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Draft Guidelines for the Standardization of Mapping and Monitoring Methods of Marine Magnoliophyta in the Mediterranean

In the framework of a sustainable development approach, this document will be available only in electronic format during the meeting

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Study Context

Any attempt at management means that a prior assessment has to be made to appraise the state of knowledge concerning the resources to be managed. Therefore marine magnoliophyta distribution maps are an absolute prerequisite to any conservation activity for these assemblages, but an enlightened decision is not to be limited to the sole information of knowing that it is present or absent (Mc Kenzie *et al.*, 2001) and thus additional data is required such as the typology of the seagrass, its abundance, its state of health and/or conservation and a suitable monitoring system being set up.

These elements are indeed amongst the priority activities to be undertaken within the framework of the Action Plan for the Conservation of Marine Vegetation in the Mediterranean, adopted in 1999 by the Contracting Parties to the Barcelona Convention (UNEP-MAP-RAC/SPA, 1999). During the implementation evaluation of this Action Plan in 2005 (UNEP-MAP-RAC/SPA), it transpired that very few countries were able to set up this monitoring system, and even if some mapping programmes had been initiated in several sites, the areas which had really been mapped were very few in view of the potential surfaces occupied by the seagrasses in the Mediterranean (over 35 000 km² just for the *Posidonia oceanica* seagrass; Pasqualini *et al.*, 1998).

A round table on the mapping and monitoring methods was organized, to improve this situation, at the Third Mediterranean Symposium on Marine Vegetation in Marseilles in March 2007. The managers present expressed their need for “Practical Guides” so as to harmonize the methods and comparison of results which had been obtained on a regional level, so as to facilitate decision making for the management of coastal environments (UNEP-MAP-RAC/SPA, 2007). Using the marine vegetation as an environment evaluation tool was also pointed out and a suggestion was made to propose specific protocols to create a “tool box” which could cater for their needs (UNEP-MAP-RAC/SPA, 2007).

Thus at their 15th Ordinary Meeting in Almeria (January 2008), the Contracting Parties asked the Regional Activity Centre for Specially Protected Areas (RAC/SPA) to improve the existing inventory tools and to propose a standardization of the mapping and monitoring techniques for these assemblages.

In September 2009, RAC/SPA organized within the framework of the Second Workshop on Mediterranean Marine Magnoliophyta in Hvar from 6 to 10 September 2009, a round table on the “standardization of mapping and monitoring methods of marine magnoliophyta in the Mediterranean region” so as to obtain the views of the scientists concerned and also to elaborate the guidelines.

Approach adopted

The approach adopted consisted of two parts: first the organization of a round table to assess the experiences in this domain in the Mediterranean and then an analysis of the international literature.

1. Synthesis of the round table

The round table took place at the 2nd workshop on Mediterranean marine magnoliophyta in Hvar, Croatia, from 6 to 10 September 2010. A brief presentation of the theme (Annex 1) made it possible to have a fruitful exchange between approx. sixty participants (Annex 2).

At the end of the discussions (Annex 2) it transpired that:
For mapping:

- There are numerous methods which have proved their worth and several specific programmes have already been devoted to this (e.g. the Interreg IIIB “POSIDONIA” Programme; MESH programme).
- These methods are well known and therefore standardization can be envisaged.
- All the methods are usable in the region but some of them are more suitable for a given species (e.g. large-sized species) or particular assemblages (dense seagrasses).
- The available methods can be used in most of the Mediterranean countries even though there are implementation problems due to the absence of training, competence and/or specific financing. Efforts must therefore be in an order of priority (e.g. sites to be studied as a priority) and equilibrium is to be ensured between the mapping objectives and the method(s) implemented.

There is however a wide consensus to propose common tools which are applicable everywhere and by everyone.

Monitoring:

- Today there are several monitoring systems for marine magnoliophyta backed up by several years of experience and which have been successfully implemented worldwide and in the Mediterranean (e.g. SeagrassNet, MedPosidonia programme, Posidonia national monitoring networks).
- Even though the monitoring methods are similar (regular follow-up in the course of time with very often the establishment of fixed markers), the monitoring objectives and the descriptors taken into account during these operations are quite diverse. These descriptors are to provide information on the state of the seagrass, the plant or the interactions between the latter and its environment.
- Some descriptors are used by all the Mediterranean scientific community (e.g. seagrass density) but the measuring techniques are often very different, so that, even though a precise standardization is technically feasible, it seems to be difficult to promote.
- The Mediterranean monitoring systems are highly specific inasfar as they are mainly dedicated to *Posidonia oceanica*. In contrast, the SeagrassNet has the advantage of being able to be used for almost all the magnoliophyta species but is less relevant for some genera (e.g. *Posidonia*) or some sectors (deep bathymetric tranche).
- The experience with the MedPosidonia programme shows that the different monitoring methods implemented seem to be applicable to all the Mediterranean

countries in asfar as those persons responsible for the monitoring receive appropriate training in this domain.

Even though there is no clear consensus as in the case of the mapping methods, it seems desirable, in view of the strong demand expressed by the managers, to try and come up with some common and standardized tools. These tools should be selected from the existing monitoring systems and could be classified according to their relevance depending on the monitoring objectives and their ease of implementation.

2. Analysis of available data

In the light of the round table discussion results, an additional bibliographical research was undertaken to take into account the latest techniques and recent works carried out by the scientific community on an international level in this domain.

This approach was based mainly on data published in indexed international reviews and on databases being consulted online (e.g. Web of Science).

Proposals for Guidelines for Mapping Magnoliophyta Seagrasses in the Mediterranean

1. Problem

Today it is commonly recognized that the Mediterranean shallow coastal sea beds (between 0 and -50 m) host important ecosystems, such as the calcareous bio-concretions and magnoliophyta meadows (UNEP-MAP-Blue Plan, 2009).

These magnoliophyta are flowering plants of terrestrial origin which returned to the marine environment approx. 120 to 100 million of years and there are about sixty species throughout the world, five of which are in the Mediterranean (*Cymodocea nodosa*, *Halophila stipulacea*, *Posidonia oceanica*, *Zostera marina* and *Zostera noltii*; Fig. 1). They form extensive stretches of submarine prairies (still called meadows) between zero and about fifty m depth in the open sea, coastal lagoons (brackish and hyperhaline) and play an important ecological (primary production, spawning areas and nurseries) and sedimentary role (fixation of sediments & protection of the littoral: Pergent, 2006). It is believed that on a worldwide level the submarine prairies, in view of their usefulness, have a major economic value (over 17 000 $ per ha and per annum, *in* Costanza *et al.,* 1997).

Despite this it must be admitted that the available information on the exact geographical distribution of these meadows is still very fragmentary on a regional level (UNEP-MAP-RAC/SPA, 2009) and that very little of the coastline has been inventoried as only 5 States out of the 21 have a mapped inventory covering at least half of their coasts (UNEP-MAP-Blue Plan 2009). To explain this situation, one of the reasons given is i) the often high cost of these inventories, ii) absence of specific technical means, iii) gaps in terms of competence on a local level and also iv) the multiplicity of tools available and the difficulty in identifying the most suitable methods to deal with a given situation.

Cymodócea nodosa (Ucria) Ascherson – Lesser Neptune grass

This warm-water species is present throughout the Mediterranean and in the Atlantic (from Senegal to southern Spain).

It develops in the open sea between 0 and 10 m in depth (exceptionally until – 50 m) and in lagoons.
Its serrated apex leaves (20 to 40 cm long and 3 to 4 mm wide) are regrouped in leaf bundles, its brown reddish rhizomes are fine with foliar scarring.

Halophila stipulacea (Forsskål) Ascherson

A tropical affinity species, originating from the Red Sea and introduced into the Mediterranean via the Suez Canal.

It is present throughout the whole Eastern basin, in the open sea, between 1 and 35 m depth.
Its small leaves (3 to 6 cm long and 3 to 8 mm wide) are regrouped in foliar bundles; its mainly horizontal rhizomes are fine and clear.

Posidonia oceanica (Linnaeus) Delile – Posidonia

A Mediterranean endemic species which forms huge meadows between 0 and 43 m depth. It is present throughout the whole Mediterranean except in the extreme South-east, Upper Adriatic and the Gibraltar sector.

On average its leaves are 30 to 80 cm long and 1 cm wide and are regrouped in foliar bundles, its brown rhizomes and its roots constitute a particular structure: a mat.

Zostera marina Linnaeus – Marine Zostera

A cold-water, widely distributed species (Atlantic, Pacific, Black Sea)- it is basically to be found in the Northern Mediterranean.

It develops on the high seas and in lagoons, between 0 and 12 m depth.

Its ribbon-shaped leaves (40 to 60 cm long on average and 4 to 8 mm wide) are regrouped in foliar bundles; its yellow and brown rhizomes are very fine.

Zostera noltii Hornemann – The dwarf eelgrass Zostera

A more temperate species, it is present throughout the whole Mediterranean and in the Atlantic (from Mauritania to Scandinavia) and the Black Sea.

It develops in the open sea and in lagoons at a depth of 0 to 3 m and can tolerate lengthy exposure.

Its ribbon-shaped leaves (10 to 20 cm long and 1 to 2 mm wide) are regrouped in foliar bundles, its light yellow to beige rhizomes are very fine.

Fig. 1: Presentation of Mediterranean magnoliophyta species. Distribution maps according to Green & Short (2003) updated.

