inférieur de la roche littoral*). Moreover, due to the different type of substrate they apparently occupied, rarely they can be definitely identified as C *de plateau* according to its original definition. In addition, all the peculiar and different morphological expressions of the Apulian C fall into the bank category.
Nowadays seafloor mapping techniques allow obtaining large scale high-resolution seafloor images useful for understanding the submarine environment. Properly thank to this scale of observation, we documented the high variability of Apulian C build-ups in term of geometry, dimension, areal distribution and settled substrate.
In this work, we distinghuish different of C build-ups. Considering the first three aspects (geometry, dimension and areal distribution) we reported C build ups forming topographic relief from 0.5 up to 4 m high, with a lateral continuity ranging from 0.5 m up to hundreds of meters and with an areal coverage of several square kilometers, definitely falling into the bank category. Such term (i.e.: *bank*) is evocative of build-ups characterized by lateral continuity. Indeed the definition reports *flat frameworks with thickness ranging from 0.5 to 4 m mainly built over more or less horizontal substrata* (Ballesteros, 2006). Generally Apulian C build-ups are characterized by the same order of thickness, and more or less the same horizontal substrate. The limit lies in the spatial definition of the adjective "flat". Indeed, the ridge structures we identified surely represent flat structures that can be ascribed to this category, but the isolated columns or all the intermediate situations we found from isolated columns to ridge, can be hardly ascribed to bank category, although this is the only existing category we can use to describe such structures.
As a result of the Habitat Directive (92/43/EC), marine bioconstructions, generically indicated as "reefs", have been recognized as marine habitats worth of protection and among Mediterranean marine bioconstructions, C undoubtedly is one of the most important in extension and biodiversity. Acoustic seafloor mapping technique used to investigate the continental shelf, are able to produce images of the seafloor with a suitable scale to properly depict the extension of benthic habitats (Kenny *et al*., 2003; Savini, 2011). Such remote images are therefore instrumental to fulfill the gaps in the current

scientific knowledge on the different geomorphological expression that C build-ups can show, and to refine the general, but still efficient, definition of bank. Such acoustic devises allow especially measuring the morphometric features of C build-ups, to precisely describe their pattern of distribution and to quantify their areal coverage, without losing the natural variability of C itself.

Seismo-stratigraphic profiles could be useful to investigate another substantial aspect for the definition of C: the substrate. The definition of the substrate should be considered essential to provide a geomorphological definition (which requires also the definition of the genesis of build-ups). Furthermore the substrate represents the key-element to distinguish C bionomic typologies (C *de plateau* or C *d'horizon inférieur de la roche littoral*), although it also represents a difficult aspect to investigate. Even in this case the term *de plateau* is evocative of the C on the continental shelf with more or less horizontal substrate, but actually it represents a very precise definition. Consequently it is not correct to apply this definition in most of the Apulian cases, because of the lack of data or evidence of other type of substrate (non mobile sediment). Actually Apulian C build-ups are often surrounded by soft sediment, although its occurrence does not mean that it serves as substrate for the C build-ups. We cannot exclude the outcropping of hard substrate or the occurrence of relict hard structures that could provide a solid substrate for C development. On chirp sonar profiles, especially in the ones that cross the large ridges, the topographic highs are formed by C build-ups that seem to be grown over an inherited complex morphology, we thus confidently suppose that such highs are not only the result of C development.

The bionomic definitions of C *de plateau* can be instead properly applied to fossil records, where the substrate can be easily distinguishable (Basso *et al*., 2007).

Nevertheless the substrate represents a descriptive aspect that can be directly correlated to different geomorphological expressions. The problem is that it must be conveniently investigated, and this is not an easily aspect to consider because seismo-stratigraphic survey rarely have the necessary sub-metric resolution (under the meter). The solution should be the direct sampling *via* appropriate tools like vibro-corers, but it represents a destructive method not easily applicable to a protected habitat.

Finally we indicated Apulian C build-ups as "C settled along the shelf growing on variable, quite horizontal substrate", encouraging a discussion on the lack of suitable framework of geomorphological definitions for describing and mapping all the types of C outcrops.

Acknowledgments

This study benefited from funding and ship-time through the BIOMAP project (P.O FESR 2007/2013, Puglia Region, Italy). The authors' work also benefited from the RITMARE project funded by the Italian Ministry of University and Research. F. Marchese was funded through a PhD fellowship in Earth Sciences by the Milano-Bicocca University.

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CORALLIGENOUS REEFS IN LIGURIA: DISTRIBUTION AND CHARACTERIZATION

Abstract
One of the major gaps concerning the current state of knowledge of coralligenous reefs, a key habitat in the Mediterranean Sea, is the scarcity of information on its geographical and bathymetrical distribution. This paper reviews and updates the existing knowledge on the coralligenous reefs of Liguria (NW Italy), as an essential step in view of management measures for their conservation according to the EU Marine Strategy Framework Directive. The existing information was collected from scientific publications, detailed acoustic mapping, grey literature and records of divers, to build a database on the distribution and typology (both geological and biological) of coralligenous reefs of Liguria. The database has been implemented on a GIS platform. A total of 18 coastal localities resulted to possess coralligenous reefs, ranging from 10 m to 113 m depth and covering in total an area of 146.9 ha. Seven localities are situated along the Eastern Ligurian Riviera, 11 along the Western Riviera; 41 ha (28%) are already included in marine protected areas. Three main geomorphotypes (cliffs, rockfalls and shoals) were recognized, and 13 different biological facies (6 of them not included in the EUNIS list) were identified. 61% of the localities with coralligenous reefs showed signs of impact by anchors, fishing activities, invasive species or occasional mucilaginous events. The major part of these coralligenous reefs have never been studied in detail; our preliminary inventory pointed to a major dearth of knowledge for the Western Riviera and to the need of updating the biological data for the whole Liguria.

Key-words: Coralligenous, Liguria, GIS, facies, geomorphotypes

Introduction
Mediterranean coralligenous reefs are considered one of the most important and characteristic habitats of the Mediterranean Sea and the climax biocenosis of the circalittoral zone (Pérès & Picard, 1964), with richness, biomass and production values comparable to tropical reefs and economic values higher than Mediterranean seagrass meadows (Morten, 2010). Their biogeographic uniqueness, highly diversified physical structure, high species biodiversity, very diversified occurrence stratified throughout the different benthic marine zones and their slow growth make them being considered of high conservation interest (Agnesi *et al*., 2008). The scientific knowledge concerning several aspects of this peculiar biogenic concretion (*e.g.* taxonomy, processes, functioning, biotic relationships, dynamics) has been currently increasing, but it is still far away from the knowledge we have from other coastal ecosystems, such as intertidal zone, kelp beds, seagrass meadows, shallow coastal rocky areas, rockpools (Ballesteros, 2009). One of the major gaps concerning the current state of knowledge of the coralligenous habitat is the absence of geographical as well as depth distributional data. This information is essential in order to know the real extent of coralligenous reefs in the Mediterranean Sea and to

implement appropriate management measures to guarantee their conservation (UNEP-MAP-RAC/SPA, 2008). Modelling and mapping, using geographic information systems (GIS), provides the basis for informed decision making (Sardá *et al.*, 2012). This paper reviews and updates the existing knowledge on the coralligenous reefs of Liguria (NW Italy), as an essential step in view of management measures for their conservation as requested by the EU Marine Strategy Framework Directive.

Materials and methods

Ligurian coast falls into the Ligurian Sea, the northernmost sector of the Western Mediterranean with a 350 km arch-shaped coastline from Ventimiglia in the west border with Provence-Alpes-Côte d'Azur (France) and La Spezia in the east border with Tuscany (Italy) (Fig. 1). The existing information on coralligenous reefs was collected from scientific publications, detailed acoustic mapping, grey literature and records by divers to build a database on the distribution and typology (both geological and biological) of coralligenous in Liguria. The database has been implemented on a GIS platform using the ArcGIS 10.2 software with Spatial Analyst extension.

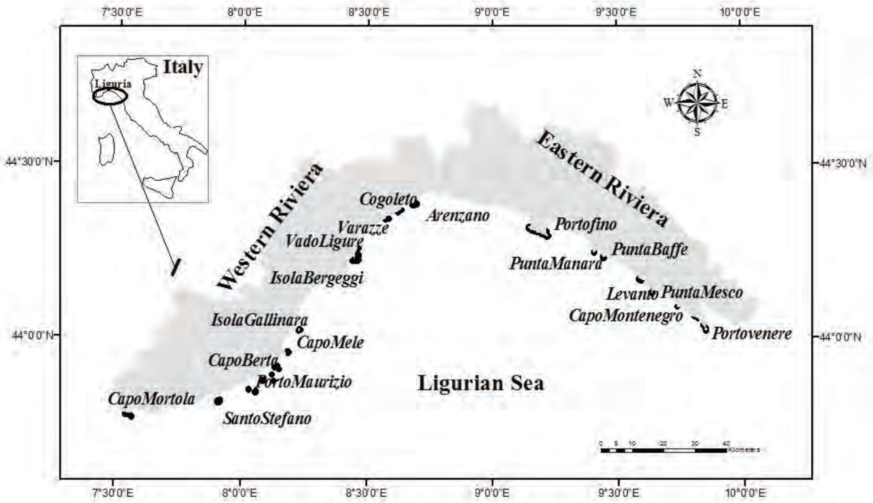

Fig. 1: Region of Liguria with coralligenous reefs distribution

Light values

January 2002-December 2012 vertical attenuation coefficient of downward irradiance (K_{PAR}) calculated from Secchi Disk records at Portofino (Rapallo, GE) together with Photosynthetically Active Radiation (PAR) from Goddard Earth Sciences Data and Information Services Center (GES DISC) Interactive Online Visualization and Analysis Infrastructure, "Giovanni", were used to calculate % light values of surface irradiance (Kirk, 1994).

Results

From 1937, with the work of Tortonese & Faraggiana (1937) that first described some fishing material from the "fondi a coralline" of Levanto, to date, 68 studies have described some aspects of the coralligenous habitat of Liguria, 51 (76%) of them in the last two decades due to improvement of diving technology that allowed direct survey. 28 studies were selected for cartography purposes and implemented into a GIS. 18 localities (Tab. 1, Fig.1) have been found to have coralligenous reefs with an extent of 146.9 ha, seven localities and 56.2 ha along the Eastern Ligurian Riviera and

11 localities and 90.7 ha along the Western Riviera with the furthest location at 4 km from the coast at Capo Berta and the closest near the shoreline at Portofino. Regional and National protection laws apply for 41 ha (28%) situated in Portofino, Cinque Terre and Portovenere. The shallowest coralligenous reef in Liguria is that of Portovenere at 10m, the deepest that of Bergeggi at 113 m.

Tab. 1: **Ligurian localities with coralligenous reefs and their descriptors. N/A: No data available. * Facies not included in the EUNIS Habitats 2004 for Mediterranean coralligenous communities (Davies *et al.*, 2004). Massive sponges: *Spongia lamella*, *Sarcotragus foetidus*, *Scalarispongia scalaris*, *Axinella polypoides*, *Chondrosia reniformis*, *Petrosia ficiformis*.**

Locality	Depth (m)	Geomorphotype	Lithology	Facies	Impacts	Area (ha)
Capo Mortola	14-43	Paleocliff Shoals	carbonate/dolomite rock and metamorphic carbonate rock	*Eunicella cavolini* *Paramuricea clavata*	*Caulerpa cylindracea*	4.5
Santo Stefano	25-40	Shoals	detritic clay rock with alluvial deposits	*Paramuricea clavata*	Fishing gears	21.8
Porto Maurizio	34-56	Shoals	detritic clay rock with alluvial deposits	*Paramuricea clavata*	Fishing gears Anchors	7.5
Capo Berta	30-60	Shoals	detritic clay rock with alluvial deposits	*Eunicella singularis* *Eunicella verrucosa** *Leptogorgia sarmentosa* Massive sponges* *Paramuricea clavata*	*Caulerpa cylindracea*	14.5
Capo Mele	29-40	Shoals	detritic clay rock with alluvial deposits	*Eunicella spp.* *Paramuricea clavata*	N/A	7.2
Isola Gallinara	25-45	Plunging cliff	quartz and conglomerate rock with alluvial deposits	*Leptogorgia sarmentosa* Massive sponges*	Anchors	3.7
Isola di Bergeggi	25-113	Paleocliff Shoals	carbonate/dolomite rock and metamorphic carbonate rock	Massive sponges* *Paramuricea clavata*	N/A	28.4
Vado Ligure	20-38	Shoals	clay rock with alluvial deposits	*Cystoseira zosteroides* *Leptogorgia sarmentosa* *Paramuricea clavata* *Parazoanthus axinellae*	Fishing gears Plastic bags Anchors	0.1
Varazze	29-45	Shoals	conglomerate rock with alluvial deposits	*Eunicella verrucosa** Massive sponges*	N/A	1.5
Cogoleto	28-42	Shoals	basic/ultrabasic metamorphic rock	*Paramuricea clavata*	Fishing gears	0.4
Arenzano	30-48	Shoals	magmatic and metamorphic rock with alluvial deposits	Massive sponges* *Paramuricea clavata*	Fishing gears	1.1
Portofino	11-84	Plunging cliff Rockfall Shoals	conglomerate rock	*Cystoseira zosteroides* *Eunicella cavolini* *Eunicella singularis* *Corallium rubrum** *Leptogorgia sarmentosa* *Leptopsammia pruvoti** *Paramuricea clavata*	Mucilagenous Fishing gears	37.4
Punta Manara	21-35	Shoals	sandstone rock	*Leptogorgia sarmentosa* Massive sponges* *Paramuricea clavata*	Fishing gears	0.4

Tab. 1 (continued): Ligurian localities with coralligenous reefs and their descriptors. N/A: No data available. * Facies not included in the EUNIS Habitats 2004 for Mediterranean coralligenous communities (Davies *et al.*, 2004). Massive sponges: *Spongia lamella*, *Sarcotragus foetidus*, *Scalarispongia scalaris*, *Axinella polypoides*, *Chondrosia reniformis*, *Petrosia ficiformis*.

Locality	Depth (m)	Geomorphotype	Lithology	Facies	Impacts	Area (ha)
Punta Baffe	20-40	Rockfall	sandstone rock	*Leptogorgia sarmentosa* *Paramuricea clavata*	N/A	9.8
Levanto	15-35	Shoals	basic/ultrabasic metamorphic rock with alluvial deposits	*Cladocora caespitosa** *Leptogorgia sarmentosa* *Paramuricea clavata*	N/A	1.2
Punta Mesco	17-44	Paleocliff	sandstone rock	*Leptogorgia sarmentosa* *Paramuricea clavata*	*Caulerpa cylindracea*	1.7
Capo Montenegro	18-27	Plunging cliff	sandstone rock	*Leptogorgia sarmentosa*	N/A	0.3
Portovenere	10-30	Plunging cliff Shoals	carbonate/dolomite rock	*Eunicella singularis* *Eunicella verrucosa** *Leptogorgia sarmentosa* Massive sponges* *Paramuricea clavata* *Pentapora fascialis**	N/A	5.5

Light

In Portofino, light values vary from 0.003% and 25% of surface irradiance (Tab. 2).

Tab. 2: Portofino light values (mean ± SE)

Site	Depth (m)	% of surface irradiance	mol photons/m^{2}day
Punta Chiappa	33-50	0.18-1.56 ±0.006	0.06-0.5 ±0.006
Secca dell'Isuela	15-55	0.1-15.11 ±0.006	0.03-4.83 ±0.006
Punta Targhetta to Punta Bussago	11-40	0.65-25.00±0.006	0.21-8.00 ±0.006
Punta Bussago to Punta del Buco	25-45	0.35-4.29 ±0.006	0.11-1.37 ±0.006
Cala dell'Oro W	30-40	0.65-2.28 ±0.006	0.21-0.73 ±0.006
Cala dell'Oro E	30-35	1.22-2.28 ±0.006	0.39-0.73 ±0.006
Punta Torretta	30-48	0.24-2.28 ±0.006	0.08-0.73 ±0.006
Punta Volpe	20-40	0.65-8.05 ±0.006	0.21-2.58 ±0.006
San Fruttuoso W	25-35	1.22-4.29 ±0.006	0.39-1.37 ±0.006
Cristo degli Abissi	23-30	2.28-5.51 ±0.006	0.73-1.76 ±0.006
Tetto del Dragone	18-40	0.65-10.35 ±0.006	0.21-3.31 ±0.006
Scogliera del Dragone	40-60	0.05-0.65 ±0.006	0.016-0.21 ±0.006
Punta Carega	18-40	0.65-10.35 ±0.006	0.21-3.31 ±0.006
Secca Gonzatti	30-60	0.05-2.28 ±0.006	0.02-0.73 ±0.006
Scoglio del Raviolo	23-33	1.56-5.51 ±0.006	0.5-1.76 ±0.006
Testa del Leone	25-38	0.83-4.29 ±0.006	0.27-1.37 ±0.006
Punta Fregante	20-42	0.5-8.05 ±0.006	0.16-2.58 ±0.006
Punta dell'Altare	32-55	0.1-1.77 ±0.006	0.03-0.57 ±0.006
Punta Vessinaro	27-50	0.18-3.33 ±0.006	0.06-1.07 ±0.006
Casa del Sindaco	30-50	0.18-2.28 ±0.006	0.06-0.73 ±0.006
Chiesa San Giorgio	20-40	0.65-8.05 ±0.006	0.21-2.76 ±0.006
Punta Faro	30-50	0.18-2.28 ±0.006	0.06-0.73 ±0.006
Dorsale Portofino	52-84	0.003-0.14 ±0.006	0.001-0.05 ±0.006
Punta dell'Aurora	25-40	0.65-4.29 ±0.006	0.21-1.37 ±0.006
Punta Aurora to Punta Coppo	20-30	2.28-8.05 ±0.006	0.73-2.57 ±0.006
Punta Cervara (castello di Paraggi)	16-33	1.56-13.32 ±0.006	0.5-4.26 ±0.006

Geomorphology
In Liguria three different coralligenous geomorphotypes can be distinguished.
Cliffs: vertical or near vertical walls from a steep rock face, either active (plunging cliff) or inactive (paleocliff), ending occasionally in a flat bottom with high level of sediments. Rockfalls: sets of masses of rocks of different sizes and shapes that lay on a bedding plane originated from the face collapse of the cliff. Shoals: isolated outcrops surrounded by sand or biodetritic sediments, originated by past erosional events of the cliff, rise level of the sea and deposition of sediments. Shoals are the dominant morphology in Liguria in terms of extent with 69.1 ha mainly represented in the Western Riviera while plunging cliffs, paleocliffs and rockfalls cover 34.4 ha, 29.8 ha and 13.6 ha respectively.

Impacts
Impacts reported in the literature are mainly due to fishing activities, as the presence of abandoned gears such as nets, traps and "palamiti"(type of long-lining) on the reefs (Bo *et al*., 2014). Species are also damaged by anchors, plastic bags, presence of invasive species such as *Caulerpa cylindracea* and occasional mucilagenous events. In Portofino, the major cause of mortality in *Paramuricea clavata* is the damage by fishing line, followed by the attachment of numerous epibionts (Bavestrello *et al*., 1997). Coralligenous habitat has been invaded by *Caulerpa cylindracea* with consequent loss of the original assemblages structure and biodiversity (Piazzi *et al*., 2007a). In Liguria, 11 of 18 localities were found to be impacted.

Discussion
Bibliography dealing with coralligenous reefs in Liguria is more detailed for the Eastern Riviera, where its distribution is mainly associated with cliffs. Western Riviera has been poorly studied and characterised due to its particular distribution in isolated rocky outcrops of little extent found patchily along the coast.
41 ha (28%) are inside National or Regional Marine Protected Areas. Among the 105.9 ha without management plan, coralligenous reefs of Bergeggi stay outside of the limits of the close Marine Protected Area "Isola di Bergeggi" (Parravicini *et al*., 2007), as happens with deep (>70 m) coralligenous reefs in Portofino. According to Ballesteros (1992), coralligenous communities develop between 0.05% and 3% of the surface irradiance. "Dorsale Portofino" reaches light values below 0.05% (0.003-0.14%) where coralligenous reefs grow on shoals between 52 and 84 m in communities dominated by suspension feeders: gorgonians, anthipatarians and sponges with little or no calcareous concretions. Light values >3% correspond with coralligenous reefs above 27 m depth with a high frequency of *Cladocora caespitosa*, *Codium bursa*, *Flabellia petiolata*, *Halimeda tuna* and *Sarcotragus fasciculatus* as components of coralligenous communities with high light tolerance.
Coralligenous reefs developed on sandstone rock appear to share some particular characteristics: high levels of turbidity and mud detritic bottoms with little or null percentage cover of calcareous algae and big sediment deposits with the presence of *Leptogorgia sarmentosa* and big massive sponges (*Spongia lamella* and *Sarcotragus foetidus*).
Six out of 13 facies found in Liguria where not included in the EUNIS list. Coralligenous communities dominated by massive sponges in the majority of the cases developed in shallow shoals (around 30 m) surrounded by muddy sediments and low levels of current flow. The lower energy inputs associated to the low flow speed (Gili & Coma, 1998) could favour sponges' communities to the detriment of gorgonians

due to the active suspension feeding strategy of the formers. Less diverse food availability could also explain the absence of gorgonians in the community by allowing a reduced number of strategies of exploitation of energy to exist. In any case, an effort in quantifying the trophic ecology of coralligenous communities is needed to better understand their function and development.

Acknowledgements
This research was financially supported by PRIN 2010-11 Bioconstruction.

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ASSESSMENT OF CORALLIGENOUS ASSEMBLAGES STATUS IN THE LIGURIAN SEA

Abstract

The Action Plan for the conservation of coralligenous bio-constructions in the Mediterranean Sea requires widening of the inventories of sites and species, especially in deeper zones. Such data are of paramount importance and represent the baseline knowledge for the establishment of effective monitoring activities, that should be able to detect the possible effects of anthropic and natural threats. For this purpose, coralligenous assemblages in 10 sites along the Ligurian coasts were investigated by photographic and video sampling at three bathymetric ranges: 25-39, 40-70, 71-100 m. Epibenthic organisms were identified to the lowest possible taxonomical level and their abundance was estimated in terms of percent cover. Signs of injuries and diseases, as well as the presence of lost fishing lines and nets, were recorded.

Overall, 14 vegetal and 156 animal taxa were considered. Despite the assemblages were very heterogeneous, species composition varied according to geographical and bathymetrical gradients. In contrast to deep coralligenous assemblages, shallow assemblages showed higher abundance of bioconstructing species, suggesting more dynamic conditions. Deep-water assemblages revealed a higher coverage of sediment, greater signs of human impact, especially litter and lost nets and fishing lines. These results show that deep coralligenous assemblages are more vulnerable, suggesting the adoption of more stringent protective measures.

Key-words: Bioconstruction; Benthos; gorgonians; fishing gears

Introduction

Coralligenous outcrops are a formation including secondary hard bottoms resulted by the accumulation of biogenic carbonate by calcareous algae at dim light conditions and the biota inhabiting them (Sarà, 1969). It is a key ecosystem recognised at the European level (92/43/CE Habitat Directive 1992, habitat code 1170-14: Reefs, coralligenous assemblage). In the Mediterranean Sea, coralligenous assemblages (Perès & Picard, 1964; Sarà & Pulitzer-Finali, 1970) develop from 15–20 to 150– 200 m, both on rocky shores and on biodetritic beds, in relatively constant conditions of temperature, current and salinity, wherever irradiance is reduced between 2–3% and 0–0.5% of the surface irradiance (Garrabou & Ballesteros, 2000). Habitat conservation, threatened by anthropic activities and climatic changes, requires the monitoring of the changes occurring over time in populations and communities and the assessment of their viability and reaction towards natural or anthropic stresses. The building of datasets as a starting point for a spatial and temporal monitoring are necessary tools to attain this target. The monitoring of such habitats requires information not only related to the presence and abundance of species, but also about their health status, the presence of diseases and/or necrosis and direct signs of anthropic damage, in order to create a baseline to construct chronological series and face anthropic pressure and climate changes (Garrabou *et al.*, 1998, 2001).

The difficult accessibility of coralligenous habitat and the high heterogeneity of communities, but also the absence of standardised protocols (Ballesteros 2006; Zapata-Ramírez *et al.,* 2013) delay actual international measures of protection.
Here we have analysed by photographic and video sampling coralligenous assemblages in 10 sites along the Ligurian coasts at three bathymetric ranges: 25-39, 40-70, 71-100 m. Characterization of epibenthic assemblages, signs of injuries and diseases on gorgonians, as well as the presence of lost fishing lines and nets, have been recorded. Overall, 14 vegetal and 156 animal taxa have been considered.

Material and Methods
Ten sites along the Ligurian coasts (Fig.1) were investigated by scientific divers with photo and video sampling at three bathymetric ranges: 25-39, 40-70, 71-100 m. The analysis of the pictures allowed to characterize the epibenthic assemblages. Organisms were identified to the lowest taxonomical level and their abundance was estimated in terms of percent coverage. The analysis of the video allowed to detect signs of injuries and diseases, as well as the presence of lost fishing lines and nets. Sampling sites included both protected and unprotected areas.

Fig. 1: Sites from where photos and videos have been recorded. 1.Maledetti (MAL), 2.Canaloni (CAN), 3.Ramoni (RAM), 4.Due Balconi (SDB), 5.Isuela (ISU), 6.Altare (ALT), 7.Punta del Faro (PTF), 8.Punta Manara (PMA), 9.Punta Mesco (PME), 10.Tinetto (TIN).

Photographic surveys had standard surfaces of 16 cm x 24 cm. In each site a minimum of 20 photographic samples were haphazardly collected, at a minimum distance of 50 cm from each other and close to the video-transects.
Video-transects have an horizontal length of 10 m and were replicated 4 times at each site (four transects per site). The diver, maintained a regular distance from the sea bed and performed the entire length of the transect at a constant speed, recording parallel to the bottom. A couple of laser pointers were fixed on the camera as a measure of reference. The coordinates of the start and end of each transect were recorded.
Cover percentage of sessile organisms was quantified by superimposing a grid of 400 cells (*i.e.* 0.25% each) using the free available photoQuad software (Trygonis & Sini, 2012). Slight differences among sampling areas, due to dark and blurred zone or portion covered by motile organisms, have been accounted by standardising to the total readable area

of each image (Ponti *et al.*, 2011). Similarity patterns were displayed by unconstrained ordination plots using the principal coordinate analysis (PCO, *i.e.* metric multidimensional scaling; Gower, 1966). Vectors superimposed on to the PCO plot represented the correlations of the abundances of the most relevant taxa with the PCO axes.

Results

The PCO analysis of sites and depth highlights that the assemblages are all different among them, with an evident separation between shallow and deep sites, and the intermediate assemblages dispersed inside these two main groups. The most typical species are encrusting coralline algae and *Flabellia petiolata* for shallow assemblages, and *Corallium rubrum* and several sponges were important in deep-water assemblages (Fig. 2).

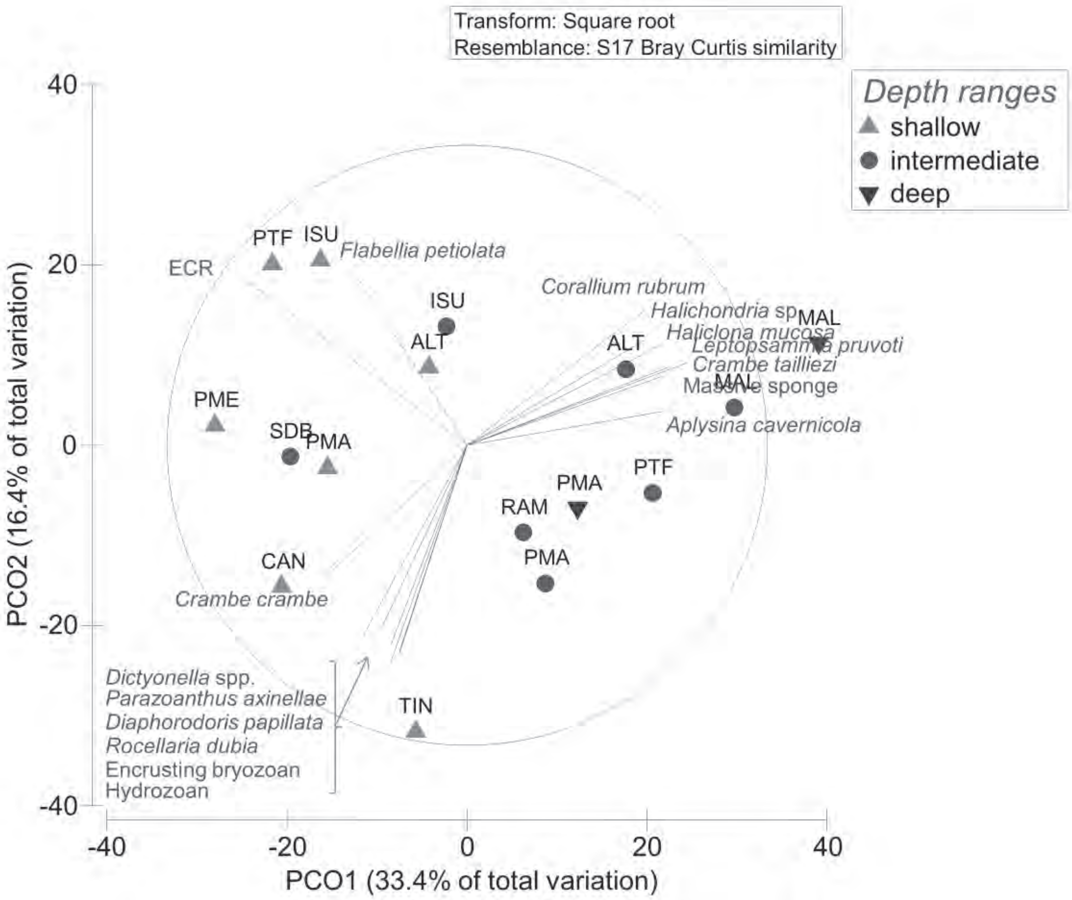

Fig. 2: PCO (Principal Coordinate Analysis) regarding the percent coverage data, transformed with square root and applying the Bray Curtis index of similarity and superimposed vectors (>0.65). Symbols represent the three considered depth ranges (shallow = 25-39 m, intermediate = 40-70 m, deep = 71-100 m) while the letters indicate the studied sites (ALT = Altare, CAN = Canalone, RAM = I Ramoni, ISU = Isuela, MAL = Maledetti, TIN = Palmaria-Tinetto, PTF = Punta del Faro, PMA = Punta Manara, PME = Punta Mesco, SDB = Secca dei Due Balconi).

Damaged gorgonian colonies were recorded at all the considered sites. The highest level of damage was recorded on *Paramuricea clavata* at Punta Mesco (40%), Altare (30%) and Manara (20%) at intermediate depths. All the other sites showed a percentage of damaged colonies around 7-9%.

In general, the lost gears were found preferentially in the intermediate and deep bathymetric range. Regarding fishing lines the sites most affected were the Maledetti, Due Balconi and Punta Manara. Results shows that sites in protected areas were less impacted from fishing gears. Anyway, in the MPA of Portofino the greater impact was documented at Punta del Faro (Fig. 3).

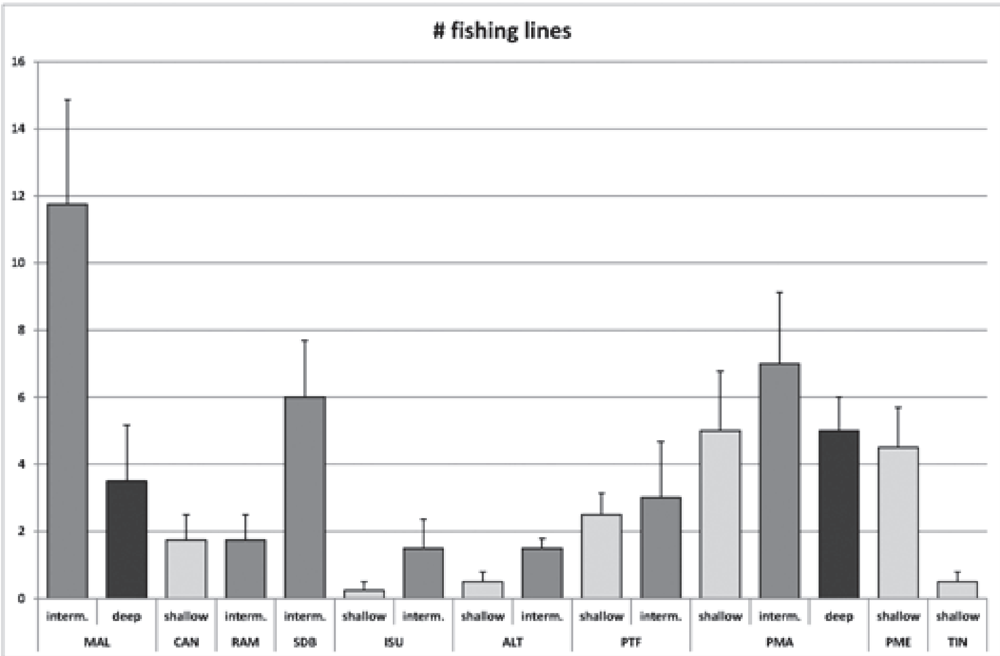

Fig. 3: Average number of lost fishing lines for each video-transect in the different sites and at the different bathymetric ranges.

Lost fishing nets were recorded mainly at Maledetti, Due Balconi and Punta Manara (Fig. 4).

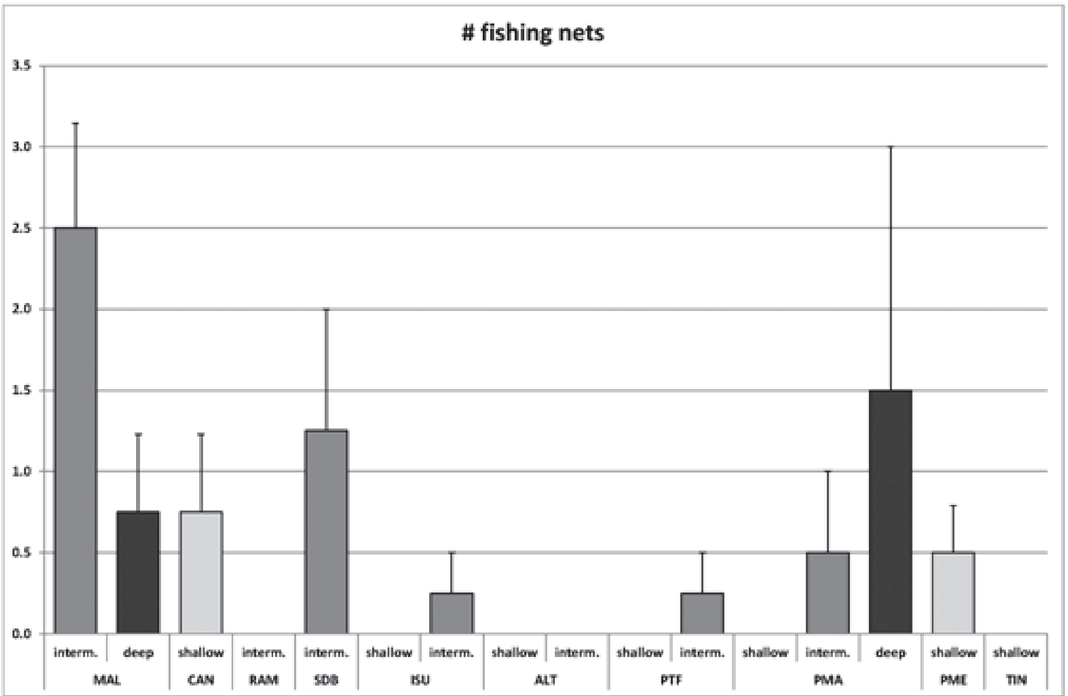

Fig. 4: Average number of lost nets for each videotransect in the different sites and at the different bathymetric ranges.

Conclusions

Despite the assemblages being very heterogeneous, species composition varied according to geographical and bathymetrical gradients. Shallow coralligenous assemblages were well separated from deep coralligenous assemblages. The shallow ones showed higher abundance of bioconstructing species, suggesting more active processes related to coralligenous growth. Deep-water assemblages revealed a higher coverage of sediments, greater signs of human impact, especially litter and lost nets and fishing lines. These results suggest that deep coralligenous assemblages is less dynamic and consequently more vulnerable, asking for the adoption of more effective measures of protection, especially regarding the impact due to fishing gears. The data on the abundance of lines and nets clearly show that the protective effect triggered by the presence of a Protected Area is well detected but it is not enough to reduce this type of impact.

Acknowledgments

This research was supported by the scientific research program of national interest “Coastal bioconstructions: structures, functions, and amanagement” (2010-11 PRIN prot. 2010Z8HJ5M_003).

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CIGESMED PROTOCOLS: HOW TO IMPLEMENT A MULTIDISCIPLINARY APPROACH ON A LARGE SCALE FOR CORALLIGENOUS HABITATS SURVEYS

Abstract
The European program CIGESMED addresses the Good Environmental Status of the coralligenous habitats. Its implementation on the field is firstly attempted by 4 protocols to be applied in France, Greece and Turkey. They have been tested in Marseille's region, since early 2014. These protocols are the following: (i) cartography of chosen coralligenous sites, (ii) spatial variability analysis by means of photo-quadrats and image processing, (iii) population genetics study of two common biobuilding species that may be cryptic (the bryozoan Myriapora truncata, and the rhodophyta Lithophyllum cabiochiae), and (iv) metagenomic approach of benthic species. The ultimate aim of these protocols is to link the results from the population genetics analysis and the spatial variability analysis to the sites' features thanks to the cartography. First results suggest that different clades exist for both complex of the previous species. Cartography forshadows models of repartition for species assemblages; they will then be compared between regions in the second part of the project.

Key-words: Coralligenous habitats, monitoring protocols, cartography, photo-quadrats, population genetics.

Introduction

The term "coralligenous", meaning coral producer, was first used by Marion in 1883 to describe the hard bottoms called *broundo* by the fishermen from Marseilles. But the meaning of this term is nowadays different, including different types of hard bottoms communities in the Mediterranean Sea. In 2006, Ballesteros recommends to use the terms "coralligenous habitats" since there exist many distinct types of coralligenous habitats.
In the current European legislation context, coralligenous habitats are considered habitats of "community interest" (Habitats Directive 92/43/CEE, habitat code: 1170-14) and should be shortly promoted as "priority" habitat. It is currently considered as the second "hotspot" of biodiversity in the Mediterranean Sea (*Posidonia* meadow being the first one), with than 1,600 species hosted by these habitats (Ballesteros, 2006). Since few years, the EU Marine Strategy Framework Directive (MSFD) requires that each country develops a strategy and an action plan in order to reach and maintain a "Good Environmental Status" for its marine habitats.
There are currently a few programs and networks for the monitoring of coralligenous habitats. CIGESMED (Coralligenous Indicators based to Evaluate and Monitor the "Good Environmental Status" of the Mediterranean coastal waters) involves three countries (France, Greece and Turkey), on a collaborative effort from 2013 to 2016. CIGESMED objectives are (1) to fulfil the key gaps in the current scientific knowledge,

(2) to enhance the knowledge on coralligenous populations by deciding on reference states and setting up a network of Mediterranean experts (for the production of long term series), (3) to monitor networks, locally managed and coordinate them on a regional scale, (4) to test population genetics criteria as tools to monitor the GES of the coastal Mediterranean Sea, (5) to implement a "citizen science" network and (6) to use trees of knowledge as tools to sort, organize and illustrate the large heterogeneous sets of produced data. This work includes habitats cartography, population genetics studies to understand species relations and dispersal potential, and the setting up of a monitoring protocol.
A phase of inter-calibration of methods/material/operators has been implemented. This step is essential in order to evaluate the variability related to these experimental parameters. It allow comparability of results obtained by different underwater protocols. Moreover, this phase of test helps to select the best protocol to apply (the easiest, and most reliable), depending on the habitats types. The next phase will be the study of natural variability inter-site or intra-sites.

Material and methods

Observations and cartography of coralligenous habitats

Intercalibration methods

The French studied sites are located in Marseilles Bay. They are transects of 10 meters long at 28 meters depth. To date, three variables of the protocol implementation have been studied: the sampling method, the quality of the camera, and the level of knowledge of operators in charge to identify species. The protocol was implemented as follow. Divers made photo-quadrats using a frame of 50 cm by 50 cm. The pictures were analysed by operators using the software Photoquad® (Trygonis & Sini 2012). Hundred points were distributed by stratified randomization. Then the operator assigned each point to one category among these three: (i) higher taxa (such as phyla, orders), (ii) abiotic, (iii) indeterminate. In the first category (i) the sub-categories are lower taxa (such as genus or species). The second category (ii) is subdivided into four sub-categories: sediment, bare rock, organic detritus or debris. In the third one (iii), there are three sub-categories: fuzzy image, shadow/hole, and unidentified taxon.

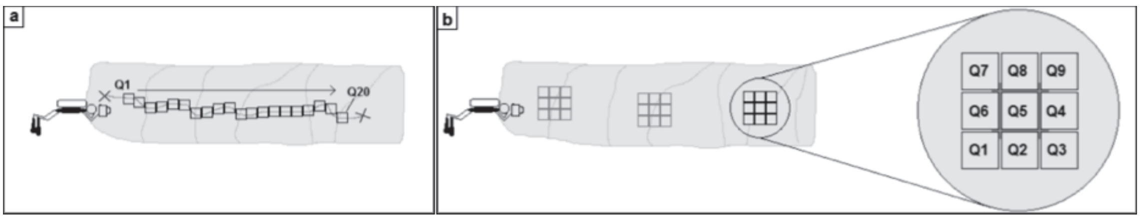

Fig. 1: The two types of transects tested. Linear transect (a): 20 photo-quadrats are taken at a given depth, located by permanent marks. Random patch transect (b): 3 groups of 9 photo-quadrats are taken, following the indicated numbers scheme from 1 to 9, several times at a same depth.

The two sampling methods compared were: (i) the permanent linear transect and (ii) the random patches transect (fig.1). To compare the sampling methods 20 photo-quadrats done by the permanent transect method were compared to 18 photo-quadrats (2 patches) done by the random patches method.
The second variable studied was the quality/performance of the camera. Two cameras have been compared: (i) a camera of medium quality and (ii) a camera of high quality. The models used are (i) GoPro®, and (ii) Nikon® D300s. To compare both cameras, two sets of 8 photo-quadrats done on a permanent transect at the exact same place, were used.
The third variable studied was the level of knowledge of the operators in charge to identify

the taxa on photo-quadrats. Two levels of operators were compared: (i) novice and (ii) experienced. The set of operators participating were: one novice and two experienced operators. Each of them analysed separately the first 5 photo-quadrats of the transect (series 1). Then they met to exchange their results (taxon identification) about this first set and re-do the identification work together to produce "validated data". Again, they studied separately the 2nd series of 5 photo-quadrats. Finally, they met again to exchange their knowledge and produce "validated" data on this 2nd series. Therefore, there is an iteration loop of 4 subsequent cycles to analyse the 20 photo-quadrats of the permanent transect.

<u>Profile characterization and cartography</u>
For each site, two depths were sampled around 28m deep (±1m), and around 45 m deep (±1m). Samples were collected along transects cut into segments of 5m long and 1m wide.

<u>Population genetics studies</u>
The aim here is to understand the population structure of the coralligenous species by studying the intraspecific diversity of demes and their connectivity. For the study of the target species, which are living throughout the Mediterranean Sea, we will use the barcoding method consisting in sequencing a part of the mitochondrial gene COI. We will eventually complete with other alternative or complementary markers. The objective is to test whether the previously-mentioned taxa consist of cryptic species in the Mediterranean.
The two chosen species are (i) the erect-like and tree-like bryozoan *Myriapora truncata*, and (ii) a complex of bioconstructing coralline algae *Lithophyllum stictaeforme /cabiochiae*. Both are identifiable *in situ*. They were selected since they have a widespread occurrence in the coralligenous communities, on all the facies and at all depths (even at very low irradiance). Standard PCR protocols is used to amplify COI fragments for both the bryozoan and the red alga, as well as another marker that is not from the mitochondrial genome, for each species (detailed methods to be published): an intron for *M. truncata* (Chenuil *et al.,* 2010; Gérard *et al*., 2013) and a chloroplast marker for *Lithophyllum sp.* (Broom *et al*., 2008). PCR products are sent to the industry for DNA sequencing, then after alignment, haplotype network reconstruction is made using the Median Joining Network software (Bandelt *et al*., 1999).

Results

<u>Photo-quadrats inter calibration</u>
The preliminary results are presented on figure 3. It shows that at the phylum level, the two methods give equivalent results. Differences of headcounts are significant only in the phylum *Porifera*. Thus results are comparable.
To compare both cameras, the pictures were not taken at the exact same time; the species *P. clavata* disturbed the observations as it had its polyps spread out or not, depending on the set. To release the experiment from this disturbance, all observations of *P. clavata* were removed from both sets. Figure 4 shows that at the species level both cameras give equivalent results. But the camera of high quality made it possible to reduce the number of "indeterminate" and these observations were assigned to other categories, in the majority at the genus level.
The preliminary results on certain categories are shown on the figure 5. After only one exchange between the three operators, the novice improves a lot his/her capacity of identification. For some categories, the level of knowledge of the three operators gets quickly homogenized: for instance for the categories *Cnidaria* and *Porifera*.

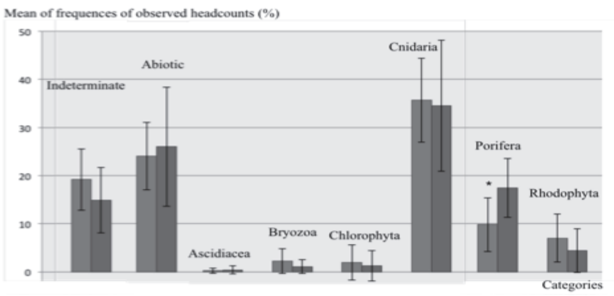

Fig. 3: Comparison of results given by the permanent transect method (light grey) and the random patches method (dark grey). *significant difference according to the Mann-Whitney- Wilcoxon test with a 5 % risk.

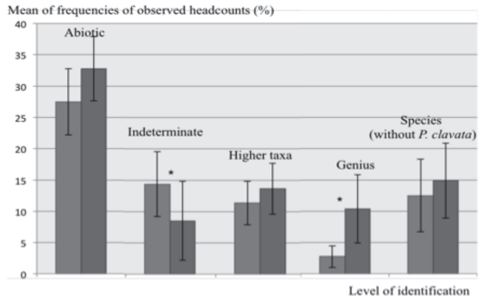

Fig. 4: Comparison of results obtained with a GoPro® (light grey) and a Nikon D300® (dark grey). The star marks a significant difference according to the Mann- Whitney-Wilcoxon test with a risk of 5 %.

They are in most case very hard to identify on photography. From this work, it appears that cnidarian species are easiest to identify on photography by beginners while poriferan species are mostly very hard to identify without specific training.

<u>Analysis of the preliminary cartography results</u>
Using Hierarchical Ascendant Classification (HAC) and Correspondence Factorial Analysis (CFA) on all processed data allowed: (i) to group species according to values of orientation, slope and roughness, and (ii) to pool profile parameters according to species observed per segment of transect. First results shows that cluster of species are better supported using combined factors of slopes and orientations. Roughness less explain the different groups. Using Factorial Correspondence Analysis and Ascending Hierarchical Classifications, preferential profiles of coralligenous species can be determined: bryozoans, encrusting and foliose red algae and foliose green algae occur preferentially on horizontal walls South-oriented with large roughness. *Eunicella cavolinii* is mainly present on inclined walls facing West/North-West with low or medium roughness. Porifera and *P. clavata* are preferentially present on vertical walls facing North. *Codium* genus and encrusting green algae are more present on walls facing South- East and North-East with tiny roughness.

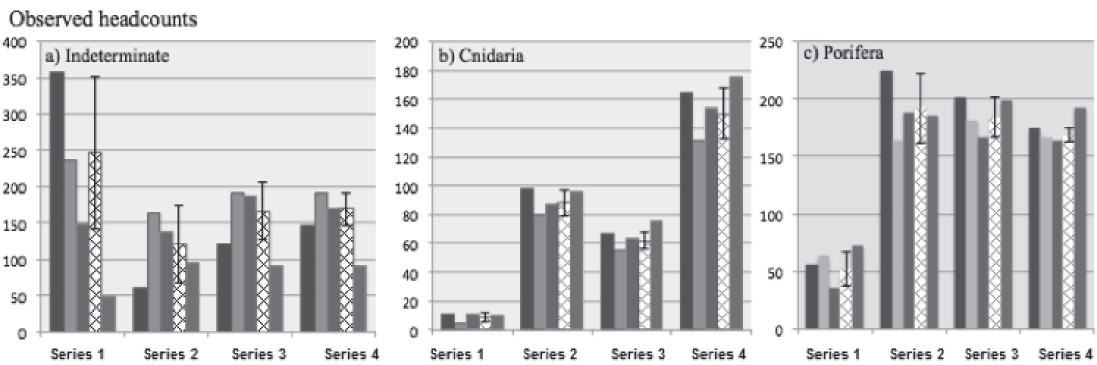

Fig. 5: Comparison of number of headcounts (example for 3phylum) observed by different operators: one novice (1st bar from left) and two experienced (2nd and 3rd bars from left). Mean and standard deviation between the three operators are in white cross-brace. The identifications validated by the three operators are represented by the bar on the right.

A "profile" is thus a combination of orientation parameters combined with inclination and roughness. Further detailed study will be conducted on associations of profile features to determine the preferential profiles of different coralligenous communities.
The cartography details the environmental profiles: depth, orientation, slope, roughness of the coralligenous wall, and main stands. The aim of this protocol is to identify the main species assemblages according to the profile type. The inter-calibration phase of the protocol in order to test the material and methods is done. The study of the variability of the results, linked to the observers and operators implementation, shows which metrics are the most robust. This phase was preliminary in order to make the results workable whatever the country of implementation. The running step permits to identify accessible metrics that are relevant, reliable and efficient to explain the "natural" spatial variability regarding the environmental context. The genetic study of *Myriapora* and *Lithophyllum* used data of sequences and molecular markers to answer taxonomic questions about these species complex and descriptions of connectivity patterns. The preliminary results are promising: the genetic study of *Myriapora* and *Lithophyllum* highlights different clades which strongly suggest that there are most probably mixtures of different species.

Discussion and conclusion

Assessment of the environmental status

The assessment consists of the analysis of the coralligenous megabenthic assemblages by means of direct observation, photographic/video surveys (which are directly influenced by competencies and experience of the operators).
The study of both sampling methods shows that observations made at a phylum level of identification are comparable if they are made according to the one or the other method. To compare Porifera observations from one site to another, it would be recommended to implement the same method in both sites, as it's shown that there might be significant difference of headcounts according to the applied method. As the random patch method is easier to perform, it should be recommended. Concerning the effect of the quality of the camera on the observations made, it has been proven that the medium quality camera is sufficient to identify as much species as the high quality camera. Difference between the two is observed for species difficult to differentiate at the genus level. Indeed, the high quality camera enables to give a taxonomic level at some individuals that were indeterminate with the medium quality camera. The study of the operator's knowledge shows that the discussion between operators enables novices to quickly improve their capacity of identification for a given set of taxa. Discussion is very useful at the beginning, and then operators reach a step, and would need a proper training to progress, if more precise identification is needed.

Population studies

The objective of the cartography goes beyond than mapping habitats; it provides information about environmental profiles that will be used to understand species preferences. Population genetics approach which will complete the analyses is essential to investigate species diversity, population structure and connectivity.
The first results about genetic differentiation of demes from distinct localities for each taxon illustrate the fact that gene flow (migration) is limited even at the small scale of Marseilles region for those important coralligenous builders. Genetic barrier were previously evidenced for other species as different as the mysid *Hemimysis margalefi* (Lejeusne *et al*., 2006) or the irregular sea urchin *Echinocardium cordatum* (Egea *et al*., 2011).

It may also be linked to ecological conditions (distribution of divergent groups of each species depending on currents and ecologic profiles to be carried out).
This preliminary work yet enables to better understand the importance of the skill and training of operators (human factor rarely taken into account) and of the implemented sampling. Indicators, from communities to infra-specific level, will be co-constructed by scientists and PMA managers, and through the implementation of a "citizen science" network. The outcome will be an integrative assessment of the GES within the MSFD.
To build the network, the community is developing a metadata catalogue and shared typologies; we are working on (i) harmonization of data collection methods and normalization of data access (European standards) (ii) initiation/animation of thematic network about coralligenous habitats in Mediterranean Sea gathering all competent actors. This network is meant to be perennial, open, and fully decentralized (to allow for continuous update) at local, regional, national and international scales. This organisation will permit data diffusion and upper accessibility and will ensure continuous improvement.

Acknowledgements

We are grateful to the organizing committee who invites us to present the first results of the project. We thank A. Haguenauer, S. Chenesseau, F. Zuberer and all the underwater diving team for their participation to the sampling in Marseilles and T. Dailianis for samples from Crete. We thank M. Verlaque who helps us for the identification of Corallinales and A. Le Gall for helpful advices. A special thanks to the SIP (Computing Service of the OSU Pytheas) who provides all the hardware part and assistance for developments. This project was funded by the SeasEra program CIGESMED (CNRS- ANR convention n° 12-SEAS-0001-01).

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POPULATION GENETICS OF *PARAMURICEA CLAVATA* (RISSO, 1826) IN THE EASTERN ADRIATIC SEA: IMPLICATIONS FOR ITS CONSERVATION AND MANAGEMENT

Abstract
The red gorgonian Paramuricea clavata is a long-lived and slow growing cnidarian. It is characterized by a fragmented distribution throughout the western Mediterranean, the Adriatic and the Aegean Sea including the neighbouring Atlantic Ocean. This species contributes significantly to the biomass and structural complexity of coralligenous assemblages. Over the last decade, P. clavata received particular attention due to ongoing threats that jeopardize its persistence, such as habitat destruction, invasive species, mucilaginous algal aggregates and global warming.
In the western Mediterranean Sea, a global picture of the population genetic structure and diversity of the species is available. However, data is still deficient in the eastern Mediterranean region. To address this gap, we have studied for the first time the conservation genetics of P. clavata in the eastern Adriatic Sea. In particular, we assess genetic diversity, population genetic structure, patterns of gene flow and levels of connectivity among populations based on a hierarchical sampling scheme (13 populations belonging to 4 regions) and using seven microsatellites. Overall, our results are concordant with previous studies on P. clavata showing a significant pairwise genetic differentiation at the local scale in combination with isolation by distance and regional genetic clustering at the global scale. Nevertheless, we demonstrate the occurrence of four regional clusters and high and specific genetic diversity when compared to previously studied regions. Moreover, this study is among the first to furnish data on low dispersive species in the eastern Adriatic Sea, thus providing new perspectives for the creation and improvement of management plans for P. clavata and associated coralligenous communities in this part of the Mediterranean.

Key-words: population genetics, red gorgonian, conservation biology, genetic clustering, isolation by distance

Introduction
The study of spatial genetic structure allows insights into various parameters such as dispersal, which have strong implications for the conservation of biodiversity (Broquet & Petit, 2009). The red gorgonian *Paramuricea clavata* is an anthozoan with a central structural role in coralligenous assemblages because it increases habitat complexity (Ballesteros, 2006). Thriving mainly on vertical rocky walls, this species is widespread along the western part of the Mediterranean Sea and in the Adriatic Sea, and sporadically in the Aegean Sea and Atlantic Ocean. Populations show patchy distribution and can be found from 5 to 200 meters in depth (Mokhtar-Jamaï *et al.,* 2011).
P. clavata is a long-lived species with a low population dynamics characterized by a slow growth rate and low recruitment rates (Linares *et al.,* 2007). It is a gonochoric species that

reproduces only sexually (Coma *et al.,* 1995). The population genetics study previously conducted by Mokhtar-Jamaï *et al.* (2011) at the scale of the whole Mediterranean Sea only considered on population from the Adriatic and demonstrated that this population belong to a distinct genetic cluster. This result called for a complementary study to characterize this fraction of the genetic pool of *P. clavata*.

The major goal of our study was therefore to define the spatial distribution of genetic diversity of *Paramuricea clavata* in the eastern part of the Adriatic Sea. To achieve this aim, we conducted a hierarchical sampling scheme (from local to regional scale) and focused on two main aspects:

i. gene diversity and population structure
ii. dispersal patterns and connectivity among populations

Materials and methods

Around 35 apical fragments of *P. clavata* colonies larger than 20 cm in height were collected at 13 sites at depths from 30 to 50 meters and distributed in four geographic regions: Senj Archipelago, Kornati Archipelago, Rogoznica Area and Pakleni Islands (Fig. 1a, Tab.1). The resulting 456 *P. clavata* fragments were genotyped using seven microsatellites: Pcla 09, Pcla 10, Pcla 12, Pcla 14, Pcla 17, Pcla 81 (Molecular Ecology Resources Primer Development Consortium *et al.,* 2010) and Pcla-a (Agell *et al.,* 2009). PCR products were analysed on an ABI 3130 Genetic Analyser at the Plateforme Genome Transcriptome de Bordeaux (France). STRand v.2.2.30 was used for scoring alleles (UC Davis Veterinary Genetics Laboratory). Microsatellite characteristics and Hardy-Weinberg equilibrium were analyzed following Ledoux *et al*. (2010).

F_{ST} for all populations and all population pairs was computed using Weir & Cockerham's estimator of F_{ST} in GENEPOP v.4.1.4 (Rousset, 2008). Pairwise genotypic differentiation between samples was tested with the exact test in (Raymond & Rousset, 1995).

Isolation by distance (IBD) pattern was analysed through the correlation of genetic (F_{ST}/ (1-F_{ST})) and the logarithm of geographic distances between populations (Rousset, 1997). Geographic distances in meters were measured among locations using GOOGLE EARTH v.7.0. The significance of the correlation between two distancematrices was tested by the Mantel test (1967) using 10000 permutations.

Analyses of molecular variance (AMOVA) were computed using ARLEQUIN v.3.5.1.3 (Excoffier *et al.,* 2005) to quantify the genetic variation among groups defined by the clustering analyses (see below; F_{CT}), among populations within groups (F_{SC}) and within populations (F_{ST}). Significance tests were conducted using 1000 permutations.

Clustering analyses were conducted in STRUCTURE v.2.2 (Pritchard *et al.,* 2000) to evaluate the number of different genetic clusters (K) from the individuals' genotypes dataset. Computations were done considering a model of admixture with correlated allele frequencies between clusters and the recessive allele option. Ten independent runs were preformed for each K (varying from 1 to 10) with a burn-in period of 200 000 followed by 500 000 iterations. The K value capturing the major structure in the data was determined based on the logarithm of the likelihood of observing the data - *lnP(D)* as a function of genetic cluster - K (see Ledoux *et al.,* 2010 for details).

Tab. 1: Details on sample locations of *Paramuricea clavata* with measures and estimations of genetic diversity based on seven microsatellite loci.

Geographic region	Sample location	Protection status	Population label	Depth (m)	No. of samples	Ho	He	f
Senj Archipelago	Ćutin Mali	unprotected	CUT	30-40	32	0.627 (0.239)	0.640 (0.190)	0.035
	Lun	unprotected	LUN	30-40	23	0.645 (0.076)	0.626 (0.126)	-0.008
	Rt Šilo, Prvić	Special Reserve	SIL	30-35	30	0.646 (0.266)	0.610 (0.244)	-0.042
	Rt Vrutak	unprotected	VRU	38-50	48	0.616 (0.224)	0.683 (0.127)	**0.109**
Rogoznica area	Smokvica	unprotected	SMO	30-40	35	0.733 (0.129)	0.732 (0.115)	0.014
	Planka	unprotected	PLA	30-40	35	0.694 (0.185)	0.702 (0.169)	0.025
	Mulo	unprotected	MUL	30-40	35	0.713 (0.189)	0.748 (0.108)	**0.062**
Kornati Archipelago	Balun	National Park	BAL	30-37	31	0.678 (0.202)	0.679 (0.194)	0.017
	Balun	National Park	BLU	35-40	39	0.690 (0.140)	0.724 (0.165)	0.061
	Mali Obručan	National Park	OBR	35-40	31	0.727 (0.170)	0.731 (0.165)	0.023
	Mana	National Park	MAN	35-40	29	0.732 (0.124)	0.717 (0.134)	-0.003
Pakleni Islands	Kampanel	Protected landscape	KAM	30-40	55	0.786 (0.125)	0.788 (0.144)	0.013
	Lanterna	Protected landscape	LAN	30-40	33	0.707 (0.194)	0.771 (0.132)	**0.100**

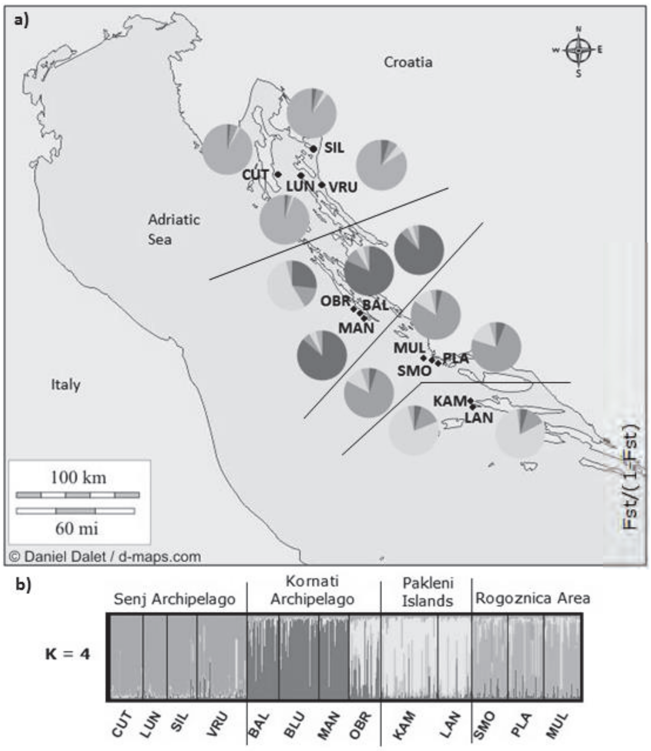
Ho - observed heterozygosity, He - gene diversity (Nei 1973), f - Weir & Cockerham (1984) estimator of F_{IS}. Presented values correspond to the mean value over all samples. Standard deviations are in brackets. Values in bold are significant at the 0.05 level after FDR correction.

Results

The mean observed heterozygosity (Ho) over populations was 0.69. The mean expected heterozygosity (gene diversity, He; Nei, 1973)over populations was 0.71. Mean He observed in MPAs is slightly higher (0.72) than in non-protected areas (0.69). However, comparing individual He values to the overall He mean, no significant difference was found between protected and non-protected areas ($p = 0.17$). Multilocus values of Weir & Cockerham's estimator of F_{IS} ranged from -0.042 for SIL to 0.109 for VRU, with a mean value of 0.032 per population. All F_{IS}were significant at the 0.05 level after correctionfor multiple tests (Tab.1).

Pairwise FST among all pairs of populations were scattered from 0.001 between BAL and BLU to 0.178 between BAL and SIL, with a mean value of 0.097. All pairwise comparisons except BAL vs. BLU were significant after correctionfor multiple tests. The correlation between $F_{ST}/(1-F_{ST})$ and logarithm of geographic distances was significant ($P < 0.001$) supporting the occurrence of an IBD model of gene flow (Fig. 2).

