The Mediterranean Biodiversity Centre

SPA/RAC

PROCEEDINGS OF THE 6th MEDITERRANEAN SYMPOSIUM ON MARINE VEGETATION

ANTALYA, TURKEY, 14-15 JANUARY 2019

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Proceedings of the 6th Mediterranean Symposium on Marine Vegetation

FORWARD

Dear Friends and Colleagues,

Following the recommendations of:

- the **Action Plan for the Conservation of Marine Vegetation in the Mediterranean Sea** (adopted by the Contracting Parties to the Barcelona Convention in 1999 and updated in 2012)
- the **Action Plan for the Conservation of Coralligenous and other calcareous bio-concretions of Mediterranean** (adopted by the Contracting Parties to Barcelona Convention in 20018 and updated in 2016)
- the **Action Plan for the conservation of habitats and species associated with seamounts, underwater caves and canyons, aphotic hard beds and chemo-synthetic phenomena in the Mediterranean Sea** (Action Plan for Dark Habitats adopted by the Contracting Parties to the Barcelona Convention in 2013), and
- the **Action Plan concerning Species Introduction and Invasive Species** (Adopted by the Contracting Parties to the Barcelona Convention in 2003 and updated in 2016)

a series of scientific symposia, dedicated to these habitats and NIS, was initiated in 2000 by organising the first Mediterranean Symposium on Marine vegetation. These initiatives aimed essentially to take stock of the recently available scientific data and to promote the cooperation between specialists and key actors working in the Mediterranean.

The Mediterranean Symposia on Marine Key Habitats are an important output, not only of the UNEP/MAP Mid-Term Strategy for the period 2016-2021 (Decision IG.22/1)[1], but also for MedKeyHabitats II Project[2] “Mapping of marine Key habitats and assessing their vulnerability to fishing activities in the Mediterranean” financed by MAVA foundation under its Mediterranean Strategy.

The "Mediterranean Symposia on Marine Key Habitats and NIS" will also provide an opportunity to discuss best practices in the monitoring of marine key habitats and non-indigenous species and provide elements to further improve the Integrated **Monitoring and Assessment Programme of the Mediterranean Sea and Coast and related Assessment Criteria (IMAP)**, of the Ecosystem Approach (EcAp) in the Mediterranean.

The organization of the "Mediterranean Symposia on Marine Key habitats and NIS" together back to back in Antalya from 14 to 18 January, is a joint collaboration among **UNEP/MAP-SPA/RAC** and the **Turkish Ministry of Environment and Urbanization**, as follows :

- 6th Mediterranean Symposium on Marine vegetation (from 14 to 15 January 2018)
- 3rd Mediterranean Symposium on the Conservation of Coralligenous and other Calcareous Bio-Concretions (From 15 to 16 January 2018)
- 2nd Mediterranean Symposium on the Conservation of the Dark Habitats (17 January 2018)
- 1st Mediterranean Symposium on the Non-Indigenous Species (From 17 to18 January 2018)

The Turkish Marine Research Foundation, **TUDAV**, as **SPA/RAC** partner will support the local organization of this event.

This edition will also be a good opportunity to discuss new topics such as monitoring and definition of Good Environmental Status (GES) in the Mediterranean and so strengthen links between scientists and scientific institutions.

Khalil ATTIA
SPA/RAC Director

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[1] https://wedocs.unep.org/bitstream/handle/20.500.11822/6071/16ig22_28_22_01_eng.pdf?sequence=1&isAllowed=y
[2] http://www.rac-spa.org/medkeyhabitats2

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PROGRAMME

Monday 14 January 2019

8:00-9:00 Participants welcome and registration

9:00-10:00 **Opening of the Symposium**

- **Welcome speech** by **Mr. Khalil ATTIA**, *Director, UNEP-MAP-SPA/RAC*
- **Opening Speech** by **Ahmet DERMITAS** Deputy General Director for the Protection of National Assets/Ministry of Environment and Urbanisation
- Presentation on the Mediterranean Key Habitats and NIS in Turkey by **Mr. Bayram Öztürk**
- Mediterranean Sea and Biological Invasion**,** a documentary by **Turkish Radio and TV**

10:00-10:30 ***Coffee break***

10:30-11:00 Keynote conference: "**Strategy to study blue carbon ecosystems in Corsica**" by **Gérard PERGENT**, BARRALON E., MONNIER B., PERGENT-MARTINI C., VALETTE-SANSEVIN A.

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Chair : Ivan GUALA, **Rapporteur** : Atef LIMAM

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11:45-12:00 "**Characterisation of the *Posidonia oceanica* meadow in Rachgoun Island (Ain Temouchent, Algeria)**" by **Raouf HADJ AISSA**, BOUSTILA S., BENIDIR N., BENABDI M., RAMOS ESPLA A., VALLE C., FORCADA ALMARCHA A., SGHAIER Y.R.

12:00-12:15 "**Mapping of *Posidonia oceanica* (L.) Delile in the bay of Gülbahçe**" by **Güzel YÜCEL-GIER**, KOÇAK G., AKÇALI B., İLHAN T., DUMAN M.

12:15-12:30 "**Almost a century of monitoring of the *Posidonia* barrier reef at Port-Cros (Provence) and the platform reef at Saint-Florent (Corsica)**" by **Alizée BOUSSARD**, BARRALON E., BOUDOURESQUE C.F., BOURSAULT M., GOUJARD A., PERGENT G., PERGENT-MARTINI C., ROUANET E., SCHOHN T.

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14:15-14:30 "**Regression of *posidonia oceanica* lower limit: a consequence of climate change?**" by **Gérard PERGENT**, BARRALON E., PERGENT-MARTINI C.

14:30-14:45 "**The withdrawal of the lower limit of the *Posidonia oceanica* seagrass meadow in the Bay of Hyères (NW Mediterranean): a combination of natural and human-induced recent and ancient phenomena?**" by **Charles-F. BOUDOURESQUE**, ASTRUCH P., GOUJARD A., ROUANET E., BONHOMME D., BONHOMME P.

14:45-15:00 "**Construction underwater landscape by using *Posidonia oceanica* transplanting combined with innovative artificial reefs**" by **Agostino TOMASELLO**, PIRROTTA M., COSTANTINI C., CALVO S.

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Session 2: Seagrass beds and other habitats

Chair : Yelda AKTAN, **Rapporteur** : Yassine Ramzi SGHAIER

16:00-16:15 "**Habitat mapping in marine protected areas: contributions to management plans in Foça and Kaş-Kekova special environmental protection areas**" by **Barış AKÇALI**, KABOĞLU G., BIZSEL K.C., KAVCIOĞLU R., SAVAŞ Y., BENGIL F., ÖZAYDINLI M., KAYAALP J., SÖNMEZ FLITMAN R., ERGÜN G., GÜÇLÜSOY H.

16:15-16:30 "**An ecological survey of benthic bioseonosis and bottom types around the Kerhennah archipelago with a view to designation as a Marine Protected Area**" by **Cyrine BOUAFIF**, PERGENT G., KHERIJI A., LIMAM A., ASMI S., LANGAR H.

16:30-16:45 "**Seagrass in Tunisian lagoons: *Cymodocea nodosa* meadows facing pollution threats**" by **Imen ZRIBI**, MNASRI I., CHARFI-CHEIKHROUHA F., ZAKHAMA-SRAIEB R.

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8:45-9:00 "**Marine algal forests in the Levantine Basin: the case of *Cystoseira rayssiae* along the Israeli coast**" by **Martina MULAS**, SILVERMAN J., ISRAEL A., GOLOMB D., RILOV G.

9:00-9:15 "**When life history matters: contrasting conservation actions for two co-occurring *Cystoseira* species in NW Mediterranean**" by **Pol CAPDEVILA**, MEDRANO A., ASPILLAGA E., MONTERO-SERRA I., PAGÈS-ESCOLÀ M., ROVIRA G., HEREU B., LINARES C.

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9:30-10:00 **Poster Session**

10:00-11:30 ***Round table on restoration activities examples in Mediterranean Sea***
Moderators: Agostino TOMASELLO

11:30-12:00 **Awards for best poster**

12:00-12:15 **Closure of the Symposium**

12:15-14:00 ***Lunch***

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KEYNOTE CONFERENCES

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Université de Tunis El Manar, UR17ES10, Département de Biologie,Faculté des Sciences de Tunis, 2092 Tunis, Tunisie
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PREDICTING *CYSTOSEIRA* SPECIES DISTRIBUTION IN TUNISIA USING MAXIMUM ENTROPY METHOD (MAXENT)

Abstract

The potential spatial distribution of Cystoseira *species in Tunisia was predicted by combining observed occurrence records with environmental variables. This technique seems to be effective when the occurrence records are scarce, or the distributions are restricted or even in the case of low sampling effort. Models were developed and evaluated for 30 species of Tunisian* Cystoseira*, most of them are endemic to Mediterranean Sea and rare at regional scale. Predictions were based on 14 environmental data layers and were generated using the maximum entropy method (MaxEnt).*

Predictive distribution maps generated of Tunisian Cystoseira *species followed the general trend of their actual distribution. The presence-only models indicated that species appear distributed mainly according to their affinity to water temperature and wave exposure and allowed to classify them into (i) northern species having affinities for cold waters, hard substrata and for strong wave action, (ii) south-eastern species with an affinity to warm waters and preferring low hydrodynamism and (iii) ubiquitous species.*

Our analyses showed that geographical predictions developed from small numbers of occurrence records would be particularly useful for predicting the geographical distribution of species of special status. It could be helpful for developing possible management strategies for Cystoseira *species and their habitats.*

Key-words: *Cystoseira*, MaxEnt, species-distribution, modelling, Tunisia.

Introduction

Information on the spatial distribution of species and communities in ecosystems is a crucial requirement for the understanding of ecosystem functioning and processes as well as for guiding the conservation planning. Unlike the terrestrial systems, species in the marine environment are quite difficult to access and monitor since biogeographical data are scarce and fragmentary due to ambiguous habitats, locally restricted distributions and/or low sampling effort. Therefore, predictive methods became important to overcome these problems (Raxworthy *et al*., 2003, Guisan & Thuiller, 2005). Predictive modeling of species geographic distributions based on the environmental conditions of sites of known occurrence constitutes an important tool to address various issues in ecology, detection of unknown distributional areas and undiscovered species, predicting species invasions, projecting potential impacts of climate change and conservation planning (e.g. Peterson *et al*., 1999; Ferrier *et al*., 2002; Raxworthy *et al*., 2003; Peterson & Shaw, 2003 ;Thuiller *et al*., 2005).

Being the main habitat-forming species of the photophilous rocky substrates, species of the *Cystoseira* genus C. Agardh (Fucales, Phaeophyceae) are of high natural and heritage value in the Mediterranean. Most of these species are threatened and endangered, so they are listed in the amended Annex II of the Protocol of the Barcelona Convention concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD protocol) (UNEP-

PAM-RAC/SPA, 2012); In Tunisia, the field investigation to make an inventory of species of the genus *Cystoseira* does not cover the whole Tunisian littoral and is insufficient to implement a strategy for the conservation of different species along the entire coastline. To address these challenges, we used distribution modelling technique, in particular, "Maximum Enthropy Mothod (MaxEnt)" developed by Phillips *et al*. (2006). This method allows establishing relationships between occurrences of species and environmental conditions in the study area. In this context, this work was conducted and aimed to (1) predict distribution models of Tunisian *Cystoseira* species along the Tunisian coast; (2) identify the environmental factors that likely influence *Cystoseira*'s habitat distribution; (3) assess the usefulness of the predictive modelling based on species/environment relationships to blend data from scattered samples into rational maps of distributions of species and habitats at the southern Mediterranean; and eventually (4) to propose the use of this predictive technique at regional scale for all the Mediterranean coasts.

Materials and methods

<u>Study area and data collection</u>

This study was conducted with data relating to 27 *taxa* of *Cystoseira*, 12 of which are endemic to the Mediterranean and rare or new for Tunisia. Field survey was carried out from March 2012 to December 2015 and concerned 124 sampling stations distributed all along the Tunisian coast from the Algerian border (Melloula Bay, 36° 57' 46.65"N; 8° 42' 55.35"E) to the Libyan border (Tunisian port of El Ketef, 33°10'54.77" N; 11°29'3.49" E). Moreover, some historical reports of certain of these 27 *Cystoseira* were added to constitute a database that includes information on the sampling stations of each species (latitude, longitude, habitat description).

<u>Environmental data layers</u>

A total of 14 predictive variables were pre-selected for modelling. Among them, 3 are qualitative (categorical variables): type of substratum, hydrodynamism and anthropic pressure and 11 are quantitative (continuous variables): Mean Annual Minimum and Maximum Temperature, Min Temperature of Coldest Month, Max Temperature of Warmest Month, Max and Min Temperature of the sea surface, Monthly Mean Insolation, Maximum and minimum Salinity, Precipitation and Evaporation. The climatic and geomorphological characteristics of all Tunisia and its coastal coastline come from various reliable databases. The categorical variables are derived from *in situ* observations during the sampling. For bioclimatic variables, data were provided by the National Meteorological Institute as a series of data between 2007 and 2011 and were supplemented and adjusted by data available from World clim bioclimatic database (http://www.worldclim.org/). All data were integrated into a Geographical Information System using the "ArcGIS 10.2" software for the development of georeferenced maps representing the different geomorphological and environmental features along the Tunisian coastline. All predictors were previously tested for multicollinearity of independent variables using the Pearson correlation test, and only those with a correlation coefficient lower than 0.8 were considered ($r<0.8$). These analyses were performed with IBM® SPSS® version 20.0.

<u>Species distribution modeling</u>

The ecological niches of the 27 Tunisian *Cystoseira* species are built using a presence-only niche modelling technique based on the maximum entropy principle MaxEnt (Phillips *et al*.,2006). To obtain a species distribution model, two types of input were used: (1) the presence data (a set of all the occurrence stations where the considered species is reported in the actual and historical literature) and, (2) the environmental (bioclimatic and topographic) layers. MaxEnt fits an unknown probability distribution within the environmental space defined by the input variable to the pixel values (or location) of known species occurrence records. The unknown probability distribution is proportional to the probability of occurrence (Elith *et al.,* 2011). The importance and the relative contribution of each environmental variable in the construction of the model were evaluated using a jackknife procedure. The analysis of changes in model gain based on the jackknife procedure described the impact on model gain of removing each variable from the models, in addition to provide what would be the model gain if each variable would be used alone. The performance of the model was estimated using the Area Under Curve (AUC), by reference to the Receiver Operating Characteristics (ROC) curve, where a value of 1 represents the best possible fit and a value of 0.5 corresponds to a random model. MaxEnt combines presence-only data with the biophysical covariates to construct a habitat suitability index for each cell ranging from 0 (least suitable habitat) to 1 (most suitable habitat) and defaults to a color gradient map to represent the probabilities of presence. Continuous values can be thresholded to establish six distinct zones: a certain probability of occurrence, strong, average, low, very low and zero. For a better visibility and to exploit full MaxEnt potential with GIS data, the probability distribution maps produced have been visualized and modified on a Geographic Information System DIVA-GIS.

Results and discussion

A total of 420 presence records were used for the modeling of the predictive distribution of the 27 *Cystoseira* species of Tunisia. From the 14 variables, 10 variables were selected for the modeling of the distribution of *Cystoseira* species and 4 variables, highly correlated ($r>0.8$) (Precipitation, evaporation, minimum salinity, mean annual maximum temperature), were omitted prior to further analyses and modelling.

AUC values of the different models built ranged between 0.72 and 0.98. The predictive models, are then considered acceptable ($0.7<AUC<0.8$) to excellent ($AUC>0.9$) according to Hosmer & Lemeshow (2000) and Araùjo *et al*. (2005). The highest AUC values were obtained for *Cystoseira compressa*, *C. barbata, C. schiffneri, C. compressa* subsp. *pustulata, C. foeniculacea,* and *C. spinosa* (as *C. montagnei*); the lowest ($0.7 <AUC <0.75$) are recorded for *C.foeniculacea* f. *dubia*, *C. brachycarpa* var. *claudiae* and *C. spinosa* var. *tenuior* (as *C. montagnei* var. *tenuior*).

Among the 10 environmental variables considered in this study, 5 have proved to be very important for the distribution of species: (i) "Maximum Sea surface temperature"; (ii) "insolation", affecting light and sea surface temperature, (iii) " exposure of the species to the wave", and to a lesser degree (iv) " type of substratum" and (v) "anthropic pressure" (Tab. 1). The MaxEnt model calculated the relative contribution of the environmental variables rather well (Fig. 1).

According to the predictive distributions, *Cystoseira* species can be grouped in:

♦ **Species having biogeographic affinities with northern part of Tunisia**: These cold-affinity species prefer cool waters of the North of Tunisia, hard substrates, a medium to strong hydrodynamism, and low salinity: *Cystoseira algeriensis, C. amentacea, C. amentacea* var. *stricta, C. barbatula, C. brachycarpa, C. brachycarpa* var. *claudiae, C. compressa* f. *plana, C. crinitophylla, C. foeniculacea* f. *latiramosa, C. hyblaea, C. mediterranea, C. montagnei* (as *C. micheleae*), *C. sauvageauana, C. sedoides* and *C. spinosa var compressa* (as *C. montagnei* var. *compressa*).

♦ **Species having biogeographic affinities with southeastern part of Tunisia:** These warm-affinity species prefer warm waters of the east and southeast facades of Tunisia, soft substrates, moderate to low hydrodynamics, and high salinity. This includes *Cystoseira barbata* f. *aurantia, C. Schiffneri* and *C. foeniculacea* f. *dubia.*

♦**Ubiquitous species**: not very demanding in terms of temperature and exposure to hydrodynamics. These species occupy fairly common variable ecological niches, found either on the northern coasts of Tunisia than on the southeastern ones. This group includes *Cystoseira compressa, C. foeniculacea, C. barbata, C. crinita, C. elegans, C. spinosa* (as *C. montagnei*), *C. foeniculacea* f. *tenuiramosa, C. compressa* subsp. *pustulata, C. spinosa* var. *tenuior* (*C. montagnei* var. *tenuior*) and *C. susanensis.*

The Maxent model's internal jackknife test showed that:

- 'Hydrodynamism' was the most influential environmental variable in determining suitable habitat with highest gain when used in isolation for *Cystoseira algeriensis, C. brachycarpa* var. *claudiae* and *C. crinita*. According to jackknife test, the most influential environmental variable present the higher gain *i.e*. a variable giving the most information when used alone compared to other variables (Fig. 2 for 6 selected species).
-'Temperature' was the most influential environmental variable in determining suitable habitat for *Cystoseira hyblaea, C. montagnei* (as *C. micheleae*), *C. sedoides* and *C. spinosa var compressa.*
- 'Insolation' was the most influential environmental variable in determining suitable habitat for *Cystoseira amentacea* and *C. compressa* f. *plana.*
- 'Type of substrate' was the most influential environmental variable in determining suitable habitat for *Cystoseira amentacea* var. *stricta, C. barbatula* and *C.elegans.*
- 'Anthropic pressure' was the most important predictor in determining suitable habitat with highest gain when used alone for *Cystoseira brachycarpa, Cystoseira barbata* f. *aurantia, C. barbata, C. crinita, C. elegans, C. compressa, C. compressa* subsp. *pustulata, C. crinitophylla, C. foeniculacea, C. foeniculacea* f. *dubia, C. foeniculacea* f. *latiramosa, C. foeniculacea* f. *tenuiramosa, C. mediterranea, C. spinosa, C. spinosa* var. *tenuior, C. sauvageauana, C. schiffneri* and *C. susanensis.*

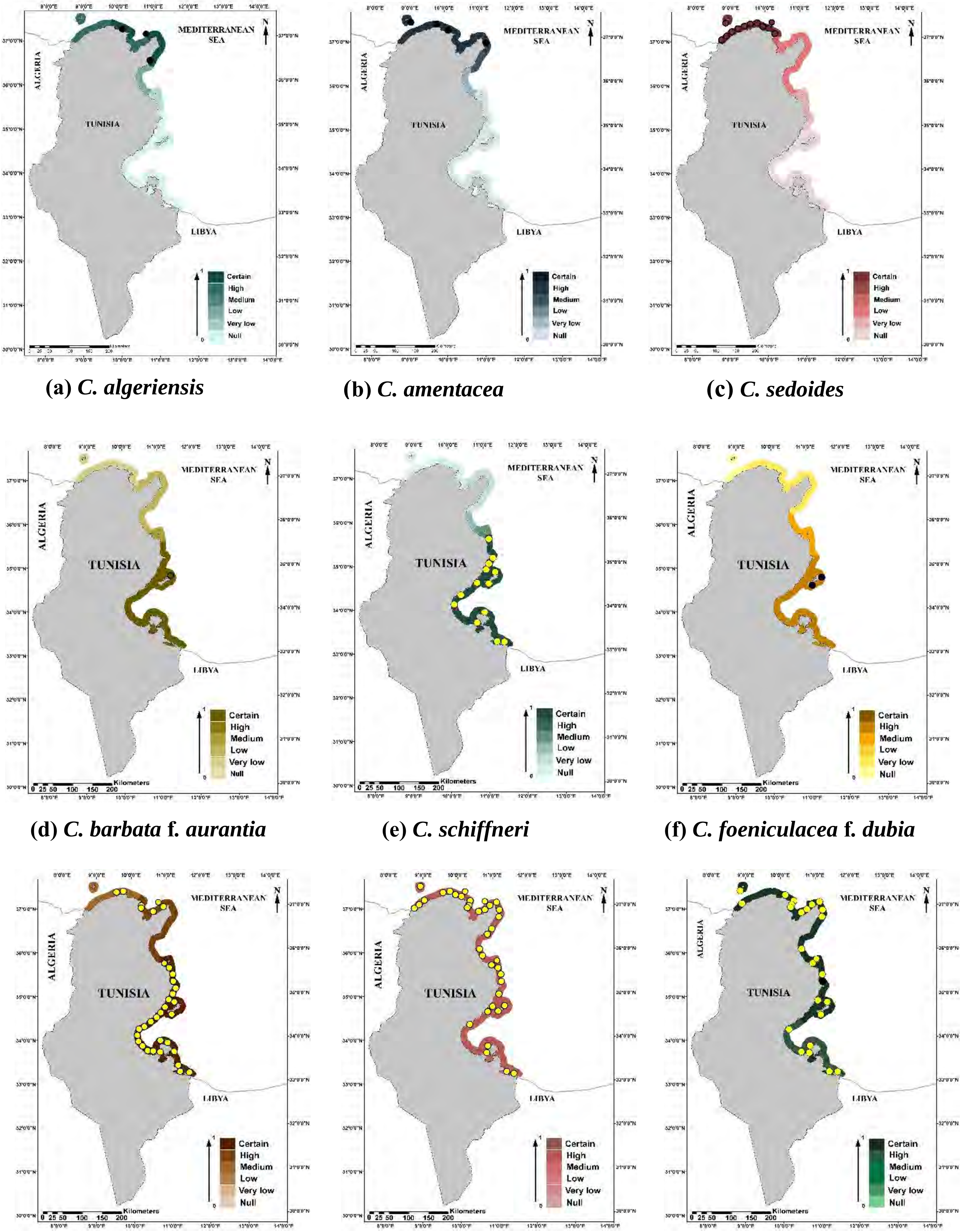
Conclusion

Although the distribution models are highly relevant for understanding marine benthic systems, for predicting future changes in marine ecosystems and for their protection, predicting the location of suitable habitat or centres of endemism, only few studies have modelled distributions of marine species. This is the first study of modelling *Cystoseira* species distribution to predict their potential suitable habitat. The MaxEnt model predicted potential suitable habitat for the 27 *Cystoseira* species here studied with high success rates of AUC. All in all, the modeling of the *Cystoseira* species distribution has generated predictive distribution maps in accordance with the ecological organization of *Cystoseira* in Tunisian coast and follow the general distribution patterns confirming the latitudinal gradient of species distribution.

For the 27 species studied, distribution models established showed that species distributions are influenced by a restricted number of environmental predictors, however, in practice distribution models consider the synergistic effect between several environmental variables such as hydrodynamism/substratum and water temperature/insolation. This work emphasize the utility of the MaxEnt model for predicting potential distributions of Tunisian *Cystoseira* species.

Tab. 1: Estimation of relative contributions of the environmental variables to the Maxent model. In bold are the most relevant contributions (> 15%).

	Contribution (%)																										
Species / Variables	*C. algeriensis*	*C. amentacea*	*C. ament. v. stricta*	*C. barbata*	*C. barbata f. aurantia*	*C. barbatula*	*C. brachy. v. balearica*	*C. brachy. v. claudiae*	*C. compressa*	*C. comp. f. plana*	*C. comp. ssp. pustulata*	*C. crinita*	*C. crinitophylla*	*C. elegans*	*C. foeniculacea*	*C. foeni. f. dubia*	*C.foeni. f. latiramosa*	*C. foeni. f. tenuiramosa*	*C. hyblaea*	*C. mediterranea*	*C. montagnei*	*C. sauvageauana*	*C. schiffneri*	*C. sedoides*	*C. spinosa*	*C. spin. v. tenuior*	*C. susanensis*
Insolation	**43,2**	**56,5**	**53,9**	0	**20,8**	**37,1**	**49,7**	**25,3**	**41,8**	**64,3**	0	**24,5**	**54,9**	0	0,2	**23,2**	**35,9**	0	**33,7**	**17,5**	**51,6**	**43,1**	0	**41,2**	**37,1**	0	0
Hydrodynamism	**18,3**	9,4	10,2	12,5	**23,3**	**25,5**	**33**	**51,6**	13,2	10,4	**55,4**	**28,8**	**21,8**	**36**	**16,9**	**21,2**	**38,7**	**32,2**	**24**	**26,3**	3,4	24,7	**21,6**	10,3	**17,5**	14,9	**23,2**
Maximum Sea surface Temperature (max-temp-ss)	8,7	6	8,7	7,9	10,5	7,2	1,5	4,5	8,7	**17**	**15**	**29,3**	4,4	**39,4**	7,2	11,6	10,3	**25,9**	10,3	**46,6**	**42,2**	10	10,2	**37,3**	1,3	8	11
Min Temperature of Coldest Month (t°_min_col)	0	0	0	**18,6**	0	0	0	0	0	0	0	0	0	0	**18,9**	0	0	0	11,3	0	0	0	**21,2**	0,1	6,4	0	0
Minimum Sea surface Temperature (min-temp-ss)	2,1	1	3,4	**42,1**	12,7	0	0,9	0	12,2	0	0,3	0,2	0	0	14,2	11,4	0	0	0	0	0	0	**34,5**	0	8,4	0	0
Anthropic pressure (anthr_press)	8	9,1	10,1	7,9	14,2	12	9,3	**16,5**	11,3	3,3	**19,9**	6,9	14,4	**16,5**	12,7	14,8	9,6	**29,7**	9,2	1,2	2,6	8,5	9,9	0,5	**20,1**	**61,3**	**43,4**
Type of Substrate (substratum)	13,2	13	5,3	8,1	3,9	12,4	4,9	2,1	3,9	3,3	7,3	5,7	2,7	4,3	5,2	2,8	2,3	2,3	5,1	1,2	0,2	5,2	2,1	10,2	5,5	**15,1**	12,3
Max Temperature of Warmest Month, (t°_max_war)	6,5	10	5,6	1,9	8,4	4,7	0,1	0	7,2	0	2,1	3,1	0	0	2	9,3	0	0	6,4	0	0	5,7	0	0	2,2	0,7	10,1
Mean annual minimum Temperature (annmin t°)	0	0	2,5	0	6,2	0	0	0	0,6	1,3	0	0	0	0	0,1	5,7	0	9,9	0	5,9	0	0	0	0,4	0	0	0
Maximum Salinity (max_salinity)	0	0	0,3	1	0	1	0,6	0	1,1	0,4	0	1,6	1,8	3,8	**22,5**	0	3,2	0	0	1,3	0	2,8	0,5	0	1,5	0	0



(a) *C. algeriensis* (b) *C. amentacea* (c) *C. sedoides*

(d) *C. barbata* f. *aurantia* (e) *C. schiffneri* (f) *C. foeniculacea* f. *dubia*

(g) *C. barbata* (h) *C. compressa* (i) *C. foeniculacea*

Fig. 1: Distribution maps (probability of occurrence) and observed occurrence (black circles) of selected *Cystoseira* species: 3 selected species having northern biogeographic affinities (a, b, c); 3 selected species having southern biogeographic affinities (d, e, f) and 3 selected ubiquitous species (g, h, i).

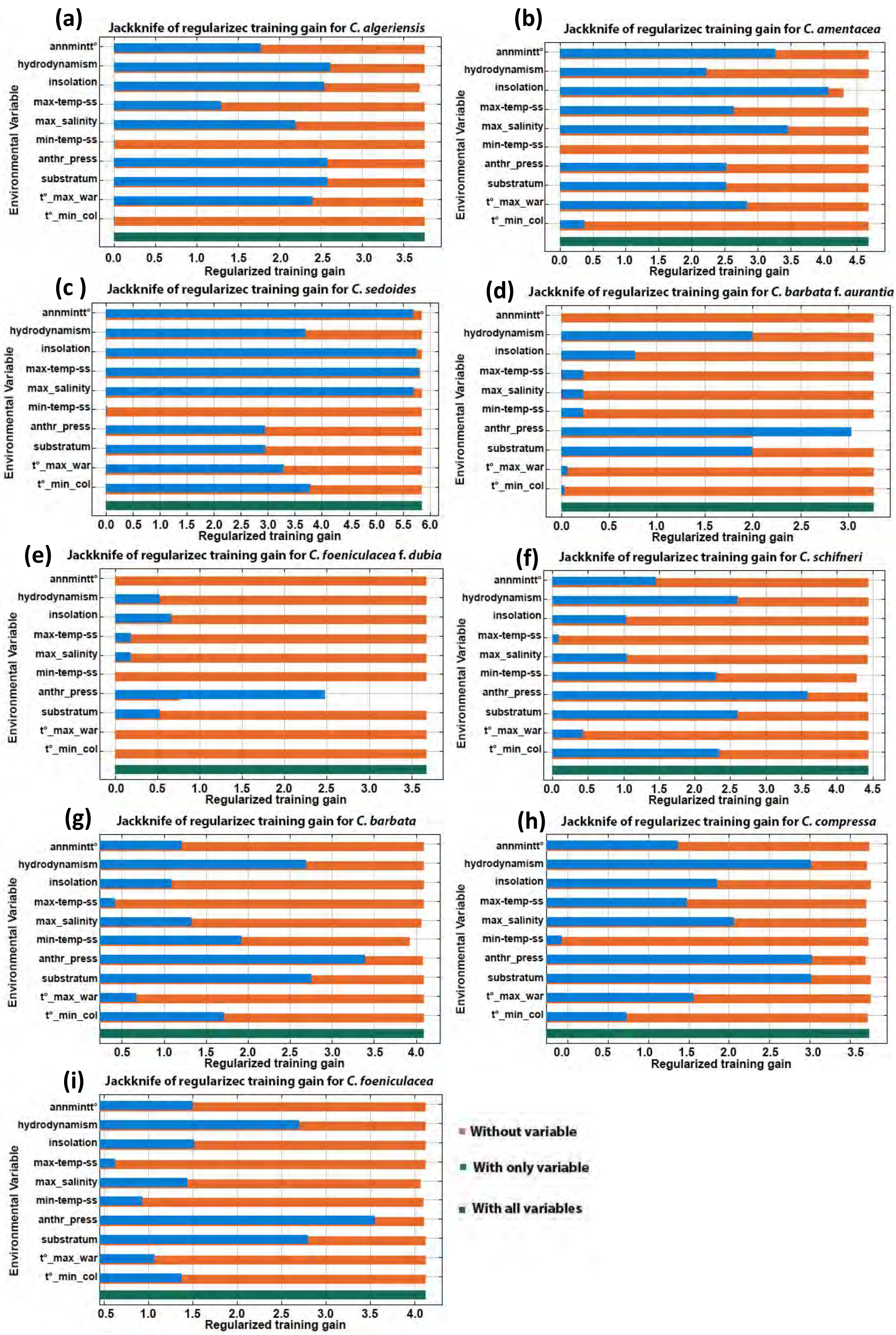


Fig. 2: Results of jackknife test of relative importance of predictor variables for selected *Cystoseira* species MaxEnt model: 3 selected species having northern biogeographic affinities (a, b, c); 3 selected species having southern biogeographic affinities (d, e, f) and 3 selected ubiquitous species (g, h, i).

The distribution predictions generated from high or small numbers of occurrence records may be of great value, particularly in identifying field surveys to facilitate the detection of unknown populations and species. The MaxEnt method for predicting species distribution by combining observed occurrence records with environmental variables seems to be a good alternative for providing information on species distribution. This can be extremely useful for regions that have been poorly surveyed and when information about the species and habitats are fragmentary and/or when species are difficult to detect in field surveys. It would be also particularly useful for predicting the geographical distribution of species rare or of special status, in order to develop possible management strategies for these species and their habitats. On the other hand, the prediction of species distribution by the MaxEnt method, as conducted in this work, despite its weaknesses ((Elith *et al*., 2002), could also be an ideal tool for monitoring the spatio-temporal dynamics of species and forecasting the effects of environmental or climate change.
Extending this type of study in a Mediterranean scale would be promising for a best knowledge on the distribution of the *Cystoseira* species of great interest for conservation at regional scale (UNEP/MAP, 2012). The greater the number of occurrence, the greater the reliability and accuracy of MaxEnt models. Hereby, we propose sharing knowledge across the Mediterranean and we recommend gathering all information concerning the occurrence data of *Cystoseira* and existing environmental databases at the Mediterranean level to establish predictive distribution models as accurate as possible for *Cystoseira* species in the Mediterranean.

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STRATEGY TO STUDY BLUE CARBON ECOSYSTEMS IN CORSICA

Abstract
Despite its very small surface area, coastal vegetation fixes a large amount of the Blue Carbon and plays a major role in its sequestration. These carbon sinks contribute to the mitigation of the effects of climate change. Among them, Posidonia oceanica*, a Mediterranean endemic seagrass species, appears to be the most efficient in carbon storage due to a unique structure: the matte. Consequently, in accordance with the Paris Agreement (COP 21) which states that "Parties must take measures to conserve and, where appropriate, enhance the sinks and reservoirs of greenhouse gases", the Corsica regional authority has introduced a specific strategy to follow these recommendations.*
Three main steps have been identified and a large amount of data are already available, while further studies are in progress:

(i) The Inventory of the Blue Carbon Ecosystem, based on a precise map of coastal ecosystems, confirms the very extensive range of the P. oceanica *(53 736 ha; >60% of the bottoms between 0 and -40 m) and* Cymodocea nodosa *(nearly 2 000 ha) meadows.*

(ii) The Monitoring of the Blue Carbon Ecosystem, with the setting up of the Posidonia Monitoring Network (39 sites), highlights the direct impact of human pressure (sewage outfall, aquaculture, trawling), and also a general regression of the lower limit in relation with sea level rise.

(iii) The Blue Carbon balance (fixation, sequestration and stocking) is in progress at a NATURA 2000 site, corresponding to 38% of the surface area covered by P. oceanica *meadows in Corsica. Preliminary results indicate that the fixation is estimated at 1.38 Mg C ha^{-1} $year^{-1}$, while the sequestration could reach 0.7 Mg C ha^{-1} $year^{-1}$. In addition, preliminary results from seismic investigations underline the high matte thickness (2.1 m in average).*
The integration of all these data will provide a basis for drawing up a reference state of coastal carbon sinks, but the major effort should be devoted to their conservation.

Key-words: Seagrass, mapping, monitoring, Carbon cycle, climate

Introduction
At the 21st meeting of the Conference of the Parties (COP 21), all participants adopted the Paris Agreement. This agreement stipulates in Article 5 that '*Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases*'. On the other hand, while previous conferences had focused on forest-based sinks (Kyoto Protocol), for the first time COP 21 noted '*the importance of ensuring the integrity of all ecosystems, including oceans*'. Major carbon sinks such as Peatlands, coastal vegetation and phytoplankton are, therefore, for the first time considered.

Despite a very small surface area (less than 0.5% of the oceans), coastal vegetation plays a major role in the fixation and sequestration of Blue Carbon (Nellemann *et al.*, 2009; Fourqurean *et al*., 2012). Among the sixty species of seagrass, *Posidonia oceanica*, a Mediterranean endemic species, appears to be the most effective in carbon storage; the *P.*

oceanica meadow is the only ecosystem able to 'compete' with peatlands and mangroves because it builds a unique structure: the matte. Made up of rhizomes and roots with sediment that fills the interstices, this small, putrescible structure can reach several meters in height, and the organic matter inside can persist for millennia (Mateo *et al*., 1997). Due to the exceptional extension of *P. oceanica* meadows in Corsica (Valette-Sansevin, 2018), the environment authorities in Corsica have implemented a global strategy for the study of these carbon blue sinks in the early 2000s, in collaboration with scientists. Three main steps have been identified, (i) inventory of the main Blue Carbon Ecosystems (mapping), (ii) monitoring of major Blue Carbon Ecosystems to ensure their conservation (Posidonia Monitoring Network - PMN), and finally (iii) assessment of the role of these Blue Carbon Ecosystems with regard to the overall Carbon balance of the Region, with the possible enhancement of this sink (PADDUC-CHANGE programme).

Material and methods

The inventory of seagrass beds was carried out: (i) for the deep zone (-10 to -50 m), through several oceanographic surveys (CAPCORAL 2010-2011, CORALCORSE 2013 and POSIDCORSE 2015), (ii) for the shallow zone (surface to -15 m), by remote sensing based on aerial images (BD ORTHO® of the National Geographic Institute), with a 0.5 m resolution and, (iii) for the other sectors, by a synthesis of existing data (Valette-Sansevin *et al*., 2015). The deep zone was mapped using exhaustive acoustic coverage (coupling a multibeam echosounder EM 1000™ and a side-scan sonar Klein 3000™). This data, which was processed using the Caraibes 3.6® software programme, enabled us to develop a mosaic (0.5m resolution). For the shallow zone, remote sensing was applied to each photograph (Envi 4.4®) following the method of Bonacorsi *et al.* (2011). All the data were integrated into a Geographic Information System.

A Posidonia Monitoring Network (PNM) has been set up since 2004, around the island in 15 sites (lower limit) and 15 sites (upper limit), corresponding to sites with no or with low identified human pressure (references sites), and sites exposed to significant human pressure. In 2013, 6 new sites at the lower limit were set up in the Réserve Naturelle des Bouches de Bonifacio. The PMN procedure consisted in setting up fixed markers along the edge of the lower limit to compare the patterns of change in the location of this limit over time. Several descriptors were also measured to assess the vitality of the meadow (Pergent *et al*., 2015) and the quality of the water body (indice BiPo; Lopez y Royo *et al*., 2010). For the upper limit, remote sensing of aerial photos was performed (see above). The PMN sites were monitored in 2013 and 2017.

The Blue Carbon balance was estimated at six sites (between 5 and 30 m depth) along 3 transects at the NATURA 2000 site, corresponding to 38% of the surface area covered by *P. oceanica* meadows in Corsica. Three complementary approaches were performed (i) Carbon fixation, with an assessment of primary production by the lepidochronology method (Pergent & Pergent-Martini, 1991), (ii) Carbon sequestration based on carbon fluxes (consumption by herbivores and detritivores, leaf litter exportation and sheaths/ rhizomes buried in the matte; Pergent *et al*., 1997) and Carbon stocks by the means of Seismic reflection during three oceanographic surveys (CORALCORSE 2013, POSIDCORSE, 2015 and SISMAT, 2018), and coring in *P. oceanica* matte using a gravity corer (Kullenberg) during the CARBONSINK 2018 oceanographic survey to estimate the thickness of the matte and characterize the carbon.

Results

The mapped area covers more than 310 000 ha, with survey results obtained for coastal areas down to a depth of 150 m deep at Cap Corse (Fig. 1). In the subtidal zone, *P. oceanica* meadows are predominant with an area of about 53 735 ha, or nearly 59% of the sea bottom; the lower limit regularly reaches a depth of more than 35 m. Along the the eastern coast, seagrass meadows have the largest surface area, with 20 425 ha for *P. oceanica* and 798 ha for *Cymodocea nodosa*, that is to say respectively 38% and 47% of the island's seagrass beds.

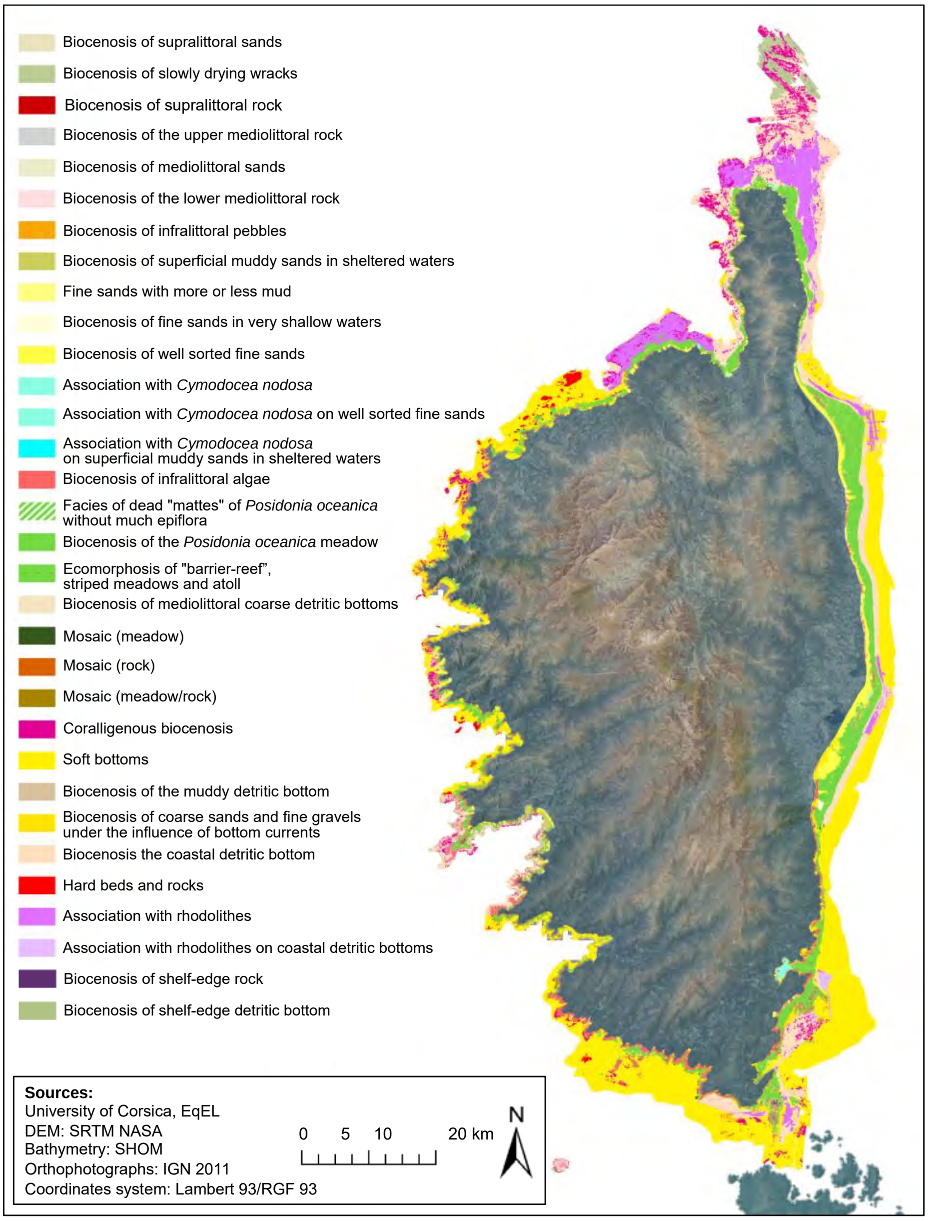

Fig. 1: Map of the main assemblages and bottom types around the coast of Corsica

At the lower limit the PMN shows, between the date of implementation and the first follow-up (2013): (i) a regression of the position of the lower limit for 40% of the sites (6 sites out of 15); (ii) a decrease in the vitality of the seagrass for 40% of the sites; and (iii) a decrease in the quality of the water body for 27% of the sites (4 sites out of 15).