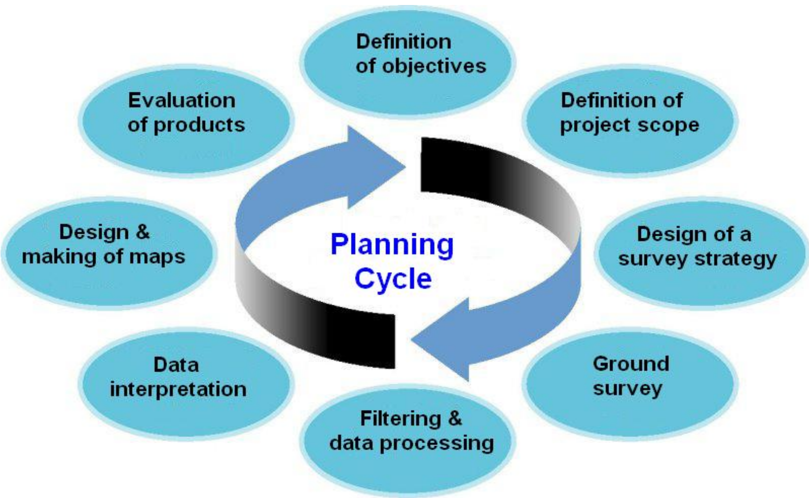
2. Which approach to be taken?

The approach advocated for mapping the marine magnoliophyta meadows in the Mediterranean is similar to that established for the mapping of the marine habitats within the framework of the European MESH programme (Mapping European Seabed Habitats: MESH project 2008).

The different actions to be undertaken (Fig.2) are detailed below and can be regrouped into three main stages:

- Initial planning
- Proper surveys
- Processing and interpretation of data

Initial Planning means the identification of the objective so as to determine the surface to be mapped and the necessary precision to achieve the targeted objective. These are two fundamental elements to determine the tools to be used in the later phase & to evaluate the effort (and thus the human, material & financial costs) necessary to produce the mapping.
This is the key-phase for a successful mapping approach.



programme (according to the MESH project, 2008).

The survey phase is the practical phase for data collection. It is often the most costly phase as it generally requires in situ interventions with their attendant constraints (such as availability of personnel and technical means, competences, weather conditions etc.) which must be met to obtain reliable and reproducible data. There must also be a prior inventory phase of the already existing data for the sector being studied so as to reduce the amount of work or to have a better targeting of the work to be done.

The processing and data interpretation phase is doubtlessly the most complex phase as it necessitates knowledge and experience so that the data gathered can be usable. The products obtained must be evaluated to ensure their coherence and the validity of the results obtained.

a) What precision for what surface area to be mapped?

Selecting an appropriate scale is a critical stage in the planning phase (Mc Kenzie *et al.*, 2001). Even though there is no technical impossibility in using a high precision over large surface areas (or inversely), there is generally an inverse relationship between the precision used and the surface area to be mapped (Mc Kenzie *et al.*, 2001; Fig. 3.).

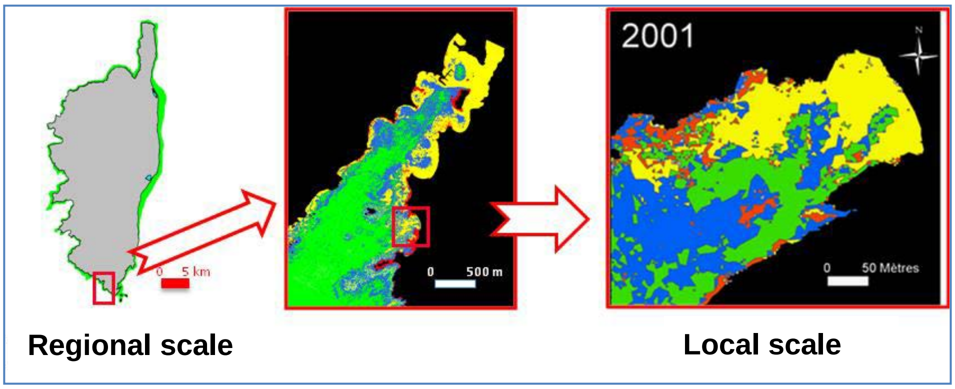


Fig. 3: scale and precision of a map

Thus the mapping objectives for large surface areas means using average precision levels inasfar as what is wanted is a global approach and even a probable habitat distribution or an identification of its extension limits. This type of approach is used for national or sub-regional studies and the minimum mapped surface area is 25 m² (Pergent *et al.*, 1995a). Inversely, mapping objectives for smaller surface areas often necessitate a much higher precision level (minimum surface area below or equal to square-meter: Pergent *et al.*, 1995a). What is sought here is an accurate localization of the habitat for control and monitoring purposes over a period of time. This type of approach is used for test-zones or remarkable sites to be most accurately monitored. As highlighted by the MESH Project (2008), most of the environment management and marine area planning activities require a range of habitat maps between these two extremes.

b) What available tools for mapping surveys?

In less than half a century the mapping survey techniques have become highly diversified and several of them have been successfully applied to marine magnoliophyta meadows (see synthesis in Walker, 1089: Pergent *et al.*, 1995a; McKenzie *et al.*, 2001; Dekker *et al.*, 2006; POSIDONIA project, 2007). In as far as the mapping of these meadows was in shallow depths (0 to 50 m), it is possible to use optical imaging techniques (satellite images, multi or hyper spectral imaging, aerial photography) and acoustic techniques (side-scan sonar, mono- or multi-beam sonar). The simultaneous use of several instruments makes it possible to optimize the results as the information obtained is different but can be complementary (Tab. 1).

Tab.1: Synthesis on main survey tools used for mapping marine magnoliophyta. Whenever possible, the bathymetric tranche and the surface area being used, accuracy, the area mapped per hour, the main interest or the limits of utilization are to be indicated with the corresponding bibliographical references.

Survey tool	Depth	Surface area to be mapped	Geometrical precision	Area mapped in km²/hour	Interest	Limit
Satellite images	from 0 to -20 m but adapted to tranche 0 to 10 m	Starting with a few km² but esp. adapted to large surface areas (over 100 km²)	From 0.5 m	Over 100 (Kenny *et al.*, 2003)	Usable everywhere without authorization, high geometric precision. Possible to find free access images with low resolution but useful for superficial areas.	Good weather conditions required (no clouds & no wind). Possibility of confusion between close tonality population (e.g. seagrass on rock & photophilic population on rock. Interpretation error due to bathymetric variations (the same meadow may have different tonalities depending on whether it is at -3 m or at -10 m).
Multispectral and/or hyperspectral images	From 0 to -25 m (Mumby & Edwards, 2002) but adapted to superficial tranches (up to -15 m; Gagnon *et al.*, 2008)	CASI used on surface areas of 50 km² to 5000 km² (Mumby & Edwards, 2002)	from 1 m (Mumby *et al.*, 2003)		Very high spectral resolution which makes it possible to distinguish the magnoliophyta species (Dekker *et al.*, 2006). Possible to obtain data in bad weather.	Complex acquisition & processing procedures requiring the presence of specialists. Necessary to obtain field data & spectral data at the same time & to possess plenty of data to validate the observations. Identification difficulty in case of very fragmented populations (Dekker *et al.*, 2006).

Tab.1: Synthesis on main survey tools used for mapping marine magnoliophyta – next.

Survey tool	Depth	Surface area to be mapped	Geometrical precision	Area mapped in km²/hour	Interest	Limit
Aerial photos	from 0 to -20 m but adapted esp. to tranche of 0 to -10 m	Adapted to small surface areas (10 km² ; *in* Diaz *et al.*, 2004) but can be used for surface areas over 100 km²	from 0.3 m (Frederiksen *et al.*, 2003)	over 10 (Kenny *et al.*, 2003)	Possible to adapt image precision to sought after objective (Pergent *et al.*, 1995a) Manual, direct & easy interpretation possible. Sizeable images library with access to chronological series. Good identification of limits between populations.	Same limit as for satellite imaging. Difficult geometrical corrections and strong deformations if verticality is not respected or if image covers a small area (low altitude view). Authorisations for imaging difficult to obtain in some countries.
Side-scan sonar	over -8 m (Clabaut *et al.*, 2006)	Can be used for large surface area but adapted to medium surface areas (some dozens of km²).	From 0.1 m (Kenny *et al.*, 2003)	0.8 to 3.5 (Kenny *et al.*, 2003)	Realistic representation of seabed & good identification of limits of facies & quite dense meadows. Quick execution.	Small forms (under m²) or low surface density cannot be distinguished (Paillard *et al.*, 1993). Loss of definition at image edge & slight adjustment between profiles necessary. Great signal amplitude variations (levels of grey) which can lead to interpretation errors (same population may appear in different levels of grey; Kenny *et al.*, 2003)

Tab.1: Synthesis of main survey tools used for mapping marine magnoliophyta – next.

Survey tool	depth	Surface area to be mapped	Geometrical precision	Area mapped in km²/hour	Interest	Limit
Acoustic sonar mono-beam acoustic sonar	beyond -10 m (Riegl & Purkis, 2005)		From 0.5 m (Riegl & Purkis, 2005)	1.5 (Kenny et al., 2003)	Good geo-referencing	Low discrimination between habitats & less reliable than satellite techniques
Multi-beam sonar	from -2m to -8m (Komatsu *et al.*, 2003)		From 1m (Kenny *et al.*, 2003)	0.2 (Komatsu *et al.*, 2003)	Possible to obtain 3 D image of meadows & gain biomass information per surface area unit.	Huge amount of data necessitating very efficient computer systems for processing & archiving. Complex data processing.
Transect or permanent square	Bathymetric tranche easily accessible with scuba diving (0-20 m) but esp. adapted to 0 to -10m tranche	Surface areas under km², generally 25 m to 100 m² for permanent squares (Pergent *et al.*, 1995a)	from 0.1 m	0.01	Very great precision in identifying small structures (tufts of seagrass) & localisation of population limits	Many working hours or necessitating numerous observers
Video camera	Whole bathymetric tranche of seagrass distribution	Adapted to small surface areas under km²	from 0.1 m (Kenny *et al.*, 2003)	0.2 (*in* Diaz *et al.*, 2004)	Easy to use & possible to record seabed images for later interpretation	Long time to gain & process data Positioning error due to gap between boat's position & camera when dragged (POSIDONIA project, 2007)

Tab.1: synthesis on main survey tools for mapping marine magnoliophytes - next.