The IBD may bias the clustering analyses. Nevertheless, simulation studies demonstrated that clustering analyses are robust when considering the range of population genetic differentiation observed here (Aurelle & Ledoux, 2013). Therefore, the spatial genetic structure of *P. clavata* in the Adriatic results from the combination of IBD and regional clusters.



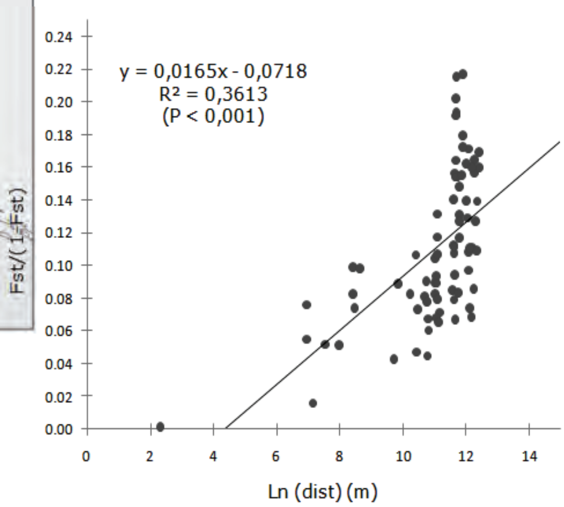


Fig.1: a) Map of 13 sampled populations of *P. clavata*. BAL and BLU are the same location but at different depths. Lines divide the four geographical areas selected for hierarchical sampling. Circles correspond to the level of assignment of each population in one of the four clusters defined by STRUCTURE as shown below the map. b) Every vertical line represents one colony

Fig. 2: Linear regression of the genetic distance (FST/(1-FST)) over the logarithm of geographic distances (m).

Using STRUCTURE, four different clusters concordant with the geographic regions analyzed were found (Fig. 1b). The AMOVA supported the clustering structure (differences among four cluster groups: 7.58%, $P < 0.001$).

Discussion

This is the first study to characterize the genetic diversity and population structure of an engineering and species with limited dispersion in the Adriatic Sea.

<u>Gene diversity and spatial population structure</u>

The level of genetic diversity was comparable to the West-Mediterranean populations of *P. clavata* (mean He by samples: 0.71 vs. 0.74). These results contrast with previous studies focused on *Posidonia oceanica* (Ruggiero *et al.*, 2002; Arnaud-Haond *et al.*, 2007) in which low levels of genotypic diversity were reported in the Adriatic samples compared to the rest of the Mediterranean. Different hypothesis such as the impact of reproductive strategies or generation time should be tested to explain the discordance between the two species.

All populations were genetically differentiated except BAL and BLU that were sampled at the same location but at different depths (30 and 40 m). Mokhtar-Jamaï *et al.* (2011) suggest that local genetic differentiation through depth may be driven by the occurrence of a spring-summer thermocline (reproductive season in *P. clavata*). Complementary studies are needed to formally test this hypothesis. However, in the Adriatic, the thermocline occurs deeper than the depths considered here (50 m, Artegiani *et al.,*1996) explaining putatively the genetic homogeneity observed between BAL and BLU. We also demonstrate the occurrence of IBD suggesting that close populations in space are more genetically connected than populations further apart in accordance with Mokhtar-Jamaï *et al.* (2011). Besides IBD, clustering and AMOVA analyses reveal the occurrence of four well-defined genetic clusters concordant with the four regions under survey.

<u>Conservation implications</u>

Considering the specific genetic diversity of *P. clavata* in the Eastern Adriatic compared to the rest of the Mediterranean, these populations should receive particular conservation attention. No significant differences in gene diversity were observed between populations inside Marine Protected Areas and the ones living in non-protected areas in spite of the time since these MPAs have been declared (1963 and 1980 for the Kornati National Park and the Pakleni Islands respectively). This should stimulate the creation of scientifically based management plans for these MPAs. Accordingly, we propose the definition of four different management units (MU) corresponding to the four regions under survey. Within each of these MUs, the MPAs should maintain networks of connectivity concordant with the IBD reported by our study and should target populations with high genetic diversity such as KAM or MUL.

Overall, this study provides crucial information that should improve the management of *P. clavata.* Accounting for the structural role of *P. clavata* in the coralligenous assemblage, these conservation measures should benefit other coralligenous species in the Eastern Adriatic region.

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ENVIRONMENTAL FACTORS EXPLAINING TAXONOMIC HETEROGENEITY OF CORALLIGENOUS OUTCROPS ACROSS FRANCE (NORTHWESTERN MEDITERRANEAN)

Abstract
Determining which environmental variables shape the assemblages observed at different sites remains a central question in ecology. Mediterranean coralligenous assemblages although comparable to tropical reef assemblages in terms of richness, biomass and production, are less known and studied, especially because of their presence in deep waters. Our goal is to investigate at a large scale the patterns of taxonomic diversity in relation to environmental and spatial factors. We used 120 stations sampled for sessile macro-organisms (vegetal and animal) with photographic quadrats all along the French Mediterranean coast (RECOR program). The influence of five physical environmental variables (longitude, latitude, surface temperature, turbidity, depth, sediment percent cover, crevice percent cover, biological remains percent cover) and three spatial variables (latitude, longitude, depth) was tested on the structure of taxa assemblages (relative abundance). In total, 173 taxa were identified. The species assemblages were explained at 28.75 % by the complete model: spatial factors explained 19.02 % of the variance while environmental factors explained 9.73 % of the remaining variance. The best model (R^2=0.27) included all the factors except two: longitude and crevice percent cover. The number of taxa was best explained by water turbidity while the shannon index was best explained by the crevice percent cover.

Key-words: alpha diversity; rocky substrate; benthos; community; macroalgae

Introduction

Understanding the influence of the environment on the spatial (bathymetric and geographical) distribution of species and/or on species assemblages is a basic question in ecology. Considering the recent literature it remains topical especially in marine ecology and moreover in sciaphilic ecosystems (Ballesteros, 2006; Balata & Piazzi, 2008; Piazzi *et al.,* 2012). Mediterranean circalittoral waters (12 - 200 m but mostly 20 - 120 m depth) harbor a unique hard substratum of biogenic origin: the coralligenous habitat. Coralligenous outcrops are built by an accumulation of calcareous encrusting algae growing in dim light conditions secondarily consolidated by sciaphilic invertebrates (polychaetes, bryozoans, gorgonians and scleractinians). Knowledge concerning coralligenous habitat does not cease to increase but remains quite local and mostly focused on a few species or only on the algal community (Balata *et al.,* 2005; Linares *et al.,* 2008; Rossi *et al.,* 2008; Piazzi *et al.,* 2012). RECOR is a large-scale program focused on coralligenous reefs monitoring along the French coast (http://www.observatoire-mer.fr/en/recor.html). Using the database generated by RECOR, we recently analyzed (Doxa *et al*, paper in preparation) three facets of biodiversity (taxonomic, phylogenetic and functional diversity). We showed that the spatial structure of taxonomic diversity differs from that of functional and phylogenetic diversities at the station level, in particular, no significant variation was observed over depth for taxonomic diversity, whereas functional and phylogenetic diversities significantly decreased vertically. However, taxonomic, functional and phylogenetic dissimilarities among assemblages increased over depth mainly in east of the French riviera certainly because of environmental variables. Now, using a large-scale database (2000 km of coastline), our goal is to investigate the patterns of species diversity in relation to environment and geographical place.

Materials and Methods

Sampling method. Between 2010 and 2013, 120 stations presenting coralligenous bioconstructions were sampled (depth between -17 and -90 m) along the French Mediterranean coast. Each station was sampled once (in June) at a rate of 1/3 of the coast per year. Temporal changes in species assemblages are assumed to be small from one year to another (Deter *et al.*, 2012; Garrabou & Harmelin, 2002) apart from exceptional events (Garrabou *et al.,* 2009; Teixido *et al.,* 2013) that did not occur since 2006 along the French coast. The stations were chosen in order to represent different environmental conditions with a minimum of one site per water body (body of water having relatively homogeneous physical-chemical characteristics according to the Water Framework Directive (WFD, Directive 2008/56/EC)). Coralligenous assemblages (sessile macro-organisms) were described from photographic quadrats taken at each station by a CCUBA (Closed Circuit Underwater Breathing Apparatus) diver according to Deter *et al.* (2012). Relative abundances were calculated after the analysis of each picture (64 random points per quadrat) with CPCe 4.1 "coralligenous assemblages version" (Kohler & Gill, 2006). Environmental parameters like sediment, biological remains (mostly fragments of bryozoans, gorgonians and calcareous algae) and crevice percent covers were estimated by the same way. Taxonomic nomenclature follows (WoRMS Editorial Board, 2014) and (Guiry & Guiry, 2014). Where identification at the most detailed level of taxonomical resolution was not possible, animals were grouped in phyla. Hydrozoa and encrusting Bryozoa (except *Schizomavella mamillata*) were not identified further and were classified as "Hydrozoa" and "Encrusting Bryozoa". Unidentifiable organisms were classified as "unknown" and were not considered in analyses after verifying they never exceeded 10 %. Similarly, mobile organisms (fish, crustacean) were not considered in analyses. Most of the data are available on the Medtrix cartographic platform available at http://observatoire-mer.fr/en/.

For each station, spatial variables i. e. latitude, longitude and depth were sampled by the divers with a GPS and a depth-meter. Environmental variables consisted in sediment, crevice and biological remain percent covers obtained from the pictures analysis but also data obtained from PREVImer (http://www.previmer.org): mean surface temperature and water turbidity. Environmental variables are supposed to highly vary in function of the region because of the dominant East-West flow (North Mediterranean current) and the Rhône river discharge that increases turbidity West of Marseille.

Statistical analyses. First, the influence of the region (three regions: French Riviera (roughly, East of the Rhône river), Languedoc-Roussillon (roughly, West of the Rhône river) and Corsica) on the environmental and spatial variables was explored using ANOVA. Second, community data were analysed with Primer 6.1.11 and PERMANOVA+ for PRIMER software (Primer-E). The matrix of species relative abundances obtained from photos was "log X + 1" transformed (because it was based on percent covers) and similarity between samples was estimated using Bray-Curtis indices. The run of ordination by non-metric multidimensional scaling (nMDS) on the similarity matrix provided a visual representation of the pattern of proximities and allowed to eliminate potential outliers. The existence of a regional effect on species assemblages was tested using an ANOSIM (two-way analysis of similarities). Variance partition of a model containing the spatial and environmental variables was calculated using a Distance-based linear model (DIST LM). The same procedure was used in order to select the best model explaining the taxa similarity matrix with AICc. A distance-based redundancy analysis allowed visualizing the variation captured by the fitted model with two axes. All *P*-values were obtained with permutation tests (9 999 permutations). The influence of the environmental and spatial data on three diversity indices (number of taxa, Shannon index and Simpson index) was also searched using Generalized Models and AICc. This latter was performed using Statistica 8.0 (Statsoft, Inc. 2007).

Results

After extraction of eight outliers (the deepest and shallowest stations), analyses were performed on 112 stations (62 sites). These stations ranged between 24 and 75 m (52 m on average). Environmental variables showed significant differences (all $P < 0.001$) depending on the region except for biological remains, crevice percent cover and turbidity ($P > 0.2$). The deepest stations and the lowest sediment percent covers were sampled in Corsica where the communities were different from the other regions ($P < 0.01$). No relationship was found between depth and sediment cover ($r = -0.059$; $p = 0.534$).

Considering the assemblages, in total, 173 taxa were identified including species and phyla for unidentified organisms. All of the taxa reported here were commonly listed by other studies focusing on coralligenous habitats. The species assemblages were well explained by the complete model (28.75 %): spatial factors ($P = 0.001$) explained 19.02 % of the variance while environmental ($P=0.001$) factors explained 9.73 % of the remaining variance. The best model ($R^2=0.27$) included the following factors: latitude (pseudo-F=11.39, P=0.001), depth (pseudo-F=7.23, P=0.001), water temperature (pseudo-F=7.81, P=0.001), water turbidity (pseudo-F=4.45, P=0.001), sediment percent cover (pseudo-F=5.71, P=0.001) and biological remains percent cover (pseudo-F=1.93, P=0.038). The distance-based redundancy analysis (Fig. 1) showed that the deepest stations were characterized by two sponges, while the shallowest ones were characterized by algae. Filamentous algae were more characteristic of Northern latitudes and lower temperatures while non-identified green macroalgae were linked to higher temperatures. *Peyssonnelia* sp and erect bryozoans were more abundant at stations presenting higher biological remains and sediment percent covers.

The number of taxa was best explained by water turbidity (W stat. = 5.62, $P = 0.018$) according to a negative relationship (Fig. 2). The shannon index was best explained by the crevice percent cover (W stat. = 4.84, $P = 0.028$). No factor was found to significantly explain the Simpson index.

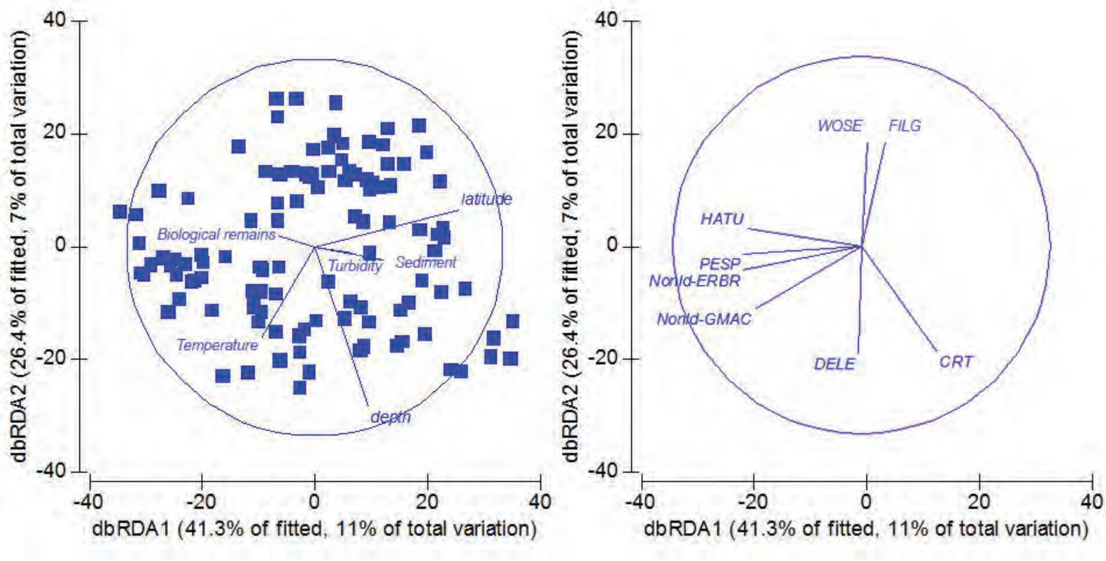

Fig.1: Distance-based redundancy analysis performed with the taxa matrix and the spatial and environmental factors selected within the best model. Only taxa presenting Spearman coefficients higher than 0.55 are showed. HATU = *Halimeda tuna*, WOSE = *Womersleyella setacea*, FILG = non identified green filamentous algae, CRT = *Crambe tailliezi*, DELE = *Dendroxea lenis*, NonId-GMAC = non identified green macro-algae, NonId-ERBR = non identified erect bryozoa, PESP = Erect *Peyssonnelia* sp.

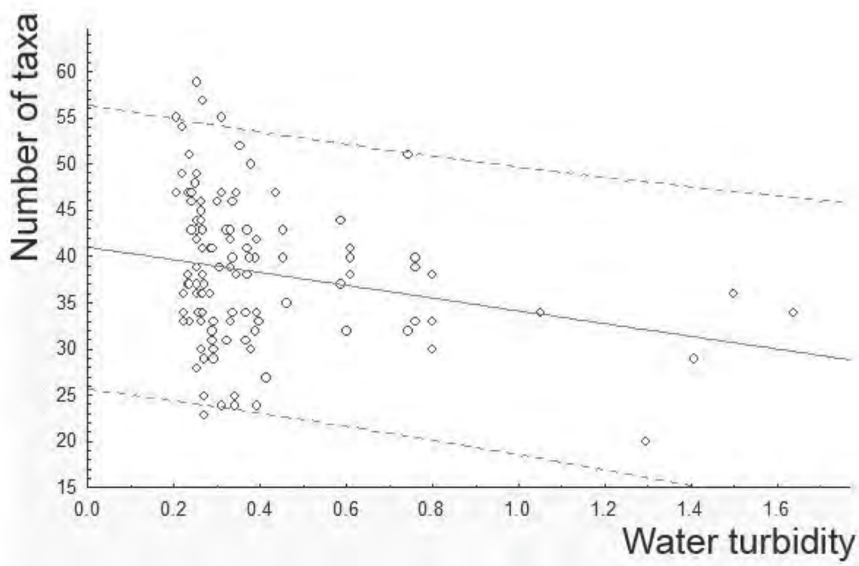

Fig. 2: Number of taxa in function of the water turbidity (in Nephelometric Turbidity Unit). The 0.95 confidence interval of prediction is presented

Discussion

As expected, coralligenous assemblages showed regional dissimilarities in particular Corsica which concentrates extreme geographical localizations (East, South) and environmental particularities. The Corsican waters are oligotrophic and thus very clear allowing the coralligenous outcrops to develop deeper than along the French continent.

The similarity within the coralligenous assemblages was mostly explained by spatial data: 3D coordinates allow explaining almost 20 % of the similarity within the assemblages (the depth participated at 6 %). This has an important impact for conservation that often forgets the depth component. Adding environmental data added 10 % of explanation. The most parsimonious model was quiet good and included two spatial variables (latitude, depth), two water characteristics (temperature, turbidity) and two local parameters (sediment and biological remains percent covers). Longitude was certainly too much redundant with environmental variables to be kept within the model and crevices certainly most influences the communities within the crevices (not sampled) than around. The influence of turbidity was commonly showed on coralligenous communities (Ballesteros, 2006; Balata & Piazzi, 2008). The deepest stations were characterized by two sciaphilic sponges (*Dendroxea lenis* and *Crambe tailliezi*), while the shallowest were characterized by algae especially *Halimeda tuna*, a green algae common on shallow water banks (Ballesteros, 2006). Filamentous algae were more characteristic of low temperatures while the contrary would have been expected, this could be due to a confounding effect of nutrient enrichment which is higher along the continent and thus at Northern latitudes and lower temperatures.
Peyssonnelia sp. and erect bryozoans were often at the origin of the biological remains observed, it explains why they were more abundant at stations presenting higher biological remains. *Peyssonnelia* sp and erect bryozoans were also more abundant at stations presenting higher sediment percent covers suggesting a siltation tolerance for these taxa. The shannon index was best explained by the crevice percent cover which means that the available space and/or the reef 3D structure might influence the coralligenous diversity.

Conclusion

This study confirms the importance of geographical but also bathymetric localization of coralligenous outcrops on their taxonomic diversity. It presents important implications for the preservation of this rich habitat. Identified influential environmental parameters were temperature, turbidity-sediment and substrate. We highlighted several taxa in relation with environmental variables, however an analysis performed species per species will permit to precise the ecological preferences of each species.

Acknowledgments

This study beneficiated of a financing from the French Water Agency (Agence de l'eau Rhône-Méditerranée-Corse) in the framework of RECOR, the monitoring network for coralligenous assemblages. Florian Holon received a PhD grant (2013-2016) funded by LabEx CeMEB (Laboratoire d'excellence "Centre méditerranéen de l'environnement et de la biodiversité") and Andromède Océanologie. We thank the other members of the 2010-2013 RECOR teams for the logistical support during the field work. We are also grateful to Marc Verlaque, Jean Vacelet and Enrike Ballesteros for their punctual help with species identification. Many thanks also to Pierrick Beretta, Aggeliki Doxa and OSU OREME for their help in building the data base.

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MEDTRIX: A CARTOGRAPHIC DATABASE FOR MARINE ECOLOGY AND ANTHROPOGENIC PRESSURES ALONG THE MEDITERRANEAN COAST

Abstract

Biodiversity hotspot, commercial exchanges area and major touristic destination in the world, the Mediterranean sea concentrates important and paradoxical stakes. In this context, it is even more essential to analyze species and habitat distribution, environmental variables and human threats but also their correlates, and likely consequences. The spatial distribution of anthropogenic pressures is particularly interesting because this is the basis of numerous other studies: ecological indicators development, species distribution analysis, reserve design, conservation plan…But the data that we need in order to provide spatial resolution relevant for management considerations are still lacking or not easy to reach. Here we describe Medtrix (http://www.medtrix.fr), a cartographic platform that regroups different databases made available for marine professionals (scientists, managers, stakeholders). This meta-database is the first one available at such a good resolution (20 m for the anthropogenic pressures) all along the French Mediterranean coast and along some other countries (Tunisia, Italia). These cartographic data concern for the moment anthropogenic pressures (harbors, wastewater, population density, aquaculture), 1:5000 seabed habitat maps, marine mammals observations but also monitoring of the two most important ecosystems in Mediterranean sea: Posidonia oceanica seagrass (presence/absence, vitality) and coralligenous habitat (presence/absence and diversity data). The platform proposes different functionalities like editing maps but also to directly comparing sites. One of the databases is already the basis of a management tool: DONIA® application which helps yachtsmen to anchor in a safe (environment and security) way.

Key-words: coastal; water quality; marine habitats; human-driven; impact; modelling

Introduction

Conservation biology interests in addressing the biology of species, communities and ecosystems that are directly or indirectly perturbed by human activities or other agents in order to preserve biodiversity. It necessitates data from different scientific fields, at a spatial resolution relevant for management considerations and appropriate analysis tools. Large-scale data are more and more available concerning biodiversity data (Kaschner *et al.*, 2013) or human threats (Halpern *et al.*, 2008) but the resolution remains low (mostly 0.5 ° (=75 km) or sometimes 0.1° =15 km).

Here we describe Medtrix, a cartographic platform that regroups different databases made available for marine ecologists. Medtrix makes available seabed habitat maps and ecological data concerning the two most important Mediterranean marine ecosystems (*Posidonia oceanica* seagrass and coralligenous habitat), but also anthropogenic pressures (man-made coastline, wastewater, population density, aquaculture, boat anchoring, land use, macrowaste, hydrocarbon pollution localization and/or impact). This meta-database is the first one available at such a good resolution (20 m for the anthropogenic pressures) all along the French Mediterranean coast and along some other countries (Tunisia, Italia).

Materials and Methods

The data hosted by Medtrix are only disabled for logged-in people trough the “connection” index at http://www.medtrix.fr/. Interested people need thus previously to freely create a count at the homepage by clicking on « inscription ». Data made available on the platform Medtrix are provided according to the terms of the Creative Commons Attribution-Non Commercial-NoDerivs 3.0 Unported License.

Medtrix uses the open source application LizMap, a complete solution for the publication of QGIS maps on the web. The basic operations of Medtrix consist of making available different databases (projects) related to the Mediterranean coastal water quality and proposing dynamic and cartographic results. Once the user is logged-in, he can choose the project he wants to open.

Results

For the moment (August 2014), 338 professionals are registered on Medtrix.fr and we count two new users, 55 connections and 40 prints of maps every day.

Five databases (called “projects” on the platform) are made available on Medtrix; they concern water quality monitoring networks (RECOR, TEMPO), pressure monitoring networks (Anthropo-map, MEDOBS) and a seabed habitat description (DONIA® expert with its so-called application). The methodologies used for each project are detailed on the website http://www.observatoire-mer.fr/en/.

Briefly, MEDOBS identifies and positions pressures (activities and pollution) undergone by the Mediterranean Sea since 2010 with the help of a sophisticated numeric video camera taken on a plane. Since 2012, data concerning marine mammals and tuna are also referenced (Fig. 1).

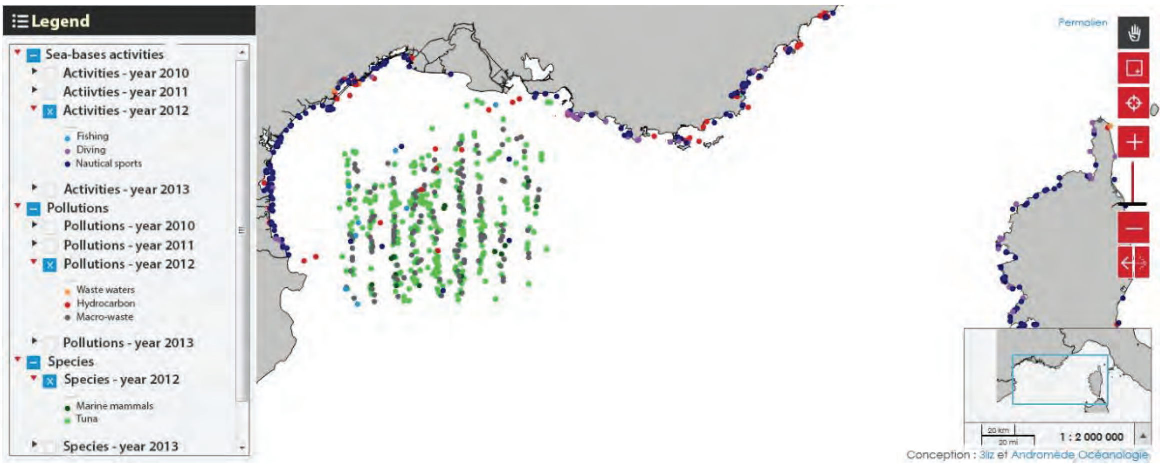

Fig. 1: Example of map built with MEDOBS data (activities, pollutions and species) collected in 2012

Anthropo-Map consists in modeling at a large-scale (French Mediterranean) the spatial extent (resolution = 20 m) of anthropogenic pressures impacts on the marine environment. Six different pressures (bases on quantitative data) are visualized for their spatial extent: aquaculture, boat anchoring, sewage, man-made, land use and costal population density.

RECOR is a monitoring network for coralligenous assemblages using a non-destructive methodology (Andromède océanologie, 2013a). Along the French coast, RECOR includes 157 stations regrouped in 86 sites (several stations = sampling depths per site)

localized within the coralligenous habitat distribution known from DONIA (see thereafter). These stations are distributed between 17 and 90 meters deep and are monitored every three years at the end of spring (June). Coralligenous assemblages (sessile organisms) are described from photographic quadrats taken at each station by a CCUBA (Closed Circuit Underwater Breathing Apparatus) diver (Deter *et al.*, 2012a).
TEMPO is a monitoring network that collects descriptive data concerning *Posidonia oceanica* beds dynamics and studies their evolution in time and space. Since 2011, 60 sites (100 m² in average) between 5 and 40 m depth are monitored all along the Mediterranean French coast at a rate of one third of the coast per year. Each TEMPO site is monitored at the end of spring (June) according to the method detailed in (Andromède océanologie, 2013b).
DONIA®expert makes available a 1:5000 map for seabed habitats using ten habitat classes. Besides the complete French Mediterranean coast (L-R, PACA, Corsica), several Mediterranean islands are concerned in DONIA®expert: Galite archipelago in Tunisia, Zembra island in Tunisia and Tavolara - Punta Coda Cavallo in Sardinia (Italy). This work pools, homogenizes and completes the maps built in the framework of numerous programs (see acknowledgments). A simplified database called DONIA® intended for general public is also available on Medtrix without any login. The same regions are concerned but habitats were simplified into four classes (seagrass, dead matte, sand, rock) instead of ten. This simplified dynamic map is freely accessible to all though DONIA® application (App Store and Google play), helping boat to anchor safely outside of sensitive habitats.

Discussion

Since its opening in September 2013 with only two databases at the beginning, the cartographic platform Medtrix has largely expanded with six projects in August 2014. Its utility is demonstrated by its 338 professional users with varied profiles: stakeholders, managers, researchers, engineers and other ecologists. In spite of its opening in the first place, RECOR and TEMPO (respectively 1837 and 1659 views) are largely less visited than DONIA® and DONIA®-expert (8113 and 6375 views) opened three months later. But the perspectives remain huge and we briefly expound them thereafter. The success of DONIA ® is easily explained by its general public target without any log-in and the communication it beneficiated thanks to two awards received: "enterprise and biodiversity" from the French Ministry of environment and "bateau bleu" from the French nautical industrials. Linked to this simplified database and proposing more general data, DONIA®-expert is thus naturally more consulted than RECOR and TEMPO. Note that these maps are now available in two dimensions but the passage to 3D is in progress and will permit to calculate real areas covered by habitats in reliefs (Andromède océanologie, 2013c; Andromède Océanologie, 2014; Hoechstetter, 2008). This will be the aim of the next project available soon on Medtrix: SURFSTAT (Andromède océanologie, 2013c).
RECOR, TEMPO (and to a lesser extent MEDOBS) provide abundance and localization data for diverse species among which several ones are protected (*Corallium rubrum*, *Pinna nobilis*, *P. oceanica* …). Moreover, sampling at a community scale (RECOR) permits to consider conservation questions on the base of an integrated ecosystem approach more than on some charismatic species (Fraschetti *et al.*, 2002, 2005). Data were already used for different studies (Deter *et al.*, 2012a, 2012b) (Doxa *et al.* in preparation; (Holon *et al.*, 2014).

Anthropo-map is particularly interesting for all the scientists working on the Mediterranean Sea as it regroups spatial quantitative data concerning the most important pressures undergone by the basin. Some data already do exist but they are either very localized and restricted to one or some pressures (Forchino *et al.*, 2011; Kress *et al.*, 2004) or very extended with a higher resolution (one degree = 25 km; (Halpern *et al.*, 2008; Micheli *et al.*, 2013). The fine resolution of Anthropo-map (20 m) allows at last apprehending the spatial scale managers are interested in.

Conclusion

The cartographic platform Medtrix is a prodigious source of information for a large community of scientists with varied questions. Different functionalities allow to display information concerning the project, see pictures, print a pdf of the map at the chosen scale, measure areas, perimeters or lengths and geolocalized your position via the web navigator. Moreover, stations may be easily and directly compared between each other thanks to the generation of tables and graphic cursors.
Medtrix is continually updated and suggestions-collaborations from other researchers are welcome.

Acknowledgments

This study and all data samplings beneficiated of a financing from the French Water Agency (Agence de l'eau Rhône-Méditerranée-Corse) in the framework of the different monitoring networks it supports. MEDOBS data are collected by Observatoire MEDOBS. TEMPO, RECOR data are collected by Andromède océanologie. Anthropo-map maps were created on the basis of data collected by Andromède Océanologie, IFREMER, INSEE, MEDAM, MEDOBS, MEDAM and SHOM. Maps available with DONIA® were created from data collected byAndromède océanologie; Agence de l'Eau RMC;Conservatoire du Littoral; DREAL PACA; EGIS EAU; ERAMM; GIS POSIDONIE; IFREMER; Institut océanographique Paul Ricard; Nice Côte d'Azur; TPM; Programme CARTHAM - Agence des Aires Marines Protégées & Andromède océanologie, ASCONIT Consultants, COMEX-SA, EVEMAR, GIS Posidonie, IN VIVO, Sintinelle, Stareso; Programme MEDBENTH; Université de Corse (EQEL); Ville de St Cyr sur mer; Ville de Cannes; Ville de Marseille; Ville de St Raphaël; Ville de St Tropez. TEMPO and RECOR are part of OSU-OREME within the observation system "littoral et trait de côte". Florian Holon received a PhD grant (2013-2016) funded by LabEx CeMEB (Laboratoire d'excellence "Centre méditerranéen de l'environnement et de la biodiversité") and Andromède Océanologie. We thank all the people who participate to field work and/or map making in the framework of these monitoring networks.

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LONG-TERM MONITORING OF *CLADOCORA CAESPITOSA* REEFS IN THE COLUMBRETES ISLANDS: FROM MAPPING TO POPULATION DYNAMICS AND THREATS

Abstract
Cladocora caespitosa is the only zooxanthellate reef-building scleractinian coral endemic to the Mediterranean Sea. Today, living banks of this long-lived structural species appear to be restricted to few locations. The population of C. caespitosa in the Illa Grossa Bay (Columbretes Islands Marine Reserve, NW Mediterranean) has been studied and monitored continuously since 2002. The extensive field of colonies shows a cumulative cover of 2900 m^2 with a highly aggregated distribution and geographical isolation. Our results show that C. caespitosa exhibits highly parsimonious dynamics: slow growth (~2.5 mm yr^{-1}), low recruitment (~ 0.30 recruits m^{-2} yr^{-1}) and natural mortality rates close to 1 %. The study of its reproductive biology shows that spawning occurs at the end of summer when algal cover is low, thus favouring coral larvae settlement. However, global change is rapidly altering Mediterranean marine habitats such as Cladocora banks, primarily through warming and the spread of invasive species. Positive thermal anomalies have severely impacted this population from 2003 to 2012, causing the necrosis of about 50 % of the area covered by this coral. On the other hand, invasive algae (Lophocladia lallemandii and Caulerpa racemosa) have overlapped their distribution with C. caespitosa. While no lethal effects of the invasions have been detected, sublethal effects on other stages of the corals life cycle cannot be disregarded. In long-lived corals such as C. caespitosa, recovery from impacts relies mostly on recruitment. However, the low recruitment rates are exceeded by the recurrent mortalities and both warming and invasive algae may have delayed and synergetic effects on the coral. These results highlight the endangerment of this species and its reefs facing rapid environmental changes.

Key-words: Bioconstructions, population dynamics, global change, mortality, endangered species

Introduction
In the Mediterranean Sea long-lived ecosystem engineer species are well represented in circalittoral coralligenous outcrops (*e.g.*, *Paramuricea clavata* and *Corallium rubrum*; Garrabou & Harmelin, 2002; Linares *et al*., 2007). However, long-lived animal species with an important structural role are quite rare in Mediterranean shallow infralittoral communities and the endemic coral *Cladocora caespitosa* is one of the few examples. This reef-builder coral inhabits mostly in shallow communities (Zibrowius, 1980), although it may also occur in greater depths, including circalittoral communities (Kersting & Linares, 2012; Morri *et al*., 1994).
While drastic shifts should not be expected in these organisms, nowadays global change is forcing rapid alterations that trigger complex and highly variable responses; reinforcing the crucial need for long-term studies to assess changes and trends in the biological parameters of long-lived, slow-growing species.

Cladocora caespitosa banks are in regression in the Mediterranean Sea (Morri *et al.,* 2001) and this process in being accelerated by impacts driven by climate change (Kersting *et al*., 2013a; Rodofo-Metalpa *et al*., 2005). In this context of general decline the gathering of baseline data on the distribution and health status of the *C. caespitosa* populations is highly needed in order to evaluate the general status of the species and to assess the resilience and future viability of its emblematic banks.
Here we review the main results of 12 years of continuous monitoring of the *C. caespitosa* population in the Illa Grossa Bay (Columbretes Islands, NW Mediterranean). The research has been mainly focused in studying the structure and dynamics of this population as well as its resilience to the main threats.

Materials and methods

The volcanic archipelago of the Columbretes Islands is located 30 miles off the coast of Castelló (Spain, NW Mediterranean). The biggest of its islets, Illa Grossa, encloses a drowned volcanic caldera, which hosts the studied *Cladocora caespitosa* population.
Studies started in 2002 and have lasted until 2013. The main characteristics of this population have been studied during this period: spatial distribution, growth rates, reproductive traits and population dynamics. Its responses to the global change-related disturbances have also been studied: warming and invasive algal species. This has been achieved by using mapping techniques and the monitoring of permanent plots and transects (250 colonies) to obtain recruitment and mortality rates (during 5 and 12 years, respectively) and information on the interaction of the coral with the invasive algae *Lophocladia lallemandii* and *Caulerpa racemosa* (8 years). Laboratory techniques were applied to describe its reproductive biology through histological analyses, to assess the coral's toxic activity using Microtox® bioassay and to obtain growth rates by means of alizarin red staining and x-ray techniques.
Sea surface temperature (SST), used to assess the relation between warming and necrosis in *C. caespitosa* colonies, has been measured daily since 1991 in the Columbretes Islands. Summer SST anomalies (*i.e*., the temperature obtained in the studied summer minus the average of the summers from the original data set [1991 - 2013]) were obtained for the studied summers (June - September, 2002 - 2013).

Results

The cover of *Cladocora caespitosa* colonies in the Illa Grossa Bay was estimated in 2900 m^2. The spatial distribution of the colonies in the bay was significantly aggregated (Moran's I, $p < 0.01$) and highly related to bottom morphology.
Cladocora caespitosa exhibited highly parsimonious dynamics: slow growth (~2.5 mm yr^{-1}), low recruitment (~ 0.30 recruits m^{-2} yr^{-1}) and natural mortality rates close to 1 %.
Histological analyses showed that the species is gonochoric in W Mediterranean (Fig. 1), with a spawning period at the end of summer - beginning of autumn, in coincidence with decreasing water temperature.

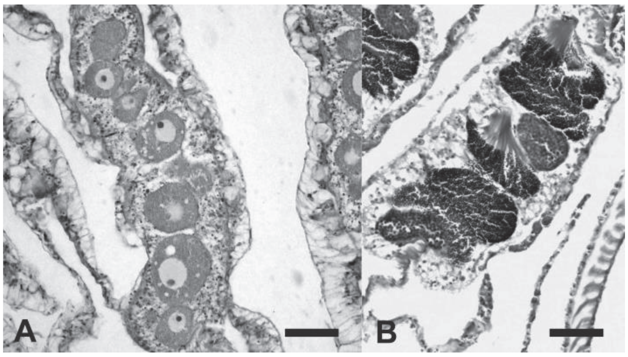

Fig. 1: Gonads of *Cladocora caespitosa*. (A) Female septum packed with mature oocytes (July 2008). (B) Male with spermaries filled with spermatozoa (August 2008). Scale bars = 50 µm. Adapted from Kersting *et al.* (2013b).

The results of 12 years of monitoring showed that necrosis was significantly associated to positive thermal anomalies ($r = 0.76$, $p < 0.005$). During that period, over 50 % of the coral cover in the bay was lost due to recurrent necrosis events that occurred after 9 summers (2003-2006, 2008-2012) (Fig. 2).

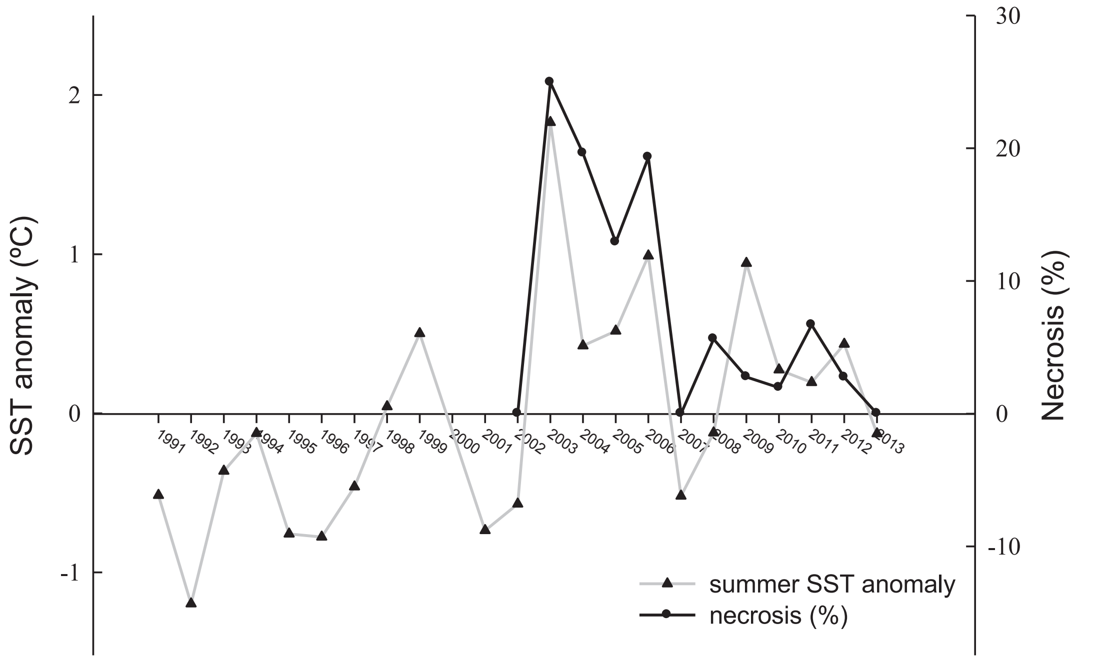

Fig. 2: *Cladocora caespitosa* necrosis rates (2002-2013) and summer SST anomalies (1991-2013). Adapted from Kersting *et al.* (2013a).

No lethal or sublethal effects of the invasive algae *Lophocladia lallemandii* and *Caulerpa racemosa* were detected on *C. caespitosa*. There were no significant effects on the warming-induced necrosis in colonies affected by *L. lallemandii* and *C. racemosa* compared with unaffected colonies (repeated measures ANOVA, $F_{2,57} = 0.283$, $p = 0.754$) and no significant differences were found when comparing measured *in situ* photosynthetic efficiency on *C. caespitosa* colonies affected and unaffected by *C. racemosa* and *L. lallemandii* (one-way ANOVA, $F_{2,207} = 0.482$, $p = 0.618$). On the other hand, our results showed that *C. racemosa* significantly avoids growing on living coral colonies (repeated measures ANOVA, $F_{3,186} = 7.280$, $p < 0.001$) (Fig. 3) and the Microtox® bioassay showed that the coral shows toxic activity.

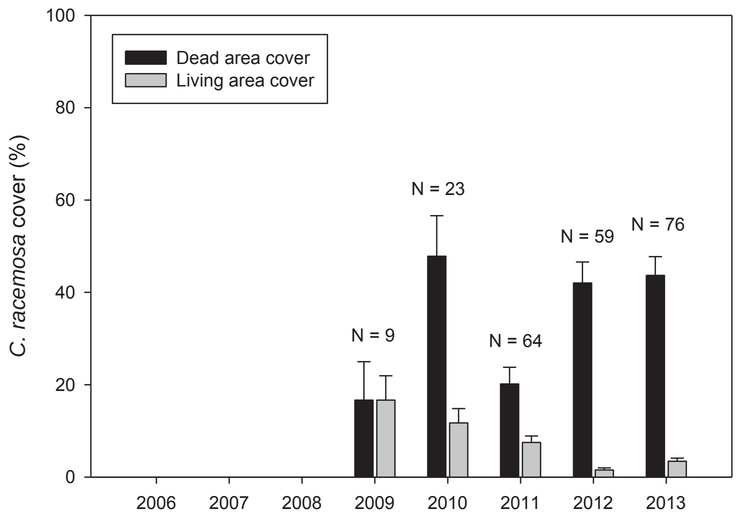

Fig. 3: Annual percentage of necrosed and living coral colony areas (mean ± SE) covered by *Caulerpa racemosa* (N = number of *Cladocora caespitosa* colonies with *C. racemosa*). Adapted from Kersting *et al.* (2014a).

Discussion and Conclusions

The *Cladocora caespitosa* population of Illa Grossa Bay and its bioconstructions can be considered, in terms of colony number and cover, as one of the most relevant at a Mediterranean level together with the bank described in Mljet National Park (Croatia, Adriatic Sea) by Kružić & Benković (2008).

As our results showed, global change and specially warming has become one of the major threats to this coral, demonstrating its role as bioindicator of climate change effects in shallow environments. Necrosis and SST anomalies showed a significant association and during the studied period every summer with positive thermal anomaly triggered necrosis to some extent. It has to be highlighted that extremely hot summers, like 2003, have the potential to cause devastating effects in this coral. After the summer of 2003 mass mortalities of benthic organisms were described over thousand kilometres of coastline in NW Mediterranean (Garrabou *et al.*, 2009). This summer triggered 25 % of average necrosis in the *C. caespitosa* colonies of Illa Grossa Bay and 13 % of the colonies died completely. But the effects of the summer of 2003 went beyond. The results obtained through long-term monitoring of marked colonies showed that this summer had a great influence in the necrosis rates of the oncoming milder summers (2004 and 2005), causing higher mortality rates than expected (Fig. 2).

Climate models predict an increase in extreme events for the 21st century in the Mediterranean (Déqué, 2007; Diffenbaugh *et al.*, 2007) and, in fact, the frequency of positive thermal anomalies has increased in the Columbretes Islands 4 times when comparing the 1990s decade to the 2000s (Fig. 2). Therefore, high rate necrosis events are very probable to occur in the near future.

On the other hand, the presence of invasive algae had no lethal effects in adult *C. caespitosa* colonies, although sublethal effects on other life cycle stages (*e.g.*, recruits and juvenile colonies) cannot be disregarded. The capacity of this coral to keep the invasive *C. racemosa* out of its colonies is probably related to anti-fouling mechanisms (coral's toxic activity), which are undoubtedly an advantage when competing in dynamic, algal dominated communities. The spawning period of the species, after the summer when algal cover decreases, is another example of adaption to the dynamics of such environments.

Recovery from disturbances depends highly on recruitment; however our results showed low recruitment rates for this species. Problems arise when catastrophic disturbances become more frequent and mortality exceeds sporadic recruitment (Hughes *et al.*, 1999; Kersting *et al.*, 2014b).

Overall, the slow dynamics and reduced recovery potential of *C. caespitosa* highlight the vulnerability of the sole scleractinian reef-builder endemic to the Mediterranean Sea, especially in front of the rapid alterations forced by global change (Kersting *et al.*, 2013a; 2014a). This species and its bioconstructions must be seriously considered for urgent inclusion on the national and international protection lists.

Acknowledgments

We acknowledge M. Zabala for continuous encouragement during this study. We thank the Secretaría General de Pesca (MAGRAMA) and the Columbretes Islands Marine Reserve staff for their logistic support.

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CROATIAN CORALLIGENOUS MONITORING PROTOCOL: THE BASIC METHODOLOGICAL APPROACH

Abstract
Development of the national coralligenous monitoring protocol has been recently initiated in Croatia in the framework of the MedMPAnet project, with intention to primarily fulfill reporting and monitoring requirements of the EU Habitat Directive (92/43/EEC). However, basic information on coralligenous habitat along the Croatian coast is still lacking, which hinders a fixed definition of the monitoring methods and metrics to be used. Instead, we propose the basic methodological approach that will enable gathering the information needed and that will serve as a basis for reformulation of the adopted methods. The proposed monitoring protocol is based on the most recent (although scarce) knowledge on the monitoring approaches for this habitat, the compilation of available information for the coralligenous thriving along the Croatian coast as well as on the results of the fieldwork devoted to testing of the monitoring methods within the project. At each site, photosampling of minimum of three areas of 2.5 m^2 *(comprised of 10 contiguous photos of 50 x 50 cm quadrats to ensure species identification) will be combined with visual census along 10 m long horizontal transects, to gather information on habitat structure and function (species composition, habitat complexity, bioconcretion and bioerosion), as well as on the degree of impact of the main disturbances (mass mortalities, invasive species, sedimentation, mucilaginous aggregates, fishing gear). Down to 40 m depth this work will be carried out by SCUBA divers whereas the use of the Remote Operate Vehicles (ROVs) is envisaged at greater depths. The obtained information will both enhance knowledge on the coralligenous habitat along the Croatian coast and will provide an original data set to validate future indices of coralligenous health status, currently under development within other Mediterranean initiatives.*

Key-words: Coralligenous assemblages, monitoring, EU Habitat Directive, Adriatic Sea, Croatia

Introduction

Coralligenous assemblages are hotspots of biodiversity in the Mediterranean (harboring approximately 20% of species) that exhibit great structural complexity, provide habitat for several species of commercial interest and offer a diving attraction (Harmelin & Marinopoulos, 1994; Ballesteros, 2006). These ecologically, aesthetically and economically valuable bioconstructions are facing major threats (Ballesteros, 2006) and are included in the priority habitat type “1170 Reefs“ by the EU Habitat Directive (92/43/EEC). To fulfil reporting and monitoring requirements of this Directive, the development of the national coralligenous monitoring protocol has been recently initiated in Croatia in the framework of the MedMPAnet project. Although coralligenous habitat is widespread along the Croatian coast, it is insufficiently studied and there are no precise historical as well as recent data on its distribution, structure, dynamics and current status. This lack of data hinders a fixed definition of the monitoring methods and metrics to be used. Therefore, we propose the basic methodological approach that will enable gathering the information needed and that will serve as a basis for reformulation of the adopted methods. The proposed monitoring protocol is based on the most recent (although scarce) knowledge on the monitoring approaches for this habitat (*e.g.* Kipson *et al.*, 2011; Gatti *et al.*, 2012; Deter *et al.*, 2012), the compilation of available information for the coralligenous thriving along the Croatian coast as well as on the results of the fieldwork devoted to testing the monitoring methods within the project.

Material and Methods

The protocol has been applied by SCUBA divers at 11 sites within the pilot area of the Kvarner Bay (Northern Adriatic Sea) in the depth range from 30 to 40 m. See Fig. 1. for illustration of the sampling scheme.

Photosampling

A minimum of three areas of 2.5 m^2 (comprised of 10 contiguous photos of 50 x 50 cm quadrats to ensure species identification) were photosampled within the same depth range. Photos were taken with Canon D30 digital SLR camera fitted with a 17-55mm lens and housed in Ikelite housing. Lighting was provided by two electronic strobes fitted with diffusers. Photos were further analysed in the laboratory and species at each study site were identified to the lowest possible taxonomic level. For some taxa, voucher specimens were collected to enable their identification.

Visual census along transects

Visual census along three 10 x 1 m horizontal transects was carried out to assess the erect layer (by estimating the abundance of arborescent and massive species that can reach heights above 15 cm). To help with the estimates, divers used a bar of one meter long and noted species present and estimated their density within each 1 m^2. In this manner, the diver evaluated the density over the surface that extends 50 cm over and below the bar and afterwards he/she moved to the next m^2. To avoid counting of all colonies, several categories of density were used and the values were noted for each quadrat. Visual census along the same transects was also carried out to estimate the abundance of macro-bioeroders such as sea urchins *Sphaerechinus granularis* and *Echinus* sp. (by counting total N of individuals of each species in each quadrat along the same transects) and to assess the cover of mucilaginous aggregates. The following classification was applied: (i) Category 0 (Null): 0% cover of the transect; (ii) Category 1 (Low): low abundance in the basal-intermediate layers (composed of species below 15 cm in height) and/or in the erect layer; (iii) Category 2 (Medium): High abundance either in the basal-intermediate layers or in the erect layer; (iv) Category 3 (High): High abundance both in the basal-intermediate layers and in the erect layer.

Visual census

This method was applied to assess degree of impact of disturbances such as fishing and mass mortalities of gorgonian populations. Direct observation on the presence and type of fishing gear at the study site was made. If fishing net/long line was observed on the coralligenous habitat, its length was also estimated. The assessing of the conservation status of gorgonian populations (to provide estimates on the impacts of mass mortality on gorgonian populations), was carried out quantifying the percentage of affected colonies at each study site where gorgonians were present in well developed populations. A colony was considered as affected when the necrosis rate was above 10% of its total surface.

For affected colonies was also noted whether the necrosis was recent (approximately 1- 12 months old injury, denuded axis or axis colonized by pioneering species such as hydrozoans), old (approximately ≥ 12 months, axis covered by long-lived species such as bryozoans, calcareous algae) or displays both types of necrosis. At each site a minimum of 100 colonies (of each species present) was examined within a 5 m depth range.

Assessment of environmental parameters (temperature records)
To detect potential temperature anomalies, temperature data loggers were set up along vertical transect (placed at every 5 m down to 40 m depth) at the selected site within the region. For more information see www.t-mednet.org.

Results
The application of the described methodology in the field required a group of four divers to carry out the complete assessment of one site per dive: 2 divers were engaged in photosampling, 1 in visual census along transects and 1 in gorgonian assessment. Between 12 and 15 min of bottom time was needed to carry out photosampling of 3 replicates (*i.e*. to take 30 photographs) at each site, 6 to 10 min for visual census along 3 transects and around 5 min for gorgonian assessment.
Preliminary analysis of photoquadrats has allowed to obtain a list of 101 macrobenthic taxa, mostly sponges, macroalgae, anthozoans, bryozoans and tunicates. Considering the structural complexity, the main contributors to the basal layer were identified as encrusting algae (*e.g*., *Mesophyllum macroblastum* and *Peyssonellia* spp.), foliose/layered algae (*Lithophyllum stictaeforme*), encrusting macroinvertebrates (*e.g.* sponges *Crambe crambe*, *Spirastrella cunctatrix* and tunicate *Diplosoma* sp.), boring sponges (*Cliona* spp.), turf (aggregates of small organisms such as seasonal hydrozoans, filamentous algae), bare rock and sediment. Intermediate layer was composed mainly of massive or bush-like organisms below 15 cm in height such as sponges (*Agelas oroides*. *Ircinia* spp., *Cacospongia* spp., *Chondrosia reniformis*, *Axinella damicornis*), anthozoans (*Leptopsammia pruvoti*, *Caryophillia smithii*), bryozoans (*Myriapora truncata*, *Smittina cervicornis*, *Adeonella pallasi*) and tunicates (*e.g.* *Halocynthia papillosa*). Visual census has allowed to identify the gorgonians *Paramuricea clavata* and *Eunicella cavolini* as well as sponges such as *Axinella polypoides, A. cannabina* and large specimens of *Aplysina cavernicola* as the main components of the erect layer. Along transects, macrobioeroders such as sea urchins were scarce (max. 2 individuals per transect), and mucilaginous aggregates were absent at the time of assessment. Invasive macroalgae were not observed at investigated sites. Whereas percentage of affected colonies (with >10% of injured surface) was low at 5 sites (not exceeding 15%), between 40 and 60% of colonies were affected at other 3 sites. Discarded fishing gear was present at all sites, with long-lines being the most common one, but nets and traps were also recorded.

Discussion and conclusion
The proposed protocol that combines photosampling and visual census enables the acquisition of a comprehensive dataset to assess coralligenous structure and function as well as the degree of impact of the main disturbances within a reasonable time frame, working in the depth range 30-40 m. In the future, the development of new high-resolution video cameras may offer the opportunity to use these devices instead of photo cameras, which would further speed up the time of data acquisition.

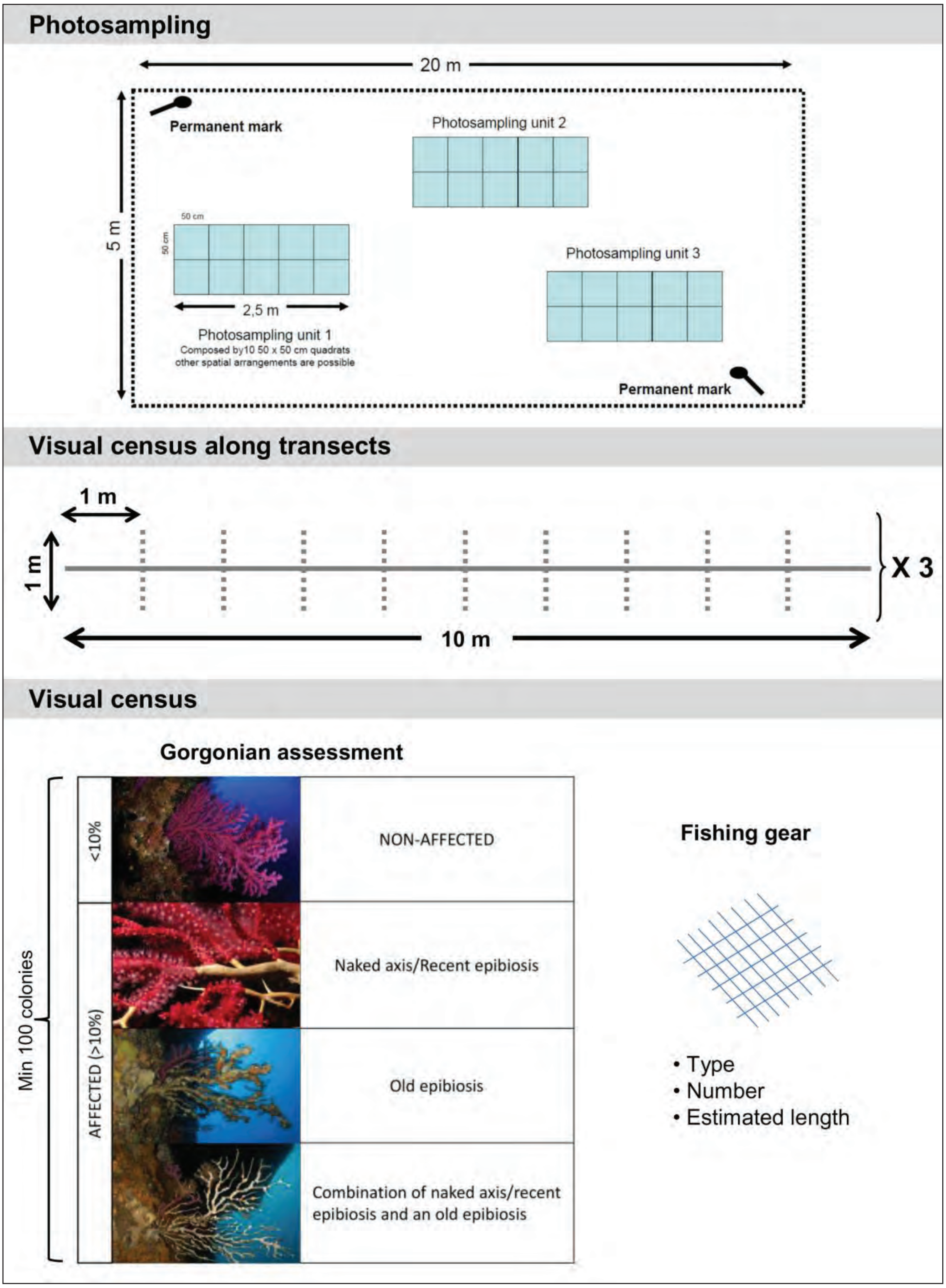

Fig. 1: Sampling scheme of the proposed Croatian coralligenous monitoring protocol.

The performance of *SCUBA* divers is envisaged down to 40 m depth whereas the Remote Operate Vehicles (ROVs) could be used at greater depths.
Photosampling that satisfies minimal sampling area requirements allows for subsequent more accurate and objective analysis than the one stemming from direct underwater

observations, as well as it provides a permanent record that enables the extraction of different levels of information on demand, which is useful for future development of the monitoring metrics to be applied in the Adriatic context. It is further complemented by visual census that enables the assessment of phenomena over a wider area and that provides almost immediate data after minimal subsequent analysis. At each monitored site, data gathered in this way furnish: (1) information on community composition of macrobenthic species/categories; (2) data useful to feed indicator of habitat complexity (based on the combination of cover/abundance data obtained for each layer); (3) Information on the degree of impact of main disturbances affecting the coralligenous habitat, and (4) Information on environmental conditions e.g. temperature regimes (recorded by dataloggers) and sedimentation (based on photo analysis).

The dataset obtained will furnish the basis for the development of indicators on the condition and status of typical species. Several efforts have been initiated to establish the most suitable indicators (Gatti *et al*., 2012; Deter *et al*., 2012, Project Index-Cor) but at this moment there is still lack of consensus on the indices to be applied. Nevertheless, all initiatives are based on the acquisition of information proposed in the monitoring protocol.

In conclusion, the obtained information will both enhance knowledge on the coralligenous habitat along the Croatian coast and will provide an original data set to support the implementation of future indices of coralligenous health status.

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IMPACT OF CLIMATE CHANGES ON CORALLIGENOUS COMMUNITY IN THE ADRIATIC SEA

Abstract
Several episodes of mass mortalities, affecting populations of corals and other sessile invertebrates, have been recorded over the past 20 years in the eastern part of the Adriatic Sea. The coralligenous community, one of the most diverse in the Mediterranean Sea where suspension feeders are dominant, has been also strongly affected by these events. Current hypotheses about the causes of mass mortality events mostly focus on their relationship with the occurrence of distinctive climatic anomalies during the late summer and early fall, when the thermocline shifted to deeper areas, to more than 40 m depth. Their occurrence and characteristics differed among regions and years and were usually related to the local hydrological conditions. The species affected were mostly long-lived sessile epibenthic invertebrates, such as sponges, anthozoans, bivalves, bryozoans and ascidians. During the two large mass mortality events in 2003 and 2012 in the Adriatic Sea, sea temperatures reached up to 6°C above the average with prolonged water column stability during late summer, and affected approximately 30 marine species down to 40 m depth. The main goal of this study is to provide a comprehensive report on the impact of the mass mortality events by providing data on the species affected, the intensity of the impact, the depth range, and the timing of the event for three study areas in the eastern Adriatic Sea. According to the data obtained, the sites surveyed in the northern part of the Adriatic Sea were the least affected, while the sites in the central and southern Adriatic displayed the highest impact.

Key-words: climate changes, coralligenous, temperature anomalies, Adriatic Sea.

Introduction
Mass mortality events associated with positive thermal anomalies in the Mediterranean Sea have been recorded during the last three decades with increasing frequency (Garrabou *et al*., 2009). During the two largest mass mortality events in 1999 and 2003 in the Mediterranean Sea, sea temperatures reached up to 4°C above the average with prolonged water column stability during late summer, and affected approximately 30 marine species (most of which have cold-water affinity) down to 40 m depth (Cerrano *et al*., 2000; Rodolfo-Metalpa *et al*., 2000, 2005; Garrabou *et al*., 2001, 2009; Cupido *et al*., 2009; Bensoussan *et al.*, 2010; Crisci *et al*., 2011).
The species affected were mostly long-lived sessile epibenthic invertebrates, such as sponges, anthozoans, bivalves, bryozoans and ascidians. The occurrence of such climatic anomalies during late summer implies prolonged exposure of organisms dwelling above the thermocline to high temperatures and relatively low food availability during late summer (Garrabou *et al*., 2009).
The coralligenous community, one of the most diverse in the Mediterranean Sea where suspension feeders are dominant, has been strongly affected by several mass mortality events (Garrabou *et al*., 2001, 2009; Linares *et al*., 2005).

Fig. 1: Three study areas (a - Cres, Krk and Plavnik Islands, b - Telašćica Nature Park and Kornati National Park, c - Lastovo Nature Park and Mljet National Park) in the Adriatic Sea where surveys of the mortality events were conducted.

Current hypotheses about the causes of these events in the Mediterranean Sea mostly focus on their relationship with the occurrence of distinctive climatic anomalies during the late summer and early fall, when the thermocline shifted to deeper areas, to more than 40 m depth.

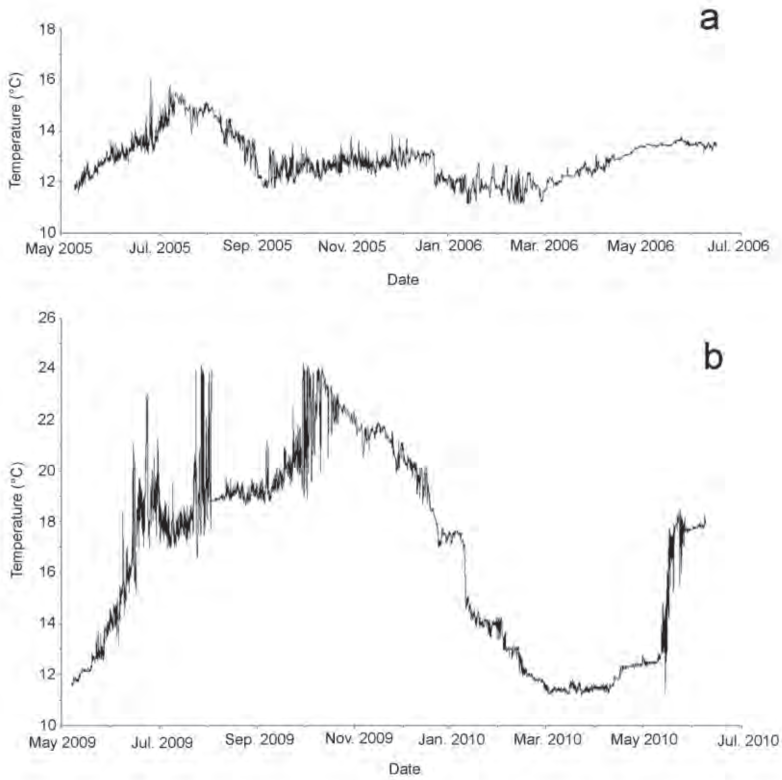

Fig. 2: Sea temperature oscillations at 40 m depth measured in Telašćica Nature Park during the summer of 2005 (a) and 2009 (b).