During the second follow-up (2017), regression in the location of the lower limit affected 67% of the sites (10 sites out of 15). Regression is particularly evident for the most impacted sites (urban effluent discharge, fish farm), but for sites where pressures are decreasing (establishment of a sewage treatment plant, cessation of solid waste discharges at sea) the position of the lower limit has stabilized or is even in progression. On the other hand, even if to a lesser degree, a regression in the location of the lower limit has also been recorded at reference sites (6 sites out of 8). Carbon fixation by the *P. oceanica* meadow varies, depending on water depth, between 0.34 and 3.51 tons (Mg) C ha^{-1} $year^{-1}$, for a total of 28 569 tons C $year^{-1}$ in the NATURA 2000 site, which represents for all the Corsican meadows, 86 701 tons C $year^{-1}$ (1.61 tons C ha^{-1} $year^{-1}$ on average). Carbon sequestration in the matte (primary production allocated to the sheaths, rhizomes and roots) is estimated at 9 851 tons C $year^{-1}$ for the NATURA 2000 site, or 36 208 tons C $year^{-1}$ for the whole of Corsica (0.67 tons C ha^{-1} $year^{-1}$ on average).
Matte thickness of the *P. oceanica* meadow shows a high variability in thickness, with a mean value for the NATURA site estimated at 2.1 m. The thickness of the matte also seems to be greater along the coast, when the slope is slight; maximum thickness (up to 8 m) is recorded at the mouth of the main coastal rivers. The 49 cores made between water depths of 10 m and 40 m at the NATURA 2000 site have an average length of 2.1 m, with a maximum value of 3.9 m; the base of the matte (reflector) is thus regularly reached, which makes it possible to calibrate the seismic reflection data in tandem with measurements carried out at the level of the 'matte wall' (intermatte) by SCUBA diving. The 979 collected samples are being analyzed to determine the carbon content according to their age in order to specify the dynamics of edification of the matte.

Discussion

The integration of all the collected data will provide a basis for drawing up an estimation of the value of the *P. oceanica* meadow as a major carbon sink around the coasts of Corsica. However, while carbon fixation and sequestration is a major element in reducing the effects of climate change, the most important compartment, which must be precisely quantified and, above all, conserved, corresponds to the carbon stored over millennia in the matte. At the NATURA 2000 site, the average matte thickness (2.1 m) makes it possible to estimate this stock at nearly 25 million tons of carbon (based on 58 kg C m^{-3} *in* Serrano *et al*., 2012), which corresponds to the sequestration of nearly 92 million tons of carbon dioxide. Even if these values will have to be refined by the analysis of the matte cores carried out during the CARBONSINK 2018 survey, the carbon stock present in the matte of *P. oceanica* (1 218 tons C ha^{-1}) is comparable to that accumulated at the peatland in terrestrial environments (IPS, 2008; Pan *et al*., 2011; Fig. 2). At the Mediterranean scale, the area covered by the *P. oceanica* meadow has been estimated at between 2.5 and 4.5 million hectares (Pasqualini *et al*., 1998), but more recently the works of Telesca *et al*. (2015) and especially Topouzelis *et al.* (2018), for Greece, indicated a lower value, of between 1.5 and 2.0 million hectares. In fact, the areas covered by *P. oceanica* in Greece (32% of the Mediterranean coast) are relatively small compared to those recorded in the north-western basin, with an average of 18 ha km^{-1} of coast against 33 ha km^{-1} of coast for Spain, France and Italy. This difference between the two basins is particularly visible in the large Mediterranean islands (Tab. 1). The annual carbon fixation would thus be between 2.4 and 3.2 million tons (Tg) C yr^{-1}, and sequestration between 1.0 and 1.3 million tons C yr^{-1} for the entire Mediterranean basin. However, it is at the level of carbon stocks that *P. oceanica* plays a major role, with a value of between 1 827 and 2 436 million tons C; this value corresponds in average to four years of CO_2 emissions by all the Mediterranean countries (year 2016, http://globalcarbonatlas.org/fr/CO2-emissions).

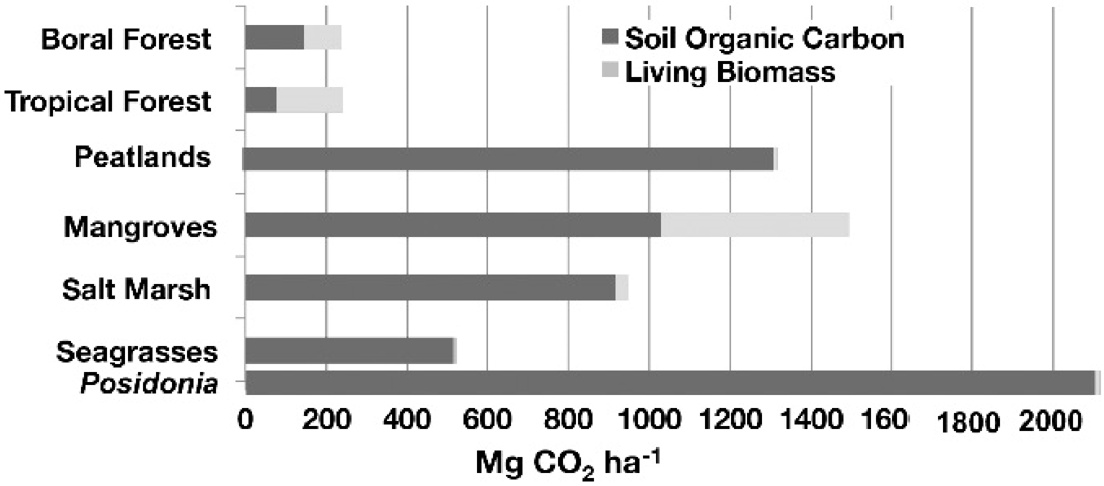

Fig. 2: Organic carbon stock in the soil of several ecosystems. Data correspond to the top one meter of sediment. From Fourqurean *et al*. (2012); Pan *et al*. (2011) (modified).

Tab. 1: Areas covered by *Posidonia oceanica* in large Mediterranean islands (from Valette-Sansevin, 2018). * http://gadm.org/country; ** http://emodnet-bathymetry.eu.

	Length of coast (km)*	Areas 0 to 40m (ha)**	*P. oceanica* (ha)	*P. oceanica* (ha.km^{-1})	*P. oceanica* (% 0 to 40m)
Balearica	1 435	112 022	63 316	44.1	56.5
Corsica	1 177	88 509	53 735	45.7	60.7
Sardinia	2 403	303 740	153 382	63.8	50.5
Sicily	2 007	318 393	76 000	37.9	23.9
Crete	1 590	64 910	14 500	9.1	19.3
Cyprus	648	93 174	9 040	14.0	9.7

However, degradation of these sinks is likely to compromise this major ecosystem service; even worse it could initiate a new source of emissions through the remobilization of carbon stored in these ecosystems (Belshe *et al*., 2017).

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ORAL COMMUNICATIONS

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HABITAT MAPPING IN MARINE PROTECTED AREAS: CONTRIBUTIONS TO MANAGEMENT PLANS IN FOÇA AND KAŞ-KEKOVA SPECIAL ENVIRONMENTAL PROTECTION AREAS

Abstract
Habitat forming species are under threat in the Mediterranean ecosystem due to anthropogenic pressures. Information on habitat distribution is one of the important components in struggling against these threats. Turkey has 11 Special Environmental Protection Areas (SEPAs) along the Mediterranean coasts. There have been several habitat mapping efforts in the SEPAs for preparation of management plans. One of these efforts that were delivered in present study were the mapping the Posidonia oceanica *(Linnaeus) Delile meadows of the Foça SEPA (on the Turkish Aegean coast) in 2005, and the mapping habitats in Ölüdeniz of the Kaş-Kekova SEPA (on the Turkish Levantine coast) in 2010.*

Key-words: Habitat mapping, *Posidonia oceanica*, SEPA, GIS.

Introduction
Habitat forming species are under threat in the Mediterranean ecosystem due to anthropogenic pressures. Without immediate action to mitigate these impacts, it is predicted that by the middle of the 21st century commercial fish and seafood stocks will collapse beyond the point of recovery (Worm *et al.,* 2006; Brown *et al.,* 2011). In fact, there is no place that is unaffected from those pressures on a global scale. On the other hand, it is estimated that only 5-10% of the seafloor is mapped (Wright and Heyman, 2008; Brown *et al.,* 2011). Information on habitat distribution patterns over spatio-temporal scales is one of the most critical components for being able to cope with these threats. Consequently, mapping such habitats has a greater value for management initiatives, especially those for marine protected areas in the Mediterranean since protecting marine ecosystems has become a priority objective worldwide. The current trend in Europe for conserving marine ecosystems is to use area-based measures, focusing on establishing marine protected areas (MPAs) (Barbera *et al.,* 2012). Marine areas should be protected with a managerial perspective against human impacts. Therefore, the production of base maps of physical and biological resources is inevitably needed. Habitat and species mapping are actually also essential for global biodiversity conservation programmes when considering fundamentality of spatial data on the distribution and extent of the marine biodiversity, for managing the marine environment (Barbera *et al.,* 2012).
Seagrasses (phanerogams) have been represented with quite a few species relative to the marine algae. Nevertheless, they have quite a large biomass and coverage in Mediterranean Sea ecosystem. They have important ecological and economical roles on coastal ecosystem and landscape with their roots, rhizomes and leaves; they create ideal biotopes for survival, protection and reproduction of several marine organisms (Boudouresque and Meinesz 1982; Meinesz *et al.,* 1991). Considering all these characteristics, seagrasses are among the most important species for the Mediterranean

ecosystem, as habitat engineers. However, the habitats created by these species have been destroyed by anthropogenic impacts such as habitat destruction by increased coastal settlements and relevant activities, and thus, pollution, industry, illegal trawling etc. *P. oceanica* is the most vulnerable species and it has been included to the protected species list for these reasons (Grissac, 1989; Larkum and Hartog, 1989; Meinesz *et al.,* 1991; Boudouresque *et al.,* 1994). On the other hand, in recent years, it has been observed that *Caulerpa racemosa var. cylindracea* (Sonder) Verlaque, Huisman & Boudouresque, an alien-invasive marine alga, has developed over the places where seagrass meadows have disappeared (Meinesz *et al.,* 1991; Peirano *et al.,* 2005).

Such incidents have also been observed in Turkey so that it has been established 11 Special Environmental Protection Areas (SEPAs) at the Mediterranean coasts (Fig 1.), in which several habitat mapping efforts, as precautionary actions, have been carried out for preparation site specific management plans. In this proceeding, two of these efforts presented are mapping the habitat formed by *P. oceanica* meadows of the Foça SEPA (on the Turkish Aegean coast) in 2005 and mapping Ölüdeniz habitats in the Kaş-Kekova SEPA (on the Turkish Levantine coast) in 2010, in order to emphasize the essentiality of acoustic methods in habitat mapping, and thus, investigating biodiversity and ecosystem functioning over spatial and temporal scales.

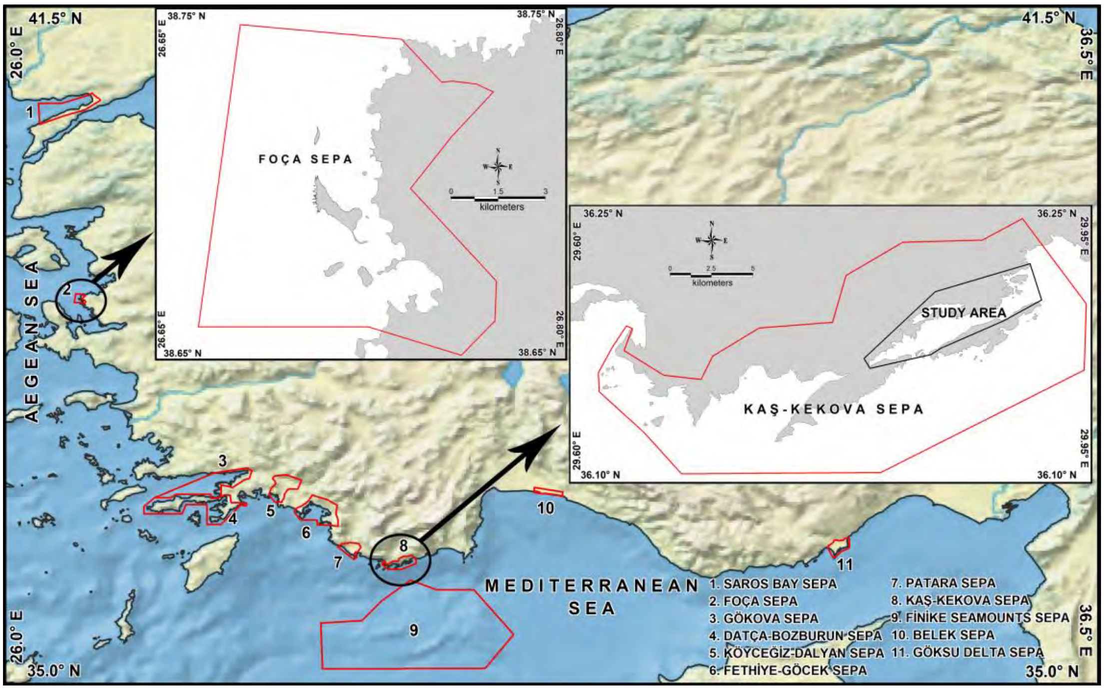

Fig. 1. Coastal SEPA's along Turkish Coastline (Aegean and Mediterranean Sea) and Study areas (Foça SEPA and Kaş-Kekova SEPA) (Basemap from Natural Earth database, http://www.naturalearthdata.com).

Materials and methods

We applied two different techniques in this study. In the first technique, for the Foça SEPA *P. oceanica* mapping, upper limits were digitized from Quickbird satellite image, after in-situ verifications by using a hydroscope whereas lower limits were obtained by drop-down camera survey. Once the lower limit was detected at each study sections, drop-down camera survey was performed along the lower limit, taking GPS coordinates at 100 to 500 m intervals, depending on the smoothness of the border (more points in rapidly changing areas). In the second technique, for Kaş-Kekova SEPA Ölüdeniz habitat-mapping focusing on all physically distinguishable habitats, SCUBA and snorkelling transects performed to obtain upper and lower limits (by acquiring both GPS coordinates and depth data). Real-time observations were conducted in 15 snorkelling and 17 SCUBA diving transects in the Kaş-Kekova SEPA Ölüdeniz area. The diving transects were performed at 0-5 m and 0-45 m respectively. The reason for this kind of depth separation is due to rocky/gravel coastal structure in the 0-5 m depth range, which creates a significant difference in the substrates. Afterward, the habitat distributions were digitized by using in-situ GPS coordinates and supplementary bathymetry data obtained by Elac-SeaBeam 1050D multibeam system mounted on R/V K. Piri Reis (ÖÇKKB, 2011). Nonetheless, all mapping procedures performed were in Geographic Information Systems (GIS).

Results

In the Foça SEPA, the total area of *P. oceanica* distribution was about 6.7 km^2. *P. oceanica* meadows distributed along the whole coasts of SEPA except for the port area (Küçük deniz and Büyük deniz) (Fig. 2).

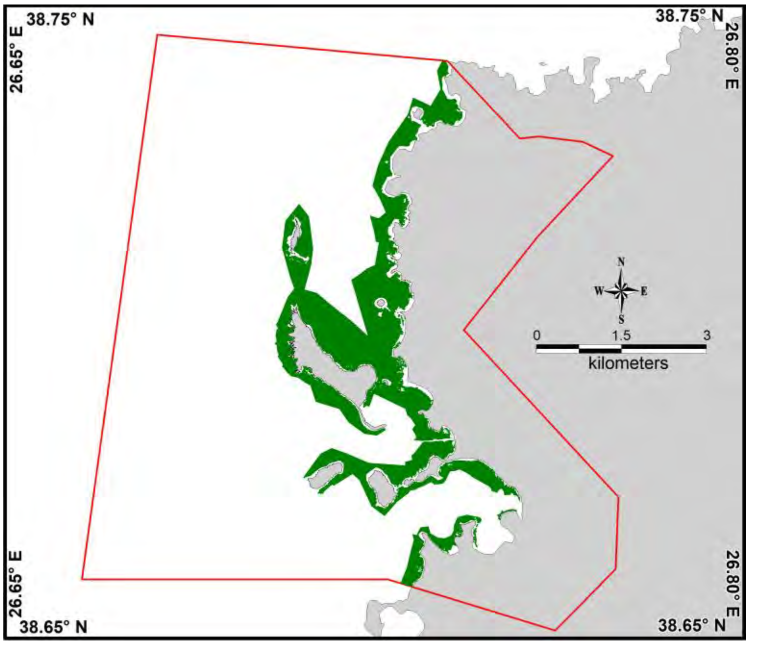

Fig. 2. ***Posidonia oceanica*** **map of the Foça SEPA.**

In Ölüdeniz (Kaş-Kekova SEPA), the total areas covered by the habitats formed by *P. oceanica*, *Penicilus capitatus*, Corallinales, Cystoseira sp., *Cymodocea nodosa*, *Zostera marina* and *Halophila stipulacea* was about 5.7 km^2. 10 habitat types were defined by considering their solitaire and mixed distribution patterns: *P. oceanica* (1.047 km^2), *P. capitatus* (0.099 km^2), Corallinales (1.3 km^2), Cystoseira sp. (0.268 km^2), *C. nodosa* (0.718 km^2), *Zostera marina*. (0.344 km^2), *Halophila stipulacea* (1.375 km^2), Cystoseira sp. with Corallinales (0.185 km^2), *C. nodosa* with *Zostera marina*. (0.146 km^2) and Cystoseira sp. with *Zostera marina*. (0.181 km^2) (Fig. 3). Five species and two genus formed these habitats, which associate the main ecosystem structure. Five species forming these habitats were; *C. nodosa*, Zostera *marina*, *P. oceanica*, *H. stipulacea* and *P. capitatus*. Two genus forming habitats were species of Cystoseira and Corallinales (Fig. 3). The widest area covered by *H. stipulacea* with *P. oceanica* and Corallinales species within the area of 0-50 m band the study area. However, the habitats intricately or discretely formed *by C. nodosa* and *Z. marina* covered the 20% of the total area of the habitats. The habitats formed by *Cystoseira* species and of *P. capitatus* have a fairly low coverage percentage in the study area. As the depth goes deeper, the rocky/gravel substrates rapidly transforms into sand, sandy mud and muddy substrates. In some segments of deeper points, however, rocky substrates were reappeared. The changes in the substrate structure and depth reflect in the distribution of the living organisms and thus indicating variations in habitat diversity.

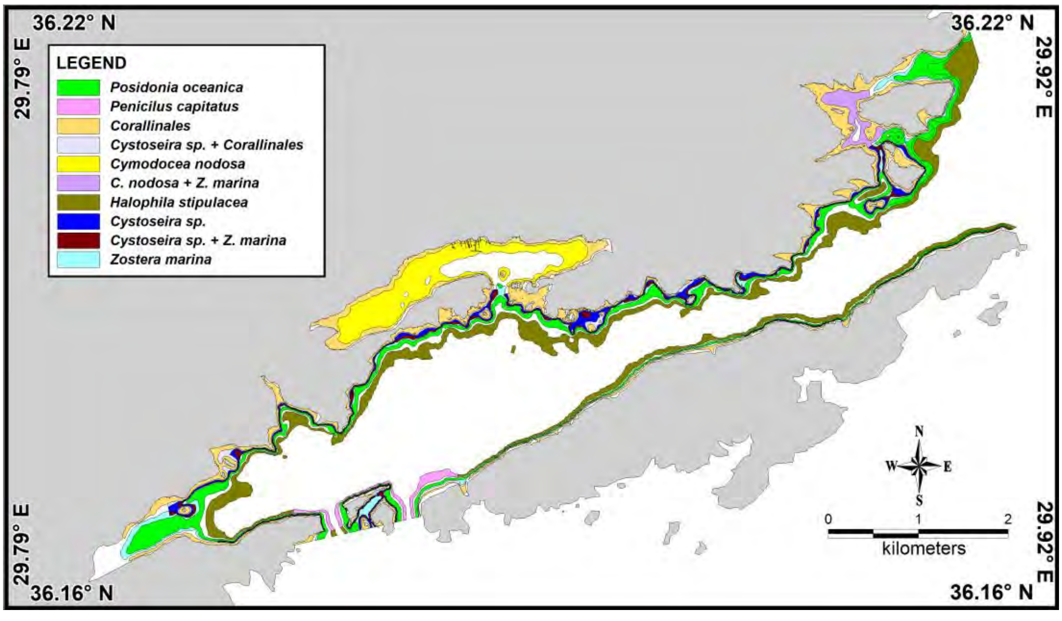

Fig 3. Map of habitats at the Kaş-Kekova SEPA.

Discussion and conclusions

The habitat mapping activities are fundamental and unavoidable steps that enable us to understand the biodiversity and ecosystem functions within its holistic feature in terms of precise and testable quantities. These quantities contain robust and concrete set of observation/monitoring parameters which can provide the scientists more exploratory data and clues they can guide managers more reliably, since the presented results contains spatial and temporal scales on the variation to be detected. This was the case, as one of the best example, in protected area management plans, *i.e.*, specifically for assessing marine vessel carrying capacity and for selecting mooring sites (Akçalı *et al.,* 2013). However, the quality of distribution maps in terms of accuracy and resolution is strongly dependent on the techniques used in both data acquisition and GIS mapping procedures.

Considering the distribution of habitats within the Ölüdeniz area, observations on the habitat was spreading to larger areas, due to the relatively shallow water depth and slope of the northern shores. The northern coastline of the Sıçak Peninsula and Kekova Island, which made up the southern shores, the spread of habitats are restricted in quite a narrower area due to the suddenly deepening waters by steep slope. On the other hand, the area called the Akvaryum, which was located between the channel and the rocks between the Sıçak Peninsula and Kekova Island to the south of Ölüdeniz, had a quite different habitat combination due to the fact that Ölüdeniz was the most dynamic interaction with the open sea. In particular, the *P. capitatus* meadows were observed only at this point. Other different habitat combinations were observed in Üçağız and Gökkaya bays. Due to the lagoon features, Üçağız is dominated by *C. nodosa* over its soft (sandy and / or muddy) substrates, and Corallinales species in shallow hard (rocky and / or gravel) substrates of upper infralittoral which are shaping the coastline. In Gökkaya Bay, it created a unique habitat combination due mainly to there were multiple strait entrances created by the islands which supplies open sea waters and fresh water entrances from steep rocky mountain creeks and fractures. Regarding the habitats formed by Cystoseira species and of *P. capitatus* having a fairly low coverage percentage in the study area, the stenotypic features of these species in terms of water flow rate and substrate structure seems as the most satisfying explanation. The fact that they are present at every point with suitable conditions within the study area is a positive indicator for the general ecosystem health in the study area. Nonetheless, Cystoseira species on rocky substrates spreading within a 3 to 10-meter depth range seemed quite severely damaged by tour boat activities as well as invasive herbivorous organisms (Sala *et al.* 2011).

In Ölüdeniz, *P. oceanica*, which normally can reach down to the depths of 40 meters, is restricted at about 12-30 meters, *H. stipulacea,* an alien phanerogam species of indo pacific origin, spread from 30 meters to 40-50 meters. Although spreading ability of *H. stipulacea* is not as effective as *C. racemosa var. cylindracea*, it is certain that this species could filled in all the gaps where it has the opportunity, by occupying the lower segments of *P. oceanica* meadows in the study area. The very same observation was also noted for the Foça SEPA.

Considering the fact that disappearance of seagrass meadow has created opportunity for many alien-invasive plant species, including *C. racemosa var. cylindracea*, the biodiversity in *P. oceanica* habitats had been increasingly stressed and altered. This result has promptly led to initiate some international research projects, cooperation and thus, some precautionary and protective measures for this issue have put forward (Meinesz *et al.,* 1993; Piazzi *et al.,* 2005; Bianchi and Morri, 2000). The main overall outcome was the fact that the healthier seagrasses, the less risk of the development and further the colonization of alien-invasive marine plants. Thus, any anthropogenic impact that weakens the seagrasses, will eventually lead to their extinction and thus colonization by alien-invasive species (*C. racemosa var. cylindracea, Caulerpa taxifolia, Stypopodium schimperi, H. stipulacea* etc.) and consequently a series of radical changes in the integrity of the ecosystem in terms of its biodiversity and function.

Regarding the technical approaches presented in two cases, i.e., Foça *P. oceanica* mapping and Ölüdeniz habitat mapping, the former case exhibits a high resolution of upper limit using satellite imagery, but lower resolution of the lower limit since only GPS data of CCTV observations was used for polygonization (more straight lines in lower limits of Figure 2), while the latter case, much more uniform resolution acquired for both limits by integrating bathymetry data to the observation GPS coordinates in order to align upper and lower limits on the bathymetry contours.

It is therefore that use of acoustic techniques (e.g. sonar imaging, multibeam sounding) in combination with remote sensing data should be benefited without further delay for providing full spatial coverage of habitats, so that any loss of habitats in any ecosystems due to antropogenic and/or natural (climate change) impacts can be coped with properly and reliably. In this context, we would like to note that the habitat maps constructed for two SEPA, which are still partially under human use will form the baseline information for future works, particularly those on to DPSIR (Driver- Pressure- State- Impact-Response) evaluations.

Acknowledgments

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AN ECOLOGICAL SURVEY OF BENTHIC BIOCENOSIS AND BOTTOM TYPES AROUND THE KERKENNAH ARCHIPELAGO WITH A VIEW TO DESIGNATION AS A MARINE PROTECTED AREA

Abstract
The Kerkennah Archipelago, located in the gulf of Gabès in southeastern Tunisia, has an outstanding environmental potential, which in 2012 helped the islands to earn the status of natural reserve. The northeastern part of the archipelago, considered an area with a fragile ecosystem, is classified at national scale as a sensitive coastal zone, according to a decree dated 28/10/1998.The present study reveals the main results of a large-scale benthic survey carried out in 2015 within the framework of the MedMPAnet project of the SPA/RAC. The main purpose of the survey was to highlight the potential ecological features of the North-East zone of the Kerkennah Archipelago to justify designation as a marine protected area (MPA). The survey of the main biocenoses and bottom types in the northeastern part of the Kerkennah islands revealed the presence of outstanding marine habitats. They mainly consist of extensive associations with Cymodocea nodosa*, an ecomorphosis of* Posidonia oceanica *'tiger' meadow,* Neogoniolithon brassica-florida *concretions, and a biocenosis of infralittoral algae that is established on an organogenic concretion. The latter biocoenosis is characterized by the variety of associations with* Cystoseira spp. *that comprise habitats of of high conservation interest. The unique biological formations recorded from the survey area, such as the* Posidonia oceanica *'tiger' meadow and organogenic concretions comprise some of the most extensive and rarest of their kind in the Mediterranean Sea. Their presence in the studied sites highlights the urgent need for conservation measures to protect the area and to implement medium- and long-term monitoring of the state of conservation through the establishment of monitoring programs. The excellent environmental status of the site and its high ecological, cultural and aesthetic values make this northeastern part of the Kerkennah islands an excellent candidate for the designation of MPA status.*

Key-words: Mapping, benthic habitats, Posidonia ecomorphosis, Kerkennah archipelago, Tunisia.

Introduction
Situated on the eastern coast of Tunisia in the Gulf of Gabès, the Kerkennah Islands constitute an archipelago having rich and varied environmental features that earned it in 2012 the status of natural reserve. The northeastern part of Kerkennah Islands is one of the five sites identified by the Tunisian Agency for the Protection and Development of the Littoral (APAL) within the framework of the National Program for the Creation of Marine and Coastal Protected Areas. This program is part of the national biodiversity policy and aims to establish a network of protected areas along the Tunisian coast. The MedMPAnet Project ('Regional Project for the Development of a Mediterranean Marine and Coastal Protected Areas (MPAs) Network through the boosting of MPAs Creation and Management') has therefore given priority to the northeastern zone of the Kerkennah islands. This study presents the main results of a large-scale benthic survey carried out within the framework of the MedMPAnet project in the northeastern zone of the

Kerkennah archipelago to justify the granting of the status of Marine and Coastal Protected Area to the island.

Material and methods

The northeastern area of the Kerkennah Islands is bounded to the north by geographical coordinates 34° 48'33,80"N / 11°18'41,06"E and 34°48'19,37"N / 11°22'05,87"E and to the south by 34°46'07.90"N / 11°18'36.40"E and 34°45'50.95"N / 11°21'45.06"E (Fig. 1). The islands cover an area of almost 34 km².

A satellite image of the studied area taken by Pléiades satellites (DIMAP format - Airbus Defense & Space), and having a resolution of 50 cm resolution, orthorectified, and dating from March 2012, was used for analysing the distribution of the main marine biocenosis present in the study area. Analysis of the remotely sensed data was undertaken using Exelis® ENVI 5.0 software. After masking of the terrestrial part of the study area, supervised classification was carried out using reference polygons derived from data acquired from the field in July 2015 using transect survey techniques. A total of 1100 observations were made by direct observations within the 0 to 4 m depth range, using snorkelling or visual assessment from the surface with the help of a bathyscaphe, to identify the main marine habitats of interest for conservation.

The cartography was integrated into a Geographic Information System (GIS) using the ArcMap component of the ESRI® ArcGIS 10.2 software.

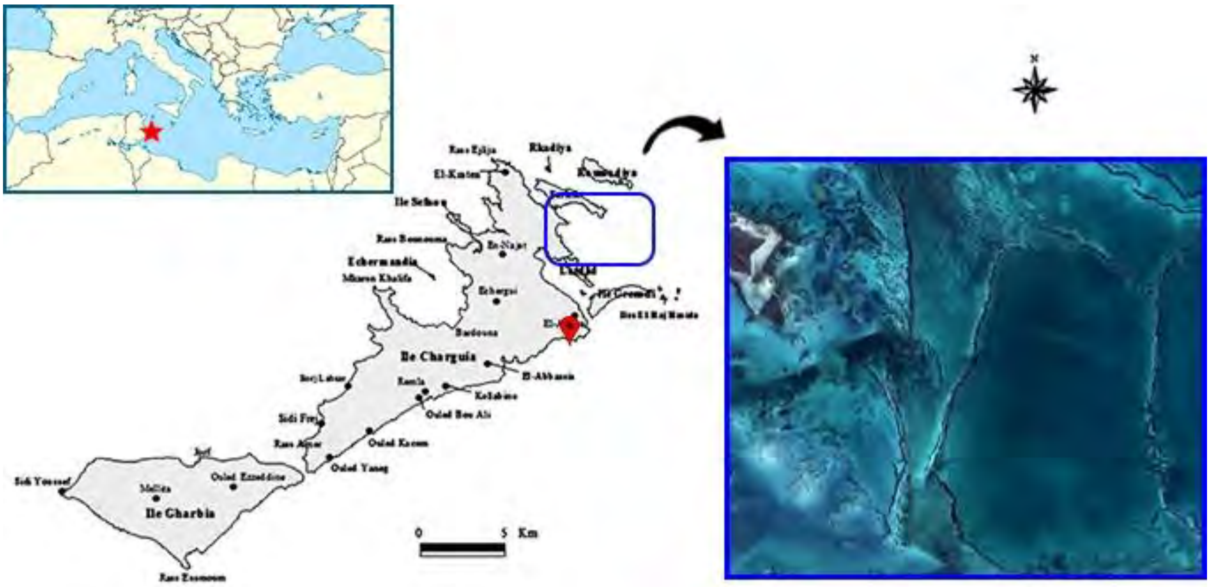

Fig. 1: Map showing the Kerkennah Archipelago and location of the study area

Results and discussion

The biocenosis map for the northeastern part of Kerkennah Island (Fig.2, Table 1) reveals an extensive area with *Cymodocea nodosa* beds (over 3,000 ha, or nearly 93% of the marine area studied). *Cymodocea nodosa* is often associated with the chlorobionte *Caulerpa prolifera* with which it forms mixed stand. *Cymodocea nodosa* beds having high density (>75%) are the most representative (62%). The *Cymodocea nodosa* beds are interspersed with specific bed types of the seagrass *Posidonia oceanica*; the latter corresponding to strips several tens of meters in length and nearly 2 meters in width separated by "dead matte" occupied by *Cymodocea nodosa* and / or *Caulerpa prolifera*.

Cymodocea nodosa beds mostly exhibit a low density (less than 25% of cover), but can reach 100% locally. These specific bed types are designated under the term of 'ecomorphosis of the *Posidonia oceanica* tiger meadow'; and exhibit three subtypes: (i) 'classical / typical configuration[1]; (ii) 'circular configuration', consisting of bands arranged in a circle, the smallest forming 'atolls'[2]; and (iii) 'cord configuration', consisting of strips arranged along a more or less straight line. The cords, several kilometers in length, are in places more than thirty meters wide. The meadow is generally outcropping and the leaves reach the surface during low tide. They cords delineate vast areas on a generally muddy bottom at a depth of around 2 m, where dense *Cymodocea nodosa* beds are present, often associated with *Caulerpa prolifera*.
The results of the survey are indicate the presence of low to moderately dense *Cymodocea nodosa* beds that are interspersed with organogenic concretions composed mainly of sedimentary carbonate rocks due to accumulation of skeletal fragments or limestone shells of marine organisms. The rhodobionte *Neogoniolithon brassica-florida* is often associated with such concretions. These organogenic concretions, present in the infralittoral as well as in mediolittoral, constitute a substratum for 26 macrophytes including 7 species of *Cystoseira* listed in Annex II of the Special Protected Areas and Biological Diversity protocol (UNEP-PAM-RAC/SPA, 2012).
The mediolittoral zone supports a particular biocenosis made up of sandstone concretions, often stratified, and usually called 'beach-rock'. Non-vegetated areas either are present around the beaches, and constitute in this case the biocenosis of the superficial muddy sands, or are scattered within the low-density *Cymodocea nodosa* beds, and contributing to formation of the biocenosis of coarse sand and fine gravel.

Table 1: Main biocenoses and associations recorded in the northeastern area of Kerkennah Islands.

Habitat	Area (ha)	%
Beach-rock	7.08	0.21
Biocenosis of muddy sands and muds	5.21	0.15
Biocenosis of infralittoral algae on organogenic concretion	44.20	1.30
Association with *Cymodocea nodosa*]0-25[%	503.02	14.80
Association with *Cymodocea nodosa*]25-75[%	703.88	20.70
Association with *Cymodocea nodosa* > 75%	1980.58	58.26
Biocenosis of coarse sands and fine gravels	5.72	0.17
Biocenosis of *Posidonia oceanica* meadow	150.00	4.41
Total area	3399.69	

The study area is therefore characterized by: (i) ecomorphosis of *Posidonia oceanica* tiger meadow in various forms, some of which (cords) are unique in the Mediterranean Sea; (ii) extensive *Cymodocea nodosa* beds; and (iii) a wide diversity of species and habitats of conservation interest. Added to this, the topography of the area, made up of a succession of flat lands occupied by 'sebkhas', 'schorres' and small irregular hills, makes it unfit for urban development and tourism, which gives it a degree of natural protection and a certain aesthetic value. These characteristics make the northeastern area of the Kerkennah archipelago a potential candidate for claiming the status of Marine and Coastal Protected Area. However, the insularity and small size of the islands contribute to vulnerability to environmental changes in relation with global warming and the consequent sea level rise.

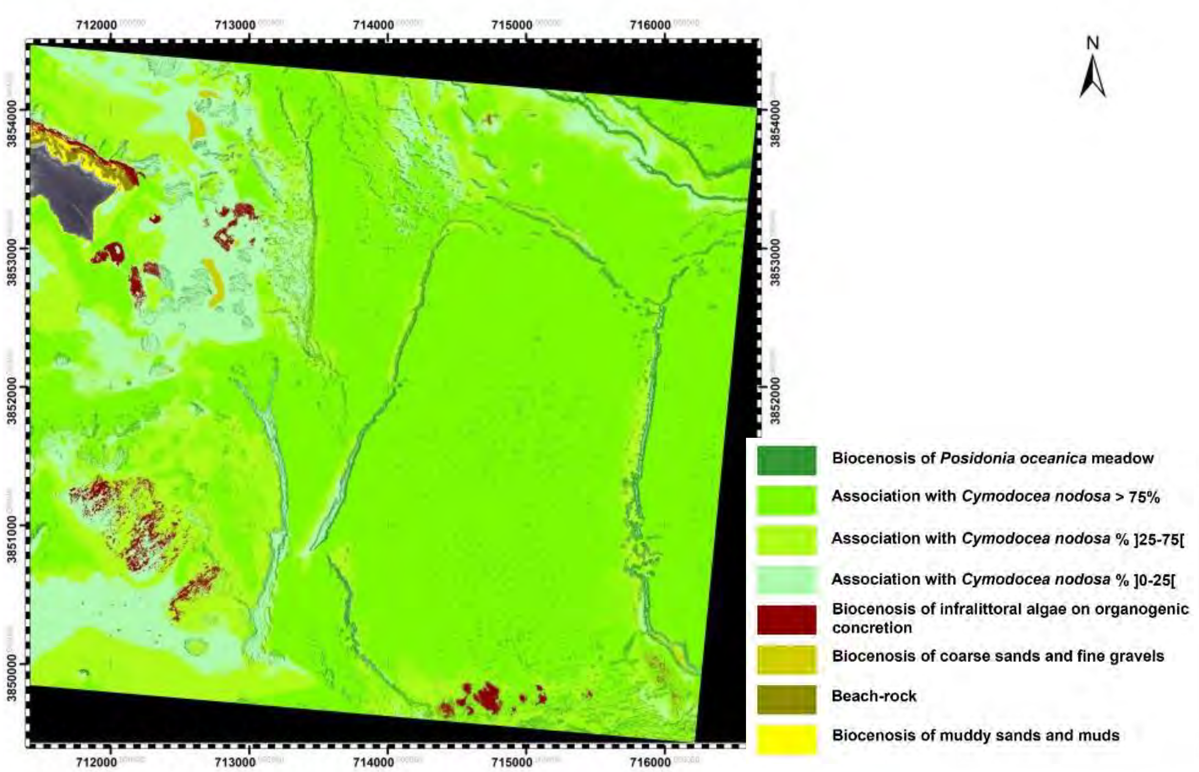

Fig. 2: Map from GIS showing the different types of benthic biocenoses recorded from the study area.

Conclusion

The area studied, lying north-east of the Kerkennah archipelago, possesses rich, diversified marine and coastal resources. The results obtained confirm that the area possesses an original landscape made up of species of fauna and flora and formations that are outstanding at national and regional level. The unique extension of the *Posidonia oceanica* striped meadow confirms the area's high value. This meadow seems to be in a good state of conservation, demonstrating the good quality of the littoral water in the area of study. The outstanding marine flora is characterized not only by the abundance of the meadows of the marine phanerogam Posidonia oceanica but also the predominance of the phanerogam of heritage interest Cymodocea nodosa, which, mixed with the Chlorobionta Caulerpa prolifera, form prairies that have a vital role that is both ecological (important primary production, a spawning area and nursery for many species of fish and crustacean of economic interest) and hydrodynamic (fixing sediment, reducing hydrodynamics). There is undeniable biological richness due to the presence of species that are rare and/or threatened at Mediterranean level, i.e. Pinna nobilis and *Cystoseira* forests (*Cystoseira barbata, C. compressa, C. schiffneri, C. foeniculacea f. tenuiramosa, C. montagnei* and *C. susanensis*).

Because of its physical vulnerability due to its low-lying topography and the fragility of the litho-stratigraphic layers, the area is more threatened by the rapid rise of water around the Kerkennah Archipelago than elsewhere in Tunisia through the combination of subsidence and global warming.

The increase in seawater temperature would have a significant impact on various plant-dominated biocenoses. It could induce a weakening of the meadows or a replacement of indigenous species by other marine magnoliophytes that have a warm water affinity (e.g. *Halophila stipulacea* which already occurs in the vicinity of the Kerkennah, or more opportunistic introduced species of low ecological and heritage value). It could also affect the distribution of several algal species of interest. These changes are likely to have a major impact on phytobenthic communities and on the ecosystem role played by the seagrass meadows. A medium- and long-term survey of the state of conservation of this natural heritage site should be considered, through the establishment of environmental monitoring programs.

Although the structure and dynamics of the *Posidonia oceanica* meadows have not yet been extensively studied, this is not the case for the study of the processes of formation of the cord structures that originate from the island and extend to the open sea in the form of coastal sedimentary constructions (arrows) or 'continental wrinkles'. These processes would appear to be related to the underwater topography of the area, the nature of the sediment and the water movement.

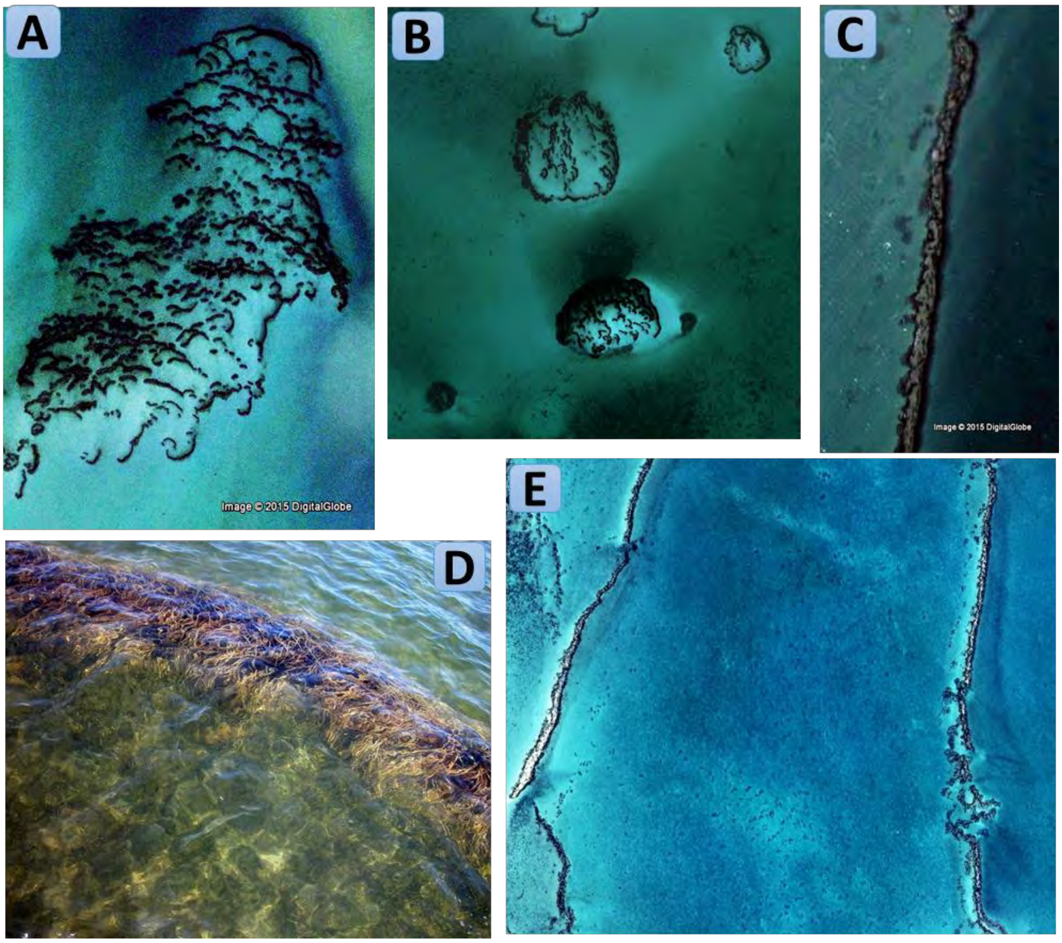

Fig. 3: Striped meadow: (A) typical configuration, (B) circular configuration, (C) belt configuration, (D) a strip of *Posidonia oceanica* near the surface interrupted by a mosaic of *Cymodocea nodosa* and (E) belts of striped meadows (tsir) marking out a bhirat where isolated strips of *Posidonia oceanica* are scattered.