Survey tool	depth	Surface area to be mapped	Geometrical precision	Area mapped in km²/hour	Interest	Limit
Laser-telemetry	Bathymetric tranche easily accessible in scuba diving (0-20 m)	Adapted to small surface areas under km²	Some centimeters (Descamp *et al.*, 2005)	0.01	Very accurate localisation of population limits or remarkable structures. Monitoring possible in course of time.	Range limited to 100m in relationship to base so not possible to work over large surface areas. Necessity for markers on seabed for positioning of base if monitoring over time is envisaged Possible acoustic signal perturbation due to great variations in temperature or salinity. Specific training needed for equipment. (Descamp *et al*., 2005)
GIB	Bathymetric tranche easily accessible in free scuba diving (0-20 m)	Adapted to small surface areas under km²			Same characteristic as acoustic telemetry but greater range (1.5 km) c	Quite cumbersome technique (a lot of equipment, team of divers and related equipment ; POSIDONIA project, 2007)

Once the surveying is finished, the data obtained needs to be organized (type of data, the whole point of obtaining the data, producer organism, method used, site studied and acquisition date) so that the data can be used later on as well and be appropriately archived so that it can be easily consulted, does not deteriorate with time and can be easily integrated into similar data from other sources (MESH project, 2008).

1) Optical data

Satellite images are from satellites in orbit around the earth. Data is obtained continuously and today it is possible to buy data which can be of great precision (Tab. 2).

Satellite	Panchromatic precision	Bibliographical reference on marine magnoliophyta
Landsat 7	15 m	Cerdeira-Estrada *et al*., 2008
SPOT 5	2.5 m	Pasqualini *et al*., 2005
IKONOS (HR)	1.0 m	Mumby & Edwards, 2002
QuickBird	0.7 m	POSIDONIA project, 2007
Geoeyes	0.5 m	-

Tab. 2: Types of satellites & precision of sensors used for mapping of marine magnoliophyta - : absence of data

It is also possible to ask for a specific programming of the satellite (programmed passing over an identified sector with specific requirements) but this entails a much higher cost.
The rough data must undergo a prior geometrical correction to compensate for errors due to the methods the images are obtained (e.g. errors of parallax, inclination of the satellite) before it can be used. Images already geo-referenced should also be obtained even if their cost is much higher than the rough data.

In view of the changes of the light spectrum depending on the depth, these techniques should be reserved for superficial bathymetric tranches (Tab. 1). In clear water it can be said that:

- With the blue channel it is possible to see up to approx. 20 to 25 m depth
- With the green channel up to 15 to 20 m
- With the red channel up to 5 to 7 m
- Channel close to infra-red – approx. tens of cm (POSIDONIA project, 2007) and experience in the Mediterranean has shown that for types of well differentiated seabeds (e.g. loose substrate/meadow) they can be used with no problem up to a depth of about twenty meters (UNEP-MAP-RAC/SPA 2009b).

Multispectral or hyperspectral imaging is based on obtaining simultaneously images composed of numerous close and contiguous spectral bands (generally 100 or more). There is a wide variety of airborne sensors (CASI1[1], Deaedalus Airborne Thematic Mapper; Godet et al 2009) which provide data in real time and under unfavourable lighting conditions (Tab. 1). It is possible to create specific spectral response libraries so that measured values can be compared and this makes it possible to appraise the vegetation cover and even to differentiate the component species (Ciraolo *et al.*, 2006; Dekker *et al.*, 2006).

Aerial photographs obtained through various means (e.g. aeroplanes, drones, ULM etc.) may have different technical characteristics (e.g. Shooting altitude, verticality, optical quality…). Even though more expensive, shooting films from a plane which is equipped with an altitude and verticality control system and using large size negatives (24 x 24) makes it possible to make better use of the results (e.g. geometrical precision). For example, on a photo at 1/25000 the surface area covered is 5.7 km x 5.7 km (Denis *et al.*, 2003). In view of the

[1] CASI: Compact Airborne Spectrographic Imager

progress made in the last few decades in terms of shooting (e.g. the quality of the film, filters, lens etc.) and later processing (e.g. digitalization, geo-referencing), aerial photographs today constitute one of the most preferred surveying methods for mapping marine magnoliophyta meadows (Mc Kenzie *et al.*, 2001; POSIDONIA project 2007).

2) Acoustic data

Sonar provides images of the seabed through the emission and reception of ultrasound. Amongst the main seabed acoustic mapping technologies, Kenny *et al*. (2003) distinguish: (1) wide acoustic beam systems like the side-scan sonar, (2) single beam sounders (e.g. RoxAnn®QTC-View®), (3) multiple narrow beam bathymetric systems and (4) multi-beam sounders (Fig. 4).

The side-scan sonar towfish with its fixed recorder emits acoustic signals. The images, or sonograms, obtained, indicate the distribution and the limits of the different entities over a surface area of 100 to 200 m along the pathway (Clabaut *et al.*, 2006); Tab. 1). The precision of the final mapped document partly depends on the means of positioning used by the boat (e.g. radiolocalisation or satellite positioning). The existence of a sonogram atlas (Clabaut *et al.*, 2006) could be helpful in interpreting the data.

Single-beam acoustic sounder is based on the simultaneous emission of two frequencies separated by several octaves (38 kHz and 200 kHz) so that information can be obtained about the seafloor characterization.
The sounder's acoustic response is different depending on whether the sound wave is reflected from an area covered or not covered by vegetation. (POSIDONIA project, 2007).

The multi-beam sounder (Fig. 4) makes it possible to precisely and rapidly obtain: (i) topographical images of the submarine relief (bathymetry), (ii) sonar images representing the local reflectivity of the seafloor and thus its nature (imagery). The instrument simultaneously measures the depth in several directions, determined by the system's receiver beams. These beams form a beam perpendicular to the axis of the ship. The seafloor can thus be explored over a wide band (5 to 7 times the depth) with a high degree of resolution (POSIDONIA project, 2007). 3D images of the seafloor are thus obtained and the meadows can be visualized and the biomass can be evaluated too (Komatsu *et al.*, 2003).

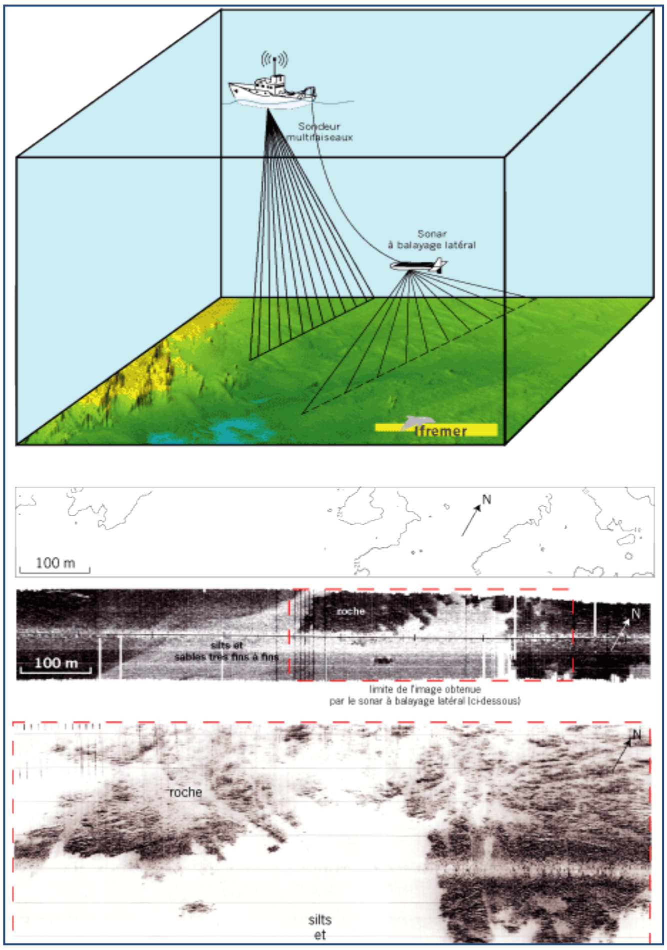


Fig.4. Multi-beam sonar working principle and examples of bathymetric recording (multi-beam sounder) and acoustic images (multi-beam sounder and side-scan sonar); www.ifremer.fr

3) *Samples and observations in situ*

Field samples and observations provide discrete data (sampling of distinct points regularly spread out in a study area). They are vital for the validation of continuous information (complete coverage of surface areas on portions of the study sectors or along the pathway) obtained through the different survey instruments and must be sufficiently numerous and distributed appropriately so as to obtain the necessary precision and also in view of the heterogeneity of the habitats. As for the mapping of meadows such as *Cymodocea nodosa*, *Posidonia oceanic*, *Zostera marina* or *Zostera noltii*, destructive sampling (using dredger buckets, core samplers, trawls, dredgers) must be forbidden in view of the protected character of these species (UNEP-MAP 2009) and direct samples being taken by hand should be limited as much as possible.

Surface observations can also be made (e.g. bathyscope) by observers diving in or by using submarine imagery techniques such as photography and video. Photographic equipment and cameras can be mounted on a vertical structure, a sleigh or remotely-controlled vehicle (ROV). The cameras on a vertical structure are submerged over the side of the ship as it advances very slowly (under 1 knot), the sleighs are at the back of the ship and the ROVs have their own propulsion system and are remotely controlled from the surface (MESH project, 2008).

The use of video cameras (or ROVs) during the survey operations makes it possible to see the images on the screen in real time, to identify or to locate any changes in the facies and any other characteristic element of the seafloor. After the maritime operations, the images are reviewed to have a cartographical restitution using GIS for each of the areas surveyed (POSIDONIA project, 2007). To facilitate and to improve the results obtained with these cameras, joint acquisition modules integrating the depth, images of the seafloor and geographical positioning have been developed (e.g. the TRITONE system or MOBIDIC; POSIDONIA project, 2007).