Two main types of positive thermal anomalies with mass mortality events were detected: a short-term anomaly (lasting up to 5 days) with high mean temperature (reaching 27°C in some regions) and a long-term anomaly (lasting nearly a month) with warm temperature (around 24°C). Their occurrence and characteristics differed among regions and years, related to the local hydrological conditions. Biological responses to

these events differed among species and their populations at local and regional scale (Garrabou *et al*., 2009; Bianchi *et al*., 2012). An analysis of the biological impacts of the mass mortality events mentioned has revealed differential responses among species and their populations at all spatial scales considered.
All reports about mass mortality events were encompassing different areas in the NW Mediterranean (along the Spanish, French and Italian coasts), while there were no data about similar events in the eastern part of the Mediterranean Sea (including the Adriatic Sea). It seems likely that the anomalous temperatures after the unusually warm periods played a key role in the observed mortality events. A correlation between temperature conditions and degree of mortality impact seems to support this hypothesis (Garrabou *et al*., 2009; Bensoussan *et al*., 2010; Crisci *et al*., 2011).

Materials and methods
Surveys on the mass mortality events were carried out in three study areas in the eastern part of the Adriatic Sea from 1999 to 2012. A total of 28 sites were surveyed throughout the study, including two National Parks (Kornati and Mljet) and two Nature Parks (Telašćica and Lastovo) (Fig. 1). Seawater temperatures in the study areas (at one site per each study area) were recorded at 1 h intervals using Onset Computers Corporation's temperature data loggers (HOBO Pendant), set in 5 m intervals from 1 to 40 m depth.
The species selected for the survey were sponges, cnidarians and bryozoans, all showing clear signs of recent necrosis. All the species selected are abundant in study areas and easy to identify. Data on mortality impact were based on qualitative (lists of species showing recent necrosis) and quantitative surveys (focused on abundant species at all study areas and with mortality effects that were easy to quantify - at least 10% of specimens should be affected). Necrosis on these species appears like denuded skeletons in sponges, gorgonians, scleractinian corals and bryozoans. The quantitative surveys were focused on gorgonians and scleractinian corals. Affected species and colonies were quantified within 1 m on each side of the vertical line transect (3 transects per site) down to 40 m depth. All affected species were photographed and their number was noted underwater on a diving slate.

Results
In period between 1999 and 2012 positive temperature anomalies in the Adriatic Sea were observed only in four years (2000, 2002, 2004 and 2008). Sea temperature oscillations at 40 m depth measured in Telašćica Nature Park during the summer of 2005 and 2009 are shown in Fig. 2. In 2005 summer temperature at 40 m depth ranged from 13.7 to 15.4°C (from June to September) with high peaks up to 15.9°C. From June to January of 2009 sea temperature ranged from 13.8 to 22.7°C, causing mass mortality events.
During surveys in three study areas in the eastern part of the Adriatic Sea from 1999 to 2012, a total of 14 benthic species were affected by mortality events in coralligenous community (Table 1). The depth range involved was limited to 40-45 m. Between sponges, the main species affected were *Hippospongia communis*, *Petrosia ficiformis*, *Spongia officinalis* and *Aplysina cavernicola*. Specimens showed total or partial death with skeletons remained attached to the substratum as proof of recent mortality (Fig. 3c). Affected cnidarians were mostly gorgonians and scleractinian corals. Gorgonians *Paramuricea clavata* and *Eunicella cavolini* showed tissue necrosis displayed as a decomposition of the organic parts (usually a sudden process lasting just a few days),

leaving only denuded skeletons (Fig. 3a and b). In *P. clavata* populations, the highest impacts (affected colonies) were found in Nature Parks Lastovo (57.56%) and Telašćica (56.11%), followed by Kornati NP (54.27%). The yellow gorgonian, *Eunicella cavolini*, displayed the highest impact again in Telašćica (28.08% affected colonies) and Lastovo Nature Parks (25.71%). The Kornati NP and Cres area showed intermediate impact values of 15.02% and 16.01%. Skeletons of earlier affected species (a year before the new mortality event) became colonized mostly by algae, hydroids and bryozoans. Mortality of *Corallium rubrum* resulted in partial or complete loss of the coenenchyme, and latter denudation of the colony skeleton in populations below 30 m depth. The scleractinian zooxanthellate coral *Madracis pharensis* suffered extensive tissue loss through tissue necrosis or after bleaching events (loss of zooxanthellae), resulting in the total or partial mortality (Fig. 3d). Coral *M. pharensis* showed the highest impact in southern part of Adriatic Sea, in Mljet NP (68.34% affected colonies) and Lastovo Nature Park (66.84%). Similar mortality events were found in coralligenous community on solitary corals *Leptopsammia pruvoti* with the degree of impact varied from 46.97% in the most impacted area (Mljet NP) to 16.25% in the least impacted (Kornati NP). High levels of necrosis were also noted in bryozoan species (*Myriapora truncata, Pentapora fascialis* and *Reteporella beaniana*), especially in southern surveyed sites.

Tab. 1: Impact characteristics and species affected during mass mortality event in the five study areas in the Adriatic Sea from 1999 to 2012. (A - affected; NA - not affected).

	Study				
Species name	**Cres**	**Telascica**	**Kornati**	**Lastovo**	**Mljet**
Porifera					
Petrosia ficiformis	A	A	A	A	A
Aplysina cavernicola	NA	A	A	A	A
Ircinia dendroides	NA	NA	NA	A	A
Agelas oroides	NA	A	NA	A	A
Cnidaria					
Parazoanthus axinellae	NA	A	A	A	A
Madracis pharensis	A	A	A	A	A
Leptopsammia pruvoti	A	A	A	A	A
Caryophyllia inornata	A	A	A	A	A
Corallium rubrum	A	A	A	NA	A
Eunicella cavolini	A	A	A	A	-
Paramuricea clavata	A	A	A	A	-
Bryozoa					
Myriapora truncate	NA	NA	A	A	A
Pentapora fascialis	NA	NA	NA	A	A
Reteporella beaniana	NA	NA	NA	A	A

Discussion

The Mediterranean Sea is considered one of the world`s biodiversity hotspots, where the impact of climate change together with other anthropogenic pressures could be most devastating (Garrabou *et al*., 2009). A big problem for the benthic suspension feeders is the fact that summer conditions have become much more prolonged in recent decades.

During 1999, 2003 and 2009, not only temperatures were high, but the warm and stable conditions lasted for an unusually long time (more than one month). Mass mortality events reached 45 m depth in most parts of the affected areas (usually no signs of mortality having been recorded below 45 m). Since all surveyed sites in the Adriatic Sea are away from inhabited places and possible sewage discharge, mortality events therefore excluded pollution or bacterial infection as possible causative agents, leaving temperature as the most probable cause.
Summer temperatures conditions at 40 m depth were playing crucial role in mortality events at studied areas, when during the warmest studied year (2003) in Cres area affected species were exposed for 82 consecutive days to temperatures above 20°C. Kornati NP had much longer episode of 137 days and Mljet NP even 162 days with temperatures above 20°C at 40 m depth. In previous studies, experimental data demonstrated that long duration exposure to warm sea temperature (~23°C for 40 days), similar to the conditions observed during long-term anomalies, could cause the appearance of the firsts signs of necrosis (Coma *et al*., 2009).

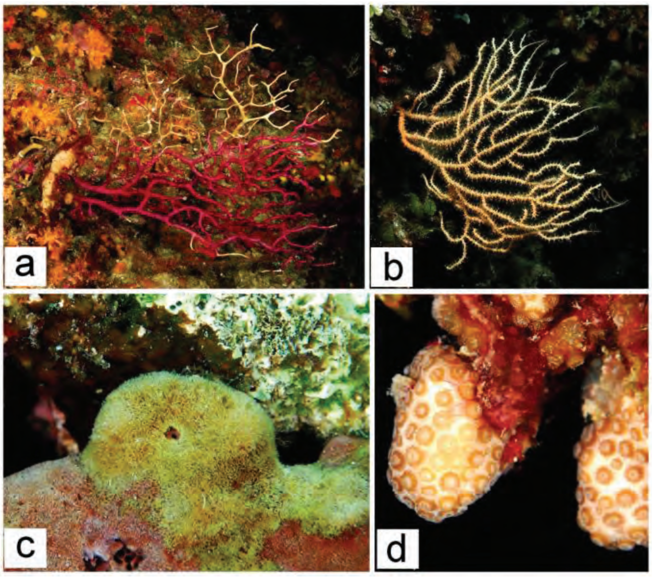

Fig. 3: Species affected by the mass mortality events in the Adriatic Sea. (a) *Paramuricea clavata* colony showing partially loss of tissue (light brown branches) (Kornati National Park - 40 m depth). (b) *Eunicella cavolini* showing recent signs of partial mortality (peaks of branches with tissue necrosis) (Telašćica Nature Park - 32 m depth). (c) *Petrosia ficiformis* displaying partial mortality (yellow parts) (Cape Grota, Cres area - 18 m depth). (d) *Madracis pharensis* colony with necrosed polyps (Kornati National Park - 28 m depth).

Among target species, the scleractinian corals and gorgonians suffered extensive damages during the mass mortality events. *Eunicella cavolini* populations exhibited a lower proportion of injured colonies than those of *Paramuricea clavata*, although the upper limit of distribution of *E. cavolini* ranged between 6 and 20 m at surveyed sites. The proportion of colonies affected was much lower in the surveyed sites in the Adriatic Sea in comparison with the mass mortality events in the late summer of 1999 in Ligurian Sea (from 60 to 100%) (Cerrano *et al*., 2000) or in other studied sites in the NW Mediterranean (Garrabou *et al*., 2009). During 2009, the colonial coral *Madracis pharensis* suffered bleaching and tissue necrosis in all surveyed sites. The northern colonies show a lower resistance to elevated temperature in comparisons to the southern populations. Numerous cases of injuries of the red coral *Corallium rubrum*,

resulting in the total or partial death of colonies, were also observed during 2009 and 2012 at study sites, but without mass mortality events like in NW Mediterranean described by Garrabou *et al*. (2001). One of the reasons for lower mortality events could be the depth of *C. rubrum* habitat. Red coral populations could rarely be found in shallow waters (above 40 m depth) at study sites, because most of shallow populations were drastically diminished, even in protected areas.
Because of the future climatic projections for the Mediterranean region, new mortality events can be expected during the next decades. Consequences of these events could severely expose populations of affected species to local ecological extinction processes, threatening the conservation of the rich Mediterranean biodiversity.

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POPULATION GENETICS STUDIES OVER CONTRASTED SPATIAL SCALES OF TWO STRUCTURAL GORGONIAN SPECIES FROM THE CORALLIGENOUS: STATE-OF-THE-ART AND CONSERVATION IMPLICATIONS

Abstract

The Mediterranean coralligenous is a striking example of the complex issues induced by global change. Numerous conservation biology studies using different approaches and covering various spatial, temporal and taxonomic scales have been developed in the last decades to understand the evolution of this community in the current environmental shift. In this study, we present the state-of-the-art combined with new results regarding the population genetics of two structural octocorals belonging to the coralligenous: the red coral, Corallium rubrum, and the red gorgonian, Paramuricea clavata. These two long-lived species display fragmented distributions and are characterized by a slow population dynamics and a restricted larval dispersal. Moreover, they are submitted to strong anthropogenic pressures. Our main aim here is to demonstrate how the study of neutral genetic polymorphism at different spatial scales can shed new lights on the conservation of the targeted species and associated community. First, we demonstrate the interest of comparative approaches between species at global scale (hundreds to thousands of km) to characterize the long-term evolutionary processes (gene flow and genetic drift). Then, focusing on a regional scale (tens of m to km) and combining population genetics and demographic studies, we disentangle the relative impacts of short-term evolutionary processes (connectivity and contemporary genetic drift) on the functioning of the populations studied. Finally, considering a local scale (cm to m), we further our understanding of the population biology of these species with a particular emphasis on their reproduction. We discuss the conservation implications of these results for: (i) the definition of management units (MU), (ii) the design of marine protected areas (MPA) within MUs and (iii) the restoration actions of populations within MPAs.

Key-words: *Corallium rubrum*, *Paramuricea clavata*, population genetics, contrasted spatial scales, conservation biology.

Introduction

Studying the patterns of genetic structure at different spatial scales allows inferring the evolutionary and ecological processes acting at various temporal scales (Selkoe & Toonen, 2006). These studies can shed new light on the biology of a species with direct implications for its conservation (Ferrière *et al*., 2004).

The red coral, *Corallium rubrum*, and the red gorgonian, *Paramuricea clavata*, are key species of coralligenous assemblages due to their structural roles (Ballesteros, 2006). These two long-lived octocorals display fragmented and overlapping distributions and are characterized by a slow population dynamics, a sexual reproduction and a restricted larval dispersal. They are directly impacted by global change (*e.g*., mass mortality events;

overharvesting) and thus received particular conservation attention over the last decades (Ballesteros, 2006).

Our main objective is to demonstrate the relevance of considering contrasted spatial scales in population genetics to enhance the conservation of the species targeted and associated community. Using available and recently generated data from *C. rubrum* and *P. clavata*, we demonstrate how the study of population genetic structure: i) at global scale (hundreds to thousands of km) may be used for the definition of management units (MUs); ii) at regional scale (tens of m to km) may improve the design of marine protected areas (MPAs); iii) at local scale (cm to m) may have implications for restoration actions.

Material and Methods

At global scale (hundreds to thousands of km), 35 and 31 populations of *C. rubrum* and *P. clavata* covering three regions of the North Western Mediterranean Basin (Marseilles, Corsica, Catalonia; Fig. 1a) were sampled resulting in 1140 and 1076 individuals, respectively. For the regional scale study (tens of m to km), nine supplementary populations of *P. clavata* were sampled in Ibiza (Spain; Fig. 1b) resulting in 329 individuals. At local scale (cm to m), 75 and 87 colonies were sampled and geo-referenced over a half and two square meters for *C. rubrum* and *P. clavata*, respectively (Fig. 1c). In each population, apical fragments of colonies were collected. Sample preservation, DNA extractions, genotyping procedure, microsatellites characteristics and Hardy-Weinberg analyses are described in Ledoux *et al*. (2010a, b) for *C. rubrum* and Mokhtar-Jamaï *et al*. (2011, 2013) and Arizmendi *et al*. (submitted) for *P. clavata*. Genotypes were obtained based on 10 and 7 microsatellites for *C. rubrum* and *P. clavata* respectively.

At global and regional scales, pairwise genotypic differentiation between samples was tested using an exact test in GENEPOP v.4.1.1 (Raymond & Rousset, 1995; Rousset, 2008). The genetic distances between populations were estimated using the Weir and Cockeram's (1984 estimator of F_{ST}. Geographic distances between populations were estimated using GOOGLE EARTH v.7. Correlations between genetic and geographic distances were tested using Mantel (1967) tests (1000 permutations) to look for isolation by distance (IBD) between populations. Clustering analyses were conducted to evaluate the number of different genetic clusters (K) from the individuals' genotypes dataset in STRUCTURE v.2.2 using admixture model with correlated alleles frequencies (Pritchard *et al.,* 2000).

At global scale, we used the coalescent Bayesian framework implemented in Migrate (Beerli, 2006) to estimate the effective population size (theta: $4N_e\mu$) and the connectivity between the three regions in order to evaluate the long-term genetic drift and gene flow between regions.

At regional scale, we conducted a demographic survey of the populations by estimating the density of colonies per square meter and the mean percentage of injured surface (see Linares *et al.,* 2008). We computed the local F_{ST}s (F'_{ST}), which account for differences in effective sizes and migration rates among populations, in GESTE v.2 (Foll & Gaggiotti, 2006). We also evaluated the recent migration rates in BayesAss v.3 (Wilson & Rannala, 2003) and the contemporary effective population size in ONeSAMP v.1.2 (Tallmon *et al.,* 2008) as estimators of contemporary connectivity and contemporary genetic drift.

At local scale, genetic distance between colonies was estimated using Rousset genetic distance ($\hat{e}$; Watts *et al.,* 2007) for *C. rubrum* and Moran's I relationship coefficient (M_I; Moran, 1948) for *P. clavata*. Geographic distances between colonies were estimated using photogrammetric approach (Ledoux *et al.*, 2010b) or direct measures (Mokhtar-Jamaï *et al.*, 2013). IBD between colonies was tested using Mantel tests (1000 permutations). We also divided colonies in different stage classes accounting for their sizes. We then analyzed the relationships between the individuals within and between the stages classes using COLONY v.2 (Wang, 2004).

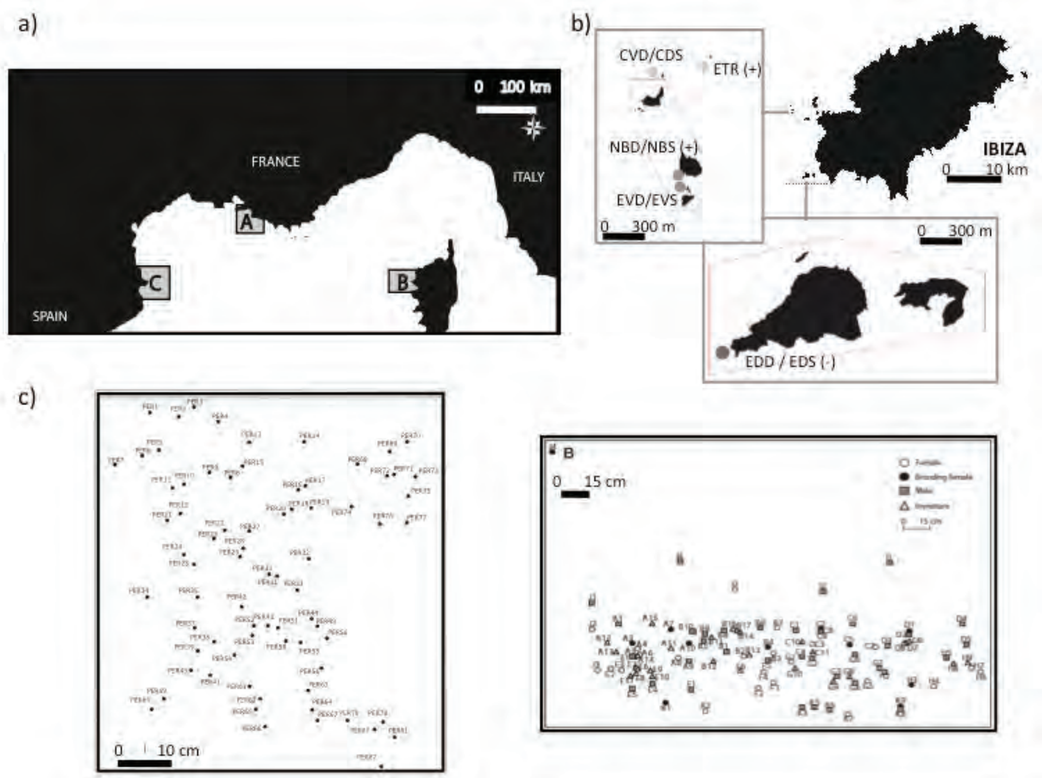

Fig. 1: The three different sampling scales considered in this study. a) At global scale (from hundreds to thousands of km), the sampling was focused on three regions (A: Marseilles; B: Corsica; C: Catalonia) and composed by 35 and 31 populations of *C. rubrum* and *P. clavata* respectively; b) At regional scale (from tens of m to km), nine populations of *P. clavata* were sampled; c) At local scale (from cm to m), 75 and 87 colonies were sampled and geo-referenced over a half and two square meters for *C. rubrum* (left panel) and *P. clavata* (right panel) respectively.

Results

At global scale and for the two species, pairwise genetic differentiation tests between populations were mainly significant even for populations separated by tens of meters. Global F_{ST}s were 0.09 and 0.08 for *C. rubrum* and *P. clavata*, respectively. In the two species, tests of IBD were significant ($P < 0.01$; Fig. 2a). Nevertheless, for a same geographic distance, higher genetic distances between populations were observed in *C. rubrum* than in *P. clavata*. The clustering analyses revealed the occurrence of concordant regional genetic clusters between the two species (Fig. 2b). Migrate analyses demonstrated a higher connectivity but lower effective population size in *C. rubrum* compared to *P. clavata*. The migration rate ranged from 0.03 to 0.05 and 0.002 to 0.01 and the theta parameter ($4N_e\mu$) ranged from 1.5 to 8.5 and 3.7 to 7 for *C. rubrum* and *P. clavata*, respectively.

At regional scale, all but four pairwise genetic differentiation tests were significant. A significant IBD ($P < 0.01$) was detected between the nine populations. Three genetic clusters concordant with the geographic groups were revealed. Local F'_{ST}s ranged from 0.01 (95% HPDI: 0.01-0.02) to 0.09 (95% HPDI: 0.06-0.13). Contemporary N_e ranged from 50 (95% CI: 36-92) to 135 (95% CI: 88-304). Recent migration rates ranged from 0.19 to 0.33. Heterogeneity between populations was also demonstrated for the two demographic parameters under survey. The density of populations ranged from 6.8 to 57.6 colonies·m^{-2} whereas the percentage of injured surface varied between 2.2% and 25.2% (Tab. 1).

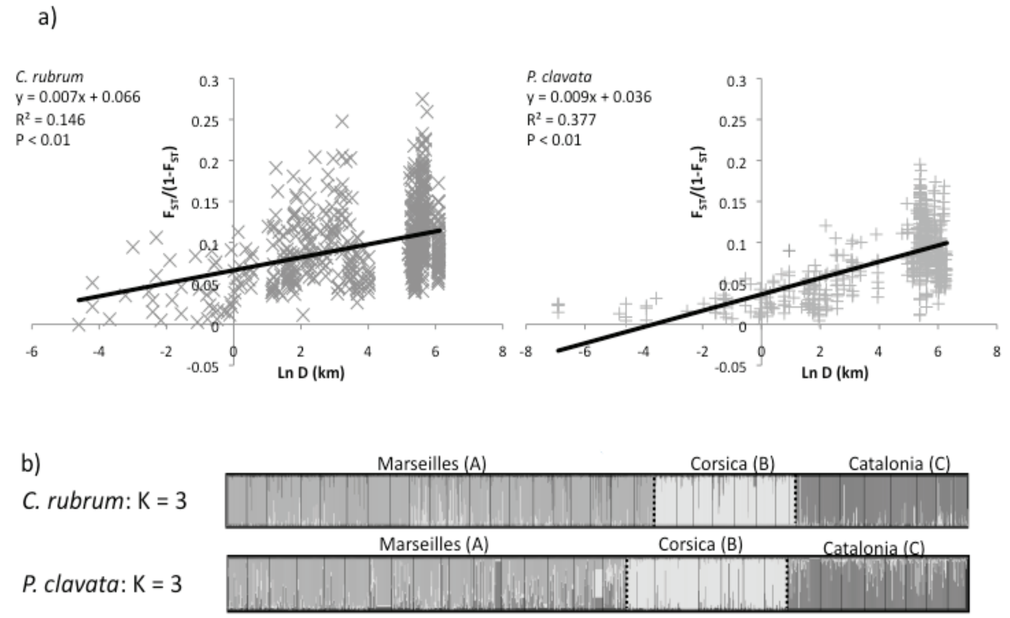

Fig. 2: a) Linear regression between the genetic ($F_{ST}/(1-F_{ST})$) and the geographic (*ln m*) distances; b) Three regional genetic clusters inferred by STRUCTURE, each individual is represented by a vertical line partitioned into three colored segments that represent the individual's membership fraction in each of the three clusters. The clustering analysis was conducted based 1140 individuals from 35 populations in *C. rubrum* and 1076 individuals from 31 populations *P. clavata*.

At fine spatial scale, the analyses of relationships demonstrated the occurrence of complex networks of full sib, half sib or parent-offspring relationships for the two species. Significant IBD ($P < 0.01$) was revealed between *C. rubrum* colonies but not between the colonies of *P. clavata*. Based on the IBD in *C. rubrum*, we estimated the effective dispersal, σ_g, between 22 and 32 cm.

Tab. 1: Population genetics at regional spatial scale: summary statistics of genetic differentiation (F'_{ST}), contemporary effective population size (N_e), recent migration rate, density and mortality of two healthy (ETR, NBD) and two vulnerable (EDD, EDS) populations of *P. clavata* from Ibiza Island.

Population	F'_{ST} (95%HPDI)	N_e (95% CI)	Migration rates	Density (colonies·m^{-2})	Mortality (% of injured surface)
ETR	0.01 (0.01-0.03)	135 (88-304)	0.33	6.8	2.2
NBD	0.01 (0.01-0.02)	60 (42-114)	0.32	11	16.6
EDD	0.09 (0.06-0.13)	50 (36-92)	0.19	11.8	25.2
EDS	0.08 (0.05-0.11)	54 (41-106)	0.19	31.1	17.8

Discussion

At global scale, *C. rubrum* and *P. clavata* displayed the same pattern of spatial structure combining IBD and regional clusters. Nevertheless, the underlying long-term evolutionary processes appeared contrasted. The connectivity between regions is higher in *C. rubrum* than in *P. clavata*, whereas the effective population size is smaller in *C. rubrum* than in *P. clavata*. The resulting balance between gene flow and genetic drift leads to a higher genetic differentiation in *C. rubrum* compared to *P. clavata*. From a conservation perspective, these results suggest that three different management units (MU) corresponding to the three geographic regions should be considered and that efforts should be done to preserve the IBD pattern of connectivity between populations. Moreover, we could expect that the demographic and genetic stochasticity resulting from the decrease of population density linked to global change could impact more significantly *C. rubrum* than *P. clavata*. This implies that the former species should be considered more vulnerable.

At regional scale, our main result is the occurrence of a substantial heterogeneity in the patterns of genetic and demographic structures and, accordingly, in the underlying processes, as shown by the estimates of short-term connectivity and effective population size. In addition to recommendations resulting from the occurrence of IBD and genetic clusters, we are thus able to target populations that should receive particular conservation actions within the marine protected area. On the one hand, we identified vulnerable populations as populations being genetically isolated and depauperated, and showing more injuries due to mass mortality events. On the other hand, we detected recently founded and expanding populations, as well as healthy populations acting as larvae supplier for the system studied (Tab. 1).

At local scale, sibship analyses revealed the occurrence of dense networks of relationships due to a family structure in the two species. This underlines the importance of local processes (e.g. local recruitment) in the population functioning of *C. rubrum* and *P. clavata*, a rare pattern for marine species (Palumbi, 2003). Nevertheless, the results of the IBD analyses differ between the two species. Regarding *C. rubrum,* we demonstrated a significant IBD between colonies. We were thus able to quantify the small effective dispersal ability of the species (between 22 and 32 cm). Accordingly, breeding units in the red coral seem to be highly restricted in space. On the contrary, IBD was not revealed in *P. clavata*, suggesting that breeding units may be bigger than the sampling area (2 m^2). From a conservation perspective, these studies at local scale suggest that the populations of the two species are closed and that recovery from larvae coming from external sources may be limited. In this context, restoration actions may be an important conservation tool. Based on our data, these actions should restore dense and small-size patches of colonies in order to re-establish functional breeding units.

Because *C. rubrum* and *P. clavata* are structural species of the coralligenous, improving their conservation will benefit associated species. The different management tools defined by our study, from global MUs, regional MPAs to local restoration actions, may inspire management plans in other species. The development of population genetics studies at various spatial scales focusing on other coralligenous species is also needed to reinforce our abilities to protect this biodiversity rich community.

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RESPONSE OF CORALLIGENOUS TO GLOBAL CHANGE: EVIDENCES FROM FIELD AND EXPERIMENTAL STUDIES IN GORGONIAN FORESTS

Abstract
Global change is one of the major concerns for the conservation of the rich biodiversity of coralligenous assemblages. In the Mediterranean Sea, there is a strong likelihood of increasing frequencies of mass mortality events linked to global warming and the spread of invasive species. Gorgonian forests, one of the most emblematic facies of coralligenous outcrops, are especially vulnerable to global change. The presentation will focus on the study of the responses of gorgonians, mainly the red gorgonian Paramuricea clavata, to warming and exotic algae invasions from observational and experimental approaches in NW Mediterranean Sea. Long-term monitoring of recurrent warming-induced mortalities in marine protected areas such as Cabrera Archipelago and Columbretes Islands showed that warming may act as an important driver for long-term shifts in the bathymetrical distribution of gorgonian forests. Aquaria experiments and field surveys indicate that thermal stress may also have important sublethal effects on the reproduction and the viability of early life stages of gorgonians. Additionally, manipulative experiments demonstrated that invasive algae, such as Caulerpa cylindracea and Womersleyella setacea, have the capacity to reduce gorgonian recruitment and juvenile survival. The final aim of the presentation is to discuss the future consequences of global change on the persistence and recovery of gorgonian forests, in particular, and of coralligenous assemblages in general.

Key-words: Coralligenous, Gorgonians, Warming, Invasive species

Introduction

Among marine Mediterranean communities, coralligenous assemblages are highly diverse and exhibit great structural complexity. Currently, these communities are subjected to cumulative threats such as overfishing, habitat destruction, warming and invasive species (Ballesteros, 2006). Among these stressors, climate change and invasive species are among the most worrying impacts in the Mediterranean Sea (Coll *et al.,* 2010). Indeed, during the last decade, Mediterranean benthic communities have been affected by large-scale mass mortality events associated to global warming. In addition, coralligenous assemblages dominated by gorgonians are suffering from the invasion of introduced species (Ballesteros, 2006). Most likely, the most remarkable invasive species thriving in these assemblages are the filamentous red alga *Womersleyella setacea* (Hollenberg) R. E. Norris and the green coenocytic alga *Caulerpa cylindracea* Sonder (formerly *C. racemosa* var. *cylindracea*) (Cinelli *et al.,* 2007). Both invasive algae have dramatic effects on native assemblages: they form thick and persistent turfs that can completely cover the substrata and also in some cases overgrow other erect species. Understanding the impacts of current warming trends and algal invasions, as well as their potential combined effects on the resilience of populations of key species of coralligenous assemblages, such as gorgonians, is crucial for the conservation and management of these emblematic Mediterranean assemblages. While the impact of warming-induced mortalities on gorgonians has been widely studied during the last decades (Perez *et al*., 1999; Cerrano *et al*., 2000; Linares *et al*., 2005; Coma *et al*., 2006; Cupido *et al*., 2008; Garrabou *et al*., 2009; Huete-Stauffer *et al*., 2011), the effects of invasive species on coralligenous assemblages remain poorly studied. Likewise, subtle effects associated to thermal stress on the reproduction and early life stages of coralligenous species have been largely ignored in comparison to the attention lavished on population decline. However, changes in fecundity, fertilization success, larval dispersal and recruitment play a major role in promoting shifts in species' abundance and composition. Here we show the responses of gorgonians, in particular the red gorgonian *Paramuricea clavata*, to warming and invasive algae from different observational and experimental approaches performed during the last years in different NW Mediterranean localities.

Material and methods

Field surveys

Red gorgonian populations were monitored in Columbretes Islands (Castelló, Spain), in 2001 and 2009 through permanent transects, and in Cabrera National Park (Mallorca, Balearic Islands), in 2007 and 2013 using 50x50 cm random quadrats, in order to obtain data on density, size and extent of injuries of the populations through time.

Aquaria experimental setups

We experimentally examined the response of the reproduction and early life stages of *Paramuricea clavata* to high summer water temperature (25°C), which has been previously found as a critical temperature for the species. Besides, this temperature also simulates the end-of-century predicted warming (+3°C) on the temperature maxima during the species' reproductive period (mid-June). We submitted male and female colonies to control and thermal stress conditions in aquaria. After three weeks, surviving colonies without any sign of injury from thermal and control treatments were examined to evaluate their reproductive output and the potential differential responses exhibited by both sexes. To document the potential effects of elevated temperature on early embryogenesis, separate batches of eggs were kept in 2 l jars in both control and stress treatment baths and sampled after 7 h. Samples were preserved in 3% glutaraldehyde for subsequent examination using a scanning electron microscope (SEM).

Field experimental setups

To assess the effect of invasive species on gorgonian populations, and specifically on *P. clavata* recruits and juveniles, we used *P. clavata* fragments of 5–10 cm in length to simulate juvenile colonies. The fragments were subjected to overgrowth by invasive species (invaded treatment) or held 7 cm above the natural rocky substratum to avoid the contact with invasive species (control treatment). 80 healthy colony apical tips of *P. clavata* were randomly collected from healthy colonies at depths of 25–30 m at the Scandola Marine Reserve and at the Port-Cros National Park (France), where the experiment of *W. setacea* and *C. racemosa* was respectively performed.

Results

Field surveys

The density of *P. clavata* colonies at their upper depth limit of distribution (between 35 and 37 m depth) in Columbretes Islands Marine Reserve and Cabrera National Park

(NW Mediterranean Sea) significantly decreased over time after recurrent mass mortality events linked to positive thermal anomalies (Fig. 1). While almost 60% of the colonies died in Columbretes Island, in Cabrera the recurrent mortalities caused the loss of about 95% of the colonies at the shallowest depth.

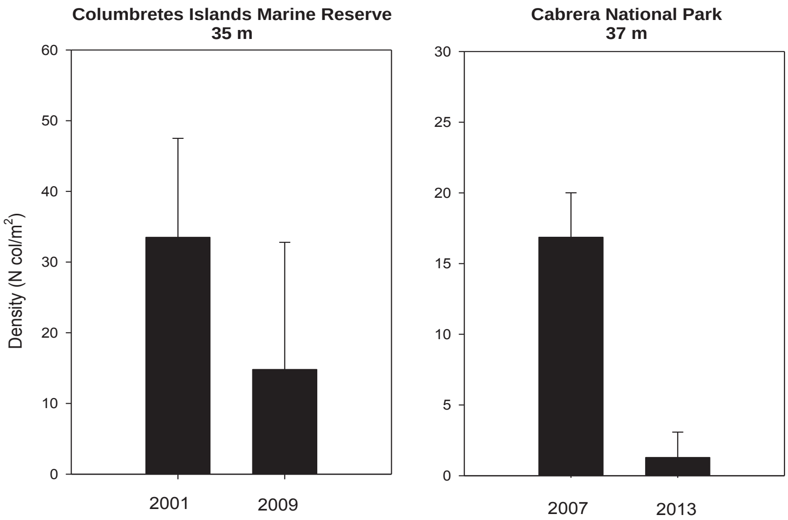

Fig. 1: Changes in the density of red gorgonian *P. clavata* colonies (mean ± SD) at the upper depth limit of its distribution (35-37 m depth) in Columbretes Islands and Cabrera National Park

<u>Aquarium experimental setups</u>

Female and male colonies submitted to the experimental thermal stress (25ºC), which did not display injuries, showed a significant decrease of their reproductive traits. Indeed, the three reproductive parameters studied (fertility, number and maximum diameter of gonads) showed a high affectation under thermal stress in both female and male colonies. While the fertility and number of gonads showed a larger reduction in female than male colonies, the diameter of gonads of male colonies displayed a higher decrease in comparison to the diameter of females (Fig. 2).

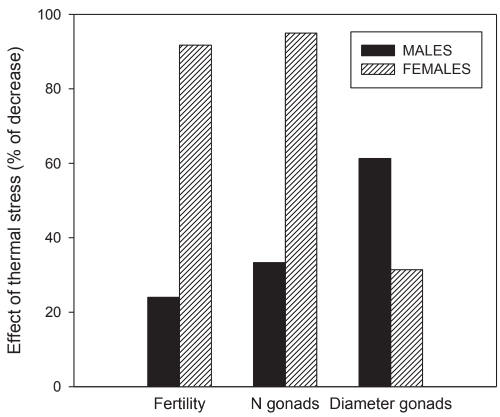

Fig. 2: Percentage of decrease in fertility, number of gonads and the maximum diameter of gonads in female and male colonies under thermal stress (25ºC) compared to colonies reared in control aquaria (17ºC)

Regarding to the viability of *P. clavata* embryos and larvae, the results obtained from laboratory experiments also showed a severe negative impact of thermal stress (25ºC). We observed a reduced survivorship, completely abnormal embryonic development (Fig. 3) and impaired metamorphosis in comparison to the development observed in control conditions (17º).

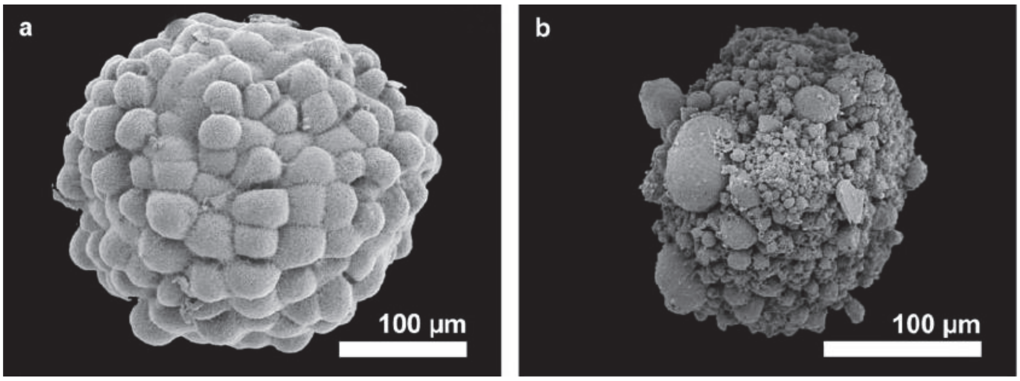

Fig. 3: Scanning electron microscope images of blastula stage: (a) normal blastula developed at ambient temperature (17°C) and (b) abnormal blastula after 7 h of exposure to thermal stress (25°C). Images adapted from Linares *et al.* (2008a) and Kipson *et al.* (2012).

Field experimental setups

Survival rates of small fragments of red gorgonian colonies (< 10 cm) submitted to *Caulerpa racemosa* and *Womersleyella setacea* overgrowth (invaded treatments) were significantly lower than in control transplants (Fig. 4). In addition, the invaded treatments displayed a higher percentage of injured colonies and a larger injured surface compared to the control treatment.

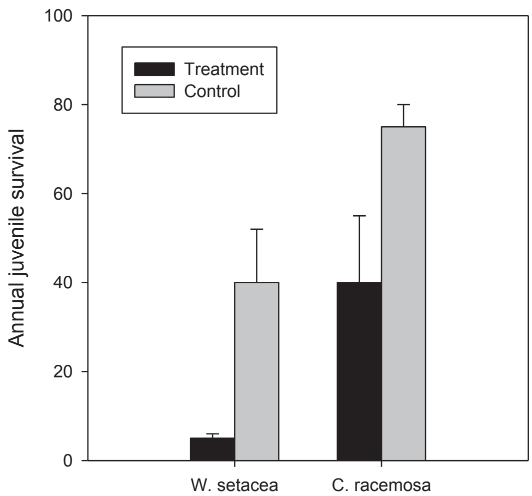

Fig. 4: Annual survival rate of *P. clavata* transplants (<10 cm) (mean ± SD) submitted to *Caulerpa racemosa* and *Womersleyella setacea* overgrowth (treatment) and control conditions. Adapted from Cebrian *et al.* (2012)

Discussion and conclusions

Beyond the direct impacts of mass mortality events on population structure and dynamics of *P. clavata* populations previously reported in several NW Mediterranean localities (Perez *et al*., 1999; Cerrano *et al*., 2000; Linares *et al*., 2005; Cupido *et al*., 2008; Garrabou *et al*., 2009; Huete-Stauffer *et al*., 2011), long-term monitoring of recurrent warming-induced mortalities in Cabrera Archipelago and Columbretes Islands showed a great affectation of red gorgonian colonies thriving at the upper depth distribution limit. The dramatic decrease on density to about 95% demonstrates that warming may lead to the local extinction of this species at the shallowest depth of its distribution. These results emphasize the role of warming as an important driver for long-term shifts in the bathymetrical distribution of gorgonian forests, with important consequences for shallow water coralligenous seascape.

Our results also showed severe effects of thermal stress on the reproduction of *P. clavata*. The greater reduction of fertility and number of gonads observed in female colonies compared to male colonies (95% vs. 22% and 97% vs. 35%, respectively) highlights that female colonies are more vulnerable to thermal stress as suggested in previous studies where female injured colonies showed a higher impact than male injured colonies (Linares *et al.*, 2008b). In addition, our results showed that non-injured colonies submitted to thermal stress also display important subtle impacts. On the other hand, the apparent higher sensitivity of embryos suggests that thermal stress during embryonic development may be the most critical factor for the viability of *P. clavata* larvae (Kipson *et al*., 2012). The reproductive impairment has further implications for the recovery of affected populations in the long term. In the context of an ongoing warming trend and considering the importance of self-recruitment in *P. clavata,* the reduced reproductive effort and viability of early life stages would jeopardize the persistence of affected populations.

The manipulative experiments demonstrated that both *C. racemosa* and *W. setacea* displayed strong and consistently negative effects on juvenile colonies of *P. clavata*. The lower survival and higher injury rate of juvenile colonies submitted to *W. setacea* and *C. racemosa* overgrowth suggests that in areas invaded by these species and affected by mass mortality events the recovery of gorgonian populations would be even more difficult (Cebrian *et al*., 2012).

Negative effects of warming and exotic seaweed invasions on *P. clavata* populations could be extrapolated to the great number of species with similar life-history traits dwelling in coralligenous outcrops (Ballesteros, 2006; Teixidó *et al*., 2011). In conclusion, further investigation of the effects of global change on the distribution, the reproduction and the viability of early life stages of species (such as gorgonians, but also algae, sponges or bryozoans, among others) are needed to improve our understanding of the long-term consequences of environmental global change in coralligenous assemblages.

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SPATIAL ALLOCATION OF FISHING ACTIVITY ON CORALLIGENOUS HABITATS IN PORTOFINO MPA (LIGURIA, ITALY)

Abstract

Coralligenous habitats are considered to be important for Mediterranean coastal biodiversity. One of the widely recognized principal threats to this habitat is recreational and artisanal fishing that may cause severe damage or mortality events to long-lived, key structural species. Consequently, the monitoring and sustainable management of fishing are the most important concerns when protecting vulnerable habitats and their biodiversity. The assessment of fishing activity in the Mediterranean region requires complicated approaches due to the increased heterogeneity and combination of gears, the variation of target species and the poor data availability. Therefore, common strategies in fisheries management have failed to capture this heterogeneity or improve understanding of fleet and effort allocation, and their impacts on benthic habitats. The present study identifies and describes the spatial and temporal patterns of selected recreational and artisanal practices having a direct physical impact on coralligenous habitats, such as nets and longlines, in Portofino MPA (Liguria Sea, Italy). Our results reveal areas vulnerable to the impact of overlapping fishing practices and may additionally provide baseline information on vulnerability and impact assessments, ecological and ecosystem modeling, fisheries resource management and conservation planning. Similar approaches could contribute to the decision-making process with regards to fishing activity and vulnerable habitats in Mediterranean MPAs.

Key-words: Coralligenous habitats; spatial analysis; fishing effort; resource management; Marine Protected Area

Introduction

Coralligenous are vulnerable habitats that confer great structural and functional complexity and biodiversity (Garrabou *et al.*, 2002). Although many vulnerable, endangered or commercially important species are known to live, feed or reproduce in this biotope (Salomidi *et al.,* 2012), there is still a limited understanding of this habitat for achieving adequate monitoring and adaptive management. Fishing activity is considered one of the main threats of coralligenous environments that may cause severe damage to long-lived, key structural species (Piazzi *et al.*, 2012) and may alter the habitat's health status (Ballesteros, 2006), directly through mechanical destruction and abrasion or indirectly, from abandoned gear (Bavestrello *et al.*, 1997). Particularly in Marine Protected Areas (MPAs), even though in most cases these activities are allowed and regulated, due to the considerable numbers of fishermen they involve (Font *et al.*, 2012), a specific management and protection plan should be developed in order to ensure their conservation targets (UNEP-MAP-RAC/SPA, 2008). Artisanal fisheries in the Mediterranean Sea (coastal local activity involving small capital investment and small boats - length ≤12m), has been characterized as a challenging

process that requires complicated approaches due to the strong heterogeneity and combination of gear, the change of target species during the year and poor data availability (Freire & García-Allut, 2000). Several approaches have been suggested to improve the understanding of the patterns of fleet and effort, such as the *métiers*, that describe fisheries with regard to fishing gear used, main target species, fishing area and season (Tzanatos *et al.*, 2013), or indicators measuring the level of fishing intensity and extend on the habitat using spatial analysis tools (*e.g*. Stelzenmüller *et al.*, 2008).
The present study identifies and describes the spatial and temporal patterns of selected recreational and artisanal bottom gear practices (Tab. 1) that may cause an effect on coralligenous habitats of Portofino MPA (Liguria Sea, Italy). This MPA, established in 1999, is the third smallest Italian MPA (3.74 km^2). Since 2005 Portofino MPA obtained the *status* of Specially Protected Area of Mediterranean Importance (SPAMI), also for the presence of coralligenous and its key structural species. Fishing activity is regulated and monitored by the MPA. Artisanal fishing is allowed only for the residents of the three municipalities involved in the Consortium of the MPA (Portofino, Santa Margherita Ligure and Camogli), the majority of which are based in Camogli (70%). Recreational fishing is permitted under authorization in Zones B and C for residents of the three municipalities and in Zone C for non-residents. Recreational longlines, trolling and "*natelli*" are regulated through a fixed number of 120 authorizations. For both recreational and artisanal fishing other restrictions such as the fishing of certain species, seasonal closures, prohibitions or modifications of fishing techniques, regulations in fishing effort and minimum landing sizes are also implemented in the MPA in order to control the activities. Results aims to reveal those areas vulnerable to the impact of overlapping fishing practices and may provide a reference point for vulnerability and impact assessments, ecological and ecosystem modeling and conservation planning in Portofino MPA.

Materials and methods

The MPA has been divided into 18 smaller management units for monitoring convenience (Fig.1). Data on fishing activity were obtained by fishing diaries, interviews and mental mapping with fishermen of Portofino MPA during the period 2011-2012 (Canella, 2012; Mariotti, 2013; present study). Information coming from 27 out of 28 artisanal fishermen that use practices that can have a direct impact on the coralligenous, were mapped. Additionally, the areas of activity of 113 recreational fishermen that use the fishing techniques under study were mapped, corresponding to 33.25% of all 400 recreational fishermen estimated in Portofino MPA (Cappanera *et al.,* 2012). Data was charged in a Geographical Information System (ArcGIS 10.2). Spatial allocation of fishing activity was based on integration of heterogeneous data from GPS points indicating the position of the nets, fishing trip routes, fishing depth, bottom type, locate areas with access from the coast using Google Earth, mental maps and acronyms of areas. In the case of artisanal fishing, accounting for uncertainty of the nets' location, the spatial deviation equal to 10% of the net length was drawn around the location of gear deployment (Stelzenmüller *et al.*, 2008). There was no possibility of discrimination between pelagic and bottom longlines as the information monitored does not distinguish between the two activities. The coralligenous habitat layer was retrieved from Liguria Region (2009). Bathymetry was extracted from acoustic data (Zapata-Ramirez *et al.,* 2014). The pressure on sea bottom (hereafter referred to as *fishing effort*) was expressed in total number of hours per year (hrs/yr) in order to compare recreational and artisanal fishing.

We superimposed grids with 1 m^2 cell sizes and aggregated all fishing effort by the sum total of hours per year for each tool. Most impacted coralligenous habitats were identified as those areas that receive 90% of the total footprint occurring for a specific bottom fishing fleet, in accordance with the suggestion of the Data Collection Framework (DCF) of the Common Fishery Policy (EC, 2008a;b), for long-term surveying and the provision of scientific advices towards ecosystem-based fisheries management. To assess the effect of each type of fishing practice on coralligenous habitats we compared the total area impacted (in m^2) and the habitat affected, expressed as surface (in m^2) and percentage (%) of the total coralligenous habitat inside the MPA (Tab. 1).

Results

Coralligenous habitats in the wider area of Portofino cover a surface of 1.553 km^2, of which 11.34% (0.176 km^2) are located inside the MPA. The remaining 88.66% (1.377 km^2) falls outside the MPA limits and is currently unprotected. The management units with higher surface areas of coralligenous are 6 (19.63%), 7 (14.35%), 11 (11.71%) and 14 (10.98%) (Tab.1; Fig.1). The use of artisanal gears is highly seasonal with gillnets, combined nets and fishing cephalopods mostly employed during autumn (maximum number of boats 9-10, 4 and 2 respectively). During spring and summer, use of trammel nets and longlines is increased (maximum number of boats 8-3 and 4 respectively). October was the most popular month for recreational fishing with 13.3% (337 fishermen) of the annual recreational effort. Data mapping also indicated incidents of fishing within restricted areas. The assessment for each fishing practice and the total fishing effort is shown in Tab. 1. Artisanal fishing effort of tools potentially harmful to coralligenous habitats ranged from 636 to 16098.3 hrs/yr, while recreational fishing was much smaller (0-596.31 hrs/yr). The total fishing effort of artisanal and recreational fishing techniques under study ranged from 693 to 16098 hrs/yr. Most of the impacted coralligenous habitats overlapping with the 90% of the total fishing footprint (14.488 hrs/yr) were located in the management units 6-11 at 30-40 m depth, with surface area exceeding 0.035 km^2 (20.58%) of the total coralligenous in Portofino MPA.

Discussion and conclusions

Understanding the spatial and temporal patterns of fishing effort is fundamental for the sound conservation of benthic ecosystems and seafloor integrity (Stelzenmüller *et al.*, 2008), particularly for vulnerable habitats of limited extent. The artisanal fishing sector of Portofino MPA resembled a typical northwestern Mediterranean coastal fishery with a mean boat size of <10m and engine power <75kW (Leleu *et al.,* 2014). Even though similar studies allowing the comparison of results are limited, data on the number of boats suggest that Portofino MPA artisanal fishing is rather limited but locally intensive targeting vulnerable habitats. On the contrary, the trend has been for recreational activity to increase since 2008, and it is assessed as high (Cappanera *et al*., 2012). Due to low representativeness of recreational fishers in the sample this was not so evident in our results. However improved MPA monitoring, particularly for recreational fishing, is expected to improve the pressure assessment of this activity in 2015. The most impacted coralligenous habitats in Portofino MPA are located at a depth of between 40-60 m, with special reference to depths of 30-40 m at the southeastern part. Nets were considered the most impacting tools based on the extent of the pressure (effort, surface, % surface of total habitat). However for a deeper analysis, the intensity and weighting of the different practices should be also included in future analysis.

Tab. 1: MPA of Portofino - Assessment of recreational and artisanal bottom-fishing practices combined: Techniques, range of effort (hrs/yr) and threshold account for 90% of the total activity for identifying most impacted areas, most impacted MPA management units (Fig. 1) and depth range (m), total area (m^2) most impacted by a tool, total area (m^2) of coralligenous mostly impacted by a tool, % most impacted coralligenous area of the total coralligenous in the MPA. In bold are the values of high concern for coralligenous habitats regarding the above criteria. (§) Artisanal technique; (†) recreational technique (*) Underestimated value due to inadequate data.

Fishing technique	Effort range, threshold (hrs/yr)	Units & depth range most impacted	Total area most impacted (m^2)	Surface area of habitat most impacted (m^2)	% of total habitat most impacted
Big game with rod†	5.5-120.0 (108.8*)	6-9 (15 -85m)	426280.7	67531	**38.37**
Big game with handline †	7.17-92.93 (83.63*)	14 (20 -50m)	100205	18694	10.62
Bottom longlines †	0.38-175 (157.5*)	6 (50-75m), 14 (40-60m)	278500	14200	8.06
Cephalopods †	0-9.74 (8.76*)	13 (20-50m)	2319947	10052	5.71
Vertical jigging †	5.8-40.34 (36.31*)	14 (20- 55m)	222776	19053	10.82
Bottom troling †	9.95-269.07 (**242.16***)	6 (20-80m)	149560	34567	**19.64**
Bottom fishing †	0.4-323.745 (**291.37***)	5,15 (0-30m)	27720	2356	1.33
Gill nets §	**540-4980 (4482)**	6-11 (35-45m)	363700	33750	**19.17**
Trammel nets§	**96-8878 (7990.2)**	6-11(25-35m)	105000	3850	2.18
Combined nets§	**0-2608 (2340)**	9 (45-55m)	300	200	0.11
Bottom longlines§	57.5-467.5 (420.75)	15 (20-25m), 6-11 (40-45m)	195600	12200	6.93
Cephalopods§	0-285 (256.5)	5-15 (20-80m), 3 (20-25m)	249600	166880	**94.81**
Overall artisanal and recreational fishing †§	**636-16311.5 (14680)**	**6-11 (30-40m)**	**88929**	**36226**	**20.58**

Even though the spatial allocation of some fishing practices was broad, the identification of most impacted areas seems to have been successful. Vezzulli *et al.* (2013) collected data supporting the high vulnerability of gorgonians at depths of 20-50 m in Portofino MPA as being due to high diving pressure and fishing activity that made them susceptible to bacteria. Management units 6, 15 and 16 at depths of 30-40 m have also been reported in the past for the great amount of lost gear originating from the big game fishing (Cattaneo-Vietti, personal communication), and as having suffered from massive mortality events (Cerrano *et al.*, 2000). The mapping of fishing activity outside the MPA still remains a challenging issue that could generate a new management strategy for the enlargement of Portofino MPA and the protection of the deep coralligenous that covers almost 90% of the coralligenous habitats in the wider area. This is a first attempt to map fishing activity in Portofino MPA by integrating information coming from a wide variety of sources and forms that are regularly adopted in the monitoring strategy of Mediterranean MPAs (Font *et al.*, 2012). The results of this study provide a baseline of information for improving the management of the fishing activities on vulnerable habitats within Portofino MPA.

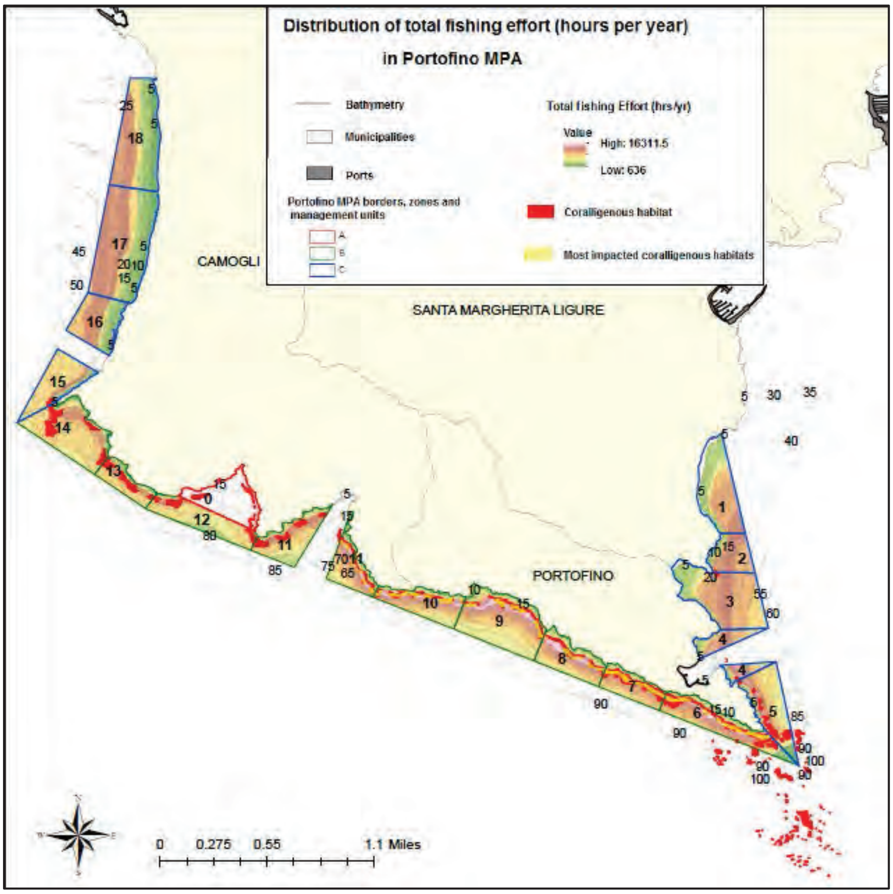

Fig.1: Total effort (hours per year) of all the fishing tools potentially harmful for coralligenous practiced in the Portofino MPA.

Acknowledgements

This research was funded by the European project "Training Network for Monitoring Mediterranean Marine Protected Areas" (MMMPA: FP7-PEOPLE-2011-ITN, Grant Agreement no. 290056).

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LONG-TERM DEMOGRAPHIC TRAITS OF RED CORAL POPULATIONS IN THE NW MEDITERRANEAN: INSIGHTS INTO MANAGEMENT STRATEGIES

Abstract
The Mediterranean red coral, Corallium rubrum, is an emblematic species of coralligenous assemblages which has been intensively harvested since antiquity. However, the lack of long-term studies over broad geographic scales hinders our understanding of the general dynamics of red coral populations. Based on long-term photographic series from nine populations separated from few to hundreds of kilometers across the NW Mediterranean, we estimated temporal stability, demographic traits and the main drivers of population recovery and persistence. Overall, the nine studied populations displayed a consistent pattern of high temporal stability regardless protection level and size-class distribution. The high temporal stability was driven by extremely high adult survival and low recruitment rates. Colonies suffering partial mortality from harvesting also displayed high survival rates and showed rapid signs of re-growth demonstrating a key role of this mechanism on the recovery processes of C. rubrum. However, despite of the persistence of the species, harvesting strongly reduced the biomass and triggered a general simplification of the affected populations. Our results demonstrate the ecological impacts of harvesting on this species and highlight the need to develop new regulations (especially in harvesting practices) to enhance the resilience of this emblematic species.

Key-Words: Recovery processes, Precious corals, Fisheries management, *Corallium rubrum*, Mediterranean Sea.

Introduction

The Mediterranean red coral, *Corallium rubrum*, is one of the most emblematic species of coralligenous assemblages which has been intensively harvested since antiquity (Tsounis *et al*., 2010). Red coral is a long lived marine sessile invertebrate with low dispersal capabilities. Given its life-history, *C. rubrum* is expected to be low resilient to increases in mortality due to external perturbations. Interestingly, the shallow populations of this species have persisted after being long-time subjected to overexploitation. Thus, challenging questions on the general dynamics and recovery mechanisms of red coral populations remain unresolved.

This study aims to explore the long-term dynamics of red coral populations in the NW Mediterranean to provide some insights on the general demographic strategy of this species, the effects of harvesting, and the recovery mechanisms of affected populations. Based on long-term photographic series from nine populations widely distributed in the NW Mediterranean, we estimated temporal stability, demographic traits and the main drivers of population recovery and persistence. Our results bring some light to the dynamics of this long-lived invertebrate, showing how a deep knowledge on the demographic processes can help to improve management strategies.

Methods

The present study was conducted in five localities located along the North-Western Mediterranean region. In each locality one to three populations were monitored resulting in a total of 9 monitored populations. Four localities were within Marine Protected Areas (MPA) were harvesting is not allowed but other human uses are submitted to different regulations. For our study the main differences regard the recreational diving which is allowed in Parc Natural del Montgrí, Illes Medes i Baix Ter (Spain) and completely forbidden except for scientific studies in Réserve Naturelle Marine Cerbère-Banyuls (France) (none human use allowed), Parc Marin Côte Bleue (Carry-le-Rouet, France) and the Réserve Naturelle de Scandola (Corsica, France). The last locality was the archipelago of Riou near Marseilles (France) where harvesting and recreational diving are allowed (Fig. 1). Therefore, these populations were submitted to three protection levels (integral reserve, natural reserve and non-protected) resulting in a differential disturbance pressure and contrasted population structures.

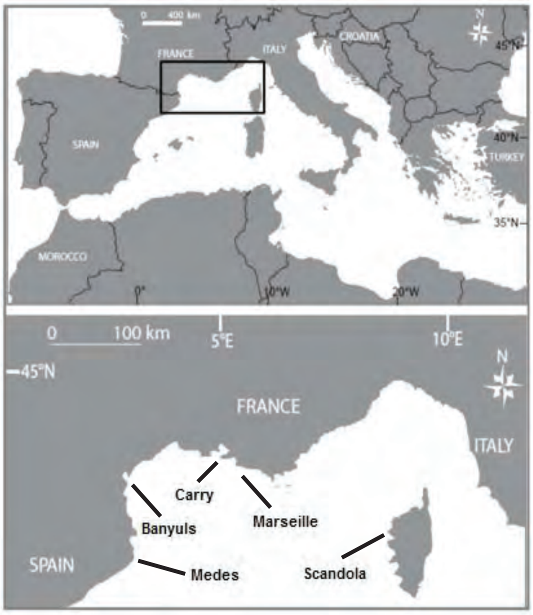

Fig. 1: Study area. Nine red coral populations widely distributed in the NW Mediterranean

Once a year, permanent transects of about 2 m^2 installed within red coral populations dwelling between 15 and 25 meters depth were monitored using a photographic sampling. During sampling, a cord was deployed between the screws and a 20 x 20 cm quadrat (covering 400 cm^2), sequentially positioned and photographed throughout the length of each transect. Based on these photographic series, we estimated colony heights using photogrammetric techniques (Drap *et al*., 2013). We also estimated adult population densities, recruitment rates, and mortality rates.

On the other hand, we investigated harvesting effects and recovery patterns on two populations that were harvested (Riou and Maire). We estimated changes in size-structure, survival and re-growth rates of affected populations. Further, we calculated biomass changes during the study period on the harvested populations by applying a height-weight relationship to the measured colony heights. The height-weight relationship was calculated from 300 dead colonies and the resulting equation was: Weight (g) = 0.001(Height, mm)^2 + 0.096(Height, mm) - 4.010 ($R^2 = 0.868$, $P < 0.001$).

Results

Overall, the nine red coral populations displayed a general pattern of high temporal stability in abundances. Annual recruitment rates were very low in most of the analyzed populations (Fig. 2). On the other hand, adult colonies showed extremely high survival rates during the study period (98.86% ± 1.02). These patterns were consistent across the study area regardless the protection level, disturbance regimes and size-class distribution of the studied populations. However, when calculating annual net population growth rates we found negative trends in six out of the nine studied populations and ranged from 0.5 to 2.8%, while in the remaining three populations annual net growth was approximately zero.