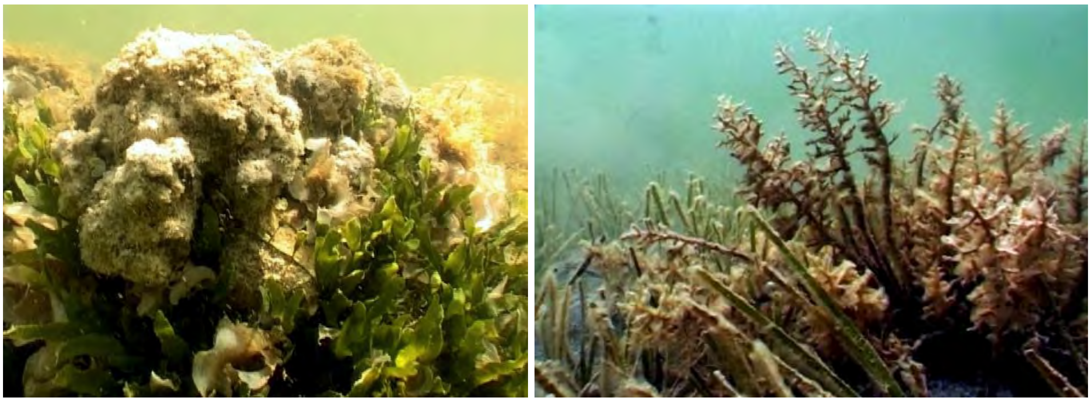

Fig.4: Biocenosis of infralittoral algae on organogenic concretion: Facies with organogenic concretions (left); Biocenosis of photophilous algae (right)

A Marine Protected Area groups the totality of the environments deemed to present heritage interest; the area studied possesses all the advantages that justify setting up a Marine and Coastal Protected Area (MCPA) that encompasses either part or all of this sector. Setting up a MCPA would help protect all the marine ecosystems of high heritage value that are present. It would also enable ecologically viable human activities to be pursued and developed, via encouraging the use of fixed fisheries and conserving the traditional and aesthetic side of this practice, which seems to be declining all around the Kerkennah archipelago.

A multidisciplinary approach combining geomorphology, hydrodynamism and ecology, would provide elements of response regarding the formation of these particular structures, unique in the Mediterranean Sea. It would also help clarify the mechanisms of formation of the various concretions observed in the study area. Overall, the present findings make the Kerkennah northeastern area a site worthy of promotion and monitoring in a context of global change.

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THE WITHDRAWAL OF THE LOWER LIMIT OF THE *POSIDONIA OCEANICA* SEAGRASS MEADOW IN THE BAY OF HYÈRES (NW MEDITERRANEAN): A COMBINATION OF NATURAL AND HUMAN-INDUCED RECENT AND ANCIENT PHENOMENA?

Abstract
The Posidonia oceanica *seagrass meadows are very sensitive to disturbance of human or natural origin. Here we consider the losses of the seagrass localized near the lower limit of the meadow in the Bay of Hyères (France). Samples of dead* matte *were taken near and beyond the current lower limit of the meadow, between 26 and 37 m depth. Radiocarbon* ^{14}C *analyses were used for dating the withdrawal. The death of* P. oceanica *possibly occurred between 160±100 (-29 m) and 1050±110 years BP (-37 m). The deeper and the further from the shore the sampled dead* matte *was, the more ancient it was. This withdrawal appears to be a general feature, which concerns both highly human-impacted areas (Bay of Hyères) and pristine areas, such as Port-Cros Island (National Park). Several non-mutually exclusive hypotheses might explain this recent vs. ancient and actual vs apparent withdrawal:* ***(i)*** *trawling;* ***(ii)*** *post mortem erosion of the roof of the dead* matte*, by hydrodynamism or trawling;* ***(iii)*** *compaction of dead* matte *over time;* ***(iv)*** *current and ancient rise in sea level;* ***(v)*** *current and past climate change and/or* ***(vi)*** *human induced changes (e.g. turbidity). The lower limit withdrawal is more marked in highly human-impacted areas than in pristine areas, where it may reflect global forcings such as sea level rise, warming and climate episodes).*

Key-words: *Posidonia oceanica*, radiocarbon analysis, withdrawal, global change

Introduction
The seagrass *Posidonia oceanica* (Magnoliophyta) is the engineer species of a key Mediterranean ecosystem. Like many other seagrasses worldwide, it provides many ecological goods and economic services (Pergent *et al.,* 2012; Boudouresque *et al.,* 2016). *Posidonia oceanica* meadows are very sensitive to disturbance caused by human activity (e.g. coastal development, pollution, trawling, fish farming) (Boudouresque *et al.,* 2009, 2012; Giakoumi *et al.,* 2015). However, in pristine areas, such as Port-Cros Island (Port-Cros National Park, Provence, France) and the nature reserve of Scàndula (Corsica), withdrawal of the lower limit of *P. oceanica* has also been observed (Bonhomme et al., 2010; Pergent *et al.,* 2015).
The *P. oceanica* seagrass meadow in the Bay of Hyères (Provence, France), with a ~10 000 ha surface area, is one of the largest in the north-western Mediterranean Sea (Boudouresque & Meinesz, 1982). The state of conservation of the meadows in the Bay of Hyères is affected by: **(i)** river mouths and water flow, **(ii)** bottom currents and storms, **(iii)** military activities such as the mooring of large warships and the presence of bombs dating from World War II, and **(iv)** trawling (Boudouresque *et al.,* 2009).

The *P. oceanica* meadow of the Bay of Hyères was mapped by Blanc & Jeudy de Grissac (1978) between 1972 and 1975 (a map obviously lacking in accuracy because of the unsophisticated methods available at that time), Paillard *et al.* (1993) in 1990 and Andromède Océanologie (2012) in 2011; the latter authors mapped a ~1 km wide belt of dead *matte* of *P. oceanica* at the lower limit of the meadow. The aim of the present work was: **(i)** to check the presence of this broad belt of dead *matte*; **(ii)** if actually present, to date the death of the *P. oceanica* meadow; **(iii)** and finally to investigate the possible origin of such a spectacular withdrawal.

Material and methods

The Bay of Hyères is situated in Provence (France, north-western Mediterranean Sea). Two small rivers flow into the Bay of Hyères, Gapeau River and Maravenne River.

Thirteen samples of dead *matte* (*i.e.* dead roots and rhizomes of *P. oceanica,* mixed with sediment) were taken by means of a small shovel above, near and beyond the current lower limit of the meadow by SCUBA diving, between 26 and 37 m depth. Only the superficial surface layer, 5-10 cm thick, of the roof of the dead *matte* was sampled. Radiocarbon analyses (^{14}C) of the *P. oceanica* remains were used for dating the withdrawal of the meadow beyond its current lower limit. Before the isotopic analyses, samples were carefully cleaned of macroalgae and sediment (terrigenous and organogenous carbon), in order to avoid contamination; then samples were dried 48 h at 70°C and packaged with aluminium foils and plastic bags to keep them dry during shipping. Isotopic analyses were done by GEOCHRON laboratory (Chelmsford, Massachusetts, USA).

Results

The ^{14}C analyses show that the death of the *P. oceanica* meadow possibly occurred between 160±100 (P02, -29 m) and 1050±110 years BP (P13, -37 m) (Fig. 1). The shallowest samples contained roots and well-preserved rhizomes, while the deepest ones contained only a maze of roots with only some degraded sheaths detached from the rhizomes which once bore them; thus the rhizomes were degraded *post mortem*. There was a significant correlation between depth and the age BP of the dead *matte* samples (Spearman's rank correlation, $p = 0.01$, $R = -0.68$); the deeper and more distant from the shore and the current lower limit the sampled dead *matte* was, the greater was its age. Only two exceptions were observed: P01 (470±100 years BP; -26 m) and P09 (740±110 years BP; -29 m), close to the lower limit, were older than the subsequent deeper samples.

Trawl marks were found on 10 of the 13 sampling sites. No evidence of anchoring marks was found. Macro-waste items (bombs, World War II), were observed at 4 of the 13 sample sites. The invasive Chlorobionta *Caulerpa cylindracea* was observed on dead *matte* or detritic coastal sediment at 11 out of the 13 sampling sites. The two sites where *C. cylindracea* was not observed correspond to the deepest sites P04 and P13 (both 37 m depth).

Patches of living *P. oceanica* were found not only close to the lower limit, as localized by the most recent map (Andromède Océanologie, 2012) (P01, P05, P09; 26-29 m depth; cover 5-50%) but also deeper (P02, P03, P06, P08, P11, P12; 29-33 m depth; cover 1-10%), up to 1.5 km beyond the mapped lower limit. The deepest sites (P04, P13; 37 m depth) correspond to coastal detritic assemblage with neither patches of living *P. oceanica* nor dead *matte* not buried under coastal detritic sediment (Table 1).

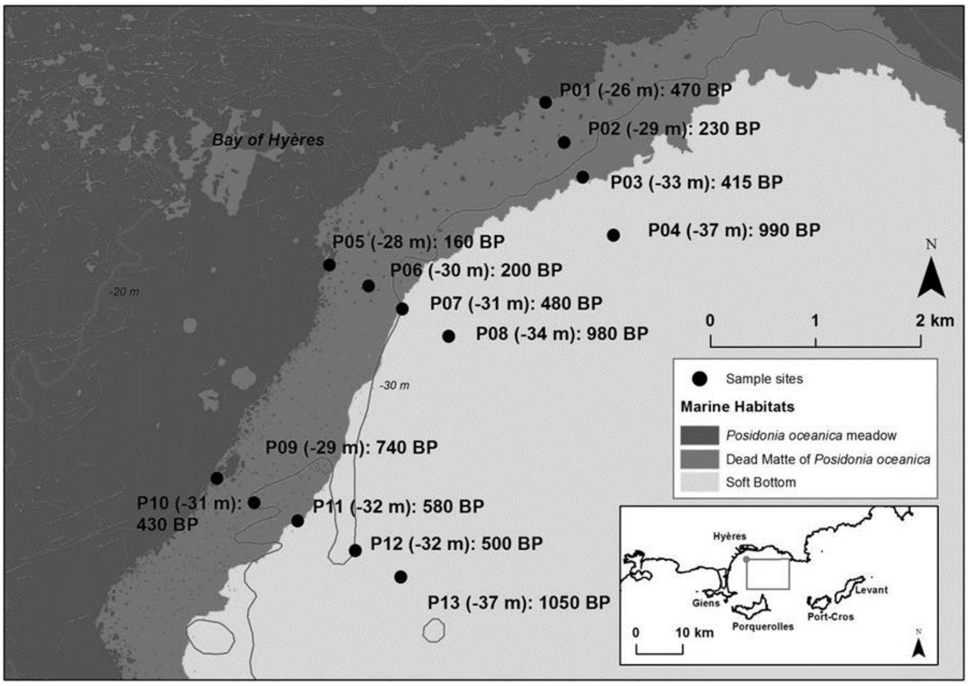

Fig. 2: Age of the dead matte samples for each of the sample sites. Source of the map of marine habitats: Andromède Océanologie (2012). Lines: depth contours (metres).

Discussion and conclusions

We observed the lower limit of the *P. oceanica* meadow at 29 m depth. However, isolated patches were observed down to 34 m depth. We extrapolated the Blanc & Jeudy de Grissac (1975) limit at about 32 m depth. Paillard *et al.* (1993) estimated the mean depth at -30 m depth. Finally, Andromède Océanologie (2012) placed the lower limit between 26 and 29 m depth.

The lower limit, at 29 m depth, is one of the shallowest in eastern Provence. However, it is not as shallow as expected, taking into consideration the human pressure in the area. The lower limit in pristine areas such as the Port-Cros Archipelago is only a few metres deeper: (29)31-33(35) m (in parentheses: minimum and maximum values; Astruch *et al.,* 2012). Deeper limits, down to 39 m, have been observed in Corsica (Meinesz *et al.,* 1987; Pergent *et al.,* 2015). Comparison of the four studies (**Tab. 1**) is difficult: **(i)** the map by Blanc & Jeudy de Grissac (1978) lacks accuracy (positioning and habitat identification); **(ii)** the map by Paillard *et al.* (1993) lacks ground truth; **(iii)** the map by Andromède Océanologie (2012) is clearly the best one, although lacking in ground truth beyond the lower limit. Congruence between the maps, where observed, evidenced the absence of change (e.g. P01, P04 and P13). The observation of dead matte with sparse meadow (this work) at sites where only a coastal detritic assemblage was previously mapped was not regarded as a progression of the meadow; rather, it is assumed that isolated shoots escaped detection owing to the low resolution of the methods used (e.g. P08). Despite these caveats, a withdrawal of the lower limit probably occurred over the last four decades (e.g. P05 and P06).

Tab. 1: Nature of the seabed at the sample sites, according to the historical maps and the present work. Comments refer to the *P. oceanica* meadow.

Sample sites	Depth (m)	Blanc (1975)	Paillard *et al.* (1993)	Andromède Océanologie (2012)	Present work	Comments
P01	26	*P. oceanica* meadow	*P. oceanica* meadow	Lower limit of the *P. oceanica* meadow	*P. oceanica* meadow	No change
P02	29	*P. oceanica* meadow	*P. oceanica* meadow	Dead *matte* with patches of *P. oceanica*	Dead *matte* with sparse meadow	Decline ?
P03	33	Sand of the coastal detritic assemblage	*P. oceanica* meadow	Dead *matte*	Dead *matte* with sparse meadow	No change?
P04	37	Sand of the coastal detritic assemblage	Coastal detritic assemblage	Coastal detritic assemblage with rhodoliths	Coastal detritic assemblage	No change
P05	28	*P. oceanica* meadow	*P. oceanica* meadow	Lower limit of the *P. oceanica* meadow	Dead *matte* with sparse meadow	Decline
P06	30	*P. oceanica* meadow	*P. oceanica* meadow close to the coastal detritic assemblage	Dead *matte* with patches of *P. oceanica*	Dead *matte* with sparse meadow	Decline
P07	31	*P. oceanica* meadow	*P. oceanica* meadow close to coastal detritic assemblage	Coastal detritic assemblage	Coastal detritic assemblage	Decline
P08	34	Gravels and coarse sand with broken shells (bioclastic sand)	Coastal detritic assemblage	Coastal detritic assemblage	Dead *matte* with sparse meadow	No change
P09	29	*P. oceanica* meadow	Coastal detritic assemblage close to the *P. oceanica* meadow	Lower limit of the *P. oceanica* meadow	Dead *matte* with sparse meadow	Decline ?
P10	31	*P. oceanica* meadow	Coastal detritic assemblage	Dead *matte* with patches of *P. oceanica*	Dead *matte*	Decline ?
P11	32	Gravels and coarse bioclastic sand, close to the *P. oceanica* meadow	Coastal detritic assemblage	Dead *matte* with patches of *P. oceanica*	Dead *matte* with sparse meadow	No change?
P12	32	*P. oceanica* meadow close to the coastal detritic assemblage	*P. oceanica* meadow surrounded by the coastal detritic	Coastal detritic assemblage	Dead *matte* with sparse meadow	Decline
P13	37	Sand of the coastal detritic assemblage	Coastal detritic assemblage	Coastal detritic assemblage	Coastal detritic	No change

Radiocarbon analyses of the roof of the dead *matte* situated at 37 m depth and 2 km away beyond the present lower limit indicate that the death of the plants might be much earlier, ~1 000 years old. Radiocarbon dating at other sites in Provence (Marseille and the Port-Cros Archipelago), also indicated a much earlier death, well before the industrial era (Boudouresque *et al.*, 1980; Gravez *et al.*, 1992). Could a *post mortem* erosion of the roof of the dead *matte*, by storms, currents or trawling, exposing older layers, constitute a bias?

The growth rate of orthotropic rhizomes is 5-6 mm a^{-1} at the lower limit of the meadow (Mossé, 1984). Erosion would have had to remove a layer of *matte* 2.4-6.3 m thick to account for a current or recent death of the meadow, which seems unrealistic.

Several hypotheses could explain the apparently early date of the death of *P. oceanica* beyond the current lower limit of the meadow, in the Bay of Hyères. **(i)** Rising sea level. 20 000 years ago, the sea level was 120-130 m below the present one. Since then, it has risen continually. Since 1000 CE, sea level rise is estimated at a few tens of centimetres in Provence (Morhange, 2001). In any case, *P. oceanica* meadows have spread upwards, following the rise in sea level, leaving behind dead *matte* of natural origin. This pattern of change in the range of the meadow could be confused with contemporaneous withdrawal (Boudouresque *et al.,* 2009). When the slope is slight, as in the Bay of Hyères, a 40-cm rise in sea level may result in a ~200-m withdrawal. **(ii)** Compaction of the *matte*. Dead rhizomes, roots and sheaths of *P. oceanica* are regarded as rot-proof, within the *matte*. This is clearly an over-simplification. We observed, at 8 out of the 13 sampling sites, that the proportion of *P. oceanica* remains was lower than in the *matte* of a living meadow. This could lead to the deepening of the roof of the dead *matte.* **(iii)** Climate changes. During the last millennium, three successive climatic periods occurred: the Medieval Warm Period (950 to 1350 CE), the Little Ice Age (1300-1850 CE) and the current Modern Warm Period. *P. oceanica* is sensitive to both low and high water temperatures (Boudouresque *et al*., 2009). **(iv)** Human induced changes. From the 9th century, a politically stable period (Carolingian dynasty), allowed fast and unprecedented demographic growth. The consequence was massive deforestation; this probably induced extensive flooding that brought to the coastal areas a large amount of terrigenous materials, decreasing both water transparency and the compensation limit of *P. oceanica*. This could explain an early withdrawal of the *P. oceanica* meadows. Overall, the withdrawal is probably linked to a combination of natural and anthropogenic factors, both ancient and recent.

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ALMOST A CENTURY OF MONITORING OF THE *POSIDONIA* BARRIER REEF AT PORT-CROS (PROVENCE) AND THE PLATFORM REEF AT SAINT-FLORENT (CORSICA)

Abstract
The dynamics of natural monuments such as the Posidonia oceanica *reefs is poorly known. The* Posidonia *barrier-reef Port-Cros has served as a laboratory for Molinier and Picard back in the 1950s and enabled them to describe the process of building of* P. oceanica *fringing and barrier-reefs, while the Saint-Florent platform-reef, mapped for the first time in the 1980s, appears to be a unique structure the construction of which remains a mystery. The availability of postcards dating from the early 20th century, aerial photographs dating from 1948, and the development of remote sensing and georeferencing techniques associated with the use of drones and 3D models, have made it possible to monitor, for the first time, the precise evolution of these reefs and associated structures. Since the early 20th century, the barrier-reef at Port-Cros has been undergoing a steady decline. Anthropogenic pressures more than natural pressures may underlie this regression. Despite a number of management measures aimed at its protection, regression of the barrier-reef continues inexorably, at an unchanged pace, such that its ultimate disappearance now seems predictable. With regard to the Saint-Florent platform-reef, the surface area covered by* Posidonia oceanica *has remained stable (around 2.5 ha), although some differences can be observed from year to year; essentially due to the quality and resolution of the aerial images used for analysis. Moreover, the main atoll observed on the platform has regularly increased in size, from 40 m^2 in 1948 to the current 189 m^2. The conservation of these natural monuments, both included within MPAs, must be given priority by environmental managers.*

Key-words: *Posidonia* reefs, mapping, temporal dynamics

Introduction
Posidonia oceanica (Linnaeus) Delile is a magnoliophyte species that is endemic to the Mediterranean Sea. It forms extensive meadows composed of the seagrass shoots on "matte" (rhizomes, roots and sediment). There are particular morphological formations of *Posidonia* meadows, including the so-called *Posidonia* reefs which are considered as a "natural heritage monument" (UNESCO, 1972; PNUE-PAM-CAR/ASP, 1999).
Under sheltered conditions, the matte can rise up with the leaf tips close to the sea surface, while the structure is found very close and parallel to the coast forming a fringing reef. The continued growth of the *matte* coupled with containment between the coast and the reef cause leaf shoot mortality on the inshore front of reef. A lagoon is then formed which can be colonized by *Cymodocea nodosa* (Ucria. Asch) and *Zostera noltei* (Hornemann). The reef develops seaward, forming a barrier reef. This type of reef may be observed at Port-Cros (Molinier and Picard, 1952). A specific triangle-shaped form is observed at Saint-Florent, which is referred to as a platform reef. This probably resulted from alternate and/or opposite currents running towards the two external sides of the triangle, where two barrier reefs, back to back, have progressed seaward, forming a triangle-shaped lagoon (Boudouresque *et al*., 1985).

Posidonia reef structures are mainly located in sheltered areas, at the inland end of bays, near the coast where human activities have the greatest impact (Giakoumi *et al*., 2015; Holon *et al*., 2015) and as a result detract from the integrity of the original reef structure, leading to their disappearance (Rouanet *et al*., 2019). Threats are numerous (coastal development, harbours, domestic pollution, artificial beaches, fish farms, etc.); moreover in the context of climate change, these structures are particularly vulnerable (rise in sea-level and shallow water temperatures) whereas they could play a role, just like mangroves, in the protection of coastlines facing extreme climate events (Pergent *et al.*, 2014 ; Howard *et al*., 2014).
The Port-Cros barrier reef and Saint-Florent platform reef are among the best-known and most frequently investigated. The aim of this work, which formed part of the CANOPé programme, was to try to reconstruct the pattern of change of these structures according to time and human impacts.

Materials and methods

Posidonia reef structures have been retraced from various data sources: postcards dating from the early 20th century, memories of the elderly, aerial photographs by the National Geographic Institute (IGN) dating from 1948, and the use of drones and photogrammetry modelling. For the oldest maps, ground truth data was not available, but since the 1970s field data for Port-Cros and 1980' for Saint-Florent have been collected by scientists.
Maps drawn during the present study are based on remote sensing using 2016 IGN photographs (pixel size 20 and 50 cm) for Saint-Florent (unusable for Port-Cros) and on ones acquired by drone (DJI Phantom 4 Pro) for both sites. The overflights were conducted at a height of between 100 m (Port-Cros) and 120 m (Saint-Florent), according to the extent of the site, for a resolution of 2.7 to 3.3 cm/pixel, respectively. These aerial images have an overlap of 70% to generate a 3D model (Agisoft PhotoScan). Data for Port-Cros were directly integrated within GIS (Esri ArcGIS 10.5®) where a geoprocessing was applied: a learning phase of automatic recognition of polygons based on the RGB colorimetric spectrum, followed by a classification phase by maximum likelihood. Data for Saint-Florent were previously integrated on Envi 4.4® software (see method of Bonacorsi *et al.* (2013)) which replaces the learning and classification phases. Therefore, all maps have drawn using GIS (Esri ArcGIS 10.5®). Errors and aberrations were manually corrected from a 3D model by means of microtopography analysis (canopy heights of *P. oceanica* and dead matte, sandy breaks) and *in situ* observations by GPS surveys. A Reliability Index was applied to estimate the credibility and relevance of data (Valette, 2018).
The temporal dynamics of the reefs were considered with regard to anthropogenic and natural pressures. Based on the frequency and intensity of human activities, and on the sensitivity of *P. oceanica* to these drivers, the main factors underlying the dynamics were identified and quantified (see method in Boursault, 2018).

Results

Port-Cros: the *Posidonia* barrier-reef has been mapped on 9 dates from the early 20^{th} century up to 2018 (Tab. 1, Fig. 1). Although the accuracy and interpretation of data have progressed, comparisons are possible with the same scale used (1/2 700). At the beginning of the 20^{th} century, the area occupied by barrier-reef was 5 846 m², and in 2018 it occupies 2 350 ha. A decline of around 60% in one century has been quantified. Although data from the early 20th century are not very precise, they allow to draw the contours of the barrier reef. The periods where regression has been the most rapid are recent: (1) from 1998 to 2010, with 21% of regression, *i.e.* 1.8% per year and, (2) from 2010 to 2018, with 20% of regression, *i.e.* 2.5% per year. The north part of barrier reef is mainly affected. Other major regression periods, especially ones since 1970, should be interpreted with caution because of the low RI of maps. Nowadays, predation by sea urchins and *Sarpa salpa* is the main pressure which accounts for a regression of 23%, followed by urban discharges (22%) and harbor construction (21%) even if the latter is relatively small in magnitude (75 places on quay and 40 places on ecological mooring).

Tab. 1: Sources of data and change in the area over time covered by the *Posidonia* barrier reef at Port-Cros and the *Posidonia* platform reef at Saint-Florent over time. RI: Reliability Index; md: missing data. * Georeferenced by Pasqualini *et al.* (1995)

Site	Date	References	Data acquisition method	Initial scale of map	*P. oceanica* (m²)	RI (%)
Port-Cros	~ 1900'	Boudouresque *et al*., 1975	Postcard	1/4 250	5 846	50
	1935	Boudouresque *et al*., 1975	Interview	1/4 250	md	28
	1968	Picture of Pombart	Postcard	1/5 000	4 481	53
	1970	Augier & Boudouresque, 1970	Transects + ground truth	1/1 785	3 902	78
	1975	Boudouresque *et al*., 1975	Postcard + interview	1/4 250	3 874	47
	1986	Augier & Nieri, 1988	Aerial photo + ground truth	1/490	3 727	81
	1998	Bonhomme *et al*., 2001	Aerial photo + ground truth	1/500	3 740	89
	2010	Goujard *et al*., 2010	Aerial photo + ground truth	1/800	2 937	89
	2018	This study	Drone + ground truth	1/40	2 350	89
Saint-Florent	1960	Bonacorsi *et al*., 2013	Aerial photo	1/25 000	24 723	61
	1983	Boudouresque *et al.*, 1985	Aerial photo + ground truth	1/3 000	21 800*	78
	1994	Pasqualini *et al*., 1995	Aerial photo + ground truth	1/6 500	21 400	81
	1996	This study	Aerial photo + ground truth	1/20 000	27 208	83
	2006	Bonacorsi *et al*., 2013	Aerial photo + ground truth	1/500	23 680	89
	2016	This study	Aerial photo + ground truth	1/500	22 257	89
	2018	This study	Drone + ground truth	1/40	22 275	89

Saint-Florent: The *P. oceanica* platform reef exhibits a small regression estimated at 10% since 1960 (less than 0.2% per year), while the area of dead matte has increased by 5% (Fig. 2; Tab. 1). The *P. oceanica* atoll, located at the base of the platform reef, has increased in area regularly over the same period (Mann & Kendall test, p-value = 0; $\alpha = 0{,}05$; Tab. 2) as has that of the *C. nodosa* meadow from 1996 (2 184m^2) to 2018 (5 879 m^2). The main pressures are seasonal beach activities (17%), harbor construction at a distance of less than one kilometer (around 800 places) in 1973 (16.5%), and agriculture effluents (16%).

Tab. 2: Progression of the surface area of the atoll located at the St Florent reef platform.

Date	**1948**	**1960**	**1985**	**1994**	**1996**	**2006**	**2016**	**2018**
***Posidonia* atoll**	39.6	42,8	53.3	94.9	105.0	120.5	177.5	188.9

Discussion

The use of drones for mapping offers the means to have images georeferenced quickly, cheaper and without the problems of sun reflection. For this purpose, 2016 IGN aerial photographs for Port-Cros are unusable. On the *Posidonia* platform reef at Saint-Florent, comparison between images from IGN and drones shows similar results for large surfaces (differences under 0.1% for *P. oceanica* on the platform reef), but indicate a larger difference for small structures because of higher pixel precision (more than 3% difference for the *Posidonia* atoll).

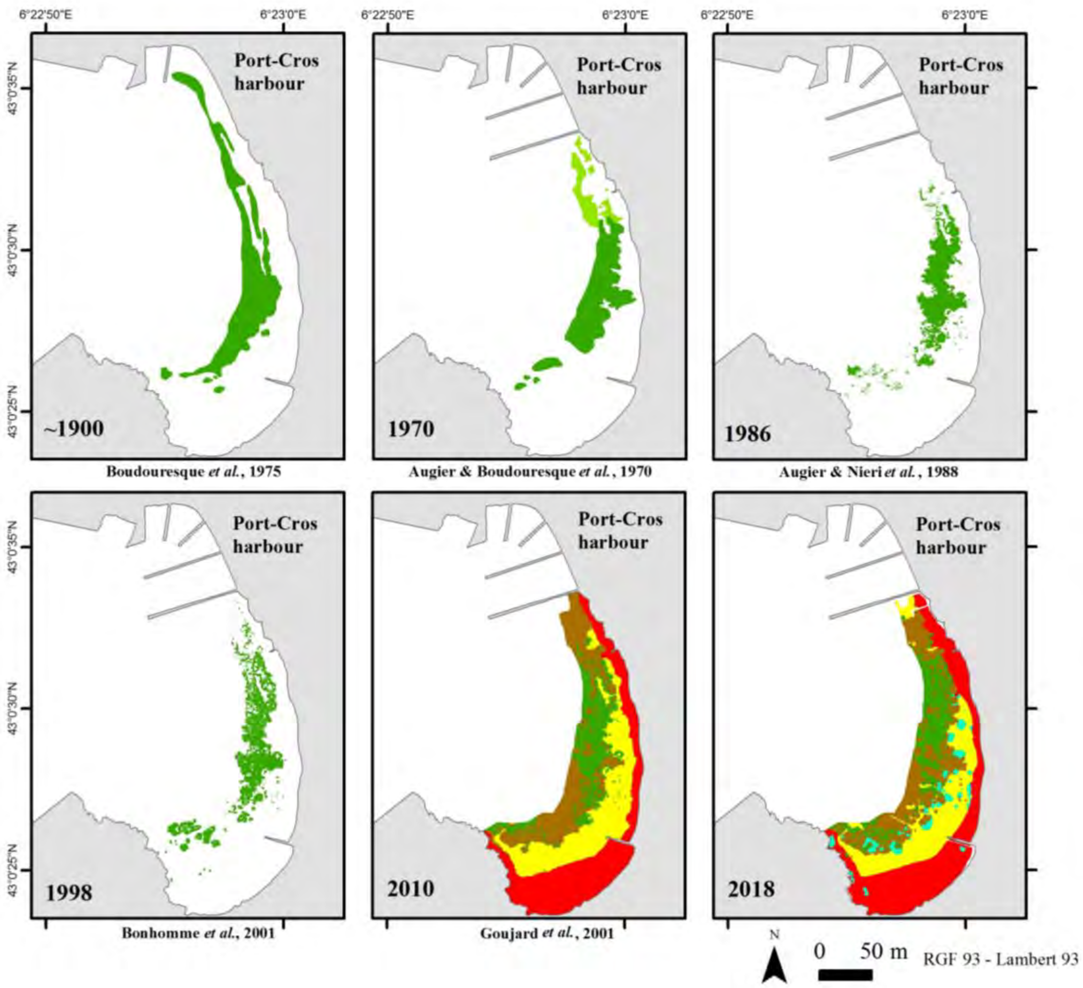

Fig. 1: Changes in the *Posidonia* barrier reef at Port-Cros from early 20th century to 2018. See legend at Fig. 2.

The temporal dynamics of the *Posidonia* barrier reef at Port-Cros and the *Posidonia* platform reef at Saint-Florent indicate a higher rate of regression at Port-Cros, especially during the two last decades, although the barrier reef there is integrated within a National Park with specific management measures (anchoring is prohibited and only clean boats are allowed access to the harbor). The spatio-temporal patterns of change in the Saint-Florent reef platform show an overall stability of the *P. oceanica* meadow since 1960, despite construction of the port and occasional damage due to trampling and anchoring of boats, which are observable despite the presence of a Biotope Protection Order (APB, May 7, 1998). The dynamics of the atoll, located at the base of the formation, corresponds with the model proposed by Pergent *et al*. (2007). These finding provide MPA managers with levers for action for the purpose of limiting regression.

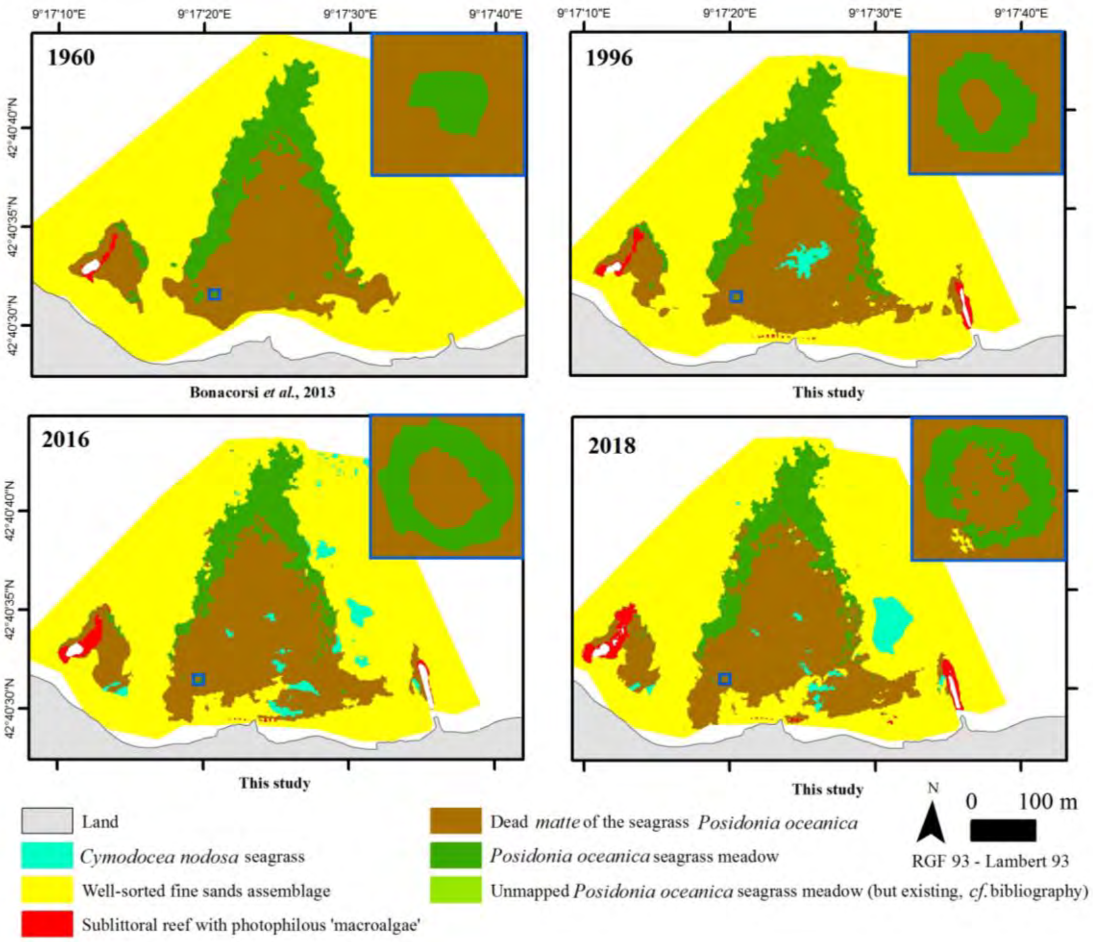

Fig. 2: Change in the *Posidonia* platform reef at Saint-Florent from 1960 to 2018.

Acknowledgments
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WHEN LIFE HISTORY MATTERS: CONTRASTING CONSERVATION ACTIONS FOR TWO CO-OCCURRING *CYSTOSEIRA* SPECIES IN NW MEDITERRANEAN

Abstract
Cystoseira *(class Phaeophyceae) species are major habitat-forming organisms with a key ecological role; however, there is a lack of understanding about their life history and population dynamics, what hinders conservation actions. This is especially worrying considering that these assemblages have undergone local declines in many Mediterranean regions over the last decades. The ultimate goal of our research is to unravel the natural dynamics of* Cystoseira *forests in order to design effective management tools. We will present results from different studies carried out in the Medes Islands Marine Reserve and nearby areas (NW Mediterranean Sea), based on two emblematic* Cystoseira *species (*C. elegans *and* C. zosteroides*). We demonstrated that these species display contrasting conservation tendencies.* C. zosteroides *is a deep water and long-lived species with slow recovery rates and is threatened mostly by local stressors. Conversely,* C. elegans *is a more dynamic species inhabiting in shallow waters, which have expanded their distribution from the marine reserve to non-protected areas during the recent years (with the exception of those dominated by sea urchins barrens). These contrasting dynamics provided the opportunity to test different restoration techniques for closely related species but with divergent life histories. Our results evidence the importance of understanding species life history when designing management strategies and restoration tools.*

Key-words: life-history traits, MPA, population dynamics, restoration, seaweeds.

Introduction
Understanding the population dynamics and the life history of species is essential to develop effective conservation (Kindsvater *et al.*, 2016) and restoration actions (Montero-Serra *et al.*, 2017). One group of organisms that have been especially neglected in population ecology and demography are macroalgae (Schiel & Foster, 2006). Different research traditions between ecologists and phycologists may have limited our comprehension about macroalgae population dynamics (Schiel & Foster, 2006). Historically, most of the ecological research has focused in trophic and community dynamics (e.g. Sala *et al.*, 1998), while phycologists focused on taxonomy, biology, or physiology (e.g. Amico, 1995). Besides, macroalgae have complex life cycles, combining microscopic and macroscopic life stages, adding additional layers of difficulty to study their population dynamics (Schiel & Foster, 2006). Beyond the causes of such biases in macroalgal studies, the main consequence is that there is a limited comprehension about their population dynamics and life histories that hinders management strategies.
In this study, we have focused on macroalgal forests dominated by *Cystoseira* species, which play a key ecological role in many coastal zones in the Mediterranean Sea. *Cystoseira* forests create complex habitats that provide food and shelter for many

associated species, increasing local biodiversity and they play a key functional role as primary producers, constituting the primary source of carbon for benthic systems where they inhabit (Boudouresque *et al.*, 2016). Unfortunately, *Cystoseira* species are heavily imperilled in the Mediterranean Sea, with already documented declines and even local extinctions (Thibaut *et al.*, 2005; Airoldi & Beck, 2007). Given its decaying trends in the Mediterranean coast, five *Cystoseira* species (*C. amentacea*, *C. mediterranea*, *C. sedoides*, *C. spinosa* and *C. zosteroides*) are protected by the Bern Convention (Annex I 1979), and all the Mediterranean species, except *C. compressa*, have been listed under Annex II of the Barcelona convention (2010). These protection acts impose restrictions on taking species from the wild and on exploitation but do not contemplate the monitoring of their conservation status. Consequently, additional protection measures have been recommended for *Cystoseira* species, including the development of reforestation actions (Gianni *et al.*, 2013).

In the Mediterranean Sea, there are more than 30 *Cystoseira* species, inhabiting from shallow waters to deeper than 50 m (Oliveras-Plá & Gómez-Garreta, 1989; Ballesteros *et al.*, 2006; Hereu *et al.*, 2008). Because of their widespread distribution and wide bathymetric range, it is likely that different *Cystoseira* species may have evolved contrasting life history strategies (Capdevila *et al.*, 2016), meaning that they would require contrasting conservation and restoration actions. Therefore, in this study, we examined the dynamics of two common *Cystoseira* species dwelling in different bathymetric ranges (Fig. 1). *C. elegans*, that inhabits in shallow waters from 0 to 20 m depth and *C. zosteroides* that lives in relatively deep-waters from 15 to more than 40 m depth. Besides, we evaluated the influence of life histories in restoration success by comparing the outcomes of different restoration techniques applied to both species.

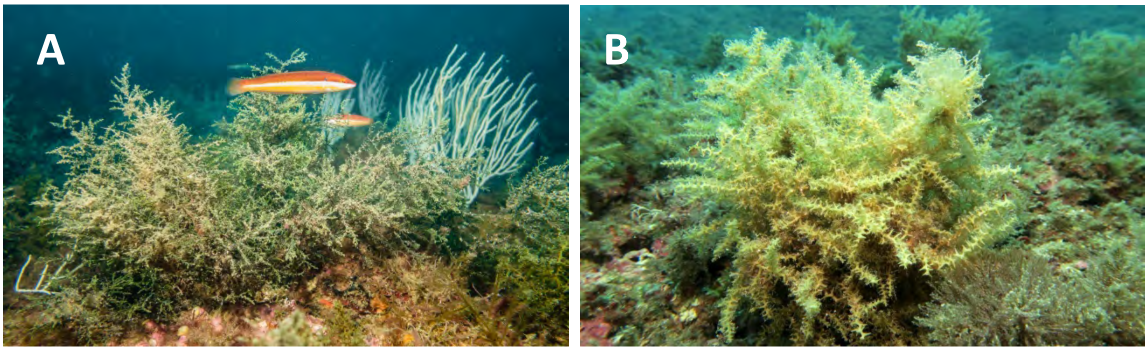

Fig. 1. Model *Cystoseira* species. A: *C. zosteroides*. B: *C. elegans*.

Material and Methods

Population dynamics study design

In order to study the population trends and life histories of these two *Cystoseira* species, we adapted the experimental designs accordingly to the particularities of each species.

For *C. elegans* we installed six permanent plots of 1 m^2 between 5 to 8 meters depth during the spring of 2017 inside Medes Islands marine protected area, where *C. elegans* populations are mature and well-preserved. All the *C. elegans* specimens found in the plots were measured and identified. To quantify their development and survival we revisited the permanent plots annually, up to date (2018).

The results of *C. zosteroides* population dynamics were based on the data obtained in our previous studies (Capdevila *et al.*, 2015; 2016), in which three *C. zosteroides* populations were monitored at different populations located in Montgrí, Illes Medes and Baix Ter Natural Park during four years (from 2008 to 2011). Demographic data of survival and growth were obtained from the annual monitoring of individuals from permanent transects installed at these populations, between 20 and 28 m depth. Each transect was 1 m wide and 3 m long and was partitioned using 50x50 cm^2 quadrats. We identified each individual by mapping their position at each of the quadrats inside the permanent quadrat, and we measured the length of the main perennial axis using a calliper with 1 mm accuracy. Sampling was performed by SCUBA diving and transects were visited annually by experienced observers at the beginning of the summer (between July and August) when the deciduous branches are more developed and *C. zosteroides* individuals attain their highest seasonal biomass (Ballesteros, 1990).