In situ observations can in fact constitute proper surveying techniques when they are used along the lines (transect) or over small surface areas (permanent square) marked accurately on the seabed and also to follow the limits of a population.

The transects consist of lines marked on the seafloor by means of graduated ribbons stretched from fixed points on the coast and in a precise direction (Boudouresque *et al.*,1980 in Pergent *et al.,* 1995a). Any changes in the populations and types of seafloor over a surface area of 1 to 2 m on each side of the line are recorded. The information report makes it possible to prepare a precise map of the sector studied (Tab. 1).

Demarcating the limits of a meadow also makes it possible to obtain a distribution map. Laser-telemetry is a useful technique for highly precise mapping surveying over small surface areas (Descamp *et al.,* 2005). The GIB system (GPS Intelligent Buoys) has 4 buoys with hydrophones and GPS and a submarine acoustic emitter is quite comparable. The buoys measure the arrival time of an acoustic signal whose emission is synchronous with the GPS time. Knowing the moment of emission of these signals and the sound propagation speed in the water, it is possible to directly calculate the distances between the pinger and the 4 buoys. The depth is indicated by the pressure sensor. To optimize the meadows mapping operations, the pinger can be fixed on a submarine scooter driven by a diver. The maximum distance of the pinger in relationship to the center of the polygon formed by the 4 buoys can be approx. 1500 m (POSIDONIA project, 2007).

Free diving monitoring with a differential GPS can also be envisaged to locate the upper limits of the meadows. The diver follows precisely the contours of the limits and the DGPS continuously records the diver's geographical data. The mapping data is integrated under

GIS using the route followed. The acquisition speed is 2-3 km/hour; the sensor precision can be sub metric (POSIDONIA project, 2007).

c) What methods of analysis to interpret the data?

The MESH (2008) project identified three prior stages for the production of a habitats map:

- Processing, analysis and classification of the biological data,
- Selecting the most appropriate physical layers (e.g. substrate, bathymetry, hydro dynamism)
- Integration and modeling of data by collating biological habitats classes and physical layers and then regrouping similar corresponding groupings, direct interpretation of acoustic and optical images by having recourse to the practical experience of the experts or statistical modeling.

The map thus produced must then be evaluated for its accuracy, i.e. its capacity to represent reality as it truly is, its accuracy and therefore its reliability.

During the processing analysis and classification stage, the reference list of the Mediterranean habitat types should be consulted (UNEP-MAP-RAC/SPA, 1999) which was adopted by the Contracting Parties to the Barcelona Convention at their 11th ordinary meeting. This list identified the specific "meadow" habitats which are also to be found in the annex of the Habitats Directive (Directive 92/43/EEC of the 21 May 1992 Council) and which must be taken into consideration within the framework of the NATURA 2000 programmes (Fig. 5).

A precise description of the reference habitats and the criteria to identify them are also available (Bellan-Santini *et al.*, 2004). In view of this classification, the habitats which could be on the map are as follows:

- *Cymodocea nodosa* meadows
- *Halophila stipulacea* meadows
- *Posidonia oceanic* meadows
- *Zostera marina* meadows
- *Zostera noltii* meadows
- Mixed meadows (a mix of the preceding species)

As for *Posidonia oceanica* meadows, the discontinuous meadows (on a rock or sand) should be identified, the dead mats and natural monuments such as:

- Striped meadows
- Barrier reefs and reef platforms
- Atolls (micro or macro-atolls)

I.SUPRALITTORAL
- I.1. MUDS
- I.2. SAND
  - I.2.1. Biocenosis of supralittoral sands
    - I.2.1.5. Facies of phanerogams which have been washed ashore (upper part)
- I.3. STONES AND PEBBLES
- I.4. HARD BEDS AND ROCKS

II. MEDIOLITTORAL
- II.1. MUDS, SANDY MUDS AND SANDS
- II.2. SUNDS
- II.3. STONES AND PEBBLES
  - II.3.1. Biocenosis of mediolittoral coarse detritic bottoms
    - II.3.1.1. Facies of banks of dead leaves of *P. oceanica* and other phanerogams
- II.4. HARD BEDS AND ROCKS

III.INFRALITTORAL
- III.1. SANDY MUDS, SANDS, GRAVELS AND ROCKS IN EURYHALINE AND EURYTHERMAL ENVIRONMENT
  - III.1.1. Euryhaline and eurythermal Biocenosis
    - III.1.1.4. Association with *Zostera noltii* in euryhaline and eurythermal environment
    - III.1.1.5. Association with *Zostera marina* in euryhaline and eurythermal environment
- III.2. FINE SANDS WITH MORE OR LESS MUD
  - III.2.1. Biocenosis of fine sand of high level
  - III.2.2. Biocenosis of well sorted fine sands
    - III.2.2.1. Association with *Cymodocea nodosa* on well sorted fine sands
    - III.2.2.2. Association with *Halophila stipulacea*
  - III.2.3. Biocenosis of superficial muddy sands in sheltered waters
    - III.2.3.4. Association with *Cymodocea nodosa* on superficial muddy sands in sheltered waters
    - III.2.3.5. Association with *Zostera noltii* on superficial muddy sands in sheltered waters
- III.3. CORSE SAND WITH MORE OR LESS MUD
- III.4. STONES AND PEBBLES
- III.5. *POSIDONIA OCEANICA* MEADOWS
  - III.5.1. *Posidonia oceanica* meadows (association with *Posidonia oceanica*)
    - III.5.1.1. Ecomorphosis of stripped meadows
    - III.5.1.2. Ecomorphosis of “barrier-reef” meadows
    - III.5.1.3. Facies of dead matte of *Posidonia oceanica* without important epiflora

Fig. 5. Extract from Reference list of Mediterranean habitats (UNEP-MAP-RAC/SPA. 1999), only those habitats in connection with marine magnoliophyta are indicated.

As these assemblages are generally small in size, they can only be identified with high (metric) precision mapping.

The selection of physical layers may been to be an interesting approach within the general framework of mapping marine habitats so as to reduce the processing time but it is of little use for the Mediterranean meadows in asfar as none of the classical physical parameters (e.g. substrate, depth, hydro dynamism, or salinity) are discerning enough to forecast the distribution of species (Fig. 6).

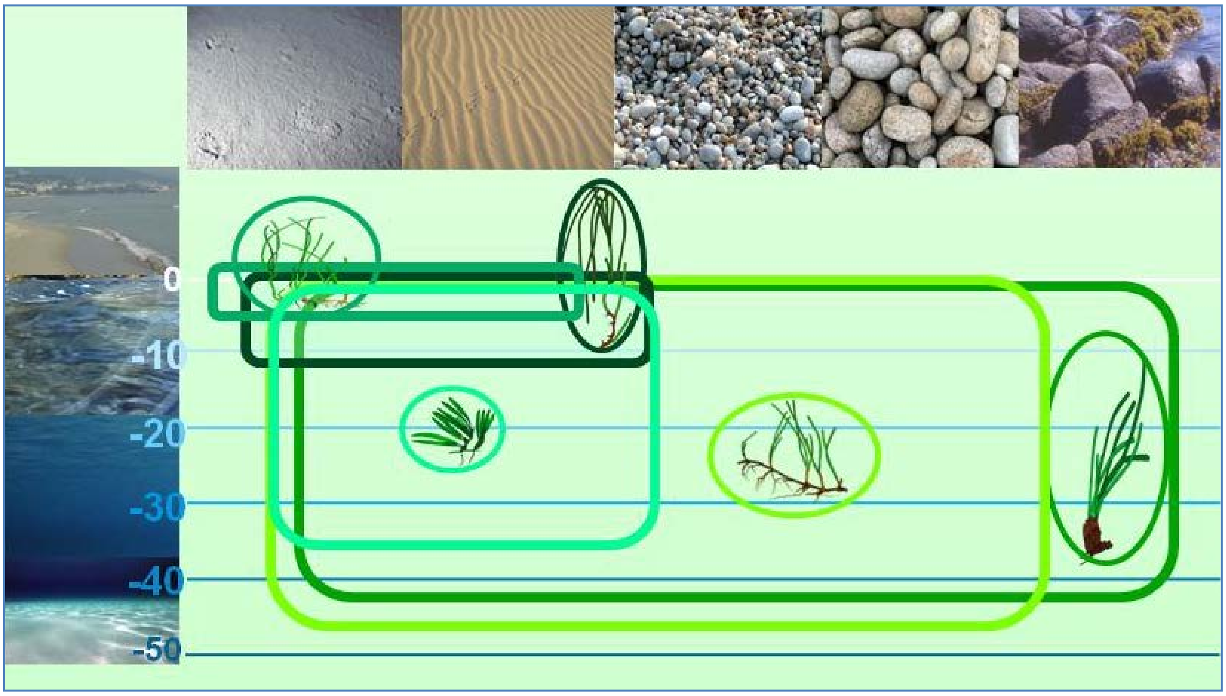


Fig. 6. Distribution of the marine magnoliophyta species depending on the nature of the substrate and the depth in the Mediterranean.

The data integration and modeling stage will differ depending on the survey tools and the acquisition strategy used. In view of their acquisition rapidity, aerial techniques usually make it possible to completely cover the littoral and the shallow intertidal zones which are to be mapped and this greatly reduces interpolation. Inversely, surveys from vessels which are often limited because of the time factor and costs involved, only rarely make it possible to obtain a complete coverage of the site. Coverage under 100 % automatically means that it is impossible to obtain high resolution maps and therefore interpolation techniques have to be used so that from partial surveys a lower resolution map can be prepared (MESH project 2008, Fig. 7).
An “overlapping” survey strategy combining a partial coverage of a large surface area and a more detailed coverage of smaller zones of particular interest could be an interesting compromise.