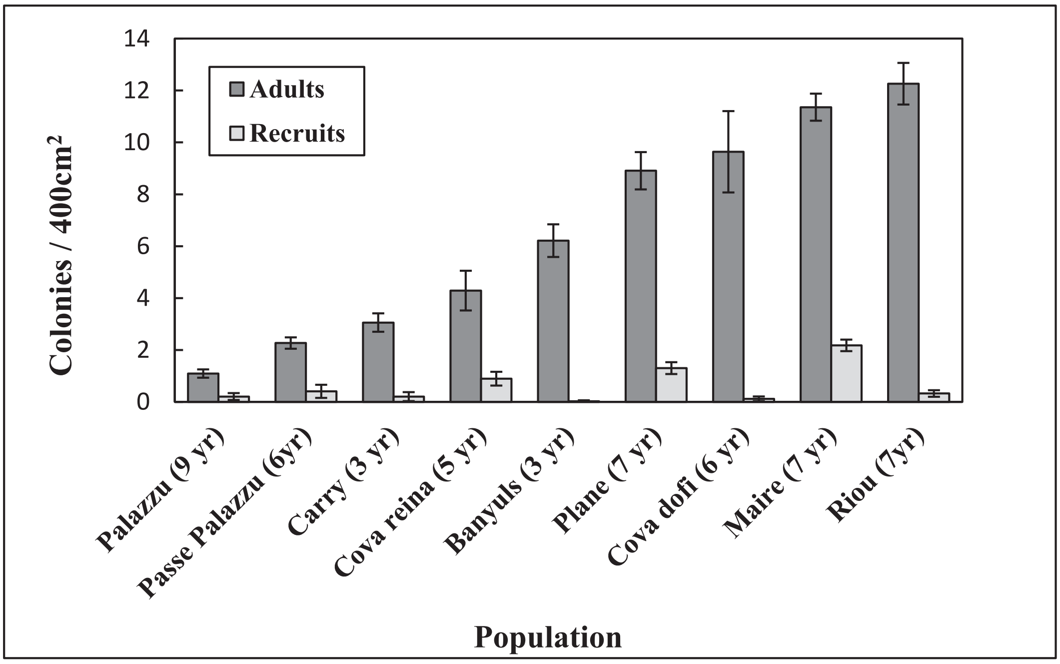

Fig. 2: Long-term demographic traits at nine red coral populations from the NW Mediterranean. Bars show mean ± SD density of adults (dark grey) and recruits recorded on yearly basis (light grey). Length of the study periods is shown in parenthesis (yr = number of years).

Harvesting heavily impacted Riou and Marie populations, causing large decreases in biomass and size-class distribution shifts towards populations dominated by small colonies. For instance, at Riou the proportion of large colonies (>80mm) decreased from 31.7% before harvesting to zero after harvesting and only 1.9% of these size-class was observed four years after the harvesting event (Fig. 3). Mortality rates of affected colonies were very low (0.31% ± 0.30 at Riou and 0.23% ± 0.25 at Maire) and similar to those recorded for non-affected/harvested colonies. Besides affected colonies showed rapid signs of re-growth, with more than 80% of the colonies showing new branches after 4 years at both analyzed populations. However, at the end of the study, only partial recovery was observed. For instance, at Riou, only 22% of the initial biomass was observed four years after harvesting.

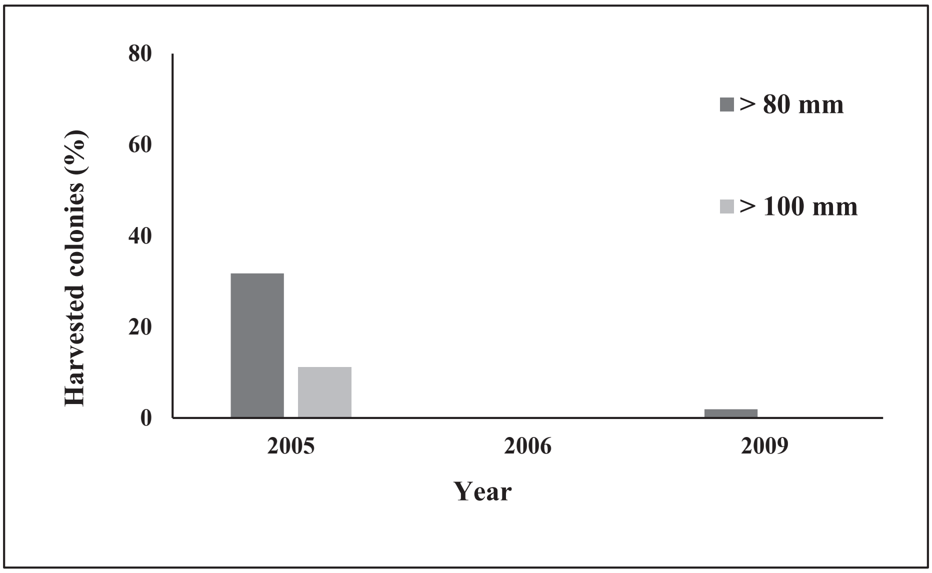

Fig. 3: Harvesting effects on the proportion of large size-class colonies at Riou: before harvesting (2005), right after harvesting (2006), and four years after harvesting (2009).

Discussion

Red coral populations were highly stable in terms of abundance. Within the slow-fast continuum, temporal stability is a demographic trait commonly observed species with a long life span, where low mortalities can buffer the lack of reproductive success. Indeed, our results are concordant with this hypothesis and showed that the temporal stability among red coral populations can be linked to the observed extremely high adult survival and low recruitment rates. Although our study periods (between 3 and 9 years) may have failed to detect a recruitment-by-pulses pattern expected in this species (Garrabou & Harmelin, 2002), six populations showed worrying negative temporal trends. These negative trends may also be the result of the recent increases in frequency and intensity of new sources of perturbations, which are leading to higher mortality rates. In fact, several positive thermal anomalies related to climate change have impacted shallow populations during the last decades causing mass mortality events (Garrabou *et al.,* 2001; 2009), while harvesting is still an important source of mortality (Tsounis *et al*., 2010; Linares *et al*., 2012).

We investigated harvesting effects and recovery patterns on two populations that were affected (Riou and Maire from the Marseilles' area) during the study period. Our results confirmed the long-lasting negative effects of harvesting in long-lived sessile organisms and highlight the unsustainability of current extractive practices. We went beyond of that by exploring for the first time two potential recovery mechanisms in harvested populations. The observed low recruitment rates and high mortality of recruits contrast with the high survival of adult colonies that were partially harvested. Further, affected colonies showed rapid signs of re-growth suggesting that this mechanism plays a key role on the recovery of red coral populations after harvesting. Thus, these results may help to explain the observed persistence of shallow populations due to high survival of partially harvested colonies. Given the low capacity of this species to recover through sexual reproduction (*i.e*. recruitment) after high mortality events and the importance of re-growth for the recovery of coral populations, new regulations that establish a ban on the total removal of the colony when harvesting are urgently needed.

Finally, this study demonstrate the importance of ecological monitoring programs to understand the dynamics of long-lived species dwelling in coralligenous assemblages and highlight the need to develop new regulations (especially in harvesting practices) to enhance the resilience of this emblematic Mediterranean species.

Acknowledgements

We acknowledge the support of all the people that helped us during the field work. Support for this work was provided by a FPI grant (BES-2013-066150) to IMS and by a Ramon y Cajal research contract (RyC-2011-08134) to CL. This study was partially funded by the Spanish Ministry of Economy and Innovation Biorock project (CTM2009-08045) and Smart project (CGL2012-32194). The authors are part of the Marine Conservation research group (2009 SGR 1174) from the Generalitat de Catalunya.

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NEW DATA CONCERNING THE CORALLIGENOUS ATOLLS OF CAP CORSE: AN ATTEMPT TO SHED LIGHT ON THEIR ORIGIN

Abstract
A new coralligenous morphotype named 'atolls' was discovered in 2011 in northern Cap Corse (Western Mediterranean Sea). With the aim of inventorying and characterizing these structures, and to attempt to shed light on their origins, two oceanographic campaigns (using e.g. side scan sonar, multibeam echosounder, sparker, ROV and submarine with 3D photogrammetry) were carried out in 2013 and 2014, in this sector, and in the south of the island in search of similar structures.
Off Cap Corse, nearly one thousand atolls were identified between 105 and 130 m depth; the majority of them are situated between 110 and 125 m depth. These atolls are generally grouped (several tens to several hundred) and are to be found in two main sectors, situated between 22 and 31 km from the coast. They occur on subhorizontal bottoms, in rocky depressions occupied by coastal detritic bottom, and are 1 to 2 m thick. The average size of these atolls ranges from 20 to 25 m in diameter, but a few smaller or more extensive structures have been identified. The height of the central core ranges from 0.5 to 3.0 m, the intermediate zone, which surrounds this core, presents a width of about 10 m, and the exterior crown has a width of 1 to 5 m. No atoll was found along the south coast although the topography is similar (bathymetric patterns, presence of a seamount).
Several typologies have been evidenced; these typologies could correspond to atolls at different stages of evolution in relation to phenomena of bioerosion or bioconstruction. Furthermore, the occurrence of 'fossil coralligenous' formations, between 138 and 140 m depth, with still living rhodoliths at the summit, might support the hypothesis of a biological origin, with the original formation occurring during a period when the sea level was lower, several thousand years ago.

Key-words: Coralligenous, Atolls, Rhodoliths, Corsica

Introduction

The coralligenous habitat is considered as a typical underwater seascape and a highspot of biodiversity in the Mediterranean Sea. It consists of biogenic concretions mainly produced by the accumulation of calcareous encrusting algae, growing in dim light (Ballesteros, 2006; Michez *et al*., 2014).
A new coralligenous morphotype was discovered in 2011 off northern Cap Corse (Western Mediterranean Sea) in the vicinity of underwater seamounts (Bonacorsi *et al*., 2012). These structures, never previously identified in the Mediterranean Sea, are named 'coralligenous atolls' because of their circular shape. They are formed of:
- A massive central core constituted by a massive coralligenous structure;
- A halo of detritic bottom, with few sparse rhodoliths and a large amount of organic debris;
- A peripheral crown consisting of free rhodoliths (pralines) and many invertebrates.
The sector concerned by these atolls is of particular importance as it might be included in the future Cap Corse Marine Natural Park.

Two oceanographic campaigns were carried out in 2013 and 2014 in this sector with the aim of drawing up as exhaustive an inventory as possible of these structures (localisation, number), specifying their morphology and researching into their origin and / or their dynamics.

Material and methods

The study of the atolls was carried out mainly during the CoralCorse cruise, in the summer of 2013 (from 3 to 7 August and from 4 to 8 September). The aim of this cruise, carried out on board the IFREMER oceanographic research vessel Europe, was to produce an exhaustive map of the seabed, from 100 to 150 m depth, in the Cap Corse sector, and also more sporadically in the south of the island (on 23 and 24 August) between Corsica and Sardinia, off Mount Asinara, a sector presenting morphological similarities with the seamounts of Cap Corse.

A range of data acquisition systems were used simultaneously: side-scan sonar (Klein 3000) and a multibeam echosounder (EM 2040) for the cartography and a 2.5 KHz sediment sounder and a sparker (seismic reflection) to identify possible vertical structuration that might explain the origins and dynamics of these atolls; field validation was performed using a Van Veen grab and a Remote Operated Vehicle (ROV).

Complementary investigations were carried out, in the course of the MedAtolls cruise, on 27 July and 2 August 2014, on board the COMEX oceanographic research vessel Minibex. The aim was to characterise the different forms of atoll, identified on the sonograms of the previous cruise, to reconstitute an atoll in three dimensions (photogrammetry) and to identify the main species present. The observations were carried out using a ROV Super-Achille equipped with high resolution cameras and a sample collection system (pincers and basket) and a Remora 2000 submarine equipped with a system for taking photogrammetric images.

Side-scan sonar and multibeam data were processed with the Caraibes 3.8® software program and a digital Terrain Model (DTM) and a mosaic (resolution of 0.5 m) were developed. All the data were integrate into a Geographic Information System (GIS; ArcGis 10®; projection Mercator-WGS84).

Several species present on the photographs and video were directly identified and localized on the GIS; for the other species, samples were sent to taxonomists from Aix-Marseille University, IFREMER and the Muséum National d'Histoire Naturelle. The 3D reconstitution of a representative atoll was realised by the COMEX Team.

Results

The mapping of the seabed in the Cap Corse sector, allows identifying almost a thousand coralligenous atolls between 105 and 130 m depth; the majority of these atolls are situated between 110 and 125 m depth. On the other hand, no atoll was observed in the sector between Corsica and Sardinia.

These atolls are generally grouped (several tens to several hundred), around the edge of rocky outcrops, in two main sectors situated between 20 and 30 km to the north of Cap Corse. The map of the distribution of the atolls shows that they are localized on subhorizontal bottoms in rocky depressions (Fig. 1 and 2).

Their average size generally ranges from 20 to 25 m, but a few smaller or more extensive structures were identified. In addition, the central core would appear to vary according to the sector (diameter, apparent height), as do the thickness and the density of the peripheral crown. In certain cases, the central core would even appear to be totally absent.

However, it is difficult to characterize these structures with greater precision on the basis solely of the acoustic sensors (side-scan sonar and multibeam echosounder).

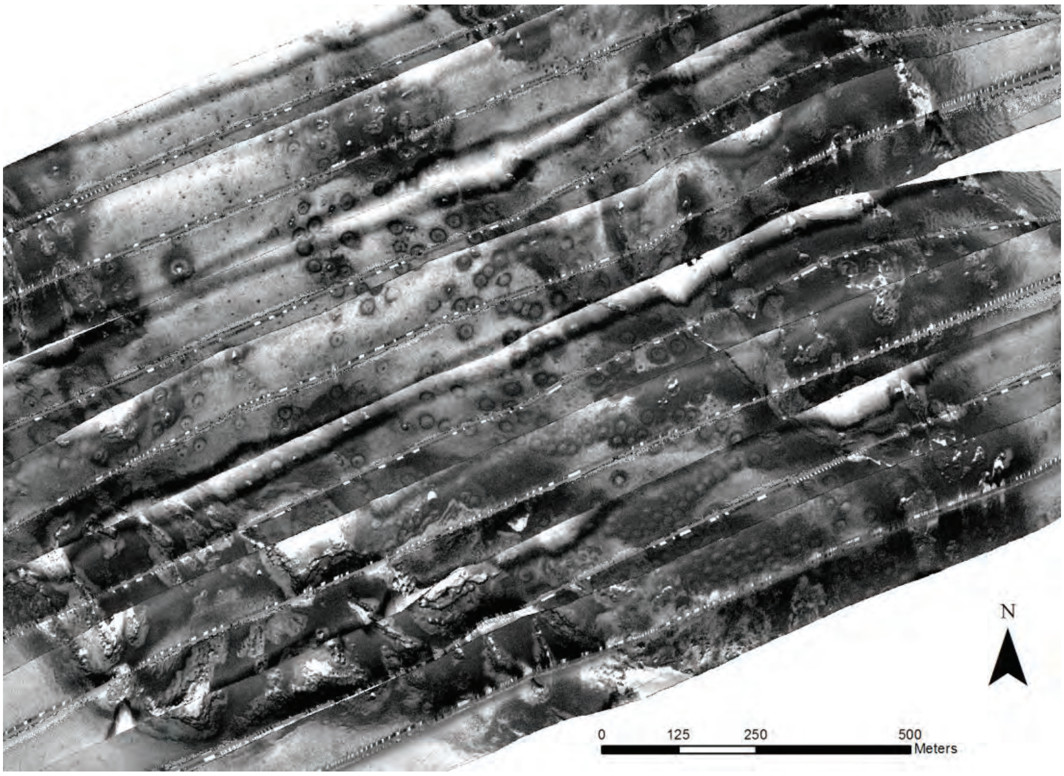


Fig. 1: Example of the concentration of atolls on a mosaic of sonograms.

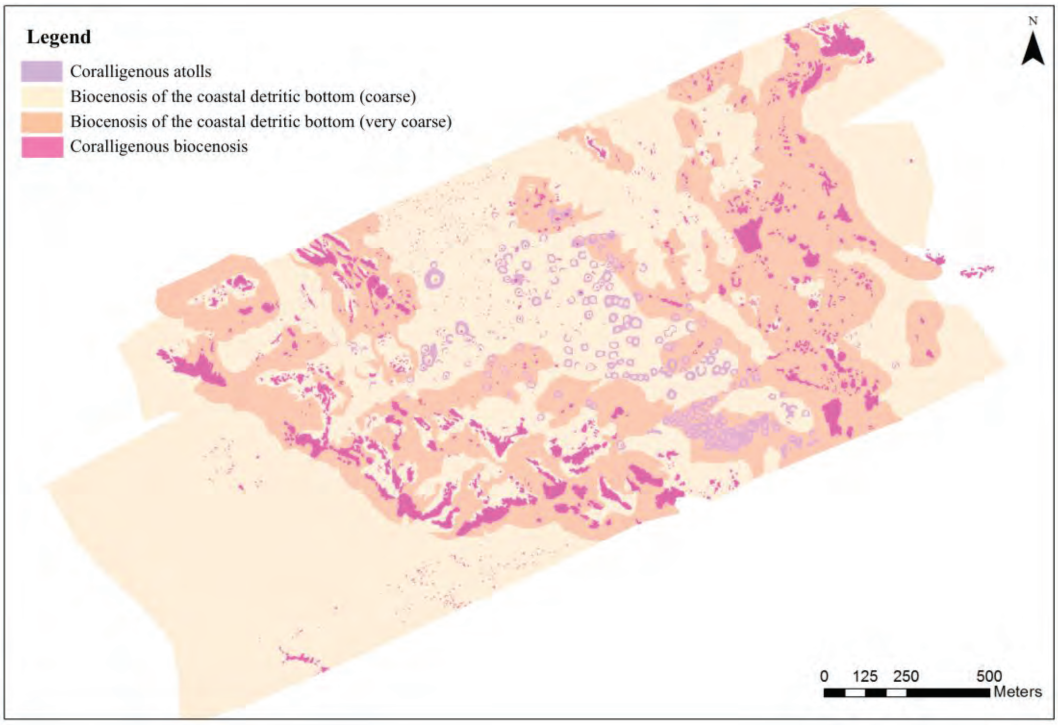
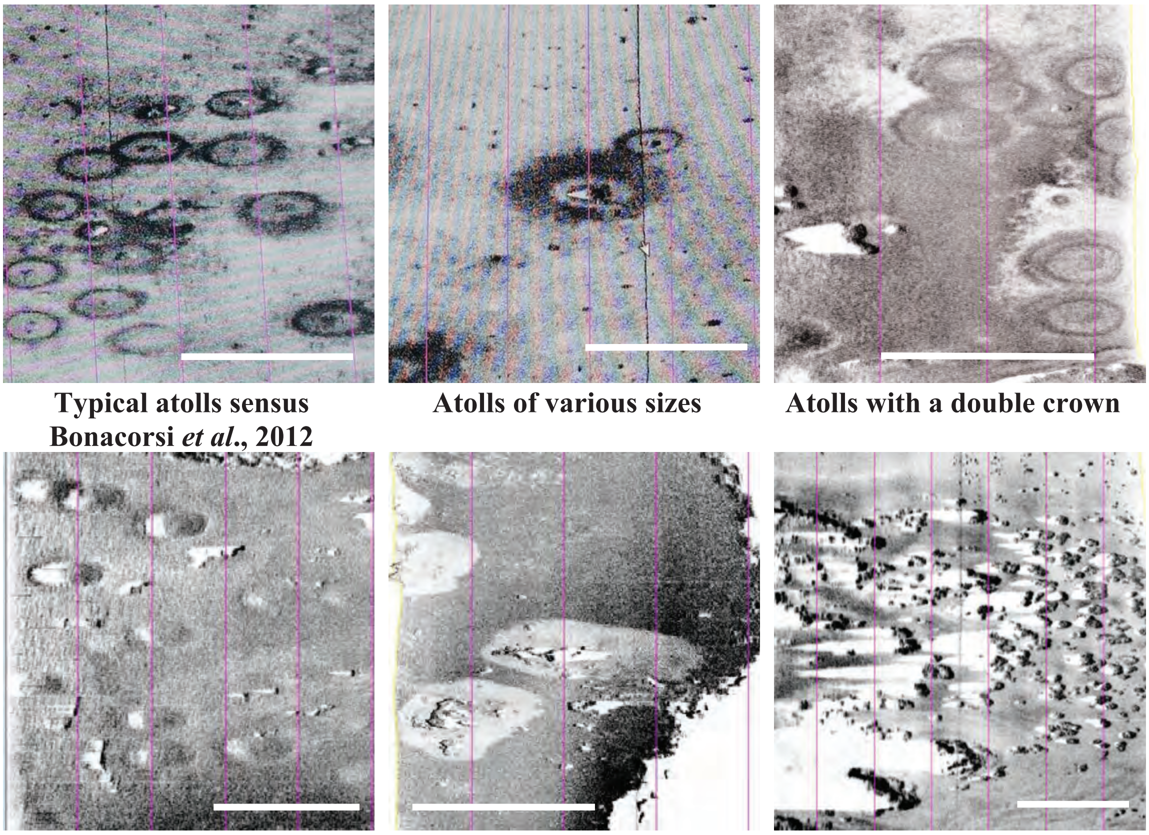


Fig. 2: Map of the main assemblages and bottom types of the zone of concentration of the coralligenous atolls.

Hydrodynamic forces would appear to play a major role in the constitution of the peripheral crown since this type of structure is also observed around the edges of certain rocks; on the other hand, in the presence of very strong hydrodynamic forces (exposed flat rocks, areas characterized by large ripple marks), no atoll was observed. Furthermore, the information obtained by the seismic reflection would appear to indicate that these structures are present on coarse sediment soft bottoms of a thickness of 1 to 2 m. When the sediment layer is thicker (more than 3 or 4 m), no atoll is observed. Several characteristic structures, identified among the mapped atolls, were investigated by means of the ROV and the submarine (Fig. 3). Other observations were also made at greater depths (138 to 140 m) in sectors corresponding to hard substrates and in particular around the 'rock fields' scattered over soft substrates (Fig. 3).

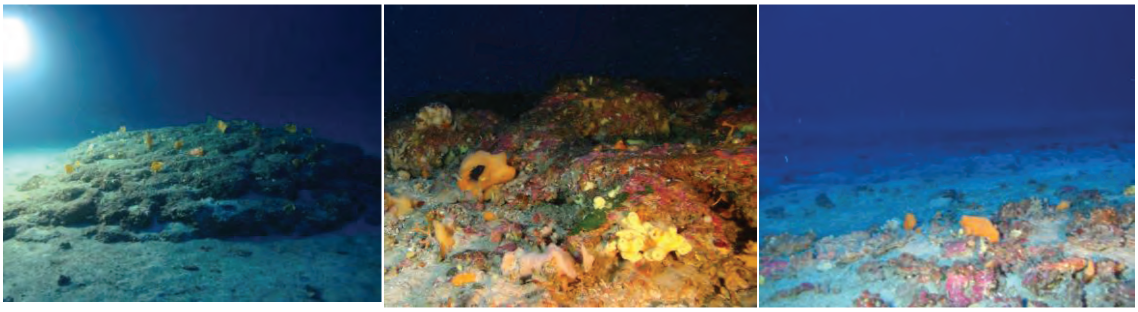


Typical atolls sensus Bonacorsi *et al*., 2012 | **Atolls of various sizes** | **Atolls with a double crown**

Dome-shaped atolls | **Haloes around rocks** | **Rock fields**

Fig. 3: Different structures observed using side scan sonar; the white line corresponds to 50m.

The central core presents a range of morphologies: it is generally constituted by a massive bio-concretioning in the classic atolls, but it may present extensive erosion with more or less collapsed overhangs around the edges and fragmentation of the core (Fig. 4). In certain cases, the central core is only represented by small, more or less contiguous blocks scattered over the substrate (dome-shaped atolls). On the other hand, the core appears to be raised above the surrounding sediment, and this slope would appear to be present as far as the peripheral halo.



Massive core | **Core in the process of erosion** | **Core fragments**

Fig. 4: Different morphologies of the central core observed by means of the ROV.

Between the core and the peripheral crown the sediment appears to be coarse, with abundant biogenic debris.

The peripheral crown is constituted of praline-shaped rhodoliths of various sizes (0.5 to 8 cm), on which numerous invertebrates are fixed (Fig. 5). At certain sites, this crown is subdivided by a band of sand (Fig. 6). Around the crown, various concretioned structures may be observed; they may correspond to the beginnings of a new core.

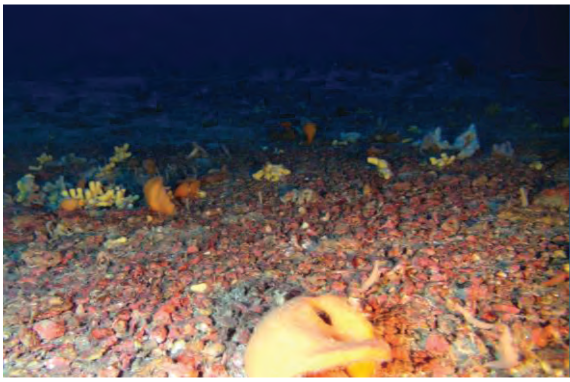


Fig.5: Accumulation of rhodoliths around the peripheral crown

Fig. 6: Double crown of rhodoliths around the central crown of an atoll

Discussion and conclusion

The analysis of the data collected in the course of the campaigns should continue over the next few months, both in order to be able to offer an explanation of the occurrence of these structures and to understand their dynamic, and to provide an initial inventory of the species present. The three dimensional reconstitution of a 'characteristic' atoll should enable us to better understand its structure and in particular to dispose of a bathymetric record fine enough to confirm the existence of a slope between the core and the peripheral crown.

Similarly, the presence of large colonies of *Callogorgia verticillata* on the periphery of certain atolls should enable us to detect the presence of possible circular currents around these structures (orientation in relation to the prevailing currents).

Nevertheless, in the light of the available data, a tectonic origin would appear to be less and less likely and a biological origin, corresponding to earlier coralligenous formations that might have formed at an earlier period when the level of the sea was lower, is favoured (Waelbroeck *et al*., 2002; Henderson, 2005). This hypothesis is supported (i) by what would appear to be phenomena of bioerosion, or even of bioconstruction, giving rise to atolls presenting different stages of evolution, and (ii) by the presence of ‘fossil coralligenous’ formations observed between 138 and 140 m depth, with a few still living rhodoliths at the summit, which had been identified as ‘rock fields’ with the side scan sonar (Fig. 7).

Fig. 7: Coralligenous formation observed at 139m depth.

Acknowledgments

This research is a part of the University of Corsica and the Collectivité Territoriale de Corse CHANGE programme (FRES 3041). This work would not have been possible without the support of the oceanographic research vessels N/O L’Europe (Ifremer-Genavir-Insu/UMS Flotte Océanographique Française) and the N/O Minibex (COMEX), and the financial support of the Agence des Aires Marines Protégées.

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VISUAL AND PHOTOGRAPHIC METHODS TO ESTIMATE THE QUALITY OF CORALLIGENOUS REEFS UNDER DIFFERENT HUMAN PRESSURES

Abstract
This paper aims at evaluating the effectiveness of some descriptors obtained from photographic methods and visual assessment techniques to detect changes in ecological quality of coralligenous habitat. From the photographic methods we obtained the following descriptors: i) mean number of the main taxa/morphological groups, ii) mean cover of the main taxa/groups iii). beta-diversity of assemblages. From the visual techniques we measured and estimated the following descriptors: i) mean thickness of the calcareous layer, ii) maximum height of gorgonians, iii) mean cover of the species characterizing the coralligenous upper layer, iv) percentage of epibiosis and/or necrosis in the upper layer. Surveys were carried out in sites subjected to different human-induced pressures in three areas of the north-western Mediterranean Sea, in order to evaluate effectiveness of the selected descriptors at large spatial scale (100s of kms). Results showed that some taxa identified from the photographic method decreased in sites subjected to high human pressure, while encrusting bryozoans and filamentous algae increased their abundance. From the visual technique, in the high human pressure sites, the mean thickness of the calcareous layer was lower, the abundance of some gorgonian species decreased, and some taxa/groups appeared, e.g. the erect and massive sponges. Descriptors applied with both methods were able to reveal differences across human pressure gradient and therefore could provide precious insights to determine the quality of coralligenous reefs.

Key-words: Coralligenous, Ecological quality, Human pressures, Visual assessment, Photographic technique

Introduction
Coralligenous (Ballesteros, 2006) is considered one of the most relevant Mediterranean "special habitat types" that should be assessed under the Marine Strategy Framework Directive (EC, 2008). The development of monitoring programs requires effective descriptors to evaluate the ecological status of coralligenous habitat and to detect changes in its ecological quality. Coralligenous habitat is considered sensitive to most of human-caused impacts (Piazzi *et al.*, 2012; Roghi *et al.*, 2010). Severe shifts in the structure of coralligenous assemblages subjected to several kinds of anthropogenic stressors have been highlighted (Balata *et al.*, 2005; 2007a; 2007b; Gennaro & Piazzi 2011; 2014; Piazzi *et al.*, 2007; 2011), which include reduction in species richness (Balata *et al.*, 2007a; Piazzi *et al.*, 2007) and beta-diversity (Balata *et al.*, 2007b; Piazzi *et al.*, 2011), disappearance or decrease of the most sensitive species and an increase of tolerant and opportunistic species (Piazzi *et al.*, 2012). Moreover, mortality of key invertebrates has been observed following mechanical damages and climate anomalies (Bavestrello *et al.*, 1997; Cerrano *et al.*, 2000; Coma *et al.*, 2007; Garrabou, *et al.*, 1998). Some possible candidate descriptors have been proposed for assessing the ecological status

of coralligenous habitat (Cecchi *et al.*, 2014; Deter *et al.*, 2012; Gatti *et al.*, 2012; Kipson *et al.*, 2011). Both the visual techniques (Rapid Visual Assessment, Gatti *et al.*, 2010) and the photographic methods (Ecological Staus of Coralligenous Assemblages, Cecchi *et al.*, 2014) have been used to assess the status of some Italian coralligenous habitats.

This paper aims at evaluating the effectiveness of some descriptors obtained from photographic methods and visual techniques to detect changes in the assemblages that could provide insights in the ecological quality of coastal areas subjected to different levels of human-induced pressure.

Material and methods

The study was carried out in three areas of the north-western Mediterranean Sea (Liguria, Tuscany and Sardinia) on vertical reefs between 30 and 40 m depth. Photographic methods were applied in 14 sites, visual techniques in 10 sites (both methods in 3 sites). For each site, human-induced pressures were evaluated through a method inspired to that proposed by Lopez y Royo *et al.* (2009). Eight pressures were considered: urbanization and urban waste, ports, tourism, industrial activities, sediment load, aquaculture, agricultural waste, and fishery. For each pressure a score from 0 to 3 has been assigned, with the total pressure ranging from 0 to 24: score 0 (no source of pressure), score 1 (low level of pressure), score 2 (moderate level), and score 3 (high level of pressure). The presence, the intensity and the distance from the source of pressure were used to classify each pressure in each site (Lopez y Royo *et al.*, 2009). Values of the total pressure found ranged between 0 and 17 (Tab. 1).

For photographic methods, two locations 100s of meters apart were randomly selected in each site and 30 photographic samples of 1875 cm^2 were collected in each location, for a total sample surface of 11.2 m^2 per site. For each sample, the following descriptors were evaluated through the Image J software (Cecchi *et al.*, 2014): i) the mean number of the main taxa/groups, ii) the mean percentage cover of the main taxa/morphological groups, iii) the β-diversity of assemblages, evaluated as the mean distance of all photographic samples from centroids calculated in the PERMDISP analysis (Anderson *et al.*, 2006).

For visual techniques, in each site three replicated rapid visual samplings, 10s of meters apart, were performed over an area of about 4 m^2 each. The following descriptors were measured and/or estimated: i) the mean thickness of the calcareous layer (measured with a handheld penetrometer, 6 replicates per sample), ii) the percentage of epibiosis and/or necrosis in the upper layer, iii) the maximum height of gorgonians (measured at 1 cm precision), iv) the mean percentage cover of the species characterizing the coralligenous upper layer. Mean values of each descriptor were compared by means of 1-way ANOVA between sites characterized by a low level of human-induced pressure (score ≤ 5) and sites with a high level of pressure (score > 5) (Tab. 1).

Results

A total of 25 taxa/morphological groups were found with the photographic method. ANOVA analyses detected significant differences between conditions for the mean number of the main taxa/groups, the mean distance from centroids (i.e. β-diversity of assemblages), the mean percentage cover of erect algae and bryozoans, turf-forming algae, *Halimeda tuna* and *Eunicella cavolini*. All the descriptors obtained from photographic samples had higher values in low pressure conditions, except for the abundance of turf and encrusting bryozoans that showed an opposite pattern (Fig. 1).

Significant differences between conditions were also detected for the mean thickness of the calcareous layer (ranging from 0 to 0.7 cm) and for the mean cover of some taxa/groups in the upper layer of coralligenous, i.e. *Eunicella verrucosa*, *Cystoseira zosteroides*, *Leptogorgia sarmentosa*, erect and massive sponges (Fig. 1).

Tab. 1: Scores attributed to each pressure in the sites investigated and methods adopted during surveys (P = photographic samples; V = visual assessments).

SITE	Methods	Urbanization/ urban waste	Ports	Tourism	Industrial activity	Sediment load	Aquaculture	Agricultural waste	Fishery	Total
Montecristo (Tuscany)	P	0	0	0	0	0	0	0	0	0
Pianosa (Tuscany)	P	0	0	0	0	0	0	0	0	0
Capo Carbonara (Sardinia)	V and P	0	0	1	0	0	0	0	0	1
Capraia (Tuscany)	P	0	0	1	0	0	0	0	0	1
Tavolara (Sardinia)	P	0	0	1	0	0	0	0	0	1
Giglio (Tuscany)	P	0	0	1	0	0	0	0	1	2
Elba (Tuscany)	V and P	0	0	1	0	1	0	0	1	3
Portofino Secca Gonzatti (Liguria)	V and P	0	0	1	0	2	0	0	1	4
Portofino Isuela (Liguria)	V	0	0	1	0	2	0	0	1	4
Portofino Casa del Sindaco (Liguria)	V	0	0	1	0	2	0	0	1	4
Formiche (Tuscany)	P	0	0	1	0	2	0	2	1	6
Punta Chiappa (Liguria)	V	1	1	2	0	2	0	0	2	8
Meloria (Tuscany)	P	0	2	1	2	2	0	1	0	8
Vada (Tuscany)	P	0	0	1	2	2	0	1	2	8
Argentario (Tuscany)	P	0	0	2	0	2	1	1	2	8
Punta del Faro (Liguria)	V	1	1	2	0	2	0	1	2	9
Cogoleto (Liguria)	V	3	0	2	1	2	0	1	1	10
Arenzano (Liguria)	V	2	1	2	1	2	0	1	1	10
Vado Ligure (Liguria)	V	2	3	1	2	3	0	1	1	11
Livorno (Tuscany)	P	2	3	3	2	3	0	0	2	15
Piombino (Tuscany)	P	2	2	1	3	3	1	3	2	17

Discussion

Results of this study confirmed the utility of selected descriptors to anthropogenic stress. In sites subjected to low human-induced pressure, the assemblages were characterized by a stratified structure with a thick calcareous basal layer and with abundant erect taxa, showing the typical structure of coralligenous (Balata *et al.*, 2007b; Piazzi *et al.*, 2011). In sites subjected to higher pressure, sensitive taxa, such as *Halimeda tuna*, erect Rhodophyta and erect bryozoans decreased while encrusting bryozoans, filamentous algae, erect and massive sponges increased their abundance and *Cystoseira zosteroides, Leptogorgia sarmentosa* and *Eunicella verrucosa* appeared.

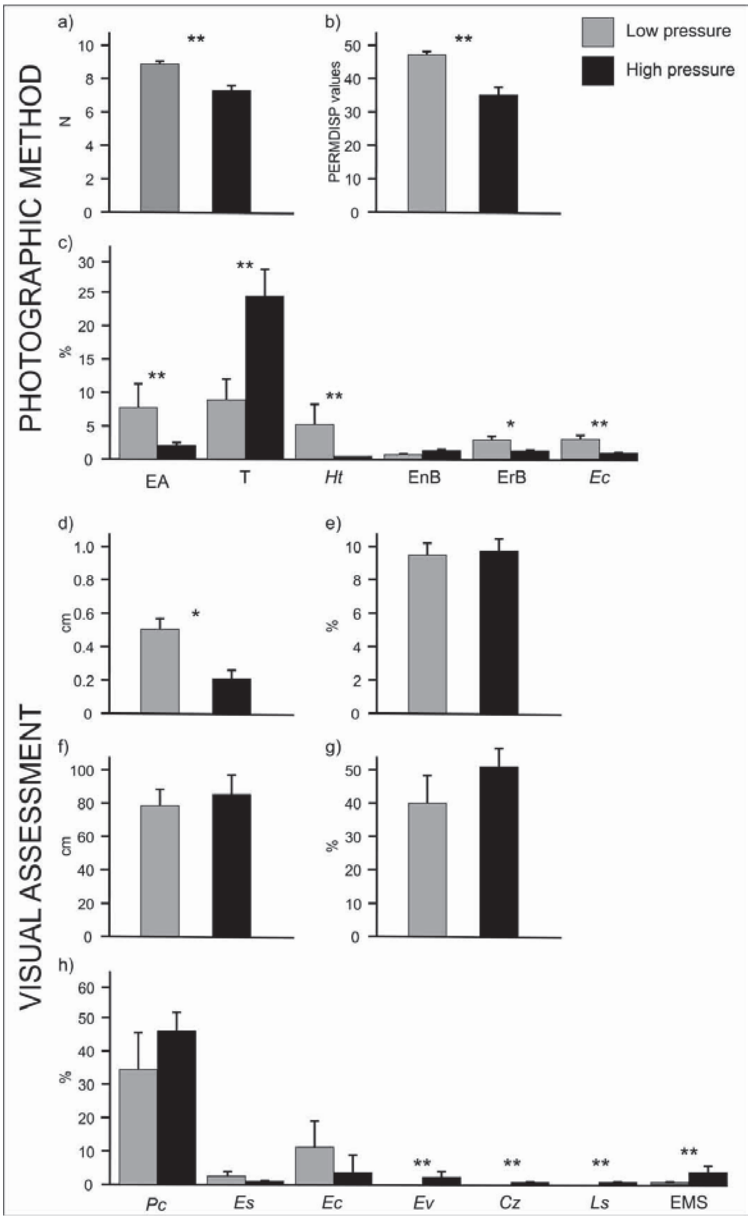

Fig. 1: Mean values (±s.d.) of the descriptors obtained from photographic samples (a, b, c) and from visual assessment (d, e, f, g, h). a) number of taxa/groups; b) β diversity; c) cover of the main taxa/groups; d) calcareous layer thickness; e) percentage of epibiosis and/or necrosis in the upper layer; f) maximum height of gorgonians; g) total cover of the species characterizing the upper layer; h) cover of the main taxa/groups in the upper layer. EA = erect algae; T = turf; *Ht* = *Halimeda tuna*; EnB = encrusting bryozoans; ErB = erect bryozoans; *Ec* = *Eunicella cavolini*; *Pc* = *Paramuricea clavata*; *Es* = *Eunicella singularis*; *Ev* = *Eunicella verrucosa*; *Cz* = *Cystoseira zosteroides*; *Ls* = *Leptogorgia sarmentosa*; EMS = erect and massive sponges; * = $p < 0.05$; ** = $p < 0.01$; grey bars = low pressure; black bars = high pressure.

These findings confirm a patterns already highlighted by other studies (Balata *et al.*, 2005; 2007a; 2007b; 2011; Gatti *et al.*, 2010; Piazzi *et al.*, 2011; 2012). Turf forming species may be advantaged under stressed condition both directly, enhancing their nutrient uptake in eutrophic conditions, and indirectly, enhancing their competitiveness compared to erect species, thanks to their ability to quickly recover after disturbance (Airoldi, 1998).

Under stressed conditions, the decrease of erect algae and bryozoans was probably due to the combined effects of low light levels, inhibition of recruitment and mechanic disturbance; moreover turf-forming species can outcompete erect macroalgae through pre-emption of substrate (Airoldi, 1998). Both richness and beta-diversity responded significantly to human pressure reducing their values in stressed sites. Beta-diversity may be a more valid descriptor of ecological quality of coralligenous assemblages. In fact, due to the influence of biological interactions, coralligenous assemblages usually show a patchy distribution, maintaining habitat heterogeneity at very high levels of beta-diversity. The loss of structuring perennial species and the spread of ephemeral algae under stressed conditions lead to a widespread biotic homogenization and the consequent loss of beta-diversity (Balata *et al*., 2007a; Piazzi *et al*., 2012). The maintenance of coralligenous habitat is related to a delicate balance between bio-construction and bio-erosion, which can be easily broken by any environmental alteration (Sartoretto & Francour, 1997). Thus, the consistence of calcareous basal layer may represent a valuable descriptor of the health of coralligenous habitat. A null penetration means that the calcareous substrate was either absent or completely lithified (i.e. bioconstruction was not more active), a centimetric penetration suggests the presence of an unconsolidated calcareous substrate that results from an active bioconstruction with little or no consolidation, undermined by the action of biotic and abiotic erosion, a millimetric penetration suggests the presence of active bioconstruction resulting in a compact calcareous biogenic substrate (Gatti *et al.*, 2012). For many sessile animals, their presence may be not a suitable indicator of degradation of ecological quality of habitat. In fact, several erect anthozoans exhibit high tolerance to the main stressors normally acting on coralligenous habitat, such as sedimentation or pollution, while they may be more sensitive to episodic stress (Cerrano *et al.*, 2000; Coma *et al.*, 2007;) or to mechanical damage (Bavestrello *et al.*, 1997). Thus, other variables than their presence and cover should be considered in order to use these organisms as bioindicators (Coma *et al.*, 2007; Garrabou *et al.*, 1998).

Results of this study showed that photographic and visual methods allow to detect changes in coralligenous assemblages submitted to different human pressures. Coupling data obtained through these different sampling techniques can give a more complete information about alteration of ecological quality of coralligenous habitat.

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THE RESOLUTION IN BENTHIC CARTOGRAPHY: A DETAILED MAPPING TECHNIQUE AND A MULTISCALE GIS APPROACH WITH APPLICATIONS TO CORALLIGENOUS ASSEMBLAGES

Abstract
Benthic maps are one of the most powerful tools of which a marine biologist may benefit. In the last decades several techniques (e.g. side scan sonar) became available at reasonable costs and allowed the total coverage of study areas. Biologists usually exploit these maps for several purposes, from biodiversity conservation to habitat modelling and forecasts. We present two case studies: the MedMPAnet study carried out in the Boka Kotorska Bay (Montenegro) and the detailed cartography of the MPA "Secche di Tor Paterno". We then illustrate a multi-zoom approach to map marine habitats and a new technique allowing to draw up high resolution cartographies (up to assemblages and species). The case studies and the acquired experiences demonstrated that the proposed approach and method are very powerful for the conservation and the management of both protected species and priority habitats (e.g. the coralligenous assemblages).

Key-words: GIS, marine mapping methods, coralligenous, benthic biocenoses, priority habitats

Introduction

The thematic mapping (*e.g.* habitats and soil uses) is a fundamental tool to plan and manage the natural resources. On land the techniques are decades in advance and are more widely and cheaply available than in the marine environment. The gap is mainly due to technical and logistic difficulties that during centuries discouraged to think at the seabottom as a continuum of the emerged lands (Ardizzone, 2000). In the last decades the availability of new technologies (in particular acoustic equipment, scuba dives and GIS) allowed to represent an increasing number of themes, with constant improving of the accuracy and resolution. The acoustic techniques, such as the side scan sonar (hereafter SSS), allow to map (full coverage) large areas in a reasonable time. In addition the improvement of the GPS systems, the underwater positioning and the use of GIS strongly facilitated the diffusion of marine maps (Montefalcone *et al.,* 2013).
The cartography is essential in different frameworks (e.g. the biodiversity conservation and the Environmental Impact Assessment) and is the best tool to characterize and evaluate the marine environment (Bianchi *et al.,* 2012). Moreover, maps help to understand the spatial dynamics and to create prevision modeling. The "Description and GIS-based mapping of the spatial distribution of sensitive habitats" is also a priority action identified in the Strategic Action Programme for the Conservation of Biological Diversity (SAP/BIO) in the Mediterranean Region (UNEP-MAP-RAC/SPA, 2003).
In the present paper, we faced with two issues: the planning of habitat mapping at different resolution and its management using a multi-scale GIS (multi-zoom approach) and a new technique to draw up very detailed marine habitat charts (up to scale 1:50). We present two case studies: a marine habitat mapping carried out in the Boka Kotorska Bay

within a MedMPAnet Project and a detailed cartography of the "Secche di Tor Paterno" Marine Protected Area (MPA).

Materials and methods

Case study 1

The inner part of the Boka Kotorska Bay (Montenegro) is a semi-enclosed bay (26 km^2 area and 35 km perimeter). In January 2013, a geophysical survey covered the whole area by mean of a SSS (C-MAX CM2), a single beam echosounder (Navitronics Navisound 205) and the navigation software PDS2000 (Teledyne Reson). A total of 69 navigation lines were coursed (177 km). The SSS operated at 325 kHz and lateral range of 150 m. The coastal perimeter of the bay was surveyed adopting a 100 m lateral range, and a site colonized by *Posidonia oceanica* meadow was investigated adopting a 50 m lateral range. Once the SSS photomosaic showed the most relevant seabed features (e.g. morphologies and marine habitats), a second field survey was conducted on soft bottoms (Van Veen grab in 15 stations) and on rocky bottoms (towed camera along 26 transects and scuba divers). The positions of the videos, the photos and the direct observations were recorded connecting the GPS with the GIS during the survey.

All available information was summarized in a biocenotic map (1:5.000 scale) of the whole area. Higher resolution maps (1:2.000 scale) were elaborated in five sub-areas characterized by the presence of marine seagrasses or colonized by dense assemblages of the gold coral *Savalia savaglia.* The operators drawn up the biocenotic maps according to the most relevant scientific literature (Pérès & Picard, 1964; Bellan-Santini *et al*., 2002; Bianchi *et al.,* 2003) and symbols (Meinesz *et al*., 1983; Tunesi *et al*., 2002; Bianchi *et al*., 2012). A comprehensive WebGIS project was developed in ESRI ArcGIS 10.1 and included the data collected during the survey and the bibliographic information.

Case study 2

The MPA "Secche di Tor Paterno", is located in the central Tyrrhenian Sea and is a complex rocky (coralligenous) formation (1387 ha). In the zone where scuba diving are allowed (about 5 ha from - 21 m to - 35 m depth), the detailed cartography of the area was drawn up during the spring and summer 2013-2014 and required 72 dives (about 53 hours of field survey). The surveyors started the characterization from the reference points, which coordinates were recorded by a GPS, and travelled several planned underwater lines. The distances were measured by two 50 m long measuring tapes and relevant waypoints were georeferenced by triangulation with an underwater compass. To reduce the possible error in positioning, a new reference point was marked at each 10 m for linear movements and at each change in path direction or in seabottom morphology. The divers noted all significant information (e.g. extension measures, depth) and taken high-resolution photos and sketches of the area (Fig. 1). The slope of the seabottom was also estimated, at fixed distances.

All the information was also supported by the photographic reconstruction of the waypoints in Adobe Photoshop CS6. High-resolution panoramic photos (in ambient light and with strobe light) were taken to describe in details the relevant waypoints in the area. The close up and macro photos were very useful also to identify the organisms colonizing the seabottom (Trainito & Baldacconi, 2014). The final maps (scale 1: 250) were produced in the open-source GIS (QGIS 2.4).

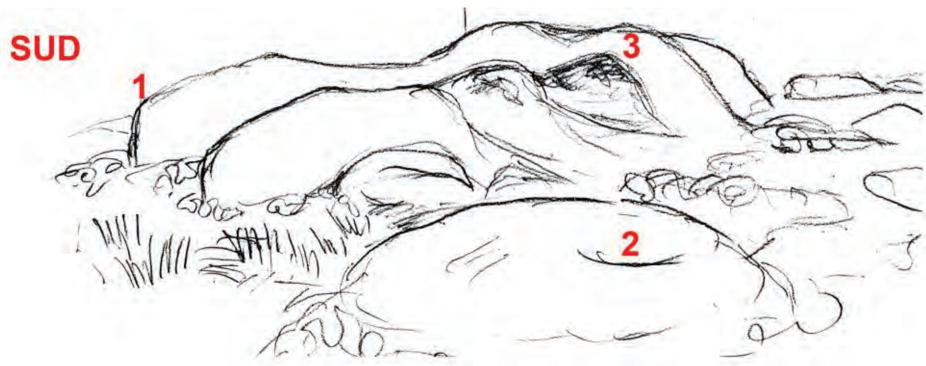

Fig. 1: The sketch of an investigated area shows the morphology observed from the Southern side. The numbers indicated relevant notes taken by the scuba divers.

Results

Case study 1

In the Boka Kotorska Bay 21 benthic habitats and 226 taxa were identified (among them, 20 species reported in the Annex II of the SPA/BD Protocol, 3 species in the Annex III, four rare species and three species of biogeographic interest).

The Biocenosis of the Coastal Terrigenous Muds is the predominant (about 87% of the area). The Coralligenous assemblages cover only the 2% of the seabottom but represent a *unicum* in the Mediterranean because of the extraordinary density and abundance of the gold coral *S. savaglia,* the colonies of *Cladocora caespitosa*, the presence of other cnidarians (e.g. *Leptogorgia sarmentosa* and *Parazoanthus axinellae*) and large-sized sponges (*Axinella* spp.). In most cases, given the complex geomorphology of the seafloor, at the scale 1:5.000, the Coralligenous assemblages are sometimes represented in mosaic with Sciafilous Algae or soft bottoms. On the contrary, the detailed map (1:2.000) allowed to clearly mark the Facies with *S. savaglia* and *L. sarmentosa.*

The Boka Kotorska Bay webGIS included data with different scale and resolution; therefore the layers were scaled and optimized for the dynamic visualization.

Case study 2

The area mapped by mean of the new mapping technique within the Tor Paterno MPA was about 5 ha and the detailed cartography shows the distribution of five habitats: the patchily *P. oceanica* meadow, the Coralligenous biocenoses, the coralligenous platforms, the Facies with *Paramuricea clavata,* the Facies with *Eunicella cavolinii,* and the Facies with *Eunicella singularis*. The methodology allowed identifying the distribution of several species of conservation concern, the areas potentially threatened by scuba activities, the most critical areas and the paths where scuba should be forbidden due to the high potential risks. Moreover the presented techniques allowed to highlight some other impacts not related to scuba diving (*e.g.* illegal fishing activities).

Methodological results

Fitting the experience gained during the case studies and other relevant survey in the Mediterranean, a “multi-zoom cartographic approach” may be defined. The basic approach may consist in three main levels. In the first level a small-scale biocenotic map (1:10.000 – 1:5.000) is produced for zones in which data are not available or out-dated. A relatively wide area is totally covered by acoustic techniques (*e.g.* SSS and/or multibeam echosounder) with a medium lateral range (100 – 150 m). The main applications of these

maps are: (i) the monitoring of the biocenoses; (ii) the management of the area (*e.g.* to face the integrated coastal zone management); (iii) the management of MPAs and their eventual zonation; and (iv) the monitoring of the spread of alien species.
In the second stage, few important areas are mapped in more detail (1:2.000 – 1:1.000) with acoustic techniques (lateral range between 25 and 50 m), to characterize the Biocenoses/Facies colonizing the seabottom. The main applications of this second zoom may be the management of the priority habitats (in particular within MPAs) and the monitoring of the colonization of alien species. To correctly identify the biocenoses, acoustic surveys must be integrated with direct observations: almost visual inspections (*e.g.* ROV and underwater towed cameras) on hard bottoms and sediment sampling on soft bottoms (Bianchi *et al.*, 2003). Even if a standardized protocol for ground-truthing has never been proposed (Montefalcone *et al.*, 2011), almost all doubts given by SSS interpretation must be clarified and some more random investigations must be carried out. Generally the sampling effort should be proportional to the required resolution.
The third step, for small areas (up to few hectares), is based on detailed maps (between 1:50 and 1:500). The maps allow discriminating the main Facies, the relevant assemblages and even the position of the single species of conservation concern (Fig. 2H). Their main applications may be: (i) the management of protected species; (ii) the assessment of possible damages/ threats on Facies/species; (iii) the assessment of human impacts on a very local scale; (iv) the monitoring of the species of conservation concern; and (v) the scientific studies on the biology of species.

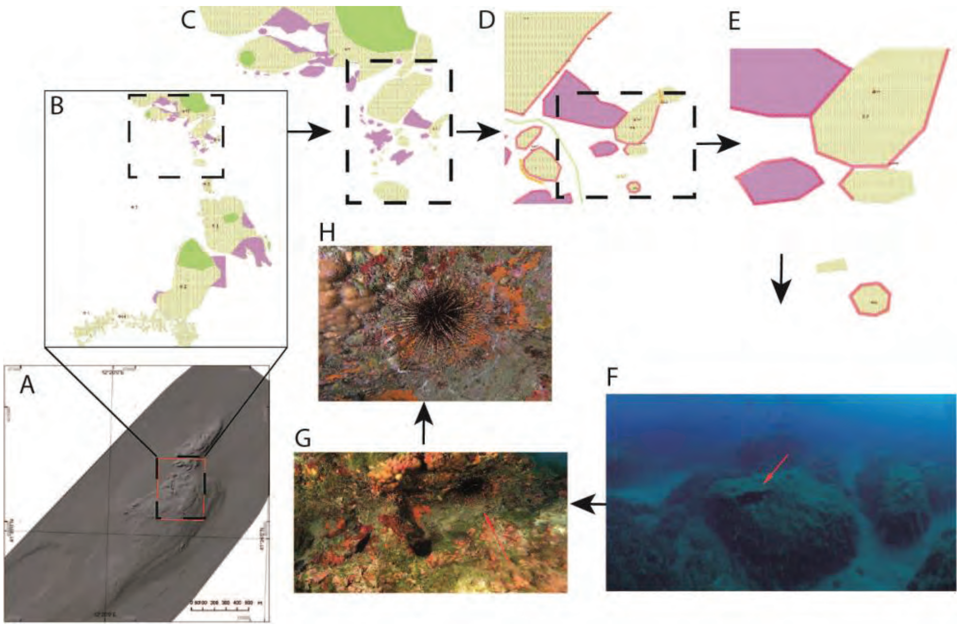

Fig. 2: The multi-zoom cartographic approach. A) The first level (scale smaller than 1:5000); B-C) The second level (scales from 1:2.000 to 1:1.000); D-H) the third level, the phases of the new proposed mapping methodology (scale from 1:500 to species level).

As the positioning is one of the most critical points (Ardizzone, 2000), the first two levels require a differential GPS and some additional positioning methods, such as the layback and the USBL (Pititto *et al.*, 2005). The third step also requires several underwater waypoints marked with triangulation methods. The multi-zoom cartographic approach should fit within a multi-scale GIS project that allows setting up different ranges for the visualization of the maps and the metadata, depending on the scale and the purposes of the users.

Finally, particular emphasis must be given to the new technique developed to map in detail the assemblages/species (scale between 1:50 and 1:500). The field technique can be schematized in three steps, followed by data processing in a GIS environment:

- the first inspection to achieve an overall picture of the study area;
- the survey with the compass and the metric tapes, to characterize in detail the study area, by means of triangulation measures, notes, photos and drawings;
- the finer level photographic characterization (different zooms) to refine the maps and the collected information about species distribution.

The detailed mapping field survey depends on the site complexity but is relatively rapid: for example to cover an area of 600 m^2 within the Tor Paterno MPA the surveyor needed three dives (each one less than one hour long). The methodology requires good visibility conditions and the surveyors may investigate a corridor of about 10 m.

Discussion and conclusion

Within the framework of biodiversity conservation, we propose a three level multi-zoom approach for marine biological maps that allow producing:

- a small-medium scale biocenotic map (between 1:10.000 and 1:5.000);
- a big scale biocenotic map (between 1:2.000 and 1:1.000);
- a very big scale – and high detailed – biocenotic map (between 1:500 and 1:50).

The detailed mapping methods of the multi-zoom approach allow representing species assemblages, colonies or even individuals. The tool may be powerful for research studies, and for the management of the threats (e.g. the scuba diving and the fishery) affecting priority habitats (e.g. the coralligenous assemblages). Apart from the Case study 2, the proposed mapping method has been successfully tested also in different MPAs and several seabed typologies. With specific adaptation the method has been applied also to holes and caves (Trainito *et al.,* 2007). Moreover, the new proposed technique complies with the requirements for cartographic data (Ardizzone, 2000).
The field survey for detailed mapping is generally rapid (depending on the site complexity) and the reliability of the final maps is very high. The GIS environment results the best tool to draw and manage the multi-scale charts within the proposed multi-zoom approach and allows in particular to set up a framework to selectively visualize different maps and metadata (at different scale) depending on the purpose of the users.
So far, the symbology for map scale till 1:500 has been standardized only in grayscale (Meinesz *et al*., 1983). Even if several papers deal with colors (*e.g*. Tunesi *et al*., 2002; Previati *et al*., 2010), no standardized symbols are available up-to-date for big scale maps. Therefore the next step should be to normalize the symbology for detailed cartography of assemblages and species also at scales greater than 1:500 and in colors.
A further challenge to face with is the possibility to create a 3D model reconstruction of the physical environment, starting from the detailed photographic survey.
In conclusion, concerning the Boka Kotorska Bay, we think that the *unicum* environment characterized by the gold coral *S. savaglia* deserves the full application of the multi-zoom approach and that detailed maps should be produced.
The multi-zoom approach and the new detail mapping technique herein described allow to create a point zero to carry out time series analyses, at different resolution levels, and in particular to follow in detail the evolution of assemblages, colonies or species. The tool is then very powerful to trace eventual human impacts (*e.g.* recreational activities, fishery and urbanization) on threatened habitats and especially on coralligenous assemblages.

Aknowledgements

The mapping of marine habitats of Boka Kotorska was conducted within the MedMPAnet Project, led by RAC/SPA in collaboration with the Montenegrin authorities. We would like to thank J. Knežević (Montenegrin Ministry of sustainable development and tourism) and M. Bataković (Agency for environmental protection). We also wish to thank to Roma Natura, managing autority of the "Secche di Tor Paterno" MPA and in particular the Director Dr. G. Fancello and the Scientific Responsible Dr. C. Forniz. Special thanks also to S. Marchionni (Blue Marlin Dive Center) and her staff, A. de Vellis (Tor Paterno Diving Center) and C. Presutti (Mediterranea Dive Center), and Dr. D. Pani for her expert advice.

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BETA DIVERSITY PATTERNS IN NORTHERN ADRIATIC CORALLIGENOUS OUTCROPS

Abstract
Recent studies have investigated spatial and temporal variability of coralligenous assemblages on coastal rocky cliffs, while structure and variability of platform banks have been rarely investigated. In the northern Adriatic continental shelf, coralligenous biogenic reefs are scattered on sandy and muddy bottoms, and may be separated by a few tens of meters to tens of kilometres. Their benthic assemblages were investigated by photographic sampling in two main areas about 100 km away: off Chioggia-Venice and Grado-Trieste. Within each area six outcrops, 1-2 km away, were sampled. Assemblages on reefs closer to the coast were dominated by algal turfs and boring sponges, while offshore they were generally characterised by the richest and most diverse communities. Contributions to the total species richness increased with the investigated spatial scale up to areas, while variation in species diversity monotonically decreased by increasing distance. Dominant species, including the main reef builders (i.e. encrusting calcified Rhodophyta), spatially changed following a geographical pattern. Among others, coralline algae (e.g. Lithophyllum incrustans), sponges (e.g. Chondrosia reniformis) and colonial ascidians (e.g. Polycitor adriaticus) were the main species responsible for the observed spatial differences, in terms of species replacement (β diversity).

Key-words: Bioconstructions; Species diversity; Tegnùe; Trezze; Adriatic Sea

Introduction
Recent studies have investigated spatial and temporal variability of coralligenous assemblages on coastal rocky cliffs (Balata & Piazzi, 2008; Piazzi & Balata, 2011; Piazzi *et al.*, 2010), while structure and variability of platform banks have been rarely investigated. In the northern Adriatic continental shelf, coralligenous biogenic reefs, ranging from a few to several thousand square metres in surface, and up to 4 m in height, occur. They are scattered on sandy and muddy bottoms and may be separated by a few tens of meters to tens of kilometres. Until now, spatial variability of the epibenthic assemblages living on the northern Adriatic coralligenous outcrops were investigated locally (Curiel *et al.*, 2012; Ponti *et al.*, 2011). The aim of the present study is to compare spatial variation in species diversity across different spatial scales, ranging from a single reef to the basin.

Materials and methods
Species composition and abundances of the epibenthic assemblages on coralligenous biogenic reefs were investigated in 2013-2014, on 12 randomly selected sites in two areas of the northern Adriatic basin: 6 off Chioggia-Venice and 6 off Grado-Trieste (Fig. 1). Within areas, sites are 1-2 km distant, while the two areas are about 100 km away. Sites were located between 15 and 25 m in depth, and 6–18 km from the coast.

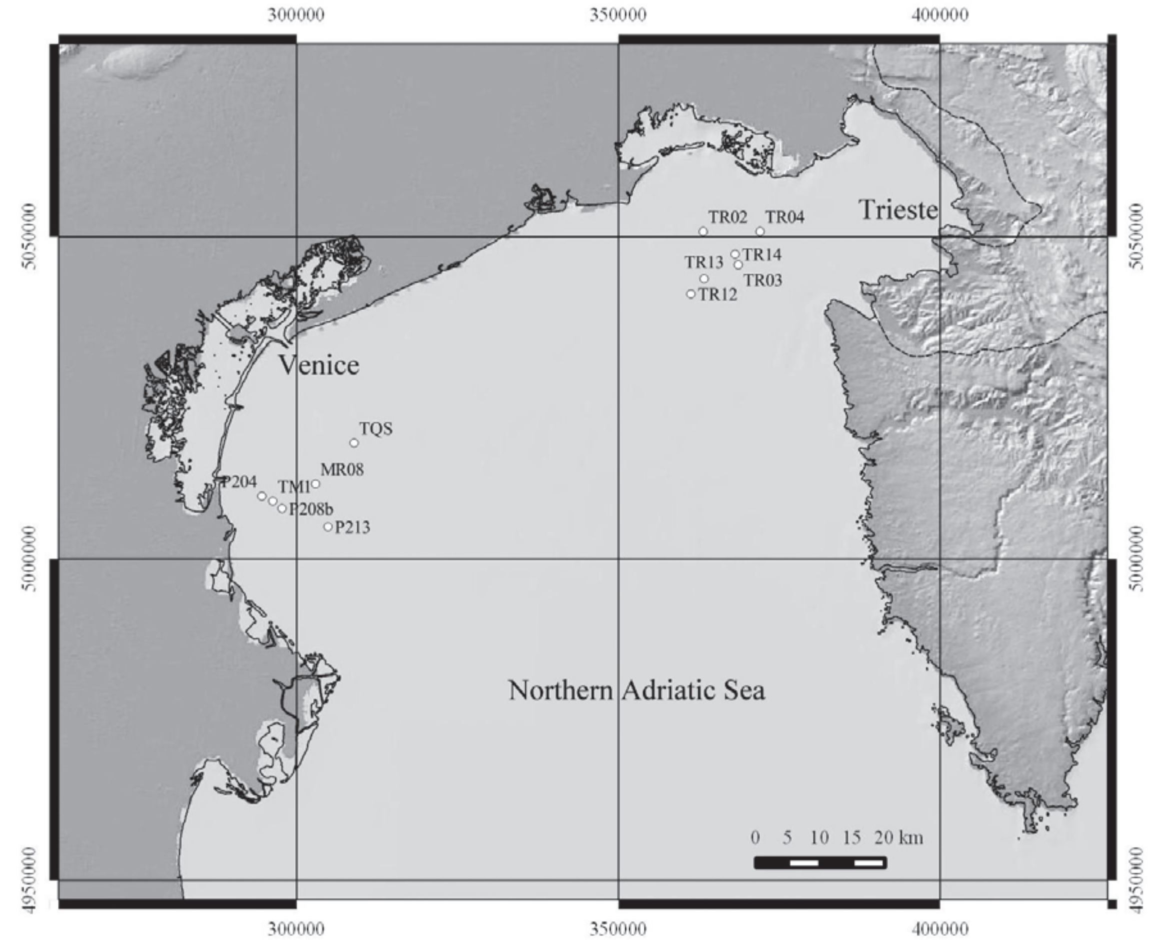

Fig. 1: Study area and sampling site (grid UTM33 WGS84).