Restoration techniques

For both species, *C. elegans* and *C. zosteroides*, we tested three different restoration actions: (i) Translocation of adult individuals and (ii) juvenile individuals, by transplanting ten adults and twelve juvenile individuals from a donor population to a "recipient" population. We also transplanted ten individuals in the donor population as well, as a control to measure the impact of transportation on the survival of transplants. (iii) Recruitment enhancement, by collecting fertile branches from a well-preserved population and place them into a recipient population. To enhance the recruitment of new populations, we added free and available space in all the detailed treatments. To evaluate the success of each action we measured the survival of the new recruits, the survival of the transplanted individuals and we compared them with the natural survival rates. These restoration techniques were performed during the spring of 2017, and experiments were revisited during the summer of 2017 and at the spring and summer of 2018.

Given the impact of herbivory from sea urchins for *C. elegans* populations, we combined the transplant techniques with facilitation actions to promote the formation of forests in degraded shallow habitats, like sea-urchin barrens. These facilitations actions implied the removal of sea-urchins individuals in the locations where restoration actions were performed.

Results

Natural dynamics of shallow vs. deep Cystoseira *forests*

Through the monitoring of the two *Cystoseira* species studied here, we derived a set of fundamental traits and ecological processes to understand the dynamics of our target species (Tab. 1).

Restoration actions of C. elegans vs. C. zosteroides.

One year after the restoration actions, the most successful restoration technique to promote the formation of *Cystoseira* forests in degraded-shallow habitats was the combination of the complete removal of all the sea-urchins coupled with the transplantation of fertile apexes of *C. elegans* and the enhancement of the recruitment of the new population (Fig. 2).

C. zosteroides restoration outcomes showed that transplants of adult and juvenile individuals have high survival rates, both in natural and transplanted conditions. In contrast, the seedling technique showed that there is a high variability on the survival rates of early stages (settlers, germlings and recruits). Furthermore, the development of such early stages needed an uncolonized substrate to develop.

Tab. 1: Set of traits and ecological processes measured through the monitoring of *Cystoseira elegans* and *Cystoseira zosteroides* populations in Montgrí, Illes Medes and Baix Ter Natural Park.

Ecological process/trait		Shallow forests: *Cystoseira elegans*	Deep forests: *Cystoseira zosteroides*
Development	Growth rate	Fast	Slow
	Front development	April-September	March-September
	Perennial axis	Present (reduced)	Present
Reproduction	Reproductive season	April-July	March-June
	Fertile Maturity	First year	≥3 years
	Reproductive output	Unknown	High
Survival	Lifespan	Unknown	Long
	Survival rates	Unknown	High
Turnover	Generation time	Unknown	Long
	Population stability	Unknown	High
Intra/interspecific interactions	Density-dependence	Unknown	Negative
	Herbivory pressure	High	Low

Fig. 2: Shallow sea-urchin barrens before (2017, left) and one year after the restoration action (2018, right) promoting the formation of *C. elegans* forests.

Discussion

Our results show that two co-occurring and phylogenetically related species, but with contrasting bathymetric distribution, can display very distinct population dynamics. *Cystoseira elegans* showed “fast” life history traits, with high growth rates, early maturation and was highly affected by herbivory. In contrast, *C. zosteroides* had “slow” life history traits, with very slow growth rates, late age at maturity and with long generation times. Some traits that we were able to measure in *C. zosteroides* could not be estimated in *C. elegans*, because of the limited duration of the present work. However, life history traits are related to each other through trade-offs (i.e. budgetary compromises in the resources that can be invested in one trait or another; Stearns, 1992), meaning that with the known information some hypothesis could be made.

Recent developments on life history theory and demography suggest that deep-water macroalgal species have high survival rates, at the expense of reproductive processes as a mechanism to deal with the limited energetic resources (i.e. light and nutrients) available in such environments (Engelen *et al.*, 2005; Capdevila *et al.*, 2016). In contrast, shallow-

water species, inhabiting in more dynamic environments (subject to higher hydrodynamic forces and higher light availability), their population dynamics highly depend on growth and reproductive processes (Capdevila *et al.*, 2016). Since *C. elegans* has a fast development, it seems likely that their populations are sustained mainly through reproductive and growth processes. This life history strategy is common in environments with high availability of resources or with frequent disturbances (Grime, 1977; Capdevila *et al.*, 2016), where fast development and early reproduction are beneficial to rapidly capitalize the available energy, and to recover fast from high biomass losses through disturbances (i.e. herbivory or hydrodynamics). Therefore, our results suggest that *C. elegans* has a very distinct life history strategy than *C. zosteroides,* bringing up that different conservation actions are needed to effectively restore their populations.
The relevance of understanding the dynamics of our two *Cystoseira* species has implications both for life history and for conservation. The success of the tested restoration techniques was related to the differences in the population dynamics of both species. *C. elegans* was mostly benefited by restoration actions targeting early life stages, what may resemble to its natural population dynamics. Besides, in some cases, the recovery of *C. elegans* was very quick, in line with the fast development of this species. In contrast, the most effective restoration technique for *C. zosteroides* was adult transplantation, what again is related to the dependence of their populations on adult survival. This link between the population dynamics of the species and the effectiveness of restoration techniques may help conservation scientist to anticipate the outcomes (i.e. success/failure) of management actions. Despite the limited information that we provide here, our results yield useful information for future studies on macroalgal restoration and highlight the importance of population studies and monitoring programs for species conservation.

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THE MATRIX RELOADED: CARLIT ASSESSMENT TEN YEARS LATER IN THE SINIS COAST (SARDINIA, ITALY) COUPLED WITH DRONE TECHNOLOGY

Abstract

Mapping and monitoring of marine habitats are crucial tools for coastal management and the implementation of conservation measures. CARLIT index is based on the cartography of littoral assemblages and their sensitivity to changes of environmental conditions. It has been widely tested and applied in the Mediterranean Sea since its introduction in 2007, to assess the ecological status of water bodies within the Water Framework Directive (WFD). Sinis coast (Sardinia, Western Mediterranean) comprises Penisola del Sinis - Isola di Mal di Ventre MPA, being a poorly inhabited and almost devoid of man-made structures. The methodology was for the first time applied in 2008, representing the first application in Sardinia and among the first ever. In 2018, we re-monitored the same coastline coupling a drone technology integration of the classic methodology. The aim of the study was to compare the ecological status 10 years later and to develop a GIS database with more detailed information respect to previous data that will be available at high resolution for future monitoring and developments (e.g. coverage, DTM). Data were gathered by boat or by walking along the coast and high-resolution images were acquired by a commercial drone, elaborated using Structure from Motion (SfM) technique and georeferenced. CARLIT revealed an overall stability of ecological status of water bodies 10 years later, with some slight differences along restricted stretches of coast. The implementation of high resolution GIS based mapping of littoral habitats will allow to obtain more detailed data on the vertical zonation and extent of the most abundant assemblages. Furthermore, the drone technology will represent even more a historical baseline to follow temporal dynamics of marine vegetation, for both the early detection of native species regression and the spreading of non-indigenous one.

Key-words: CARLIT, *Cystoseira*, GIS, MPA, UAV

Introduction

The Mediterranean coastal seascape has sharply changed in the last decades, mainly due to the disappearance of species sensitive to local anthropogenic disturbances and global climate changes. Benthic communities associated with rocky littoral habitats are known to respond significantly to slight changes of environmental conditions, thus they are considered as good bioindicators of water quality for the implementation of Water Framework Directive (WFD) 2000/60/EC. Their occurrence is taken into account for the assessment of the ecological status of water bodies in the Mediterranean Sea, according to the Cartography of littoral and upper-sublittoral rocky-shore communities (CARLIT) method (Ballesteros *et al.* 2007). They include shallow species, such as *Cystoseira* spp., threatened (UNEP/MAP-SPA/RAC, 2018) because experiencing a huge decline in Mediterranean Sea (Thibaut *et al.* 2015). This is especially noticeable where an historical baseline of long phycological tradition is present, allowing to recognise an appropriate reference point and correctly interpret the possible decline. On the contrary, this is not

evident when proper dated historical records are lacking. Despite the CARLIT methodology is widespread all around the Mediterranean Sea (Badreddine *et al.* 2018 and reference therein), only a few examples of re-surveys after many years have been reported in literature, namely for France (Blanfuné *et al*. 2017) and Spain (Torras *et al*. 2015).
The method proposed by Ballesteros *et al.* (2007) has been modified, simplified (Blanfuné *et al*. 2017 and references therein) and empirically adjusted (Lasinio *et al.* 2017). Notwithstanding, to date, no technological improvements have been yet considered to increase the amount and resolution of collected information during the monitoring of rocky shore communities, especially for detailed shift detection. In recent years, Unmanned Aerial Vehicles (UAVs) or briefly 'drones' became a powerful tool for environmental applications including surveying and monitoring, that are essential for the implementation of habitat mapping and conservation measures (Lorah *et al*. 2018; Ventura *et al.* 2018).
In the Sinis Peninsula (Western Sardinia, Italy), apart from former punctual references, i.e. phycological lists (Cossu, 1992; Gueneau *et al.* 1992), the CARLIT assessment of Guala *et al.* (2010) performed during spring 2008 is the most significant oldest semi-quantitative baseline of macroalgal assemblages.
This paper aims to re-evaluate the CARLIT along the same strength of the coast, exactly 10 years later, in order to assess historical change of macroalgal communities and water quality along the Sinis Peninsula. Additionally, the potential of a commercial drone have been assessed i) to test the feasibility of data acquisition for the addition to the CARLIT protocol; ii) to explore new type of data available from this type of approach; iii) to built a detailed reference baseline for future comparisons in the study area.

Material and methods

This study was carried out along the Marine Protected Area of Penisola del Sinis - Isola Mal di Ventre (thereafter, MPA) located in the Middle-West coast of Sardinia (Italy). The shoreline is characterized by different coast typology: low rocky shores and cliffs alternating with sandy beaches for about 27 km of coastline. Northwards the MPA is exposed to western winds, while southwards (inside the Gulf of Oristano) it is sheltered from dominant winds and waves. The study area is contiguous to a wide wetland system (Cabras and Mistras lagoons) and the Tirso mouth, the main river in Sardinia, both affecting the Gulf of Oristano, where they flow into. The area is scarcely urbanised with a demographic density of about 90 inhabitants/km^2 almost stable during the decade 2008-2017 (ISTAT, 2017). As a matter of fact, it can be considered very low compared to other Mediterranean sites where Fucales assemblages were assessed (Thibaut *et al.* 2015; Grech, 2017) such as Portici in the Gulf of Naples (Italy) with 12,000 inhabitants/km^2. In the entire Sinis coast, 12,000 is the mean number of touristic influx per season. A treatment plant system, devoted to civil and industrial wastewater, is located about 10 km apart from the MPA. It was settled in the 80s and was dedicated at the beginning to the industrial area and the Oristano city. Between the years 1990-2000, the plant system was extended to treat also neighbouring municipalities wastewater outputs. The treatment plant receives wastewater for a Population Equivalent or unit per capita loading (PE) of 79.423 (N. ab/eq) with a flow of 31.111 mc/g. (Provincia di Oristano, 2014). Discharge outlet flows into the industrial port channel and then into the Gulf of Oristano. The water circulation is mainly forced by the NW wind and is characterised by a short water-residence time (Cucco *et al.* 2006), with a fast and intense exchange of water masses with the open sea. Under the most common wind forcing, 1.5 days is required to renew the

70% of the gulf water.
The re-monitoring of CARLIT was carried out along the entire coastline of the MPA through the traditional method, by assigning the sensitivity level (SL) to benthic communities detected along the rocky coast and assessing the Ecological Quality Ratio (EQR) according to Ballesteros *et al*. (2007). The EQR values were calculated for each of the two water bodies (WB1 and WB2, respectively inside and outside the gulf) as defined by Guala *et al.* (2010) on the basis of the different geographic orientation and exposure to prevailing winds. In addition, we used a DJI Phantom4, a consumer grade drone, to collect macroalgal assemblage orthophotos. Take-off and landing were controlled manually from a small boat or by walking along the coastline. Different geomorphologic relevant features (*sensu* Ballesteros *et al.*, 2007) were selected to test the cruise feasibility and the cartographic rendering (i.e. accuracy, distortion, coverage) at different flying height (from 5 to 20 m a.s.l.). All the images were edited using the photogrammetric software Agisoft PhotoScan Professional and Structure from Motion (SfM) techniques to obtain a digital model of the coast and analysed through free and open source Geographic Information System (QGIS) to compute the surfaces covered by the most abundant assemblages.

Results

The EQR values after 10 years were maintained both in WB1 (from 0.64 to 0.60) and WB2 (from 0.97 to 0.95), with the same 'Good' and 'High' ecological status respectively. Superimposing the stretches of coastline with corresponding SL assigned to thriving communities in 2008 and 2018, some slight differences were detected and are represented in Fig. 1.
Through the drone survey, more than 2,500 high-resolution orthophotos of macroalgal assemblages were collected. The best compromise between sampled area and resolution was found at 15 m of flying height. Through the image processing, high-resolution ortho-mosaics (0,5 cm/px; Fig. 1) and digital terrain models (DTMs) were obtained. From the digital models and orthophotos of the coast, the coverages of the shallow subtidal communities and terrain attributes (slope, aspect, rugosity) were estimated with a decimetric accuracy and a sampling effort of 2.6 h/km. As additional result, here we defined the Index of Cystoseirety (IoC), namely the ratio between surface of the species and the coastal length (see example reported in Fig. 1).

Discussion and conclusions

The CARLIT index shows that the water quality did not changed from the first assessment in the MPA. The drone survey allowed to integrate the CARLIT data with more accurate information on the distribution and the surfaces covered by the most abundant communities.
This study demonstrated the high stability of the 10-years-later-CARLIT assessment (among the first in the Mediterranean Sea and the first reported in Italy). Despite this index could be performed every three years across all the water bodies without significant reduction in the confidence of EQR classification (Cavallo *et al*. 2016), it was no longer monitored in the study area after 2008 and this contribution updated the information to 2018.

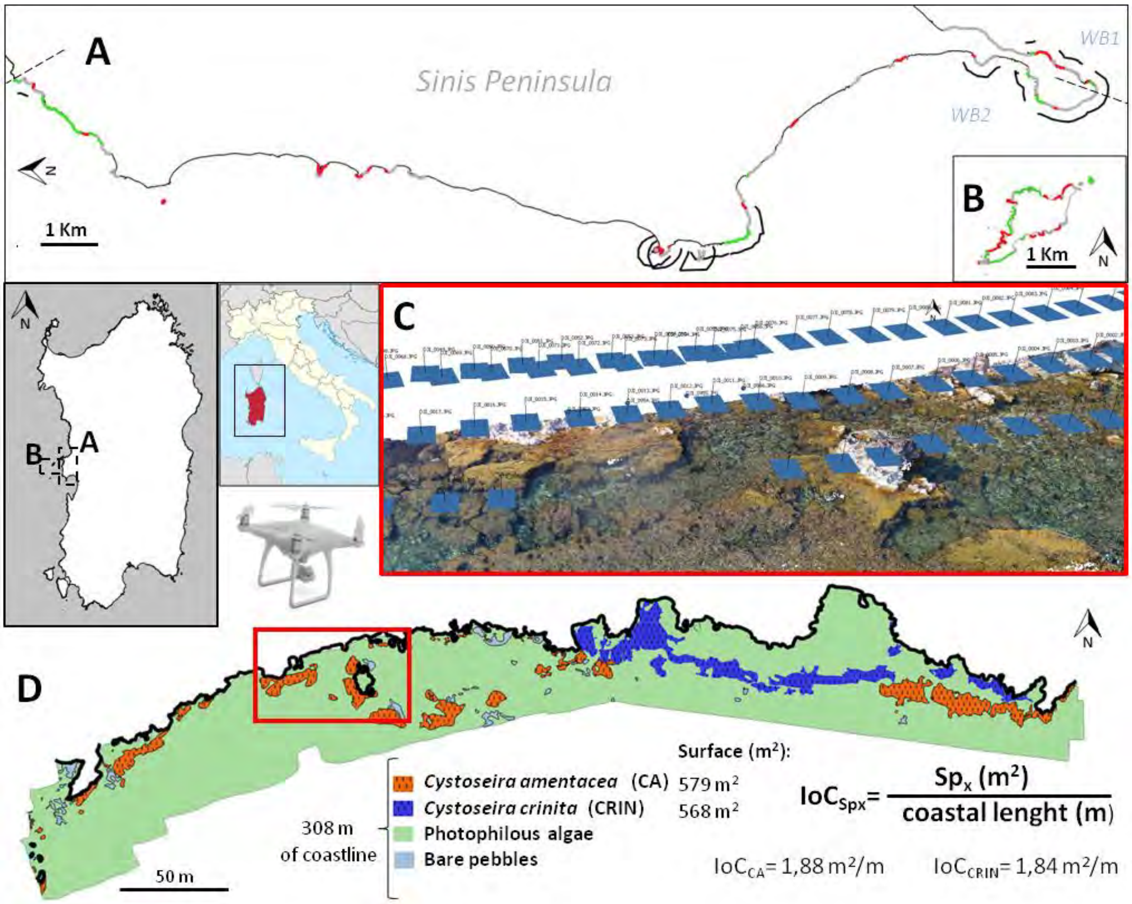

Fig. 1: SL variation after 10 year along the Sinis coastline (Red=decrease; Green=increase; Grey=stable). Black line below the coastline indicate the sectors where orthomosaic photos where acquired (A, B). Example of a 3D model coastline with the superimposed orthophotos (C). Final result of drone survey with delimited macroalgal assemblages (D).

Our results point out once more, as suggested by Guala *et al.* (2010), that Sinis coast (outside the gulf) is the ideal candidate to represent a proper reference site, at least for the biogeographic area that includes the coastline of Sardinia and the north Tyrrhenian sea (see Bianchi, 2004), with highly biodiverse stands along a very heterogeneous geomorphologic coastline. Considering the high level of EQR in WB2, with lushy forests of *Cystoseira amentacea* and *C. crinita*, the area is worth of conservation measures, detailed investigations and more frequent monitoring programmes. On the contrary, higher trophic conditions are evident inside the gulf, probably because of the influence of surrounding inland water systems. Although the assessment of the anthropic pressure was beyond the scope of this work, tourism activities in the Sinis area have shown a definitely slight increase in recent past. We felt confident that habitat destruction could be excluded at present, however human trampling should be monitored as some patterns may be significant and no data are currently available.
The slight difference of SLs recorded along a few stretches of coast (Fig.1), could be due to both natural temporal dynamics of algal communities and the influence of human pressure. Notwithstanding we cannot exclude the bias of the subjectivity of the CARLIT index assessors.

The innovative technique of post-processing images from drone allowed us to compute coastal surfaces covered by the most abundant community assemblages with a decimetric accuracy, through a relatively low sampling effort considering also the increased amount of information acquired. The current contribution is far to propose a further integration of CARLIT, that is complete for the purpose for which it was conceived. However, the information coming from ortho-mosaics and terrain attributes allow to detaily characterize the forests and open new scenarios of studies and analysis such as the IoC and the computation of spatial patterns through a seascape ecology approach.
This study suggests that new developments are available for the assessments of shallow rocky shores and that complementary data collected by drone could be coupled to raise the amount and the quality of data from standard monitoring. The use of drone technology, in conjunction with SfM algorithms, will offer a powerful contribution, that is additional to the EQR assessment, used until now. Furthermore the post processing workflow could be remarkably improved and the selection with mapping of the communities could be considerably simplified through algorithms (Adams, 2008), i.e. Object-based Image Analysis (OBIA; Ventura, 2018). Once implemented, such an analysis could automatically detect CARLIT categories on the ortho-mosaics to be furtherly validated by an expert and trained eye. Future habitat mapping, with improved sensors and longer battery life of drones, will easily advance the classic visual method, adding detailed and georeferenced data about assemblage coverage and terrain attributes (i.e. slope, aspect, bathymetry and DTM) with relatively low cost, sampling effort and high accuracy. These achievements will give a detailed baseline to follow temporal dynamics (e.g. the early detection of macroalgal community shifts and slight SL changes with high resolution models of coastline), and could allow to disentangle global changes to local one (punctual pollution or habitat destruction) in an area that is still far from to be properly studied from a phycological point of view.

Acknowledgments

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REGRESSION TREND OF *POSIDONIA OCEANICA* IN A PILOT REGION (TURKEY) WITHIN THE MONITORING PROGRAMME OF THE MED*POSIDONIA*

Abstract
Widely distributed throughout Mediterranean coastal waters, Posidonia oceanica *(L.) Delile seagrass meadows form monospesific meadows that comprise an important benthic habitat type. However, recent anthropogenic pressures on coastal regions have caused irreversible regression and loss of this habitat. Due to its low resilience to the anthropogenic pressures,* Posidonia oceanica *is used as a bioindicator or 'biological quality element' in long-term monitoring programmes, including in the European Commission's Water Framework Directive (WFD 2000/60/EC) for evaluation of the status of coastal water bodies. In order to develop seagrass monitoring networks and establish sustainable management programmes in Turkey and three other Mediterranean countries (Algeria, Libya and Tunisia), a long-term monitoring programme was set up. The programme included determination of* P. oceanica *parameters and cartographic surveys through the "MedPosidonia" Programme in 2008. After 8 years had elapsed, the* P. oceanica *meadows in the pilot region (Gökçeada, North Aegean) were surveyed again according to the monitoring procedure of the "MedPosidonia". The results showed that the location of the lower limit of the seagrass meadow has regressed (mean 3.21±1.1 m), besides other ecological parameters that indicate regression, and accordingly the* Posidonia Biotic Index *declined from 'Good' to 'Moderate' status (0.63 to 0.41). The regression might be attributed to human-induced pressures that have increased in the region during the past eight years. Furthermore, other environmental factors and events may have also contributed to the observed change. Since* P. oceanica *is protected by the European Commission's Habitat Directive (Annex I - EC Directive 92/43/EEC) and is listed as a priority habitat throughout the Mediterranean, it is recommended to rectify deficiencies in data on the seagrass in Turkey within implementation of long-term monitoring for biodiversity conservation.*

Key-words: Biotic index, habitat loss, regression, Gökçeada

Introduction
Posidonia oceanica (L.) Delile seagrass forms monospecific meadows that comprise an important benthic habitat type and provide a functional ecosystem service in the Mediterranean. However, changing climate conditions and recent anthropogenic pressures within coastal regions have resulted in irreversible regression and loss of this habitat (Bianchi and Morri, 2000; Ruiz and Romero, 2003; Short *et al*., 2007). Due to its low resilience to the anthropogenic pressures, *P. oceanica* is used as a bioindicator or 'biological quality element' (BQE) in long-term environmental monitoring programmes of coastal waters (Pergent *et al*., 1995; Balestri *et al*., 2004; Boudouresque *et al*., 2009). This BQE is also adopted by the European Commission's Water Framework Directive (WFD 2000/60/EC) for the evaluation of the ecological status of coastal waters in as wide spatial extent as possible (EC, 2000). Within this concept, the *Posidonia* Biotic Index was

developed by Lopez y Royo *et al* (2010) in order to quantify and classify the ecological quality ratio (EQR) that compares the status of a given waterbody against a reference condition.
The present research was aimed at evaluating the status of *P. oceanica* seagrass meadows as part of a monitoring iniative that was started in 2008 as part of the Med*Posidonia* Programme; a RAC-SPA (Regional Activity Centre for Specially Protected Areas) project held in partnership with Foundation Total. The project is aimed at developing seagrass monitoring networks, which will compile information on the state of marine ecosystems and set up long-term monitoring programmes in four Mediterranean countries (Turkey, Algeria, Libya and Tunisia).

Material and methods
Gökçeada, the largest island in Turkey (289 km^2) is located in the North Aegean (Fig. 1), has distinct hydrodynamic characteristics compared to the northwestern Mediterranean due to the effects of the Turkish Straits System. The region is characterized by low salinity and low temperatures and is influenced by waters from the Black Sea that enter the Mediterranean via the Dardanelles Strait (Ignatiades, 2005; Siokou-Frangou *et al.*, 2009; Sayın & Beşiktepe, 2010). As a result, the distribution of stenohaline *Posidonia oceanica* meadows that are adapted to typical Mediterranean seawater conditions are also affected by the hydrological conditions present around the island. Yıldız Bay, located on the northeastern coast of Gökçeada, was selected as the pilot region for the long-term monitoring programme. In 2008, a long-term monitoring system was set up between depths of 25.5 m and 27.4 m; which correspond to the lower limit of the meadows. The geographical coordinates of the study area are: 40°14'16.9" North latitude and 25°54'15.8" East longitude. Descriptive ecological and biometric parameters for *P. oceanica* and ecosystem status attributes were determined and a cartographic survey made. Following an eight years period, the meadows in the monitoring area were re-surveyed according to the monitoring procedure of 'Med*Posidonia*'; ecosystem status was determined according to the BiPo index based on evaluation and integration of four individual metrics: lower limit depth of the meadow, type of the lower limit, shoot density and shoot length or foliar surface at a depth of 15±1 m. Differences in values of descriptors of *P. oceanica* for the period 2008 to 2016 were tested using *t*-tests for independent samples when conditions were normal and distributed homogeneously. Significance was tested with α set at 0.05.

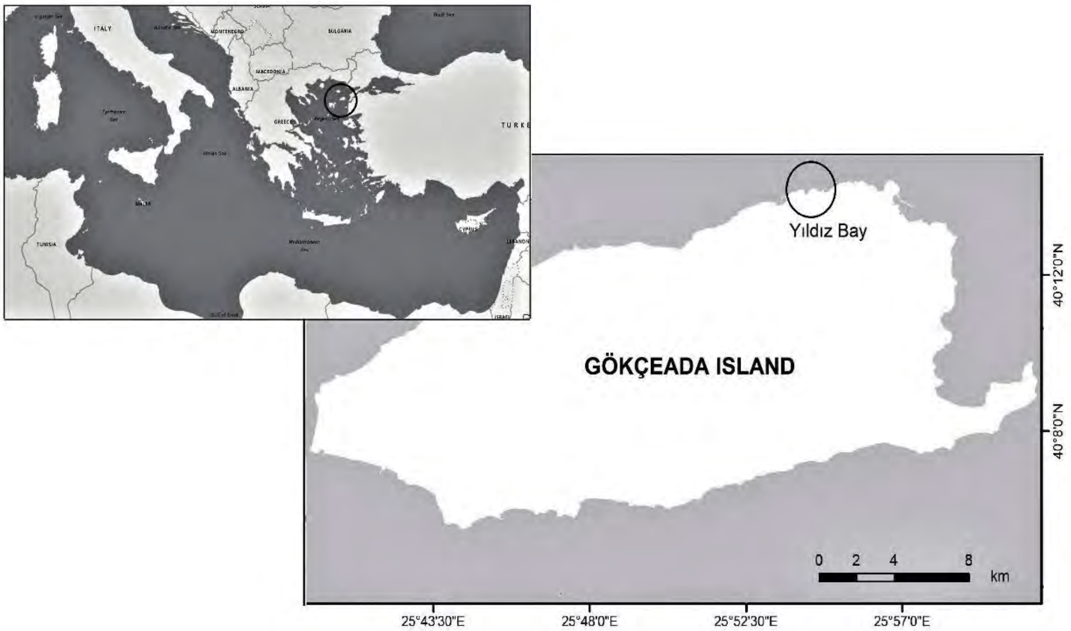

Fig. 1: The monitoring area: Yıldız Bay in Gökçeada Island (North Aegean, eastern Mediterranean)

Results

Values of the measured descriptors and of the corresponding index reported for the pilot region are given in Table 1.

Tab. 1: Values of ecological descriptors of *Posidonia ocenica* and of the ecological quality ratio (EQR), along with the identified status in Yıldız Bay (mean values ± 95% confidence interval). P: Progressive, Sp: Sparse limit.

Year	Lower limit				15 ± 1 m		
	Depth (m)	Type	Cover (%)	Plagio (% shoot^{-1})	Shoot density (shoot m^{-2})	Foliar surface (cm^2 shoot^{-1})	EQR (Status class)
2008	26.6±0.4	P	50.9±11.0	80.2±11.1	198.4±14.9	309.2±17.7	0.63 (Good)
2016	23.4±0.7	Sp	37.4±18,1	45.7±7.8	108.4±38.8	195.7±11.6	0.41 (Moderate)

The present results indicated that the location of the lower limit of the seagrass has regressed (by 3.21±1.1 m), while regression is also indicated by the obtained values for the other ecological parameters considered in the present study. Values of the *Posidonia* Biotic Index, based on the four descriptors used in the present assessment, indicate that the status of the meadows has declined from "Good" to "Moderate" status (0.63 to 0.41). Plagiotrophic rhizomes were present in front of the lower limit in 2008; however dead matte of *P. oceanica* extended at the lower limit with a cover of <50 % in the present assessment; therefore the type has changed to a "sparse" limit. The sediment type at the lower limit is dominated by gravel (2-20 mm) (24.5 %) and very coarse sand (1-2 mm) (20.0 %). Shoot density (t-test; p=0.026); meadow cover (t-test; p=0.012); plagiotrophic rhizomes (t-test; p=0.0001) and rhizome baring (t-test; p=0.012) declined significantly at the lower limit depth, as did other parameters (rhizome growth, leaf production, shoot length and coefficient A) (Fig. 2).

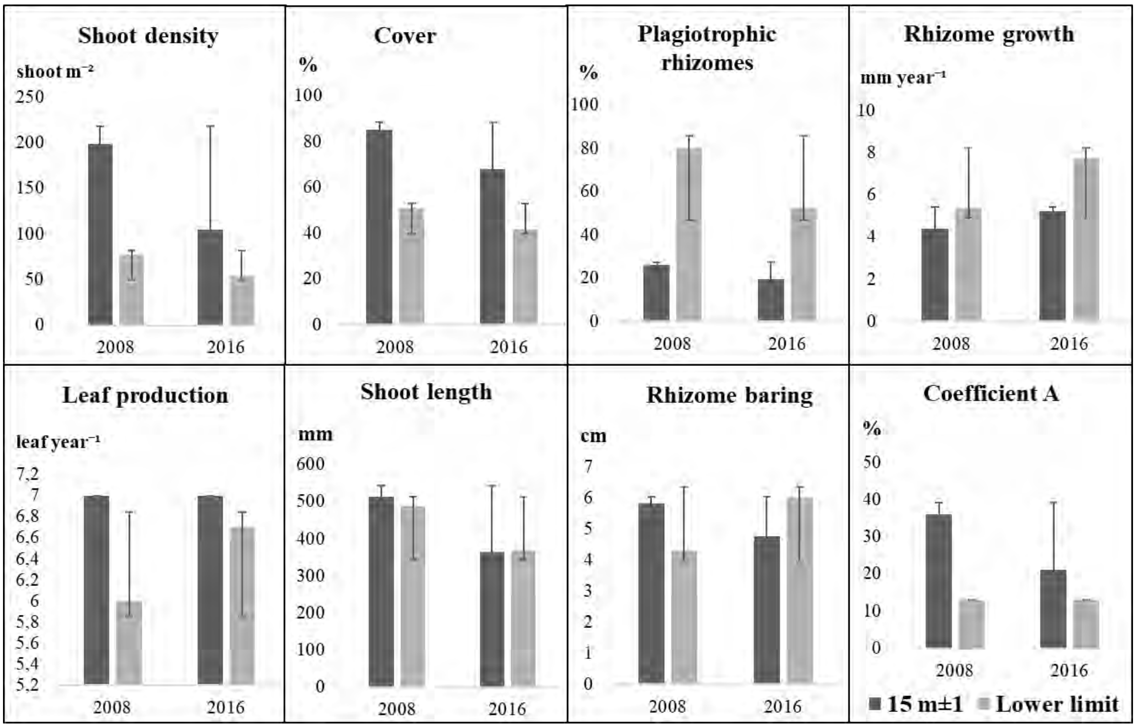

Fig. 2: Values of ecological and biometric descriptors of *Posidonia oceanica* at the reference (15±1 m) and lower limit depths.

Discussion and conclusions

The presence of *Posidonia oceanica* meadows sensitive to direct or indirect environmental conditions, is critical in terms of biodiversity of Gökçeada Island (North Aegean). The regression in vitality of *P. oceanica* meadows in the region may be attributed to anthropogenic pressures (tourism and agriculture activities) that have increased during the last 10 years as a result of population growth. Furthermore, other environmental factors and processes (for example the benthic mucilage phenomenon that occurred in 2010; freshwater input; strong hydrodynamism; and sedimentation) may have contributed to the observed regression.

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CHARACTERISATION OF THE *POSIDONIA OCEANICA* MEADOW IN RACHGOUN ISLAND (AIN TEMOUCHENT, ALGERIA)

Abstract
A Posidonia oceanica *meadow in Rachgoun Island, localized using hydroplane transect surveys, has been characterised at its lower limits (-17 m to -18 m) and its upper limits (-0.5 m). The shoot density varies from 482 ± 29 shoot m-^{2} at the upper limit to 102 ± 7 shoot m-^{2} at the lower limit. According to UNEP/MAP-RAC/SPA, 2015, the estimated densities at both limits are "bad". The leaf surface per shoot increases slightly with depth. Because of density, the leaf area index at the upper limit is four times higher than it is at the lower limit. The average leaves production varies from 7.64 ± 0.46 to 8.15 ± 0.5 leaves per year. The average rhizome growth ranges 6.49± 0.79 to 6.85 ± 0.7 mm per year in the upper and lower limits respectively. Over the 40 sampled shoots, five floral peduncles were found. The vitality measurements were estimated using standardized grids, according to five levels of quality, defined in UNEP/MAP-RAC/SPA, 2015 standards. The interpretation of the different results suggests that the quality of the meadow in the lower limit varies from bad to good. However, the low values recorded are probably due to the close proximity of the meadow to the mouth of Oued Tafna River and its impacts rather than to anthropic pressures.*

Key-words: Mapping, *Posidonia oceanica*, Rechgoun islands, lower limit, Algeria.

Introduction

The Algerian Ministry in charge of the Environmental aspects, and in collaboration with the SPA/RAC, has implemented the activities related to the "MedKeyHabitats" project in Algeria. In the framework of this project, mapping and characterisation of marine habitats of conservation interest has been conducted in the Rachgoun Island (Wilaya of Ain Témouchent).

Posidonia oceanica is the most important endemic seagrass species of the Mediterranean Sea and it can form meadows or beds extending from the surface to 40 m depth. *P. oceanica* is present almost throughout the Mediterranean. In the west, it disappears just before the Strait of Gibraltar, near Calaburros in the north and Melilla in the south. In the east, it is absent from the Egyptian coast (east of the Nile delta), Palestine to Lebanon (Boudouresque, 2006).

Despite *P. oceanica* being one of the most important and well-studied Mediterranean species, until recently there has been a limited effort to study the habitat distributional range and the condition of the habitat's typical species and communities. This should be done especially in accordance with the integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and related Assessment Criteria (IMAP) particularly in the limit distribution area of *P. oceanica* in the Mediterranean Sea. Rachgoun Island lies is in the western coast of Algeria and less than one hundred kilometres to the known limit of *P. oceanica* distribution

in the south west Mediterranean Sea. However, the distribution, the status of *P. oceanica* meadows in Rachgoun Islands is still unknown.
The aim of the present study is to evaluate the health status of *P. oceanica* in Rachgoun Island at the upper and lower limits of the meadow through investigating structural, morphological and growth parameters.

Materials and methods
The Rachgoun island (35°19'16.49"N, 1°28'48.12"W) is approximately 950 m long and 500 m wide on the widest part. The approximate area of the island is roughly 28.5 ha. The study was conducted while scuba diving in June 2016 along the western coast of Algeria. *P. oceanica* meadow in Rachgoun Island, was located and identified during hydroplane transect surveys. The characterisation of the meadow was described at its lower limit (-17 m to -18 m) and its upper limit (-0.5 m).
Meadow cover was measured by direct visual observation using vertical photography from the top with ten replicates. Shoot density was estimated *in situ* at each station by counting the number of shoots present in a 40 cm x 40 cm quadrat with ten replicates. *P. oceanica* orthotropic rhizomes were sampled at random in each station for laboratory analysis. For the two limits, the evaluation of the rhizomes' burial and the percentage of plagiotropic rhizomes was carried out in each density quadrat according to Boudouresque *et al.* (1980) and Charbonnel *et al.* (2000).
Leaf length and width were measured according to Giraud (1979), leaves were detached from each shoot and their length and width were measured to be divided in the following categories: adult leaves (length greater than 50 mm with sheath), intermediate leaves (length greater than 50 mm without sheath) and juvenile leaves (length less than 50 mm without sheath). Two leaf indices were calculated: The leaf Area Index, which corresponds to the leaf surface area in m^2 per m^2 of meadow; The coefficient A, which indicates the number of leaves having lost their apex (due to grazing by herbivores or due to hydrodynamic action).
The annual rhizome growth (cm $year^{-1}$) and the leaf formation rate (number of leaves $year^{-1}$) were determined for the last decade (2006-2016) following the standardized procedure of lepidochronology analysis (Pergent *et al.,* 1995).

Results and discussion
Despite its small surface of the meadow (16 hectares) and the high fishing pressure around Rachgoune Island, the *P. oceanica* meadow is relatively stable and overall the coverage of the meadow rate is high (100% cover in the upper limit and 35% cover the lower limit). The shoot density increased from 482 ± 29 at the upper limit to 102 ± 7 at the lower limit. According to Giraud's (1979) classification, the meadows at the lower limit is Type V and described as a "Semi-Meadow " while the meadow at the upper limit is of Type II and described as a "Dense Meadow ". According to UNEP/MAP-RAC/SPA (2015), the classification of shoot density shows that the densities estimated at the two limits are "bad". The density is in direct relation to the light and the transparency of the waters; it decreases with increasing turbidity (Pergent *et al.,* 1995). Therefore, the close proximity of the mouth of the Oued de Tafna river could result into high turbidity in the water from the sedimentation and consequently the low-density values observed.
With 14% of plagiotropic rhizomes at the lower limit, the meadow is considered stable according to Charbonnel *et al.* (2000). The Baring is estimated to be 30 ± 18 mm at the lower limit of the seagrass, which indicates a strong hydrodynamic activity and / or a deficiency in sediments. Exposed rhizomes are very vulnerable to hydrodynamic activities

(swell, currents, storms…. etc.), trawling (deep) and anchoring of boats. In the long term, these rhizomes could be destroyed due to these factors (Boudouresque *et al.,* 2006). Usually, the division of *P. oceanica* shoots occurs in spring and autumn seasons (Caye in Pergent *et al.,* 1995), In the Rachgoun Island's meadow, it was found that the percentage of shoots in division is 10% of the upper limit. This result would indicate that the meadow is progressively renewing itself. The upper limit has a total number of leaves (adult and intermediate), higher than their equals in the lower limit (6 ± 0,5 leaves in the upper limit and 5,2 ± 0,4 leaves in the lower limit). Pergent (1987) reported that the increase in the number of leaves is usually related to the change in depth. However, this change in the average number of leaves is not always noted (Pergent-Martini, 1994). For juvenile leaves, the highest values were recorded at 17 m depth. The high number of juvenile leaves is due to overproduction relative to physiological responses of *P. oceanica,* which is an adaptation to environmental changes and in response to stress conditions, as highlighted by Balestri *et al.* (2004). Despite the proximity of the two stations, which were sampled at the same time period, there were significant variations were in the average length of adult leaves and petioles as a function of depth. The lower limit has a higher mean leaf length of 373 ± 56 mm against 296 ± 30 in the upper limit. Among the hypotheses that can explain the reduced size of the adult leaves at the upper limit is the fairly hydrodynamic activity near the coast. Also, the average width of adult leaves and petioles was found significantly different to other studies in the region. In Algeria, Semroud (1993) reported the presence of a "broad leaf" population of 7 to 15 mm, which is the widest leaves found in the literature, and attributed such a phenomenon to the strong hydrodynamics in the area. The end of the leaves were either whole, more or less rounded, or broken; this may correspond to grazing by various consumers (Alcoverro *et al.,* 1997) such as Echinodermes (Danis *et al.,* 2005), crustaceans (Boudouresque & Meinesz, 1982), fish (Jadot *et al*., 2003), the action of hydrodynamics (favoured or not) or by the presence of epiphytes (Semroud, 1993).

The state of the leaves apex can provide information on the grazing rate for a given site. The state of apex decreases as a function of the depth in the Rachgoune Island meadow (95% at the upper limit and 61% at the lower limit) this is probably due to a higher consumption of leaves (or epiphytes) or leaf breakage due to hydrodynamics in the superficial seagrass leaves (upper limit). In the lower limit, cut apex leaves represents 71% of the total growth. For the upper limit, grazing by herbivores accounts for the loss of 51% of the leaf's apex (39% by sea urchins and 19% by saupe) and hydrodynamics is the source of leaf failure at 49%. Also, the leaves' 'area per shoot' increase slightly with depth. Because of this density, the leaf area per m² at the upper limit quadrupled (9.6 ± 1.6 against 2.4 ± 0.4) at the lower limit. This difference can be explained by the fact that the leaf area per square meter depends on the leaf biometry, number of leaves per shoot and their density. In Rachgoune Island, *P. oceanica* meadow leaf production varied from 8.15 ± 0.50 to 7.64 ± 0.46 leaves per year. There is no significant difference between the limits. Regarding rhizome growth, it ranges from 6.49 ± 0.79 to 6.85 ± 0.70 mm per year between the two limits. No significant difference is detected there either.

The flowering of *P. oceanica* was considered rare in the western Mediterranean (Boudouresque, 2006). Since then, many flowers have been observed, and *P. oceanica* flowering have become common both at shallow depths (Semroud, 1993) and at great depths (Pergent, 1987, Rico-Raimondino, 1995). The lepidochronological analysis allowed us to highlight some flowerings that occurred during the previous year to the study (2015). Out of 40 bundles harvested, 5 floral peduncles were found in the Rachgoune Island meadow (2 at the upper limit and 3 at the lower limit).

Conclusion

According to the protocol of evaluation grids for the establishment of *P. oceanica* seagrass monitoring (UNEP/MAP-RAC/SPA, 2015), the quality of the lower-lying seagrass varies from bad to good. However, the low values recorded are probably due to the proximity of the meadow to the mouth of Oued Tafna river and not to anthropogenic pressure.