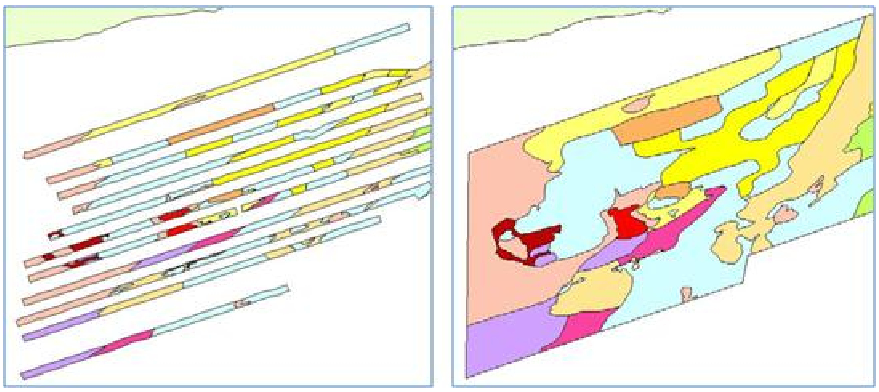


Fig. 7: Example of partial coverage survey (left) and produced through interpolation (right). The area surveyed was approx. 20 km wide (MESH project, 2008).

To obtain a potential meadows distribution map, it might be useful to have precision mapping only of the extension limits (upper and lower) of the population, and the presence between these two limits could be reduced to occasional investigations and interpolation could play its part. (Pasqualini *et al*., 1998). The processing and digital analysis of data (whether optical or acoustic) makes it possible on the basis of in situ observations to create plots which associate tonalities of grey, facies or textures with a type of population and to generalize this information to the whole image thus creating the map which in turn should at least make it possible to identify the loose substrates, hard substrates and the magnoliophyta meadows. Specific processing (e.g. analysis of the roughness, filtering and thresholding) make additional information accessible such as the seagrass cover or the presence of anthropogenic traces (Pasqualini *et al.,* 1999).

To facilitate a comparison of the sites, a single graphic representation should be adopted for each type of population (Fig. 8). When the cartographical precision is good enough, it is possible to indicate the discontinuous meadows which are characterized by a coverage below 50 %, (the colour of the spots makes it possible to identify the species concerned) or the two main species which constitute a mixed meadow. As for *Posidonia oceanica* striped meadows and the atolls, no representative plan is envisaged as these are typical forms (bands, circular structures) which are easily identifiable.

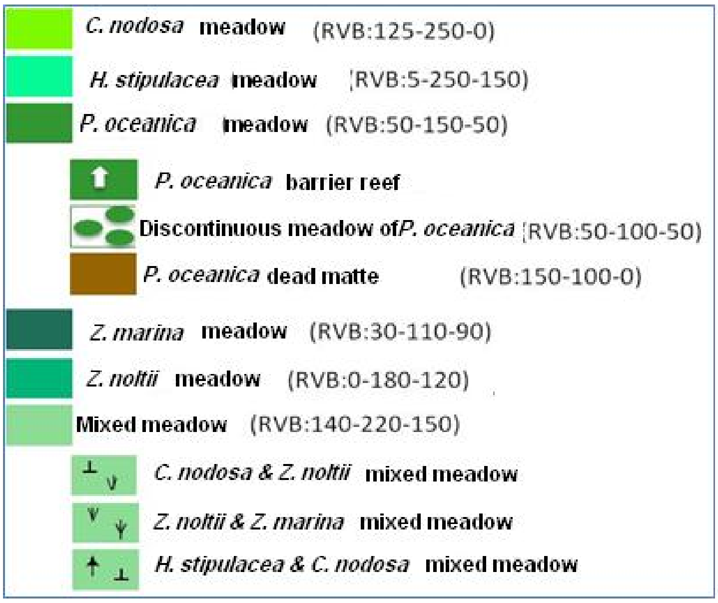


Fig.8: graphic representation of the main marine magnoliophyta assemblages. RVB: values in red, green and blue for each type of meadow.

The results should be integrated into the GIS (Geographical Information System) so that they can be consulted and used later on much more easily.

Thus by making a comparison with previous data (bibliographical data), it is possible to note any changes in some of the populations over a period of time (Mc Kenzie *et al.,* 2001; Barsanti *et al.*, 2007).

The reliability of the map produced should also be questioned. Several evaluation scales have already been proposed and may be useful for the magnoliophyta meadows. Denis *et al.*, 2003, propose a reliability index of the bibliographical cartographical data based on the map scale (scale of 5; Fig. 9), the mode of positioning (scale of 5; Fig. 9) and the observation acquisition method (scale of 10; Tab. 3).

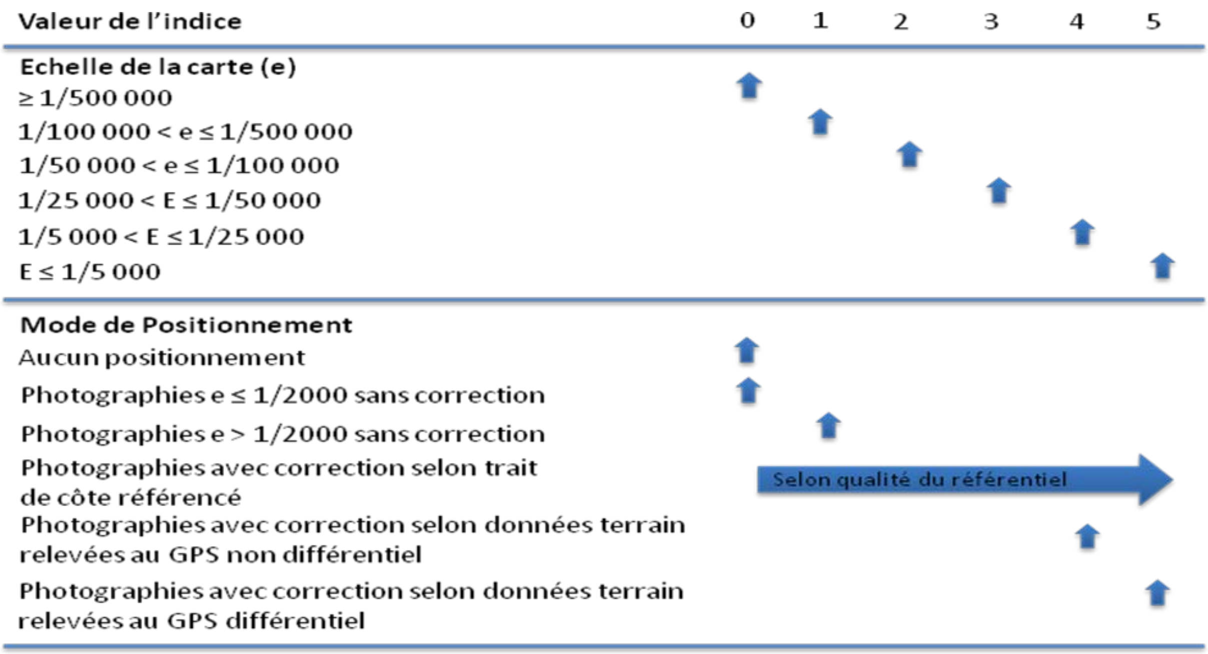


Fig. 9: Attribution criteria of the scale/rating corresponding to the parameter “map scale” and to the “mode of positioning” parameter of the reliability index of old maps (according to Denis *et al.*, 2003 modified).

The reliability index (from 0 to 20) can vary from one point to another of the map depending on the bathymetry or the technique used. Pasqualini (1997) proposes a reliability scale in relationship to the image processing of the aerial photos (Tab. 4.) which can also be applied to satellite images or another one in relationship to the processing of sonograms. (Tab. 5). Reliability lower than or equal to 50 % means that the author should try to improve the reliability (increasing the number of segments during image processing for example) or else the scale needs to be adapted. Even though this is hardly ever mentioned, apart from the map, it seems to be important to provide information on the distribution, the number and the percentage of data acquired so as to distinguish between what is interpolation and what is the actual field data.

Tab. 3: Attribution criteria of the scale corresponding to the “data acquisition mode” parameter of the reliability index of old maps (Denis *et al.,* 2003).

Profondeur de 0 à 5 m

Mode d'acquisition	Sonar	Prélèvement, observations ponctuelles, balisage, etc.		Images satellites	Photographies aériennes ou Images satellites + vérités-terrain	Photographies aériennes + vérités terrain
Note (/10)	0	0 à 6 selon la maille (M)		6	8	10
		M ≥ 1000 m	0			
		1000 m > M ≥ 500 m	1			
		500 m > M ≥ 250 m	2			
		250 m > M ≥ 100 m	3			
		100 m > M ≥ 50 m	4			
		50 m > M ≥ 20 m	5			
		20 m > M	6			

Profondeur de 5 à 15 m

Mode d'acquisition	Prélèvement, observations ponctuelles, balisage, etc.	Images satellites	Photographies aériennes ou Images satellites + vérités-terrain	Sonar	Photographies aériennes et/ou sonar+ vérités terrain
Note (/10)	0 à 6 selon la maille (M)	4	6	8	10

Profondeur de 15 à 40 m

Mode d'acquisition	Photographies aériennes	Images satellites	Prélèvement, observations ponctuelles, balisage, etc.	Sonar	Sonar+ vérités terrain
Note (/10)	0	0	0 à 6 selon la maille (M)	8	10

Tab. 4: Attribution criteria of the reliability index of maps produced through image processing from aerial photos. *: Criterion subdivided into two elements, each being weighted with a coefficient of 0.5 (Pasqualini, 1997).