Assemblages were sampled using a non-destructive photographic sampling method. Photographic samples (~0.06 m^2) were collected using a digital camera equipped with a strobe. Ten randomly selected photos were analysed at each site. Organisms were identified to the lowest possible taxonomical level according to a reference collection of specimens previously photographed and withdrawn from the same sites. Percent cover of sessile organisms was quantified by superimposing a grid of 400 cells (*i.e*. 0.25% each) using the free available photoQuad software (Trygonis & Sini, 2012). Slight differences among sampling areas, due to dark and blurred zone or portions covered by vagile organisms, were accounted by standardising to the total readable area of each image (Ponti *et al.*, 2011).The endolithic bioeroder bivalve *Rocellaria dubia* (Pennant, 1777) was identified and quantified by counting its typical '8-shaped' calcareous siphon holes. This photographic method could underestimate the abundance of some species, like the coralline algae, sometimes partially hidden by other organisms, but it has been widely used in studies dealing with spatial and temporal variability of hard bottoms epibenthic assemblages (Bianchi *et al.*, 2004 and references therein).
Species richness (number of taxa, *S*), species diversity (log base 2 Shannon's index, *H'*) and the corresponding evenness component (Pielou index, *J'*) were calculated for each replicate sample (Magurran, 2004). β diversity was analysed in terms of 'variation' in species diversity and community structure among sets of sample units (Anderson *et al.*, 2011). Species richness and species diversity were partitioned at the different spatial scale: within sites (α), among sites (β_{sites}), areas (β_{areas}) and whole basin (β_{basin}) using the

additive approach proposed by Crist *et al.* (2003). Multivariate measure of β diversity was obtained by the Jaccard similarity index, which is based on presence/absence data. Similarity patterns were displayed by unconstrained ordination plots using the principal coordinate analysis (PCoA, *i.e*. metric multidimensional scaling; Gower, 1966). Vectors superimposed on to the PCoA plot represented the correlations of the abundances of the most relevant taxa (Pearson correlation > 0.4) with the PCoA axes.

Results

A total of 56 taxa of macrobenthic invertebrates (18 Porifera, 4 Cnidaria, 3 Polychaeta, 1 Bivalvia, 6 Ascidiacea) and algae (17 Rhodophyta, 4 Ochrophyta, 2 Chlorophyta, plus mixed algal turf) were found, 33 of which were identified to species level. Assemblages on reefs closer to the coast were dominated by algal turfs and boring sponges, while offshore reefs were generally characterised by richest and most diverse communities. Contribution to the total species richness increased with the investigated spatial scaled up to the area level, which alone explained about 42%, while the variation of species richness at the basin scale is similar to that observed at the sites scale (Fig. 2).

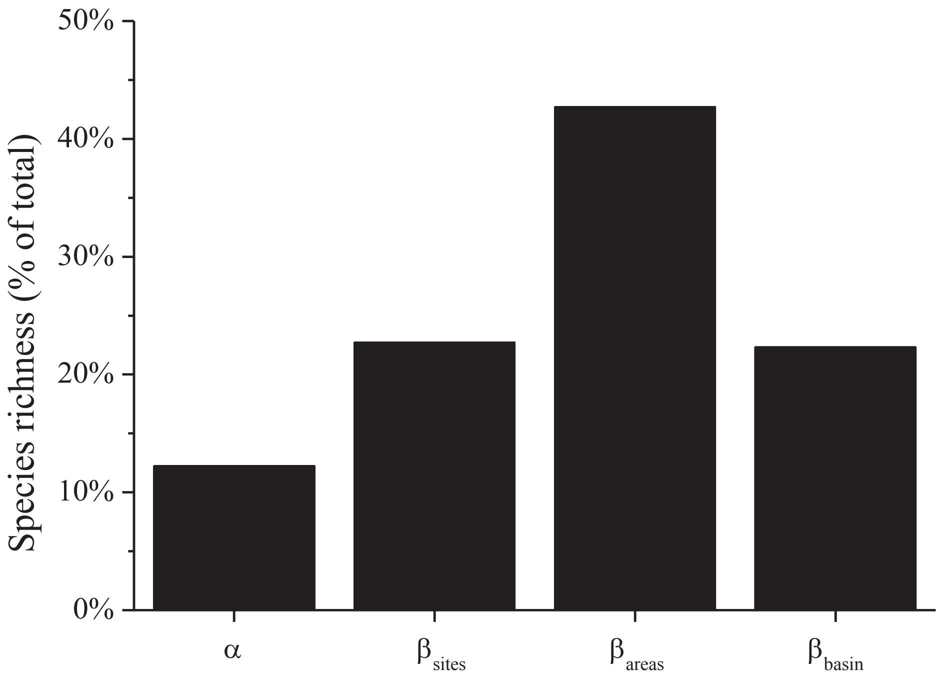

Fig. 2: Additive partition of species richness across three sampling spatial scales (α: within sites; β_{sites}: among sites; β_{areas}: between areas; and β_{basin} at the whole basin). Values are expressed as percent of the total diversity of epibenthic species explained by each hierarchical level.

Taking into account the species abundances, using the Shannon's index, the greater contribution to species diversity, on average, comes from α (within sites). Variation in species diversity monotonically decreases by widening the investigated zone (Fig. 3).

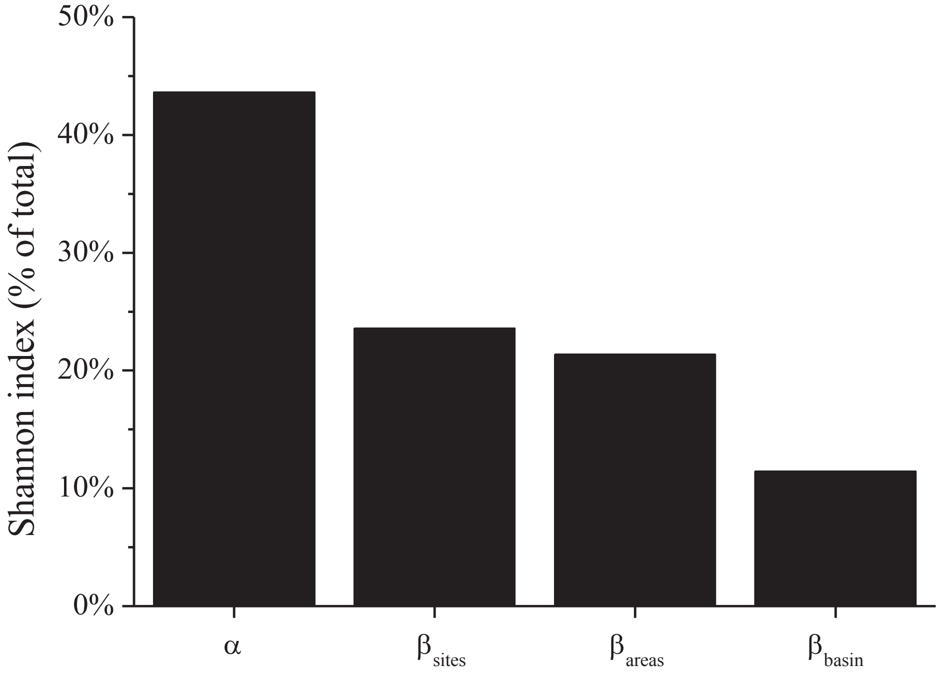

Fig. 3: Additive partition of Shannon's diversity index across three sampling spatial scales (α: within sites; β_{sites}: among sites; β_{areas}: between areas; and β_{basin} at the whole basin). Values are expressed as percent of the total diversity of epibenthic species explained by each hierarchical level.

Multivariate analysis, based on presence/absence data, revealed a complex similarity pattern with a clear shift in species composition between the Chioggia-Venice and the Grado-Trieste areas (Fig. 4). Moreover, within the Chioggia-Venice area, epibenthic assemblages tended to diverge in two compositional groups that mainly resembled the distance from the coast. The Grado-Trieste assemblages were characterised by the sponge *Chondrosia reniformis* Nardo, 1847 and the rhodophyte *Peyssonnelia rosa-marina* Boudouresque & Denizot, 1973 and *Lithothamnion* sp., the latter largely responsible for the bio-construction processes. Offshore Chioggia-Venice assemblages were characterised by the ascidian *Polycitor adriaticus* (Drasche, 1883), and the encrusting calcareous rhodophyte *Mesophyllum* sp. and *Lithophyllum incrustans* R.A. Philippi, 1837, while assemblages closer to the coast were dominated by the filamentous algae *Cladophora* sp. and *Antithamnion* sp., and by the boring bivalve *Rocellaria dubia*.

Discussion

Evidences that epibenthic assemblages on some northern Adriatic coralligenous reefs differed according to their distance from the coast, depth, water turbidity and sediment load were already provided by Ponti *et al.* (2011) and Curiel *et al.* (2012); nevertheless, variation in species diversity and community structure at different spatial scales have never been investigated. Surprisingly, areas distant about hundred kilometres, provide the greatest contribution to β species richness. The major proportion of species diversity, considering the relative abundances, was found within single coralligenous outcrops, supporting the existence of a high local heterogeneity.

Finally, dominant species, including the main reef builders (*i.e.* encrusting calcified red algae), varied in space following a geographical pattern.

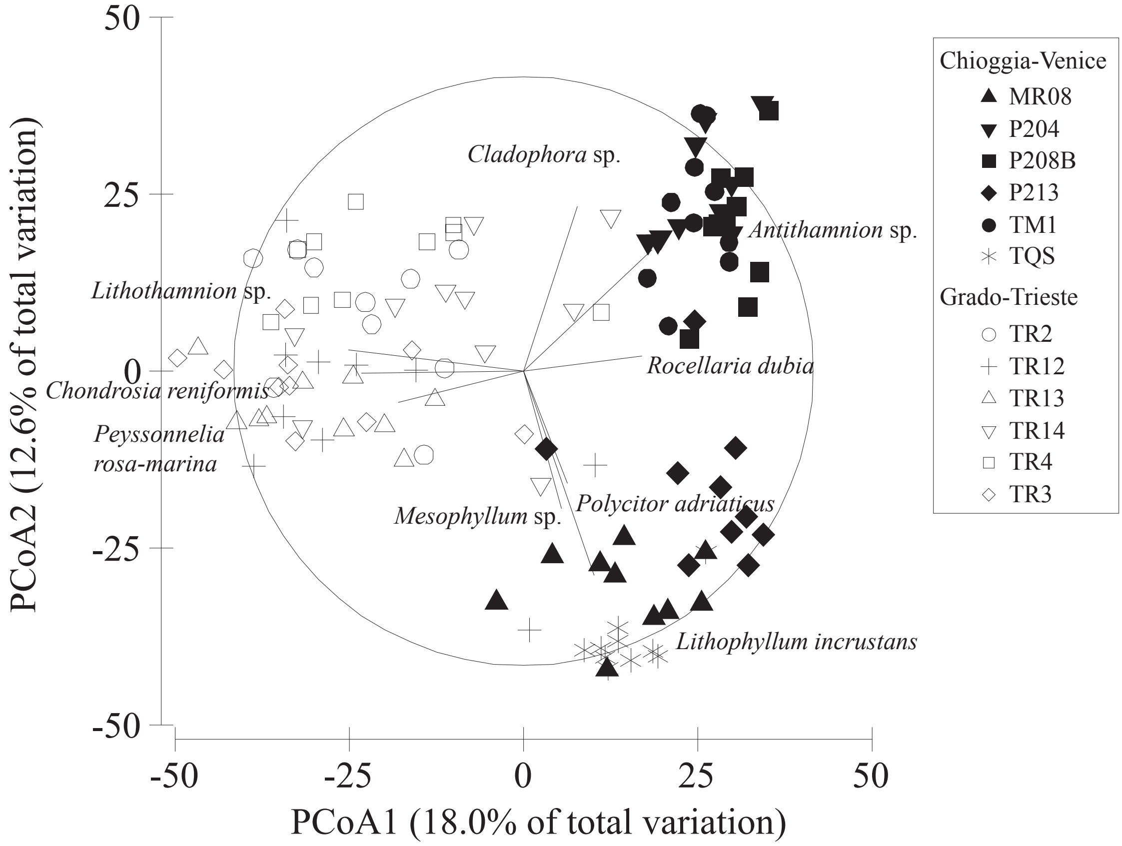

Fig. 4: PCoA based on Jaccard similarity index calculated on presence/absence data. Superimposed vectors represented the correlations of the abundances of the most relevant taxa (Pearson correlation > 0.4) with the PCoA axes.

Acknowledgments

This study has been funded by the Italian Ministry of Education, Universities and Research within the scientific research program of national interest "Coastal bioconstructions: structures, functions, and management" (2010-11 PRIN prot. 2010Z8HJ5M_003). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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AN ECOSYSTEM-BASED APPROACH TO ASSESS THE STATUS OF THE MEDITERRANEAN CORALLIGENOUS HABITAT

Abstract
Coralligenous outcrops are a Mediterranean sciaphilic habitat whose three-dimensionally layered communities develop on a basal biogenic concretion of calcareous red algae, along with a rich assemblage of sciaphilic sessile animals. The complexity of the evaluation of the ecological status of coralligenous is on a par with the complexity of this habitat. Biotic indices developed to implement the EU Water Framework Directive reflect the ecological status of the environment using species whose function, population or status depend on the quality of the water column. However, the state or achievement of good quality in a water body and the apparent health of some biological indicators are not always indicative of good structure and functioning of the whole ecosystem, even if they are key-species or ecosystem engineers. The new indices to be developed according to the Marine Strategy Framework Directive (MSFD) of the EU require an ecosystem approach, which takes into account the functioning of the ecosystem. Here, on the basis of a simplified conceptual model of the ecosystem, we propose an Ecosystem-Based Quality Index (EBQI) focused on the structure and functioning of coralligenous outcrops. The coralligenous EBQI is based upon (1) a set of representative functional compartments, (2) the weighting of these compartments and (3) the assessment of their quality by comparison with an assumed baseline. The implementation of the EBQI is non-destructive, relatively robust, according to the selection of the compartments and to their weighting, and is associated with confidence indices (both at the level of each compartment, and for the overall score), thus indicating possible weaknesses and biases in the data and therefore the need for further field data acquisition.

Key-words: Coralligenous; Ecosystem-based approach; Marine Strategy Framework Directive; biotic index; Mediterranean Sea.

Introduction

Depending on a number of biotic and abiotic factors, several assemblages could coexist or dominate in coralligenous habitats, over a wide depth distribution range (from 20 m down to −120 m). Even if coralligenous outcrops are not a single habitat but a combination of different habitats, we will use hereafter the term of 'ecosystem'. According to Ballesteros (2006), the coralligenous outcrop is a hard substratum of biogenic origin mainly produced by encrusting calcareous algae growing in dim light conditions. Even if such algae could also grow near the surface, shallow-water concretions are excluded from this work. Human activities can profoundly alter the environment, species composition and the functioning of the coralligenous ecosystem. Biotic indices, which reflect the quality of the environment, are extensively used in the marine realm, especially in the context of European Directives, to (i) assess the quality of a water body, (ii) to indicate the respective weighting of processes such as e.g. currents, sedimentation and climate under natural and anthropogenic forcing, and (iii) to monitor the status of species of interest, whether emblematic species, indicators of ecosystem health or indicators of pollution. However, does an index based on the health of a single species give information about the health of the entire ecosystem to which it belongs, even if it is a key-species or an ecosystem engineer? A key point in the Marine Strategy Framework Directive (MSFD, 2010/477/EU) is based on the ecosystem-wide evaluation of the 'good environmental status' in order to ensure that the marine environment is at a level that allows uses, exploitations and activities by current and future generations.

Material and methods

The method developed by Personnic *et al*. (2014) for *Posidonia oceanica* meadows has been adapted to the coralligenous ecosystem. The first step was to design a simplified conceptual model of the functioning of the ecosystem; it includes 10 functional compartments and 11 parameters (Fig. 1; Tab. 1). The DELPHI process was used to integrate the expert judgment (Dalky & Helmer, 1963). For each ecosystem compartment, a set of relevant parameters according to expert judgment was chosen and assessed through a semi-quantitative scale: very bad (0), bad (1), moderate (2), good (3), and very good (4) ecological status (S in equation 1). Compartments were balanced, according to their relative weight (W) in the ecosystem functioning according to expert judgment, from 5 (highest weight) to 1 (lowest weight). The scores of all compartments were added up, is on a par with which gave the final mark of the ecosystem status (Ecosystem Based Quality Index EBQI) at a given site. For practical purposes, the EBQI was converted to a scale from 0 (worst quality) to 10 (best quality) (equation 1).

$$EBQI = \left[\sum_{i=1}^{11}(W_i \times S_i) / \sum_{i=1}^{11}(W_i \times S_{max})\right] \times 10 \qquad \text{Equation (1)}$$

For each compartment status, a Confidence Index (CI) was proposed. The CI was evaluated through a semi-quantitative scale: (0) no quantitative field data and no suitable expert judgment; (1) no quantitative field data, but ancient expert judgment; (2) no quantitative field data but recent expert judgment; (3) field data recent, partially completed with expert judgment and (4) field data available, recent and suitable, obtained with the recommended methods. The Confidence Index of the EBQI (CI_{EBQI}), which ranges between 0 (worst) and 10 (best), was obtained by equation 2:

$$CI_{EBQI} = \left[\sum_{i=1}^{11}(W_i \times CI_i) / \sum_{i=1}^{11}(W_i \times CI_{max})\right] \times 4 \qquad \text{Equation (2)}$$

Results

A simplified conceptual model of the functioning of coralligenous ecosystem has been designed using scientific expert judgement and information collected from the literature (*in* Ballesteros, 2006 and references therein). This model encompasses the following compartments (boxes; Fig. 1):

The builders, *i.e.* MPOs (Multicellular Photosynthetic Organisms) and invertebrates (box 1; Fig. 1). The framework of coralligenous outcrops is the bioconcretion by mainly encrusting, foliaceous and articulated calcareous 'macroalgae' (MPOs) belonging to the Corallinales (red algae). This biogenic concretion is not only due to primary producers, but also to invertebrate builders (bryozoans, serpulid annelids, etc.), with more than 120 species are known to contribute to the frameworks (Hong, 1980).

The non-calcareous MPOs (box 2; Fig. 1). This compartment encompasses erect macrophytes (arborescent and shrubby; *e.g. Phyllariopsis brevipes*, *Sebdenia dichotoma*).

Benthic filter- and suspension-feeders (box 3; Fig. 1). A large number of filter- and suspension-feeders dwell in the coralligenous outcrops: bryozoans (*e.g. Pentapora fasciata*), cnidarians (e.g. *Paramuricea clavata, Eunicella cavolini*), sponges (*e.g. Agelas oroides*), etc.

Bio-eroders (box 4; Fig. 1). Numerous organisms, whether microborers, macroborers or grazers (*i.e.* raspers), erode calcareous concretions, in particular the excavating sponges (Clionaidae), cyanobacteria, molluscs, and sea urchins.

Browsers - Grazers (box 5; Fig. 1). This compartment encompasses herbivores and carnivorous organisms that browse benthic non-calcareous MPOs and invertebrates, other than builders.

Planktivorous teleosts (e.g. *Anthias anthias*), **predatory teleosts** (*e.g. Diplodus* spp.) and **cephalopods** (e.g. *Octopus vulgaris*), **high-level predators** (*e.g. Epinephelus marginatus, Dentex dentex*) (boxes 6, 7 and 8; Fig. 1) encompass all teleosts and cephalopods that could be sampled by visual censuses. Planktivorous teleosts, although exploiting the water column, and therefore another ecosystem, are taken into account here because they spend part of their life (*e.g.* at night) in coralligenous outcrops.

Benthic POM (box 9; Fig. 1). This compartment corresponds essentially to the fraction of dead MPOs, detritus imported from adjacent habitats, and all kinds of particulate matter.

Detritus feeders (box 10; Fig. 1). Detritus feeders constitute a complex compartment. Here we have chosen to quantify Holothurioidea and *Bonellia viridis* as proxies.

Other compartments, not numbered in the conceptual model (Fig. 1; plankton, POM, pelagic microbial loop, pelagic DOC, POM), will be not quantified here because of the difficulty of obtaining data in the framework of a monitoring approach.

Compartments 1 to 5, 9 and 10 were sampled in part using 30 photographic quadrats 0.5-m × 0.5-m along a 40-m long transect (Deter *et al*., 2012) and species seen during the field work. The coralligenous composition in terms of species was evaluated as 1 666 species (315 MPOs, 61 unicellular eukaryotes, 1290 metazoans including 110 fish species) according to Ballesteros (2006). Here, the builder (box 1), filter (box 3) and browser-grazer species (box 5) taken into account are the principal species to be considered for the inventory listed by UNEP-MAP-RAC/SPA (2011). For browser-grazers, we have added 5 opistobranchs (*Cratena peregrina, Flabellina affinis, F. pedata, Felimare picta, Peltodoris atromaculata*). The number of strata for builders (box 1) was evaluated by the use of the Rapid Visual Assessment (RVA) method proposed by Gatti *et al.* (2012) and modified by the INDEX-COR method (Stéphane Sartoretto pers. comm.).

The compartments of teleosts and cephalopods (boxes 6 to 8; Fig. 1) were estimated by visual censuses at a standardized daytime (10:00 to 16:00 UT) during the warm season (summer-autumn) in the same site than benthic compartments.

All teleosts and cephalopods were counted within ten linear 20-m long and 2-m wide transects. Total length (to nearest 2 cm) of individuals and the number of individuals per species were noted. These data enable calculation of teleost biomass.

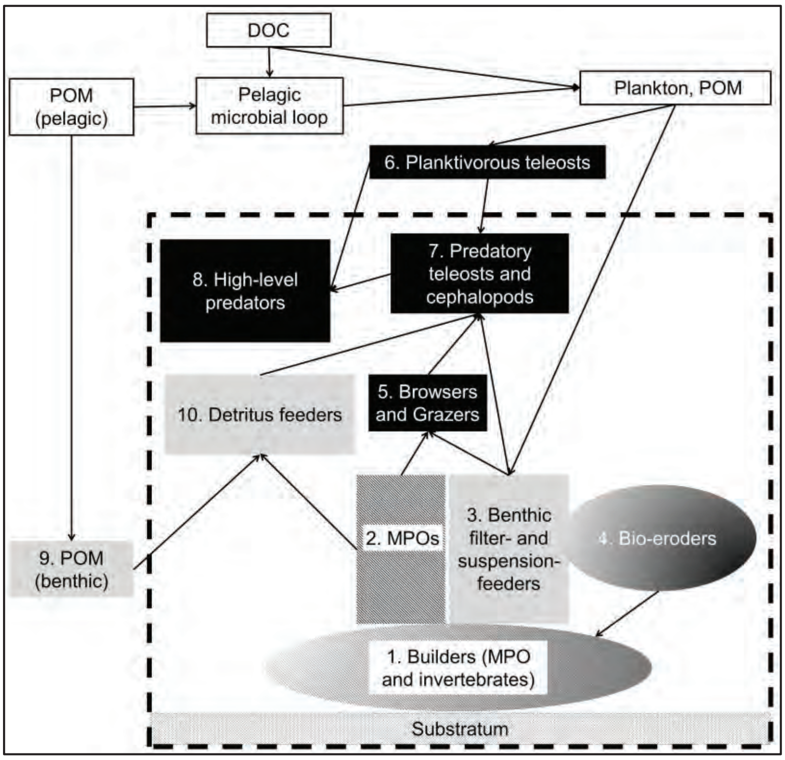

Fig. 1: Conceptual model of the functioning of a coralligenous ecosystem. For functional compartments and box numbers, see text. Primary producers (MPOs) are in hatched frame; predators and browsers - grazers are in black; pelagic particular organic matter (POM), pelagic microbial loop, plankton and dissolved organic carbon (DOM) are in white; benthic POM, detritus feeders, benthic filter-feeders are in grey; compartments that belong to several categories are in gradient color. The sensu stricto coralligenous ecosystem is included within the hatched rectangle.

The Specific Relative Diversity Index (SRDI) is the mean number of species met with per transect. Considered components of the coralligenous habitat and respective evaluation criteria are presented in Table 1.

Discussion and conclusion

The assessment of the EBQI in coralligenous outcrops usually calls for complex diving logistics because of the depth at which they thrive. We have chosen the use of photographic quadrats as sampling method because it involves spending less time for diving and provides information for several compartments. In fact, photographic quadrats are currently used in several protocols (Cecchi & Piazzi, 2010; Kipson *et al*., 2011; Deter *et al*., 2012). However, the photographic methods involves image processing, which is also time-consuming. The use of the EBQI needs to (i) to assess the status of the compartments in non-human impacted areas and (ii) to be adapted according to biogeographic features. A similar methodology has already been tested on *Posidonia oceanica* meadows, the best documented marine ecosystem of the Mediterranean coastal areas, and it has been applied to seventeen sites (Personnic *et al*., 2014), showing that (i) EBQI was not redundant with already existing indices and (ii) EBQI was robust even if some arbitrary choices are possible for the considered compartments and their weighting (expert judgment).

Tab. 1: Functional compartments of the coralligenous ecosystem, box number, weight and parameters used to evaluate the ecological quality (status from 0, very bad to 4, very good). cp: calibration in process, * species listed by UNEP-MAP-RAC/SPA (2011), ϴ 5 opistobranchs added (see the text).

Box number / weight	Functional compartment	Parameters	Status				
			4	**3**	**2**	**1**	**0**
1 / 5	Builders (MPOs and invertebrates)	Number of builders species (34 listed)*	≥25	15 to 24	10 to 14	6 to 9	≤5
		Cover of non-disrupter species (%) (others than invasive, eroder, tolerant species)	>75%	>50 to 75%	>25 to 50%	>0 to 25%	0%
		Number of strata (basal (0-5 cm height), intermediate (5-15 cm) and upper (>15 cm)	3 strata >50% of cover	3 strata <50% of cover	2 strata	1 stratum	0 stratum
2 / 3	Non-calcareous MPOs (facies dominated by MPOs)	Number of MPO species (34 listed)*	≥25	15 to 24	10 to 14	6 to 9	≤5
		Cover of non-disrupter species (%)	>75%	>50 to 75%	>25 to 50%	>0 to 25%	0%
		Number of strata (arborescent, shrubby, turf-forming, encrusting)	4 strata	3 strata	2 strata	1 stratum	0 stratum
	Non-calcareous MPOs (facies dominated by fauna)	Number of strata	4 strata	3 strata	2 strata	1 stratum	0 stratum
3 / 5	Filter and suspension feeders	Density (m^{-2}) or cover (%)	cp	cp	cp	cp	cp
		Number of filter species (43 listed)*	≥30	20 to 29	12 to 19	6 to 11	≤5
4 / 5	Bio-eroders	Eroding sponges (Clionaidae)	Scarce papillae	Few papillae	Moderately abundant papillae	Abondant papillae	Massive specimens
		Density of sea urchins (*Echinus melo* and *Sphaerechinus granularis*) or erosion marks	cp	cp	cp	cp	cp
5 / 3	Browsers and grazers	Density of invertebrates (m^{-2})	cp	cp	cp	cp	cp
		Number of browsers and grazers (12 listed)* ϴ	≥10	7 to 9	4 to 6	3 - 2	≤1
6 / 2	Planktivorous teleosts 'planktivorous'	Zooplankton feeders (kg WM 100 m^{-2})	cp	cp	cp	cp	cp
		Omnivores teleosts (kg WM 100 m^{-2})	cp	cp	cp	cp	cp
7 / 2	Predatory teleosts	Teleosts (kg WM 100 m^{-2})	cp	cp	cp	cp	cp
8 / 4	Piscivorous teleosts	Teleosts (kg WM 100 m^{-2})	cp	cp	cp	cp	cp
6-8 / 3	All teleosts	Specific Relative Diversity Index (SRDI)	≥8	<8 to ≥6	<6 to ≥4	<4 to ≥3	<3
9 / 2	Benthic detritus matter (POM)	Cover (%)	0-10%	>10 to 25%	>25 to 50%	>50 to 75%	>75%
10 / 3	Detritus feeders	Density of Holothurioidea, and *Bonellia viridis*	cp	cp	cp	cp	cp

However, since coralligenous outcrops are a much more complex and less well-known ecosystem than *P. oceanica* meadows, calculation of coralligenous EBQI will require the participation of experts in several fields of marine ecology. Its implementation may require the participation of several Mediterranean research teams and could contribute to the development of new scientific networks.

Acknowledgements
This work is included in the scientific program GECO med, funded by the French Water Agency Rhône Méditerranée Corse (AERMC) and the French Agency of Marine Protected Areas (AAMP).

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AN INTEGRATED APPROACH TO EVALUATE AND MONITOR THE CONSERVATION STATE OF CORALLIGENOUS BOTTOMS: THE INDEX-COR METHOD

Abstract
Coralligenous outcrops represent a "hotspot" of Mediterranean marine biodiversity. Algae and sessile invertebrate taxa (mainly sponges, cnidarians, bryozoans and tunicates) structure the associated benthic assemblages and constitute remarkable seascapes. Nevertheless, this fragile habitat is submitted to a wide array of human impacts such as sewage outfalls, eutrophication, physical impacts linked to fishing and diving activities, as well as global warming effects. The current European legislative context (EU WFD, EU Habitat Directive, EU MSFD) imposes to reach or maintain a good environmental status for marine ecosystems. In this context, the MPA stakeholders need to have robust and accessible tools allowing the evaluation of the conservation state of the habitats. Concerning coralligenous bottoms, we propose a new method based on an integrated approach taking into account (i) the ratio between sensitive and tolerant species according to human impacts, (ii) the richness of macrotaxonomic descriptors assessed from direct observation (in situ or from images) and (iii) their structural complexity (basal, intermediate and upper layers present in coralligenous bottoms). These three metrics are combined into a global index called INDEX-COR. Datasets were acquired along the French coasts. In each site, 2 transects 15m long were installed on the bottom. Along each transect, 15 photo quadrats (40 cm x 60 cm) and 1 video were recorded and notes were taken by a SCUBA diver-Observer. This method was applied between 15 and 50 meters depth and can be also performed by a ROV (Remotely Operating Vehicule) or an AUV (Autonomous Underwater Vehicle). INDEX-COR is intended to be applied to other Mediterranean areas using metrics and species lists adapted to the different regional contexts.

Key-words: Coralligenous outcrops, conservation index, monitoring, Marine Protected Area

Introduction

There is no real consensus among scientists studying benthic communities in the Mediterranean Sea about what a coralligenous habitat is. Nevertheless, coralligenous concretions area is usually considered to be biogenic formations mainly built by the accumulation of encrusting calcareous algae (Ballesteros, 2006). This bioherm grows in dim light conditions and is very complex in structure, allowing the development of several kinds of communities (Laubier, 1966). Along with the *Posidonia oceanica* meadows, it represents the main "hotspot" of Mediterranean marine biodiversity (Ballesteros, 2006). This fragile habitat is submitted to a wide array of human impacts such as sewage outfalls, eutrophication, physical impacts linked to fishing and diving activities, as well as Global Change effects (increasing water temperature, acidification, etc). The current European legislative framework (EU WFD, EU Habitat Directive, EU MSFD) imposes the states to reach or maintain a good environmental status for marine ecosystems. In this context, the MPA stakeholders need to have robust, easy-to-use and accessible tools allowing the evaluation of their conservation state (UNEP-MAP-RAC/SPA, 2009). During the last years, some methods based on photographic sampling or direct observation by SCUBA divers were proposed to evaluate and monitor the coralligenous bottoms. Cecchi and Piazzi (2010) defined an index based on the evaluation of the heterogeneity of assemblages according to the ecological values of the different species (ESCA Index). The Rapid Visual Assessment Method (RVA method) relies on a seascape approach to characterise the ecological quality of coralligenous reefs (Gatti *et al.*, 2012). At last, the Coralligenous Assemblage Index (CAI) is composed by three metrics: (i) the bryozoa percent cover, (ii) the sludge percent cover, (iii) the builder species percent cover (Deter *et al.*, 2012). In order to further contribute to these first studies and methodological recommendations for the characterisation of coralligenous assemblages (Kipson *et al.*, 2011), we hereby present a new method (INDEX-COR method) based on an integrated approach taking into account the impact of human activities on the biodiversity, the composition of benthic assemblages and the 3D structure of coralligenous outcrops (Hong 1983; Gatti *et al.*, 2012).

Materials and methods

Data were collected during two field campaigns carried out in winter of 2013 and 2014. In total, 22 stations were sampled along the coasts of Provence (France) taking into account (i) "natural", (ii) moderate and (iii) highly impacted sites (sewage outfall, industrial activities, fishing, diving) (Fig. 1). Due to the proximity to the Rhône Delta, in the eastern part of the Gulf of Fos coralligenous outcrops develop between 10 and 20 m depth (sites 1 and 2). In the other sites located between Marseilles and St Tropez (sites 3 to 22) data were collected between 30 and 40 m depth.

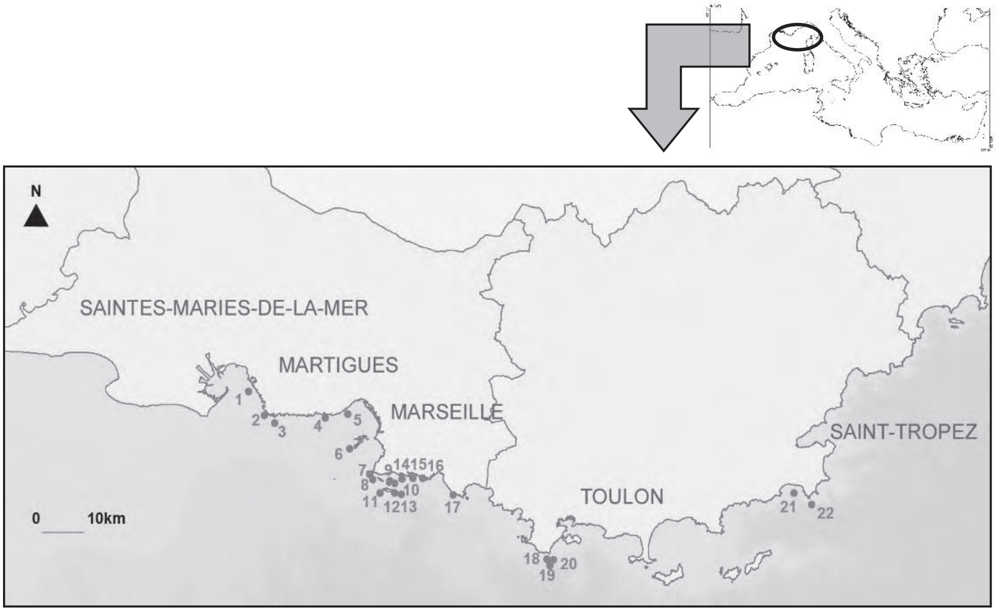

Fig. 1: Study area and sampling stations. 1: Auguette, 2: Arnette, 3: San Christ, 4: Méjean, 5: Large Niolon, 6: Pointe La Luque, 7: Fromage, 8: Matelot, 9: Ile Plane nord, 10: Ile Plane sud, 11: Moyade, 12: Caramassaigne, 13: Grand Congloue, 14: Sormiou, 15: Morgiou, 16: Devenson, 17: Egoût Figuerolle, 18: Sêche Pêcheur Ouest, 19: Sêche Pêcheur Sud, 20: Sêche Pêcheur Est, 21: Tombant Maconnais, 22: Quairol.

Sampling with the INDEX-COR method is based on the Reef Check Benthos method usually applied to monitor the conservation state of the coral reefs in tropical zone (Hill & Wilkinson, 2004). We also take into account the non-destructive protocol for the biodiversity assessment and monitoring of coralligenous outcrops proposed by Kipson *et al.* (2011). In each site, sampling by SCUBA diving was performed along two transects (15 m) randomly installed at the same depth and orientation. Along them, 30 photographs (15 per transect) were taken by one diver using a digital camera perpendicularly fixed to a 60x40cm quadrat frame (72000 cm² in total) (NEX-5 Sony with a 2.8-16 mm zoom-lens Sony used with a housing and a dome NAUTICAM® and four SOLA® 1200 lights). On the same transects, a "diver observer" with an adapted submersible plate with two lights and a GoPro camera, was in charge of recording: (i) characteristics of the site (depth, orientation, type of slope), (ii) information regarding benthic communities (general development and gorgonians populations) and (iii) species recognizable *in situ* without sampling. Considering the constraint of diving (depth and time), below 30m depth we followed a decompression procedure with oxygen (-6 m).

To evaluate the conservation state of coralligenous outcrops, we selected three metrics: (i) the Ratio between Sensitive and Tolerant Species (RSTS), (ii) the Observable Taxonomic Richness (OTR) and (iii) the Structural Complexity (SC). To assess the RSTS, we analysed photographs taken along transects, using PhotoQuad 1.0 software (Trygonis & Sini, 2012). On calibrated images, uniform 100 sampling points were used. The OTR was determined from the total sessile and vagile benthic taxa (at the genus level minimum) recognizable without sampling. We referred to a list of 160 sessile and patrimonial vagile species (algae, foraminifera, sponges, bryozoans, cnidarians, platelminth, annelid polychaeta, echiurians, mollusca, echinoderms, crustaceans and ascidiaceans). This list was based on those ones established during the MEDCHANGE and EU project CIGESMED (www.cigesmed.eu).

At last, the SC was obtained with 3 sub-metrics: (i) the percentage of species belonging to the basal layer (encrusting species from 0.1 to 5 cm thick), (ii) the number of species belonging to the intermediate layer (5-15 cm) and (iii) the notes of the "diver observer" on the species belonging to the upper layer (>15 cm) with a classification within 5 classes of density. Statistical tests were performed with R Statistical Software (Fox & Andersen, 2005). To define the sensitivity level of species regarding to the organic matter and sediment input, for the first metric (RSTS) we used the delta distribution model modified by Sefánsson (1996). To calculate the third metric (SC), we used a Factor Analysis for Mixed Data (FAMD) (Escofier, 1979; Pagès, 2004). At last, as a first approach, we have chosen an arithmetic mean of the three metrics selected as the INDEX-COR index formula (IC):

$$IC = (10RSTS+OTR+SC)/3.$$

Results

For each site, the INDEX-COR method required a dive time of 25 minutes on the bottom and one to two days for data analysis. The application of the modified delta distribution model allowed us to establish a list of 46 species classified in 3 levels of sensitivity according to the level of organic matter and sediment: opportunistic species (Group 1), tolerant species (Group 2) and sensitive species (Group 3). The percentage of each group was calculated from the number of points obtained with the PhotoQuad analysis. To calculate the RSTS value, these percentages were aggregated using a formula based on the Biotic Index defined by Borja *et al.* (2000) to establish the conservation state of soft bottom benthic communities:

$$RSTS = (0\times\%Group\ 1+5\times\%Group\ 2+10\times\%Group\ 3)/100 \text{ (RSTS values from 0 to 10)}$$

The lowest RSTS values obtained (0.57 to 2.39) corresponded to the stations severely disturbed by the input of sewage outfalls or the Rhône river (Matelot, San Christ, Ile Plane Nord, Fromage, Sêche Pêcheur Ouest, Auguette, Figuerolle). At the opposite, the highest values (4.31 to 5.67) corresponded to the sites least impacted by input of organic matter or sediment (Quairol, Moyade, Devenson, Grand Congloue, Caramassaigne). Concerning the OTR values, they ranged from 18 (Auguette) to 72 species (Sêche Pêcheur Est) according to the general level of anthropogenic impacts estimated by expert judgement (knowledge of local current and human activities in the area). At last, the SC metric was based on the value of the axis I of the

FAMD performed with the classification of the basal, intermediate and upper layers (Fig. 2a). This axis represent 29.9% of the information and is mainly explained by the basal and intermediate layer values as well as the extreme values of the upper layer. In order to embed this value in the INDEX-COR index formula with OTR metrics, it was increased by a factor of 10. Results obtained classify sites according to the general level of pressure, ranging SC values from 0 for Auguette (the most impacted site) to 55.27 for Quairol ("natural" site) (Fig. 2b).

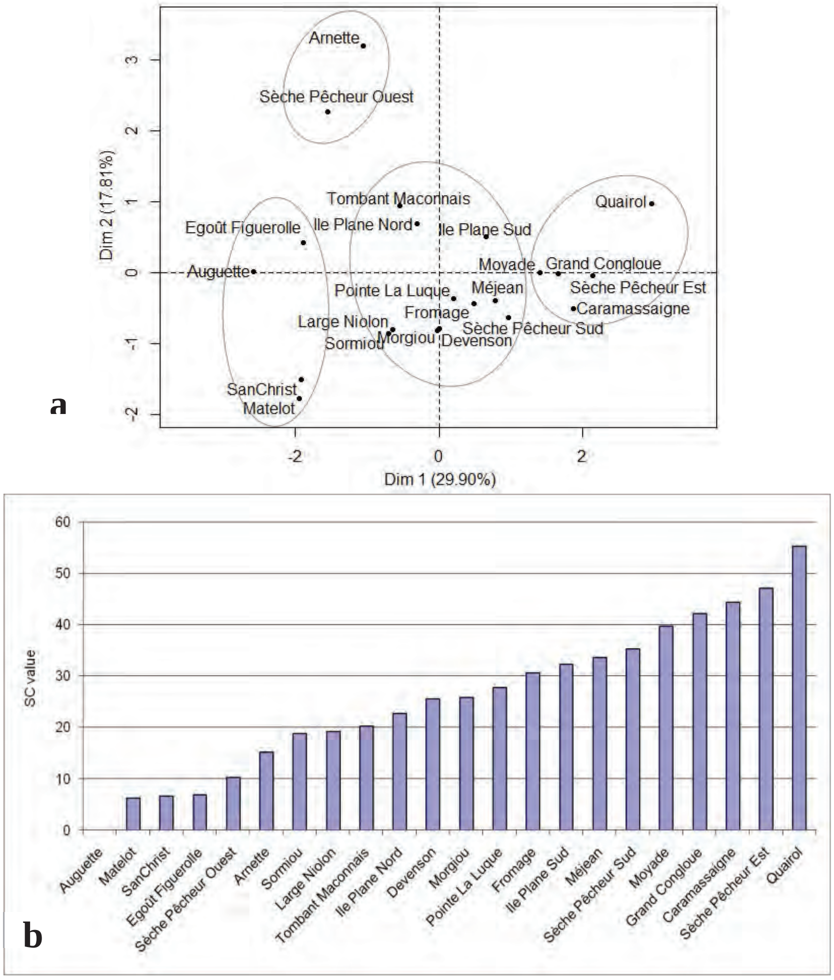

Fig. 2: Classification of sites by the SC value. a: FAMD results. 4 groups of stations can be identified linked to the estimated level of pressure. b: classification of station according to the SC value.

The IC index values ranged from 13.89 (Auguette) to 54.34 (Caramassaigne) (Fig. 3). According to the level of anthropogenic impact evaluated by expert judgement. IC values less than 20 classify stations as highly impacted with a bad conservation state whereas values greater than 40 reflect low impacted station with coralligenous assemblages in a good health.

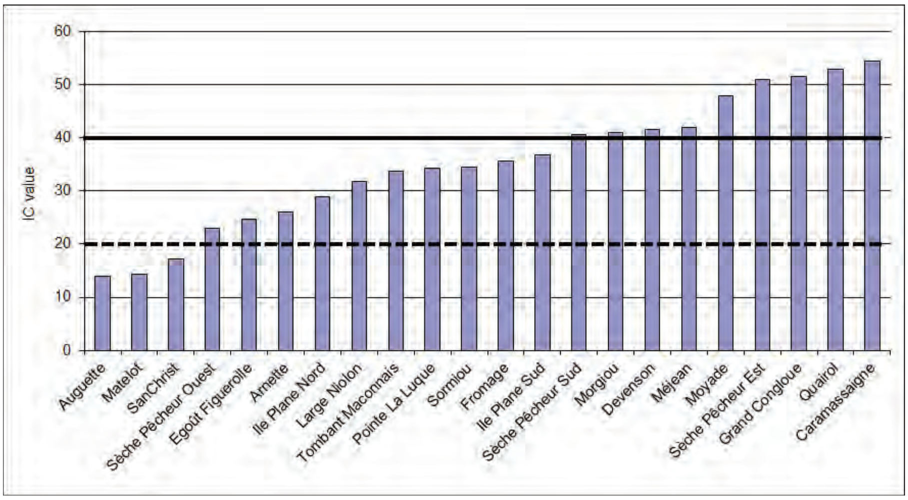

Fig. 3: Classification of stations by the INDEX-COR. The dashed bar (IC=20) marks the value boundary for the highly impacted sites and the bold black bar (IC=40) the value boundary for the low impacted stations.

Discussion

The INDEX-COR method seems to meet the expectations of the stakeholders constraints: rapidity of data acquisition and easy-to-use for analysis, safety diving process and robustness of the index. It can be applied down to 50-60 m depth but an adaptation with ROV (Remotely Operating Vehicule) and AUV (Autonomous Underwater Vehicle) could be considered in deeper zone. The data analysis is not lengthy and does not require specialization in taxonomy knowledge but only the naturalist's experience and a limited training. RSTS, OTR and SC metrics seem to respond well to the level of pressure estimated by the expert judgement. Nevertheless, a more objective anthropogenic impact index is needed to improve this correlation. Unfortunately, the structural complexity of coralligenous outcrops lead to a differentiation of the human impacts at a low scale. The results obtained in the "Sêche des Pêcheurs" site illustrate this fact. Three stations were selected in this site (Sêche des Pêcheur Ouest, Sud and Est) according to their exposure to a sewage outfall. These three stations, less than 200 m away from each other, present different values of the IC index (24.07, 38.51 and 51.60) characterizing a difference in conservation state in coralligenous outcrops. Similar observations can be made for the physical impacts linked to fishing and diving activities (impacts of anchoring and divers). Therefore, a global index specifying the level of impact at low scale (including physical impacts and sediment/organic matter input) is needed to precise its correlation with our three metrics and to precise the best ending formula for the IC index. The next step of work will include a definition of this anthropogenic index and testing of IC index with a more comprehensive set of data (39 other sites have been sampled and will be analysed during next months). At last, this method will be adapted and applied in eastern mediterranean basin (Greece and Turkey) during the EU project CIGESMED.

Acknowledgments

We are grateful to the "Agence des aires marines protégées" for the financial supporting of the INDEX-COR program. We also thank MPA Staffs involved during the field works.

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A FIRST INSIGHT INTO THE CORALLIGENOUS ASSEMBLAGES OF THE WESTERN SARDINIA SHELF (ITALY)

Abstract

In the context of Marine Strategy Framework Directive (MSFD, 2008/56/EC), coralligenous assemblages are considered as "special habitat type". The knowledge of their distribution and the assessment of their status can contribute to the definition of the environmental status of Mediterranean regions. Seafloor mapping was implemented through multibeam echosounder surveys and video transects in areas not formerly explored within the continental shelf along the north-western coast of Sardinia (Western Mediterranean). A high resolution digital model of the seabed (DTM) was obtained from multibeam data; the DTM was processed by using the tools of the terrain analysis to extract a number of derived variables of the seabed. Furthermore the analysis of the acoustic backscatter associated to multibeam data was used to evaluate the acoustic response of the seabed associated to different habitat types. The combination of those variables, allowed the development of maps of coralligenous distribution. The presence of coralligenous was validated in two sampling areas from 60 to 140 m depth. For each area, three random transects (about 150m length for each transect) were carried out by means of Remote Operating Vehicle (ROV) with high resolution camera. Video images were processed in order to describe the biotic component of dominant populations. The combined analysis of sonograms and video images provided information on the relevant aspects of the investigated seabeds, distinguishing between mineral and biogenic formations, highlighting their distribution, extent and conditions in terms of presence of typical species and communities. This paper reports the preliminary data of the whole study and contributes to the knowledge of deep coralligenous systems of western Sardinian coasts.

Key-words: Mediterranean Sea, Continental Shelf, Multibeam, MSFD, Black corals

Introduction

The continental shelf of Mediterranean Sea, from about 25-30 m up to 150-200 m deep, can be characterized by the presence of the "coralligenous habitat" (Piazzi *et al*., 2012), a biogenic concretion that thrives exclusively in Mediterranean waters (Ballesteros, 2006). Coralligenous habitat is considered as a hard substratum that is produced by the accumulation of calcareous coralline algae growing in low light condition (Ballesteros, 2006). The light conditions strongly influence the development of the coralligenous communities that grows in a range between 0.5% and 3% of the surface irradiance (Ballesteros, 2006). Coralligenous growth is also influenced by nutrient concentration in the water, temperature, and salinity. Moreover the coralligenous habitat is the result of the interactions between the building activities of algal and animal constructors and the biological and physical erosive processes (Martin *et al*., 2014). The coralligenous communities can be considered a carbonate sediment factory, because of their high levels of the carbonate production (Canals and Ballesteros, 1996). The knowledge of the distribution of coralligenous reefs along the continental shelves of Mediterranean Sea is

crucial for management and conservation of marine resources (Cogan *et al.*, 2009). At present, data about their presence and coverage of seafloor are unevenly and patchily distributed along the coastline (Martin *et al.*, 2014).
Under the Marine Strategy Framework Directive (MSFD, EC, 2008), aimed to improve the environmental status of the seas, coralligenous assemblages are considered "special habitat types" and their environmental status should be monitored as indicator of the descriptor "biodiversity". Direct measures for mapping coralligenous beds are often prevented by depth. To avoid this difficulties, indirect techniques of seabed mapping, including acoustic and seismic acquisition, are used (Costa & Battista, 2013; De Falco *et al.*, 2010). Aim of this work is to investigate the occurrence of coralligenous habitat on the North Western Sardinia continental shelf in a range between 50 and 200 m deep. Seabed maps were obtained by using terrain and reflectivity (backscatter) analysis on acoustics geophysical data (multibeam echosounder). Video transects were carried out to validate the presence of the reefs and to describe the main features of biotic components of assemblages.

Materials and Methods

Multibeam echosounder (MBES) and seismic data were collected along the continental shelf of the western (A3 sector) and northern (A4 sector) margin of Sardinia (Western Mediterranean Sea), from 50 m up to 200 m deep (Fig. 1). The MBES used to obtain a comprehensive morphostructural definition of the mid-outer continental shelf were: (i) Kongsberg EM 3002D (293-307 kHz, resolution 1cm) for shallow areas and (ii) Kongsberg EM 710 and SeaBat Reson 7111 (100 kHz) for deeper ones. Multibeam data were processed using the software Caris Hips and Sips, and a Digital Terrain Model (DTM) at 2.5 meters was obtained for the whole investigated area. The original DTM was subdivided in 65 square DTMs with a side of 5 km (35 for the A3 sector and 30 for the A4 sector, Fig. 1). Terrain Analysis (Qgis tools, www.qgis.org) on the DTMs was performed to obtain the areas potentially occupied by coralligenous assemblages. For each DTM the analysis were able to extract: the slope, the roughness, the plan curvature, the slope and the roughness of slope (Fig. 2). Surfaces where coralligenous assemblages might occurs were identified combining the results of DTM Terrain Analysis, and separated as shapefile areas (Fig. 2). Backscatter data, obtained by the multibeam data (side scan option), were used for a rough classification of the seabed (soft vs. hard beds). Finally, Remote Operating Vehicle (ROV) with high resolution camera was used to validate the terrain analysis results. Six random transects were carried out from 60 to 140 m depth in one area of sector A3 (Fig. 3). Video images were analyzed in order to describe the biotic component of dominant populations. In A4 area the images were acquired in the western shelf of this sector (from 60 to 120 m depth), this raw images were not analyzed and were used only to confirm the presence of coralligenous beds (unpublished data).Besides seismic profiles, using the Sparker mounted in the oceanographic vessel R/V Urania, were realized along the routes followed during MBES acquisition, this allows to investigate about the thickness of the coralligenous reefs (Fig. 3).

Results

A good agreement between the terrain analysis and the occurrence of coralligenous beds were found. In fact each video transect confirms the presence of coralligenous lived beds where the terrain analysis found a specific pattern of variability, as highlighted in figures 2 and 3. In Figure 3 we displayed the images obtained by video transects on coralligenous seabeds and the typical pattern occurred on terrain analysis maps on the same seabed area. Furthermore the analysis of Sparker profiles showed that the thickness of coralligenous assemblages can be higher than 5 m (lower left panel in Figure 3). It is not known if this thickness is due to the different steps of vertical growth of coralligenous during the eustatic oscillation of sea level.

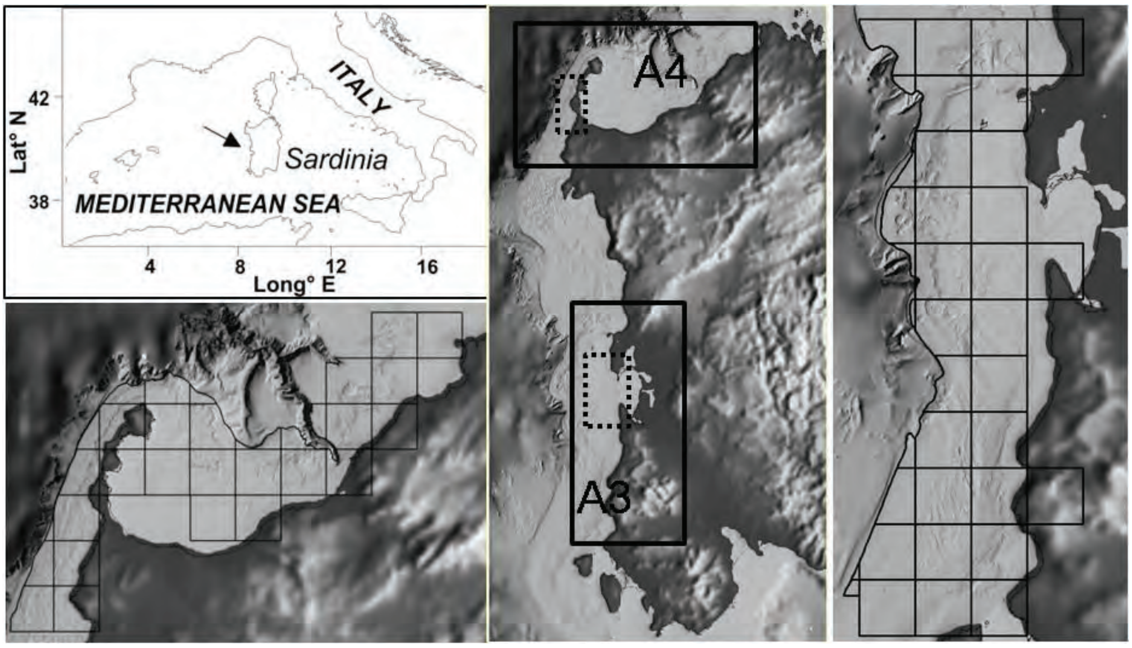

Fig. 1: Central panel - Study area; lower left panel: sector A4; right panel: sector A3; DTM subdivision for each sector using a square grid to perform the terrain analysis. The dotted rectangle indicated the area where video transects (A3) and R.O.V. images (A4) were acquired.

A total of about 4200 km^2 (2200 km^2 for A4 sector and 2000 km^2 for A3 sector), from 50 to 200 m depth, of continental shelf of North-Western Sardinia were investigated. Analysis of backscatter maps reveals that about 37% of the continental shelf surface is bedrock (various rocky formations) and about 63% is sedimentary bed. In particular on the A3 sector the bedrock covers about the 40% of the continental shelf, on A4 sector it covers about 34% of the continental shelf. In Figure 4 the results of terrain analysis, validated with the video transects, are reported, for A4 area the images acquired by ROV confirm the presence of coralligenous (unpublished data). Terrain Analysis highlighted that in the A3 sector the coralligenous beds cover about 112 km^2 (14% of the total bedrock) and in A4 area they cover about 78 km^2 (about 11% of the total bedrock).
Although the video transects have provided punctual information on very limited areas of the seabed, they have revealed the presence of some species never reported for this area of the Mediterranean. In general for shallower area (60m depth) the algae assemblages represent the main component of coralligenous framework, whilst for deeper area (120m depth) the animal component became relevant. In Figure 3, right panel top down order, the black corals *Antipathella subpinnata* (Ellis and Solander, 1786) (Family Myriopathidae) and *Parantipathes larix* (Esper, 1790) (Family Schizopathidae), and the whip coral *Viminella flagellum* (Johnson, 1863) (Family Ellisellidae) are shown.

Discussion

Our study highlighted that on continental shelf of Sardinia island, from 50 m to 200 m depth, several patch of coralligenous assemblages are found colonizing the seabed. Nevertheless, most of coralligenous assemblages were found from 50 m to 90 m, but a significant amount of coralligenous assemblages were detected on deeper sector of continental shelf (> -110m depth).

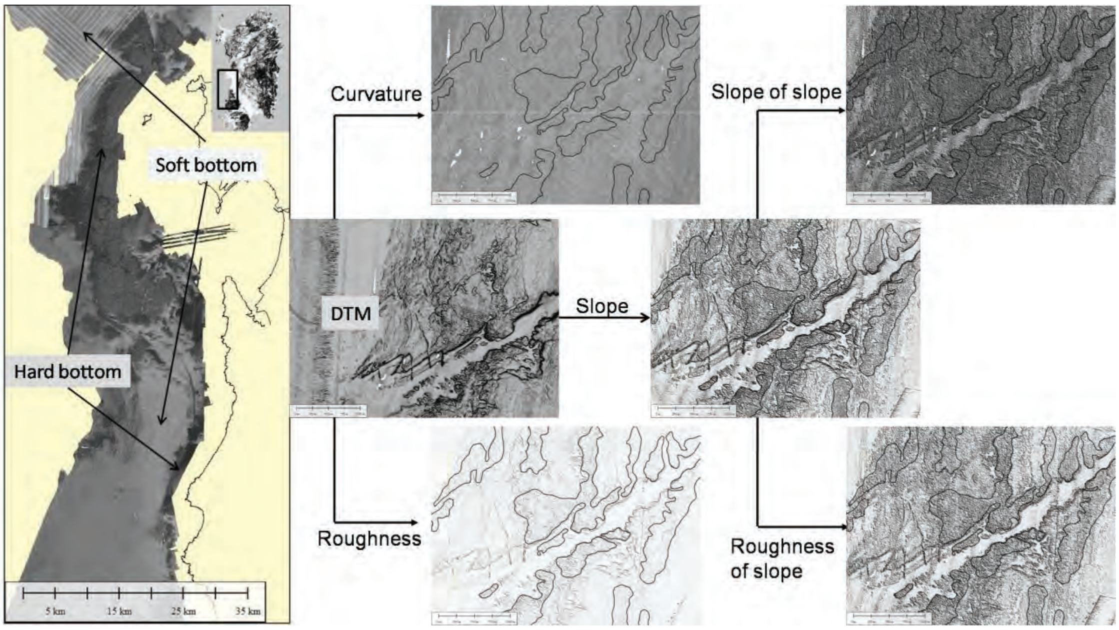

Fig. 2: Left panel: backscatter; right panel: identification of coralligenous beds using terrain analysis, coralligenous assemblages are visually determined and identified by the black contours.

It is know that coralligenous assemblages are influenced by the light penetration in to the water column (Ballesteros, 2006), and consequently the depth could influence their distribution. We found that about 50% of the total coralligenous beds occurs shallower than 90 m deep; however a considerable amount of coralligenous reefs (16% of the total) was found in deeper area of continental shelf, below 110 m. From the processing of the MBES data the coralligenous assemblages seem to be developed mainly over the outcropping bedrock and forming wide and tick banks (several hundred of m^2 of surface and several m tick). As highlighted by Martin *et al*. (2014), wide area of Mediterranean shelves are occupied by coralligenous beds; our study highlighted that the total areas of coralligenous seabed could be increased and redefined increasing the efforts on seabed mapping.

As a consequence the scientific community should increase the efforts for mapping the seabed, in particular from 50 m to the shelf break. In fact coralligenous assemblages should be granted legal protection at the same level of *Posidonia oceanica* meadows as stated in Barcelona Convention's 'Action Plan'.

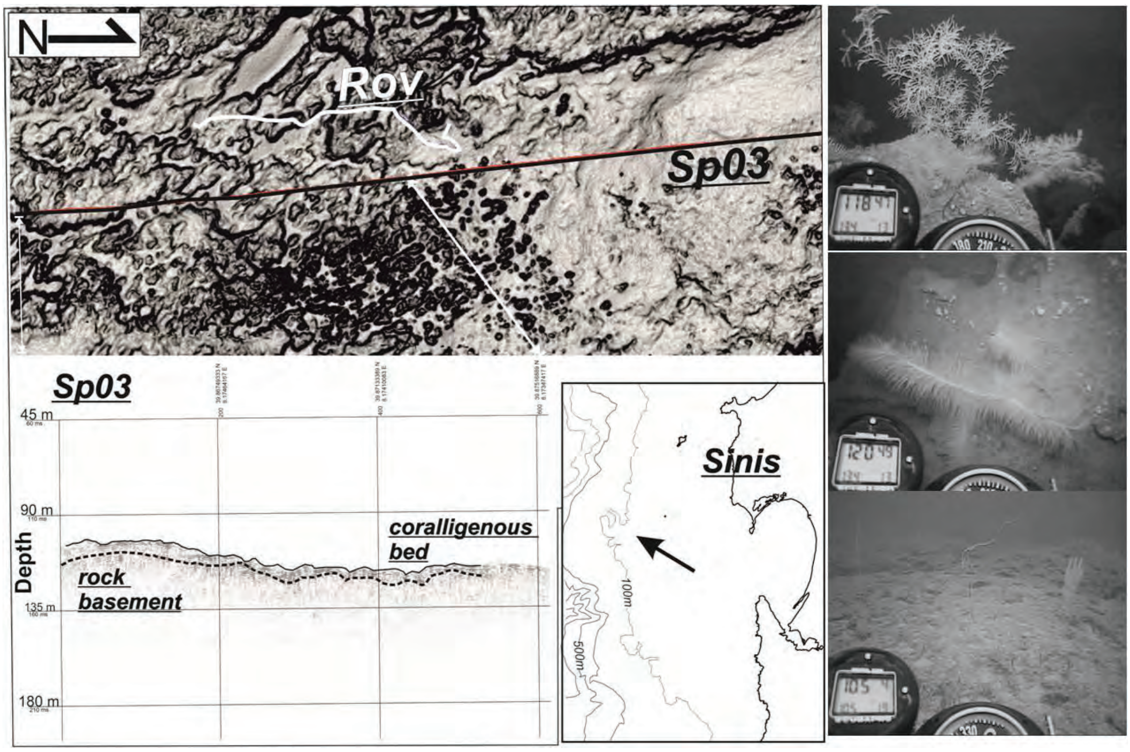

Fig. 3: Left panel: Sparker profile and thickness of the coralligenous framework (5 m);right panel: ROV images.