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INTERCALIBRATION OF SEISMIC REFLECTION DATA AND CHARACTERIZATION OF *POSIDONIA OCEANICA* MEADOW MATS

Abstract
In the Mediterranean Sea, the marine endemic species Posidonia oceanica *(L.) Delile forms seagrass meadows between 0 and 40 m depth. The mat, a remarkable bioformation built by this seagrass, is recognized as a 'carbon sink' because of its carbon storage capacity over a long period of time. The refractory nature of the roots and rhizomes and the anoxic conditions allow its accretion on several meters of height and its conservation over thousands of years. The aim of this study is to estimate the organic carbon (C_{org}) stocks sequestered in these structures. An assessment of the mat thickness has been carried out within the Natura 2000 site of the Grand Herbier de la Côte Orientale in Corsica (France), based on high-resolution seismic reflection data. The calibration of these data is performed by comparing the estimated heights of mat walls with the seismic profiles and the values measured by scuba diving, or from a Digital Terrain Model using multibeam echosounders data. Several mat cores have also been sampled and analyzed to characterize its composition. The mean velocity of the acoustic wave in the mat is 1665 ± 19 $m.s^{-1}$ (mean ± SEM), but has significant variations. Velocity was found to be correlated with the mat sand and gravel content. From these velocities, a continuous mapping of mat thicknesses has been carried out by ordinary kriging. The mean thickness of the mat at the study site is 2.1 m, but can reach locally 8 m. The C_{org} stock sequestered within these mats (20424 ha), evaluated from literature and seismic data analysis, is estimated at nearly 17-32 million Mg C_{org}.*

Key-words: *Posidonia oceanica,* carbon sinks, seismic reflection, mat coring

Introduction

Seagrass meadows, mangroves and salt marshes play an important role in climate regulation because of their ability to fix and sequester 'Blue Carbon' (Nellemann *et al*., 2009). Seagrass meadows occupy 0.2% of the ocean surface of the planet (Fourqurean *et al*., 2012), and play an important role in providing ecosystem goods and services of high value (Vassallo *et al*., 2013). These marine plants may store each year 40% of the carbon fixed by coastal vegetation (Nellemann *et al*., 2009), and according to the latest estimates (Fourqurean *et al*., 2012), this would represent between 4.2 and 8.4 Petagrams of carbon (PgC = 10^{15} gC).

In the context of global change and the rapid increase of anthropogenic impacts, the Paris Agreement acknowledges the importance of the conservation of green gas sinks, encourages the Parties to take measures to conserve and enhance the greenhouse gas sinks and to provide a national inventory report of the greenhouse gas sinks (UNFCCC, 2016). Furthermore, the recent interest in carbon trading and 'Blue Carbon' has provided an impetus for inventorying and quantifying these carbon sinks and their carbon dioxide sequestration capacity, which play a role in climate change mitigation.

In the Mediterranean, *Posidonia oceanica* (L.) Delile is an endemic seagrass forming extensive, almost continuous meadows between 0 and -40 m depth (Boudouresque *et al*., 2012). These meadows, known for their ecological, sedimentary and economic role, are considered in recent years as major carbon sinks (Pergent *et al*., 1994; Mateo *et al*., 1997; Lo Iacono *et al*., 2008; Serrano *et al*., 2012). Beneath the canopy, the *P. oceanica* meadow builds bioformations, called 'mats', formed by the intermingling of rhizomes and roots, the interstices of which are saturated with sediment or debris from the meadow. The imputrescible nature of the roots and rhizomes, as well as the anoxic conditions within these structures, allow the preservation of the mat over thousands of years and their accretion to heights of several meters (Romero *et al*., 1994; Mateo *et al*., 1997; Tomasello *et al*., 2009). The carbon storage capacity of these long-term organic carbon (C_{org}) sinks can reach values between 71 and 282 kg C_{org} m^{-2} (Romero *et al*., 1994; Lo Iacono *et al*., 2008; Serrano *et al*., 2012).
The assessment of mat thickness is typically approached by direct coring of the mat and the subsequent geochemical analysis to quantify the stocks of C_{org}. This presents considerable technical and financial constraints (Lo Iacono *et al*., 2008; Serrano *et al*., 2012). With the aim of simplifying this assessment, other means of investigation, such as seismic reflection, are being tested (Rey & Diaz del Rio, 1989; Lo Iacono *et al*., 2008; Tomasello *et al*., 2009; Blouet *et al*., 2014). This geophysical exploration method is used to determine the interfaces and compactness of geological structures of the subsurface by providing seismic profiles. The velocity of acoustic wave propagation, specific to each geological layer, coupled with the recording of the travel time by the hydrophones, are necessary for calculating the thickness between two interfaces. Nevertheless, in order to determine the velocity and to calibrate the data, ground-truthing is essential to compare the estimated thickness of a layer on the seismic profiles to direct observations in the field. The aim of this work is (i) to study the possibility of calibrating seismic reflection data by using a multibeam echosounder data, (ii) to provide a first characterization of the mat of the study site, and (iii) to carry out a first assessment of the *P. oceanica* meadow mat thickness and C_{org} stocks sequestered within these bioformations at the Natura 2000 site Grand Herbier de la Côte Orientale.

Material and methods

The data were acquired on the eastern platform of Corsica (France) within the Natura 2000 site FR9402014, Grand Herbier de la Côte Orientale. This site extends over a 99 km stretch of sandy coastline, from Biguglia lagoon inlet to the mouth of the Solenzara, between the high water mark and -50 m depth. With a total area of 43079 ha, it is occupied by a vast *P. oceanica* meadow of 20425 ha, and receives the sea outlets of several coastal lagoons (*e.g.* Biguglia, Diana and Urbino) and coastal rivers (*e.g.* Golo, Tavignano, Fium'Orbo). The acquisition of high-resolution seismic reflection and morpho-bathymetric data was carried out between -10 and -50 m depth during three oceanographic campaigns (Halgolo in 2010, CoralCorse in 2013 and PosidCorse in 2015). Three devices with distinct emission frequencies were deployed for seismic reflection data collection: a Sparker (1 kHz) and two sediment profilers; the Manta EDO (2.5 kHz) and the Pesk Avel (3.5 kHz). In total, 510 seismic profiles were acquired corresponding to 3095 km of data. The pre-processing step (corrections and options) of the raw files (SEG-Y) was initiated using Matlab®. Those seismic profiles yielding the best resolution for mat thickness discrimination were selected for the georeferencing, correction and interpretation steps undertaken with Kingdom® 8.7.1 (Fig. 1). Two lines, representing the top and the base of the mat, were plotted on the profiles (Fig. 1). The thickness of the mat (in milliseconds two-way travel time - ms TWTT) is subsequently obtained for each seismic shotpoint by measuring the difference between the upper and the lower lines.

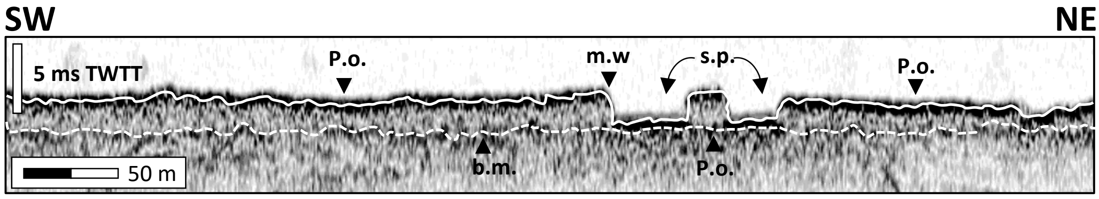

Fig. 1: Seismic profile of the Manta EDO sediment profiler in a *Posidonia oceanica* meadow (P.o., *P. oceanica* meadow; m.w., mat wall; b.m., base of the mat; s.p., sand patch; continuous line: mat upper limit; dotted line: mat lower limit).

Bathymetric data collection was performed using three multibeam echosounders (Kongsberg-Simrad EM1000®, EM2040®, and ME70®) with a frequency range of 250-400 kHz. The data decimetric position is determined using the DGPS system. The approximately 30000 ha acoustic data surveyed were processed with Caraibes 4.4® (Ifremer). The raw files were georeferenced, corrected by filtering (Delaunay triangulation method) and manual sounding invalidation. The morpho-bathymetric data were integrated into a Geographic Information System (GIS; ArcGIS 10.0®, ESRI) and compiled into a Digital Terrain Model (DTM) with a cell size of 5 m (Mercator projection-WGS1984). Shading is applied on the raster data to highlight the morphology and topology of the sea bottom. Determination of the acoustic wave velocity, necessary for the conversion of mat thicknesses in ms TWTT in meters, is undertaken by comparing the estimated heights of the mat walls on the seismic profiles and the values measured on the field or from the study site DTM:

$$\textit{Velocity }(m.s^{-1}) = \frac{\textit{Mat wall thickness measured by scuba diving or on the DTM (m)}}{\textit{Mat wall thickness measured on the seismic profile (s TWTT)}} \times 2$$

For the latter, data collection (3 measures/mat wall) is done directly on DTM. An intercalibration is conducted using mat wall measurements collected by scuba diving (3-6 measures/mat wall; Fig. 2). Conversion of mat thicknesses is obtained after calculation of the average wave velocity in the mat. Mapping of mat thicknesses is done after integrating the data into the ArcGIS® 10.0 software and using the ordinary kriging method. The map covered a range from -10 m (upper limit of data acquisition) to -40 m depth (lower limit of the *P. oceanica* meadow generally observed at this site).

Among the different intercalibration stations, 9 mat walls (heights ranged from 80 to 280 cm) equidistantly distributed within the study site (5-10 km) were selected to perform sampling and mat characterization. For each of them, 3 replicate cores were collected by hand percussion using 100 cm long-PVC pipes at 3 different levels (9 cores/station) following the protocol of Pedersen *et al.* (2011). After homogenization and sub-sampling of the material by levels, the following parameters were determined: bulk density (ρ_d), water content, porosity (φ), grain size, coarse and fine soil organic matter content (respectively %COM and %SOM) and carbonates content (%$CaCO_3$) estimated by LOI method (Heiri *et al.*, 2001).

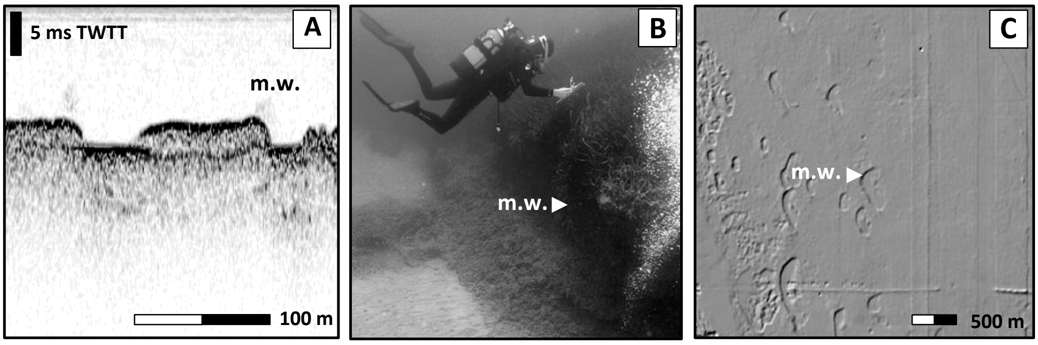

Fig. 2: Measurements of *Posidonia oceanica* mat walls on seismic profiles (A), by scuba diving (B) and on the DTM (C) of the study site (m.w., mat wall).

Results

The DTM enabled extraction of 366 measurements of mat wall heights. The values of velocity, determined from these measurements, ranged from 595.6 to 3093.3 m.s^{-1} (1664.8 ± 19 m.s^{-1}; mean ± SEM). The results suggest that the propagation velocity of the acoustic wave in the mat ranged from 1626.6 to 1703.0 m.s^{-1} (Confidence interval; P = 95%; n = 366). The intercalibration performed between the measures collected by scuba diving and on the DTM was achieved from 34 measurements. The comparison shows a significant correlation between the two methods (R^2 = 0.87; n = 34; Fig. 3).

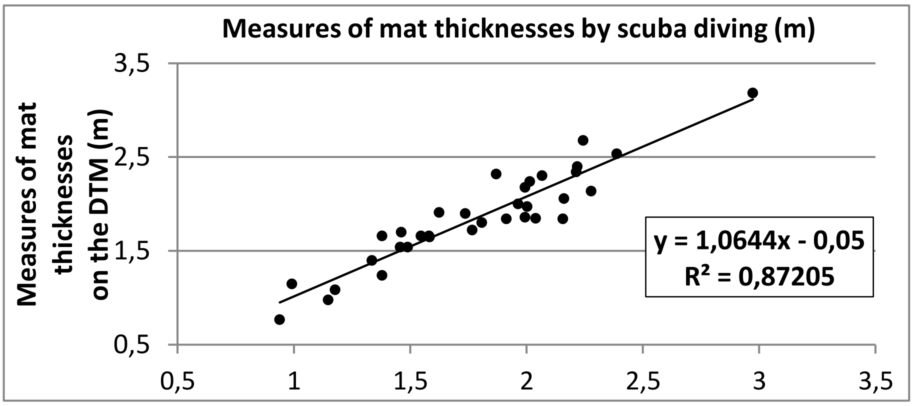

Fig. 3: Correlation between measures of mat wall heights in the field and on the DTM

The results of the analysis performed on *P. oceanica* mat samples highlight a correlation of the velocity of acoustic wave propagation in the mat with the sand (Pearson correlation coefficient; r = 0.259; P<0.05) and gravel content (r = 0.331; P<0.05) present in these bioformations. Similarly, a negative significant correlation was observed between the density and the porosity of the mat (r = -0.740; P < 0.001). Mean composition of the mat within the study site is mostly represented by mineral (75%) and organic fraction (23%; Fig. 4).

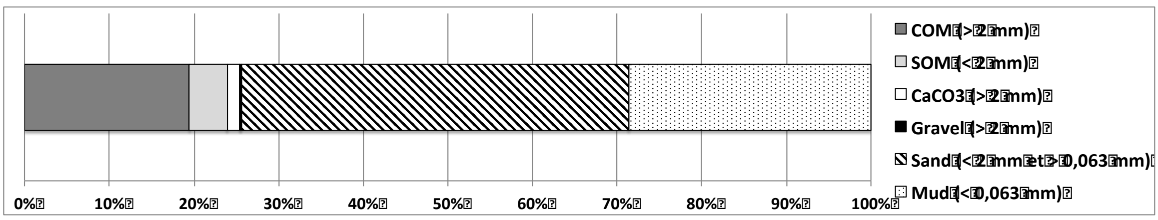

Fig. 4: Basic sedimentological characterization of the *Posidonia oceanica* mats studied

The mapping of the mat thickness of the *P. oceanica* meadow evidenced a high variability in thickness for these bioformations. The mean thickness of the mat, estimated at 2.1 m for the whole site, increased from north (1.6 m) to south (2.7 m). The average thickness of the mat also seemed to be greater along the coast (between isobaths -10 and -25 m), when the slope is slight. Maximum thickness (up to 8 m) was recorded at the mouth of the main coastal rivers but also occasionally in the deepest areas (-30 to -40 m depth) at the Golo and Tavignano underwater deltas.

Discussion and conclusion

This study has confirmed that the seismic reflection method is an effective technique to assess the potential thickness of *P. oceanica* mats (Lo Iacono *et al*., 2008; Tomasello *et al*., 2009). The bathymetric surveys have demonstrated their contribution in the calibration of seismic reflection data. Although core sampling and/or ground-truthing remain essential to calibrate seismic data, the morpho-bathymetric method has proved to be cost-effective and easy to implement. The variation of *Posidonia oceanica* mat thicknesses observed in the area could be explained by (i) the natural land-based inputs at the mouth of the coastal rivers, but also near the lagoon inlets ('hunting phenomena') and (ii) the sediment dynamics related to ocean currents (coastal drift) at the underwater deltas. The characterization of *P. oceanica* soil composition has revealed a potential relation between sand and gravel content in the mat and the velocity of acoustic waves. We hypothesize that this is derived from the correlation between sediment coefficient of reflectivity and their density, porosity, and grain size (Hicks and Kibblewhite, 1976). The C_{org} stocks sequestered in the *Posidonia oceanica* meadows of the Natura 2000 site can be assessed from the average thickness of the matte according to this study, the surface occupied by these habitats and data on C_{org} composition in the matte, available in the literature (40-75.5 kg C_{org} m^{-3}; Mateo *et al*., 1997, Serrano *et al*., 2012). Thus, the sequestration may be estimated at nearly 17-32 million Mg C_{org}, or approximately 84- 58.6 kg C_{org} m^{-2} (for a 2.1 m mat thickness), and about 62-117 million Mg CO_2. This result highlights the major role played by mat in the sequestration of Blue Carbon, and therefore in the mitigation of climate change. During the Carbonsink oceanographic survey carried out in August 2018 at the study area, around 50 vertical cores have been obtained. The study of these cores will contribute to better calibrate the mat thickness and will provide a more precise characterization of the mat by specifying the actual carbon stocks and fluxes associated with the *P. oceanica* meadows within the Natura 2000 area.

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MARINE ALGAL FORESTS IN THE LEVANTINE BASIN: THE CASE OF *CYSTOSEIRA RAYSSIAE* ALONG THE ISRAELI COAST

Abstract
The SE Levantine Basin is the hottest, fastest warming and most alien-invaded corner of the Mediterranean Sea. These characteristics make this region a natural laboratory to test the effects of climate change and bioinvasion pressures on benthic communities. Along the Israeli Mediterranean Sea coast, an endemic species of the genus Cystoseira*,* C. rayssiae*, was first described by Ramon in 2000. Since then little has been done to study its ecology. This is in contrast to the Western Mediterranean, where many* Cystoseira *species, known to be important habitat formers, have been studied extensively and are listed in the Annex I of the Conventions of Bern and Barcelona because of many anthropogenic threats. The lack of knowledge on* C. rayssiae *ecology in the SE Levantine Basin prevents the development of protection measures for this high risk species. This study presents results on the annual dynamics of* C. rayssiae *in the Haifa region in terms of growth, reef cover, biomass and metabolic ecosystem functions (associated species, oxygen production and carbon budget). Our results show that its branched form only appears in winter and spring when it provides habitat for multiple species (two-fold higher associated taxa richness compared to turf), high oxygen production (12 mmol $O_2/m^2/h$) and high capacity for C sequestration (-12 mmol $C/m^2/h$) compared to turf and alien dominated macrophyte communities. During the warmer months (July-November) it becomes branchless and dormant with lower habitat provisioning capacity, metabolism and a three-fold decrease in length from May to August, from the peak season to the dormant phase. These data suggest that the expected fast warming in the Levant basin may pose a considerable threat to this important habitat forming species and to the whole reef metabolism, with a possible replacement by similar non-indigenous, thermophilic macroalgae.*

Key-words: *Cystoseira*; SE Mediterranean; canopy-forming; Israel

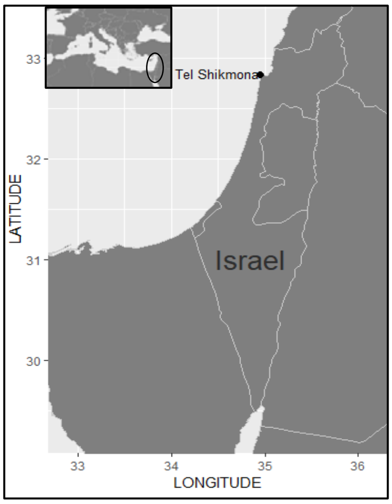
Introduction

In the Mediterranean Sea the so-called marine forests are mostly represented by two genus of brown algae from the Fucales order, *Cystoseira* and *Sargassum* (Ballesteros, 1992). Such forests are structurally complex bearing high biodiversity (Steneck *et al.*, 2002; Smale & Wernberg, 2013) and play a significant role in C turnover and sequestration (Duarte & Cebrián, 1996). In the last decades, and particularly true to the Western basin, monitoring studies revealed a significant decline in marine forests which has been attributed to combined stressors such as coastal urbanization, pollution, grazing pressure, sediment loads, invasive species and climate change (Connell, 2005; Thibaut *et al.*, 2005, 2015; Airoldi *et al.*, 2014; Vergés *et al.*, 2014; Mineur *et al.*, 2015). Comparatively much less investigations and monitoring programs of members of the order Fucales have been targeted to understand their ecology and distribution within the Eastern basin (Ramon, 2000; Einav & Israel, 2008; Israel & Einav, 2017). *Cystoseira rayssiae* is apparently an endemic species to the Israeli Med Sea (Ramon 2000) and likely plays key ecological roles in the area. In order to eventually assess the real contribution of this species, we carried out an ecophysiological study and determine metabolism during field surveys since August 2017 at a local site at Tel Shikmona, Haifa, Israel.

Materials and Methods

In August 2017, when *Cystoseira rayssiae* is at its perennial stage, 10, 50 cm^2 quadrats were marked in the Tel Shikmona area, Haifa (32°49'29.77"N, 34°57'18.93"E) at ~ 1.5 m deep (Fig.1) (South, 2011, 2012; R Core Team, 2018). The quadrats were chosen inside a medium-large patch (44 ± 12 individuals per m^2) of *C. rayssiae* at a minimum distance of 2-3 m between quadrats (Fig.1). Five specimens per quadrat were labeled in order to be easily recognized during each of the following samplings.

a)



b)

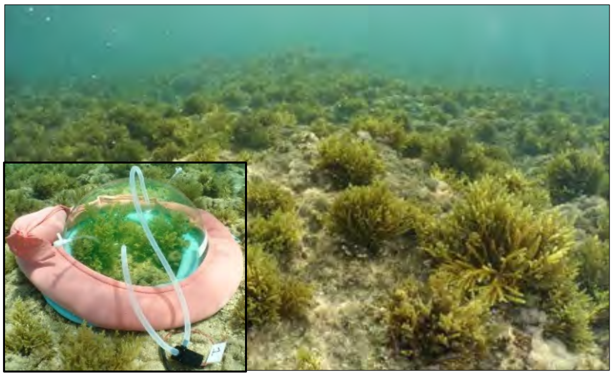


Fig. 1: a) Location of the experimental site at Tel Shikmona, Haifa, Israel. b) Overview of *C. rayssiae* patch and details of the dome-shaped benthic incubation chamber (insert).

Monthly SCUBA surveys were performed to record the number of cauloids within the quadrats, the length of the three longest axes of each tagged individual and photo-quadrats were further processed in the lab. Fortnightly snorkeling surveys were also conducted to monitor the status of the algae. Image analysis was performed by CoralNet ® (Beijbom *et al.*, 2012, 2015; Beijbom, 2015) to extrapolate the cover percentage of *C. rayssiae* and other macro-species (Mancuso *et al.*, 2018).

The same forest (Fig.1) was investigated in October 2017 (fall) and April 2018 (spring) with benthic incubation chambers to measure community metabolic rates (Peleg, 2016). The measurements were carried out by deploying fiberglass dome-shaped benthic chambers (N=5), covering a horizontal area of ca. 0.126 m^2, with internal circulation over representative reef macrophyte communities. Initially, dark incubations (darkened domes), which lasted an hour, were carried out ca. 1.5 hours before peak light conditions (noon), followed by light incubations (transparent domes), which also lasted 1 hour (Fig.1b). Net rates of dark and light metabolic rates of respiration (dark), photosynthesis (light) calcification and $CaCO_3$ dissolution were calculated from measurements of dissolved oxygen (DO), total dissolved inorganic carbon (DIC) and total alkalinity (TA) in water samples taken from each dome at the beginning and end of each incubation period. Ambient seawater temperature (T), salinity (S) and dissolved oxygen (DO) were constantly recorded by a SBE-19 CTD deployed nearby together with a PAR-probe data logger (Sea-Bird Scientific) to measure Photosynthetically Active Radiation. Finally, once the experiment ended (dark and light incubations), all the biomass covered by the chambers was scraped off the substrate manually and sucked into mesh diving bags using an underwater suction device (MANOSS) (Chess, 1978; Benson, 1989; Chatzigeorgiou *et al.*, 2012) and transferred to the lab for taxonomical identification, enumeration and biomass weighing.

Prior to the analysis, data were tested for normality and for homogeneity of variances, then processed for univariate analysis, differences were considered significant at $p<0.01$ (Underwood, 1993). We tested the length of *C. rayssiae* in the quadrats (N=23) and the cover percentage per 50 cm^2 (N=10) as a "one-way repeated measures ANOVA" followed by "Tukey's Multiple Comparisons Test" in GraphPad Prism v 5.0 (GraphPad Software, La Jolla California USA, 2007). Tests on diel net production and night-time respiration as a function of DO and DIC, as well as light and dark calcification were performed with a "t-test" in GraphPad Prism v 5.0 (GraphPad Software, La Jolla California USA, 2007).

Results

Cystoseira rayssiae showed primary and secondary branches development from March 2017, while only perennial parts 4.5 ± 1.4 cm long were found in August 2017 when the ambient seawater temperature was 31.7 ± 0.7 °C, which were the highest recorded during the study period. (Fig. 2a). Temperatures dropped to 26.0 ± 1.0°C by October-November, and down to 19.8 ± 1.3°C in December 2017 when the tophules started to appear. During winter time (December-February), the average temperature was 18.5 ± 0.3°C with mean thallus length of 5.0 ± 0.2 cm. In March 2018, when the temperature reached 19.5 ± 0.7°C, new young branches started to appear with mean length of 9.6 ± 2.5 cm. The maximum development was recorded in May-June 2018 with 13.3 ± 0.5 cm, when the seawater temperature was 26.4 ± 0.2°C. A one-way repeated measures ANOVA was conducted to compare the seasonal changes in *C. rayssiae* thalli lengths. There was a significant difference, at the $p<0.01$ for the $F(8, 22)=116.7$, $p<0.0001$ (Fig.2a).

Photo-quadrat analysis provided data about the percentage cover of different macro-species, in particular by *C. rayssiae*. From August 2017 to January 2018, it occupied less than 1 %, reaching up 4% in the following month. In March 2018, *C. rayssiae* occupied 16 % of the surface and increased to a maximum value of 35% in May 2018 (Fig.2b). A one-way repeated measures ANOVA was conducted to compare different *C.rayssiae* cover % in the months. There was a significant difference, at the $p<0.001$ for the $F(8, 9)=6.672$, $p<0.0001$ (Fig.2b).

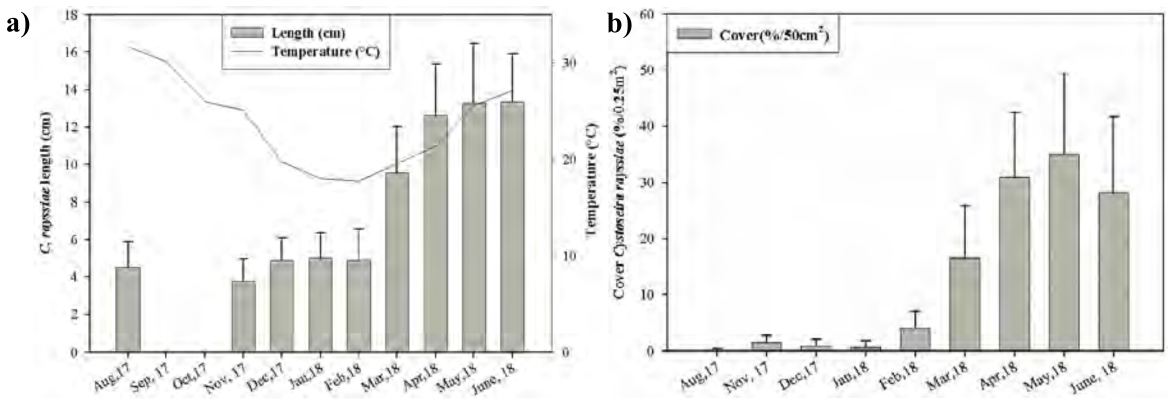


Fig. 2: a) Mean length of *C. rayssiae* (± SD) and temperature in SK1 (N=23). (b) Percentage cover/0.25m^2 (± SD) (N=10). Missing data were due to bad sea conditions.

Benthic incubation measurements of *C. rayssiae* communities showed seasonally varying differences in organic biomass (g/m^2). In spring, the mean biomass of the forest was 1510 ± 1013 g/m^2 (±SD, N=5), fourteen-fold higher than the mean biomass recorded in fall, which was 103 ± 49 g/m^2 (±SD, N=5). Net production ($Pn_{(DO)}$) and dark respiration ($R_{(DO)}$) calculated as function of oxygen differences are significantly smaller in fall 2017 (M=5.07, SD=3.44) than in spring 2018 (M=12.21, SD=0.99, $t(5) = -4.35$, $p=0.007$), while no significant difference was recorded in terms of dark respiration (Fig.3a). Net inorganic organic carbon uptake ($Pn_{(DIC)}$), was smaller in fall than in spring, but these differences were not statistically significant (Fig.3b). Dark production of inorganic carbon ($R_{(DIC)}$) significantly similar in fall and winter. Light calcification ($G_{(light)}$), with positive values as well as for the dark calcification ($G_{(dark)}$), indicated an average net $CaCO_3$ precipitation in both seasons, without any significant difference (t-test, $p>0.01$) (Fig.3c).

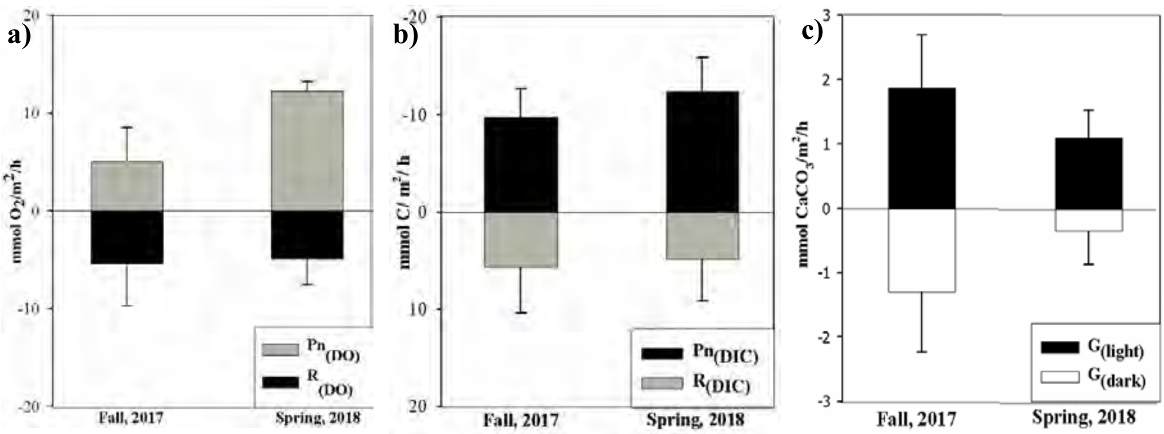


Fig. 3: Diel net production (Pn) and night-time respiration (R) of *C. rayssiae* as a function of DO (a) and DIC (b). (c) Rates of light ($G_{(light)}$) and dark calcification ($G_{(dark)}$). Data from benthic incubation experiment performed respectively, in fall, 17 and spring, 18. Error bar indicates standard deviation (N=5).

Discussion and conclusions

This study is the first attempt at describing the ecological dynamics of *Cystoseira rayssiae* in the Levantine basin. It is necessary to understand its biological and ecological role in the

Mediterranean in order to make predictions of future ecological developments in this region in response to climate change (Gattuso *et al.*, 2015). Our results show that the growth season of *C. rayssiae* in the Eastern Mediterranean is relatively short and appears to be strongly constrained by seawater temperature. Once the seawater temperature rose up to 19°C, we detected new tophules on the perennial structure, while under higher temperature conditions during May-June these algae started to revert back to its branchless morphology. Future experiments using a mesocosm infrastructure at IOLR will test the effect of different temperature and pH on the development of the species under controlled conditions. Furthermore, *C. rayssiae* communities appear to be an important carbon sink in the shallow reefs of this region. Comparisons with other key marine communities driven by seaweeds in the Levantine basin have highlighted again the primary role of *C. rayssiae* in providing habitats and additional ecological functions to the local ecosystem. The precise role and quantitative contribution of *C. rayssiae* in ecosystem functioning need further comprehensive evaluations.

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REGRESSION OF *POSIDONIA OCEANICA* LOWER LIMIT: A CONSEQUENCE OF CLIMATE CHANGE?

Abstract

The distribution and the vitality of the Posidonia oceanica *meadow were monitored in the western Mediterranean at 15 sites along the coasts of Corsica, using two monitoring systems, the Posidonia Monitoring Network and the SeagrassNet, between 2004 and 2017.*
While the vitality of the meadow is satisfactory overall, due to the low impact of human pressure along these coasts, patterns of change over time show a general regression of the position of the lower limit. The mean regression recorded for reference sites (low and stable human pressure) is estimated as 30 cm between 2004 and 2017. The rate of regression seems to be increasing from 2.2 cm per year (between 2004 and 2013) to 3.0 cm per year (between 2013 and 2017). Moreover, according to the mean slope measured for these sites (5.9%) and the corresponding light attenuation (0.15%) due to sea level rise (+5 cm according to the tide gauge at Ajaccio), the theoretical regression in relation to light available could be 140 cm. That is to say that P. oceanica *exhibits high resilience with the mobilization of its reserves (e.g. carbohydrates in rhizomes).*
Similar patterns of change are observed at different locations in the Mediterranean Sea (e.g. French Riviera, Tunisia, Turkey), and could also be related to the rise in mean sea level and perhaps to the North Atlantic Oscillation (NAO). The setting up of six new reference sites should make it possible to monitor these changes more accurately.

Key-words: Seagrass, Lower limit, Regression, Climate change

Introduction

Along the 1 000 km of coastline of Corsica, the monitoring of the state of conservation of the *Posidonia oceanica* meadow has been carried out since 2004, through the establishment of two monitoring networks: the Posidonia Monitoring Network (PMN) and SeagrassNet (Pergent et al., 2007). The aim of the PMN, set up from 2004 (15 sites at the upper limit and 15 sites at the lower limit), is to monitor the vitality of *P. oceanica* meadows, and also to use these meadows as an indicator of the quality of the environment (measurement of standardized descriptors and calculation of the BiPo index).
During the first follow-up visit, in 2013, six new sites were set up along the lower limit, in the Reserve Naturelle des Boûches de Bonifacio (southern Corsica), and all sites at the lower limit (21) were equipped with temperature sensors to precisely track the patterns of change in the water temperature along the whole coastline of Corsica (Pergent *et al*., 2015). When these sensors were replaced in 2017, additional scientific observations were made, with an estimation of the slope behind these 21 lower limit sites, and monitoring of the patterns of change in the position of the lower limit.

Materials and method

For each site, vertical photographs of the lower limit are taken behind each fixed marker (11 per site) to assess the distance between the markers and the limit of the meadow.

These photographs are complemented by horizontal photographs in order to have an accurate assessment of the distance between the markers and the meadow limit.
The depth is then measured at the level of the markers (1, 6 and 11) and 10 meters behind them to determine the average slope behind the lower limit. For this purpose, a 10 m graduated tape is attached to the ring of the marker and unrolled perpendicular to the lower limit (Fig. 1); the depth is measured at both ends of the tape using the same electronic dive computer (Suunto Viper, precision ±0.10m).

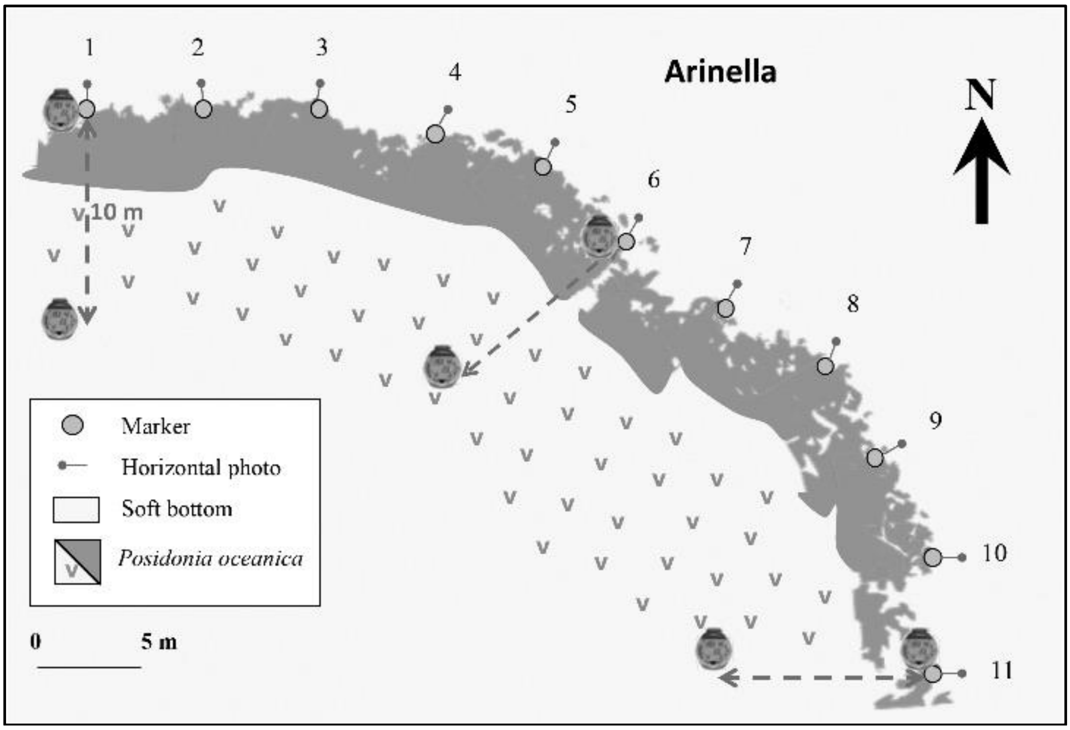

Fig. 1 Location of depth measurement along the lower limit of Arinella.

Results

There has been a regression in the lower limit of the meadow at the majority of sites (Tab. 1). This decline concerns both the sites impacted by anthropogenic activities and the reference sites, even though, for the latter, the regression is on average more limited (-30 cm instead of -53 cm, for the 15 sites set up between 2004 and 2006). That is to say that the average annual regression is estimated at 2.5 cm for reference sites and 4.2 cm for impacted sites.
For the sites most strongly impacted (sewage outfall at Arinella and fish farm at La Parata), the regression is between 166 cm (12.8 cm per year) and 180 cm (15.0 cm per year) since 2004/2005 (Tab. 1). Conversely, for impacted sites but for which pressures are decreasing (setting up of sewage treatment plant at Ile Rousse and cessation of mine spoil discharges into the sea at Canari), the position of the lower limit is progressing respectively by 7 cm and 21 cm since 2006.
The 15 sites, set up between 2004 and 2006, show an average annual regression in the position of the lower limit that is greater during the most recent period, as well for all the sites (-2.3 cm. year-1 between 2004/2013 and -5.4 cm. year-1 between 2013/2017), than for reference sites (-2.2 cm. year^{-1} between 2004/2013 and -3.0 cm. year^{-1} between 2013/2017).

Tab. 1: Patterns of change in the position of the lower limit of the *Posidonia oceanica* meadow at the different sites of the Corsican RSP (annual change).

	Set up ➔	Specifications	Distance (cm) ➔ 2013	Distance (cm) 2013-2017	Distance (cm) ➔ 2017
Cap Sagro	2004	Reference	-32 (-3.6)	+5 (+1.3)	-27 (-2.1)
Bravone	2004	Reference	+1 (+0.1)	+7 (+1.8)	+8 (+0.6)
Secteur Est	2005	Reference	-9 (-1.1)	-21 (-5.3)	-30 (-2.5)
Lavezzi	2005	Reference	-23 (-2.9)	+10 (+2.5)	-13 (-1.1)
Porto Polo	2005	Reference	-56 (-7.0)	-54 (-13.5)	-110 (-9.2)
Sagone	2006	Reference	-12 (-1.7)	-5 (-1.3)	-17 (-1.5)
Porto	2006	Reference	-4 (-0.6)	-4 (-1.0)	-8 (-0.7)
Stareso	2006	Reference	-7 (-1.0)	-35 (-8.8)	-42 (-3.8)
Les Cerbicales	2013	Reference		-5 (-1.3)	-5 (-1.3)
Sant'Amanza	2013	Reference		-25 (-6.3)	-25 (-6.3)
Lavezzi GECT	2013	Reference		+13 (+3.3)	+13 (+3.3)
Bonifacio	2013	Reference		+3 (+0.8)	+3 (+0.8)
Sardaigne GECT	2013	Reference		-9 (-2.3)	-9 (-2.3)
Figari	2013	Reference		+4 (+1.0)	+4 (+1.0)
Macinaggio	2004	Trawling	-35 (-3.9)	+11 (+2.8)	-24 (-1.8)
Toga	2004	Marina	+11 (+1.2)	-32 (-8.0)	-21 (-1.6)
Arinella	2004	Sewage outfall	-84 (-9.3)	-82 (-20.5)	-166 (-12.8)
La Chiappa	2005	Sewage outfall	-5 (-0.6)	-2 (-0.5)	-7 (-0.6)
La Parata	2005	Aquaculture farm	-60 (-7.5)	-120 (-30.0)	-180 (-15.0)
Ile Rousse	2006	Sewage outfall	+6 (+0.9)	+1 (+0.3)	+7 (+0.6)
Canari	2006	Mine spoil	+21 (+3.0)	0 (0.0)	+21 (+1.9)

The average slope measured behind the lower limit is between 1.7% and 13.0% (6.2% on average), for the 15 sites set up between 2004 and 2006 (Tab. 2).

Discussion

The Corsican PMN offers the means to highlight the impact of significant anthropogenic pressures on the *Posidonia oceanica* meadow (e.g. sites at La Parata and Arinella), and also to assess the effectiveness of the public policies that are implemented to reduce these pressures (e.g. Ile Rousse and Canari sites). These results support the strategy put in place by the Parties to the Barcelona Convention for the Standardization of Mapping and Monitoring Methods for Marine Magnoliophytes in the Mediterranean (CAR/ASP, 2015).

However, several reference sites, for which anthropogenic pressures have remained stable and of low magnitude, also show a regression of the lower limits, although to a lesser extent than at high anthropogenic pressure sites (Tab. 1). This regression cannot be imputed to the local degradation of the environmental conditions, given that they were distributed along the whole coastline of Corsica and at significant distances from potential sources of human pressure. In addition, a similar phenomenon was observed (i) for the Provence-Alpes-Côte d'Azur Region PMN, including the Parc National de Port-Cros (a reference meadow; Bonhomme *et al*., 2010), (ii) at Kerkennah Islands (Tunisia), in the southwestern basin (Pergent and Langar, unpublished data), (iii) at Gökçeada island

(Aegean Sea, Turkey, Güreşen *et al*., in press), and even (iv) in the Western Pacific region, at sites with other seagrass species and stable human impact (Short *et al*., 2014).

Tab. 2: Patterns of change in the position of the lower limit (in m), in relation with the rise in sea level (calculated), and field measurements (observed) at Corsican PMN sites.

	Depth (m)	Reduction of light (%)	Mean slope (%)	Expected distance (m)	Observed distance (m)
Macinaggio	38	0.13	5.3	-94	-24
Cap Sagro	33	0.15	2.0	-250	-27
Toga	24,3	0.21	11.7	-43	-21
Arinella	26,8	0.19	4.7	**-106**	**-166**
Bravone	36,1	0.14	2.0	-250	+8
Secteur Est	36,9	0.14	13.0	-38	-30
La Chiappa	35,3	0.14	3.0	-167	-7
Lavezzi	30,3	0.17	7.0	-71	-13
Porto Polo	32,2	0.16	5.7	-88	-110
La Parata	35,3	0.14	4.7	**-106**	**-180**
Sagone	33,2	0.15	1.7	-294	-17
Porto	36,5	0.14	11.0	-45	-8
Stareso	38,6	0.13	5.0	-100	-42
Ile Rousse	35,8	0.14	9.3	-54	+7
Canari	27,4	0.18	7.3	-68	+21

The lower limit corresponds to the depth of compensation of the species, beyond which the amount of light is insufficient to enable photosynthetic production to compensate for the losses due to respiration (Duarte, 1991); any reduction of this light will inevitably entail a decline in the vitality of the meadow and a regression of the position of the lower limit (Meinesz & Laurent, 1980). Furthermore, among the hypotheses that might explain the regression of these lower limits, the decrease of the light available at the bottom level appears to be one of the most likely.