Reliability scale	**3 points**	**2 points**	**1 point**	**0 point**
CRITERIA				
Site studied				
Topography : slope bathymetric tranche Water turbidity ; : Visualisation of populations & types of seafloors Nature of populations & types of seafloors	Low & constant 0 à 5 m 100 % of bathymetric tranche studied Very different	Low & irregular 0 à 10 m 75 % of bathymetric tranche studied Différent	Strong & constant 0 à 20 m 50 %of bathymetric tranche studied Close	Strong & irregular 0 to over 20 m < 50 %of bathymetric tranche studied Very close
film shooting				
Quality Surface effects :lens réflexion wave	Very good No surface effect	good Surface effect far from site	medium Surface effect close to site	Poor Surface effect on site
Digitalisation				
pixel size	Pixel ≤ 2m	2m < Pixel ≤ 5m	5m < Pixel ≤ 10m	Pixel > 10m
Geometrical correction				
*Control points : Number : Distribution Referentiel scale / image scale	Number ≥ 20 Dans 4 directions Referentiel > image	20 > Number≥ 10 In 3 directions Referentiel = image	10 > Number ≥ 4 In 2 directions Referentiel < image	Number < 4 In 1 direction Referentiel << image
Field data				
Surface covered by field data / study surface area	Surface ≥ 10 %of study surface area	10 % > Surface ≥ 5 % of study area	5 % > Surface ≥ 1 % of study area	Surface < 1 % of study area
Classification				
No. of polygons per population or type of seafloor	number > 30	30 ≥ number > 15	15 ≥ number > 5	number < 5
Total	**33**			

Tab. 5: Attribution criteria of reliability index of maps prepared through sonogram processing (Pasqualini, 1997).

Reliability scale / CRITERIA	3 points	2 points	1 point	0 point
Site studied				
Nature of populations & types of seafloors Topography : slope	Very different Low & constant	Different Low & irregular	close Stropng & constant	very close Strong & irregular
Acquisition of sonograms				
Quality Présence of artéfacts	Very good No artéfact	good Some artifacts on edges of sonogram	medium Some artifacts over whole sonogram	Poor many artifacts over whole sonogram
Positioning of sonograms				
Precision	Precision = 1 m	1m < Precision ≤ 10m	10m < Precision ≤ 20m	Precision > 20m
recovery of sonar profiles				
Surface prospected with sonar / Surface area studied	100 % of study area	over 50 % of study area	over 25 % of study area	Less than 25 % of study area
field data				
Surface area covered by field data / study surface area	Surface ≥ 10 % of study area	10 % > Surface ≥ 5 % of study area	5 % > Surface ≥ 1 % of study area	Surface < 1 % of study area
Interpretation precision				
Manual Interpretation (scale of sonograms)	1/500	1/1 000	1/2 000	1/4 000
Or image processing (digitalisation)	Pixel ≤ 1m	1m < Pixel ≤ 2m	2m < Pixel ≤ 3m	Pixel > 3m
TOTAL	**24**			

3. Case Studies

The following summarized case studies do not constitute “turnkey solutions” for the managers and decision-makers who want to map the magnoliophyta meadows, in asfar as preparing a map is always the result of a compromise between:

- The surface area to be processed (country, region, site)
- The desired precision, not only for the surface area but also in view of the mapping objectives and the means available
- The bathymetric tranche concerned
- The technical means available, the necessary competences to implement the techniques, the time required and the available budget
- Regulatory constraints (e.g. fly-over authorization, navigation restriction)

- Later use of data (e.g. integration into a GIS, scheduled monitoring in time, comparison with other existing or programmed cartographical data).

All these, however, are practical operations carried out in the Mediterranean for which the implementation costs are available for the sake of information. Even though several authors tried to assess the economic costs pertaining to the use of one or other of the surveying techniques (Mumby *et al.*, 1999; Denis *et al.*, 2003; Pin *et al.*, 2008; Godet *et al.*, 2009), the values obtained are difficult to transpose to other sites.

a) Distribution of *Posidonia oceanica* meadows along the coast of Corsica (Pasqualini, 1997)

Objective: Management and planning of the area - to have a general distribution map of the *P. oceanica* meadows and the main types of seafloors along the coast of Corsica.

Surface area to be mapped: whole coastline (1000 km)
Bathymetric tranche: 0 to -40 m
Expected precision: from 10 to 50 m linear
Regulatory constraints: presence of several protected areas and a military base

Surveying Tools:
- Superficial tranche (0 to -15 m): 650 aerial photos at 1/20 000 + field data.
- Deep tranche (20 to -40 m): 2 oceanographical seasons using side-scan sonar (i.e. approx. thirty mission days and 1200 km of profile) + field data.

Data Processing:
Aerial photographs (24 x 24) digitalized with an A3 scanner in 16.8 million colour, with a pixel of 5 m (102 dpi). Image processing with the Multiscope (®Matra CapSystem) software. Supervised classification. Geographical referential: BD-Ortho (®IGN).
Manual processing of sonograms for the position of the lower limit and image processing for the coverage and the presence of anthropogenic traces. Geographical referential: route of vessel – Differential GPS.
Implementation Time:
36 man/months - work of a thesis student + supervision.
Cost: 130 000 €
Results:
Identification of soft substrates, hard substrates, continuous *P. oceanica* meadows and meadow mosaics (weak coverage degraded meadow or mixed meadows with *P. oceanica* and other magnoliophyta).

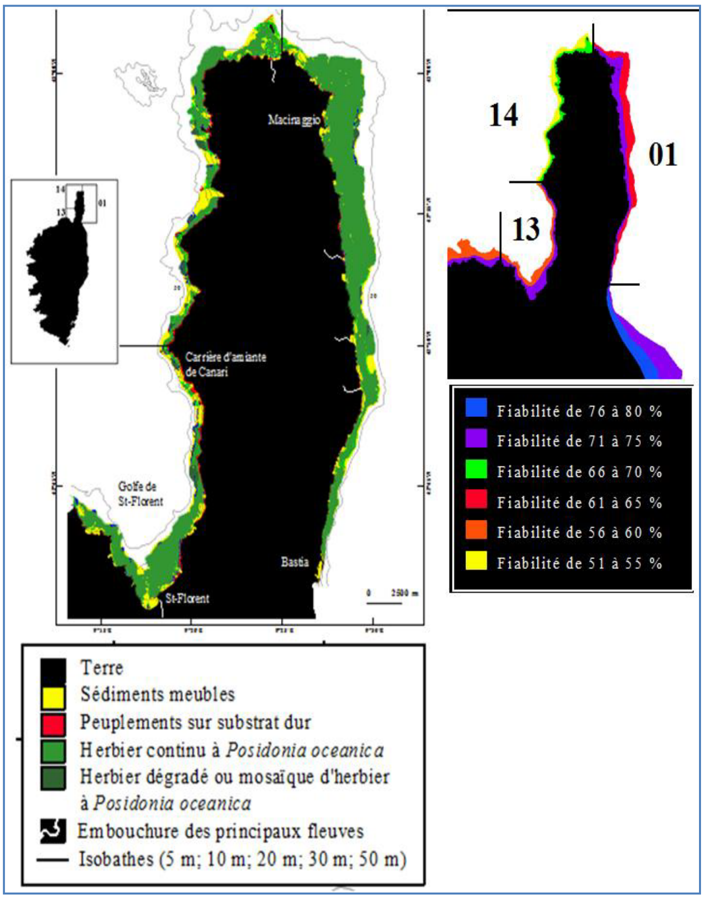


Fig. 10: Map of main populations and types of seafloors (left) and Reliability map (right) of Cap Corse (Pasqualini, 1997).

b) Cartographie de la limite supérieure des herbiers de Tunisie (PNUE-PAM-CAR/ASP, 2009b)

Objective: Management and development of an area: - to have a fairly precise map of the upper limits of magnoliophyta meadows for the medium term monitoring of anthropogenic pressures.

Surface area to be mapped: sector between Port El Kantaoui and Monastir (25 km)
Bathymetric tranche: 0 to -15 m
Expected precision: from 5 to 10 m linear
Regulatory constraints: administrative authorizations
Surveying Tools:
Satellite images SPOT 5 in 2.5. m and Google Earth + surface observations (bathyscope) and free diving.
Data processing:
Image processing with the ENVI IV® software supervised classification. Geographical referential. GPS points for limit monitoring.
Implementation time: 8 man/days
Costs: 6 000 €

Results:
Identification of natural and anthropogenic impacts, soft substrates, hard substrates, *C. nodosa* and *P. oceanica* meadows.

Preparation of a reference map (Fig. 11).

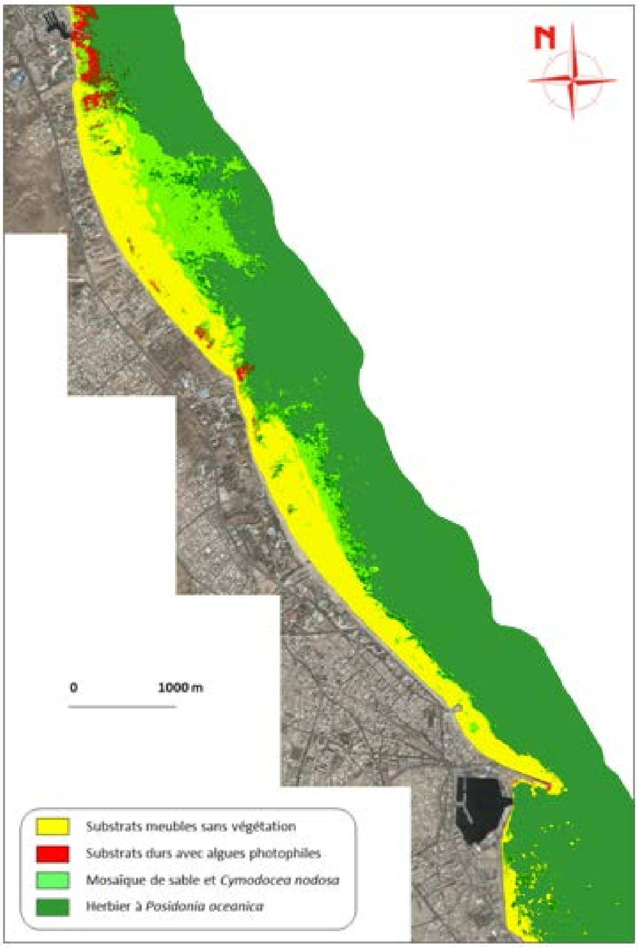


Fig. 11: Map of main populations and types of seafloors of the littoral towards Port El Kantaoui (UNEP-MAP-RAC/SPA, 2009c).

c) Mapping of magnoliophyta meadows at the aquaculture installation in the Balearic Islands (Delgado *et al.*, 1999)

Objective: Monitoring of impact of anthropogenic activity – To have a precise map of the seafloors at the aquaculture installations set up on the meadows so as to evaluate any impacts.