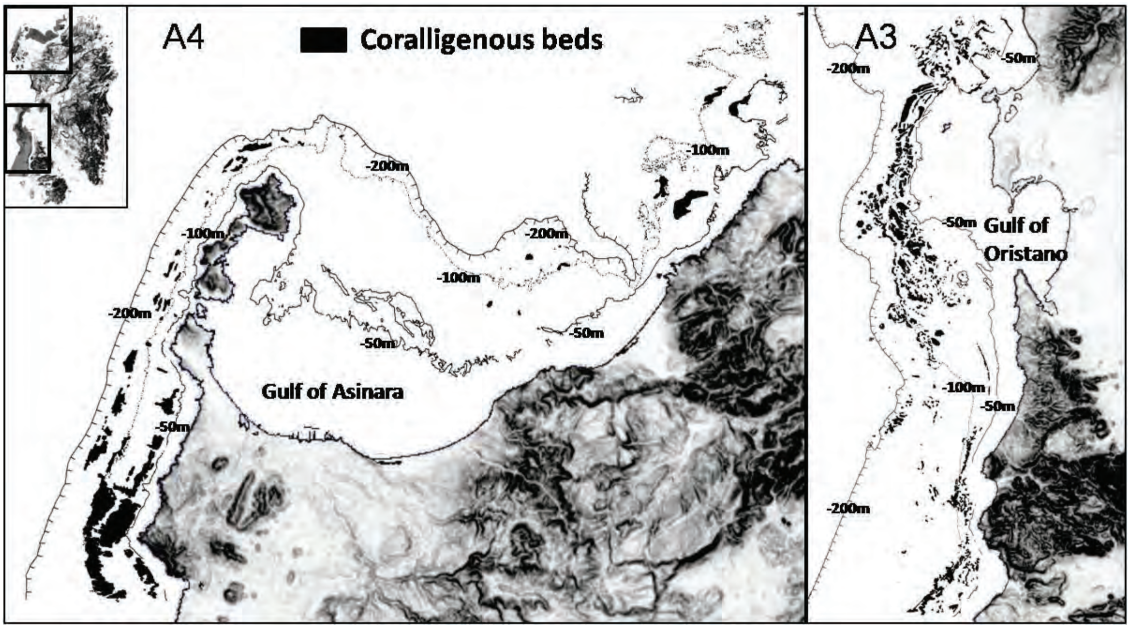

Fig. 4: Coralligenous beds distribution along the northern and western continental shelf of Sardinia (depth of -200m represent the shelf break).

In this context, the indirect measures provided by acoustic and seismic instruments, such as those used in this work, coupled with video transects acquired by HD ROV can be very useful to reduce costs of mapping and to increase the total surface of mapped areas. The finding of deep corals confirms that they are common component of the lower fringe of the circalittoral twilight environment on hard bottoms (Bo *et al*., 2008). However, because

of the relevant ecological role of benthic cnidarians as well as the presence of species (*i.e. P. larix, V. flagellum*) rarely reported for Mediterranean basin (Bo *et al*., 2014; Giusti *et al*., 2012) further and detailed studies in these areas are advocated to shed light on their distribution, abundance, population structure and conservation status. Furthermore our results, based on seismic acquisition (Fig. 3), highlight that the thickness of coralligenous assemblages can be higher than 5 m.
Based on this consideration, the growth rate of coralligenous reefs in relation to the depth and to sea level variation at millenary scale should be better investigated.

Acknowledgements
Data were collected in the framework of the following projects: RITMARE, funded by MIUR; MAGIC, funded by Italian Civil Protection Department; and Strategia Marina Funded by R.A.S.

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DIVERSITY AND STRUCTURE OF CORALLIGENOUS ASSEMBLAGES DOMINATED BY *EUNICELLA CAVOLINI* (KOCH, 1887) IN THE AEGEAN SEA

Abstract
The diversity and structure of six coralligenous assemblages dominated by Eunicella cavolini (Octocorallia - Anthozoa) were studied in three localities of the Aegean Sea (NE Mediterranean). A standardized, rapid, non-destructive method was applied at depths ranging from 18 to 35 m. Within each site, a total area of 1.5 m^2 was sampled using photoquadrats (25 x 25 cm) over three 0.5 m^2 randomly placed transects. Number and percentage cover of conspicuous macrobenthic species were measured using the image segmentation tool provided by photoQuad. A total of 95 taxa belonging to 8 taxonomic groups were identified, with sponges and coralline algae being the dominant groups in terms of cover. Results suggest that coralligenous communities dominated by Eunicella cavolini of the Aegean Sea constitute a highly diverse habitat, presenting several similarities and peculiarities to their western Mediterranean counterparts. The baseline information provided in this study allows for future monitoring and comparisons at a Mediterranean-scale level.

Key-words: Biodiversity, coralligenous assemblages, photoquadrat sampling, Aegean Sea

Introduction

Knowledge on the existence of coralligenous formations in the Aegean Sea dates back to the late 1950s (Laborel, 1960, 1961; Pérès & Picard, 1958). During the following decades, only a small number of studies dealt with coralligenous communities in the region, focusing mainly on specific taxonomic groups (Aktan, 2012; Antoniadou & Chintiroglou, 2005; Gerovasileiou *et al.*, 2009; Salomidi *et al.*, 2009; Vafidis *et al.*, 1997). Although recent assessments have outlined their widespread distribution in most parts of the Aegean Sea (Giakoumi *et al.*, 2013; Martin *et al.*, 2014), their assemblages remain largely unexplored, and there is a considerable lack of knowledge regarding their diversity and community structure. *Eunicella cavolini* (Koch, 1887) is one of the most common gorgonian species in the Mediterranean Sea. While populations of this species have been recorded in several habitat types, from shallow overhangs and caves, to deep-water reefs and the slopes of seamounts, they are primarily known for establishing dense populations and creating typical facies within coralligenous outcrops (UNEP/MAP, 2007). Focusing on this particular facies, we investigated the coralligenous assemblages in three localities of the north Aegean Sea, in order to provide comparable quantitative information regarding their species composition and structure, and enable future monitoring.

Materials and methods

Six coralligenous assemblages dominated by *E. cavolini* were investigated in three geographical localities of the north Aegean Sea (Fig. 1); Pelion (2 sites), Chalkidiki (2), and Lesvos Island (2). A rapid, non-destructive method was applied through photoquadrat sampling at depths ranging from 18 to 35 m. Voucher specimens were only collected when identification through photographs was not possible. Within each site, the assemblages were characterized using a standardized method (Kipson *et al.*, 2012), which involves the acquisition of images (25 x 25 cm) over three 0.5 m^2 randomly placed transects, covering a total sampling area of 1.5 m^2. Number and percent cover of conspicuous macrobenthic species were measured using the image segmentation tool provided by photoQuad, a free custom software dedicated to the processing of benthic images (Trygonis & Sini, 2012).

Fig. 1: Map of the Aegean Sea, sampling localities and sites

Results

A total of 144 images were analyzed, and 95 taxonomic groups were identified (see Table 1 for a list of main species), including Porifera (41), Algae (21), Anthozoa (10), Bryozoa (10), Tunicata (6), Annelida (4), Mollusca (2), and Foraminifera (1). Species richness was higher in Pelion (16.98 ± 3.3 S.D.) and Chalkidiki (15.29 ± 4.8 S.D.), compared to Lesvos (13.29 ± 3.7 S.D.). The number and cover (%) of the main taxonomic groups per locality are presented in Fig. 2a, b. Overall, 39.7% of the species were found in all localities. Porifera was the group with the highest number of species in all areas, followed by Rhodophyta. Additionally, the locality of Chalkidiki displayed a higher number of Chlorophyta (9), as well as Bryozoa (10), while Pelion had the highest number of Anthozoa species, represented primarily by scleractinians (8).

In terms of cover, algae were the dominant group in the majority of sites. Encrusting coralline algae had the highest cover (23%), being mainly represented by *Neogoniolithon mamillosum, Lithophyllum stictaeforme, and Mesophyllum alternans*, while *Peyssonnelia* species had an overall cover of 12%. Chlorophyta also presented a high overall cover (17%), mainly due to the presence of *Flabellia petiolata,* as well as several turf-forming species (*e.g. Pseudochlorodesmis furcellata, Cladophora pellucida*). Porifera was the second most important taxonomic group in terms of cover (28%), out of which "Encrusting Porifera" (unidentified), *Agelas oroides, Chondrosia reniformis, Crambe crambe*, and *Spirastrella cunctatrix* had the greatest contribution (21%). With the exception of *E. cavolini,* the remaining anthozoans (2.7%) were primarily represented by the zoantharian *Parazoanthus axinellae* and scleractinians (*e.g. Leptopsammia pruvoti* and *Caryophyllia inornata*)*,* which appeared in all sites. The main bryozoans were *Adeonella calveti, Rhynchozoon neapolitanum*, *Schizomavella auriculata* and *Reteporella* sp. but with an overall low cover (0.7%). Finally, the tunicates that appeared in most sites were *Clavelina lepadiformis* and *Halocynthia papillosa*, whereas a relatively high cover of encrusting tunicate species was observed in a single site in Lesvos.

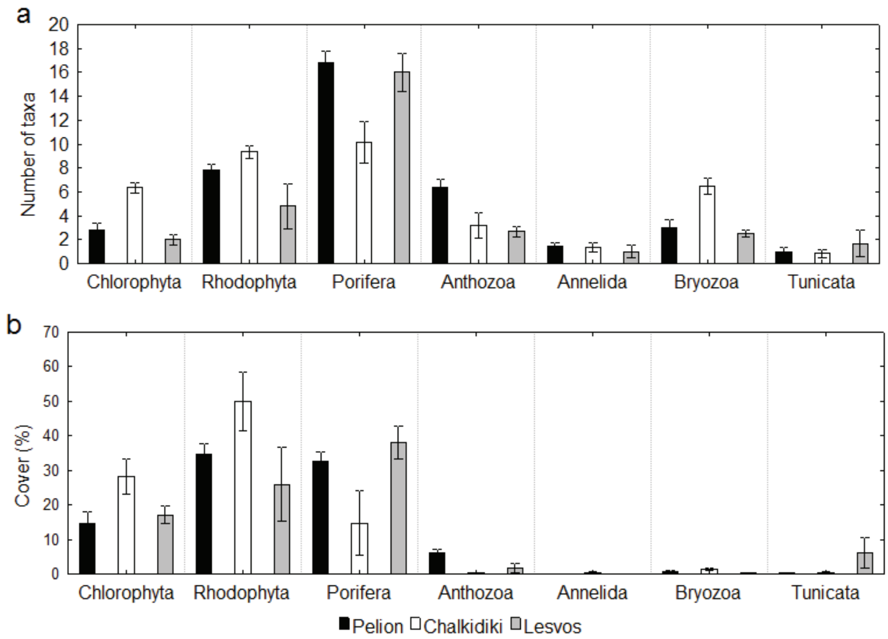

Fig. 2: a) Mean number and b) mean percentage cover of the main taxonomic groups per locality. Whisker span represents standard deviation.

Discussion and conclusions

This study is the first to provide quantitative data on the biodiversity patterns of coralligenous assemblages dominated by *E. cavolini* in the northern Aegean Sea. Results suggest that this facies encompasses a rich diversity of benthic fauna and flora. Although species richness was similar among the distinct localities, the mean number of species and mean cover per taxonomic group displayed some degree of variability. Chalkidiki was characterized by a higher number and cover of algal species, and presented the highest number of bryozoans, while the contribution of sponges was low compared to the remaining localities. On the contrary, number of sponge species was higher in Pelion and Lesvos, and their contribution to the biotic cover was similar to that of algal species. Additionally, the number and cover of anthozoans were highest in Pelion, while tunicates were more diverse in Lesvos.

Overall, community structure – in terms of species richness and biotic cover – was found to be similar to that reported in other areas of the western Mediterranean basin (*e.g.* Deter *et al.,* 2012; Gatti *et al.*, 2012; Kipson *et al.,* 2011; Teixidó *et al.,* 2013). However, there are also several differences which are mainly related to the composition of erect species. In the investigated sites, structural complexity at the upper layer of the assemblages was primarily promoted by the presence of *E. cavolini*, together with a large number of massive and erect sponges (e.g. *Agelas oroides*, *Axinella* spp., *Ircinia* spp., *Sarcotragus* spp.), while the number and cover of erect bryozoans was low and sporadically pronounced in certain sites. This result is in line with additional observations made outside the *E. cavolini* facies, where sponges remain the dominant structural group of the upper assemblage stratum (MS pers. obs.). Moreover, other octocoral species (e.g. *Paramuricea clavata, E. singularis,* and *Corallium rubrum*) are particularly rare, if not absent, in the shallow coralligenous communities of the Aegean Sea (*i.e.* <50 m, Dounas *et al.*, 2009, Salomidi *et al.*, 2009, MS pers. obs.,), while *Alcyonium* species are known to be restricted to the deep "coralligène de plateau" (Pérès & Picard, 1958). On the other hand, at the basal layer, a greater number of scleractinians were recorded in the northern Aegean localities compared to those reported for coralligenous communities in other areas of the Mediterranean.

Tab. 1 List of the main species observed in photoquadrats within the *E. cavolini* coralligenous assemblages.

Algae
Chlorophyta
Codium coralloides (Kützing) P.C.Silva
Cladophora pellucida (Hudson) Kützing
Flabellia petiolata (Turra) Nizamuddin
Halimeda tuna (J.Ellis & Solander) J.V.Lamouroux
Pseudochlorodesmis furcellata (Zanardini) Børgesen
Valonia macrophysa Kützing

Rhodophyta
Lithophyllum stictaeforme / cabiochiae cf.
Mesophyllum alternans (Foslie) Cabioch & M.L.Mendoza,
Neogoniolithon mamillosum (Hauck) Setchell & L.R.Mason,
Peyssonnelia rosa-marina Boudouresque & Denizot,
Peyssonnelia rubra / bornetii cf.
Peyssonnelia squamaria (S.G.Gmelin) Decaisne

Porifera
Acanthella acuta Schmidt, 1862
Agelas oroides (Schmidt, 1864)
Aplysilla sulfurea Schulze, 1878
Axinella cannabina (Esper, 1794)
Axinella damicornis (Esper, 1794)
Axinella verrucosa (Esper, 1794)
Chondrosia reniformis Nardo, 1847
Clathrina clathrus (Schmidt, 1864)
Cliona celata Grant, 1826
Cliona schmidti (Ridley, 1881)
Cliona viridis (Schmidt, 1862)
Crambe crambe (Schmidt, 1862)
Dictyonella incisa (Schmidt, 1880)
Dysidea fragilis (Montagu, 1814)
Haliclona (Halichoclona) fulva (Topsent, 1893)
Haliclona (Soestella) mucosa (Griessinger, 1971)
Hexadella racovitzai Topsent, 1896
Ircinia oros (Schmidt, 1864)
Ircinia variabilis (Schmidt, 1862)
Petrosia (Petrosia) ficiformis (Poiret, 1789)
Phorbas tenacior (Topsent, 1925)
Pleraplysilla spinifera (Schulze, 1879)
Sarcotragus foetidus Schmidt, 1862,
Sarcotragus spinosulus Schmidt, 1862
Spirastrella cunctatrix Schmidt, 1868

Cnidaria
Caryophyllia (Caryophyllia) inornata (Duncan, 1878)
Eunicella cavolini (Koch, 1887)
Hoplangia durotrix Gosse, 1860
Leptopsammia pruvoti Lacaze-Duthiers, 1897
Madracis pharensis (Heller, 1868)
Paracyathus pulchellus (Philippi, 1842)
Parazoanthus axinellae (Schmidt, 1862)
Phyllangia americana mouchezii (Lacaze-Duthiers, 1897)
Polycyathus muellerae (Abel, 1959)

Annelida
Eupolymnia nebulosa (Montagu, 1818)
Myxicola infundibulum (Montagu, 1808)
Filograna implexa / Salmacina dysteri
Serpula vermicularis Linnaeus, 1767

Bryozoa
Adeonella calveti (Canu & Bassler, 1930)
Beania magellanica (Busk, 1852)
Hornera frondiculata (Lamarck, 1816)
Rhynchozoon neapolitanum Gautier, 1962
Schizomavella auriculata (Hassall, 1842)
Reteporella sp.
Smittina cervicornis (Pallas, 1766)

Tunicata
Aplidium elegans (Giard, 1872)
Clavelina lepadiformis (Müller, 1776)
Cystodytes dellechiajei (Della Valle, 1877)
Didemnum spp.
Halocynthia papillosa (Linnaeus, 1767)

The results provide valuable information for future monitoring and comparisons at a Mediterranean-scale level, focusing on *E. cavolini* assemblages. Given the great geographic extent and wide bathymetric range of coralligenous communities in the Aegean Sea (Giakoumi *et al.*, 2013, Martin *et al.*, 2014; Pérès & Picard, 1958), further research will enhance our understanding of the ecology, biodiversity patterns, and conservation status of this largely unexplored habitat.

Acknowledgments

We are grateful to Vasilis Gerovasileiou, Elina Samara, and Panagiotis Papadelis for their valuable contribution in the field. We further wish to thank Kike Ballesteros for advice on identification of Algae, Dimitris Vafidis for verification of Anthozoa, and Vasilis Gerovasileiou for verification of Porifera. This work has been co-financed by the EU Social Fund and Greek national funds through the NSRF 2007-2013 Research Funding Program: Heracleitus II, Investing in knowledge society.

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BIODIVERSITY PATTERNS OF CORALLIGENOUS OUTCROPS IN THE WESTERN MEDITERRANEAN: FIRST INSIGHTS ACROSS TEMPORAL AND SPATIAL SCALES

Abstract
Coralligenous outcrops are an important "hot spot" of Mediterranean biodiversity. Most of the benthic species inhabiting these outcrops are long-lived and slow-growing, thus making them especially vulnerable. The interaction between the climatic changes projected for the 21st century and other ongoing human-induced stressors, presents a major challenge to its biodiversity. Accurate studies on biodiversity over time and large spatial scales are thus required to know its current patterns, to detect changes, and to furnish predictions in developing future scenarios of biodiversity. Here, we present data from an ongoing study to estimate the diversity of macro-species of algae and invertebrates (mainly sponges, cnidarians, bryozoans and tunicates) through photographic surveys across large spatial (~36º- 43º latitude, > 1000 Km) and temporal scales (5 years). We used a hierarchical sampling procedure to measure species richness among regions, localities within regions, and sites within localities as a standardized monitoring network. The combination of large spatial and temporal approaches of this study provides an important baseline against which future effects of disturbances (e.g. warming-induced mortalities, invasive species, dramatic storms) can be assessed. Furthermore, the need for local to regional-scale biodiversity metrics and measurements, are crucial to document and assessing changes in marine biodiversity.

Key-words: Coralligenous, biodiversity, benthic species.

Introduction
In the Mediterranean Sea, coralligenous outcrops are of special concern, as they (i) represent one of the most important hotspots for biological diversity (harboring approximately 10% of Mediterranean species), (ii) exhibit great structural complexity, (iii) contribute greatly to carbon regulation and habitat for fishes and (iv) are among the habitats facing major threats (Ballesteros *et al.,* 2006). The species that characterize coralligenous seascapes are mainly encrusting calcareous algae, sponges, cnidarians, bryozoans, and tunicates. Some of them are engineering long-lived species; hence, their low dynamics make coralligenous outcrops exceptionally vulnerable to anthropogenic disturbances, such as destructive fishing practices, pollution, invasive species or mass mortality outbreaks linked to climate change (Cebrian *et al.,* 2012, Cerrano *et al.,* 2000; Garrabou *et al.,* 2009; Teixidó *et al.,* 2011). Moreover, according to several predictions, the Mediterranean basin will undergo one of the largest changes in climate worldwide, with an increase in the frequency of hot wave extremes of 200 to 500% predicted at the end of the twenty-first century (Déqué, 2007; Diffenbaugh *et al.,* 2007; Giorgi & Lionello 2008).
Here, we present data from an ongoing study of coralligenous outcrops characterized by the abundance of the red gorgonian *Paramuricea clavata* based on photographic surveys

across large spatial (36º-43º latitude, > 1000 Km) and temporal scales (5 years). Fine-scale knowledge on the distribution of species in this sensitive habitat is crucial to furnish data for studies on marine conservation planning and their implementation (Giakoumi *et al.,* 2013; Martin *et al.,* 2014). The main aim of this study is to investigate the current extent of biodiversity of the highly diverse coralligenous outcrops, to funish data on several localities in order to detect future changes, and to create a scientific platform in developing future scenarios of biodiversity responses to global change across large spatial and mid- to long-term temporal scales.

Material and methods

Study area, field surveys, and data collecting

Field surveys were carried out along the coast of Spain and France (covering more than 1000 km of coastline) for the regional approach. We used a hierarchical sampling procedure to quantify diversity patterns among regions (n=3), localities (n=9) within regions, and sites (n=27) within localities as a standardized monitoring network. Three main regions were sampled: Southern region (Alboran Sea and Cabo de Palos), Central region (Columbretes Islands and Eivissa) and Northern region (Medes Islands, Calanques de Marseille, Port-Cros, and Scandola) (Fig. 1). These localities follow a latitudinal and oceanographic gradient. At each site, 3 replicate-transects of 8 photographic quadrats (25*25 cm) were taken according to the minimum sampling area for these communities (Kipson *et al.,* 2011). For each site, macro-species composition and abundances (number of colonies and percent cover) were measured. From each photograph, perennial sessile macro-species, mainly macroalgae and encrusting red algae, sponges, anthozoans, polychaetes, bryozoans and tunicates were identified to the lowest taxonomic level. We also performed complementary dives for species identification. For the temporal approach, field surveys were carried out in the Northern region through permanent transects from 2006 to 2010. These surveys allowed us to assess the interannual variability of coralligenous outcrops in in the Natural Park of Montgrí, Medes Islands and Baix Ter and to quantify changes due to severe threats such as an extreme storm event that affected the Catalan coast on December 2008. By using data acquired before (2006-2008) and after the impact (2009-2010), we assessed the effects derived from the storm comparing changes in benthic community composition. For more information on photographic field surveys, data collecting and species identification see Kipson *et al.* (2011) and Teixidó *et al.* (2013).

Fig.1: Map of sampling locations in the western Mediterranean Sea. Circles indicate localities that were sampled under the regional approach (36º- 43º latitude), whereas rectangles indicate sites sampled under the temporal approach (5 year data)

Results and discussion

Regional approach

In this study, we are currently examining regional-scale patterns in the composition and abundance of coralligenous outcrops. We are currently identifying and quantifying more than 100 perennial macro-species at the 27 sites sampled within the 9 localities (Fig. 1). Our preliminary results show differences in species composition and structure of *Paramuricea clavata*-dominated coralligenous outcrops at the regional scale, but also with a common pool of taxa that are present everywhere (see Tab. 1).

Temporal approach

Natural variability of coralligenous outcrops shows little changes over time (Garrabou *et al.,* 2002; Virgilio *et al.,* 2006). Studies over time provide exceptional opportunities to detect the effects of extreme climatic events and to measure their impacts by quantifying rates of change at population and community levels. The storm of December 26th 2008 was considered to be the strongest recorded in the last 50 years in the northern part of the Catalan coast (41ºN - 42º30'N), with the greatest wave power, the highest wave heights, and the longest duration (Sanchez-Vidal *et al.,* 2012). An abrupt shift in the multivariate structure of coralligenous outcrops after the storm was only observed at the most exposed and impacted site, Carall Bernat, which showed the highest compositional variability in response to the disturbance (Fig. 2).

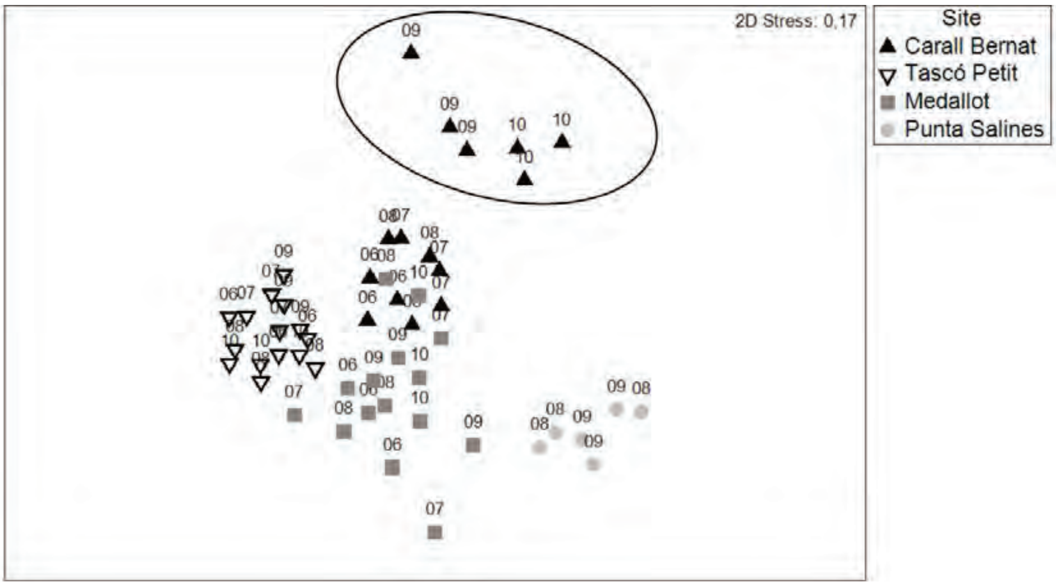

Fig. 2: Shift in the structure of the perennial benthic species in coralligenous outcrops in the Medes Islands in response to the 2008 dramatic storm episode. Non-metric multidimensional scaling (NMDS) based on the Bray-Curtis resemblance measure for species presence/absence data from 2006 to 2010. The circle indicates a SIMPROF group containing the immediate post-storm (2009) and following year (2010) data for Carall Bernat. Each symbol represents 8 analyzed photographs. Adapted from Teixidó *et al.,* (2013).

Tascó Petit and Punta Salines sites did not show any significant change on community structure before and after the storm, indicating no major effects of this severe storm at the sheltered sites.

Tab. 1: Preliminary results of the representative species of coralligenous outcrops dominated by the gorgonian *P. clavata* for each locality studied. Morpho-functional groups are also indicated. AlgE: Algae encrusting; AlgT: algae turf; AlgF: Algae filamentous; AnE: Animal encrusting; AnM: Animal massive; AnT: Animal tree; AnC: Animal cup; AnB: Animal boring; AnEpi: Animal epibiont

	Northern region				Central region		Southern region		
	Scandola	**Port-Cros**	**Calanques-Marseille**	**Medes Island**	**Eivissa**	**Coulmbretes Islands**	**Cabo Palos**	**Algeciras**	**Ceuta**
AlgE	*Lithophyllum stictaeforme* *Mesophyllum alternans* *Peyssonnelia sp*	*M. alternans* *Peyssonnelia sp*	*L. stictaeforme* *M. alternans* *Palmophyllum crassum*	*M. alternans* *Peyssonnelia sp*	*M. alternans* *P. crassum* *Peyssonnelia sp*	*L. stictaeforme* *M. alternans* *P. crassum* *Peyssonnelia sp*	*L. stictaeforme* *M. alternans* *P. crassum* *P. rosa-marina* *Peyssonnelia sp.*	*L. stictaeforme* *M. alternans* *Peyssonnelia sp.*	*L. stictaeforme* *M. alternans* *P. crissum* *P. rosa-marina* *Peyssonnelia sp.*
AlgF		*Caulerpa racemosa*							
AnE	*Cacospongia sp.* *Crella pulvinar* *Miniacina miniacea* *Serpulidae*	*Crambe crambe* *C. pulvinar* *Diplastrella bistellata* *Haliclona fulva* *Pleraplysilla spinifera* *Parazoanthus axinellae* *Prosuberites longispinus* *Schizomavella sp.*	*C. crambe* *C. pulvinar* *Haliclona mucosa* *Oscarella sp.* *P. spinifera* *P. axinellae* *Rhynchozoon sp.* *Serpulidae*	*C. crambe* *Dictyonella sp.* *P. spinifera* *Oscarella sp.* *P.axinellae* *Serpulidae*	*C. crambe* *C.pulvinar* *Dendroxea lenis* *H.mucosa* *Oscarella sp.* *P. spinifera* *P.axinellae*	*C. pulvinar* *D. lenis* *Haliclona mediterranea* *H. mucosa* *Hemimycale columella* *Phorbas tenacior* *P. spinifera* *Spirastrella cunctatrix* *P. axinellae*	*C. crambe* *Dysidea avara* *H. mucosa* *P. tenacior* *S. cunctatrix* *P. axinellae* *S. mammillata*	*C. crambe* *H.columella* *P. axinellae* *Stolonica socialis*	*D. avara* *Dysdea pallescens* *H. fulva* *H. columella* *Oscarella sp.* *Schizomavella sp.* *S. socialis* *Botryllus schlosseri*
AnM	*Ircinia variabilis* *Spongia officinalis*	*Axinella damicornis*	*Acanthella acuta* *Agelas oroides* *A. damicornis*	*A. oroides* *A. acuta* *A. damicornis* *Cystodites dellechiajei*	*A. damicornis* *Chondrosia reniformis* *Halocynthia papillosa*	*A. damicornis* *Ircinia oros* *I. variabilis* *Scalarispongia scalaris* *H. papillosa*	*H. papillosa*	*A. damicornis* *Spongia lamella* *Aplidium elegans* *Aplidium conicum*	*I. variabilis* *I.oros* *Sarcotragus muscarum* *S. officinalis* *Polycitor adriaticus* *Pseudodistoma sp.*
AnT	*Adeonella calveti* *Myriapora truncata* *Reteporella sp.*	*Eunicella cavolinii* *A. calveti* *Pentapora fascialis*	*A. calveti* *E. cavolinii*	*A. calveti* *Margaretta cereoides*	*A.calveti* *M. truncata* *Reteporella sp.*	*A. calveti* *M. truncata* *Reteporella sp.*	*Eunicella singularis* *A. calveti* *M. truncata* *Reteporella sp* *P. fascialis*	*E. singularis* *Eunicella labiata* *Leptogorgia lusitanica* *A. calveti* *M. truncata* *P. fascialis*	*Corallium rubrum* *A. calveti* *P. fascialis* *Turbicellepora cf. avicularis* *M. truncata*
AnC	*Caryophyllia inornata* *Leptopsammia pruvoti*		*C. inornata* *L. pruvoti*	*L. pruvoti*	*L. pruvoti*	*L. pruvoti*	*L. pruvoti*	*Astroides calycularis* *C. inornata*	*A. calycularis*
AnB							*Cliona viridis*	*C. viridis*	
AnEpi						*Salmacina dysteri*	*S. dysteri*		*S. dysteri*

Lithophyllum stictaeforme: includes Lithophyllum stictaeforme/ Lithophyllum cabiochae
Adeonella calveti: includes Adeonella calveti/Smittina cervicornis

This pattern of greater variability was corroborated by an increase of beta diversity in the perennial species composition after the disturbance (immediately after and in the following year). After extreme events such as this storm, post-disturbance variability is expected to be elevated and to persist for a longer period of time relative to pre-disturbance conditions, and this variability will be stabilized more gradually, only after the disturbed state has returned to the baseline condition (Fraterrigo & Rusak, 2008).
In addition, the loss of cover of slow growing benthic species was between 58% and 22% immediately after the storm at two of the studied sites, Carall Bernat and Medallot, respectively. The strong abrasive effect of the storm produced a mosaic of small remaining surviving patches of perennial benthic species (with values of perennial-slow growing species cover ranging from 10 % to 50%), associated with a decrease of habitat complexity and heterogeneity. We hypothesize that these surviving colonies and fragments (mainly encrusting algae and clonal animals such as encrusting sponges, anthozoans, and tunicates) favored faster recovery via vegetative regrowth and this partial recovery occurred more rapidly than could take place through the growth of new recruits via larvae.

Acknowledgments
This study has been partially funded by Total Foundation (medDIVERSA project, http://meddiversa.medrecover.org). N. Teixidó thanks JC Calvín for field assistance in the Southern region. Some authors are members of the Marine Conservation Research Group of the Generalitat de Catalunya (http://medrecover.org).

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USING MAXENT TO UNDERSTAND AND PREDICT THE DISTRIBUTION OF CORALLIGENOUS ENVIRONMENTS

Abstract

The Marine Strategy Framework Directive (MSFD) defines monitoring goals for coralligenous environments as well as their good environmental status assessment within the Mediterranean by 2016. Developing methods to monitor and evaluate challenging ecosystems at multiple scales is a necessity and advance to achieve these goals. Habitat distribution modelling and remote sensing techniques are important tools for ecosystem based management, conservation planning and impact assessments. Therefore, we aimed to analyse the performance of the Maximum Entropy approach (MaxEnt freeware) for modelling the distribution of coralligenous habitats. We built the habitat suitability models using i) presence data collected in the Portofino Marine Protected Area (Ligurian sea) and, ii) geophysical substrate properties extracted from multibeam sonar measures (depth, slope, aspect, rugosity, and geomorphic zones) to allocate known coralligenous communities in the MPA and to forecast new undescribed areas. We conclude that predictions based on combined model results provide more realistic estimates of the core area suitable for coralligenous environments and should be the modelling approach implemented in conservation planning, monitoring activities and management.

Key-words: MSFD, Habitat distribution modelling, MaxEnt, Ligurian Sea

Introduction

Coralligenous habitats are considered an important bioconstruction that confers great structural and functional complexity hosting more than 20% of the Mediterranean species. Besides their importance, little is known of their ecological needs to achieve adequate management. The Marine Strategy Framework Directive (MSFD) defines monitoring goals for coralligenous environments as well as their good environmental status (GES) assessment in the Mediterranean Sea by 2016. Effective implementation of these policies requires a sound understanding of the extent and distribution of benthic biological assemblages as a starting point. In addition, developing low cost methods to monitor and evaluate challenging ecosystems at multiple scales is a necessity and advance to achieve these goals. Remotely sensed data have the potential to provide a broad-scale synoptic view of benthic environments and provide temporal data that may be used to assess events in community dynamics (Zapata-Ramirez *et al*., 2013). Recent developments in marine habitat mapping using remote sensing tools (*e.g*. multibeam sonars and georeferenced photo or-underwater video) and the integration with distribution modelling techniques have resulted in an increased availability of environmental data (Brown *et al*., 2011; Reiss *et al*., 2014). MaxEnt, in particular, is now a common distribution modelling (DM) tool used by conservation practitioners for predicting the distribution from a set of records and environmental predictors (Phillips & Dudik, 2008; Elith *et al*., 2011; Fourcade *et al*., 2014). These models estimate the fundamental ecological niche in the environmental space (*i.e.* species response to abiotic environmental variables gathered by remote sensing techniques) and project it onto the geographical space to derive the probability of presence for any given area or, depending on the method, the likelihood that specific environmental conditions are suitable for the target species (Mellin *et al*., 2010; Fourcade *et al*., 2014). Effective modelling allows us to visualise spatial patterns and identify natural or anthropogenic processes as well as environmental variables governing species distribution and abundance (Mellin *et al*., 2010; Fourcade *et al*., 2014). In this context, predictive modelling based on species/environment relationships provides a potentially useful way to synthesise information from scattered samples into coherent maps of distributions of species and habitats, ecological goods, and services (Reiss *et al*., 2014). More specifically these tools can be applied (i) to explore the possible effects of climate change on benthic species distribution patterns (Elith *et al*., 2011; Reiss *et al*., 2014), (ii) to assess habitat distributions in areas that, due to their complexity, are difficult to study and therefore have limited data availability (Fourcade *et al*., 2014), and (iii) to estimate the most suitable areas for a species and infer probability of presence in regions where no systematic surveys are available (Martin *et al*., 2014). Only a limited number of coralligenous environments sites have been mapped to a certain extent, including interpretations of the different associated habitats using MaxEnt (Martin *et al*., 2014). Modelling techniques can contribute to solve this gap using the available information of species presence and environmental data from Multibeam Echosounder (MBES) records, producing Habitat Suitability (HS) maps, which describe, in high resolution, the predicted spatial distribution of the vulnerable habitats, threatened sessile species and essential fish habitats (EFH). Therefore, we aimed to analyse the performance of the Maximum Entropy approach (MaxEnt freeware) for modelling the distribution of coralligenous habitats located at Portofino Marine Protected Area (MPA) and to identify how environmental variables based on high resolution bathymetry influence their distribution.

Materials and methods

Data sources

Portofino MPA (http://www.portofinoamp.it) has a surface of 3.74 km^2. The coast is characterized by a narrow continental shelf with a very steep slope reaching a maximum of 80-90m depth. Multibeam bathymetry data was collected using a Multibeam system SONIC 2024 (Selectable Frequencies 200-400kHz) during 2010 and were provided by the Ligurian Region (Dipartimento Ambiente, Regione Liguria). Bathymetric and backscatter data were exported as 32-bit rasters with a cell size of 1m. With these data a wider area in the circalittoral zone was selected, where coralligenous formations occurred. In the study area depth ranged from -20m to -90m (total surface area considered for the model 5.287 Km^2, of which 2.57K^2 m fall inside of the MPA). We combined a suite of techniques that segment the acquired MBES data in terms of seabed morphology and composition. To determine sea-bed morphology, we applied standard layers using the Benthic Terrain Model (BTM) extension on ArcGis 10.2 platform (ESRI, Redlands, CA, USA). Geomorphometric attributes (*e.g.* slope, aspect, curvatures) were measured for each bathymetric datasets, with a particular emphasis given to attributes expressing the complexity of the seafloor, such as Bathymetric Position Index (BPI) and Vector Ruggedness Measure (VRM). In order to determine the seabed composition of the study area, we carried out a combination of morphometric and textural analyses of both bathymetric and backscatter data performing a an unsupervised Iterative Self-Organizing Data Analysis Technique (ISODATA) classification using ENVI 5.1 software (EXELIS VIS, Boulder, CO, USA) (see Zapata-Ramírez *et al*. 2013) with which we finally obtained 7 morphosedimentary classes (Mid slope, Lower bank shelf, Upper slope, Cliffs, Caves

and Overhangs, Shallow slope and Bank shelf). Since coralligenous environments occur on a variety of geomorphologies, including near vertical walls and terraced slopes, we assessed multiple sites within the MPA locations to assess variation in the structural groups relative to this factor. Using these data, the importance of seafloor morphology in structuring coralligenous habitats was studied across the MPA.
During 2013-2014 field trips were designed using a random-stratified approach identifying the checkpoints (300 points) within the GIS and correlated with the GPS locations and taking in account several parameters such as: MPA Zonation, Complexity (rugosity/slope), the 7 morphosedimentary classes and the accessibility from land that could help to guaranty future monitoring activities. From each of these checkpoints, a diver or VideoRay Pro 4 ROV system for areas deeper than 40m were used together with two calibrated Go-pro Hero (3D system) to collect images, - One Go-pro Hero 2 to gather video, lasers and strobes for the divers or ROV. The diver or ROV swam over the bottom recording benthos composition with video and still photographs for ~15 minutes (as proposed in Zapata *et al*., 2013). The video was pointed directly at the seabed and held between 1.0 and 1.5 m from the substratum. In addition we used an Underwater acoustic positioning system (USBL) to record the position of the diver and the ROV and related with the boat position. All sample data were stored using ArcGIS software, in order to facilitate the habitat distribution modelling

<u>Habitat suitability models using Maximum entropy model (MaxEnt)</u>
We built the habitat suitability models using i) presence data with the checkpoints collected in the study area and, ii) environmental variables (EVs) extracted from multibeam sonar measures of geophysical substrate properties (depth, slope, aspect, rugosity, and morphosedimentary classes). These bio-physical variables were then modelled using the machine-learning method (MaxEnt) to predict the distribution of coralligenous formation at the MPA. The default model parameters were used as they have performed well in other studies (Phillips & Dudık, 2008; Fourcade *et al*., 2014). The importance of each variable in the model was assessed using a jack-knifing procedure that compared the contribution of each variable (when absent from the model) with a second model that included the variable. The final habitat suitability maps were produced by applying the calculated models to all cells of the total surface area (5.286405 km^2) in the study region, using a logistic link function to yield a habitat suitability index (HSI) between zero and one (Phillips and Dudık, 2008). Model accuracy between the test data and the predicted suitability models was assessed using a threshold-independent procedure that used a receiver operating characteristic (ROC) curve with area under curve (AUC) for the test localities and a threshold-dependent procedure that assessed misclassification rate following the methodology proposed by Phillips & Dudık, (2008).

Results
To model the distribution of coralligenous habitat at Portofino MPA, a total of 88 presence records were used for training, 29 for testing and 10088 points to determine the MaxEnt distribution (background points and presence points). MaxEnt model was successful in predicting the distribution of Coralligenous habitats, with AUC score 0.984 for the training data set and 0.964 for the test data (Fig. 1) and were significantly different from that of a random prediction of AUC= 0.5 (Wilcoxon rank-sum test, p,0.01). This indicates that EVs chosen are relevant to distinguish the distribution of coralligenous in the study area. Slope (39%), Morphosedimentary classes (24.1%) and Rugosity (17.3%) were the three main contributors to the model, followed by Bathymetric Position Index (13.2%);

Depth (5.9%) and Curvature (0.4%). The interpretation of the Jackknife tests shows that Morphosedimentary classes was the most influential EV in determining HS as well as the one that had most useful information not contained in other EVs and was most effective in the contribution to the HS. By intersecting the known distribution of coralligenous habitats with the environmental layers, it was possible to gain insight into the species niches. (Fig.1). According to the models, in Portofino MPA, coralligenous habitats are most likely to be found on the steep rough walls (cliffs) where facies of octocorals in particular *Paramuricea clavata* is well represented, in caves and overhangs where *facies* of semi dark communities and associations of *Corallium rubrum, Parazoanthus axinellae* and *Leptopsammia pruvoti* occurs and, in less proportion, in upper slope where *facies* of scattered octocorals such as *Eunicella singularis* are characterized. The majority of records were found in areas where slopes were well represented as it is highlighted in the percentage of the contributors in the model. Figure 2 shows a representative area of steep slopes located at Isuela, a stack formation along the cliff and where *facies* of *P. clavata* is well distributed.

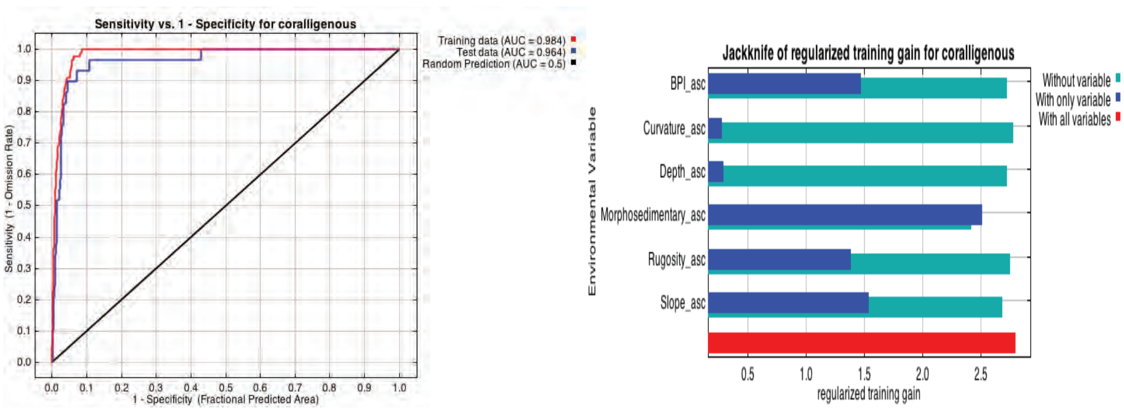

Fig.1: On the left ROC curves for the training (red) and test (blue) sets of coralligenous occurrence. The AUC index can take values between 0 and 1, where 0.5 represents a distribution indistinguishable from random; a lower value indicates performance worse than random and 1 indicates perfect discrimination. On the right result of the jackknife test of variable importance of coralligenous training data.

Conclusions

The results show that the MaxEnt model is a useful technique to characterize and give a better understanding of the distribution patterns of coralligenous habitats in relation with environmental factors extracted from multibeam sonar measures. The approach provides both high-resolution, full coverage surveys of selected areas that can be precisely revisited during monitoring activities as well as broader scale features of the terrain, such as slope, surface roughness and aspects that provide notion of the habitat structure and regarding sea floor integrity. In addition, optical information help us examining the correlations between populations and underlying bathymetric processes that determine their distribution that also provides the foundation to monitor future changes. The results presented here fits in the regional spatial mapping of coralligenous environments (MSFD: 2008/56/EC), allowing the production of high quality bathymetric and habitat maps as one of the first requirement for a sustainable management. Therefore, providing measures to achieve or maintain Good Environmental Status (GES) by 2020.

The presented methods are simple and cost-effective becoming an optimal solution for extended monitoring by the combination of innovative and new tech tools.

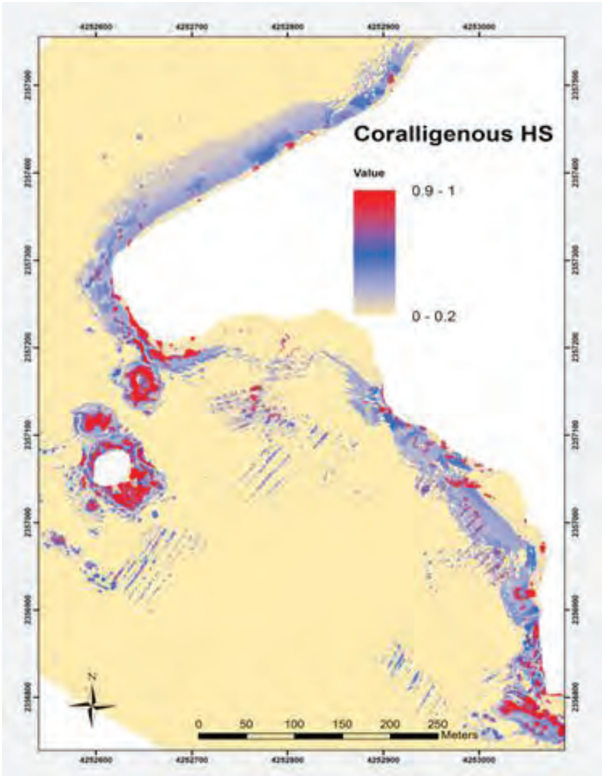

Fig. 2: Predicted occurrence probability for coralligenous formations at Portofino MPA. Yellow background indicates that coralligenous is not present, blue indicates low probability and red high probability of presence. The map shows a close up of the study area known as a Isuela, a stack formation along the cliff.

Acknowledgments

This research was supported by the European project 'Training Network for Monitoring Mediterranean Marine Protected Areas' (MMMPA: FP7-PEOPLE-2011-ITN) [grant number 290056] and by the scientific research program of national interest "Coastal bioconstructions: structures, functions, and management" (2010-11 PRIN prot. 2010Z8HJ5M_003).

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POSTERS

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THE IMPORTANCE OF HIGH-RESOLUTION RHODOLITH BED MAPS IN THE PROTECTION OF HABITATS OF CONSERVATION VALUE

Abstract

Identifying areas characterised by the presence of habitats of conservation value is crucial for the application of protection measures. The current lack of knowledge about the positioning of these areas must be addressed by producing good, up-to-date maps. For this purpose, a field survey was carried out with the aim of producing an up-to-date map of the Rhodolith beds in a pilot area selected on existing information. The survey utilized indirect (acoustic) and direct (ROV) methods. A total of 50 km^2 of multibeam data and 12 hours of video footage were collected. A preliminary map with four different classes of substratum was produced and result validation confirmed a good correspondence (about 60%) between the estimated habitat presence and ground-truth data. The combined MultiBeam Echo Sounder (MBES)/ROV approach allows to study wide areas in a timeframe of few days. The comparison between the obtained modelled map and the existing broad scale map shows that Rhodolith presence is not confirmed in all the zones indicated by previous cartography, and this shows the need for new high-resolution cartographies that will help to properly define where management actions should be enforced.

Key-words: Rhodolith beds, Multibeam, ROV, Habitat mapping.

Introduction

The availability of an accurate, high-resolution scale and recent cartographic dataset of benthic habitats of conservation value, such as Rhodolith beds (RBs), is one of the most critical aspects in the study of the marine environmental status. In particular, knowing the spatial distribution and extent of these distribution areas is particularly important for habitats requiring specific protection measures. In the Mediterranean Sea, RBs are considered habitats of conservation interest according to the EC legal framework for the marine environment (EC Council Reg. 1967/2006, EU Dir. 92/43/EEC, EU Dir. 2008/56/EEC) and by the UNEP-MAP Action Plan on marine vegetation. Nevertheless, the recent data-collection carried out within the Marine Strategy Framework Directive (MSFD) for the Italian seas has confirmed the paucity of available information, emphasizing the need for new cartographies (ISPRA, 2013; Agnesi *et al*., 2009).

Materials and methods

A five-day field survey was carried out in the Tuscan Archipelago in June 2013, within the framework of a research project on RBs funded by the Italian Ministry of Agricultural, Food, Forestry and Fisheries Policies. The study area features the largest extension of RB in Italy, as reported in the existing cartographies (Bianchi *et al*., 1996). A total of 50 km^2 of Multibeam bathymetric data were collected with a Kongsberg-Simrad EM2041 system. Bathymetry and backscatter data were processed with CARIS Hydrographic Information Processing System (HIPS). A total of about 12 hours of geo-referenced underwater video footage were shot, and more than 5000 frames were extracted from the ROV videos.

Results

Image analyses allowed for the identification of four different classes of substratum: Rocks and mixed substrata; Rhodolith beds with coverage >50%; Rhodolith beds with coverage ≤50%; soft bottom.

The basic statistics of backscatter values occurring in correspondence to the above-described classes show a correlation between the percentage of Rhodolith presence and acoustic response. A map of RB presence (Fig. 1) was created based on backscatter values combined with bathymetry and slope data. The obtained map was validated by the comparison of the modelled habitat and the ground-truth samples. This comparison shows a good correlation (about 60% of success) between the calculated pixel attribute and the related seabed habitat detected by ROV.

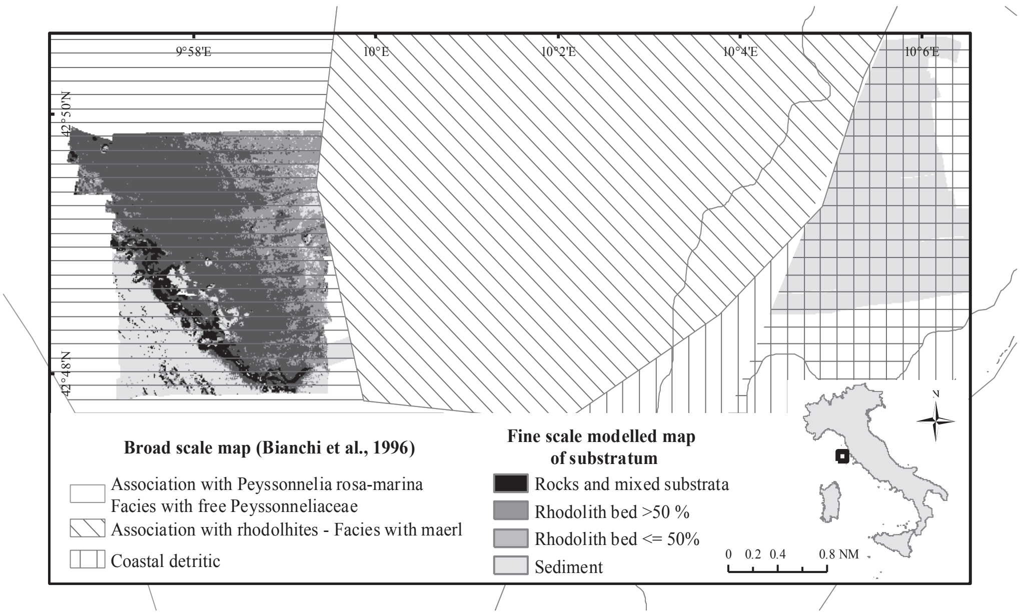

Fig. 1. Preliminary map of the presence of Rhodolith beds in the Tuscan Archipelago (solid fill symbols). The overlap of the broad scale map of Bianchi *et al.*, 1996 (line fill symbols) reveals the need for more detailed cartography.

Discussion and conclusions

The combined MBES/ROV approach tested in this study allows to investigate wide areas in a relatively short time. The resulting map provides detailed information about the presence of sensitive habitats, and allows both a good delimitation of its distribution and an estimation of coverage in percentage. Furthermore, providing a continuous investigation of the seabed, this approach allows to identify the "real" RB coverage rather than their spot presence, as occurring using grab. The comparison between the modeled map and the above-described broad-scale cartography (Fig. 1) shows that the RBs occur only in a smaller area than shown on the old map, which had been inferred based on heterogeneous and dispersed samples. These results highlight the importance of full-coverage data collection and the effectiveness of the proposed method in obtaining high-resolution cartographies. These maps provide key information that will help correctly define the actual and real RB areas where human activities require specific management.

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MORPHO-STRUCTURAL CHARACTERIZATION OF A PARTICULAR VERMETID REEF IN NORTH OF TUNISIA

Abstract
Vermetid bioconstructions are present in the Mediterranean under different morpho-structural form among which the reef-type is the less common one and generally restricted to the eastern basin and the Sicily coasts. We report here the description of a Dendropoma petraeum (Monterosato) reef observed in the Cap Serat region, along the North Tunisian coasts. The described reef presents a peculiar shape linked to the particular ecological characters of the site. It occupies an ellipsoid area covering about 12 000 m² and it lies on the sandy bottom of a little bay, between 2.5 m and 4 m depth. Height of the reef is about 0.6 m at its upper limit and about 2 m at its lower one.

Key-words: Vermetid reef, morpho-structural description, peculiar shape, Tunisia.

Introduction
Many Vermetid construction can be observed along the Mediterranean coast (Chemello and Cocito, 2009). Those latest formations are considerate as good ecological condition and sea level variation indicators. In this context, the description of a new shape of Vermitid reef from the North Tunisian coasts may be an important data source about the littoral conditions variations in the occidental Mediterranean basin.

Material and methods
The study site is localized in a little bay nearby Cap Serat on the north coast of Tunisia. General shape and delimitation of the reef has been plotted with a Garmin 76 GPS while its relief and bathymetric variations were recognized along two transects. Three-dimensional block-diagram was mapped using a 2 x 2 m square net including a 50 x 50 cm gird and a graduated rod. Blocks of the reef were collected and examination of living *vermetid* gastropods were performed under binocular microscope. Encrusting algae wereat first decalcified and then examined under microscope.

Results
The reef occupies an ellipsoid area about 12 000 m² with a major axis parallel to the coast. It lies between 1.6 and 4 m depth on the sandy bottom of the bay and its upper limit is distant about 40 m of the shore line. Height of the reef is about 0.6 m at its upper limit and about 2 m at its lower one and the reef top which is located between 1 and 2 m depth slopes gently down towards the open sea. In terms of structure and spatial organization, the reef does not form a homogeneous rocky block but it is scattered with vertical wells separated by rounded walls of several centimeters thickness (Fig. 1). Over two-thirds of the reef top area localized in its deeper part are covered with a *Posidonia oceanica* meadow. Laboratory study of the reef samples shown that *Dendropoma petraeum* is the main builder in association with the crustose coralline algae *Lithophyllum incrustans* and *Neogoniolithon brassica-florida*. *D.*

petraeum is scattered over the surface of the blocks where its density is close to 21 individuals per 4 cm² and among them some juveniles can be noted.

Conclusion and discussion

Vermetid bio-constructions are rather common on all around the Mediterranean basin but they are mainly present under the Platform-type morphologies and only a few number of sites hosts the reef-type form: the Sicilian coasts where they are described as Mushroom-like reefs and the Palestinian coasts where we can found some micro-atoll reefs (Antonioli et al., 1999).The specific shape of the Tunisian vermetid reef stands out from the previous forms and suggest some particular ecological conditions.

As vermetid are strictly associated to the intertidal zone they are highly reliable indicators of sea level variations (Silenzi *et al.*, 2004; Vescogni *et al*., 2008) and according to this, the variations reported in the reef top depth as well the presence of *Posidonia oceanica* on the deeper parts of that top suggest a rise of the sea level.

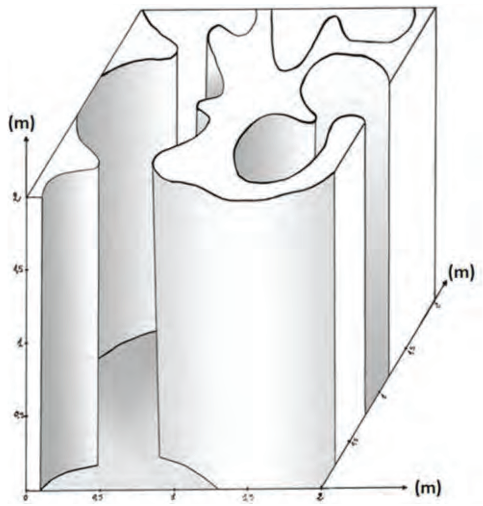

Fig. 1: Block diagram reconstitution of a part of the reef.

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A PROTOCOL FOR THE MONITORING OF MEDITERRANEAN RHODOLITH BEDS

Abstract
Mapping of Mediterranean rhodolith beds (RBs) should be focussed on areas of the seafloor with >10% cover of live calcareous red algae for a minimum surface of 500m^2, on 1:10000 scale. More detailed scales (at least 1:1000) should be used for monitoring selected RBs, in order to detect significant changes through time. Beside the location and areal extent, the description of a RB that could be provided by non-specialists should include the occurrence of macroscopic sedimentary structures of the seafloor, thickness of live cover, mean percentage cover of live thalli, and dominant morphologies of rhodoliths (unattached branches, pralines or boxwork rhodoliths). For the purpose of ecological status assessment and the evaluation of human-induced impacts, the protocol requires the support of specialists to add details on the assemblage composition.

Key-words: rhodolith beds, maerl, coralline algae, monitoring, conservation

Introduction

It was only in recent times that maerl and rhodolith beds were recognized as a non-renewable resource that is threatened by various human activities, through a suite of pressures (Bordehore et al., 2003; Aguado-Giménez & Ruiz-Fernández, 2012; Basso, 2012). The increasing awareness of the importance and fragility of the benthic habitats characterized by red algal concretions led to several international, legally binding or not, initiatives (EC 2006; UNEP, 2007) aimed at their conservation. Despite their ecological importance and conservation value, a standardized protocol to correctly identify and monitor Mediterranean rhodolith beds has not been defined yet. In particular, there is a need to reach a general consensus on the minimum spatial extent and live rhodolith cover for the identification and mapping of a rhodolith bed (RB).This contribution is based on the review of the published methods for monitoring rhodolith beds, and on more specific literature data on the structure, occurrence and composition of Mediterranean RBs.

Results

Mediterranean RBs are coastal to offshore macro-, meso- or megahabitats, more frequently recorded in the mesophotic zone, mainly at about 60 m of water depth. They occur beyond the safety limits of standard scuba-enabled sampling designs and methods, thus investigations have been largely affected by logistic and technological restrictions when compared to extra-Mediterranean shallow-water habitats. RBs are composed of a variable thickness of live and dead thalli of unattached calcareous red algae and their fragments. These habitats are unstable coarse substrates, typically exposed to bottom currents. Unlike their Atlantic counterparts, the Mediterranean RBs are structured by variable assemblages of coralline algae and peyssonneliaceans.

Discussion

Identification. In agreement with Steller et al. (2003), we define and identify a RB where >10% of the mobile substrate is covered by live corallines as unattached branches and nodules. The choice of the minimum spatial extent is constrained by the size of Mediterranean RBs, and the map scale, the latter depending on the purpose (the framework of a regional assessment or the monitoring of a specific bed in a MPA). Practically, we consider the scale 1:10000, which conforms to the Italian regional cartography (CTR) and is suitable for transfer into most international initiatives for marine habitat mapping. At this scale, it is possible to delimit areas down to about 500 m^2, which is a good compromise between precise RB detection and study effort on a regional basis. Conversely, a scale equal to 1:1000 (or smaller) should be used for detailed monitoring studies of selected RBs, where the areal definition and the boundaries of the RB should be precisely defined and monitored through time. As an example, 1 m-regression of the RB boundary, that is to say a potentially serious signal of negative impact, corresponds to the hardly detectable shift of 1 mm in a 1:1000 map. *Monitoring*. The detection of changes in the attributes of a site or habitat over time involves the evaluation of natural variability in the pristine habitat by comparative assessments, in order to set limits outside which management action is likely to be taken. The high biodiversity hosted by RBs requires laboratory analysis particularly for the identification of coralline algae, the major habitat engineers. Unluckily, there are no short cuts available for obtaining the biological data necessary for RB monitoring. In particular, videos and photos provide no information on RB composition, due to the absence of conspicuous, easy-to-detect species. Moreover, since most coralline species belong to few genera, the use of taxonomic ranks higher than species cannot be considered. The minimum information required for describing the distribution and coarse structure of a RB includes: position and depth, sedimentary structures of the seafloor, areal extension, thickness of live cover, mean percentage cover of live thalli, and dominant morphologies of rhodoliths (unattached branches, pralines, boxwork rhodoliths). For the purpose of ecological status assessment and the evaluation of human-induced impacts, the protocol requires additional details of the assemblage composition.

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CORALLINE SPECIES COMPOSITION OF TYRRHENIAN MAERL BEDS (WESTERN MEDITERRANEAN)

Abstract
The quantitative composition of three maerl beds of the Tyrrhenian Sea (Elba Is., Cilento, and Marettimo Is.) located at depth spanning 40 to 47 m, has been investigated by focussing on the volumetrically important taxa. Twelve species of corallines belonging to seven genera and two species of calcareous Peyssonnelia have been identified. The genus Lithothamnion is the richest in species and always dominant among corallines, with L. corallioides occurring at all sites. The Marettimo maerl bed hosts the highest coralline diversity.

Key-words: rhodolith beds, maerl, coralline algae, biodiversity

Introduction

Maerl is a collective term for the accumulation of various species of unattached coralline red algae. Among rhodolith beds, the maerl beds (*sensu stricto*) have a particular physiognomy and structure, due to the dominance of unattached branches. Maerl beds are composed of living or dead thalli or both, and have a patchy distribution. They have been included in the OSPAR (Convention for the Protection of the Marine Environment of the NE Atlantic) list of threatened and/or declining species/habitat, because they have been harvested for decades as soil conditioner and exploited for commercial fishing by trawling.
Mediterranean maerl is very sensitive to abrasion or crushing, smothering, increase in suspended sediment, and physical disturbance, like that coming from demersal trawl gear (Barbera et al., 2003; Bordehore et al., 2003). On the basis of the available information for the Atlantic maerl beds, the species *Lithothamnion corallioides* and *Phymatolithon calcareum* have been listed in the Annex V of the EU Habitat Directive. However, despite our poor knowledge, the Mediterranean maerl beds appear to be deeper and to have a higher coralline biodiversity compared with the NE Atlantic, both at the basin scale, and within each bed. We present the results of a pioneer investigation on the quantitative composition of three maerl beds of the Tyrrhenian Sea (Elba Is., Cilento, and Marettimo Is.) located at depth spanning 40 to 47 m.