During the study period (2004 - 2017), data from the tide gauge at Ajaccio show a rise in sea level (mean trend curve) close to 5 cm, which corresponds, due to the increase in the thickness of the water column, to a mean light reduction of 0.15% (Fig. 2).

According to the depth of the lower limits and the mean slope, it is possible to evaluate, for each site, the reduction of the light available on the bottom, and to estimate the expected regression corresponding to this increase in the height of the water column (Tab. 2). With the exception of the Porto Polo site, the regression observed for all reference sites is lower than those expected (140 cm on average), due to the increase in the water level. It therefore seems that the meadow exhibits a high resilience and that the decrease in light intensity is partly offset, at least over a period of a few years, by other mechanisms: reduction in shoot density, meadow coverage, leaf production and growth rate of rhizomes decline, mobilization of carbohydrate reserves (Alcovero *et al*., 2001, Ruiz & Romero, 2001).

Only the sites at Arinella and La Parata show a greater regression than that expected (resulting from the increase in the height of the water column), probably because of the high pressures to which they are subjected (e.g. increase in turbidity).

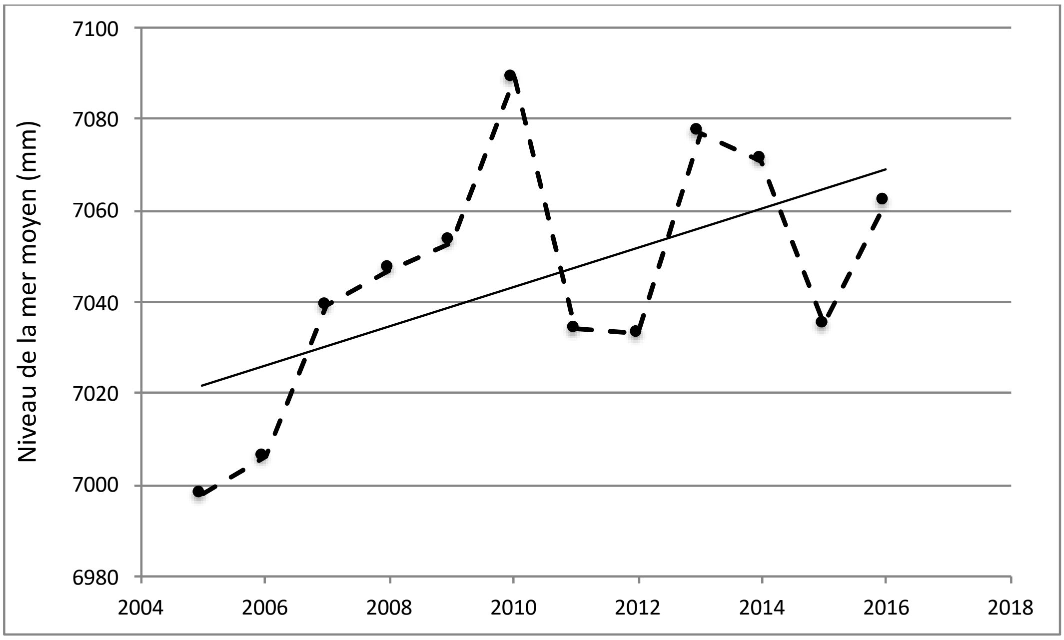

Fig. 2: Mean sea level rise (annual values) at the level of the Ajaccio tide gauge (SHOM, http://www.psmsl.org/data/obtaining/stations/1929.php).

Another hypothesis, which might act in synergy with the previous one, is the North Atlantic Oscillation (NAO), which may play a role in the penetration of the light within the water column. This climatic oscillation (NAO) may occur at Mediterranean scale (Visbeck *et al*., 2001). Compared to the high values during the 1990s, the NAO index declined, to reach higher values between 2005 and 2015 (Hurrell, 2018).
Considering the overall length of the *P. oceanica* lower limit around Corsica (Valette-Sansevin *et al*., 2015), the regression recorded over the past decade can be estimated as nearly 30 ha, and should significantly increase in the future according to IPCC scenarios.

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HOW WE LEARNED TO STOP WORRYING AND MAP THE MEDITERRANEAN SEAGRASSES WITH GOOGLE EARTH ENGINE

Abstract
In the epoch of anthropogenic climate change that nature is traversing, the vastly biodiverse coastal ecosystems in Mediterranean suffer from significant impacts. The silent, overlooked and degraded, yet remarkable ecosystem service providers, Mediterranean seagrasses can mitigate the resulting impacts by relentlessly sequestering the so-called 'blue carbon' for millennia. Recent advances in Earth Observation in terms of optical satellite sensor technology, cloud computing and machine learning classification algorithms are galvanizing the high spatio-temporal, large-scale seagrass habitat mapping and monitoring, allowing better management and conservation plans. Here, we integrate the free, multi-temporal, multi-sensor satellite image inventory available within the Google Earth Engine platform (Copernicus Sentinel-2, USGS Landsat 8) with remotely sensed in situ observations to develop a cloud-based processing workflow which could be easily adjusted in space, time and data input to accurately map and monitor the distribution of Posidonia oceanica *vegetal assemblages and co-existing coastal aquatic habitats in high spatial resolution (up to 10-m/pixel) from regional and national to basin scale. The implementation of this time- and cost-efficient workflow provides a baseline for seasonal, annual and interannual monitoring which could resolve existing dynamics, unravel data issues, allow the estimation of vital and relevant to* P. oceanica *meadows biophysical parameters–biomass, carbon sequestration, leaf area index etc–in the whole extent of the Mediterranean, given naturally availability of accurate and high quality in situ data.*

Key-words: *Posidonia oceanica* seagrass, Mediterranean, Sentinel-2, Landsat 8, Google Earth Engine

Introduction
In the era of human induced climate change, Mediterranean seagrasses have been a silent and overlooked natural ally in mitigating climate change impacts through their efficient provision of ecosystem services (Campagne *et al.*, 2014; Fourqurean *et al.*, 2012; Nordlund *et al.*, 2016). Reaching depths up to 40 m and an age of thousands of years, the dominant and endemic in the Mediterranean Sea, *Posidonia oceanica* seagrass has been relentlessly sequestering the so-called 'blue carbon' (Mateo & Romero, 1997; Arnaud-Haond *et al.*, 2012). Despite its importance and related international/national conservation status, *P. oceanica* meadows have decreased by 10.1% in the last 50 years, a number increasing to 33.6% for areas with available historical information (Telesca *et al.*, 2015) which follows the global seagrass regression of 29% since 1879 (Waycott *et al.*, 2009). The slow growth of the aforementioned seagrass along with the sparsity/absence of data on its distribution, principally in the eastern and southern Mediterranean, renders the rectification of this regression a highly challenging task. In the latter regions, the only two sources of information on seagrass extent had been point-

based and experts' personal knowledge (Giannoulaki *et al.*, 2013) until more recent large-scale satellite-based mapping (Topouzelis *et al.*, 2018; Traganos *et al.*, 2018). Generally, unmapped regions in the broader Mediterranean raise concerns regarding effective management and conservation of the therein seagrass habitats.

Parallel to the declining trend of Mediterranean seagrasses, Earth Observation technology–optical multispectral satellites, machine and deep learning algorithms, and cloud computing environments–has exponentially grown in the last five years, allowing habitat mapping and monitoring in unprecedented spatio-temporal scales in an immensely cost- and time-efficient fashion. Cloud computing platforms as the Google Earth Engine (GEE) (http://earthengine.google.org; Gorelick *et al.*, 2017) contain the whole, free and open image archive of satellites like the Copernicus Sentinel-2 (S2) and NASA/USGS Landsats. By integrating these satellite image inventories with relevant *in-situ* observations and machine learning, recent studies have mapped the global distribution of forests, soil carbon of mangroves, and surface water, and the Africa-wide extent of croplands (Hansen *et al.*, 2013; Pekel *et al.*, 2017; Xiong *et al.*, 2017) with adequate accuracies given the analyzed spatial scales.

Recently, we developed a fully GEE-based processing workflow which can be easily tuned in both space, time and satellite data input for accurately mapping and monitoring the distribution of *P. oceanica* seagrass meadows up to 10-m/pixel resolution (Traganos *et al.*, 2018). Mosaicking 1045 10-m Sentinel-2 tiles (100x100 km^2 ortho-images) and harnessing remote sensing based training data, the cloud-based workflow classified 2,510.1 km^2 as seagrass covered areas in the Greek territorial waters between 0 and 40 m of depth (40,951 km^2; 3-km buffer from the coastline), a previously largely uncharted region for seagrasses, especially at a country scale.

Our aim through this work is to further demonstrate the spatial scalability of the aforesaid workflow in mapping the Pan-Mediterranean extent of *P. oceanica* seagrass species. We apply the workflow in the coastal area of Menorca in the western Mediterranean. *In-situ* acquired data (Julià *et al.*, 2018) enable the validation of the mapping results. A secondary aim is to highlight the need for open access field datasets, ideally suitable for validation of Earth Observation products, which will allow in turn the validation of our basin-scale, algorithm-derived mapping; the greatest the availability of open in-situ data, the higher the seagrass mapping and monitoring accuracy.

Materials and methods

An analytical description of the GEE workflow can be found in Traganos *et al.* (2018) while its basic components appear in Fig. 1. First, the algorithm incorporates Copernicus Sentinel-2 top of atmosphere reflectance data at 10-m spatial resolution, 5-day temporal resolution and 12-bit radiometric resolution. We select band 1-coastal aerosol at 60-m and all the 10-m bands of S2 (b2-blue, b3-green, b4-red, b8-near infrared) due to their ability to penetrate deeper into the water column and return seabed information; b8 is used only into the sunglint correction step. Second, in the present study, the workflow composes 1063 Sentinel-2 tiles and performs a series of image corrections (i.e. cloud/cirrus, atmospheric, sunglint, water column) on them. Finally, it trains the resulting corrected satellite composite using 911 polygons (approximately 14576 10-m pixels) over the extent of the Greek waters applying the

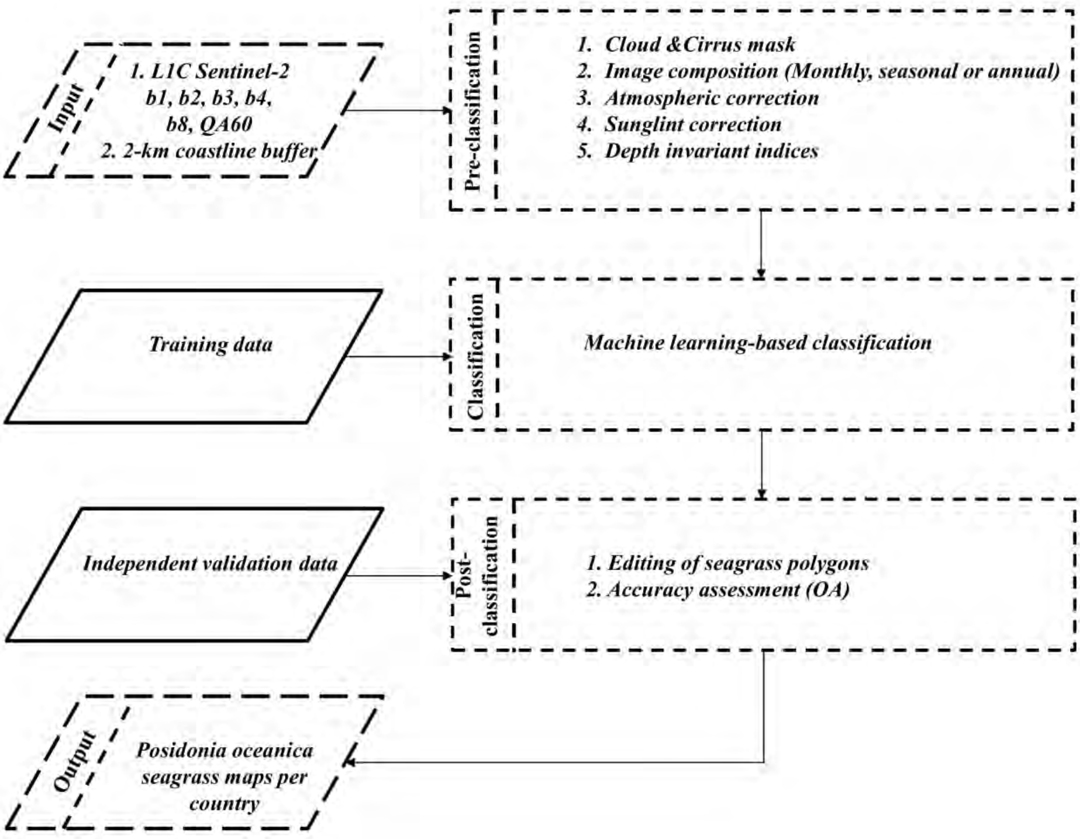

Fig. 1: Schematic representation of the Google Earth Engine based workflow in use here.

signature extension approach (Laborte *et al.,* 2010) and validates the machine learning derived mapping product in the case study area of Menorca implementing 81.7 km^2 of independently acquired *P. oceanica* polygons through dive-based fieldwork. Our satellite mosaic is based on 1 September – 1 October 2017 images, while the validation polygons were collected in the summer of 2017. The total study area of Menorca is 569 km^2.

Results

The results of each successive correction along with the classification step are displayed in the panels of Fig. 2. The workflow maps 113.3 km^2 of *P. oceanica* seagrass meadows (Fig. 2e) in 569 km^2 of the coastal seabed of Menorca. The observed accuracy of seagrass in the whole extent of the survey area is 50% following validation with the independent field dataset.

Discussion and Conclusions

Here, we scale up our cloud-based methodological workflow to map 113.3 km^2 of *P. oceanica* seagrass beds around Menorca in the Western Mediterranean basin at an accuracy of 50%. This is a particularly significant finding because it demonstrates the scalability of the implemented workflow, but also the importance of the availability of accurate and updated high quality insitu data from the area of interest; we train its machine learning classifier in Greece and validate it in Menorca, more than 1300 km away

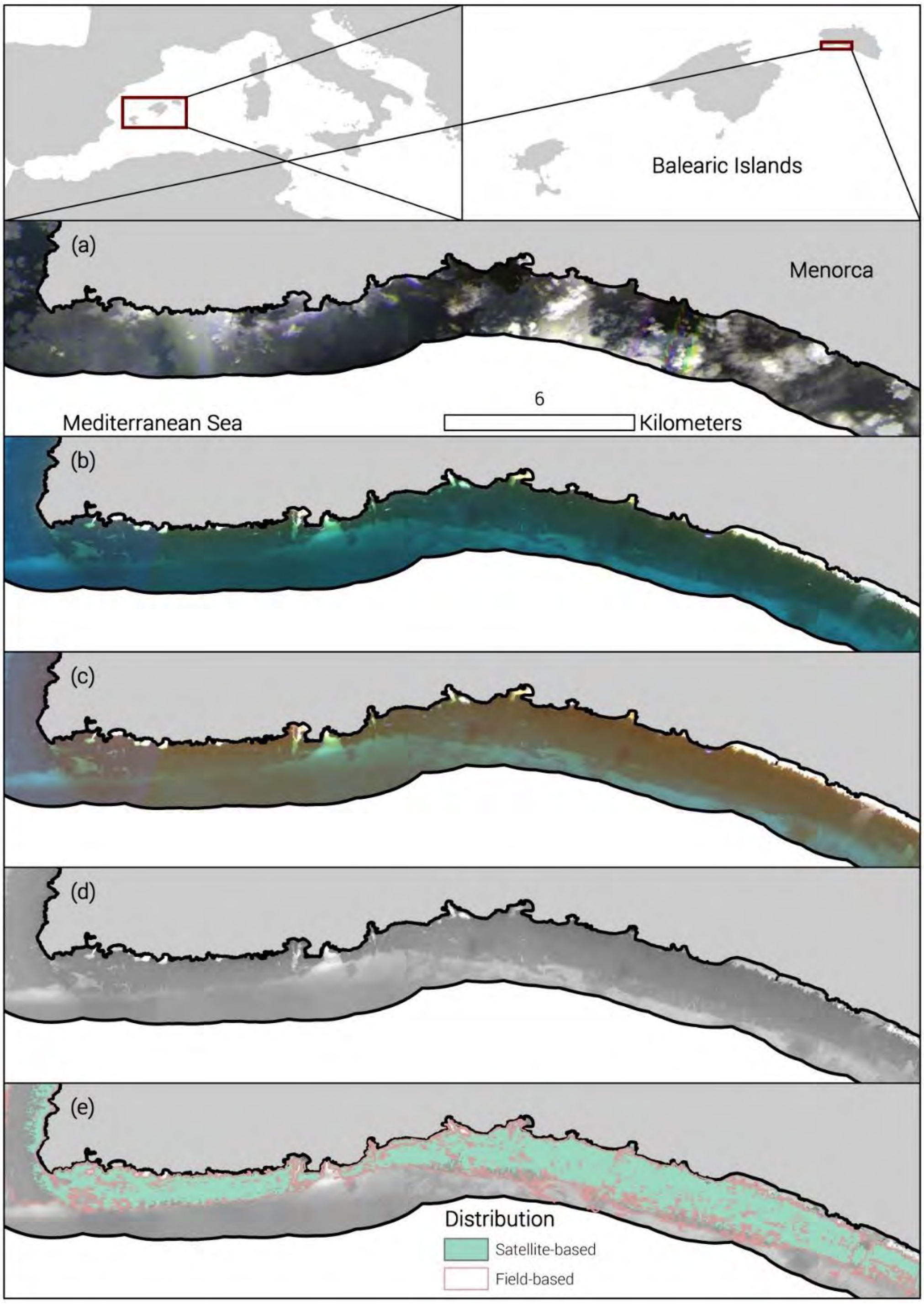

Fig. 2: Successive steps of the implemented cloud-based workflow. (a) Initial uncorrected, (b) cloud- and atmospherically-corrected, (c) sunglint-corrected, (d) water column corrected index b2-b3, (e) machine learning-based classified product over the (d) panel. The black polygon in panels (a) – (e) is the 2-km buffered study area. All panels are in GCS WGS84 World Geodetic System.

away in a different coastal environment in terms of water column conditions, seagrass abundance and scale naturally. In comparison to previous mapping efforts in the area, our satellite-based finding is 38.85% greater than the field-based distribution (Fig. 2e; 81.6 km^2) and 42.3% greater than the existing United Nations Environment Programme

(UNEP) World Conservation Monitoring Centre (WCMC) Version 5 seagrass distribution (not shown here; 79.6 km^2). As discussed, the classification results follow training of remotely sensed designed polygons in a spatially independent and remote area from Menorca and are validated using *in-situ* based estimated seagrass distribution from Menorca. While we are confident about the validity of these utilized polygons, we argue that the implementation of real *P. oceanica* distribution (namely the *in situ* estimated) for the training of the workflow will improve observed mapping accuracies and in turn its spatial scalability. Real seagrass distribution information will rise from the share of existing and/or envisaged field data acquisitions–it is mandatory to raise the importance of collaborative actions between seagrass biology/ecology and remote sensing scientists towards the designation of well documented and accurate in situ data which will be suitable for the calibration and validation of satellite data of medium to very high spatial resolution. Given suitable relevant field data, hence, the next step is the pan-Mediterranean mapping of seagrasses, mainly *P. oceanica* species due to its significance and ability to be identified due to its extensive meadows, at 10-m spatial resolution (Sentinel-2 resolution). Emergences in Earth Observation as the open satellite image archives at different spatial scales, the cloud computational power, and the machine learning classification accuracy allow such a large-scale mapping effort. As such, we postulate that the spatio-temporal flexibility of the workflow will enable the monitoring of seagrass assemblages in the whole basin in the near future, resolving possible seagrass dynamics in multiple temporal (seasonal, annual, inter-annual, decadal) scales.

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CONSTRUCTION UNDERWATER LANDSCAPE BY USING *POSIDONIA OCEANICA* TRANSPLANTING COMBINED WITH INNOVATIVE ARTIFICIAL REEFS

Abstract

Interest concerning Artificial Reef (AR) habitats has greatly increased in the last few decades throughout the world with Italy representing the leading country in Europe for AR's research. In this study very innovative ARs able to host Posidonia oceanica *transplant cuttings were designed and positioned. Four AR systems were positioned in December 2014 along the south-eastern coast of Sicily. Furthermore, over each module 10* P. oceanica *cuttings, each one bearing at least three shoots, were fixed by an innovative system, opportunely adapted for hard substrate. After two years of monitoring, cuttings survival was about 70% with visible roots production strongly anchored to the concrete AR, while shoot mortality and detachment were very low. These results suggested that* P. oceanica *can be successfully employed to improve the aesthetic value of ARs, providing evidence that its transplanting on hard substrate is less difficult than previously thought and opening new perspectives for restoring damaged meadows settled also on rock.*

Key-words: seagrass, restoration, transplanting, artificial reef.

Introduction

Interest concerning Artificial Reef (AR) habitats has greatly increased in the last few decades throughout the world (Seaman & Sprague, 1991; Stone *et al.*, 1991; Seaman & Jensen, 2000) with Italy representing the leading country in Europe for AR's research. ARs have been mainly conceived for a variety of purposes (Baine, 2001; Bulleri & Chapman, 2010), including the increase of natural productivity by providing new habitats to aggregate organisms (Thierry, 1988; Paxton *et al.*, 2018), creation of habitats for desired target species (Sheehy, 1986) and protection of small/juvenile organisms and nursery areas (Seaman, 2000). However, in this field of research, very low attention has been addressed to the aesthetical and perceptive integration of the ARs within underwater landscape (Inglis *et al.*, 1999; Dinsdale & Fenton, 2006; Needham *et al.*, 2011).
Posidonia oceanica, an endemic seagrass of the Mediterranean Sea, is able to grow on different types of sea bottom, ranging from sand, which is easily penetrable by the roots, to rock, in which the very sturdy roots are able to enter through crevices (Bellan-Santini *et al.*, 1994; Hemminga & Duarte, 2000; Mazzella *et al.*, 1993). *P. oceanica* meadows can also develop on *matte*, a typical terraced formation built up by itself, consisting of intertwined rhizomes, roots and sediment (Boudouresque & Meinesz, 1982). Since the 1970s, various transplanting and seedling techniques with *P. oceanica* have been carried out for habitat restoration. Transplant success was found to be influenced by the nature of the substratum, with dead *matte* habitat showing the highest survival and growth rates (Terrados *et al.*, 2013), while, to our knowledge, the experiences of transplants on hard substrates are still poorly documented.

In the framework of PON TETIDE project (http://www.progettotetide.com), very innovative ARs able to host *P. oceanica* transplant cuttings were designed and positioned. In the present work, we report the results of a monitoring activity on the transplanted cuttings carried out also in the framework of Life SEPOSSO (http://lifeseposso.eu).

Materials and Methods

The study was carried out in the Gulf of Augusta (Syracuse, Italy, Fig. 1), an area exposed to multiple pollution sources due to Priolo-Augusta-Melilli petrochemical activities since '50. However, recently remediation activities, focused mainly on purification and proper waste water disposal along the coast, have improved water quality (Catra & Mollica, 1993). It was therefore possible to carry out different experiments aimed to test the possibility to restore the degraded habitat with the use of *P. oceanica* transplants.

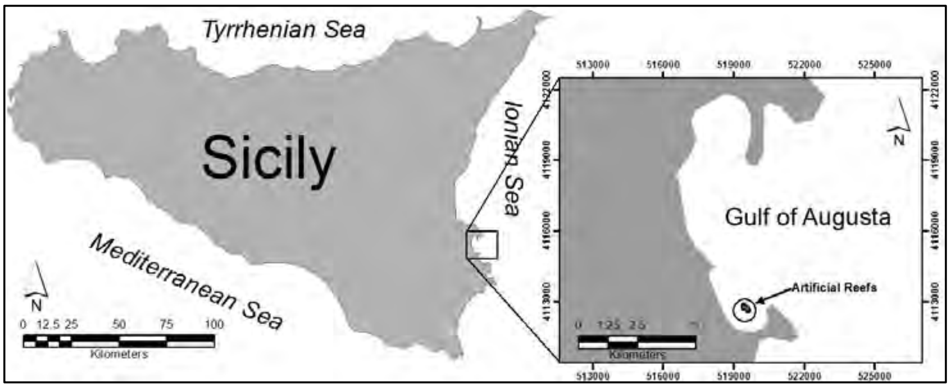

Fig. 1: Study area.

In this framework several ARs hosting *P. oceanica* transplant were positioned at about 13 m depth in December 2014. The AR design was chosen according to the characteristics of the study area and considering several aspects (i.e. hollow, size, material, shape). In particular, four ARs each one consisting of three modules of 10 tons, were located. These modules are made of reinforced concrete and composed by a common base of 2x3 m with multiple communicating shelters, and an upper form with three different heights (varying between 100and180 cm), to result shelters with different volumes, light and water movement (Fig. 2).

Fig. 2: AR sistems composed by three modules (*in situ* left).

In the same month, over each AR module 10 *P. oceanica* cuttings (Fig. 3), each one bearing at least three shoots, were fixed by an innovative system, opportunely adapted for hard substrate. Unfortunately, these transplants were soon after almost completely destroyed by illegal fishing activities. Then, a new equivalent transplant activity was again carried out in April 2016.

Fig. 3: *P. oceanica* anchor system on hard substrate (Ph. V. Raimondi).

From April 2016 to July 2018, monitoring activities by observations and measurements *in situ* were carried out to evaluate *P. oceanica* transplant performance in terms of establishment, detachment and mortality of cuttings, shoots number, leaf length. Moreover, elongation of plagiotropic rhizomes was recorded by repeated measures of the distance of the terminal apex from a fixed point on the anchoring support.

Results

For *P. oceanica* transplants on ARs positioned in the Gulf of Augusta, cutting establishment showed a decreasing trend during the monitoring period, with values of about 70% recorded in the final survey. Cuttings totally detached from the supports showed the opposite trend, reaching a final value of about 20% (Fig. 4a). The percentage of cuttings found dead was very low, reaching a final value of less than 4%.

The pattern of shoot number showed an initial increment occurred in July 2016 followed by a decrease to 44 shoots per support (Fig. 4b). Leaf length exhibited seasonal variations with the highest value in summer and the minimum in winter (Fig. 4c). Finally, plagiotropic rhizomes showed a progressive increment of length with initial steady state during the first eight months followed by a total increment of about 3 cm corresponding to an annual growth rate of 1.3 $cm \cdot yr^{-1}$ (Fig. 4d and Fig. 5).

Discussion and Conclusions

This study demonstrated that it is possible to combine ARs construction with *P. oceanica* transplanting activities, minimizing the visual impact on the underwater landscape by emulating the natural shape of the bottom. Despite the loss of cuttings in the first months after transplantation, due to the fishing activity, as similarly occurred in other areas (Pirrotta *et al.*, 2015), the subsequently transplanted cuttings exhibited good performance in terms of percentages of *P. oceanica* establishment (> 70%). The anchoring of the cuttings to the bottom favored the establishment and the expansion of the clones. This finding confirmed that *P. oceanica* has developed adaptive traits enabling to colonize hard substratum (Balestri *et al.*, 2015; Tomasello *et al.*, 2018) without the need for precursor assemblages (Badalamenti, *et al.*, 2015).

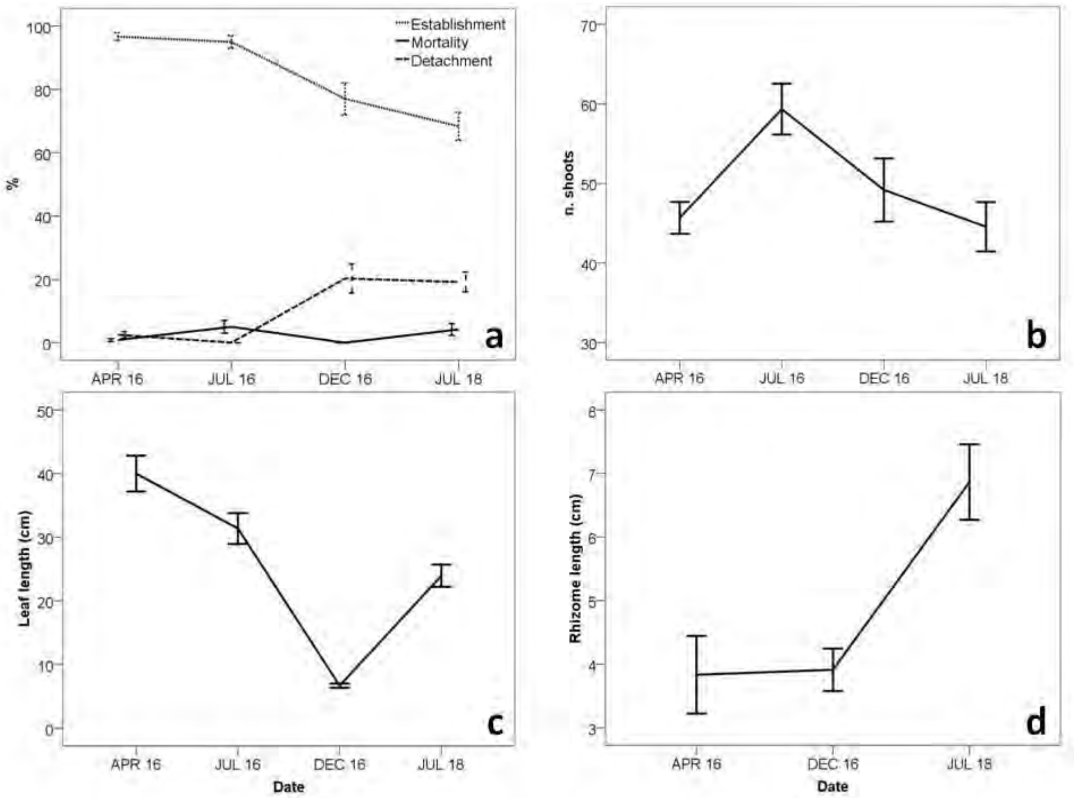

Fig. 4: Mean (± SE) percentages of establishment, detachment and mortality of cuttings (a), shoot number (b), leaf (c) and rhizome (d) length of *P. oceanica* cutting on AR.

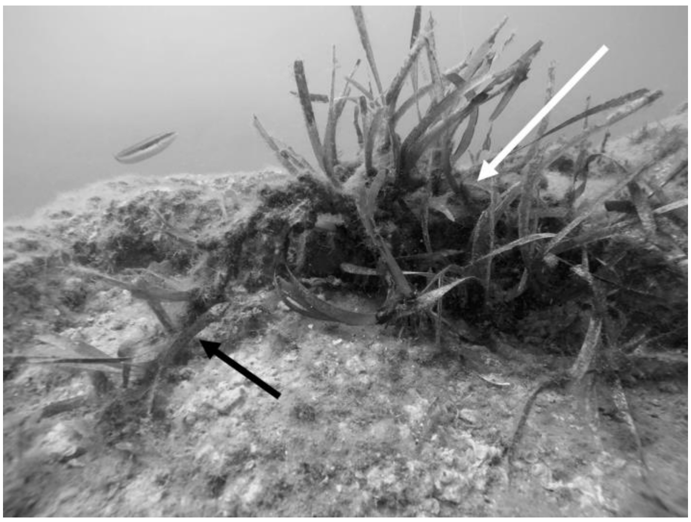

Fig. 5: Details of rhizomes growth on hard substrata above (white arrow) and beyond the anchoring support directly over the reef (black) (Ph. V. Raimondi).

The mortality recorded (about 4%) does not necessarily imply a low efficacy throughout the transplant, since this can be compensated over time by the elongation and ramification of the remaining cuttings (Calumpong & Fonseca, 2001). The growth rate of a seagrass clone increases continuously; therefore, the space occupied by a clone increases exponentially. Since *P. oceanica* is a long living species, its natural recovery is very slow (Pergent *et al.*, 2012) and the time to capture its resilience is often much longer than the conventional three years reported by most ecological studies (Cunha *et al.*, 2012). However, these results suggested that *P. oceanica* should be successfully employed to improve the aesthetic value of ARs (Fig. 6), providing evidence that its transplanting on hard substrate is less difficult than previously thought and opening new perspectives for restoring damaged meadows settled also on rock.

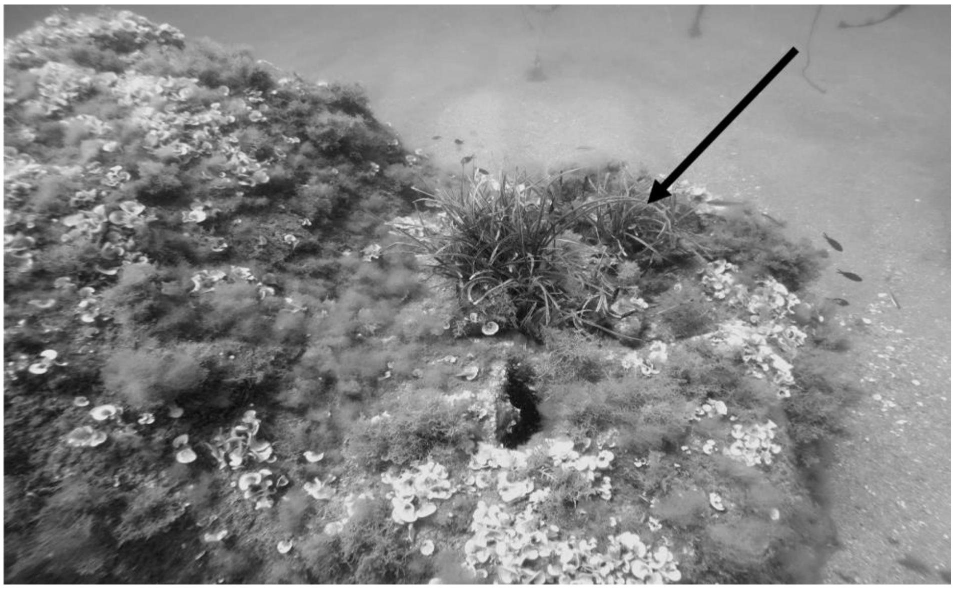

Fig. 6 - AR at 100% covered by community of algae and transplants of *P. oceanica* (arrow) (Ph. V. Raimondi).

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MAPPING OF *POSIDONIA OCEANICA* (L.) DELILE IN THE BAY OF GÜLBAHÇE

Abstract
Posidonia oceanica *is a species endemic to the Mediterranean and is protected by international treaties and national legislation. However, coastal tourism, fish farms, fisheries, coastal infrastructures, coastal wastes (industry, etc) are harming these fragile ecosystems and meadows. There is limited data on the spatial distribution and habitats of* P. oceanica *and where such studies exist most concentrations are identified by specific markers. The aim of this study is to map the distribution of* P. oceanica *in the Gülbahçe Bay (Aegean Sea, Turkey) using a sub-bottom profiler, a side scan sonar and high-resolution Worldview-2 satellite images. At depths of up to 12 meters the satellite image data was subjected to a classification process to obtain the average overall distribution of* P. oceanica*. At depths of below 12 meters, data was obtained using a combination of high-resolution sub-bottom profiler and digital side scan sonar. The results obtained by both methods were combined and these results were compared with the control data obtained from 926 sites. The overall classification accuracy for the study area was 86%. As the result of this study it was noted that, approximately 25% (1 393 ha) of the total Gülbahçe Bay area (5 800 ha) was covered by* P. oceanica*. It is suggested that the map obtained from this study should be integrated into other spatial marine data and used to coordinate effective coastal management.*

Key-words: Seagrass, *Posidonia oceanica,* habitat mapping, optical remote sensing, side scan sonar.

Introduction
Seagrass *Posidonia oceanica* L. (Delile) is the richest and most widely distributed species in the Mediterranean Basin. *P. oceanica* meadows spread at dynamic soft bottom in coastal areas and high ecological preservation. This phanerogam forms dense meadows at depths of 0-40 m and is one of the most important habitats in the Mediterranean. On a world scale, this makes the Mediterranean distinct in terms of biodiversity when compared to many coastal regions. Seagrasses constitute one of the most productive marine ecosystems and cover a large area in the Aegean Sea (Dural *et al*., 2012). There is a worldwide deterioration of these valuable ecosystems resulting from direct and indirect human impacts, including mechanical damage, eutrophication, aquaculture, siltation, effects of coastal construction, food web alterations and indirect human impacts including adverse effects of climate change (Duarte, 2002). The Republic of Turkey's Ministry of Food and Agriculture and Livestock prohibit the hunting, collecting, landing of seagrass species *P. oceanica* and *Zostera noltii* in compliance with notification No. 4/1 for commercial fishing and notification No. 4/2 for non-commercial fishing. *P. oceanica* is included in the Bern and Barcelona Conventions Annex I. The meadows of this species are also protected by EC Council Regulation No. 92/43 Annex I (Habitats Directive,1992). According to the Action Plan for the Conservation of Marine Vegetation in the Mediterranean (United Nations

Environment Program), it is stated that special attention should be paid to *P. oceanica*. While in the past "conservation" was interpreted in a relatively lacklustre manor new approaches and laws have brought about stricter and increased appliance of regulations. Nowadays "conservation" is considered a dynamic concept and is used in the management of species as well as habitats (Boudouresque *et al*., 2012). Seagrass habitats play important ecological and economical roles on ecosystems. The widespread availability of *P. oceanica* is particularly important in terms of nursery grounds for many commercially-caught species, supplying organic food to a variety of dependent food webs; stabilizing the seabed; decreasing the turbidity by capturing the sediment and total suspended matter, they structure the seabed on which they grow into a complex environment which provides a habitat for many organisms to exist. In the study area Gülbahçe Bay, the number of registered partners in the Özbek Fisheries Cooperative was 52, however an estimated 220 people make a living from related professions (Tokac *et al*., 2010). For this reason, international and national mapping of *P. oceanica* meadows should include as many groups as possible due to the extensive number of local collaborators affected. The aim of this study is to produce detailed maps in a shorter time by using side scan sonar, sub-bottom profiler, Worldview-2 satellite imaging technique of meadows with a multidisciplinary approach in determining the distribution areas of *P.oceanica* in Gülbahçe Bay.

Materials and methods

The study area, Gülbahçe Bay in the Izmir Gulf (Fig. 1) is located between 38°.31-38°40 latitude and 26°.62-26°70 longitude and covers an area of 58 km^2.The bay has a 38 km shoreline length and its depth reaches 30 m. A previous study processed Google Earth images of the study area, where three different types of *P. oceanica* meadows (tiger, atoll, and reef barriers) were identified (Massey, 2013). However, this study examined only the shallower southern part of the area and lacked ground truth. Therefore, we aimed to map the entire bay area by including the deeper northern part. On-site data were collected as well to determine the quality of the produced map. We used the Worldview-2 satellite image from March 12, 2012 for classification and georeferenced it to the WGS84 system. Five cover types were identified in the study area for further thematic mapping. Ground truth data for *P. oceanica*, *Cymodocea nodosa*, hard bottom, mud and sand classes were visually identified on the image and their coordinates transferred to a handheld GPS. Selected locations were then visited *insitu* by scuba diving and snorkelling and their agreement with the field observations were thus verified. Cover types were updated for the points where site visits revealed a different type. Ground truth data were collected for several predetermined days over a two-year period. (Tab. 1).

Data collected from 926 points was used in the classification of the WV-2 image. We divided ground truth data set into two subsets: training and testing data. Training data was fed into Maximum Likelihood (ML) and Support Vector Machine (SVM) classifiers to generate a thematic map of the study area (Richards, 2013). The testing data, independent from training set data was used in the quality assessment of the map. We carried out the classifications on the image, where land areas had been masked. No deep-water masking was included to obtain a maximum depth limit of the classification. For studies that took place in deeper bay Sub Bottom Profiler (high separation seismic profile) and side scan sonar was used.

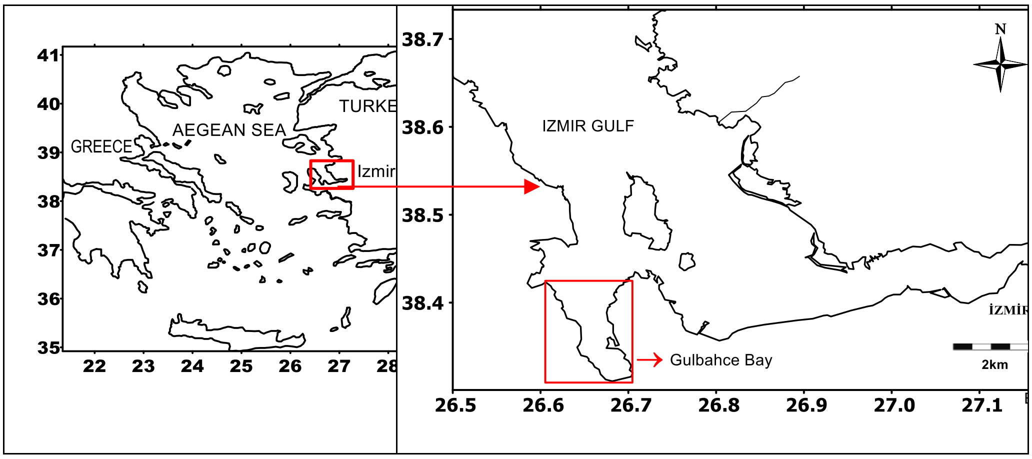

Fig. 1: Study area

Tab. 1: Types, dates and numbers of sampling

Sampling method	Date	# of sampling
Snorkelling	05.2014	170
Snorkelling	05.2015	80
Action camera	07.2015	614
Action camera	07.2016	52
Scuba dives	07.2016	10
Total		926

Results

The classification using both the ML and SVM methods produced 87.7 % and 86.3% overall accuracy rates, respectively. Overall classification accuracy is a very general criterion and producer and user accuracy for each class was also examined (Tab. 2). Although SVM classification resulted in better producer accuracies than ML for *P. oceanica* and sand classes, ML method generated superior user accuracy values relative to SVM in those classes. Spatial extent of hard bottom and *C. nodosa,* data were obtained with the least user accuracy values. One reason for lower accuracies was due to their sparsity. The number of hard bottom and *C. nodosa* samples form only 0.6 and 1.7 % of the total ground truth pixels, respectively. Samples from these two cover types have similar reflectance characteristics with the other cover types. Hard bottom cover was, for example, inaccurately labelled as *C. nodosa* whereas *C. nodosa* locations were confused with all the remaining cover types.

Tab. 2: Producer and user accuracy of the classes

	Maximum Likelihood		Support Vector Machi	
	Producer accuracy (%)	User accuracy (%)	Producer accuracy (%)	User accuracy (%)
P. oceanica	86.6	94.1	92.0	88.2
Sand	98.3	98.2	99.6	86.3
Mud	90.4	81.9	78.7	84.4
Hard bottom	90.3	50.1	66.5	43.5
C. nodosa	49.9	33.6	12.2	38.4

P. oceanica communities in the shallower southeast part of the study area could be clearly revealed by the SVM method whereas ML classified regions of the same area revealed *C. nodosa* (Fig. 2). This condition was reflected in Tab. 2 which shows that *C. nodosa* user accuracy with SVM was slightly better than the ML method. Data was collected using high definition seismic profilers and side scan sonar to test the accuracy of the produced thematic map. These data provided reliable sources of information for deeper locations where the satellite image was not sufficient due to optical conditions.