Surface area to be mapped: 100 m transects in the area where aquaculture structures were set up (< 2000 m2).

Bathymetric tranche: from -5 to -8 m
Expected precision: from 1 to 2 m linear
Regulatory constraints: authorizations required from the operator

Surveying Tools: Transects dealt with using free scuba diving + samples taken

Data Processing: Manual data processing (Fig. 12).

Implementation time: 2 men/days per year, with monitoring over several years.
Cost: 5 000 €

Results:
Identification of loose substrates, *C. nodosa* and *P. oceanica* meadows and their state of health (Fig. 13). Visualization of impact of aquaculture activity on the meadows over several years.

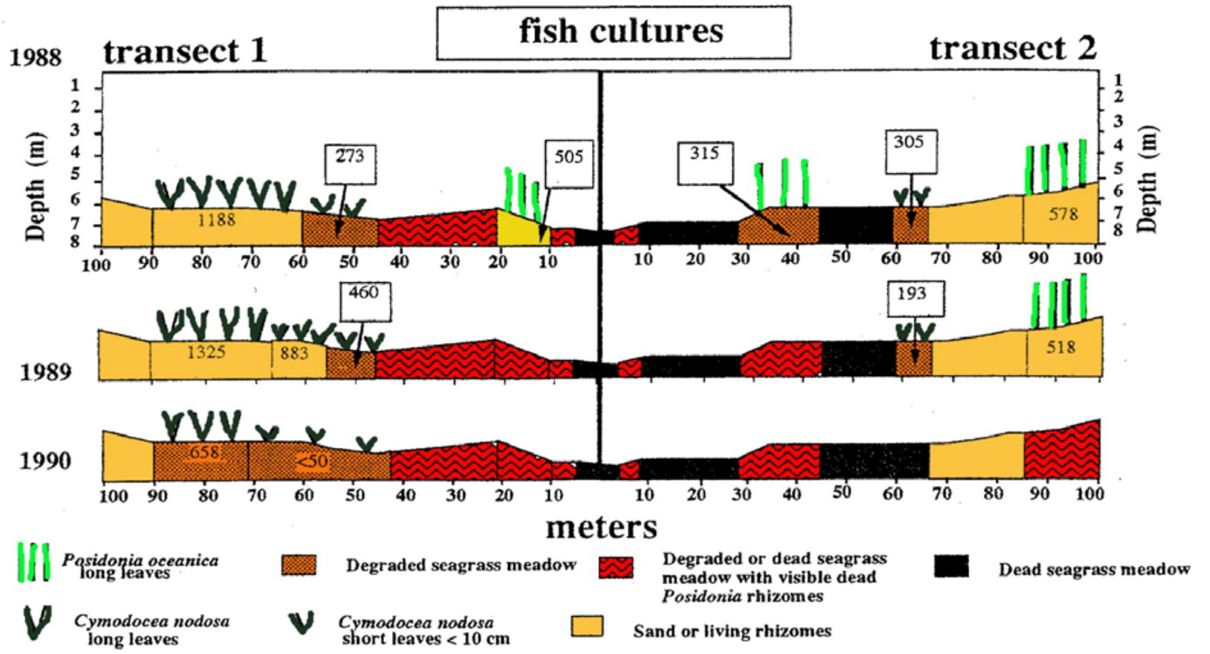


Fig. 12: Representation of populations and types of seafloors at the aquaculture installations and changes in 1988, 1989 to 1990 (Delgado *et al.*,1999).

d) Mapping of magnoliophyta meadows in view of the organized berthing in Corsica (Salivas-Decaux *et al.*, 2008).

Objective:
Reducing the impact of an anthropogenic activity – to have a precise map of the meadows so as to prepare a sensitivity map of the populations vis-à-vis foreign berthing and to propose installing organized berthing in less sensitive sectors.
Surface area to be mapped: 0.03 km² bay
Bathymetric tranche: from 0 to -15 m
Expected precision: 1 to 2 m linear

Regulatory constraints: none
Surveying Tools: Aerial photos at 1/5 000 + field data from the surface (bathyscope) and free scuba.

Data Processing:
Aerial photos (24 x 24) digitalized with an A3 scanner in 16.8 million colors, with a pixel of 1 m (127 dpi). Image processing with ENVI IV® software.
Implementation time: 10 man/days
Cost: 4 000 €
Results:
Identification of loose substrates, *C. nodosa* and *P. oceanica* meadows and their state of health (degraded meadows and dead mats (Fig. 13). To prepare a sensitivity map to berthing impacts and to propose an installation plan for organized berthing.

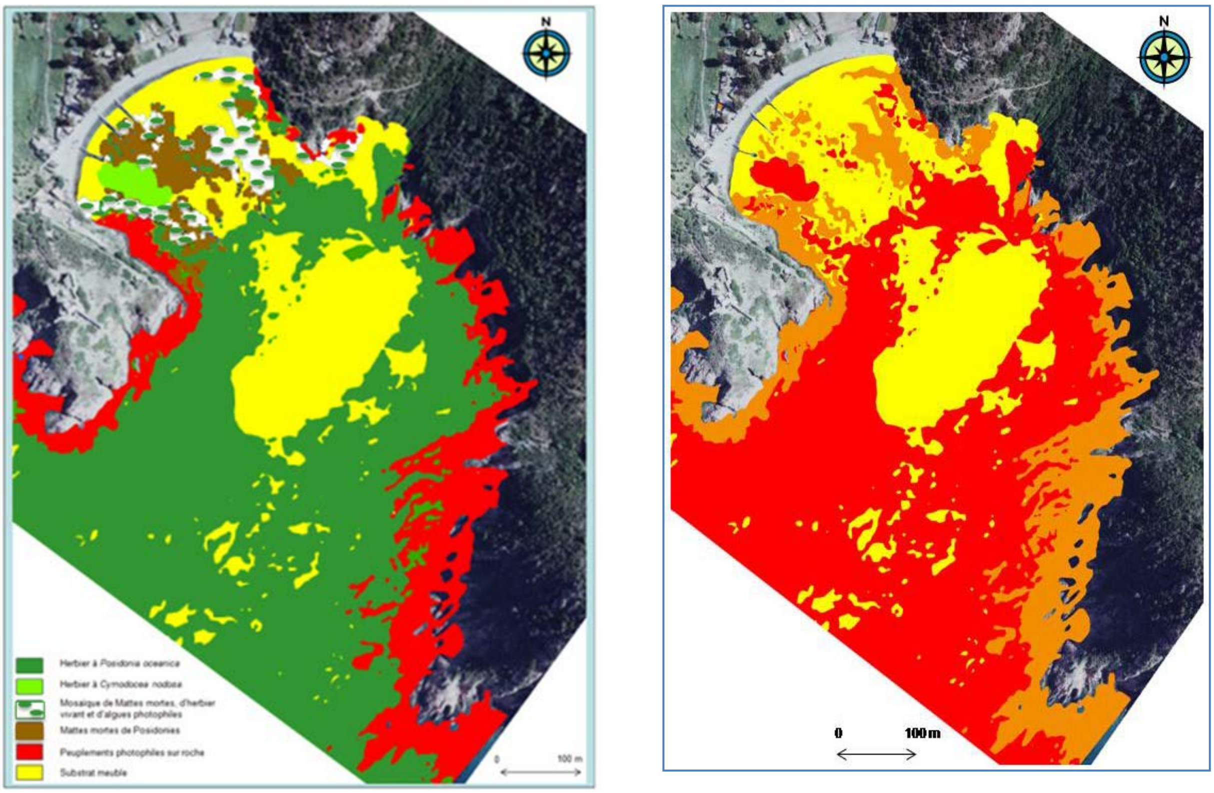


Fig. 13: Map of main populations and types of seafloors at the Girolata bay (left and map of sensitivity to berthing (right). Setting up berthing installations should be considered in the yellow sectors - Salivas-Decaux *et al.*, 2008).

Proposals for Guidelines for monitoring magnoliophyta meadows in the Mediterranean

1. Problem

The monitoring of marine magnoliophyta has today become a necessity and even an obligation for numerous Mediterranean countries due to the fact that:

- Four out of the five species present in the Mediterranean (*C.nodosa*, *P. oceanica*, *Z. marina* and *Z. noltii*) are in Annex 2 (List of endangered or threatened species) of the Protocol concerning Specially Protected Areas and Biological Diversity (Decision of the 16th Ordinary meeting of the Contracting Parties, Marrakech, 3-5 November 2009; UNEP-MAP, 2009),

- Three (*C. nodosa, P. Oceanica* and *Z. marina*) are in Annex 1 (strictly protected flora species) of the Bern Convention concerning the Mediterranean geographical region and

- The marine magnoliophyta meadows constitute one of the priority natural habitats of the European Directive No. 92/43 (EEC, 1992).

This regulatory “recognition” also means that efficient management measures are required to ensure that these habitats and the constituent species are and remain in a satisfactory state of health to look after them.

2. What steps to be taken?

What is to be done next is to set up a marine magnoliophyta meadows monitoring system comparable to that for mapping with the following stages:

- Initial planning
- Setting up the monitoring system
- Monitoring over time and analysis

The initial planning is to define the objective(s) and to determine the duration, identify the sites to be monitored, choose the parameters to be implemented with their acquisition modalities (sampling strategy) and evaluate the human, technical and financial needs to ensure implementation and sustainability. This phase therefore is not to be minimized.