Material and methods

Maerl samples, dominated by unattached branched corallines and variable amount of peyssonneliaceans were collected by grab (Elba and Cilento) and SCUBA (Marettimo). The analysis has been focussed on the volumetrically important species of calcareous algae, including the fully calcified *Peyssonnelia*. Small epiphytes have been disregarded. Within each sample, a first separation of apparently homogeneous groups of specimens, possibly belonging to different species, has been performed under dissecting microscope, based on the combination of growth form, colour, surface appearance, protuberance pattern, occurrence of multiporate/uniporate conceptacles, type of growth margins and other morphological traits. Dozens of voucher specimens from all morphological groups have then properly identified by histological sectioning after decalcification of the calcareous thalli.

Results

The three sites have live coralline cover (Ri tot) largely exceeding 10% (Elba and Cilento about 40%, Marettimo >80%), thus they are properly defined as maerl beds (Steller et al., 2003). Twelve species of corallines and two species of calcareous *Peyssonnelia* have been identified. Among corallines, Melobesioideae are represented by six species of the genera *Lithothamnion* (*L. minervae* Basso*, L. corallioides* (Crouan & Crouan) Crouan & Crouan*, L. crispatum* Hauck*, Lithothamnion sp.*), *Phymatolithon (P. calcareum* (Pallas) W.H.Adey & D.L.McKibbin), and rare *Mesophyllum* (*M. alternans* (Foslie) Cabioch & Mendoza) and are always dominant, with Dri% always >50, up to 90. Lithophylloideae is the co-dominant group in the Elba and Marettimo maerl, whereas it was not identified in the Cilento maerl. The genus *Lithophyllum* is represented by three species (*L.* cf. *incrustans, L.* cf. *stictaeforme* (Areschoug) Hauck*, L. racemus* (Lamarck) Foslie) accompanied by *Titanoderma pustulatum* (J.V.Lamouroux) Nägeli in Marettimo. *Spongites fruticulosus* Kützing and more rarely *Neogoniolithon* sp. also occur.
Elba maerl is the most diversified among those considered here (11 species including 9 corallines and 2 fully calcified *Peyssonnelia*), in contrast with the poorly diversified Cilento maerl. If we exclude the *Peyssonnelia* species, the most diversified maerl bed is in Marettimo, with 10 coralline species.

Discussion

Although focussing exclusively on the macroscopic species of calcareous algae occurring in the 3 investigated maerl beds, the observed associations are significantly different in term of dominance. Despite the similar depth range, the two dominant species are *Lithothamnion minervae* and *Peyssonnelia rosa-marina* Boudouresque & Denizot in the Elba maerl, *Lithothamnion corallioides* and *Lithothamnion crispatum* in the Marettimo maerl. Both the Elba and Marettimo maerl beds host a high coralline diversity, whereas the Cilento maerl appears oligospecific and largely dominated by *L. corallioides,* which is also the only shared species across the 3 sites. Further investigations are needed to establish whether the observed variability of the dominant species reflects distinct environmental conditions of the studied maerl beds.

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CHARACTERIZING *CORALLIUM RUBRUM* POPULATIONS OF TWO MEDITERRANEAN MPAS: STRUCTURING FACTORS AND DYNAMICS

Abstract
In the frame of two MPA management (the recently enforced Calanques National Park and the 30 years-old Banyuls MPA) Corallium rubrum (Cnidaria) populations were studied in order to give managers useful data for population management. Data on morphology, recruitment and population size-structure were collected in both MPAs using novel photogrammetric methods allowing precise tridimensional measures. We assessed size structures and population dynamics and linked it to the protection levels of both MPAs. In Banyuls, morphometrics of populations revealed population characteristics typical of long lived individuals (mean colony height of 30 cm, basal diameter >2cm). Contrastingly Calanques National Park populations were characterized by biometrics typical of earlier developmental stage (e.g. smaller and thinner colonies).

Key-words: *Corallium rubrum*, MPA, photogrammetry

Introduction
Corallium rubrum (Cnidaria) is a long-lived species from the Mediterranean Coralligenous biocenosis. It is economically exploited and threatened by both local and global scale anthropogenic stressors, notably through climate change and physical destruction (Garrabou *et al*., 2001). In the frame of two NW-Mediterranean MPA management (the recently enforced Calanques National Park and the 30 years-old Banyuls MPA) *Corallium rubrum* populations were studied in order to give managers useful data for population management.

Material and methods
Data on morphology, recruitment and population size-structure were collected in both MPAs using novel photogrammetric methods allowing precise tridimensional measures (Drap *et al*., 2014). We assessed a set of biometrics describing colony structures (Fig. 1) and population dynamics and linked it to the protection levels of both MPAs.

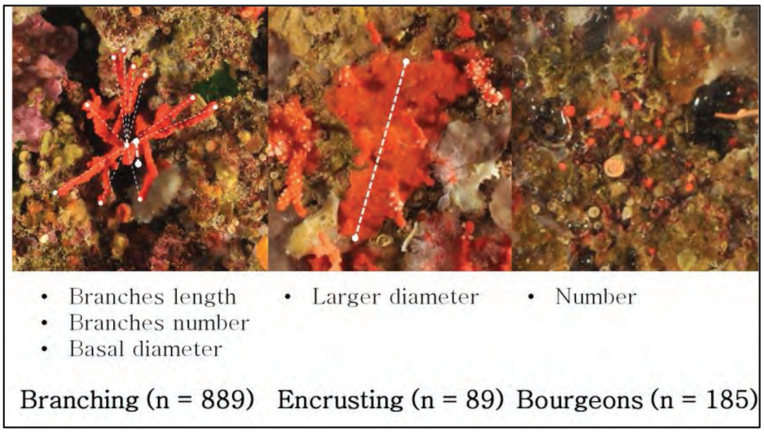

Fig. 1. Examples of measured biometrics for each colony type (branching, encrusting and bourgeons) in the case of the Calanques National Park.

Results

In Banyuls, morphometrics of populations revealed population characteristics typical of long lived individuals (mean colony height of 30 cm, basal diameter >2cm). Contrastingly Calanques National Park populations were characterized by biometrics typical of earlier developmental stage (e.g. smaller and thinner colonies); furthermore in Calanques National Park means of studied biometrics did not significantly differ between the no-take zone (NTZ) and outside the NTZ (Fig. 2).

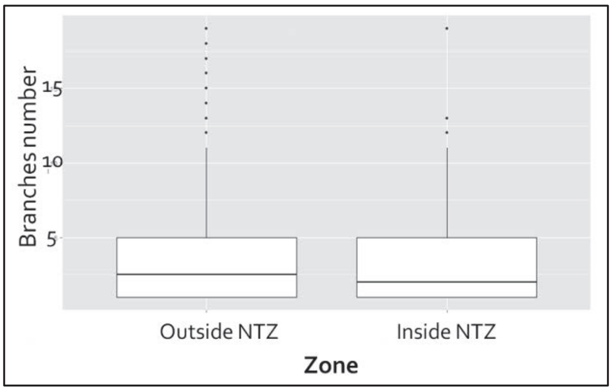

Fig. 2. Tuckey boxplot of branches number for colonies of studied sites located inside and outside the no-take zone (NTZ) of the Calanques National Park

Discussion / Conclusion

In the Calanques National Park, preliminary results showing no significant differences between *Corallium rubrum* biometrics within *versus* outside the NTZ may be related to the recent setting up of the protection. Long term monitoring is necessary to study if conservation practices will lead to population patterns as those observed in the older Banyuls MPA.

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APPLICATION DE LA METHODE DE FUSION MULTI-CAPTEURS ET DE LA SISMIQUE UHR A LA CARTOGRAPHIE DU CORALLIGENE DE PLATEAU

Résumé
Le concept de fusion des données multi-capteurs est innovant et très puissant. Il permet d'établir des cartographies extrêmement précises des biocénoses marines en minimisant les besoins en vérité terrain (plongeur, caméra, ROV). Les données surfaciques de micro-rugosité acoustique, l'imagerie sonar latéral HR-HP (haute résolution - haute précision) et la sismique UHR couplées aux données de classification constituent une approche surfacique innovante dans le domaine de la cartographie et l'imagerie structurelle du coralligène.
Cette technique a été appliquée pour cartographier et caractériser le coralligène dans l'aire marine protégée de la côte agathoise (France) en Méditerranée Nord occidentale.
La sismique UHR a permis d'imager la structure et le substrat sur lequel le coralligène se développe.
Cette approche ouvre de nouvelles perspectives pour une meilleure connaissance des surfaces, des hauteurs et du volume de l'habitat coralligène. Une étude de faisabilité est en cours afin de mesurer l'épaisseur des concrétionnements de coralligène à partir des profils sismiques.

Mots-clés : Cartographie, sismique UHR, fusion multi-capteurs, coralligène.

Contexte
L'ensemble des prospections acoustiques et des vérités ont été réalisées dans l'aire marine protégée de la côte agathoise (France), entre -20m et -25m sur un bioconcrétionnement de type "coralligène de plateau" tel que décrit par Laborel (1960, 1961). L'objet de cette étude est de développer une méthode multi-capteurs afin d'analyser la faisabilité de détecter acoustiquement du coralligène et d'établir ainsi des cartographies extrêmement précises de cette biocénose en limitant les besoins en vérité terrain (plongeur, caméra, ROV, etc.).

Méthode
Lors de cette expérimentation, différents instruments ont été déployés simultanément, dont un sonar latéral interféromètre, un sonar latéral et un sondeur de sédiment, permettant la collecte de données bathymétriques et de réflectivité acoustique du fond marin. Toutes ces données possèdent une précision extrêmement fiable puisqu'elles sont géo-référencées à l'aide d'un DGPS RTK. L'attitude (Roulis, tangage, lacet) du bateau est connue en permanence grâce à une centrale inertielle.

Résultats
Les données sonar latéral issues du levé au Klein 3900 haute résolution permettent de mettre en évidence, par un changement de texture de l'imagerie, les zones apparentées à des concrétionnements de coralligène. La méthode de classification automatique des fonds marins mise en œuvre par SEMANTIC TS permet d'effectuer une détection du coralligène en étudiant l'étalement du signal avant la détection du fond et confirmer dans

un premier temps les zones de forte probabilité de coralligène définies à partir du levé au sonar latéral.
Des recherches plus approfondies sont en cours actuellement, sur une zone plus dense en coralligène, afin de valider, la faisabilité d'utiliser les données mono-faisceau du sondeur de sédiment, fusionnées avec les données surfaciques, en vue de la classification acoustique des zones identifiées, et dans le cas du coralligène d'en mesurer l'épaisseur.

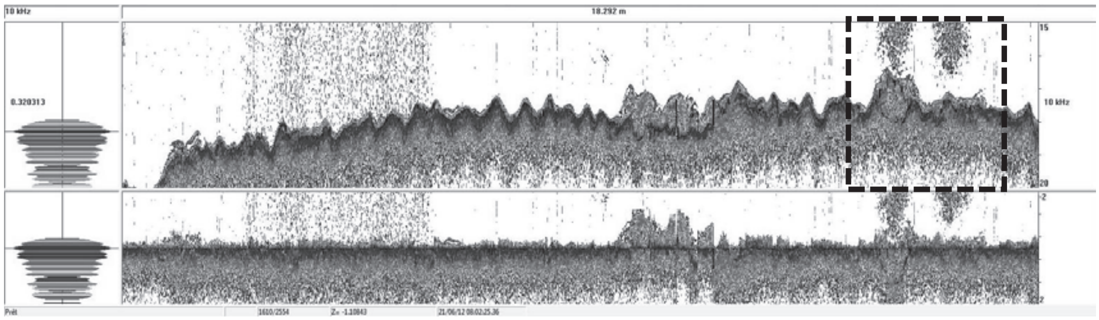

Fig. 1 : Sondeur de sédiment : historique de données : Profil de radiale à 10 kHz - Encadré : Mise en évidence d'un concrétionnement de coralligène de 1.3 m de hauteur sur de la roche et d'un banc de poissons évoluant au-dessus du concrétionnement.

Conclusions

Les données surfaciques de micro-rugosité acoustique (isobathes par pas de 10 cm) et d'imagerie sonar latéral couplées aux données de classification constituent une approche surfacique innovante dans le domaine de la cartographie du coralligène.
Compte tenu de la complexité de la zone d'étude (mosaïque de coralligène et de roche), le développement de cette méthode par fusion multi-capteurs permettrait ainsi d'envisager des cartographies de la biocénose à coralligène à une échelle plus vaste.
Des prochains travaux, prévus pour 2014, ont pour objectif d'appliquer cette méthode à l'ensemble de l'aire marine protégée de la côte agathoise (France).

Remerciements

Les auteurs remercient l'agence de l'eau Rhône Méditerranée& Corse et la DREAL Languedoc-Roussillon pour leur soutien dans cette étude.

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DISTRIBUTION AND CONSERVATION NEEDS OF A NEGLECTED ECOSYSTEM: THE MEDITERRANEAN VERMETID REEF

Abstract
Vermetid reefs are a key intertidal habitat in the Mediterranean. Despite recent evidence of local extinction in the Eastern Mediterranean, their role as habitat engineers and the high numbers of ecosystem services they provide, vermetid reefs are among the least known marine habitats of the Mediterranean. Here we present a literature-based study to assess for the first time their distribution inside the basin and provide evidence of a general lack of protection at Mediterranean scale.

Key-words: vermetid reef, distribution, MPA, Mediterranean Sea

Introduction

In recent years, many studies highlighted the need of protecting under-represented habitats in the Mediterranean Sea (Abdulla et al., 2008; Gabrié et al., 2012). However, most of these studies focused their attention on offshore and deep sea habitats. Only a single study briefly mentioned the presence of the vermetid reefs, reporting their importance for the high biodiversity levels they support (Abdulla et al., 2008). These reefs are built by the vermetid gastropod *Dendropoma petraeum* and the coralline alga *Neogoniolithon brassica-florida* which cements the shells together and triggers vermetid settlement. In temperate waters, vermetid reefs protect the coasts from erosion, regulate sediment transport and accumulation, serve as carbon sinks and provide habitat for a variety of fish and invertebrates of commercial, recreational or conservation interest (Chemello, 2009; Milazzo et al., 2014). Despite their ecological importance, vermetid reefs are not explicitly taken into account in international environmental laws, with the exception of European Habitat Directive (92/43/EEC), that generically protects the biogenic reefs (code 1170). The aim of this work is to point out the distribution of the vermetid reefs, using literature data, and to summarize their conservation status at Mediterranean scale.

Materials and methods

We searched on both scientific (ISI Web of Science and Scopus) and non-scientific (as Google) databases all the references concerning the vermetid reefs in the Mediterranean and in the adjacent Atlantic. All records have been validated – when possible – and georeferenced, approximating their position to that of the nearest place with the same geographical name. Data from Spain and Italy were then validated on our personal databases. Using the Medpan database (http://www.medpan.org/en/mapamed) records were interpolated with the presence of marine protected areas (MPAs) or Sites of Community Importance (SCI). We then calculated a frequency of protection, both at national and at Mediterranean scale, trying to identify potential conservation gaps.

Results

We have collected 112 records of vermetid reefs in the Mediterranean and in the adjacent Atlantic Ocean. Vermetid reefs have a prevailing distribution along the southern Mediterranean coast, below 40°N, with 44 sites in the eastern basin and 68 in the western one. According to the biogeographic classification of Gabrié et al. (2012), the Levantine Sea (29 reefs) and the Tyrrhenian Sea (26 reefs) are the Mediterranean ecoregions with the highest number of reefs, while Spain (29 reefs) and Italy (20 reefs) are the coastal countries with the most conspicuous number of vermetid reefs. Considering MPAs, national marine parks, coastal reserves and SCIs, 49 sites (43.75%) are theoretically protected, while 63 (56.25%) do not benefit from any form of protection activity. If we exclude SCIs, a conservation scheme applied only in Europe and often without any management plan, only 32 reefs (28.57%) are comprised within a MPA or a coastal reserve. No reefs are protected in Algeria, Cyprus and Lybia, while Lebanon, Tunisia and Turkey protect less than 20% of their reefs. Malta, Italy, Syria and Morocco protect 50% or less of their reefs. Spain and Israel protect more than 50% of their vermetid reefs, although Israeli vermetids got recently extinct (Galil, 2013).

Conclusion

We must obviously consider these as preliminary results, due to an inadequate coverage and a low quality of the published data and to a different distribution of the researchers studying vermetid reefs in the Mediterranean Sea. These also affects a likely overestimation of the true protection levels. If we take into account the well-known area of Northwestern Sicily, 53.33% in frequency and 15.6% in length of the vermetid reefs are protected (Chemello, 2009). If these percentages will be confirmed at a Mediterranean scale, this leads us to consider vermetid reefs more as a neglected habitat than an underrepresented one. Since vermetid reefs are threatened by rapid environmental change, we fear that this important intertidal habitat is in danger if knowledge gaps are not filled and conservation measures are not taken at trans-national level.

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MAPPING AND CHARACTERISATION OF CORALLIGENOUS BIOCONSTRUCTION USING ACOUSTIC AND VISUAL INTEGRATED APPROACH

Abstract
An integrated approach, based on acoustic and visual survey techniques, has been used to map coralligenous bioconstructions along the Apulian coasts (Italy). The visual investigations proved to be essential for the identification and the characterization of such typical Mediterranean habitat.

Key-words: coralligenous, marine bioconstructions, habitat mapping, Mediterranean Sea.

Introduction

As a result of the Habitat Directive (92/43/EC), marine bioconstructions, generically indicated as "reef", have been recognized as marine habitats worthy of protection. Among Mediterranean marine bioconstructions, coralligenous undoubtedly is one of the most important in extension and biodiversity. Therefore, for some years the efforts in this context were primarily aimed to quantify and to map such bioconstructions, in order to plan an appropriate protection strategy. In this regard, the Apulian Region (south-eastern Italy) has undertaken a number of activities to map and characterize the marine bioconstructions through the BIOMAP (Biocostruzioni Marine in Puglia) project.

The present study reports the techniques used to provide a large-scale mapping and characterization of coralligenous habitats, that proved to be effective in order to represent a starting point for future mapping efforts of this bioconstructions all over the Mediterranean Sea.

Materials and methods

The surveys were carried out from March to October 2012 along the Apulian coasts (Mediterranean Sea) using vessels equipped with two high frequency (100-500 kHz) Side-Scan Sonar (SSS) systems (Klein3000 and EdgeTech 4200-FS) in order to obtain a meso-scale (*sensu* Greene *et al*., 1999) backscattering map of the seabed (Kenny *et al*., 2003; Savini, 2011). Both the SSS systems were deployed at a constant distance from the seabed equal to 10-20% of the operating range (from 200 to 100 m). The SSS data processing provided geo-referenced gray-tone acoustic images of the seafloor at 1 m resolution. The vessels were also equipped with Multibeam echosounder systems (Reson Seabat 8160 operating at 50kHz and Reson Seabat 8125 operating at 450kHz) through which bathymetric data were acquired in order to obtain morphological data. The integration of multibeam and SSS data provided a tridimensional model of the seabed, representing the variety of the different geomorphological features associated to coralligenous habitats. A total of 3150 NM have been covered by the surveys. Multibeam and SSS devices allowed obtaining, respectively, real time bathymetric maps and sonographs of the seabed. Therefore it was possible to select on-board the suitable points for visual investigations, that were instrumental to support further acoustic data interpretation (Fig. 1).

Results

The acoustic data integration led to a detailed mapping of coralligenous bioconstructions. The identification of the different acoustic signals was definitely supported by a consistent analysis of the associated video data. Data interpretation allowed knowing the morphology and the height of all the mapped bioconstructions, and therefore the identification of the main coralligenous habitats occurring along the Adriatic and the Ionian Apulian continental shelf.
Video analysis allowed the characterization of the macroscopic coralligenous community (e.g. algae, sponges, cnidarians) and the identification of several key-species protected by national and international protocols (e.g. *Palinurus elephas*, *Corallium rubrum*, *Antipathella subpinnata*), as well as alien and invasive species (e.g. *Caulerpa racemosa* var. *cylindracea*).

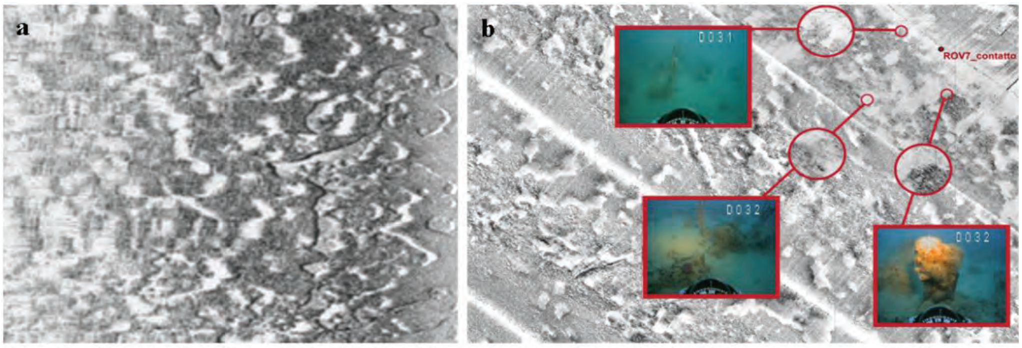

Fig. 1 – a) typical backscatter of *P. oceanica* meadow (from Savini, 2011); b) sonogram of a low and scattered coralligenous seabed with ROV ground truthing.

Discussion and conclusions

The integration of multibeam and SSS acoustic data proved to be a very sound method for the detailed mapping of coralligenous bioconstructions, providing metric and in some case decimetric morphological information about this important habitat. However, the integration between acoustic data and visual investigations was essential not only to distinguish different backscattering, but also to validate the interpretations of remote data. Despite the high resolution acoustic data, video analysis proved how difficult could be the identification of coralligenous bioconstructions based only on acoustic surveys. This is particularly true for the Apulian shallow coralligenous habitat located close to habitats with a more marked acoustic backstatter such as the *Posidonia oceanica* meadows. In fact, the acoustic signal of a shallow coralligenous, characterized by low and dense blocks and perhaps highly covered with algae or sponges, can be similar to the *P. oceanica* one (Fig. 1). In addition, the visual surveys enriched the dataset with a number of biocenotic information. The presence of certain species and their particular *habitus* could also provide useful information about the condition of the environment as well as the impacts occurring over the mapped area (e.g. fishing, diving, anchoring). Anyhow, the integrated techniques used to map the investigated habitats, have proved to be the most efficient and less invasive ones for coralligenous mapping and characterization along the continental shelf.

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PRELIMINARY ASSESSMENT OF CORALLIGENOUS BENTHIC ASSEMBLAGES ACROSS THE MEDITERRANEAN SEA

Abstract
A preliminary study of coralligenous benthic assemblages was performed in 2013 at 20 sites in Turkey, Greece and France within the framework of the EU-funded project CIGESMED. At each area the most conspicuous species were recorded using in situ observations and photoquadrats. The survey revealed a total of 267 species belonging to 11 systematic groups. Within the sampled sites, algae ranked first in terms of species richness (83 species), followed by Porifera (55 species), Cnidaria (32 species), Bryozoa (22 species) and Echinodermata (21 species). A total of 172 species were encountered in France, 107 species in Turkey and 93 species in Greece. Six alien species, Caulerpa cylindracea, Stypopodium schimperi, Acrothamnion preissii, Womersleyella setacea, Amphistegina lobifera and Synaptula reciprocans, were found at sampling sites. Taking into account the preliminary character of the performed surveys, the biodiversity reported herein is presumably underestimated. Species richness is expected to increase following the upcoming, more exhaustive CIGESMED surveys. The final species lists will later be critically evaluated to meet the needs for developing new biotic indices and also for applying already developed ones (e.g. Index-Cor) in order to be used by scientists, managers and stake holders for the effective monitoring and management of coralligenous communities.

Key-words: Coralligenous, assemblages, Turkey, Greece, France

Introduction
Coralligenous communities represent some of the most productive and diverse biological structures in the Mediterranean (Laubier, 1966; Laborel, 1987). They generally develop on rocks in dim-light conditions and mainly occur in the circalittoral zone. These assemblages are directly or indirectly subjected to human-related pressures such as sedimentation due to pollution, invasion by alien species, physical damages by divers or nets, bioerosion by borers and grazers, and climate change (Ballesteros, 2006). The fragility of the coralligenous habitats is related to the stability of the environment in which it has evolved, the combined effects of erosion and bioconstruction, and the low demographic dynamics of their inhabitants (Linares *et al*., 2010). This paper aims to summarize the results of the first field surveys performed within the framework of the EU SEAS-ERA project CIGESMED (www.cigesmed.eu), aiming to assess the diversity of benthic coralligenous assemblages across the Mediterranean.

Material and Methods
Scuba-assisted surveys within coralligenous habitats (depths down to ca. 40 m) were performed at 6 sites in Turkey (Aegean and Levantine Seas), 7 sites in Greece (Aegean

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and Ionian Seas) and 7 sites in south France (Gulf of Lions) in 2013. Coralligenous assemblages were determined through the use of visual count techniques (e.g. direct observations and photographic quadrats). Photoquadrats were analyzed using photoQuad software.

Results

A total of 267 species belonging to 11 systematic groups were encountered. Algae ranked first in terms species richness (83 species), followed by Porifera (55), Cnidaria (32), Bryozoa (22) and Echinodermata (21). The highest species richness was reported in the French sites (172), followed by those in Turkey (107) and Greece (93). Four invasive species (*Caulerpa cylindracea*, *Stypopodium schimperi*, *Amphistegina lobifera* and *Synaptula reciprocans*) were found in Turkey, 1 species (*Womersleyella setacea*) in Greece, and 3 species (*C. cylindracea, W. setacea* and *Acrothamnion preissii*) in France. Several species of algae (e.g. *Lithophyllum stictaeforme*, *Mesophyllum alternans*) and sessile animals (e.g. *Axinella* spp., *Madracis pharensis*, *Halocynthia papillosa*) were shared among all studied areas. Gorgonians (e.g. *Paramuricea* spp., *Eunicella* spp.), on the other hand, were commonly recorded at the western Mediterranean locations and, less so, in the eastern basin, since they were recorded only in one site in Greece (Ionian Sea).

Discussion and Conclusions

Through the applied underwater visual survey techniques, coralligenous habitats at different sites along the northern Mediterranean coastline exhibited a certain degree of diversity. However, all surveys performed conducted so far were preliminary, hence the number of reported species is expected to increase both following the upcoming, exhaustive CIGESMED surveys, as well as in future scheduled attempts that will elucidate the taxonomic status of species not presently identified at the species level. The present study detected different coralligenous assemblages in the western and eastern Mediterranean Sea. In the western basin, gorgonians were found to be dominant even in shallow-depths, whereas these animals were rare or absent in the first fieldwork session performed at the eastern Mediterranean sites. However, a number of algae and invertebrates were common in the different Mediterranean areas and could be useful for future monitoring programs and the implementation of biotic indices that have already been developed (e.g. Index-Cor) or will be developed within the framework of CIGESMED.

Acknowledgments

Works are supported by: France - CNRS - ANR convention n°12-SEAS-0001–01 / LIGAMEN - ANR convention n°12-SEAS-0001-02 / IFREMER - ANR convention n°12-SEAS-0001-03, Greece - GSRT 12SEAS-2-C2, Turkey - Tübitak contract n°112Y393.

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TRAWLING IN THE STRAIT OF SICILY (CENTRAL MEDITERRANEAN SEA)… ABOVE AN UNEXPECTED MAËRL BED!

Abstract
During 2012, twenty-seven hauls were randomly performed in an area of the Straits of Sicily, on board fishing vessels of Lampedusa bottom trawl fleet, at depths between 40-80 meters. The research was aimed at assessing the sustainability of the trawl fishery targeting cephalopods in the area. The retained fractions represented a small part of the total catch in weight (21%) and cephalopods represented the most abundant group reaching the 58% in weight of the retained fraction. Most of the discard, which represented almost the 80% in weight of the total catch, instead, was mainly compose by rhodoliths or Maërl (calcareous red algae) which constitute a priority habitat according to the SPA/BIO protocol (Barcelona Convention). Moreover, according to the regulation CE 1967/2006, fishing with trawl nets, dredges, shore seines or similar nets above mäerl beds are prohibited. Based on the obtained results, the trawl fishery carried out in the area is not sustainable, both from an economic and ecosystem point of view. For these reasons, in our opinion, and according to the precautionary approach to fishery, further studies should be carried out in order to map this priority habitat, identify its boundaries, and then give precious information for the fishery management in the area.

Key-words: *mäerl*, *rhodoliths*, priority habitat, SPA/BIO protocol.

Introduction

In December 2006, a Regulation on the Management of Mediterranean Fishery Resources (Reg. CE 1967/2006, later amended by Reg. UE 1343/2011) was approved by the European Commission. It introduced the adoption of the 40 mm square-mesh or alternatively 50 mm diamond-mesh codend in replacement of the old 40 mm diamond-mesh codend for trawlers of EU Member States in the Mediterranean Sea, for the benefit of a more selective catch and ultimately, a more sustainable fishery in the future.
Driven by fishermen complaints, (according to which fishery became unprofitable after the adoption of the new regulation) the Fishery Department of Sicily Region promoted a research aimed at evaluating the catch composition and yields of both retained and discards species, obtained with the new trawl mesh size in the continental shelf off Lampedusa Island.

Materials and methods

During 2012, twenty-seven hauls were randomly carried out, in an area of the Straits of Sicily at depths between 40-80 meters, on board fishing vessels of Lampedusa bottom trawl fleet. The mean biomass (kg/km^2) was calculated separately for each species/taxon of both retained and discarded fraction.

Results

A total of 55 taxa were retained whereas 120 were discarded. The retained fractions, represented a small part of the total catch in weight (22%; fig.1) and cephalopods represented the most abundant group reaching the 58% in weight of the retained fractions. The most common species encountered in this fraction were *Eledone moschata, Merluccius merluccius, Mullus* *surmuletus, Pagellus erytrhynus, Loligo vulgaris* and *Octopus vulgaris.* Most of the discard, instead, was made up by rhodoliths and macrophytes which reached, 85% in weight of this fraction. Fishes represented the second discarded group in term of % weight whereas all other groups recorded irrelevant weight percentages. The Ecological Use Efficiency ranged between 0.095-0.684 with an average of 0.292±0.179.

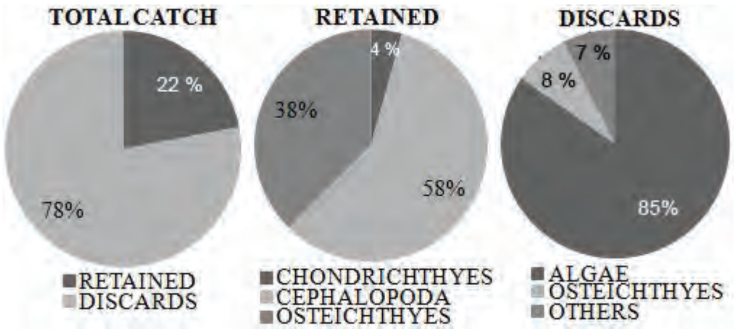

Fig.1. Percentages in weight of the retained and discarded fractions caught.

Discussion and conclusions

Discard represent one of the most important issues of the commercial fishery, especially in mixed-species demersal trawl fisheries. In the study area, trawl discards represented, more than the three-fourths of the total captured biomass. These observed values are enormously high if compared with other Mediterranean studies (Stergiou et al., 1998; Sànchez et al., 2004, Sartor at al., 2003) but the most important aspect is that most of this discard was due to the presence of rhodoliths. Then, since the composition of the catches reflects the different benthic communities affected by trawling (Demestre et al., 2000) it is easy to suppose that the area is covered by rhodoliths or Maerl beds, a collective term for various species of non-jointed coralline red algae (Corallinaceae) that live unattached. These maerl beds are biodiversity 'hot-spots' as they enhance biological and functional diversity of coastal sediments (Grall et al., 2006) and constitute a priority habitat according to the SPA/BIO protocol (Barcelona Convention). Moreover, according to the regulation CE 1967/2006, fishing with trawl nets, dredges, shore seines or similar nets above mäerl beds are prohibited. Based on the obtained results, the trawl fishery carried out in the area could not sustainable, both from an economic and ecosystem point of view. For these reasons, in our opinion, and according to the precautionary approach to fishery, further studies should be carried out in order to map this priority habitat, identify its boundaries, and then give precious information for the fishery management in the area.

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CIGESMED HABITAT'S CHARACTERIZATION: A SIMPLE AND REUSABLE TYPOLOGY AT THE MEDITERRANEAN SCALE

Abstract
The so-called coralligenous makes Mediterranean marine habitats that are of the most important in terms of complexity and biodiversity. Coralligenous is formed by the development of several types of communities where bio-constructor, bio-erodor engeneer and "habitat" species interact to build complex structures. The European program CIGESMED studies the Good Environmental Status (G.E.S.) of these habitats. Several protocols are implemented, in particular the cartography of abiotic context, and species observation by means of photo-quadrats. The cartography inventories the profiles types of the coralligenous sites with as robust as possible categories: depth, orientation, slope, roughness, and main coralligenous stands.
The objective is to establish a link between the species occurrence features, and the profiles features in order to understand the "natural" spatial variability of coralligenous habitats.

Key-words: Coralligenous habitats, protocols, cartography, photo-quadrats, contextualization.

Introduction

Many studies on coralligenous habitats have been published (Marion, 1883, Laubier, 1966; Hong, 1980). The coralligenous milieu hosts complex assemblages of more than 1,600 species. (Ballesteros, 2006). A better understanding of the variability of this habitat demands estimation/measurement, at a large spatial scale, using simple methods and variables that can explain the species assemblages.

Material and methods

Due to their topography and to their complexity, there are only a few accurate maps of coralligenous habitats. CIGESMED program is experiencing a way to symbolise them by means of easily recognizable signs. Based on the estimation of the diversity and abundance of species observed during field surveys, coralligenous habitats cartography should also take into account the profiling parameters (orientation, slope, roughness, and major covers) that favour one or another taxon. This study of the variability of the coralligenous habitats structure is made on small islands of Marseilles' bay at a constant depth of 28 (± 1) meters. Observations were done on different types of sites. Either around small islands and shoals, or along coastline with all orientations represented. Samples were collected along transects cut into segments of 5m long and 1m wide. To define the profile of each segment, a common typology has been applied. This typology can be apply easily by the under-water diver with anatomic references (finger(s), fist, head, shoulders) completed by main species covers. For data processing, the frequency of species observation for each segment was calculated for each profile setting.

Results

Using Hierarchical Ascendant Classification (HAC) on all processed data allowed: (i) to group species according to values of orientation, slope and roughness, and (ii) to pool profile parameters according to species per segment. This HAC show four groups of profile parameters (Fig. 1).

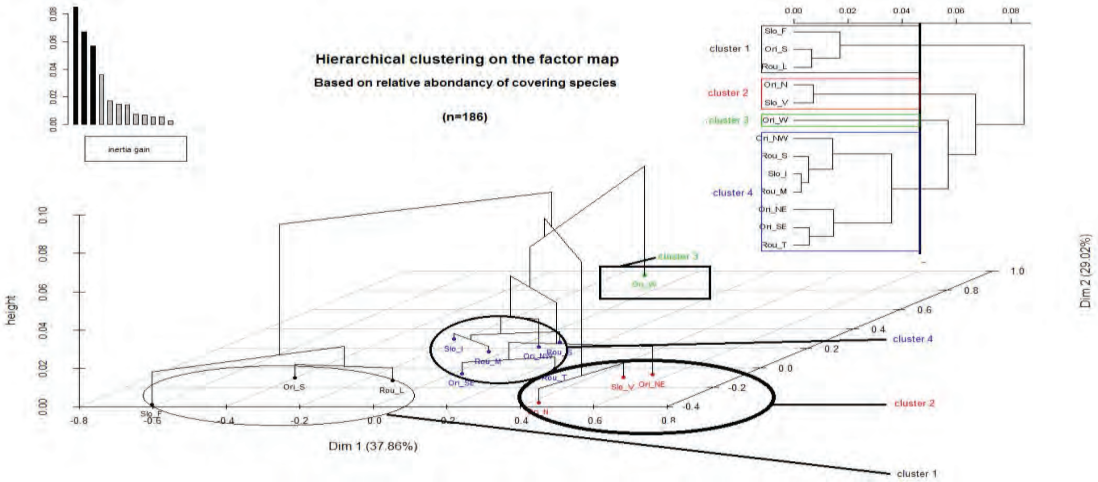

Fig.1: The two dimension HAC show a good repartition of species assemblages according to à first gradient (37,86% of the variability explanation) with two opposite clusters (cluster 1 and cluster 2), the second one for intermediates values of each categories.

Discussion and conclusion

For this first set of results, we can consider that the first axe of variability corresponds to the factor light, with two clusters grouping at opposite conditions of light. The second axis may pool factors according to light variability and currents (complementary studies are in progress). The preferences of species assemblages for different associations of parameters will permit to propose a coralligenous typology, and understand what the differences of preferences at the Mediterranean scale are. A "profile" is thus a combination of orientation, inclination and roughness parameters. Further detailed study will be conducted on associations of profile features to determine the preferential profiles of different coralligenous communities. The analysis should enable to identify metrics that are relevant, reliable, and efficient to explain this "natural" variability, taking in account the variability at the Mediterranean scale and a large panel of observers with different skills level.

Acknowledgements

Works are supported by: France - CNRS - ANR convention n°12-SEAS-0001–01 / LIGAMEN – ANR convention n°12-SEAS-0001-02 / IFREMER - ANR convention n°12-SEAS-0001-03, Greece - GSRT 12SEAS-2-C2, Turkey - Tübitak contract n°112Y393.

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MACROALGAL COMPOSITION OF RHODOLITH BEDS IN A PILOT AREA OF THE TUSCAN ARCHIPELAGO (TYRRHENIAN SEA): PRIMARY ELEMENTS TO EVALUATE THE DEGREE OF CONSERVATION OF THIS HABITAT

Abstract
Multi-Beam Echo-Sound data, Remotely Operated Vehicle video-images and grab samples were collected, within the framework of the research project funded by the Italian Ministry in charge of fisheries management - MiPAAF, in order to improve the knowledge on the Italian Rhodolith Beds Habitat (RBs). The aim of this paper is to assess the composition of RBs and of their associate macroalgal epiphytes in the North Western Mediterranean Sea. The study sites are located in the Tuscan Archipelago (Tyrrhenian Sea), where RBs occur between 50 and 70 meter depth. The most frequent calcareous taxa were: Phymatolithon calcareum, Lithothamnion minervae, Lithothamnion philippii, Lithophyllum racemus and Titanoderma pustulatum. In all the sampled sites both the taxa of Annex V of the Habitat Directive, P. calcareum and/or Lithothamnion corallioides, were collected.

Key-words: rhodolith beds, macroalgae, monitoring, conservation

Introduction

Rhodolith beds (RBs) are characterized by the accumulation of living and dead unattached thalli of coralline algae and peyssonneliaceans. They are constituted by *engineers species* that form a complex habitat, thus increasing biodiversity.
In the last decades, in many parts of the Mediterranean Sea, RBs are menaced by human impacts mostly linked to sediment increasing and trawling fishing. Furthermore, the growth of calcareous algae is related to environmental features, such as currents, nutrient and to biological interactions (i.e. boring organisms).
The aim of this work is to contribute to the knowledge of the presence and degree of conservation of RBs in the North Western Mediterranean Sea, assessing calcareous algae and their epiphytes.

Materials and methods

Multi-Beam Echo-Sound data, Remotely Operated Vehicle video-images and grab samples were collected within the framework of the project "*Studio sulla presenza nelle acque Italiane dei fondi a maërl- Corallinacee libere, habitat di interesse conservazionistico*" funded by the Italian Ministry in charge of fisheries management (MiPAAF).
The study sites are located in the Tuscan Archipelago (Tyrrhenian Sea, NW Mediterranean Sea) within an area of about 50 km^2, ranging between 50 and 90 meter depth. A total of 13 grab samples, in 7 sample stations, were collected. Only 4 sampling sites, located between 50 and 70 meter depth, were characterized by the presence of RBs.

Algal samples were preserved in 4% formalin seawater. Calcareous algae were analysed by scanning electron microscopy (SEM). Anatomical terminology follows Woelkerling (1988) and growth-form terminology follows Woelkerling *et al.* (1993). Taxonomic nomenclature follows Algabase (http://www.algaebase.org/).

Results

The most frequent calcareous taxa collected were *Phymatolithon calcareum*, *Lithothamnion minervae*, *Lithothamnion philippii, Lithophyllum racemus* and *Titanoderma pustulatum.* In all the sites characterized by the presence of RBs, both the taxa of Annex V of the Habitat Directive, *P. calcareum* and/or *Lithothamnion corallioides*, were found. However, in contrast to other studies conducted in the Tyrrhenian area we observed a higher abundance of *P. calcareum* compared to *L. corallioides* (Piazzi *et al*., 2002; Savini *et al.,* 2012).

In particular, the samples collected in the central area of a shoal showed the higher species richness and degree of conservation. They were characterized by the abundance of living thalli of calcareous algae (mainly *P. calcareum* and *L. minervae*), *Peyssonnelia* spp. and showed a rich associated flora.

Discussion and conclusions

The distribution, composition and ecology of RBs in Mediterranean have received little attention and extensive surveys are necessary to better understand the structural and functional features of these unique assemblages. RBs represent a suitable substrate for the settlement of algal spores and sessile invertebrates larvae, constituting one of the most complex assemblages of the subtidal soft bottoms of the Mediterranean Sea.

The calcareous algae of the studied bottoms represent important building organisms, confirming the value of this area from a conservationist point of view. In fact, the assemblages colonizing the rhodoliths showed a stratified structure with epiphytes distinguished in erect, turf and encrusting morpho-functional groups. However, further studies are necessary to investigate interactions among dominant organisms and their distribution at different spatial scales.

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THE NEED OF CARTOGRAPHY FOR CORALLIGENOUS AND RHODOLITHS BEDS ALONG THE MEDITERRANEAN SEA: THE BALEARIC ISLANDS CASE

Abstract
Coralligenous and rhodoliths beds are two types of biogenic habitats, structured by calcareous red algae. Widely distributed along the Mediterranean Sea, these formations create complex three-dimensional structures, where countless marine species –including those of high commercial value and endangered ones– feed, rest and nest. These characteristics confer the two habitats a great ecological and economic importance, which has motivated their protection under the European Union legislation and the development of an explicit action plan within the framework of the Barcelona Convention. During the past decades, dozens of scientific campaigns at sea have contributed to their knowledge, location and description, resulting in a substantial amount of available data about coralligenous and rhodoliths beds. The cartography of marine habitats is a necessary tool to apply certain specific conservation measures, like the closure to bottom trawling of the areas where these habitats are present (Regulation 1967/2006). Thus, the presence, characteristics and importance of these habitats are especially well known in the bottoms surrounding the Balearic Islands. A complete cartography was developed for these habitats in the Balearic area, coupling the best available scientific data (e.g. data published by the Spanish Oceanographic Institute) with the data compiled during Oceana expeditions carried out between 2006 and 2013.

Key-words: Cartography, rhodoliths beds, coralligenous, Mediterranean Sea, Balearic Islands, bottom trawling

Introduction

The coralligenous and rhodoliths beds are sensitive habitats ecologically and economically relevant, important for many marine species (Ballesteros, 2006). Thus, they are protected under EU fisheries and environmental legislation (Council Regulation EC 1967/2006 and Council Directive 92/43/EEC) and the Barcelona Convention has contemplated them in its Reference List of Habitat Types to be protected in addition to the specific Plan of Action for these habitats.

Marine habitats mapping is a priority tool (Gibson *et al.*, 2007; Brown *et al.*, 2011) that allows combining the habitats´ distribution with the threats the area holds. This facilitates the sustainable use of resources, their long-term conservation (FAO, 2009) and the effective compliance with the current legislation. The Balearic Islands are a clear example of how the mapping of marine habitats is necessary to halt protected habitats´ degradation, as the area is currently affected by illegal trawling activities.

Materials and methods

An extensive and thorough review of campaign reports, scientific papers and other literature was carried out looking for information on coralligenous and rhodoliths beds in the Balearic continental shelf. The standardization of the information was done so it could be displayed on a single map since the obtained data was transposed to 500m grid cells.

The -150m bathymetric contour was pointed as the limit distribution of coralligenous and rhodoliths beds. Data on the bottom-trawler fleet's *Vessel Monitoring System* (VMS) for the years 2008-2011 was superimposed to the final map.

Results

The resulting mapping with all the relevant data on the presence of coralligenous and rhodoliths beds included: 5 at-sea Oceana campaigns with 148 dives above -150 m with ROV and divers, conducted during the years 2006, 2007, 2008, 2010 and 2013; several at-sea campaigns conducted by the Spanish Institute of Oceanography (IEO) between 2004 and 2012, under the MIGJORN, BALAR, PESCALA, CANAL and MEDITS projects; and other sources (MAREA-MEDISEH, Spanish Government Marine Strategies and Ecocartographic Coastal Studies, EUSeaMap, LIFE + Posidonia and the Atlas of Marine Biodiversity in the Balearic Sea). The protected habitats have been demarcated, noting those directly impacted by bottom trawling. According to the data shown in this mapping, we found that bottoms with coralligenous and rhodoliths beds (4,266 km²) are present in a 24.51% of the Balearic continental shelf and a 12.82% of the Balearic promontory bottoms. When comparing with the VMS data, we found that a 36.97% of the coralligenous and rhodoliths beds (1,577 km²) were directly affected by bottom trawling between 2008 and 2011 in the Balearic Islands.

Discussion and conclusions

Almost a 25% of the Balearic continental shelf is covered by coralligenous and rhodoliths beds, evidencing the relevance of these habitats in the area, and meaning that effective management measures are needed to ensure their conservation and protection. Pursuant to Regulation (EC) 1967/2006, and as a result of this work, we found that at least 9.1% of the Balearic continental shelf has undergone illegal trawling. It is thus possible now to establish management measures –previously limited by the lack of mapping information– such as the banning of bottom trawling on the areas with known presence of coralligenous and rhodoliths beds, and the reinforcement of EU legislation, especially on the areas where the illegal activity has been detected. Thanks to the mapping, a buffer zone that softens the indirect impacts of fishing, such as turbidity and the sedimentation resulting from the materials lifted from trawled bottoms, is feasible. Oceana´s recommendation is to establish a buffer zone among the protected habitats and, at least, the -200m bathymetric contour, as a precautionary measure to avoid bottom trawling´s direct and indirect effects on these habitats. This mapping should be updated with the most recent VMS data available (in this case from 2012 and 2013) and be completed with all the known locations of coralligenous and rhodoliths beds that may not have been covered here. Finally, it would be necessary to expand the current knowledge to areas of the Balearic continental shelf that have not yet been studied, in order to develop a comprehensive mapping of the Balearic Islands´ marine habitats and thus proceed to their best possible management.

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PREDICTING THE SUITABLE HABITAT OF THE RED CORAL, *CORALLIUM RUBRUM* (LINNAEUS 1758), IN RELATION TO BATHYMETRIC VARIABLES

Abstract
The red coral Corallium rubrum (Linnaeus, 1758) is a long-living octocoral occurring in the Mediterranean Sea and in the neighboring Eastern Atlantic Ocean on subtidal hard substrates at a depth range of 10-800 m. C. rubrum, due to its workable red axial calcareous skeleton, was harvested for a long time and, therefore, is nowadays considered in decline. During two combined Remotely Operated Vehicle (ROV) and Multi-Beam Echo-Sounder (MBES) surveys, held in 2012 in the Ligurian Sea and in the Tuscany Archipelago, several populations of this species were found between 50 and 200 m depth. High resolution multibeam data were analyzed and morphometric parameters were derived. These parameters were used in an Ecological Niche Factor Analysis (ENFA) to identify the most appropriate areas for coral colonization. A Terrain Suitability Map (TSM) was developed by means of the MAhalanobis DIstances Factor Analysis (MADIFA) to predict the optimal habitat. Models were applied to three sites. Rocky sites with high inclinations were identified as preferred habitat for red coral.

Key-words: *Corallium rubrum*, Tyrrhenian Sea, ROV, MBES, Habitat modeling.

Introduction

The precious Mediterranean red coral *Corallium rubrum* (Linnaeus 1758) is one of the most intensively exploited marine benthic species. This eurybathic (10-800 m depth) and long-lived octocoral may forms arborescent colonies reaching 50 cm in height (Garrabou & Harmelin, 2002). Commercially harvested from ancient time, due to its workable red axial calcareous skeleton (Tescione, 1973), it is nowadays considered in decline. Aims of our study were to verify the possibility of using *C. rubrum* records, collected by Remotely Operated Vehicle (ROV), and bathymetry data, acquired by Multi-Beam Echo-Sounder (MBES) with its derived morphometric parameters, to map the suitable habitat of *C. rubrum* and predict new possible sites of occurrences through the use of MAhalanobis DIstances Factor Analysis (MADIFA).

Materials and methods

During two combined ROV and MBES surveys, held in the Ligurian Sea and in the Tuscany Archipelago in 2012 on board the R/V Astrea, several red coral populations were found between 28-200 m depth. Specimens were photographed by a ROV. High resolution multibeam data of the areas were collected to create georeferenced distribution maps of *C. rubrum*. Multibeam data were converted to raster surfaces (cell size 1mx1m) and used to calculate the following quantitative descriptors of seafloor morphology (Eco Geographical Variables, EGVs): slope, aspect, Terrain Ruggedness Index (TRI), curvature, plan curvature, profile curvature and Bathymetric Position Index (BPI), in an Ecological Niche Factor Analysis (ENFA). ENFA gives two measures related to the niche of the focus species: marginality and specialization. For an explanation of the method refer to Hirzel et al. (2001). A biplot was used to show the ecological niche and the environmental variables for a better understanding of the ENFA results. A Terrain Suitability Map (TSM) was developed by means of MADIFA (Calenge et al., 2008) to predict the optimal habitat. Models were applied to three sites: Isuela (Ligurian Sea); Montecristo (Tuscany Archipelago) and Tuna, a shoal located about 20 km south-west of Montecristo island (Tuscany Archipelago).

Results

- Isuela: 0.020km^2 were covered by multibeam; 801 red coral colonies were recorded between 28-47 m depth. Biplot of ENFA showed species marginality for TRI and slope and species specialization for depth and slope. MADIFA map showed that the optimal habitat for this species is in the north of the points in which were found the colonies.
- Montecristo: 0.049km^2 were covered by multibeam; 621 colonies of *C. rubrum* were recorded between 64-78m depth. The Biplot of ENFA showed species marginality for slope, plan curvature, TRI, depth, and species specialization for TRI, curvature and slope. Montecristo presents potential sites of optimal habitat for the species at north, west and in the center of the area.
- Tuna: 0.35 km^2 were covered by multibeam; 461 colonies of *C. rubrum* were recorded between 90-108 m depth. The Biplot of ENFA showed species marginality for TRI, depth, slope, and species specialization for aspect, curvature, profile curvature and slope. Tuna presents potential sites of optimal habitat for the species at north of the sites where the colonies were found.

Conclusions

Although the three sites differ regarding the depth variable, ENFA showed common points useful to describe the niche of the species in relation to the topography of the seabed, identifying rocky sites with high inclinations as preferred habitat for *C. rubrum*. The most interesting site is "Tuna". Here, MADIFA analysis highlighted that a large part of investigated area showed the characteristics of the substrate favorable for colonies settlement.

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PRELIMINARY LIST OF TYPICAL/INDICATOR SPECIES WITHIN CROATIAN CORALLIGENOUS MONITORING PROTOCOL

Abstract
Based on the list provided by UNEP-RAC/SPA (2011) and field data from 20 coralligenous sites along the Eastern part of the Adriatic Sea, a preliminary selection of typical/indicator species that should be monitored within the Croatian national protocol has been proposed. This list includes 37 species/categories: 2 algal builders, 13 animal builders, 2 agglomerative animals, 5 bioeroders, 13 species of particular importance and 2 invasive species/categories. To verify the existing list or to propose a more complete one, additional field research is needed, especially in the understudied southern part of the Croatian coast.

Key-words: Coralligenous assemblages, monitoring, EU Habitat Directive, Adriatic Sea, typical/indicator species

Introduction
Development of the national coralligenous monitoring protocol has been recently initiated in Croatia in the framework of the MedMPAnet project, with intention to primarily fulfil reporting and monitoring requirements of the EU Habitat Directive (92/43/EEC). The reporting format for this Directive asks for a list of species which have been considered in the assessment and a brief description of the method used to determine their conservation status as part of the overall assessment of habitat structure and functions. Therefore, as one of the initial steps in the development of the protocol, we have drafted a preliminary list of typical/indicator species to be considered.

Material and Methods
A preliminary selection of typical/indicator species was based on the draft list of species to be considered in the inventory and/or monitoring of coralligenous communities provided by UNEP-RAC/SPA (2011) and field data from 20 Eastern Adriatic coralligenous sites, accounting for limitations to the species' identification posed by photosampling, a method envisaged by the national coralligenous monitoring protocol.

Results
Preliminary list included 37 species/categories present at most of the sites (except of the invasive ones that were recorded at 5 sites): 2 algal builders, 13 animal builders, 2 agglomerative animals, 5 bioeroders, 13 species of particular importance (particularly abundant, sensitive, architecturally important or economically valuable) and 2 invasive species/categories.
- Algal builders**:** Coralline algae (such as *Lithophyllum stictaeforme*, *Mesophyllum macroblastum*, *Lithothamnion minervae*, *Neogoniolithon mamillosum,* etc.*)* and

encrusting *Peyssonnelia* spp. (encrusting *Peyssonnelia rubra*, *P. squamaria*, *P. polymorpha*). These two categories were chosen due to difficulty of identification of encrusting red algae by non-experts based on photo sampling.

- Animal builders: branchy bryozoans *Myriapora truncata*, *Schizotheca serratimargo*, *Pentapora fascialis*, *Smittina cervicornis / Adeonella pallasii* and encrusting bryozoans (species such as *Smittoidea* sp., *Rhynchozoon* sp., *Schizomavella* sp., *Celleporina* sp. that cannot be identified from photographs); serpulid polychaeta *Filograna implexa / Salmacina dysteri,* Serpulidae and *Protula* sp.; scleractinians *Caryophyllia inornata*, *C. smithii*, *Hoplangia durotrix*, *Leptopsammia pruvoti* and *Madracis pharensis.*
- 'Agglomerative' animals: sponge *Fasciospongia cavernosa* and bryozoan *Beania* spp.
- Species of particular importance: Uncalcified red algae *Peyssonnelia* spp.; sponges *Crambe crambe / Spirastrella cunctatrix, Petrosia ficiformis, Hexadella racovitzai, Aplysina cavernicola and Axinella polypoides;* gorgonians *Paramuricea clavata*, *Eunicella singularis*, *E. cavolini*, *Corallium rubrum;* alcyonarian *Alcyonium acaule* and zoantharian *Parazoanthus axinellae.*
- Bioeroders: *sponges Cliona* spp.*,* echinoids *Echinus* sp. and *Sphaerechinus granularis,* molluscs *Gastrochaena dubia* and *Lithophaga lithophaga.*
- Invasive species: green algae *Caulerpa racemosa var. cylindracea* and red turf algae (species such as *Womersleyella setacea*, *Lophocladia lallemandii*, *Acrothamnion preissii* that require examination of a physical sample for an unequivocal identification).

Conclusions

More than half of the species (56%) included in this work were previously listed by the UNEP-RAC/SPA (2011). We additionally compiled 5 wider categories (which partially include some of already listed taxa) to account for limitations to the species' identification from photographs. To verify the existing list or to propose a more complete one, additional field research is needed, especially in the understudied southern part of the Croatian coast.

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RESPONSE OF SYMBIOTIC SCLERACTINIAN CORALS TO SEA TEMPERATURE ANOMALIES IN THE ADRIATIC SEA

Abstract
Mortality events of the corals Cladocora caespitosa (Linnaeus, 1767), Madracis pharensis (Heller, 1868) and Balanophyllia europaea (Risso, 1826) were recorded along the eastern coast of Adriatic Sea. Coral mortality resulted from polyp bleaching (massive zooxanthellae loss) and polyp tissue necrosis, leaving the calyx rim deprived of tissue coverage. The highest mortality rates were registered after the exceptionally hot summer of 2011, when about 30% of C. caespitosa and M. pharensis colonies were affected and more than 40% of the B. europaea species died, all caused by bleaching events. Similar events were found during late summers of 2003, 2007, 2008, 2009, 2011 and 2012. In most cases bleaching has been attributed to elevated temperature. Taking into account the global warming context in the Mediterranean Sea, monitoring programs of physical-chemical parameters and vulnerable coral populations should be rapidly set up.

Key-words: Anthozoa, scleractinian corals, temperature anomalies, Adriatic Sea.

Introduction

During the last decade the scleractinian symbiotic corals living in the Adriatic Sea have experienced warm summers with increased sea temperatures up to 4°C above the mean value of 26°C. These high temperature events affected symbiotic corals living mostly in shallow water (5-35 m depth). We try to assess the long-term response of these temperate corals to the sea water warming and describe the relationship between recurrent mortality events and local sea temperature regimes in the eastern Adriatic Sea. Coral bleaching and diseases are expected to interact synergistically and will negatively influence survival, growth and reproduction of corals. Interactions with local stress factors such as pollution or sedimentation are further expected to strengthen the effects of climate change (Cerrano et al., 2000; Garrabou et al., 2009; Benssousan et al., 2010).

Materials and methods

Research was conducted in Mljet National Park, in the southern part of the Adriatic Sea (Croatia) and in the Cape Madona marine natural monument near the town of Piran in the northern part of the Adriatic Sea (Slovenia). Seawater temperatures at the investigated locations were recorded using HOBO Pendant temperature loggers (*Onset Computers Corporation*). The bleaching of symbiotic corals was investigated annually by SCUBA-diving in summer and autumn (July, August, September and October). Coral bleaching was quantified within 1 m on either side of each 10 m transects.

Results

During 2011, the highest seawater temperatures in the Adriatic Sea occurred August through October. In Mljet NP, the highest seawater temperature was measured during August (30.3°C), while in the Piran area, the highest seawater temperature was measured at the end of August (28.8°C). In the Piran area, coral bleaching substantially affected *Cladocora caespitosa* colonies for over 3 months (from August to October), whereas the colonies from the Mljet bank were affected for over 5 months (from July to November). In Mljet NP, 31.2% of all *C. caespitosa* colonies in the Mljet bank suffered coral bleaching, while in Piran 10.6% colonies suffered bleaching. Coral *Madracis pharensis* showed the highest impact in southern part of Adriatic Sea, in Mljet NP (29.3% affected colonies). During the same year, 42.2% of *Balanophyllia europaea* specimens were found dead, mostly by bleaching event (Fig. 1).

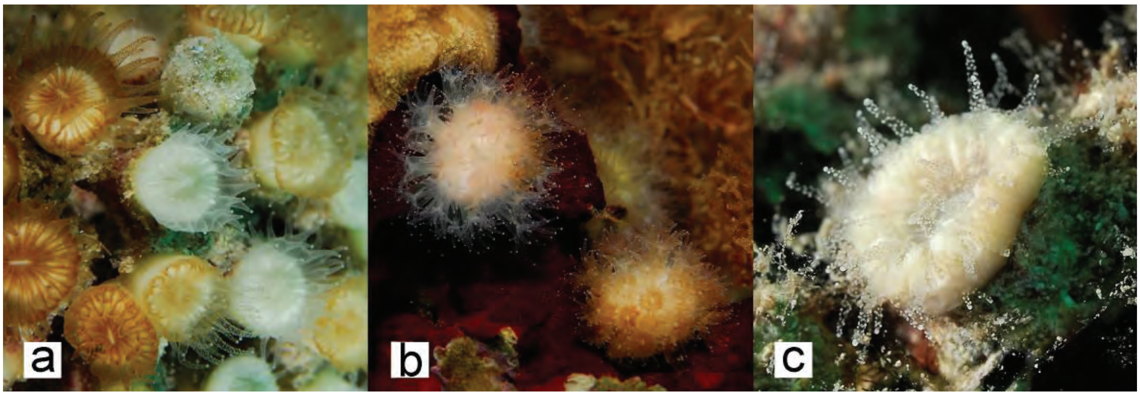

Fig. 1. Polyp bleaching in *Cladocora caespitosa* (a) and *Madracis pharensis* (b) and *Balanophyllia europaea* (c) in Mljet National Park during the summer of 2009.

Conclusions

Although coral mortalities have been reported in the Mediterranean mostly as polyp necrosis, bleaching event affects coral *C. caespitosa*, *M. pharensis* and *B. europaea*, indicating a negative impact of positive temperature anomalies (Kružić & Benković, 2008). Shallow water populations of *C. caespitosa* and *B. europaea*, and *M. pharensis* from coralligenous were clearly decimated after the 2011 outbreak in Mljet NP, with mortality rates similar to those reported for tropical seas. Mortality was preceded by polyp bleaching or polyp necrosis (the complete retraction of the polyp, leaving the calyx rim deprived of tissue coverage). Most of the species affected by the 2011 mortality event in the Adriatic Sea already suffered damages in previous events. In the Mljet NP, all *C. caespitosa* colonies that suffered complete bleaching died. Under the present climate warming trend, new mass mortality events of the scleractinian symbiotic corals may occur even more frequently during the next several decades.

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RESULTS OF DIFFERENT ANTHROPIC USES ON THE STRUCTURE OF VERMETID REEFS

Abstract
The biogenic vermetid reef is a key habitat of coastal ecosystems that modifies the shoreline morphology and increases the local biodiversity. Despite its ecological relevance, rarely it is subjected to an accurate management and is often exposed to several human activities.
This study aims to distinguish between the effects of different typologies of anthropic uses on the physical structure of the vermetid reef. A comparison between totally protected, partially protected and strongly anthropized reefs has been done and two variables have been analysed: the substratum complexity and the density of reef-building organism.
Both the variables show higher values in totally and partially protected reefs, demonstrating the importance of conservation strategies for the correct management of this important bioconstruction.

Key-words: Vermetid reef, anthropic uses, substratum complexity, Mediterranean Sea

Introduction
A vermetid reef is an example of Mediterranean calcareous habitat formed by the association of the gastropods *Dendropoma petraeum* and the calcareous algae *Neogoniolithon brassica-florida* that cemented the mollusk shells each other. This biogenic structure modifies the morphology of rocky coasts, reduces wave-induced erosion, enhances the spatial heterogeneity and the availability of refuges and resources for intertidal biota (Chemello & Silenzi, 2011). For these important ecological roles, the vermetid reef is declared a SPAMI habitat (Specially Protected Areas of Mediterranean Importance) that needs specific conservation plans.
Nevertheless, strategies for the correct management of the vermetid reef are lacking, causing an improper conservation of the bioconstruction. Several impact sources (pollution, coastal urbanisation, tourism) threaten its ecological value (Di Franco *et al.*, 2011), but other kinds of anthropic actions, aiming to limit human disturbances on marine environments (e.g. the institution of a marine protected area), can have a positive effect on the conservation of the vermetid reef.
This study describes the results of different anthropic uses on the physical structure of the vermetid reef, by means the analysis of two variables: the substratum complexity and the density of *Dendropoma petraeum*. The number of reef-building organisms is, indeed, an important attribute that influences the structure of the substratum, creating a physical relief and may be affected by environmental stresses (Bell *et al.*, 1991).