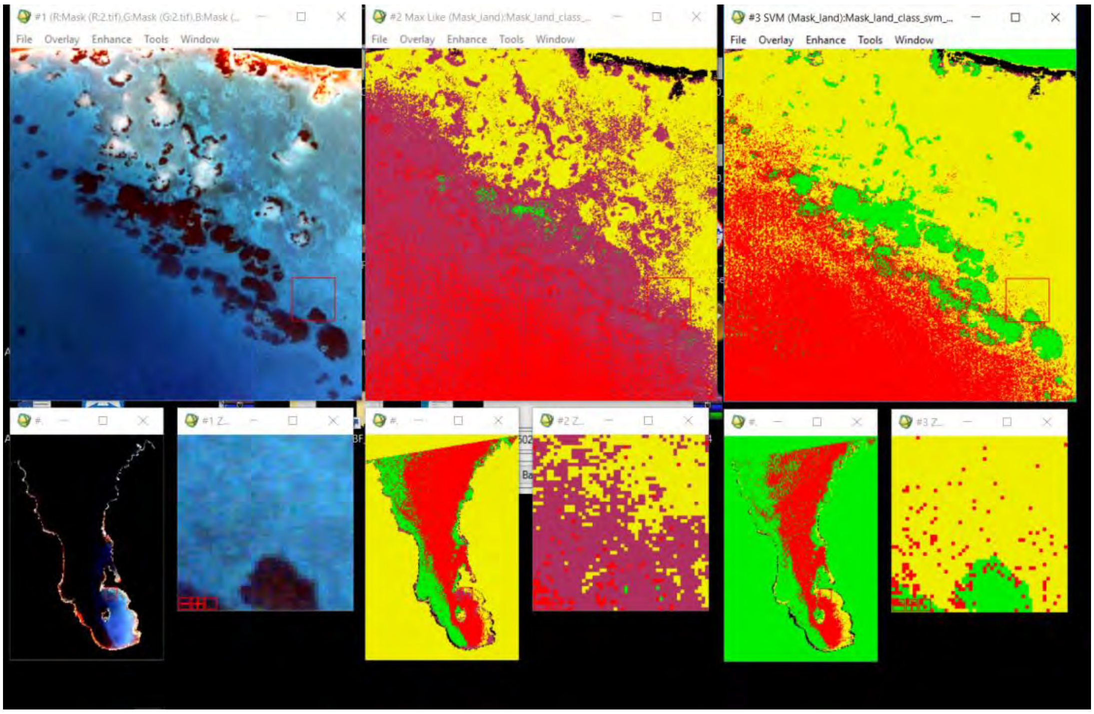

Fig. 2: Raw satellite image (l.), ML classification (m.), and SVM classification (r.) results showing southeast of the study area

Discussion and conclusions

To our knowledge this study is one of a kind as it mapped the extent of a seagrass species in Turkey for the first time with high spatial resolution. The study demarcated the boundary of *P. oceanica* in the Gülbahçe Bay within an area of 5 800 ha by using the WorldView-2 satellite image acquired in favourable atmospheric conditions and a high-resolution sub-bottom profiler and digital side scan sonar data. We could extract *P. oceanica* boundaries with the help of satellite images down to an average depth of 12 m. Deeper locations were mapped by using profiler and sonar data *P. oceanica* covers 1 393 ha an area which corresponds to nearly one quarter of the entire bay area *P.oceanica* meadows also constitute special structures depending on the environmental conditions (depth, hydrodynamics, nature of substrate).Tiger meadows, barrier reefs and atolls are natural monuments (Boudoresque et al.2006). Indeed in the southeast of Gülbahçe Bay seems to present natural monuments including tiger meadows, atolls and barrier reef. However, the construction of the coast is the threat of this important natural structure. The data obtained from this study and the resulting map is recommended to be used within an effective coastal management framework by integrating it with other spatial data.

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SEAGRASS IN TUNISIAN LAGOONS: *CYMODOCEA NODOSA* MEADOWS FACING POLLUTION THREATS

Abstract
The Tunisian coast lagoons are known as high biological productive ecosystems. However, over the last decades, both Ghar El Melh and Bizerte lagoons has been affected by anthropogenic activities being a collector of several industrial and agricultural sewages (fertilizers, pesticides, etc.). In this study, we investigated during summer 2017 the phenological parameters of Cymodocea nodosa *seagrass meadows as well as the accumulation pattern of five trace metal elements (Zn, Cu, Ni, Pb and Cd) in different compartments of this plant using ICP-OES method. Density and different biometric descriptors of both meadows showed similar values. The five trace elements were found in detectable concentrations in* C. nodosa *compartments and sediment samples. The ranking of metals content in* C. nodosa *leaves was Zn>Cu, Ni, Pb, Cd for both Bizerte and Ghar El Melh lagoons. The trace metal levels in leaves were higher than those recorded in rhizomes. Different profiles were observed for the rhizomes with Zn>Cu>Ni, Pb, Cd for Bizerte lagoon and Zn, Cu>Ni, Pb, Cd for Ghar El Melh one. Compared to* C. nodosa *meadows in Tunisian marine area, higher levels of trace elements were recorded in these lagoons. Globally,* C. nodosa *meadows in the studied lagoons showed a steep decline of several descriptor parameters that had been accelerated over the last few years.*

Key-words: lagoon, seagrass, descriptors, trace metal

Introduction
Seagrass ecosystems rank amongst the most productive habitat in coastal lagoons that play a primary role in supporting ecosystem services such as carbon sequestration, hosting biodiversity and sediment stabilization (Duarte *et al.,* 2013). Despite their importance, seagrass meadows are known a general decline in lagoons ecosystems in Tunisia (Sghaier *et al*., 2011). This lost is mainly due to increasing pressure from industrial, domestic and agricultural activities around these areas (Barhoumi *et al*., 2016). Due to their toxicity, persistence in the environment, bioaccumulative and non-biodegradable nature, trace elements (TE) are considered as potential hazardous polluants of these ecosystems (Bonnano *et al*., 2017). In order to monitor TE pollution in coastal areas, seagrasses are considered as an effective tool (Orlando-Bonaca *et al*., 2015). Few notable studies on TE distribution in seagrasses exist for Tunisian coast (El Zrelli *et al*., 2017; Zakhama-Sraieb *et al*., 2016) and none of them has explored the potential use of *Cymodocea nodosa* in metal pollution monitoring. The present study aims to (i) determine and compare several classic descriptors of *C. nodosa* meadows and (ii) to assess the TE contamination in sediments and two compartments (leaves and rhizomes) of *C. nodosa* from two Tunisian coastal lagoons, Bizerte and Ghar El Melh.

Materials and methods
The study was conducted during July 2017 in two Tunisian coastal lagoons that have been under anthropogenic pressures for many years (Figure 1). Both Bizerte (37°08’-37°14’N

and 09°46'- 09°56'E) and Ghar El Melh (37°06'- 37°10'N and 10°08'-10°15'E) lagoons have been suffering from a progressive deterioration that has led to biodiversity loss (Béjaoui *et al.*, 2016; Zakhama-Sraieb *et al.*, 2011). The *C. nodosa* meadows studied were in shallow water within a depth of 0.5-1.5 m.

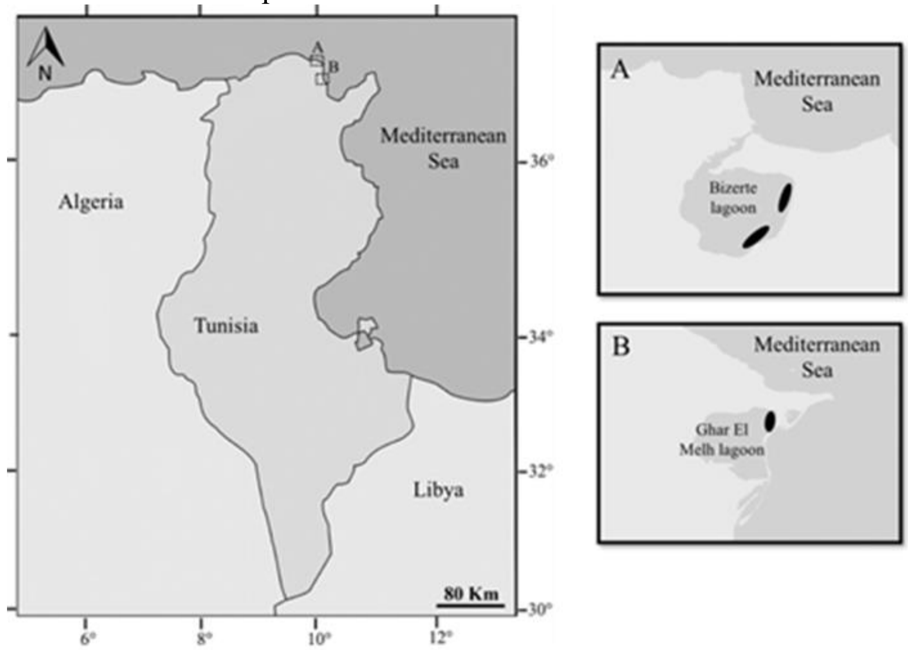

Fig. 1: Sampling sites. A: Bizerte lagoon and B: Ghar El Melh lagoon. Black ellipse indicates area of collection of *Cymodocea nodosa* in the lagoons.

In order to determine the density of each meadow, 10 replicates were performed using a quadrat of 20×20 cm. Replicates was taken about 1 m apart. Twenty shoots were collected randomly at the sampling site to measure plant morphometrics. Once in the laboratory, the leaves of each shoots were counted and separated into of differentiated leaves (with sheath) and undifferentiated (without sheath). Leaf width and length (from the meristem to the tip of the leaf) were also measured.

For TE analyses, five pools of 75 shoots of *C. nodosa* (15 per replicate) and three replicates of superficial sediment were haphazardly collected from each meadow. In the laboratory, each *C. nodosa* shoot was dissected into leaves and rhizomes and dried to constant weight at 40 °C in a drying oven. Sediment samples were also dried and sieved. The fraction (<63µm) was kept to the chemical analysis. After being dried each *C. nodosa* sample was digested using 3 ml of H_2O_2 and 5 ml HNO_3.While 2 ml of HNO_3 and 6 ml of HCL were used to digest 0.4 g from each sediment sample.

The determination of the five TE concentrations, copper (Cu), lead (Pb), zinc (Zn), Cd (Cd) and nickel (Ni), was performed by inductively coupled optical emission spectrometry (ICP-OES, PerkinElmer Optima DV 7000). The precision and accuracy of the analytical method was checked using standard reference materials: NIST-1515 Apple leaves for the plant samples and MR17M9.15 for the sediment samples (certified reference material).

Means were compared by using either the t-test or one-way analysis of variance (ANOVA). In order to comply with the assumption of parametric procedures, data were tested for normality by the Shapiro-Wilk test and for homogeneity by Levene test. All analyses were conducted using the statistical package IBM SPSS Version 20.0.

Results

Phenological and biometric parameters are shown in Table 1. Globally, no statistical differences were observed between the morphometric features of the two meadows (t-test, p> 0.005), except for the shoot density parameter, with significant higher values at Ghar El Melh lagoon.

Tab. 1: Phenological and biometric parameters of *Cymodocea nodosa* meadows in Bizerte and Ghar El Melh lagoons (mean ±SE)

	Bizerte	Ghar El Melh
Shoot density	297.50±97.64	447.50±195.50
Mean number of leaves per shoot	3.83±0.81	3.88±1.17
Percentage of differentiated leaves	42%	42%
Mean leaf length	14.36±10.39	15.75±10.14
Mean leaf width	0.31±0.06	0.34±0.04
Mean leaf area of shoot (cm^2)	18.13±9.59	22.94±10.26
Leaf Area Index (m^2m^{-2})	0.54	1.03

The variation of levels of TE in the sediments and the two compartments of *C. nodosa* samples collecting from Bizerte and Ghar El Melh lagoons are summarized in Figure 2.

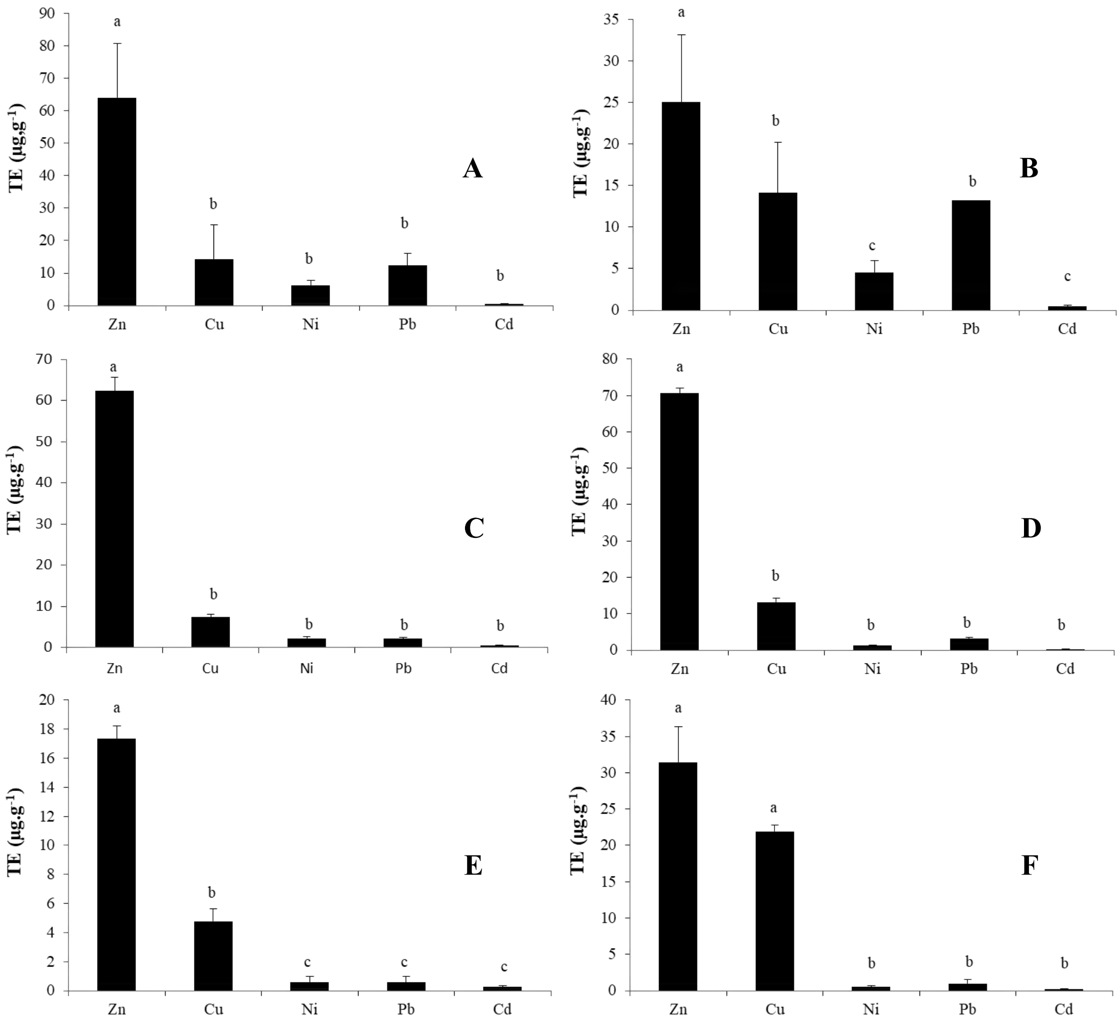

Fig. 2: Trace element (Zn, Cu, Ni, Pb and Cd) content in sediment A-B (mean ± SE, in µg g^{-1}), in leaves C-D and rhizomes E-F of *C. nodosa* (mean ± SE, in µg.g^{-1} dry wt) of Bizerte (left) and Ghar El Melh (right) lagoons. Small letters represent significance (p value) between mean concentrations.

The bioaccumulation trends of the five targets five TE in the sediment was Zn > Cu, Ni, Pb, Cd in Bizerte lagoon and Zn> Cu, Pb>Ni, Cd in Ghar El Melh lagoon. Except the Zn for which the highest level was recorded in Bizerte lagoon's sediment, the others TE is accumulated with the same order of magnitude in the two lagoons.
For both lagoons, the same pattern of TE accumulation was observed in the leaves of *C. nodosa* (Zn> Cu, Ni, Pb, Cd). In general, the leaves collected from Bizerte lagoon exhibit the highest concentration of Zn, Ni and Cd. Whereas those from Ghar El Melh lagoon have shown higher concentration of Cu. No significant difference has been observed for the Pb.
The trend of the concentrations of the five TE in the rhizome of *C. nodosa* observed in Bizerte lagoon was slightly different from those recorded in Ghar El Melh lagoon with Zn>Cu> Ni, Pb, Cd instead of Zn, Cu> Ni, Pb, Cd. Generally, TE trends in plant compartments share similarities with sediment. Results show significantly higher levels of Zn and Cu for the rhizomes sampled from the Ghar El Melh lagoon. For the other TE no significant difference has been detected.

Discussion and conclusions
This study gives an update to the state of *C. nodosa* meadow in Bizerte and Ghar El Melh lagoons after a severe year of anthropogenic pressures and an initial assessment of TE contamination using *C. nodosa* leaves and rhizomes.
In comparison with others phenological and biometric studies conducted on *C. nodosa* meadows along the Tunisian coast (Zakhama *et al*., 2010a,b), the *C. nodosa* meadows in the target lagoons exhibit lowers values of several meadows descriptors such density. According to Sghaier *et al*. (2011), in May-June 2007 the density of *C. nodosa* meadow in Ghar El Melh lagoon was roughly 800 shoots per m^2, while during our study in June 2017 the density was 447.5 shoots per m^2. Our results witness an important decline of *C. nodosa* density in the Ghar El Melh lagoon during the last ten years that can be attributed either to natural variations and/or to the anthropogenic activities.
According to the norm adapted by the EU's environmental quality standard (EQS), the sedimentary content of Bizerte and Ghar El Melh lagoon which are respectively 0.50 µg.g^{-1} and 0.32 µg.g^{-1}exceed the standard level (0.3 µg.g^{-1}). Since Cd is widely used in heavy industries such as steel (Sidi *et al*., 2018), the potential source of this trace element might be the metallurgical activities that are located in the vicinity of this lagoon (Barhoumi *et al*., 2014).
Zn concentrations in *C. nodosa* showed the highest concentration compared to other elements. This may be due to the fact that this element is considered as an essential micronutrient for growth and metabolism of plants (Bonanno & Orlando-Bonaca*,* 2017). Our results show that *C. nodosa* in both lagoons trend to accumulate the excess of Cd in its leaves, this may suggest that this seagrass adopt a removal strategy to tolerate the toxic levels of Cd in these lagoons. In fact, this strategy consists on accumulating higher concentrations of toxic trace elements in temporary organs (leaves) (Bonanno & Borg, 2018). Malea *et al*. (1999) found that the periodical leaf regeneration in seagrasses facilitate elements loss.
In general, the concentrations of trace element in *C. nodosa* compartments **(**leaves and rhizomes) are comparable with those from other Mediterranean meadows (Table 2). For instance, the zinc concentrations in Ghar El Melh lagoon are in the same magnitude with those recorded in Ebro River Delta (Spain), Sicily (Italy) and Bay of Larmyna (Greece).

This study is one of the few studies that investigates the environmental state of *C. nodosa* meadows in Tunisia and it shows that despite Ghar El Melh lagoon has been nominated as a Ramsar site since November 2007, the biodiversity in this lagoon is threaten by the steep decline of the *C. nodosa* meadow as well as the high accumulation of some toxic element as Cd. In order to preserve the different ecological services provided by *C. nodosa* meadows in Ghar El Melh and Bizerte lagoons a monitoring project for these meadows seems necessary.

Tab. 2: Range of trace element concentrations (µg.g^{-1} dry wt) in *C. nodosa* compartments in comparison to those reported in others Mediterranean regions

Geographic zone / Reference	Compartment	Zn	Cu	Ni	Pb	Cd
Agean Sea (Greece) /	Leaves	*	0.41- 43,70	2.80- 49.40	*	*
Catsiki & Panayotidis (1993)	Rhizomes	*	0.19- 11.10	1.40- 8.95	*	*
Bay of Larmyna (Greece)	Leaves	57.50	9.60	7.60	*	2.10
/ Nicolaidou & Nott (1998)	Rhizomes	23.00	7.70	1.20	*	2.10
Ebro River Delta (Spain)	Leaves	10.00-50.00	3.00- 7.00	1.00- 3.00	0.30- 4.00	0.20-0.40
/ Llagostera *et al*., (2011)	Rhizomes	10.00-50.00	2.00- 4.00	0.20- 1.00	0.20- 1.00	0.30-1.00
Mar Manor lagoon	Leaves	50.00-400.00	*	*	10.00- 400.00	0.05-0.40
(Spain) / Marin-Guirao *et al*., (2005)	Rhizomes	10.00-200.00	*	*	10.00- 300.00	0.01-0.10
Sicily (Italy) / Bonnano	Leaves	42.60-65.80	3.61- 28.80	3.20- 6.65	1.42- 3.85	0.10-0.55
& Di Martino, (2016)	Rhizomes	18.60-31.70	2.06- 23.10	0.88- 5.34	0.21- 1.87	0.04-0.22
Bizerte lagoon / Present	Leaves	62.33	7.36	2.24	2.18	0.50
study	Rhizomes	17.33	4.76	0.60	0.56	0.24
Ghar El Melh lagoon /	Leaves	70.70	13.14	1.19	3.09	0.25
Present study	Rhizomes	31.46	21.94	0.52	0.97	0.17

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POSTERS

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OPERATING A NETWORK OF INTEGRATED OBSERVATORY SYSTEMS IN THE MEDITERRANNEAN SEA: *POSIDONIA* MEADOWS AND ECOSYSTEM HEALTH ASSESSMENTS

Abstract
Posidonia oceanica *meadows are important primary producers in the marine environment that also help to structure communities of coastal areas. Recent studies have indicated that habitat loss is one notable consequence of both natural and anthropogenic stressors. Complex interactions exist between the environment and economic-, socio-cultural- and recreational activities around the Mediterranean Sea basin. There is a need for more data that can reveal interactions between different interests to secure the conservation and sustainable management of these sensitive habitats. In this paper we describe activities and expected outputs of the ODYSSEA project developed to achieve these goals based on an integrated network of Mediterranean observational and forecasting systems.*

Key-words: Seagrass, Observatory Systems, Blue Growth

Introduction

The combination of climatic change and human-induced stressors within the marine environment cause degradation of natural habitats and loss of marine biodiversity (OECD, 2002). *Posidonia oceanica* meadows represent a key habitat throughout the Mediterranean and constitute complex ecosystems with their associated fauna and flora. Recent studies have suggested that habitat loss occur in response to natural and anthropogenic stressors (Boudouresque *et al.* 2012). Due to its low resilience, *P. oceanica* has been protected internationally by EC Habitat Directive, Bern and Barcelona Conventions as well as locally by several nations. In order to contribute to the conservation and sustainable management of these sensitive habitats, there is a need for data that can reveal interactions between marine environments and the activities of different maritime sectors. Such data can be obtained from both historical records and new monitoring studies. However, the spatial and temporal resolution of existing data is limited throughout the Mediterranean Sea.

The EU supported ODYSSEA project, which is part of the Horizon 2020 Programme for Research and Innovation, will develop and operate a cost-effective platform that fully integrates a network of observing and forecasting systems across the Mediterranean basin both at open sea and in the coastal zone. The aim of the project is to make Mediterranean marine data easily accessible to end-users by harmonizing existing Earth Observing Systems, upgrading operational oceanographic capacities, improving interoperability in monitoring but also to promote blue growth jobs creation.

In this paper, we describe the ODYSSEA Project with a focus on biological data integration and the promotion of ecosystem assessments, forecasts, and scenarios. The overall aim of the said project is a deeper understanding of vulnerability, risks and interventions at local and regional levels.

Material and Methods

The ODYSSEA Project (www.odysseaplatform.eu) involves an integrated network of Mediterranean observational and forecasting systems. This platform will collect relevant data from many databases maintained by agencies, public authorities and institutions in Mediterranean EU and non-EU countries. It will integrate existing earth observation facilities and networks in the Mediterranean Sea building on key initiatives such as Copernicus, GEOSS, EMODNet, ESFRI, Lifewatch, Med-OBIS, AquaMaps, Marine IBA e-atlas and other initiatives with marine and maritime links.

Within ODYSSEA, Nine Regional ODYSSEA Observatory Prototypes around the Mediterranean Sea will be established to close existing data gaps and increase the temporal and spatial resolution of observational and marine forecasting data. One of them is the Gökova Observatory that will be located in a Marine Protected Area located in the South Aegean Sea of Turkey. ODYSSEA databases will supply homogenised and fused data in accordance with end-user requirements of different profiles across the whole Mediterranean.

Results and discussion

The use of prediction models to evaluate the state of crucial ecosystems, which are under threat of environmental stressors, should be a priority. Easy and cost-effective access to the data of marine sectors and anthropogenic impact besides environmental data is a must for sustainable and effective coastal management. It is also important to link the said information with biological data. Therefore, "ecosystem-based approach" emerged aiming the integrated management of ecosystem functioning. Long term data acquisition of crucial physico-chemical factors affecting the distribution and ecological status of these essential habitats across the Mediterranean Sea could help us to create more reliable and economic forecasting models of the ecological impact following changing environmental conditions. The first outputs of the project, produced models based on harmonised data obtained from large, systematic and diverse databases, and selected indicator parameters, illustrate how this project could contribute a better understanding of seagrass ecosystems as well as allow better management and policy decision.

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FIRST ASSESSMENT OF THE ECOLOGICAL STATUS IN THE LEVANT BASIN: APPLICATION OF THE CARLIT INDEX ALONG THE LEBANESE COASTLINE

Abstract
Macroalgae is one of the Biological Quality Elements (BQE) used by several indices conceived in the European Water Framework Directive (WFD) for the assessment of the Ecological status of coastal water bodies. Among them, CARLIT index, based on the cartography of rocky-shore littoral communities, has been extensively and successfully applied in the Western Mediterranean Sea. In this study CARLIT was applied for the first time in the Levantine Sea, along the Lebanese shoreline in order to test the suitability of this method in the peculiar ecological conditions of the Levantine Sea and have a first assessment of its ecological status. The choice of proper reference sites is a focal point in the fulfillment of the WFD. In order to ensure accurate calculation of the ecological status of the Lebanese coast, the calculations of the reference conditions (RC) were performed using the values calculated in the Lebanese reference area, the Northwestern (NW) Mediterranean RC proposed in the first application of the CARLIT method and the Adriatic Sea RC. The results showed that the calculated ecological quality ratio values (EQR) based on Lebanese RC is particularly important when considering the principle of the WFD to reach and maintain a good Ecological Status. Overall, the EQR values were well correlated with anthropogenic pressures, as assessed by the LUSI and MA-LUSI indices. In addition, this method allowed the collection of accurate information on the distribution and abundance of shallow-water communities, especially of those deserving protection (e.g. Cystoseira *forests). Thus, the present paper represents a baseline for future studies and gives useful tools for the management of human impacts on the Lebanese coast.*

Key-words: CARLIT, Ecological status, Water Framework Directive, Macroalgae, *Cystoseira*, Lebanese coast.

Introduction
The assessment of the Ecological Status (ES) by the application of the CARLIT (CARtography of LITtoral rocky-shore communities) index, based on macroalgal assemblages and conceived in the context of the WFD (2000/60/EU) was carried out along 164 km of the Lebanese coast during April – May 2016. This research represents the first application of this index in the Eastern Mediterranean Sea, providing a detailed cartography of shallow large brown seaweeds forests in a relatively poorly known region of the Mediterranean, and gives important insights on the ES of coastal waters in relation to human impacts.

Material and methods
The surveyed Lebanese coast was divided into 12 stretches. Each stretch of coast was previously divided into sectors of 50 m length using QGIS software. In each sector,

littoral/and upper littoral communities (e.g. Ballesteros *et al.*, 2007; Nikolić *et al.*, 2013) and geomorphological factors (Nikolić *et al.,* 2013) were visually recorded and noted directly into maps (scale 1:5000) previously prepared using aerial photographs taken from Google Earth®; QGIS was used to calculate the length of coasts investigated. The ES of waters (EQ) was calculated for each Geomorphological Relevant Situation (GRS) in every stretch of coast and the whole stretch of coast (EQR). The Land Use Simplified Index (LUSI), the Modified LUSI index (MA-LUSI-WB) and the Human Activities and Pressures Index (HAPI), were used to analyze the relation between the CARLIT assessment of Ecological Status and the anthropogenic pressures.

Results

Based on the Lebanese RC, the results showed that, excluding the reference site Nakoura covering 10.9 % of the surveyed coast, 29.9 % of the coast was assessed as belonging to the good, 37.1 % to the moderate, 12.1% to the poor and 9.9% to the bad ES. A comparison with the values calculated in the Northwestern Mediterranean (Ballesteros *et al.*, 2007) and Adriatic reference sites (Nikolić *et al.*, 2013) allowed to highlight relatively good correlations of EQRs, but some mismatches in the ES classes' agreement.

The results of the present study shows that CARLIT-EQR results are well correlated to human pressure indicators (Lebanese reference values: $n=11$; ES/LUSI $r = -0.85$, $p < 0.05$; ES/MA-LUSI, $r = -0.87$, $p<0.05$; ES/HAPI $r= -0.84$, $p<0.005$; NW Mediterranean reference values: $n=12$; ES/LUSI $r = 0.79$, $p< 0.05$; ES/MA-LUSI, $r = 0.79$, $p<0.05$; ES/HAPI $r=-0.84$; Adriatic reference values: $n=12$; ES/LUSI $r = 0.76$, $p< 0.05$; ES/MA-LUSI, $r = 0.76$, $p<0.05$; ES/HAPI $r=-0.84$).

Discussions

The successful application of CARLIT method for the first time in a country of the Levantine Sea gives important insights on the ecological state of its coastal waters, and on the evolution of priority assemblages as marine forests of large brown seaweeds. Hence a continuous long-term monitoring should be a priority for a better assessment of the effects of human impacts on the evolution of marine ecosystems. In this context, it is necessary to maintain the good ES of the existing coastal ecosystems (e.g. large brown algae forests) allowing to conserve current population, including restoration programs.

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TRANSPLANTATION OF ENDANGERED MEDITERRANEAN HABITAT-FORMING BIVALVE *PINNA NOBILIS* AS A PRESCRIBED CONSERVATION MEASURE: A CASE STUDY

Abstract
The noble pen shell Pinna nobilis*, an endemic Mediterranean bivalve is highly threatened by habitat loss or degradation due to intense coastal development, anchoring, trawling, illegal extraction and most recently, by a rapidly spreading disease. As a habitat-forming suspension-feeder this species contributes to water clarification and biodeposition and it enhances local biodiversity, especially in the seagrass meadows. To avoid smothering of this strictly protected species during construction of a new nautical centre in the Pula Harbour (North Adriatic Sea, Croatia), the environmental impact assessment prescribed transplantation of pen shells as a conservation measure. In the framework of EU Horizon 2020 project MERCES (Marine Ecosystem Restoration in Changing European Seas, http://www.merces-project.eu/), in coordination with the investor of the nautical centre and local volunteer divers we transplanted a total of 184 pen shells to the nearby Brijuni MPA, where their protection from adverse impacts of anchoring and illegal extraction could be ensured and monitoring of their survival could be performed. A high transplant survival confirmed that pen shell transplantation was an effective conservation/restoration method. This case represents the first official transplantation of a sessile marine species in Croatia as a measure prescribed by the environmental impact assessment and here we present our experience in connection with organisation and conduction of such action. Our aim is to facilitate and promote pen shell transplantation in the future as an appropriate and feasible conservation measure as well as to advise governing institutions on the issues that should be taken into account in the process.*

Key-words: pen shell, conservation/restoration, MERCES project

Introduction
The noble pen shell *Pinna nobilis* is listed as endangered under the 1992 European Council Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (92/43/EEC, Annex IV). It has been protected by the Protocol for Specially Protected Areas Biological Diversity in the Mediterranean (Barcelona Convention: UNEP) since 1996. It is also strictly protected by national laws. Anthropogenic and environmental threats have contributed to the decline of this species in the Mediterranean.

Materials and methods
Transplantation of *Pinna nobilis* as a conservation action to protect the species was successfully tested (Katsanevakis, 2016). Here we report that transplantation of pen shells endangered by building of new nautical centre was actually prescribed by the environmental impact assessment as a conservation measure. With a help of local volunteer divers we transplanted a total of 184 pen shells from Pula harbour to the nearby Brijuni MPA.

Results

After five months survival rate was high (>90%), indicating successful transplantation procedure. The most critical point was careful digging out of bivalves with special attention not to damage the byssus. Transplantation of Pinnas need to be done carefully, one bivalve at the time so well organized team of local divers can help in that sense. They need to be educated about the major points in the process – that can influence the success of transplantation.

Discussion and conclusions

In cases where coastal development or any type of construction work poses a threat to existing *Pinna nobilis* populations, they should be translocated to appropriate location and monitored. Besides being the first official case in Croatia to implement transplantation of a sessile marine species as a measure prescribed by the environmental impact assessment, this action additionally offered a compelling case for the citizen-science. In the light of recently reported pen shell mass mortalities due to a rapidly-spreading disease, every effort should be made to minimize more manageable impact *in situ* (e.g. of coastal construction, anchoring, trawling, illegal extraction) in order to ensure maintenance of its populations relaying on survival of adults. Due to recent catastrophic mass mortality recorded in the West Mediterranean caused by a parasite (Vázquez-Luis *et al.*, 2017), which is evidently spreading throughout the Mediterranean, it would be important to adopt additional *in situ* and *ex situ* approaches: collection of spat in nature and caged juvenile rearing as a relatively easy and cheap method (Kersting & Garcia-March, 2017) and establishment of an aquarium cultivation in a closed systems to secure stocks of healthy animals for repopulation of areas affected by the disease.

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PHENOLIC COMPOUNDS AND ANTIOXIDANT ACTIVITIES OF *CYSTOSEIRA* SPECIES (PHAEOPHYCEAE, FUCALES) FROM TUNISIAN COAST

Abstract
A screening of the phenolic composition (total polyphenols, flavonoids and condensed tannins) and anti-oxidant activities (DPPH radical scavenging activity and Ferric reducing antioxidant power (FRAP)) of 11 Tunisian Cystoseira *taxa was assessed to check whether the polyphenolic compositions could serve as a chemotaxonomic markers in* Cystoseira *genus. Significant variations in the phenolic contents were observed between the investigated taxa.* Cystoseira *species collected in northern Tunisia showed a particular richness in phenolic contents compared to southern species. A good correlation ($R^2 \geq 0.65$) between polyphenolic profiles and antioxidant properties was found for all* Cystoseira *samples. The phenolic compositions of* Cystoseira *extracts as well as the antioxidant capacities of these extracts allowed to discriminate between the Northern and the Southern species without bringing any segregating elements on the taxonomy of these species. This discrimination could be explained by a difference in the environmental conditions of the distant areas to which the living species react differently by a qualitatively and quantitatively different synthesis of phenolic compounds.*

Key-words: *Cystoseira,* Tunisia, DPPH, FRAP, polyphenols.

Introduction

Cystoseira C. Agardh (Fucales, Phaeophyceae,) is a widespread brown algae genus in the Mediterranean infralittoral and upper circalittoral zones comprising 46 taxa accepted taxonomically. Despite the large distribution of *Cystoseira* in Tunisian coast, little effort has been made to explore their antioxidant potential. Moreover, secondary metabolites isolated from *Cystoseiraceae* family as taxonomic markers (*e.g.* Valls & Povetti, 1995) may be useful for taxonomic issues. The objectives of this investigation is to provide chemical characterization and comparative analysis of the phenolic composition and anti-oxidant activities of various *Cystoseira* species collected from different location in Tunisian coasts and to assess whether the polyphenolic compositions could serve as a chemotaxonomic markers in *Cystoseira* genus.

Material and methods

Eleven species and infraspecies taxa of the genus *Cystoseira* were harvested from the seashore of the 03 region of Tunisian littoral (North, east and south coasts) in the upper intertidal zone between 0.5 and 2.0 m depth in October 2014: *Cystoseira crinita*, *C. sedoides* (from the North), *C. amentacea* var. *stricta, C. compressa, C. foeniculacea, C. foeniculacea* f. *latiramosa, C. sauvageauana* (from the east coast), *C. barbata, C. elegans, C. schiffneri* (from the south coast) and *C. foeniculacea* f. *tenuiramosa* (from east and south coast). The determination of the content of phenolic compounds was carried out by spectrophotometry according to (i) the Folin-Ciocalteu procedure (Singleton & Rossi, 1965) for the total polyphenols (TP); (ii) The Lamaison & Carnet (1990) procedure for total flavonoid contents (TF) and (iii) the acidic vanillin method according to Price *et al.,* (1978) for condensed tannins (TC). The evaluation of the antioxidant power of the phenolic extracts was performed by the estimation of the antiradical power using DPPH assay and the Ferric Reducing-Antioxidant Power (FRAP) assay according to Blois (1958) and Benzie & Strain (1996) respectively.

Results and discussion

The total polyphenol content of the different species studied varied between 0.11 (*Cystoseira barbata*) and 2.37 mg Gallic acid equivalent per gram of dry weight (GAE)/g DW (*C. compressa*). The levels recorded for the southern species are significantly lower than those of northern species. The total flavonoids content ranged from 4.10 to 0.16 mg Rutin equivalent/g DW (*C. foeniculacea* f. *tenuiramosa* from the north and *C. barbata* from southern Tunisian, respectively). The maxima are recorded for the Northern species. Condensed tannin levels were found to be higher for northern species with amounts ranging from 0.55 to 1.92 mg of Catechin equivalent/g DW, than for southern species (0.21-0.35). The maximum was recorded for *C. sauvageauana* and lowest for *C. barbata*.

The northern species exhibited, too, the strongest antiradical and ferric reducing activities and the southern species showed the weakest ones. *C. compressa* revealed the highest free radical scavenging activity and reducing power (24.86 mg Trolox E/g DW and µM Fe^{2+} E/g DW respectively). The lowest DPPH scavenging activities evaluated was 0.61 mg Trolox E/g DW for *C. barbata* and the lowest reducing capacity of methanolic extracts was determined in *C. schiffneri* (3.97 µM Fe^{2+} E/g DW).

A significant correlation ($p<0.05$) exists between the contents of TP, TF, TC and their antioxidant activities (DPPH and FRAP).

The phenolic compositions of *Cystoseira* extracts as well as their antioxidant powers allowed the discrimination between northern and southern species without providing any segregative elements useful for the taxonomy of the species. This discrimination could be related to different stresses linked to a difference between the environmental conditions of the distant areas, to which *Cystoseira* species react differently by synthesizing polyphenolic compounds of different quantities and qualities.

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JBEL MOUSSA, THE LAST REFUGE OF *ZOSTERA MARINA* IN THE MOROCCAN MEDITERRANEAN: PRELIMINARY QUANTITATIVE DATA

Abstract
Zostera marina *ecosystems are key components of the marine environment. The dramatic widespread loss of this seagrass has been well documented and may be due to natural processes and/or anthropogenic disturbances and stress. The only Z. marina meadows which still exist in the Moroccan coast, though in North Africa, are those of Belyounech and Oued El Marsa bays in the marine part of the site of 'Jbel Moussa' (southern the Strait of Gibraltar). With a lower limit up to -17 m depth, these eelgrass beds form the deeper ones in the entire Mediterranean. The present study aimed to provide quantitative data on the* Z. marina *meadows of Belyounech bay to enhance knowledge of the dynamics and functioning of this ecosystem for effective conservation actions. The shoot density was 450±182 shoots.m^{-2} and the eelgrass coverage of about 100 %. Leaves biomass was up to 131±18 g.DW.m^{-2} and represented more than 70% of the benthic primary producer biomass while 42% of macroalgae was represented by* Caulerpa cylindracea*. The concentration of six trace elements (Zn, Ni, Cu, Pb, Cr and As) was assessed in sediment and the divers parts of the plant (roots, rhizomes and leaves). Roots served as the main bioaccumulator organ with low translocation to rhizomes and leaves.*

Key-words: *Zostera marina*, biometric measurements, biomass, trace elements, Morocco.

Introduction
The only *Zostera marina* meadows that remain in the Moroccan Mediterranean coast are those of Belyounech and El Mersa bays along the marine area of the site 'Jbel Moussa' (southern coasts of the Strait of Gibraltar). For a regular monitoring program aiming to establish efficient measures to protect these important habitats, the Belyounech eelgrass meadow was characterized.

Materials and methods
The *Z. marina* survey was carried out in mid-September 2015 and the sampling was performed at the central part of the Belyounech bay meadow (Fig. 1).

Fig. 1: The Belyounech Bay in the Moroccan Mediterranean coast.

Results

The biometric and biomass measurements are reported in Tab. 1. The biomass can be expressed as 4 287, 1 700 and 1 364 g.C.m^{-2} for leaves, rhizomes and roots respectively. The total nitrogen stocks in the plant biomass may be expressed as 284, 36.8 and 60.6 g.N.m^{-2} for leaves, rhizomes and roots respectively. Values of TEs recorded in the different plant organs (Tab. 2) decreased in the same following order: root>leaf>rhizome.

Tab. 1: Values of eelgrass shoot density, and morphometrics measurements at the center of the meadows in Belyounech bay in the Moroccan coast sampled in 2015.

Parameters	Benyounech bay	
	Mean	SD
Shoot density (shoots.m^{-2})	450.0	181.9
Shoot height (mm)	310.4	96.3
Number of total leaves per shoot (leaves.shoot^{-1})	6.2	1.6
Shoot weight (mg)	263.1	136.7
Leaf biomass (g.DW.m^{-2})	130.7	17.7
Rhizomes biomass (g.DW.m^{-2})	54.9	6.0
Roots biomass (g.DW.m^{-2})	74.8	17.9
LAI (m^2.m^{-2})	2.4	1.2
Alga biomass (g.DW.m^{-2})	51.8	24.3

Tab. 2: Traces element concentrations (mg.kg^{-1}DW) and elemental contents in sediment and *Z. marina* parts in Belyounech bay in the Moroccan Mediterranean coast (southern the Strait of Gibraltar).

	Cr	Ni	Cu	Zn	As	Pb	%N DW	%C DW	C/N (w:w)
Sediments (S)	31.00	31.20	45.70	76.00	7.25	16.80	0.05	2.43	50.4
Roots (Rt)	7.86	146.00	19.20	39.20	7.94	5.89	0.81	18.23	22.6
Rhizomes (Rz)	0.32	0.35	1.69	15.20	0.99	0.45	0.67	30.94	46.1
Leaves (L)	1.32	2.42	6.61	29.50	1.82	2.64	2.17	32.81	15.1
Rz/Rt	0.04	0.002	0.09	0.39	0.12	0.08	-	-	-
L/Rt	0.17	0.02	0.34	0.75	0.23	0.45	-	-	-

Discussion and conclusions

In the Mediterranean, *Z. marina* is mostly found in shallow coastal water, the presence of deep meadows at Jbel Moussa down to a depth of 17m is probably due to the strong influence from Atlantic waters in the Strait of Gibraltar. The high TE concentrations recorded in roots with low translocation to rhizomes and leaves suggest that the possible tolerance strategy adopted by the eelgrass was the compartmentalization in underground organs leading to protect the species against toxic effects of the photosynthetic tissue (Gratao *et al.,* 2005). The highest %C of leaves (32.8%) may be related to the system respiration which determines the CO_2 availability for photosynthesis.