Materials and methods
The study has been conducted along the North-Western coast of Sicily (Italy) in two localities inside the marine protected area of "Capo Gallo-Isola delle Femmine" and one outside. These localities are subjected to different degrees of protection: the *A ZONE* is a fully protected area, *C ZONE* is partially protected but often attended by tourist; *PORT*

lies inside a small touristic harbour and is a strongly anthropized area.
In each locality the vermetid reef has been sampled in two different sites, far at least 100 m each other. For each site 5 replicates of each variable have been collected.
Non destructive methods have been used to collect data on the substratum complexity and the density of *D. petraeum* in the seaward edge of the reefs. Substratum complexity has been estimated inside frames of 400 cm² at a resolution of 2x2cm and described by using a topographic index. Density has been defined by counting directly the number of living specimens in quadrats of 100 cm².

Results
Topography differs at site level with highly variable data. Specifically we recorded similar topography mean values at *PORT* (0.232 ± 0.138 and 0.212 ± 0.238) and at one of the two sites of *C ZONE* (0.315 ± 0.246 and 0.369 ± 0.288); *A ZONE* exhibited the lowest value at site one and the highest at site two (0.15 ± 0.092 and 0.98 ± 1.09).
The mean density of *D. petraeum* showed more homogeneous data at site level (124 ± 50.3 and 103 ± 49.8 individuals/100 cmq for *PORT*; 495.2 ± 181.6 and 462.8 ± 127.4 for *C ZONE* and 365.6 ± 57 and 492 ± 82.5 for *A ZONE*).

Conclusions
The habitat structure is a complex factor, determined by several variability causes.
In this study the structure of the outer edge of the biogenic vermetid reef is compared among localities subjected to different anthropic uses.
Anthropic factors are able to affect the reef structure both in a negative or a positive way. The presence of a small port reduces indeed the density of living reef-building organism together with the complexity of the substratum, while active protection, in a marine protected area, emphasize the values of these variables.
Given the ecological relevance and the low resilience of this peculiar bioconstruction and, considering also that vermetid reefs are becoming extinct in the Levantine basin of the Mediterranean Sea (GALIL, 2013), it is necessary to enhance its conservation and to implement the existing laws on the protection of this coastal key habitat and of *D. petraeum* itself, as stated in several European directives (e.g. Barcelona Convention, Habitat Directive 92/43/EEC).

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GEOMORPHOMETRIC ANALYSIS OF CORALLIGENOUS HABITAT ALONG THE APULIAN CONTINENTAL SHELF: AN ASSESSMENT OF SEAFLOOR COVERAGE AND VOLUME

Abstract
Within the framework of the BIOMaP Project (BIOcostruzioni Marine in Puglia, - P.O. FESR 2007/2013), promoted by Puglia region, Italy, new acoustic data were acquired in order to identify and locate Coralligenous Habitats along the Apulian continental shelf (South Adriatic Sea – Northern Ionian Sea), from 10 down to 100 meters of water depth, in 21 Site of Community Interest (SCI) and 3 Marine Protected Areas (MPA). The dataset covered an area of 1000 km^2 and was obtained through the use of MultiBeam Echosounder Systems (MBES) and Side Scan Sonars. Ground-truthing were collected by 3 ROV dives (Prometeo) and more than 30 underwater camera transects. We discovered that Coralligenous habitat covers a total area of roughly 450 km^2, representing the most relevant habitat within all the SCIs and MPAs of the Apulian continental shelf. The analysis of MBES dataset allowed us to identify several morphological expression of Coralligenous Habitat. Geomorphometric techniques (developed through proper GIS-based tools) have been thus applied on the MBES data in order to (1) figure out relationships between the observed morphologies and the associated habitat distribution and (2) quantify the total volume of selected Coralligenous build-ups. Our work underlines the importance of combining acoustic survey techniques and geomorphometric analysis in order to have a preliminary quantitative characterization of Coralligenous habitat distribution and its 3-dimensional extent. Our results offer relevant quantitative information which contribute in understanding the importance of Coralligenous habitat as carbonate deposits on the Mediterranean shelf (that has been probably underestimated, due to poor knowledge of their distribution).

Key-words: Coralligenous, remote sensing, carbonate production, geomorphometric techniques

Introduction

Coralligenous habitat consists of autochthonous carbonate build-ups, formed by the overlapping growth (in dim light conditions) of organism with calcareous skeletons, especially encrusting coralline algae, that thrive in the temperate Mediterranean Sea on both stable or mobile bottom. It is further on considered a marine habitat worthy of protection in the framework of the Habitat Directive (92/43/EC). In addition, a precise knowledge of Coralligenous distribution is nowadays strongly important because this habitat produces large deposits of biogenic calcium carbonate (BASSO, 2012) and is very sensitive to the ongoing global change (KUFFNER et al., 2007; BASSO, 2012).
The Apulian Region (southern Italy) promoted the BIOMAP (*Biocostruzioni Marine in Puglia*) project to map and characterize the marine bioconstructions along its coasts, where Coralligenous represents a relevant and well developed habitat.
The present study is based on a new experimental methodology performed to analyze multibeam data collected within the framework of the BIOMAP project in order to quantify the total volume of selected Coralligenous build-ups.

Material and Methods

The experimental approach followed in this study consisted of comparing two different groups of Digital Terrain Models (DTMs) collected in selected areas where coralligenus habitat is well distributed. The first group is composed of three very high resolution DTMs (grid cell size of 30cm), provided by processing bathymetric data acquired through a Teledyne Reson 8125 MBES, from 10 to 15 m of water depth; while the second one includes three DTMs (2m grid cell size) provided by processing bathymetric data acquired through a MBES Teledyne Reson 8160 from 30 to 45 m of water depth. The first step in the analytical process required the geomorphometric analysis of the above-mentioned DTMs, in order to identify all the Coralligenous build-up structures present on the mapped seafloor. The *Topographic Position Index* (TPI) tool of the SAGA software (*System for System for Automated Geoscientific Analyses*) was used to support the performed analysis. In particular, TPI tool allowed comparing the elevation of each cell in a DEM to the mean elevation of a specified neighborhood around that cell (Guisan et al., 1999, Weiss, 2000, Wilson & Gallant, 2000). Then, using ArcGIS all the Coralligenous structures were isolated and a "reference surface" without bioconstructions was created for each DTM. A last analytical step included the comparison of the analyzed DTMs with the corresponding reference surface in order to calculate the volume of the isolated Coralligenous build-up structures. The total volume provided by all the Coralligenous buildups mapped by the BIOMAP project was then estimated comparing our results with the total distribution of Coralligenous habitats.

Discussion and Conclusion

The applied methodology provides a preliminary assessment of the total volume of Coralligenous buildups along the Apulian continental shelf. The quality of our computation resulted to be strongly dependent on the DTM resolution that heavily affects the geomorphometric analysis. In particular, it has been shown how the production of accurate and fine-scale habitat maps is mandatory to estimate the total Coralligenous volume

Our study aims at highlighting the importance of combining acoustic survey techniques and geomorphometric analysis to successfully support a preliminary quantitative assessment of Coralligenous habitats distribution and extent. Our results offer a relevant contribute to obtain a quantitative description on Coralligenous habitat distribution and give an overview of the importance of Coralligenous habitat as carbonate deposits on the Mediterranean shelf.

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CORALLIGENOUS ASSEMBLAGES IN CABO TRES FORCAS (MOROCCO, MEDITERRANEAN)

Abstract
The marine habitats surrounding Cabo Tres Forcas (Mediterranean coast of Morocco) was explored during September 2012 and 2013 in the framework of the MedMPAnet Project. The habitats distribution and its species composition were studied both by SCUBA diving and using Remote Operating Vehicle (ROV). Coralligenous assemblages were only observed below 20 meters depth in the east side of Cabo Tres Forcas, in the area of Farallones but not on the west side of the site where there are no hard bottoms below 10 m depth.. Among the most dominant and/or most emblematic species there was the cnidarians Eunicella sp., Paramuricea clavata and Savalia savaglia, which form the upper substrate. An interesting feature at Cabo Tres Forcas was the presence of coralligenous species and/or coralligenous assemblages in shallow waters. In this sense, the red gorgonian Paramuricea clavata and the gold coral Savalia savaglia were observed there from 18 m and 20 m depth, respectively.

Key-words: Cabo Tres Forcas, Marine Protected Areas, Coralligenous, Benthic assemblages.

Introduction

In spite of coralligenous assemblages are one of the most important 'hot spot' of marine biodiversity in the Mediterranean, there are an uneven distribution of data about the presence and characteristics of this habitat. Large areas of the Mediterranean, especially in the South coasts, still remains poorly explored (Giakoumi *et al.*, 2013). Thus, it is necessary to conduct studies along all this area in order to assess the priority conservational zones.

Alboran Sea has a especial ecological and conservational relevance (Templado *et al.,* 2006). This importance is especially high in the waters surrounding Cabo Tres Forcas, due to the biogeographical asymmetries between the north and the south border of the Alboran Sea. While in the north coast the composition of benthic species shows a gradual substitution of Mediterranean and Atlantic species, this transition is more pronounced in the south coast, being mainly located in Cabo Tres Forcas. So, the distribution of many Mediterranean endemisms and genuine Atlantic species only overlap at Cabo Tres Forcas (González, 1994; Cebrián & Ballesteros, 2004).

Material and Methods

Fieldwork was conducted during September 2012 an 2013. Deep bottoms (those below 30 meters) surrounding Cabo Tres Forcas were sampled using a *Remote Operating Vehicle (ROV)*. The pictures and videos were later analyzed in the computer to identify the dominant species inhabiting each station. The benthic community inhabiting the deeper bottoms in Farallones was also explored by SCUBA diving, due to the special interest of this area.

Results and discussion

Coralligenous habitat was only found in the east side of Cabo Tres Forcas in Farallones (Fig. 1) but not on the west side of the site where there are no hard bottoms below 10 m depth.

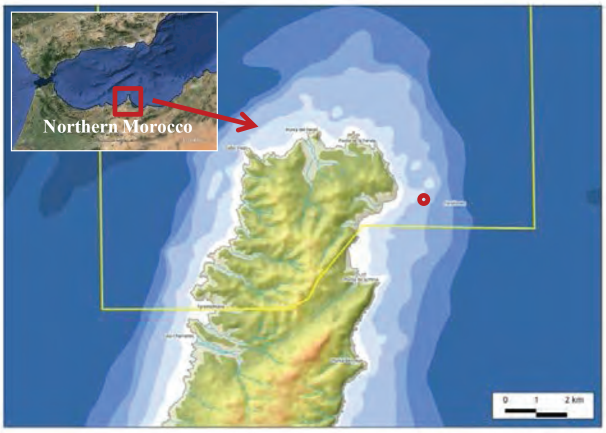

Fig. 1: Map showing the geographical situation of Cabo Tres Forcas and the localisation of coralligenous habitat in the area (red circle)

The cnidarians *Eunicella* sp., *Paramuricea clavata* or *Savalia savaglia*, form the upper substrate, and below them there was a rich invertebrate community of sponges (e.g. *Dysidea avara*, *Petrosia ficiformis*), cnidarians (e.g. *Astroides calycularis*, *Parazoanthus axinellae*), briozoans (e.g. *Myriapora truncata*, *Pentapora fascialis*) or ascidians (e.g. *Polycitor adriaticum, Pseudodistoma crucigaster*). The characterization of coralligenous habitat highlighted the existence of a healthy and well-structured assemblage. An interesting feature of this marine community at Cabo Tres Forcas was the shallow distribution of many species. In this sense, the gold coral *Savalia savaglia* was observed at 20 meters deep and precoraligenous assembalges can be found even at 10-15 meters deep in shallow substrates.

Acknowledgments

This study was conducted within the framework of the MedMPAnet Project implemented by UNEP/MAP-RAC/SPA in close collaboration with the Haut Commissariat aux Eaux et Forêts et à la Lutte Contre la Désertification (HCEFLCD) and financially supported by RAC/SPA, the European Commission (EC), the Spanish Agency for International Cooperation to Development (AECID), and the French Global Environment Facility (FFEM).

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A NEW TOOL TO MEASURE THE 3D CORALLIGENOUS COMPLEXITY AT THE MICRON SCALE

Abstract

Coralligenous bioconstruction, mainly built by overlaying calcareous algal thalli, are characterized by numerous crevices and holes hosting a high biodiversity. Here we show the internal coralligenous 3D complexity by using the X-ray computed microtomography technique and estimate its porosity. The analysed samples coming from the coralligenous of the Portofino Promontory (Ligurian Sea, Italy). We evaluate an average porosity comparable to that known for coral reefs. Moreover, a series of sections were used to evaluate the percentage of area occupied by the cryptic sponges inside the small cavities of the substrate that accounts for about 25% of the total surface of crevices. These results put in evidence how the coralligenous microcavities can actually host a rich fauna, suggesting an unexpected fundamental contribution of the cryptic community to the function of the coralligenous ecosystem.

Key-words: X-ray microtomography, Porifera, coralligenous porosity

Introduction

Coralligenous is characterized by crevices and holes with different shape and size, offering the optimal habitat to a rich cryptofauna (Ballesteros, 2006). This internal complexity has never been quantitatively evaluated in terms of volume. In other bioconstructions the structural and functional role of the cavities was recognized and evaluated (de Goeij & van Duyl, 2007); for example, Ginsburg (1983) reported values of 30-75% of the total volume in reef. Here we measure, using conventional and synchrotron X-ray computed microtomography (µCT) technique at the Elettra laboratory (Trieste, Italy), the porosity of the coralligenous substrate and we estimate the surface occupied by the sponges that represent one of the most important component of the coralligenous cryptic community.

Materials and methods

Nine samples of coralligenous were collected at Portofino Promontory (Ligurian Sea, Italy) 30 m depth. These portions were preserved in alcohol 70%. We performed conventional µCT measurements at the TomoLab station to obtain a 3D image of a 20 mm thick coralligenous samples at medium spatial resolution (about 10 µm) in order to have an overall view of the sample micro-architecture. Selected regions of the samples (≈ 1 cm^3) were studied at higher contrast resolution at the SYRMEP beamline to identify smaller morphological details. For each sample a Volume Of Interest (VOI) was extracted in order to evaluate its porosity. From three samples, a series of sections was selected to evaluate the percentage of area occupied by sponges.

Results

By applying X-ray µCT we evidenced the 3D complex holes and tunnels inside the construction (Fig. 1A). On the substratum several hard biobuilders were identified, like corals, bivalve shells and polychaete tubes, while inside mainly sponges were recognisable

(Fig. 1A). The analysis of the porosity showed an average of about 40% (Fig. 1B). The area occupied by sponges was about the 25% of the total surface of crevices (Fig.1C).

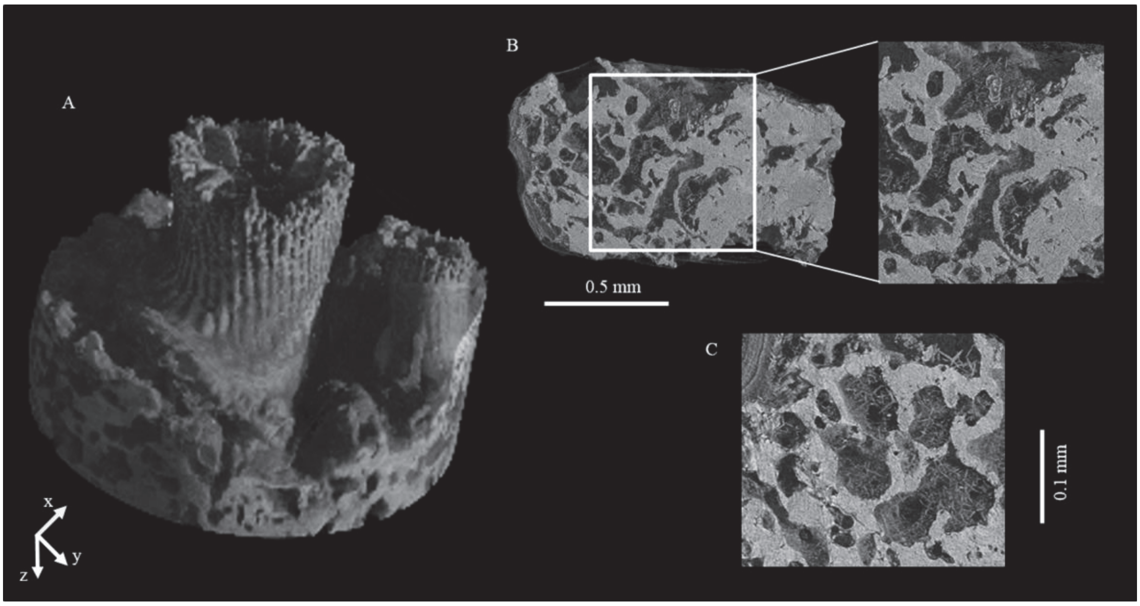

Fig. 1. Volume renderings of coralligenous blocks. A, Total volume (TomoLab). Selection of VOIs (SYRMEP): B, volume used to evaluate porosity; C, detail showing sponge spicules.

Discussion and conclusions

The biodiversity of coralligenous assemblages is underestimated (Bertolino *et al.*, 2013) and this gap of knowledge is mainly due to the lower accessibility of this habitat and to its high structural complexity. New technologies are suggested to speed up the knowledge on coralligenous at macroscopic level (Zapata *et al.*, 2013) but also other scales of observation are evidencing unexpected results. The value of micro-porosity here calculated is comparable to that of coral reefs, and reinforces the ideas on the key role that holes and microcavities can play in this bioconstruction. Sponges are among the most important components of the coralligenous cryptic community, occupying about 25% of the total surface of crevices. Microcavities can host a rich fauna, suggesting a fundamental contribution of the cryptic community to the coralligenous ecosystem functioning and asking for a redrawing of the benthic pelagic-coupling assumptions known for this key habitat.

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THE BIOGENIC FORMATION OF *CLADOCORA CAESPITOSA* (ANTHOZOA, SCLERACTINIA) DEAD CORALLITES IN THE SLOVENIAN PART OF THE GULF OF TRIESTE (NORTHERN ADRIATIC SEA)

Abstract
In the southern part of the Gulf of Trieste a biogenic plateau completely made of "subfossil" corallites of the Mediterranean stony coral (Cladocora caespitosa) has been recently discovered close to Cape Ronek (Slovenia). The plateau is characterized by the highest density of living coral colonies in waters off Slovenia. The preliminary data show that the biogenic formation is hosting an impressive benthic invertebrate biodiverisity.

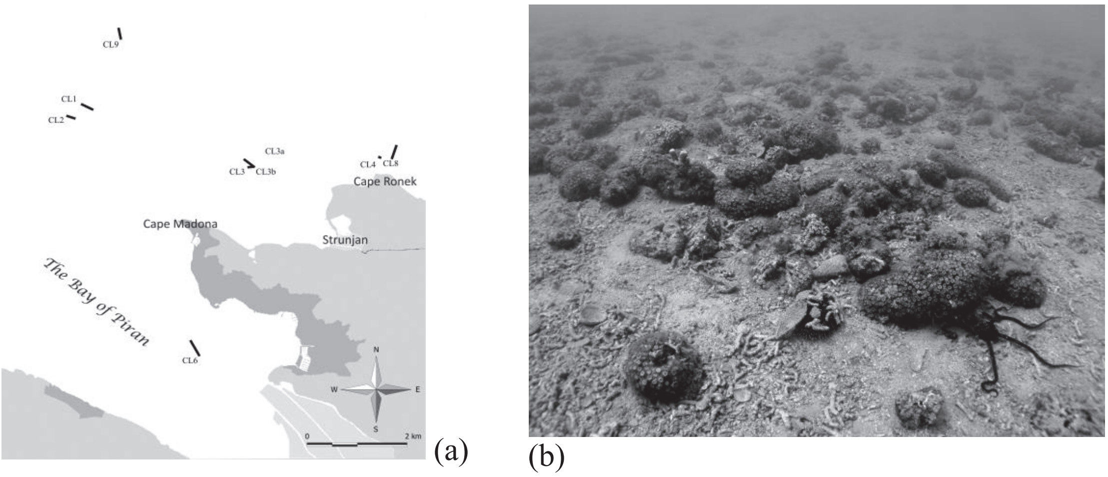
Key-words: *Cladocora caespitosa*, biogenic formation, macroinvertebrate fauna, circalittoral, Northern Adriatic Sea

Introduction

The northern Adriatic Sea is characterized by the occurrence of small biogenic formations (called *trezze, tegnue, bromboli* or *grebeni),* known for centuries such as good fishing grounds. A biogenic bank of *Cladocora caespitosa* (Linnaeus, 1767) was recently discovered close to Cape Ronek in Slovenian waters (Lipej *et al.*, 2006). In the period from 2010 to 2014 many samplings of benthic macroflora and macrofauna, and fish fauna were performed. The aim of this work is to evaluate up to date collected data on the biogenic bank in order to assess to what extent this coral formation contribute to the local biodiversity.

Material and methods

The biogenic formation extends on a surface of about 200 m x 100 m, in a depth range between 12.4 m and 21 m, and it is few meters higher than the surrounding bottom. The bank was investigated according to Marine Strategy Framework Directive (MSFD, 2008/56/EC) requirements. The bank was firstly sampled in November 2010, dredging the selected area at a constant speed. In the period from 2011 to 2014 the biogenic formation was investigated by the use of non-destructive visual sampling methods. The studied area (Fig. 1) was investigated also at other levels. The first level comprises the detritic bottom that surrounds colonies of *C. caespitosa* within the bank. Easily identifiable animals were determined on the research vessel and then released. Smallest animals were fixed in ethanol (70%) and determined later in laboratory. The second level addresses the infauna of colonies of *C. caespitosa,* which was counted and determined in laboratory. The third level comprises the visual census of the benthic macrofauna and ichthyofauna.



(a) (b)

Fig.1. a) Map of the study area with the sampling site dredged in 2010 (CL8) and other sites along the Slovenian coast sampled with the same technique in the same year. b) The biogenic bank of Cape Ronek with colonies of *C. caespitosa* surrounded by a detritic bottom, mainly made of dead corallites.

Results and discussion

The biogenic formation presents the highest density of *C. caespitosa* colonies ever recorded in Slovenian coastal waters: 6.52 colonies/m^2 on average. Colonies are surrounded by a detritic bottom made of dead corallites and, to a lesser extent, of coralline algae (mainly *Lithothamnion* spp., see Falace *et al*., 2011). A total of 121 animal taxa, belonging to 9 different phyla (Porifera, Bryozoa, Cnidaria, Sipunculida, Mollusca, Anellida, Arthropoda, Echinodermata and Tunicata) were found within the formation. Within non-colonial taxa 3605 individuals were counted. On the detritic bottom that surrounds colonies of *C. caespitosa,* 223 individuals of 26 different taxa were analyzed. Echinoderms were the most abundant phyla (70%), followed by molluscs (22%). The taxa richness was higher within molluscs (58%) and echinoderms (27%).

Within 30 colonies of *C. caespitosa* collected and analysed in laboratory, 89 taxa of infauna were determined. About 50% of them were polychaetes, 25% molluscs and 16% crustaceans. Regarding taxa abundance, 3386 organisms were counted. The most abundant were molluscs (50%), followed by polychaetes (20%) and crustaceans (7%). Many of these specimens were juveniles. The overall diversity of the community was quite high (Shannon index = 3.05).

Large biogenic formations of *C. caespitosa* are extremely rare in the Mediterranean Sea. The peculiarity and high diversity of the associated community and the threat posed by habitat loss and climate changes indicate the immediate need for more conservation actions.

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SIGNALISATION DE PAYSAGES MARINS REMARQUABLES DANS LES AIRES MARINES PROTÉGÉES D'ALGÉRIE : LES BIOCONCRÉTIONNEMENTS LITTORAUX

Résumé
Dans le cadre du développement des aires marines protégées le long du littoral est algérien, une évaluation du patrimoine biologique est effectuée dans les parties marines des parcs d'El Kala, Tazaet Gouraya. Les formations remarquables bioconstruites à Lithophyllum byssoides et à Corallina elongata y sont bien représentées. Tandis que dans la région de Tipaza-Chenoua, à l'ouest d'Alger, les bioconcrétions à Dendropoma petraeum sont bien représentées et à moindre degré les bourrelets à Corallina elongata et les encorbellements à Lithophyllum byssoides. Ces peuplements remarquables du médiolittoral devront faire l'objet d'une attention particulière dans le plan de gestion de ces parcs.

Mots-clés : Coastlines Bioconcretionments; Remarkable Landscapes; National Parks; Algeria.

Introduction

En Algérie, la connaissance des biocénoses de Roche médiolittoral est très fragmentaire, seules quelques signalisations sont faites lors d'inventaires d'espèces littorales. Les travaux sur la biodiversité réalisés au cours des études de classement des aires marines (Fig. 1) ont mis en évidence la présence de «paysages littoraux remarquables» : les encorbellements à *L. byssoides* et à *C. elongata*.

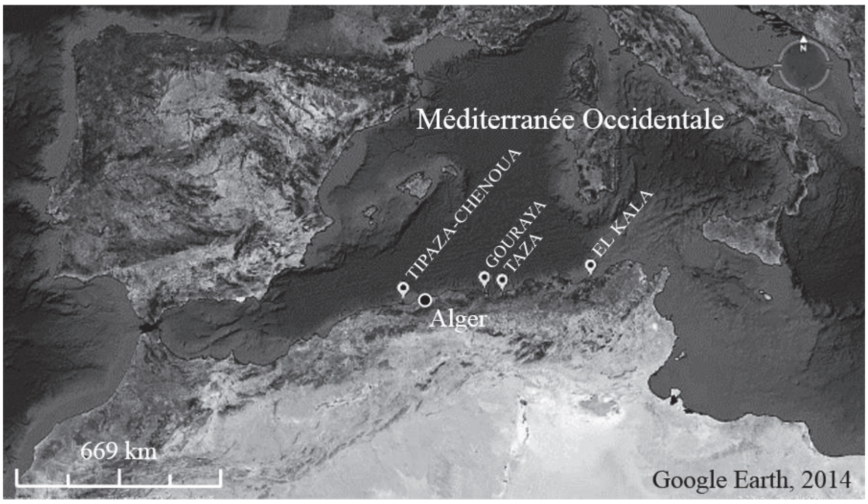

Fig. 1. Situation géographique de quelques Parcs Nationaux et Réserves Marines d'Algérie

Lithophyllum byssoides (Lamarck) Foslie, 1900

Ce Rhodophyte calcifié atteint son maximum de développement dans les biotopes légèrement ombragés ou situés en exposition nord. Il forme des concrétionnements de type III (Bianconi *et al.,* 1987) à Taza et Gouraya (Fig. 2 et 3).

Corallina elongata (J. Ellis & Solander)
Elle forme un concrétionnement de plusieurs mètres de linéaire juste en dessous des formations à *L. byssoides*. Une corniche remarquable est mise en évidence à El Kala, incluse dans une haute falaise présentant un visor (Fig. 4). Elle atteint près de 80 cm de large et les bourrelets se rencontrent à plus d'un mètre de profondeur (Fig. 5).

Dendropoma petraeum (Monterosato, 1884)
Les formations à vermets de la côte algérienne ont fait l'objet d'un inventaire (Bakalem, 2003). Ces structures, de type trottoir ou corniche (Fig. 6 et 7), sont édifiées par le gastéropode *Dendropoma petraeum* au niveau de la bordure externe.

Fig. 2. Encorbellement à *L. byssoides* et à *C. elongata* de type III (Gouraya)

Fig. 3. Encorbellement à *L. byssoides* et à *C. elongata* de type III (Taza)

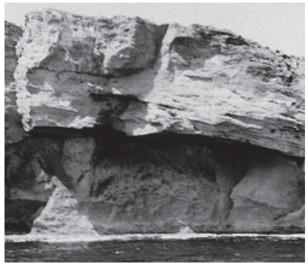

Fig. 4. Visor surplombant l'encorbellement à *C. elongata* (M'zarae, El Kala)

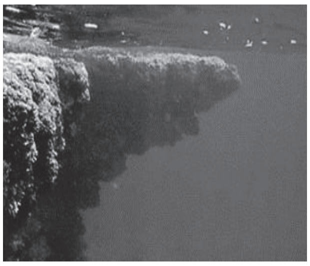

Fig. 5. Détail d'une corniche à *C. elongata* (Boutribicha, El Kala)

Fig. 6. Trottoir à vermets (Kouali, Tipaza-Chenoua)

Fig. 7. Corniche à vermets (Kouali, Tipaza-Chenoua)

Conclusion
La connaissance de la distribution spatiale de ces peuplements reste fragmentaire, il est donc préconisé d'intensifier les prospections. En outre, la mise en place de surveillance dans les secteurs, où ces peuplements pourraient fluctuer sous les actions anthropiques, est recommandée. Ces espèces, sensibles à la pollution des eaux de surface pourraient se révéler être des bioindicateurs de la qualité des eaux (Boudouresque, 1996).

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DISTRIBUTION OF *EUNICELLA CAVOLINI* (KOCH, 1887) ACROSS THE MEDITERRANEAN

Abstract
The distribution of Eunicella cavolini (Anthozoa) was mapped based on scientific data and observers' information, in order to depict its geographical range across the Mediterranean. Moreover, an overview of scientific literature was realized to assess the current state of knowledge regarding its populations. Results show that E. cavolini displays an extensive distribution, from the Alboran to the Sea of Marmara, but is more common at the Italian, French, E Adriatic and N Aegean coasts. Populations were mainly recorded at depths of <10-40 m, but also in deeper waters up to 220 m. Although E. cavolini is regarded as one of the most common structural species of Mediterranean hard substrates, including coralligenous outcrops, scientific information regarding its population dynamics, ecology, and conservation status is very limited and restricted to certain regions of the northwestern and central Mediterranean.

Key-words: Octocorallia, gorgonians, distribution, *Eunicella cavolini*, Mediterranean

Introduction
Coralligenous communities develop over a wide range of benthic habitats and encompass several assemblages. Mapping of constituent facies and acquisition of basic ecological information are key objectives to their conservation. *Eunicella cavolini* is one of the most common octocoral species in the W Mediterranean (Weinberg, 1980), while benthic assemblages dominated by this gorgonian have been acknowledged as one of the most typical coralligenous facies (UNEP/MAP, 2007). This work compiles information regarding the presence of *E. cavolini* populations across the Mediterranean, and provides new data from under-explored areas.

Materials and methods
Information on presence / absence and depth distribution of *E. cavolini* were defined based on a thorough review of scientific documents, grey literature, diving guides, communications with divers, and *in situ* scientific research. Point data were combined in a GIS platform to visualize the geographical information, while scientific literature was categorized according to geographical region and research topic.

Results
E. cavolini populations are represented by a total of 294 points, located in 13 biogeographic areas (Fig 1). Its bathymetric range was from 5 to 220 m (mean 29, S.D. 25.6 m). Although primarily recorded within the coralligenous, it was found over several habitat types (e.g. boulders, overhangs, caves, maërl, and sea mounts). Most populations were located at W Italy and France (43%), E Adriatic (34%), and N Aegean seas (14%). In the remaining areas only a few scattered populations were recorded, being generally absent along most parts of the Spanish coasts, while there is a notable lack of information in the Ionian, W Adriatic, and the southern or eastern parts of the Mediterranean basin. Furthermore, a total of 84 scientific documents reported information on *E. cavolini*, out

of which only 67.5% are included in the science citation index, while 71% concern the NW Mediterranean coasts. The majority of these documents elaborate on general species inventories / habitat mapping (40 studies), human impacts / mass mortality events (14), and taxonomy / genetics of gorgonians (7). Much fewer studies provide specific information on *E. cavolini* physiology / biochemistry (9), ecology (8), age / growth (6), or population characteristics (5).

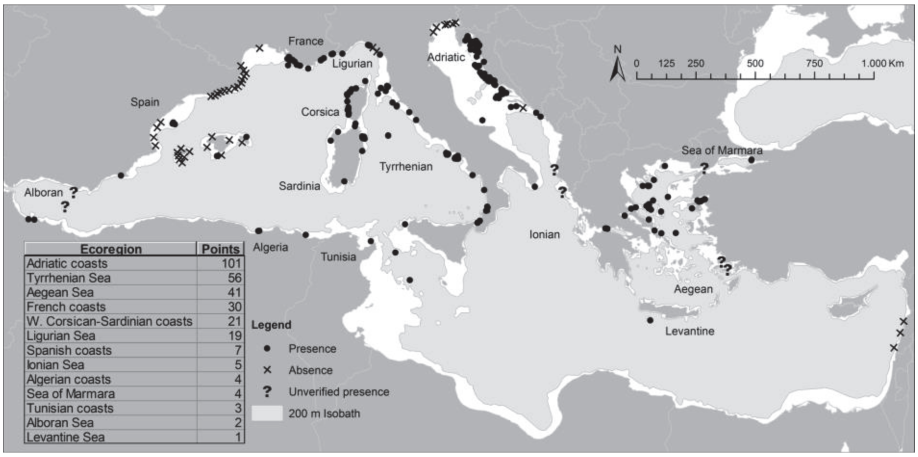

Fig. 1 Distribution of *E. cavolini* in the Mediterranean

Discussion and conclusions

E. cavolini populations display a patchy, yet relatively clustered distribution along the northern rocky coasts of the Mediterranean basin. Known to thrive on hard substrates (Weinberg, 1980), the lack of information in the W Adriatic and W Ionian coasts could partly be due to the predominance of aluvial coastal substrates in these regions. Additionally, oligotrophic conditions, higher water temperatures, and low research effort may justify the reduced presence in southern and eastern Mediterranean coasts. However, its notable absence along the well-studied rocky coasts of Spain is peculiar, especially in localities known to support dense populations of other gorgonians, e.g. *E. singularis* and *Paramuricea clavata*. Although knowledge on octocoral species has increased considerably over the last years, information regarding the ecology, demographics and conservation status of *E. cavolini* is essentially lacking, and should be reinforced to allow future monitoring of this widespread, long-lived gorgonian.

Acknowledgments

We are grateful to all observers for providing valuable information. This work was co-financed by the EU and Greek funds (NSRF 2007-2013: Heracleitus II), the Spanish Ministry of Economy & Innovation: Biorock (CTM2009-08045), and Smart (CGL2012-32194) projects, and the Croatian Ministry of Science & Education (119-0362975-1226).

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SUSPENSION FEEDER - DOMINATED CORALLIGENOUS COMMUNITIES IN THE LOWER SALINE LAYER OF THE MARMARA SEA: MAJOR OCTOCORAL ASSEMBLAGES

Abstract

This study was effectuated in the Marmara Sea where the Mediterranean waters are present after the halocline (approximately 20 m) formed by the strong salinity difference between the Aegean and Black Seas waters. Octocoral species present in the coralligenous communities were determined by scuba diving from the halocline to 40 m deep. Typical coralligenous species were found together with highly abundant atypical species: P. macrospina and S. klavereni. These two deep water Mediterranean endemic species are rarely encountered in the western Mediterranean, especially at the studied depth strate. Despite having Mediterranean waters down to 20 m, the Marmara Sea differs substantially from the Mediterranean by the constant temperature below 20 m (15ºC), high turbidity and trophic regime. These characteristics and the relatively isolation of the Marmara Sea from the Mediterranean could be the factors that influence the observed differences in suspension feeder dominated coralligenous assemblages.

Key-words: Marmara Sea, Coralligenous, Octocorals, Gorgonians, Eastern Mediterranean

Introduction

The Marmara Sea is a semi-enclosed sea, connecting the Black Sea to the Aegean Sea via the Turkish Straits System. It is characterized by the two layer stratification with the brackish surface layer formed by the Black Sea water mass, flowing into the Marmara Sea through the Istanbul Strait. 15-20 meters below this layer, resides more saline Mediterranean Sea water entering from the Aegean Sea via Çanakkale Strait. This study aimed at identifying the octocoral species that are present in the suspension feeder - dominated coralligenous communities of this particular semi-enclosed sea.

Materials and methods

Two locations in the north and south of the Marmara Sea were studied (Fig. 1).

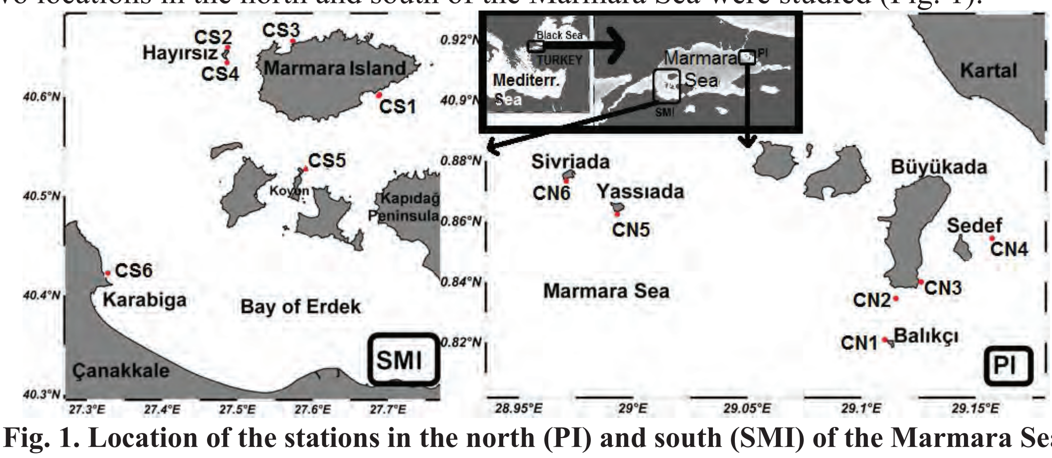

Fig. 1. Location of the stations in the north (PI) and south (SMI) of the Marmara Sea.

All sampling stations were characterized by coralligenous habitats dominated by suspension feeders (mainly polychaetes, and also hydrozoans, sponges and octocorals). Sampling took place in 6 stations at each location by scuba diving from the halocline (where the Mediterranean waters spring) until 40 m. Octocoral species that were present were photographed and sampled for identification. Samples were fixed with 10% formaldehyde and preserved in 70% ethanol.

Results

11 octocoral species were found at the study area: *Sarcodictyon catenatum, Alcyonium palmatum, A. acaule, A. coralloides, Paralcyonium spinulosum, Eunicella cavolini, E. verrucosa, E. singularis, Paramuricea macrospina, P. clavata* and *Spinimuricea klavereni*. In case of vertical walls/large rocks on steep bottoms, the substrate at the first 10 meters after the halocline was mainly colonized by polychaetes whose crevices were occupied by stoloniferous (*S. catenatum*) and encrusting soft corals (*A. coralloides*). About 28-38 m deep, the typical *E. cavolini* dominated coralligenous communities were found in both the north (CN1, CN5 and CN6) and the south (CS2). CN3 was also a station with relatively steep hard bottom composed of large rocks but the dominant gorgonian was *S. klavereni* between 27-40 m. The stations CN2 and CN4, located far from the coast where the hard bottom is an elevation from 20 to 50 m deep, the substrates were mainly occupied by Chaetopterid polychaetes colonized by *A. coralloides*, and among the tubes, an assemblage of octocorals composed mainly by *P. spinulosum*, *P. macrospina* and *S. klavereni*. In the south however, gorgonians were rarely encountered except in station CS2 and alcyonarians were the main octocorals found in the coralligenous communities.

Discussion and Conclusion

Coralligenous concretions are considered as the second key-ecosystem after *Posidonia oceanica* meadows in the Mediterranean. Animal assemblages in the coralligenous differ according to areas; in open areas, they are dominated by (mainly) gorgonians in relatively eutrophic areas whereas sponges and bryozoans dominate in oligotrophic ones (Ballesteros 2006). The coralligenous of the Eastern Mediterranean is thereby the second type; that of the Marmara Sea however, seems to be different from both types by the species composition of the suspension-feeders, particularly in the northern islands coasts. The gorgonians *P. macrospina* and *S. klavereni,* rare endemic species that are generally observed below 40 m, were present at all stations of the north from 20 m downwards, with relatively high abundances. As such, the ecosystem to which these communities are most similar in the Mediterranean, are the 70-130 m deep rocky shoals, characterized as turbulent environments, discovered off the Italian coasts (Bo *et al.*, 2012). Despite having Mediterranean waters down to 20 m, the Marmara Sea differs substantially from the Mediterranean by the constant temperature below 20 m (15ºC), high turbidity and trophic regime (mesotrophic-eutrophic). These characteristics together with the relatively isolation of the Marmara Sea from the Mediterranean could be the factors that influence the observed differences in suspension feeder dominated coralligenous assemblages. Despite the difference, they offer a similar aesthetic and economic value and deserve much concern and conservation effort.

Acknowledgments

The authors acknowledge the Istanbul University BAP Project number 4944.

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TECHNIQUE FOR THE RAPID ASSESSMENT OF CORALLIGENOUS FORMATIONS, COMBINING FISHERMEN KNOWLEDGE WITH BOAT-BASED SURVEYS: AN EASTERN AEGEAN CASE STUDY

Abstract
Coralligenous reefs are a highly diverse and structurally complex habitat, which is of fundamental importance to the productivity and longevity of fish stocks. They are therefore protected by international conventions as well as EU and national legislation. Despite their protection status, the lack of mapping of their distribution in the majority of Mediterranean countries, including Greece, results in the inefficient enforcement of these laws. This pilot study aims to develop a rapid and cost effective technique for the mapping of coralligenous formations by combining the knowledge of local artisanal fishermen with boat-based surveys in the North Dodecanese region of the eastern Aegean Sea (eastern Mediterranean). A total of 73 coralligenous locations were identified and studied in a depth range between 50-87m over a seafloor area of 13.63km². The findings of this pilot methodology will allow the efficient enforcement of national and international legislation and help to promote the protection of this productive marine habitat.

Key-Words: Eastern Aegean, Coralligenous, Mapping, Underwater video system, Mediterranean

Introduction

Coralligenous formations comprise a highly diverse and structurally complex habitat (Ballesteros, 2006). A series of established EU and national legislation concerns the protection and conservation of coralligenous habitats within the Mediterranean (European Commission, 2006; UNEP-MAP-RAC/SPA, 2008). The current lack of mapping for the presence and distribution of coralligenous formations in the majority of the Mediterranean countries results in the inefficient enforcement of the aforementioned legislation. The present pilot study aims to develop a rapid and cost effective technique for the mapping of coralligenous ecosystems, providing essential and accurate cartographic data in the eastern Aegean Sea.

Materials and methods

The pilot survey of coralligenous formations was carried out in two stages. The first stage consisted of the utilisation of the knowledge of local artisanal fishermen of Lipsi and Leros island who marked the location of coralligenous formations on both blank paper maps and boat surveys. The second stage of the survey was the verification of the locations indicated by the local fishermen using an underwater camera system, singlebeam echosounder and downscan sonar over a seafloor area of 13.63 km² (Fig. 1).

Results

The joint boat surveys with the fishermen provided 100% accuracy for the identification of coralligenous reefs in comparison with the lower accuracy on the case of indicated areas on blank maps, where the general area was identified, but not the exact location. A total of 73 coralligenous locations were identified and studied in a depth range between 50-87m. Locations indicated on boat surveys revealed 22 coralligenous reefs, whilst locations suggested via marking on blank maps showed 51 different coralligenous assemblages. The coralligenous formations were further distinguished into superficial formations and minute reefs.

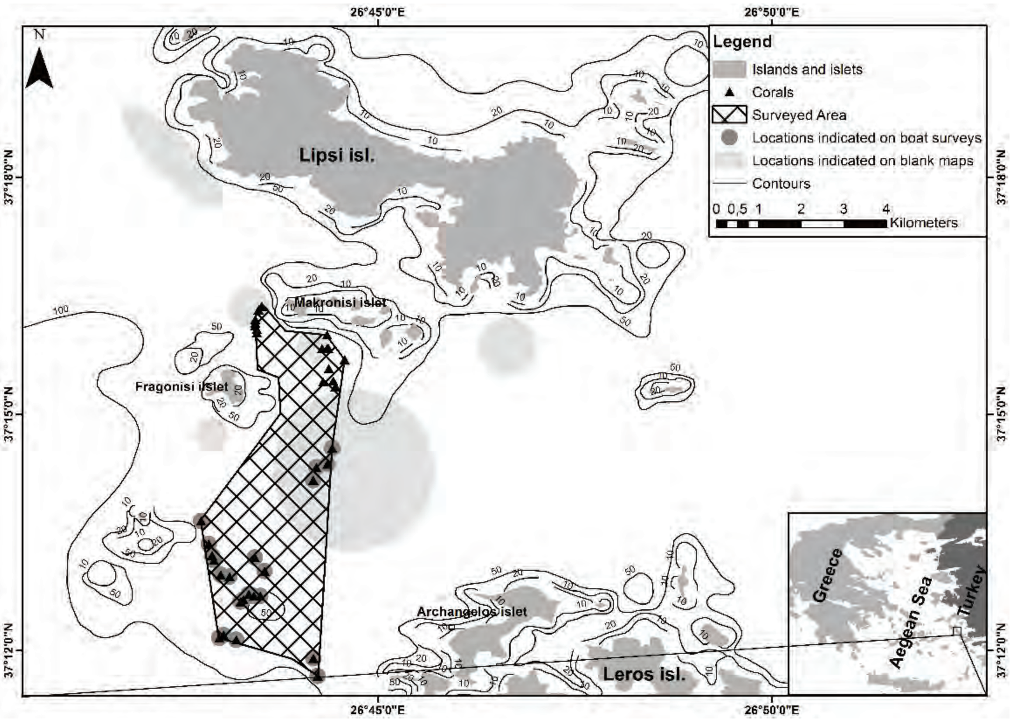

Fig. 1: Contoured bathymetric map of the marine area between and surrounding Lipsi and Leros islands, displaying the combination of the indicated locations by fishermen and the surveyed area, along where coralligenous formations were identified and mapped

Discussion

The technique implemented herein combines local fishermen knowledge, a previously neglected source of information, with boat-based surveys. This proves to be a reliable time and cost-efficient method for the qualitative assessment of the presence, distribution and morphology of coralligenous formations. The technique can help in the effective conservation and management of these fundamentally important and productive marine ecosystems.

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FIRST FINDING OF A NEW ENCRUSTING CORALLINE ALGA IN THE ADRIATIC SEA (MEDITERRANEAN)

Abstract
The genus Hydrolithon, together with Porolithon, is one of the most discussed groups of Corallinaceae, as well as one of the most poorly known. Morphological observations led to different interpretations mainly due to the lack of type material. Recently molecular surveys on the phylogeny of Corallinales supported the hypothesis of considering Hydrolithon and Porolithon as two distinct genera, but, up to now, several taxonomic questions remain partially unanswered. In this study we report the discovery of a new non-geniculate encrusting species found along the coast of Vis Island, Croatia, Adriatic Sea. Morphological observations suggest that the specimens could belong to the Hydrolithon/Porolithon complex. Molecular analyses based on the nuclear 18S rDNA (SSU) and the plastidial psbA markers were carried out. This finding represents the first report of this new coralline alga in the Mediterranean Sea.

Key-words: non-geniculate Corallinaceae, Adriatic Sea, nSSU, *psb*A

Introduction

The genera *Porolithon* and *Hydrolithon* were established by Foslie in 1909 and comprise several species characterized by non-geniculate thalli, growing usually as crusts. Non-geniculate corallinaceae are subject to phenotypic plasticity, depending on different environmental conditions (Woelkerling *et al.*, 1993).

Many species, as well as several genera, are poorly known and their taxonomic status is controversial, up to now. In fact, some characters traditionally used for species identification or genus delimitation are still ambiguous and the lack of reference type material make the systematics of this group very problematic (Maneveldt, 2005; Penrose & Chamberlain, 1993). Nowadays, it is evident that to solve taxonomic issues like the identification of taxonomic complex genera and species among Corallinaceae requires a polyphasic approach, including both observation of vegetative and reproductive features and molecular analyses.

In this study we report the discovery of a new non-geniculate encrusting species, found during a monitoring campaign along the coast of Vis Island, Croatia, Adriatic Sea. To identify the samples morphological and molecular analyses, based on the nuclear nSSU and the plastidial *psb*A markers, were done.

Materials and methods

Genomic DNA was extracted following the procedure listed in Broom *et al*., (2008). To amplify the nuclear gene nSSU two specific primers for Corallinales were constructed: 18S-MelF and 18S-MelF2. Amplification of the plastidial *psb*A gene was carried out using the primers psbA-F and psbA-R2 listed in Yoon *et al*., (2002). PCR reactions for both the genes were performed according to Broom *et al.,* (2008). Sequencing of the amplified fragments was accomplished with the same primer pairs at the BMR Genomics Sequencing Service (Padova University). Phylogenetic analyses were performed using the MEGA 5.1 (Molecular Evolutionary Genetics Analysis) program according to

Maximum Likelihood (ML), applying the GTR+I+G evolutionary model, and Maximum Parsimony (MP) Methods.

Results

The ML phylogenetic tree obtained using the nSSU marker detected 6 separate groups of sequences representing 5 different Corallinaceae subfamilies (Corallinoideae, Lithophylloideae, Metagoniolithoideae, Hydrolithoideae, and Porolithoideae) and 1 Hapalidaceae subfamily (Melobesioideae). The sequence of our Adriatic sample is sister group to the subfamily named Porolithoideae, including several sequences of species attributed to the genera *Hydrolithon* and *Pneophyllum*. Also in the *psb*A tree the sequence of our isolate formed a supported clade with sequences of specimens included in the '*Porolithon'* group and attributed to the genus *Hydrolithon* and the genus *Pneophyllum*.

Discussion and conclusions

First morphological observations of our samples reveal their possible belonging to the *Hydrolithon/Porolithon* complex and in particular to the species *Hydrolithon rupestre* (Foslie) Penrose. The phylogenetic reconstructions, based on the nSSU and on the *psb*A markers, showed that our sample is phylogenetically related to the subfamily Porolithoidae and in particular to the species *Pneophyllum conicum* and *Hydrolithon samoense*. As reported by Kato *et al.* (2011) the phylogenetic positions of some *Hydrolithon* species, *H. improcerum*, *H. murakoshii*, and *H. samoense*, is still unclear. For this reason a morphological and molecular comparison with specimens of *H. rupestre* and *H. samoense* is necessary to establish the correct taxonomic position of our specimens.

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RECOMMENDATIONS

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RECOMMANDATIONS

RECOMMENDATIONS OF THE 2nd MEDITERRANEAN SYMPOSIUM ON THE CONSERVATION OF CORALLIGENOUS & OTHER CALCAREOUS BIO-CONCRETIONS

In the light of the work presented at this Symposium, we should stress the strides made in knowledge of these formations since the first, Tabarka, Symposium in 2009. The strong participation of the Mediterranean scientific community, and the quality and number of the papers, confirm the interest of these meetings.

The main concerns are both the acquisition of new knowledge about the species or the distribution of these formations, and the means of understanding their good ecological state and how to conserve them more efficiently.

The introductory session presented the CIGESMED Programme, which, based on the coralligenous, aims at identifying indicators for assessing and monitoring the good ecological state of the coastal waters of the Mediterranean. One specific feature of the project is the geographical area that it addresses (the western and eastern basins).

Session 1 aimed to give an appraisal on the progress that has been made in the knowledge of coralligenous formations.
The discussions particularly addressed the standardization of methods for data comparison. The diversity of approaches and tools is a result of the multiple objectives pursued. Recourse to several complementary tools was often noted, and a predominance of non-destructive methods (photographs, videos, ROV, acoustic detection methods) was recorded.
There is an obvious need to have the same type of data in order to compare it over several scales and biogeographical areas. What is important is to make sure that the data is reproducible, reliable, and representative, given that the aim is always to best adapt the sampling effort to these parameters. It is also interesting to be able to keep the raw data in order to re-study it, given that one of the limiting factors is often the qualification of the operator.
Some participants recalled the need to have user-friendly tools for monitoring these formations.

Session 2 addressed the impact of global change.
The work presented showed marked differences in terms of the vulnerability of the structuring species of the coralligenous (*Cladocora caespitosa*, *Corallium rubrum*, *Paramuricea clavata*) and stressed the risks of significant changes (disappearance or appearance of new species), things which are likely to restrict these formations' capacity for recruitment and restoration. Future development of the work could consist of better identifying the share of environmental change, specifically linked to climate change, in degrading other environmental factors.

Session 3 was devoted to the mapping and monitoring of coralligenous habitats. Discussions stressed the great diversity of these formations and the complexity of the coralligenous and other bioconstructions, and the chance offered to the scientific community to discuss and propose new facies for integration within the Barcelona Convention's Habitats List. These lists can later be taken into consideration in the context of the European Commission's normative approaches.

The impact of fishing activities on coralligenous populations was mentioned by several participants; they argued that it is difficult, even within the MPAs, to find formations that are unharmed by any form of fishery (traditional, recreational or commercial).

Session 4 concerned genetic studies of key species of the coralligenous.
Genetics seems to be an innovative tool that can perhaps respond more efficaciously to the requirements of the identification of sites, adapted to the conservation of coralligenous formations and to the prediction of impacts linked to climate change. In the light of these techniques' potential, it was suggested that they be extended to other species and other parts of the Mediterranean.

During the discussion that followed, the interest of multidisciplinary approaches was mentioned with particular attention to the geomorphologic aspects that are important elements in the structuring of the coralligenous. As well as lists of characteristic species of the coralligenous formations, it would be useful to record the features of the habitat sampled.

Session 5 has concerned management of coralligenous habitats and other bio concretions. This session revealed that anthropogenic pressures on coralligenous habitats are apt to affect the deepest sites. Although many economic actors (eg divers, fishermen, coral divers) seem to be aware of the conservation issues in these habitats, it appears necessary to better evaluate and quantify the pressures exerted in standardized approach that can be comparable on a large scale

The discussion allowed to highlight the importance of shared and open information systems, where data on the ecological status and pressures would be accessible, standardized and therefore comparable. Although some broadcast platforms exist, an effort could be made in terms of availability and reliability. It was recalled that despite the emergence of new indicators to compare the ecological status or the pressures on these habitats, evaluation is often based, for lack of sufficient resources, solely on expert opinion. In the same way, several participants highlighted the dramatic lack of mapping data on these habitats for the Southern and Eastern Mediterranean.

The round table on updating the list of species to be taken into consideration in the context of mapping and monitoring habitats aroused the interest of participants in this type of approach. However, no consensus emerged as to the amendments to be made to the current list. In this respect, the participants suggest setting up, under the aegis of RAC/SPA, theme-based working groups (list of typical species, genetics, mapping, state of conservation etc.). The aim would be using themes to group efforts (synthesis of current knowledge, standardizing work methods, etc.), and sharing information to propose *in fine* conclusions likely to give better management and conservation of the coralligenous and other Mediterranean bioconstructions.

The round table on protecting coralligenous habitats based on scientific knowledge and the present legislative context recalled that European laws ban trawling over the coralligenous, rhodolith beds and marl. The absence of an official map of the distribution of these beds acts as a brake on implementing the regulations. It is thus necessary that already available information be handed to the competent bodies.
The interest in making the public aware of the importance of these formations was recalled.
An assessment of the ecosystem services rendered by these formations would also help their economic value to be highlighted.

In the light of all these considerations, the participants advise:

- Encouraging the states to elaborate their National Action Plans for the protection of the coralligenous and other bioconstructions and start implementing these as soon as possible
- Urging the states to validate existing maps so that these may be taken into consideration in the context of implementing regulations on commercial fisheries
- Suggesting that RAC/SPA:
    - Set up collaborative tools to help scientists to exchange data and share their experience
    - Help countries start awareness campaigns on the interest of protecting coralligenous habitats and training and capacity-building sessions
    - Start addressing the assessment of ecosystem services rendered.

RECOMMANDATIONS DU 2ème SYMPOSIUM MEDITERRANEEN SUR LA CONSERVATION DU CORALLIGENE ET AUTRES BIO-CONCRETIONS

Au regard des travaux présentés durant ce symposium, il convient de souligner les nombreux progrès effectués en terme de connaissance de ces formations depuis le premier symposium de Tabarka en 2009. La forte participation de la communauté scientifique méditerranéenne, la qualité et la multiplicité des communications confirment l'intérêt de ces rencontres.

Les principales préoccupations concernent aussi bien l'acquisition de nouvelles connaissances, relatives aux espèces où à la distribution de ces formations, qu'aux moyens d'appréhender leur bon état écologique et aux démarches à mettre en place pour les conserver plus efficacement

La séance introductive a permis de présenter le programme CIGESMED qui vise en se basant sur le coralligène à identifier des indicateurs à même d'évaluer et de surveiller, le bon état écologique des eaux côtières de Méditerranée. Un des originalités du projet consiste dans l'aire géographique prise en compte par le projet (bassin occidental et oriental).

La session 1 visait à faire un état d'avancement des connaissances sur les formations coralligènes.
Les discussions ont abordé en particulier la standardisation des méthodes en vue de la comparaison des données. La diversité des approches et des outils s'explique par les objectifs multiples poursuivis. On note souvent un recours à plusieurs outils complémentaires et on enregistre une prédominance des méthodes non destructives (photographies, vidéos, ROV, méthodes de détections acoustiques).
Le besoin de disposer du même type de données pour les comparer, à plusieurs échelles et dans des zones biogéographiques est évident. L'important est de s'assurer de la reproductibilité de la donnée, de sa fiabilité, de sa représentativité, sachant que l'objectif est toujours d'adapter au mieux l'effort d'échantillonnage à ces paramètres. Il est également intéressant de pouvoir conserver la donnée brute afin de pouvoir la réétudier, sachant que l'un des facteurs limitant reste souvent la qualification de l'opérateur.
Quelques participants ont rappelé la nécessité de disposer d'outils faciles à mettre en œuvre pour la surveillance de ces formations.

La session 2 a abordé l'impact des changements globaux.
Les travaux présentés ont montré des différences marquées en terme de vulnérabilité des espèces structurantes du coralligène (*Cladocora caespitosa*, *Corallium rubrum, Paramuricea clavata*) et soulignés les risques de modifications significatives (disparition ou apparition de nouvelles espèces), éléments qui sont de nature à limiter les capacités de recrutement et de restauration de ces formations. Une future évolution des travaux pourrait consister à mieux identifier la part des modifications environnementales, liées spécifiquement aux changements climatiques, de la dégradation des autres facteurs environnementaux.

La session 3 était dédiée à la cartographie et à la surveillance des habitats coralligènes. Les discussions ont souligné la grande diversité de ces formations et la complexité du coralligène et des autres bioconcrétionnements et l'opportunité donnée à la communauté scientifique de discuter et de proposer de nouveaux facies à intégrer dans la liste des habitats de la Convention de Barcelone. Ces listes pouvant ensuite être prises en considération dans le cadre des démarches normatives de la Commission Européenne.

L'impact des activités de pêche sur les peuplements coralligène a été évoqué par plusieurs participants, soulignant qu'il est difficile, même dans les AMP, de trouver des formations indemmes de toutes formes de pêche (artisanale, plaisancière ou professionelle).

La session 4 a concerné les études génétiques d'espèces-clés du coralligène. La génétique apparaît comme un outil innovant à même de répondre peut être plus efficacement aux besoins d'identification de sites, adaptés à la conservation des formations coralligène et à la prédiction des impacts liés aux changements climatiques. Au regard des potentialités de ces techniques, il a été proposé de les étendre à d'autres espèces et d'autres zones de la Méditerranée.

Au cours de la discussion qui a suivi l'intérêt des approches pluridisciplinaires a été rappelé avec une attention particulière à porter aux aspects géomorphologiques qui sont des éléments importants dans la structuration du coralligène. Au-delà de la liste des espèces caractéristiques des formations coralligènes, il serait opportun d'enregistrer les caractéristiques de l'habitat échantillonné.

La session 5 a concerné la gestion des habitats coralligènes et autres bio concrétions. Cette session a montré que les pressions anthropiques qui s'exercent sur les habitats coralligènes peuvent avoir des impacts jusqu'aux sites les plus profonds. Même si plusieurs acteurs économiques (e.g. plongeurs, pêcheurs, corailleurs) semblent avoir pris conscience des enjeux de conservation de ces habitats, il semble nécessaire de mieux évaluer les pressions qui s'exercent et de les quantifier de manière normée et comparable à large échelle.

La discussion a permis de mettre en évidence l'intérêt de systèmes d'information partagés et ouverts, où les données sur l'état écologique et les pressions seraient accessibles, normées et donc comparables. Même si quelques plateformes de diffusion existent, un effort pourrait être fait en terme de disponibilité et de fiabilité des données. Il a été rappelé que malgré l'émergence de nouveaux indicateurs permettant de comparer l'état écologique ou les pressions subies par ces habitats, l'évaluation reste souvent basée, faute de moyens suffisants, sur le seul dire d'expert. De même plusieurs participants ont soulignés le manque criant de données cartographiques, concernant ces habitats, pour les pays du Sud et de l'Est de la Méditerranée

La table-ronde relative à l'actualisation de la liste des espèces à prendre en considération dans le cadre de la cartographie et du suivi des habitats a permis de souligner l'intérêt des participants pour ce type de démarche. Néanmoins aucun consensus n'a émergé quant aux amendements à porter à la liste actuelle. A cet égard, les participants proposent de mettre en place, sous l'égide du CAR/ASP, des groupes de travail thématiques (liste des espèces typiques, génétique, cartographie, état de conservation, etc.). L'objectif serait par thématique de réunir les efforts (synthèse des connaissances actuelles, standardisation des méthodes de travail, etc.), de partager les informations pour proposer *in fine* des conclusions à même de permettre une meilleure gestion et conservation du coralligène et des autres bioconcrétionnements de Méditerranée.

La table ronde relative à la protection des habitats coralligène sur la base des connaissances scientifiques et du contexte législatif actuels a rappelé que la législation européenne interdit le chalutage sur le coralligène, les fonds à rhodolithes et de maërl. L'absence de carte officielle de distribution de ces fonds est un frein à l'application de la réglementation. Il y a donc un besoin de transférer les informations déjà disponibles aux organismes compétents.
L'intérêt de sensibiliser le public à l'importance de ces formations a été rappelé. En particulier les participants ont rappelé l'important déficit de formation des pays du sud et de l'Est du bassin et la nécessité de mettre en place un renforcement des capacités en la matière.
Une évaluation des services écosystémiques, rendus par ces formations, permettrait également de souligner leur valeur économique et de, sans doute, mieux les prendre en considération.

Au regard de l'ensemble des réflexions, les participants conseillent :

- D'encourager les états à élaborer leur plan d'action national pour la protection du coralligène et des autres bioconcrétionnements de Méditerranée et d'initier leur mise en œuvre dans les meilleurs délais.
- D'inciter les états à valider les cartes existantes, de façon à pouvoir les prendre en considération dans le cadre de l'application des réglementations relatives à la pêche professionnelle.
- De proposer au CAR/ASP de :
    - Mettre en place des outils collaboratifs pour favoriser l'échange des données entre scientifiques et toutes initiatives destinées à faciliter le partage d'expériences. A cet effet des groupes de travail, sur des thématiques scientifiques ciblées, pourraient être mis en place sur la base du volontariat et avec l'appui technique du Centre.
    - Assister les pays à initier des campagnes de sensibilisation sur l'intérêt de la conservation des habitats coralligènes et en particulier des formations profondes
    - Initier un programme d'acquisition sur la distribution des habitats coralligènes et des autres bioconcrétionnements pour les pays du Sud et de l'Est de la Méditerranée.

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