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A MEDITERRANEAN SEA VULNERABILITY MODEL FOLLOWING THE REPRESENTATIVE CONCENTRATION PATHWAYS FOR THE *POSIDONIA OCEANICA* DISTRIBUTION IN 2050

Abstract
Posidonia oceanica *(Linnaeus, 1813) Delile meadows are subjected to the impact of climate change. Despite the importance of the habitat functioning well understood by scientists, the mapping of meadows remains behind. This research presents a novel workflow to model the vulnerability of* P. oceanica *under the Representative Concentration Pathways for climate change. Extensive environmental and physical datasets were used to map the maximum entropy of areas for* P. oceanica*. This results in a climate change impact map for* P. oceanica *in the entire Mediterranean Sea for the respectively four RCPs for 2050. Under all RCPs a decline in habitat suitability was registered compared to the present situation. The intensity of suitability lost increased with the strength of the RCP. The model-based monitoring of* P. oceanica *vulnerability by remote sensing is a new approach and decreased the research time to understand and identify the ecosystem vulnerability. All in order to be in line with the aim of the EU to achieve or maintain the* P. oceanica *in "Good Environmental Status".*

Key-words: *Posidonia oceanica*, climate change, species distribution models, representative concentration pathways, vulnerability

Introduction

Posidonia oceanica (Linnaeus, 1813) Delile, meadows play a fundamental role in food web structure for coastal marine species throughout the Mediterranean (Hemminga and Duarte, 2000). Although in the last 50 years an alarming decline rate of 34% has been determined due to climate change (Telesca *et al.*, 2015). Despite international agreements having formulated action plans for the protection of *P. oceanica*, coordinated and comprehensive actions are still necessary to provide essential spatial data of *P. oceanica* distribution. To fill gaps in the spatial distribution of *P. oceanica*, modelling techniques can be applied by predicting the suitability for the presence or absence of the species (Bakran-Petricioli, 2006). Considering the new developments in remote sensing and improved measurements in oceanographic fieldwork, detailed marine environmental datasets are possible which improve the ability of species distribution models (SDMs) in coastal ecosystems, for present and future forecasts under the Representative Concentration Pathways (RCPs). The aim of the present study was to monitor the change in habitat suitability for *P. oceanica* under the RCPs for 2050.

Materials and methods

In 2015, the project called Mediterranean Sensitive Habitats (MediSeH) compiled data regarding the presence of *Posidonia oceanica* based on 263 published and non-published datasets (Telesca *et al.*, 2015). The dataset showed that the presence or absence is known for 54% of the 46,000km long Mediterranean coastline and indicates the presence of 1,224,707 ha of *P. oceanica* in the Mediterranean Sea. The presence data was used in the novel modelling method called Maxent, which is based on maximum entropy distribution (Phillips *et al.*, 2004). Maxent analysed how each environmental and physical parameter affects the presence of *P. oceanica*. For the impact of climate change on environmental conditions, the reliable data products of Bio-ORACLE v2.0 were used, which comprehend the RCPs for 2050 (Assis *et al.*, 2018). EMODnet Bathymetry was selected in Maxent for the physical parameters. To avoid outliers, the model was performed in five-fold cross-validation, with 70% training data and 30% test data from the presence dataset.

Results

The model performs with an area under curve of 0.874 and standard deviation of 0.002 ($p < 0.05$). The primary contribution of variables with 86,2% was performed by the maximum temperature and bathymetric layer. The maximum temperature layer performs in an isolated situation with the highest probability of presence, while the bathymetric layer contains the unique information inside the layer.

Changes in suitability have been analysed under all of the RCP scenarios. The suitability decrease applies primarily to the Eastern Mediterranean Basin. In the more unfavourable RCP scenarios (e.g. 8.5) the species is projected to experience stronger changes relative, to a decline trend acting from the southeast.

Discussion and conclusions

A new Mediterranean-wide model has been presented to predict the vulnerability of the endemic seagrass *Posidonia oceanica* in different climate scenarios for 2050.The Mediterranean Sea will primarily be exposed to an increase in the sea temperature for the next decades, which will trigger mortality events in the *P. oceanica* meadows. The general trend of the potential *P. oceanica* distribution under the RCPs indicates decrease in the potential habitats. The model projection for RCP scenarios by 2040 to 2050 predicts alarming decline rates around the Mediterranean Sea, up to 78.5% under RCP 8.5, and a complete loss in the Aegean Sea.

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THE IMPACT OF ANTHROPOGENIC INFLUENCES ON THE *POSIDONIA OCEANICA* PATCHINESS INDEX

Abstract
Posidonia oceanica *(L.) Delile habitats provide many ecosystem services for marine organisms, human and environmental applications. However, increased anthropogenic activities are influencing the distribution patterns of* P. oceanica*. The hypothesis is that these impacting factors will cause increased patchiness and cover loss of the meadows. When considering the large-scale monitoring of highly extensive ecosystems such as* P. oceanica*, traditional field methods are often unsuitable. Remote sensing can act as a tool for both ecologists and policymakers. This research presents a novel method to assess the patchiness and cover of* P. oceanica *by remote sensing to monitor the state of meadows. The anthropogenic pressures were then correlated to patchiness and cover of* P. oceanica *meadows, to study and describe the ecosystem vulnerability to anthropogenic impacts. This research presents a low cost and time-efficient solution for the large-scale monitoring of* P. oceanica *meadows.*

Key-words: *Posidonia oceanica*, anthropogenic impact, patchiness index, remote sensing

Introduction

The endemic seagrass *Posidonia oceanica* (L.*)* Delile is the most important seagrass species in the Mediterranean Sea (Boudouresque *et al.*, 2006). They form structured habitats in shallow coastal waters up to 40 metres deep which provide many ecosystem services and environmental applications for marine organisms and humans (Hemminga & Duarte, 2000). However, *P. oceanica* meadows are among the most threatened coastal ecosystems worldwide with anthropogenic influences often cited as the primary cause of reduction in the extent of seagrass meadows (Marbà *et al.*, 2014; Orth *et al.*, 2006). The expanding human activities have created human-dominated landscapes, which result in intensifying habitat fragmentation and loss within terrestrial and marine ecosystems (Hovel, 2003). The aim of the present study was to: i) present a preliminary method to assess the fragmentation with remote sensing, ii) to examine the effect of different levels of naturalness on the habitat fragmentation and cover.

Materials and methods

To assess the anthropogenic impact on *P. oceanica* meadows, meadows investigated by previous publications were investigated using remote sensing. PlanetScope 3-meter resolution satellite imagery analyses of the coast were conducted to characterise three types of areas: (1) natural areas with a high degree of naturalness and maximum of one source of disturbance, such as a railway, road, river, harbour, river, or tourism, (2) anthropogenic areas with a medium degree of naturalness and maximum of four sources of disturbance, and (3) anthropogenic areas with a low degree of naturalness and at least five sources of disturbance. Second, the meadows were classified for the ecological indices, patchiness and cover. Three transects of 100 m length by 10 m width of the meadows upper limit width were executed from the satellite images. Along the transects, each discrete patch of *P. oceanica* of at least 10 m^2 was counted and measured, smaller is not considered as a meadow but 'sparse shoots' (Montefalcone *et al., 2010)*. Finally, the ANOVA test has been used to assess the correlation between the level of naturalness on the habitat fragmentation and cover.

Results

One hundred meadows were studied across the Mediterranean Sea. In total 17 areas of low naturalness, 50 areas of medium naturalness and 35 areas of high naturalness under different environmental conditions (temperature, salinity, sediment loads) were discovered. *P. oceanica* cover is significantly higher in natural areas relative to anthropogenic areas ($F = 9.02$, $p < 0.05$), and is significantly less fragmented compared to areas with anthropogenic influence / disturbance ($F = 8.55$, $p < 0.05$). In general, the cover significantly decreases as patches expand ($F = 8.93$; $p < 0.01$).

Discussion and conclusions

The results of this novel workflow present that satellite imagery offers a new approach for testing the patchiness of coastal water habitats and has proven useful in this study. Furthermore, the research indicates that increasing human impact creates a more vulnerable situation for *P. oceanica.* There is a significant direct correlation between human disturbance and the patchiness and cover index of *P. oceanica* meadows. This research has uncovered similar findings to previous studies, such as that the increase in anthropogenic pressure exacerbates habitat destruction, where habitat destruction is visible in more fragmented meadows and less cover (Montefalcone *et al.,* 2010; Shochat *et al., 2007)*. To conclude, this research introduces an improvement to the existing method for mapping habitat fragmentation and anthropogenic impact in a low cost and time-efficient solution.

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ADAPTED SEAGRASS WATCH PROTOCOL TO EVALUATE *POSIDONIA OCEANICA* HEALTH (EASTERN AEGEAN SEA)

Abstract

Seagrass meadows, in particular Posidonia oceanica *(L.) Delile play an important role within Mediterranean coastal systems, providing numerous key ecosystem services, while also ensuring the maintenance of physical, chemical and biological conditions.* P. oceanica *acts as an ecosystem architect to provide a habitat for many different species, as a breeding, nursery and foraging ground. Its ecological importance and vulnerability to a variety of anthropogenic influences has resulted in an increasing interest in using* P. oceanica *as a health indicator of Mediterranean coastal systems.* P. oceanica *health was evaluated at 10 sites around Lipsi Island in order to determine the health status and the impact of various anthropogenic activities. The Seagrass Watch Protocol was partly modified and implemented to assess biological and environmental data. Concentrations of phosphorus and nitrite were determined at each site, as indicators of eutrophication, potentially influencing seagrass health. Through the modification of the seagrass watch protocol with additional simple data measurements such as phosphorus and nitrite levels of the sea water, a more accurate assessment of seagrass health can be achieved with little additional sampling effort and cost.*

Key-words: *Posidonia oceanica*, ecosystem health, citizen science, Eastern Aegean

Introduction

Posidonia oceanica is highly sensitive to disturbances and has a wide distribution along the Mediterranean coast. The well-known biology and ecology of the species, response to specific disturbances of both plant and associated ecosystem, to make it a good model to be used as a Biological Quality Element (BQE) (Romero *et al.*, 2007). In order to analyse seagrass health, it is important to assess the epibiota which is mainly controlled by the nutrient availability, the physical constraints and biological interactions. The discharge of products from anthropogenic activity such as industrial effluence, mining wastes, fish farming, drilling fluids, sewage and agricultural runoff and effluents from desalination plants can be factors influencing epibiota (Martínez-Crego *et al.*, 2010). In addition, a healthy status of seagrass meadow health is reflected by high coverage of *P. oceanica*, whereas an unhealthy status is typically associated with a low coverage (Boudouresque *et al.*, 2009). Moreover, increasing anthropogenic pressures such as agriculture and costal use may entail an increase in nitrite and phosphorus values in the water and as a result increase in the percentage of leaves colonized by epiphytes and a decrease in blade length (Romero *et al.*, 2007).

Materials and methods

Posidonia oceanica was analysed at 10 different sites on Lipsi Island, Greece. Sites were chosen around the island for either high boat traffic, touristic influence or for varied topography. Surveys were completed between May and August by freediving. The method was developed following a partly modified version of the Seagrass Watch protocol (McKenzie *et al*., 2007). At each site (between May and early July), three 50 m long linear transects were set, starting from the first seagrass patch found closest to the shore (transect line 1, T1). Transect lines 2 and 3 (T2 and T3, respectively) were laid out parallel to T1, 25 m apart from each other and perpendicular to the shore line. Along these transects, quadrates (50 x 50 cm) were placed at 5 m intervals in order to analyse: (1) depth (m); (2) sediment composition, described by grain size; (3) algae cover, percentage cover on the seafloor; (4) percentage cover of *P. oceanica*, on the seafloor; (5) seagrass species composition, identification and percentage contribution of *P. oceanica*, *Cymodocea nodosa, Halophila stipulacea*; (6) three random replicates of blade length of *P. oceanica* leaves; and (7) percentage of epiphyte cover of *P. oceanica* leaves. In addition, the shoot density was counted within a 20 x 20 cm quadrat placed at random 3 - 10 times in each *P. oceanica* patch inside the transect. The phosphorus and nitrite concentrations were measured with three replicates per site.

Results

Greater blade length and number in shoots were found at sites with bigger *P. oceanica* cover. Epiphyte cover was higher in the shortest blades, whereas certain sites with long blades showed a relatively low percentage cover of epiphytes. Sites with a higher number of touristic pressure, in terms of tourists, restaurants and boat traffic, had the highest phosphorus values, lowest percentage cover (11 % *P. oceanica* per $m^{2)}$, shorter blades (21.2 cm) and lower shoot density (283 shoots per m^2). In contrast sites with little anthropogenic disturbances and rather sheltered had the highest percentage cover (79 % *P. oceanica* per m^2), longest blades (37 cm) and high shoot density (384 shoots per m^2).

Discussion and Conclusion

As underlined by the results of this study, there are different anthropogenic parameters that influence *P. oceanica* meadows, such as high nutrient concentrations caused by land-based activities, sewage run-off and coastal infrastructures (Brodersen *et al*., 2018). Especially high concentrations of phosphorus inhibit *P. oceanica* growth (Castejón-Silvo *et al*., 2012). Besides, high touristic pressure causes physical loss where boats anchoring in the seagrass meadows (Francour *et al*., 1999). The methodology proposed is a modified version of an already existing citizen science project that is easy and cost effective and could be used to improve the knowledge on the status of this species which is crucial in the Mediterranean Sea.

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UNDERSTANDING THE ROLE OF *POSIDONIA OCEANICA* BARRIER REEFS ON HYDRODYNAMIC ATTENUATION: THE CANOPé RESEARCH PROJECT

Abstract
As part of the multidisciplinary CANOPé research project dedicated to the study of Posidonia oceanica *(Linnaeus) Delile barrier reefs, this study focused on the modification of waves by* P. oceanica *barrier reefs. This is the first step to understand their effect in limiting erosion and submersion of low-lying coasts in the context of climate change. During two small wave events, a set of pressure sensors was deployed along a transect laid across a* P. oceanica *reef at La Madrague de Giens, France. The first measurements show that the reef is exposed to wind waves, swell and infragravity wave components. An energy transfer from the highest swell waves to infragravitary waves is observed, probably associated with wave breaking. Wave attenuation seems to be related to the variation of offshore wave forcing and water depth. More measurements are needed to conclude on the role of the reef and the meadow itself on wave modification.*

Key-words: *Posidonia oceanica*, barrier reef, wave attenuation, Nature-based defenses

Introduction

Posidonia oceanica (Linnaeus) Delile, an angiosperm endemic to the Mediterranean, can form barrier reefs through bio-construction (e.g. Boudouresque *et al.*, 2014). Many authors have shown the role of seagrasses on wave modification (e.g. Manca *et al.*, 2012) but none have investigated the potential role of such bio-constructions on hydrodynamic attenuation. The present study constitutes a first step in understanding wave modification by *P. oceanica* barrier reefs.

Material and methods

The study site is located at La Madrague de Giens (Var, France). We focused on a 500 m-long transect crossing the *P. oceanica* reef present there. During northwesterly winds (maximum wind speed: 13.6 m.s^{-1}) that prevailed in January 2018, pressure sensors (10Hz) were deployed along the transect on the main axis of wave propagation. The water pressure data were processed as in Locatelli *et al.* (2017). Significant wave height(H_s) values were calculated for infragravitary waves (IG), swell (SW) and wind waves (WW). Exponential wave decay rates (K) were calculated over the reef front and the reef flat for IG, SW and WW following Kobayashi *et al.* (1993). Positive values of decay rate correspond to wave attenuation, while negative values correspond to increasing wave height.

First results

The wave energy remained small during the events, with maximum H_s recorded at the foot of the reef front (second event: H_s reached 0.12, 0.25 and 0.04 m for IG, SW and WW, respectively). Each wave component height tended to increase over the reef front. The SW height >0.15m decreased over the reef flat while the IG height increased. Such trend is related to the well-known energy transfer from short to long waves as observed in coral reef environments (Locatelli *et al.* 2017). Small SW and WW heights (<0.15m) increased all along the profile, highlighting a wave height threshold to reach wave attenuation. Wave decay increased with increasing offshore wave forcing and with decreasing water depth due to enhanced frictional dissipation (Fig. 1), as described by other authors (Manca *et al.*, 2012). Further analysis will be dedicated to better quantify the effects of *P. oceanica* barrier reefs on nearshore wave transformation and to discriminate the physical processes acting on each wave component.

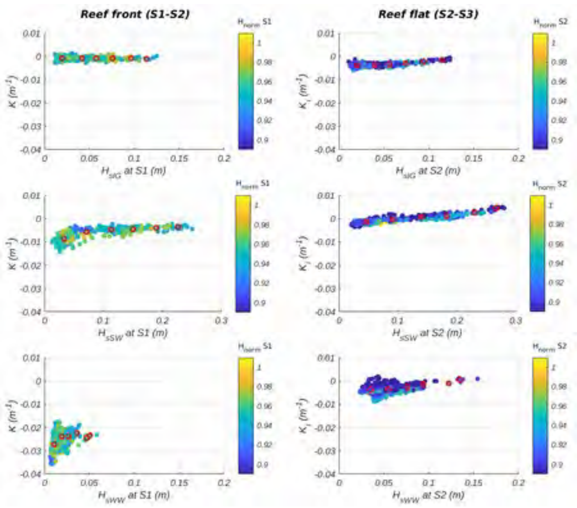

Fig. 1: Effect of wave height (H_s) and water depth (H normalized in reference to the higher depth measured) on wave height decay coefficient (K) for IG (first line), SW (second line) and WW (third line).

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INVENTORY AND MAPPING OF *POSIDONIA OCEANICA* REEFS OF THE FRENCH MEDITERRANEAN COAST

Abstract
Posidonia oceanica *reefs along the French Mediterranean coast were inventoried and mapped using bibliographical data, analysis of aerial photos, images obtained using drone and 3D models. Sixteen previously unreported reefs and another 13 reefs that had been destroyed or disappeared were identified. In all, 75 Posidonia reef structures have were known to exist but today there are only 62 left.*

Key-words: *Posidonia* reefs, conservation, mapping, Mediterranean.

Introduction

Under sheltered conditions, especially in the innermost part of bays, the seagrass *Posidonia oceanica* can build the so-called '*Posidonia* reefs'. A *Posidonia* reef is a formation built by the seagrass with leaf tips emerging from the sea surface and/or located just below it, at least during low tide and in spring and early summer when leaf length is at a maximum (see Boudouresque *et al*., 2014). *Posidonia* reefs are considered natural monuments of great heritage value. An inventory, with maps and descriptions, of all known reef structures, including ones that have been destroyed, and others that were previously unreported, was made along the French Mediterranean coast.

Materials and methods

A combination of Litto3D (bathymetry data), high resolution aerial imaging and bibliographical data was used to compile an inventory of all *Posidonia* reef. During the survey, a drone (DJI Phantom 4 Pro) was used to acquire georeferenced images. Overflights were conducted between 100 and 120 m height, according to the extent of the site, to obtain a resolution of 2.7 to 3.3 cm/pixel, respectively. The aerial images had an overlap of 70% to enable generation of 3D models (PhotoScan). Data were integrated within a GIS platform (ArcGIS 10.5) for georeferencing to obtain orthomosaics. Remote sensing was used to develop maps following the method of Pasqualini *et al*. (1998), then a maximum likelihood classification was applied. Errors and aberrations were manually corrected from a 3D model using microtopography analysis (canopy heights of *Posidonia* and dead *matte*) and *in situ* observations by GPS surveys.

Results and Discussion

The census based on reefs known in the past and newly discovered one's list a total of 75 *Posidonia* reef structures along the French Mediterranean coast (Tab. 1; Fig. 1). Of these, 16 previously unreported reefs were identified; 6 in Provence and 10 in Corsica, mainly in the regions of Saint-Tropez and Figari, respectively. On the other hand, at least 13 reefs have been destroyed or buried owing to mismanagement (*e.g.* coastal development, harbours, artificial beach construction), and due to poor knowledge of their presence, their heritage value and the ecosystem services they provide. Today, there are 62 *Posidonia* reefs (fringing, barrier, platform reefs, atolls and tiger reefs) in existence, which have been mapped to a very accurate scale and with 3D detail.

Tab. 1: Census of *Posidonia* reefs along the French Mediterranean coast.

Locality	Total of known reefs past and present	Reefs destroyed or disappeared	Previously unreported	Reefs mapped and studied
French Catalonia	3	3	0	0
Provence	25	9	6	16
French Riviera	2	0	0	2
Corsica	45	1	10	44
Total	**75**	**13**	**16**	**62**

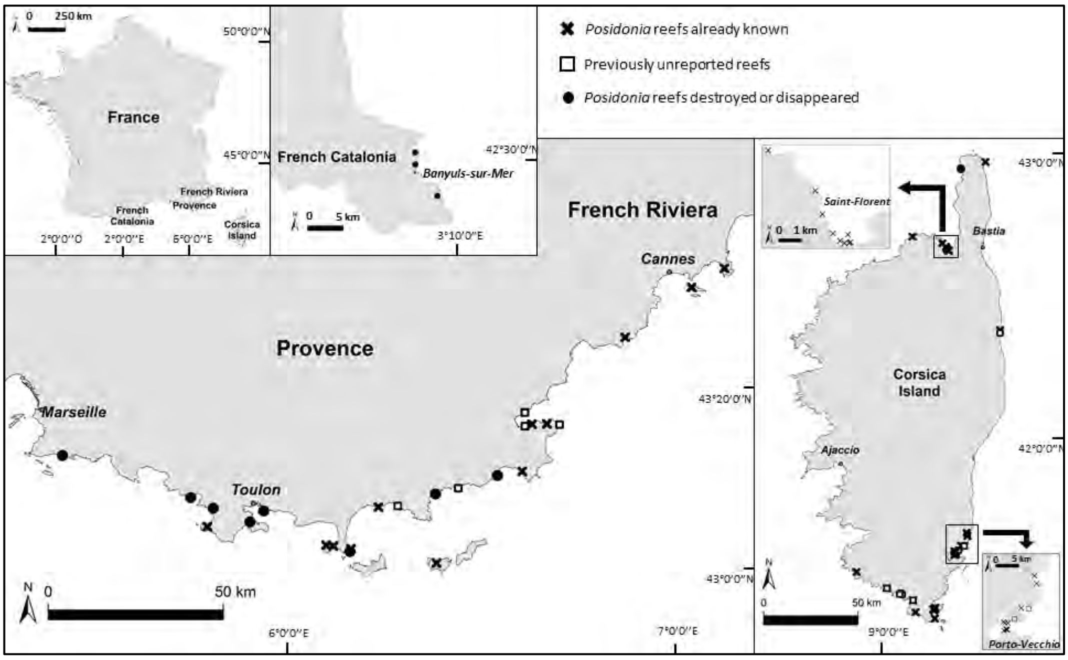

Fig. 1: Location of *Posidonia* reefs along the French Mediterranean coast.

Acknowledgments

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PRELIMINARY STUDY OF MORTALITY EVENT OF *PINNA NOBILIS* LINNAEUS, 1758 IN SOUTHERN TUNISIA (CENTRAL MEDITERRANEAN SEA)

Abstract
Visual census by snorkeling and scuba diving are periodically carried out along the Tunisian coast to monitor effects of global warming on biodiversity such as the early detection of Non-Indigenous Species (NIS) and the occurrence of extreme events. During surveys in the Bahiret El Bibans, a lagoon located in southern Tunisia, few cases of mortalities of Pinna nobilis*, have been detected. Preliminary results of a spring campaign (May 2018) showed a mortality rate between 2 and 4%, considered very low in comparison with the mass mortalities in the Iberian Peninsula and Corsica (90%). The observed clinical signs are similar to those described in* P. nobilis *in the south-east of the Iberian Peninsula and Balearic Islands in 2016 and have probably the same pathogen origin. Histopathology of digestive gland of moribund individuals revealed the absence of Haplosporidium parasite.*

Key-words: Pinnidae, Mortality event, Bivalve, conservation, endemic

Introduction
The fan shell *Pinna nobilis*, is one of the most important endemic species in the Mediterranean Sea protected by Barcelona Convention. It is the biggest bivalve in the Mediterranean, since the shell heights may reach 120 cm in some Tunisian areas (Zaouali & Beaten, 1985). This sessile benthic specie is partially endogean and presents a high ecological interest and considered as an excellent bioindicator. Moreover, its very high filtration capacity is primordial to the conservation of the marine and coastal environment (Boudouresque *et al.*, 1991). The species is present in Tunisia both at sea and in lagoons. Its geographical distribution extends from the northern coast to the extreme south-east of Tunisia with the Gulf of Gabès as a privileged area. Previous research in Kerkennah indicates that the populations remain relatively well conserved despite multiple threats such as illegal fishing (Soufi-Kechaou, 2004). Recently, mortality events have been observed in Bahiret El Bibans. Because of the proximity of both of the areas, it is urgent to identify the origin of these mortalities and to update the cartography of *P. nobilis* in the Gulf of Gabès, in particular in Kerkennah archipelagos and to increase monitoring frequency in order to delimit the infected area in the adjacent lagoon.

Material and methods
Regular surveys by scuba diving had been carried out in spring 2018 throughout Bahiret El Bibans (30km^2), an adjacent lagoon to the Gulf of Gabès. The visual census covers main habitats of *P. nobilis* (*Posidonia oceanica* and *Cymodocea nodosa* seagrass meadow and also sandy bottoms not covered by vegetation).Ten-day survey aims to delimit the distribution of the species in the lagoon, to estimate the densities and especially to detect the affected individuals. The coverage of the study area was done according to radials with no destructive survey. In this work, only the results of mortalities and densities in affected area are cited.

Results and discussion

Random observations show that the distribution of the bivalve is scarce throughout the lagoon with densities ranging between 0.03 and 9 individuals/m^2. The area of El MARSA corresponds to the highest occurrences (fig.1). Histological examination of the various organs, including the digestive gland, taken from 15 moribund specimens reveals the absence of parasite, while bacteria belonging to the genus *Aerococcus* have been observed massively in most tissues. The mortality rate is low and does not exceed 4% and the dead individuals show a very important epiphytism. The increasing frequency of monitoring in Tunisia is strongly needed to delimit the infected area in the central Mediterranean Sea and to identify the status of the populations of *P. nobilis*. Late summer visual census is essential to confirm or not the presence of *Haplosporidium pinnae*.

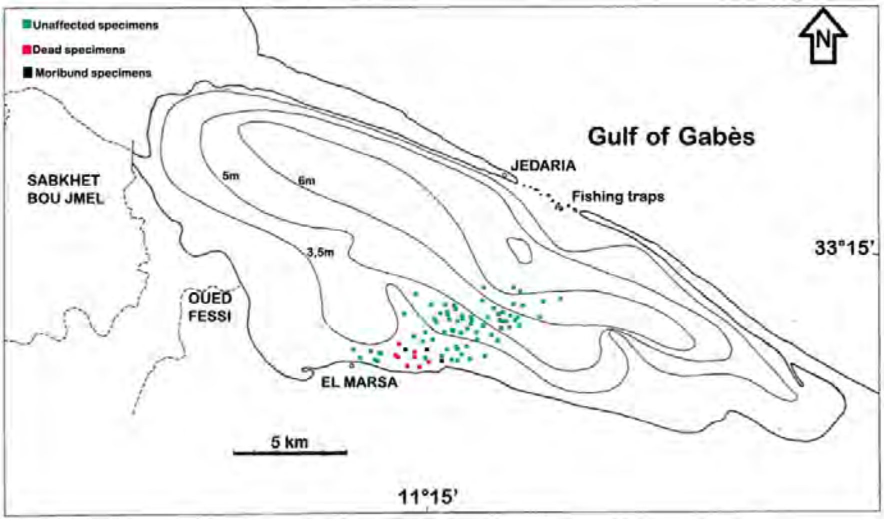

Fig. 1: Spatial distribution of healthy, moribund and dead *Pinna nobilis* in the Bahiret El Bibans (May 2018)

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THE IMPORTANCE OF *POSIDONIA OCEANICA* MEADOWS TO THE DISTRIBUTION OF *PINNA NOBILIS* THROUGH HABITAT SUITABILITY MODELLING

Abstract
Pinna nobilis *is endemic to the Mediterranean and the region's largest marine bivalve whose endangered status has been linked to habitat loss. In particular* Posidonia oceanica *meadows play a key role in modifying the landscape to create habitats for many associated species including Pinna nobilis. Snorkel surveys assessed population numbers within the first 0.5 m – 5 m depth of eleven sites around the Greek island of Lipsi in the Eastern Aegean, Greece. Habitat Suitability Modelling was used to predict location using* P. oceanica *meadows and bathymetric data as predictors. Results indicated a significant association between* P. oceanica *and* P. nobilis *within the first 0.5 m – 5 m. This study fills a gap in knowledge of* P. nobilis *distribution and is of particular relevance after the mass mortality event now linked to the* Haplosporidium pinnae *sp. nov., parasite.*

Key-words: Marine conservation, Greece, mollusc, MaxEnt.

Introduction

Destruction and fragmentation of habitat is one of the key drivers of global biodiversity loss (Worm *et al*., 2006). In the case of *Posidonia oceanica* (L.) Delile meadows, an endemic Mediterranean species, numerous anthropogenic influencers are known to contribute to decline, as well as naturally occurring periods of regression and expansion (Boudouresque *et al*., 2009). *P. oceanica* meadows are key habitats for many associated species, such species is *Pinna nobilis* (L.), the largest endemic species of marine bivalve in the Mediterranean with anterio posterior lengths of up to 120cm (Rouanet *et al*., 2015). Prior studies in shallow water marine environments indicated depth and the presence of *P. oceanica* influence distribution (Katsanevakis, 2007; Tsatiris *et al*., 2018), however reports of *P. nobilis* occurring on other substrates are not uncommon (e.g. Katsanevakis & Thessalou-Legaki, 2009; Tsatiris *et al*., 2018).). Typically. *nobilis* studies have been carried out in locations of high population density. This study aimed to assess the importance of habitat factors on *P. nobilis* populations on Lipsi Island in the Dodecanese, eastern Aegean Sea, Greece, where population densities are generally low.

Material and methods

A methodology, as outlined by Katsanevakis, (2007), was adapted to facilitate snorkel surveys, and used to access *Pinna nobilis* populations across eleven sites. Each transect started at 0.5m depth and finished at 5m with surveys only being conducted when visibility permitted an unrestricted view of the seabed. Depth was determined with a "suunto ZOOP" dive computer. When found, shell width was measured, depth recorded, and a GPS point taken (Garmin Etrex). Habitat modelling was performed using "MaxEnt" software (Phillips & Dudík, 2008) with environmental variables of bathymetric data and remotely sensed seagrass presence and absence. *P. nobilis* location data were used as training data for the model.

Results

A total of fifteen *Pinna nobilis* individuals were located at four different sites around the island. Three were omitted from the study as species verification was not possible due to small size. Individuals considered to be mature enough to identify as *P. nobilis* had shells with a width greater than 10cm. The majority of *P. nobilis* found were located between two bays, six in the west and five to the south east, only one other was located to the south of Lipsi. The MaxEnt model ran with cross validation and five replicates to help mitigate the impact of small sample size. Strong model performance (Mean AUC = 0.906) and reliability were shown, with jackknife testing indicating *Posidonia oceanica* presence (0.68) as having the highest test gain in comparison to depth (0.64). However, depth as a variable did show greater permutation importance (64.3%) to towards the model compared to seagrass (35.7%).

Discussion

A strong association between *Pinna nobilis* location and *Posidonia oceanica* presence was predicted by the model. Despite also appearing significant, depth as a predictor must be treated with caution due to the surveys being conducted within a narrow depth range. We suggest two hypotheses for the strong association between *P. nobilis* and *P. oceanica.* One hypothesis is that, where coastal conditions do not promote strong recruitment of *P. nobilis*, the conditions within *P. oceanica* beds are favourable enough to allow limited recruitment. Alternatively, *P. nobilis* are more cryptic within *P. oceanica* beds and therefore less likely to be impacted by anthropogenic factors. Lipsi relies heavily on fishing and tourism for economic stability, both of which may be impacting *P. nobilis* numbers; fishing practices are poorly regulated whilst *P. nobilis* are illegally fished for food while shells are used as decoration. It is noteworthy that the two sites with the highest *P. nobilis* numbers were infrequently visited by the public.

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RESILIENCE OF SEAGRASS *POSIDONIA OCEANICA* TO EXPLOSIVE VOLCANISM

Abstract
The present study addressed the resilience of seagrass Posidonia oceanica *in response to an exceptional and massive hydrothermal gas release that occurred in the Aeolian Islands (Italy, Mediterranean Sea) in November 2002. Growth performance and $\delta^{13}C$ in* P. oceanica *scales and rhizomes time series records were obtained by lepidochronology combined with Isotope Ratio Mass Spectrometry, while resilience profiles were estimated by segmented regression.*
Results showed an initial significant decline in rhizome elongation and ^{13}C-depletion in both scales and rhizomes of P. oceanica *in the disturbed station. The results of segmented regression indicated that the seagrass has fully recovered in about 8 years, confirming the effectiveness of* P. oceanica *use as an experimental model in providing information on ecosystem resilience in response to acute and pulse disturbance.*

Key-words: resilience, seagrass ecology, carbon stable isotopes, lepidochronology, segmented regression

Introduction
Posidonia oceanica is an endemic seagrass of the Mediterranean Sea that develops extensive meadows responsible for the creation and maintenance of valuable ecosystems and supporting highly complex and biodiverse climax communities. Despite their importance, *P. oceanica* meadows are declining at alarming rates in response to increasing anthropogenic and natural stressors, potentially affecting their capacity to recover from disturbances (Duarte, 2002). In the marine realm, explosive volcanic submarine activity, occurring in shallow vents systems, can be considered as a natural disturbance that may affect seagrass communities due to sudden changes in the physical and chemical features of seawater and sediments, with possibly large ecosystem functioning effects (Vizzini *et al*., 2010). However, seagrass resilience in response to the extreme environmental conditions arising from explosive volcanism remains to be established. In this study, we addressed the recovery of the seagrass *P. oceanica* to an exceptional and massive hydrothermal gas release that occurred in the Aeolian Islands (Italy) in November 2002, through a back-dating technique to analyse, retrospectively, *P. oceanica* stable carbon isotopes ($\delta^{13}C$) and growth performance before and after the explosion.

Materials and Methods
The study was carried out on the western coast of Panarea Island in the Aeolian Archipelago (Italy). Two sampling sites were chosen at different distances from the explosive crater: one at a distance of about 10 m (disturbed station) and the other at a distance of about 1 km (control station). At each site, *P. oceanica* shoots were sampled

by SCUBA diving at a depth of about 13 m in July 2011. In the laboratory, time series records of growth performance and $\delta^{13}C$ in scales and rhizomes were obtained by lepidochronology, according to Pergent (1990), and Isotope Ratio Mass Spectrometry. Segmented regression was used to estimate resilience profiles.

Results

Hydrothermal submarine activity was recorded by *P. oceanica*, which showed an initial significant decline in rhizome growth performance (Fig. 1a) and ^{13}C-depletion in both rhizomes and scales at the disturbed station (Fig. 1c and Fig. 1e). Both increased CO_2 availability and reduced carbon demand, as a consequence of stressful environmental conditions, combined to give much lower $\delta^{13}C$. Segmented regression indicated that the seagrass has fully recovered in about 8 years.

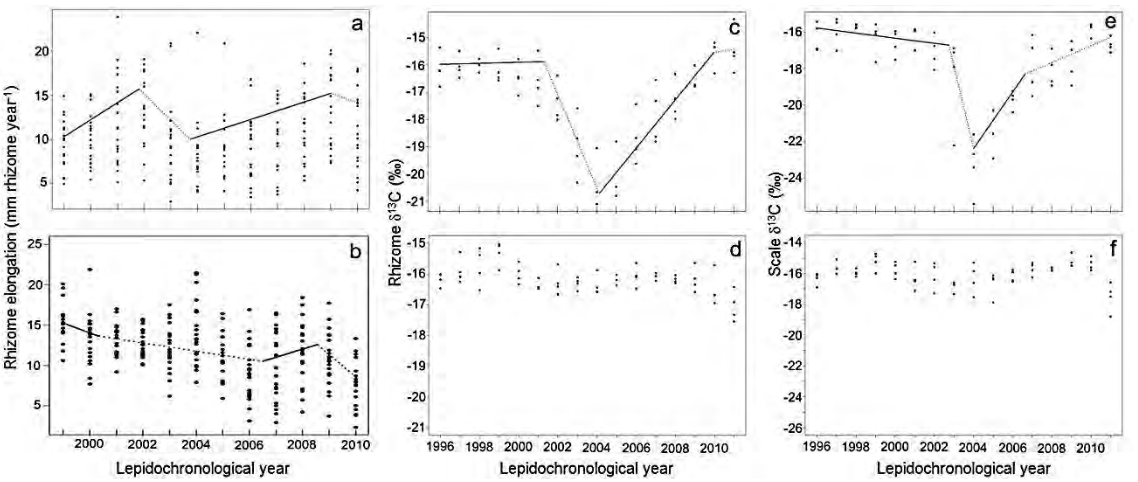

Fig. 1: Segmented regression of: *P. oceanica* rhizome elongation at the disturbed station (a) and control station (b); $\delta^{13}C$ in *P. oceanica* rhizomes at the disturbed station (c) and control station (d); $\delta^{13}C$ in *P. oceanica* scales at the disturbed station (e) and control station (f).

Discussion and conclusions

The choice of *P. oceanica* as an experimental model was particularly effective in providing information on ecosystem resilience in response to acute and pulse disturbance. This long-lived seagrass species is able to provide functional traits' time series that are long enough to cover more than two decades, allowing to observe in detail all the phases of the resilience process.

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STUDY OF *CYMODOCEA NODOSA* MEADOWS FEATURES IN TUNISIAN MARINE PROTECTED AREA, KURIAT ISLAND

Abstract
During the last decades, Marine Protected Area (MPA) has been considered as one of the key strategies to manage coastal ecosystems worldwide. The Kuriat Island is one of the recent established MPAs in Tunisia. Far away from any potential source of pollution, the island is known as a refuge for many species. In the framework of seagrass monitoring in Kuriat Island of NGO "Notre Grand Bleu", investigations on several descriptors (density, leaf phenology…) of Cymodocea nodosa *meadows were conducted during May 2017. In addition, concentrations of five trace metals (Cu, Ni, Zn, Cd and Pb) were assessed in the surface sediment and in the leaves and rhizomes of* Cymodocea nodosa*. Compared to others meadows from the Tunisian coast,* Cymodocea nodosa *meadow in Kuriat Island can be considered as a "healthy one" with high values of density (435±146) and LAI (1.29* m.m^{-2}*.). The ranking of metal contents was found to be Zn>Cu, Ni, Pb, Cd in the plant tissues. Compared to those from other typical seagrass meadows in the Mediterranean, the metal values in Kuriat Island were at low levels, revealing the still low exploitation this island. According to these results, Kuriat Island can be used as a reference site in the future metallic contamination monitoring studies in Tunisia.*

Key-words: Seagrass, MPA, density, TE, Kuriat

Introduction

Marine Protected Areas (MPAs) are key tools to protect coastal ecosystems and its fundamental services from the increasing anthropogenic pressures (Zupan *et al*., 2018). Like many other coastal ecosystems, Seagrass meadows are subject to multiple stressors including coastal development, invasive species and climate change. The main aims of this study are (i) to evaluate the statut of *C. nodosa* meadow using classic descriptors and (ii) to assess the accumulation of trace elements (TE) in *C. nodosa* compartments and in the superficial sediment in the Kuriat island.

Materials and Methods

Fieldwork was conducted in Kuriat Island (35°48'00" N, 11°01'60" E) during May 2017. Sampling and laboratory protocol were described in Zribi *et al*., (2019).

Results

The shoot density of *C. nodosa* in Kuriat Island varied from 175 to 650 shoot.m^{-2}, with an average of 435±173 shoots.m^{-2}. The average number of leaves was found as 4.4±1.30 leaves.shoot^{-1}. The mean leaf length and width are respectively 16.98±10.55cm and 0.37±0.08cm. LAI was estimate to 1.29 m.m^{-2}. TE mean concentrations in the compartments of *C. nodosa* and sediment samples are given in Figure 1. The same bioacculmulation pattern was observed for the leaves and rhizomes of *C. nodosa* (Zn>Cu, Ni, Pb, Cd). For the sediment samples, the mean level of the five TE decrease in the following order Zn> Pb >Cu=Ni >Cd. Significant differences were recorded between the concentration of Cu, Ni and Cd in the leaves and in the rhizomes.

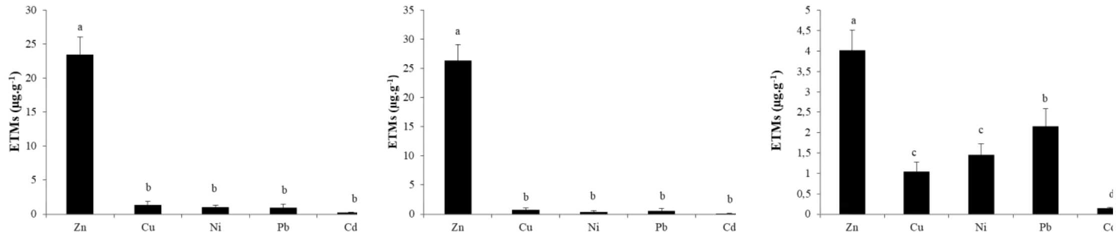

Fig. 1 : Trace element (Zn, Cu, Ni, Pb and Cd) content in leaves "A", rhizomes "B" of *C. nodosa* (mean ± SE, in µg g^{-1} dry wt), and in sediment "C" of Kuriat island (mean ± SE, in µg.g^{-1}). Small letters represent significance (p value) between mean concentrations.

Discussion and conclusions

Globally the shoot density, phenological and biometric parameters of the *C. nodosa* meadow in Kuriat island are in the same magnitude with those recorded in Ghar El Melh and in El Bibane lagoons (Sghaier *et al*., 2011; Zakhama-Sraieb *et al*., 2010). According to our results, the TEs content in Kuriat island meadows can be considered as the lowest content in the Mediterranean coast (Salvis-Decaux, 2009). This suggests the possibility of considering this MPA as a benchmark site in the future metallic contamination monitoring studies in Tunisia. The *C. nodosa* meadow in this MAP can be considered as a healthy one but in order to confirm that, it will be interesting to follow its evolution and to compare it with similar studies in unprotected areas.

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Recommendations of the 6th Mediterranean Symposium on Marine Vegetation

1. The availability of new investigation tools that enable progress in the location of habitats and to envisage their application on large areas (Copernicus Sentinel 2 Images/Landsat 8 in Greece, drones - natural monuments/reefs in France, *Cystoseira* in Sardinia…);

2. To consider the meadows, and other vegetal assemblages, as a blue carbon sink and the need for their conservation to mitigate the effects of climate change;

3. The development of restoration actions (*Posidonia*, Cystoseira) to reconstitute/ reinforce natural populations and their ecological functions. Apart from the technical aspects (survival rate, protection / herbivores), a code of good conduct is necessary;

4. The interest of having long time series to understand and quantify changes (pattern of change) of habitat / species of conservation interest (vitality, habitat limits);

5. Further promote the setting up of monitoring networks for the main marine vegetation assemblages at national and regional level, in line with the Barcelona Convention Integrated Monitoring and Assessment Programme (IMAP) principles and common indicators;

6. The establishment of new MPAs based on marine vegetation (natural monuments, diversity, protection versus impacts) associated with effective management plans, mainly in the southern and eastern part of the Mediterranean basin.

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