The setting-up phase constitutes the actual operational phase as this is when the necessary monitoring structures will be set up (e.g. fixed markers) and may turn out to be expensive (equipment necessary for going out to sea, equipment and human resources) especially under difficult weather conditions.

This must be planned for a favorable season especially as depending on the parameters chosen for monitoring purposes, return trips must be undertaken during the same period. This phase might be quite long especially if numerous sites are to be monitored.

Monitoring over a period of time and the analysis phase seem to be easy as data acquisition is a routine operation with no major difficulties if the preceding phases had been carried out correctly (e.g. evaluation of needs). It often constitutes the key element of the monitoring system as it makes it possible to:

- Interpret the acquired data
- Demonstrate its validity and interest and
- Check that the monitoring objectives have been attained.

This phase may be quite complex as the data analysis necessitates clear scientific competence and in order to be useful, it must be envisaged over the medium term at least.

a) Monitoring – why and how?

The aim of monitoring the marine magnoliophyta is generally to:

- Monitor to preserve and conserve the heritage, with the aim of ensuring that the meadows as priority habitats are in a satisfactory state of conservation and also identify as early on as possible any degradation of these priority habitats or any changes in their distribution.

- Initiate a global monitoring of the quality of the environment. The magnoliophyta are used as indicators of “biological quality “(according to the European Water Framework Directive, DCE/2000/60 CE). The “good state of the meadows” makes it possible to measure the efficacy of local or regional policies in terms of the management of the coastal environment (e.g. water treatment to be improved, less contaminants etc. Boudouresque *et al.,* 2006).

- Exercise control over development works. This type of monitoring aims to establish a “zero” state before the works began, then monitor the state of health of the meadow during the development works phase or at the end of the phase to check any likely impacts.

These objectives can converge, as in the case of the Posidonia Monitoring Networks, initiated in the Region Provence-Alpes-Côte d’Azur since 1984, where the objective was the conservation of the *Posidonia oceanica* meadows and also their use as a global indicator of the quality of the marine waters (Boudouresque *et al.*, 2000). The objective(s) chosen will then be the parameters of the other stages (.e.g. duration, sites to be monitored, parameters for measuring, no sampling; Tab. 6).

In general and irrespective of the objective advocated, it is judicious initially to focus on a small number of sites which are easily accessible and which can be regularly monitored (Pergent & Pergent-Martini, 1995).

Tab 6.: Monitoring criteria depending on the objectives.

Monitoring objective	Sites to be studied	Parameters to be taken into account	Monitoring duration & no data acquisition time
Heritage monitoring	Monitoring of site with little anthropogenic disturbances or reference site (i.e. Protected Areas) to glean information on the natural evolution of the environment (Pergent & Pergent-Martini, 1995)	Geographical extension limit of meadow. Parameters of state of health of meadow (e.g. cover, density, div. into plots)	Medium and long term monitoring (min. 10 years). Data acquisition at least annually for non persistent species and 2 to 3 years for perennial species. (Boudouresque *et al*.,2000)
Monitoring of quality of environment	Identify anthropogenic pressures likely to affect the quality of the environment and initiate monitoring in at least 2 sites, one reference site and one site with anthropogenic pressures most representative of the littoral studied (Pergent & Pergent-Martini, 1995)	Meadow parameters indicating the quality of the environment (e.g. turbidity, depth of lower limit, enhancement in nutrients, nitrogen content of leaves, chemical contamination, trace metals in plant.)	Medium term monitoring (at least 5 to 8 years) Data acquisition is variable depending on the species concerned (one to three years)
Impact control of development works	Monitoring of site subject to development works	Specific parameters to be defined depending on the probable consequences of the development works.	Short term monitoring (generally 1 to 2 years) Initiated before the works (« zero state ») it can be continued during, or just after, & control to be made one year after the end of the works. No data acquisition, generally reduced (monthly or occasionally before and after the development works.

The sites chosen must be i) representative of the portion of the coast studied (nature of the substrate), ii) cover the most complete possible range of situations and iii) regroup sensitive zones, stable zones or reference zones. Then, with the experience gained by the actors and the means available, this network could be extended to a greater number of sites.

Taking the marine magnoliophyta as an indicator of biological quality within the framework of the European Water Framework Directive, means that there has been an increase in the diversity of the descriptors to appraise the state of health of a meadow and thus these are parameters which can be measured. (Pergent-Martini *et al.,* 2005 ; Foden & Brazier, 2007 ;

Romero *et al.*, 2007 ; Orfanidis *et al.,* 2010). Some of the most common descriptors (Tab. 7) use a standardized method (especially for *P. oceanica*; Pergent-Martini *et al.,* 2005), but there are still many disparities in data acquisition despite efforts to propose a common approach (Short & Coles, 2001; Buia *et al.,* 2004; Lopez Y Royo *et al.,* 2010a).

The requirements have to be evaluated to ensure the setting up and sustainability of the system and this constitutes the ultimate stage of the planning phase and it is also the most crucial phase. To ensure the sustainability of the system means:

- Identifying the partners, competences and means available
- Planning the partnership modalities (who is doing what? when? and how?)
- Ensure training for the stakeholders so that they can set up standardized procedures to guarantee the validity of the results, and so that comparisons can be made in the course of time for a given site and also from one site to another.
- To co-opt a regional or national coordinator depending on the number of sites concerned for monitoring and their geographical distribution and
- To budgeter the minimum funding necessary for the running of the network (such as permanent payroll, procurement costs and cost of running the equipment, data acquisition, processing and analysis costs).

Tab.7: Synthesis of main descriptors (1) used for monitoring marine magnoliophyta. Whenever possible, the measuring method (2), the expected response in case of increased anthropogenic pressure and the main factors likely to affect the descriptor (3), the destructive character of data acquisition (4), the species targeted (5), interest (6) or the limits of use (7) are indicated with the corresponding bibliographical references. The targeted species are: Cn - *Cymodocea nodosa*, Hs - *Halophila stipulacea*, Po - *Posidonia oceanica*, Zm - *Zostera marina*, Zn - *Zostera noltii*.

1 - Descriptor	2 – measuring method	3 –expected response/ factors of degradation	4 – destruc charact	5 target species	6 – interest	7 – Limits
Population information						
Extension meadow surface area	Meadow mapping (Cf. Part I of present document) &/or identification of limits (Foden & Brazier, 2007)	Diminution / Coastal developments Turbidity Mechanical effects	No	All	Descriptor integrator Usable everywhere in view of multiplicity of techniques available and for whole bathymetric tranche of distribution of meadows.	For slow growing species (Po) impossible to observe any increase in surface area in the absence of pre-positioned markers and long response time (several years). Obliged to always work during season where distribution is maximal for species with marked seasonal growth (generally in summer).
Bathymetric position of upper limit of meadow (in m)	Highly precise mapping of seagrass extension limit towards surface (Cf. Part I of present document)or placing of fixed markers (e.g. permanent transects, plots, acoustic system & measuring of depth	increase / littoral developments	No	All	Easy-to-measure parameter. Interpretation scale available for Po (Pergent *et al*., 2008)	For Cn, Hs & Zn, strong seasonal variability necessitating quarterly monitoring or observations at same season for all sites monitored. Fixed markers might disappear if site is strongly frequented.

Tab.7: synthesis of main descriptors (1) used for monitoring marine magnoliophyta - next

1 - Descriptor	2 – measuring method	3 – expected response/factors of degradation	4 – destruc Charact	5 target species	6 – Interest	7 – Limits
Bathymetric position of lower limit of meadow (in m)	Highly precise mapping of meadow extension limit in depth (Cf. Part I of present document) or recording of fixed markers (e.g. permanent transects buoys, acoustic system & depth measuring.	Diminution / Turbidity	No	All	Easy-to-measure parameter not requiring any particular competence & using free scuba diving, except if acoustic system is used Interpretation scale available (Po : Pergent *et al.*, 2008)	For Cn, Hs et Zn, strong seasonal variability necessitating quarterly monitoring or observations at same season for all sites monitored. Beyond 30 m depth, acquisition difficult & costly (limited submersion time, need for experienced divers and numerous interventions) fixed markers may disappear (e.g. trailing equipment). For slow growing species (Po) long time required to see any progress (several years).
Meadow lower limit type	in situ observations	Change/ Turbidity Mechanical effects (e.g. trailing equipment	No	Po	Well studied parameter & several types described & interpretation scales (Boudouresque & Meinesz, 1982 ; Pergent, 2007 ; Monte-falcone, 2009).	Good knowledge of Po meadows necessary to identify some types of limits. Difficult & costly acquisition in great depth (> 30 m)

Tab.7: Synthesis of main descriptors (1) used for monitoring marine magnoliophyta – next.

1 - Descriptor	2 – measuring method	3 – expected response/factors of dégradation	4 – dest.char act.	5 target species	6 –interest	7 – Limits
Density (number of bundles m-²)	No. of beams (bundles) inside quadrant (fixed dimension & depth).quadrant size depends on species concerned. (Po see *in* Pergent-Martini *et al.*, 2005) & supposed meadow density (Duarte & Kirkman, 2001)	Diminution / Turbidity Mechanical effects (e.g. anchoring)	No	All	Easy-to-measure & inexpensive parameter. Can be used for whole bathymetric tranche of meadow distribution Interpretation scale available for Po (Pergent *et al.*, 2008 ; Annex C)	Strong variability depending on depth. Long acquisition time for densities over 800 beams (bundles) Replicas necessary or sampling minimum surface area to evaluate meadow heterogeneity. Considerable risk of error if: a) manipulator is inexperienced, b) high density , c) small sized species & in such a case in situ counting can be replaced by sampling in a given area and the counting can be done in the lab. (Destructive technique).
coverage (in %)	Average percentage of surface area occupied (in vertical projection) per meadow in relationship to surface area studied. Diverse techniques to measure this parameter in situ measuring by diver or in lab. Using submarine photos or video, variable observation surface area (0.16 to 625 m²), represented by quadrant or translucid plaque ; Pergent-Martini *et al.*, 2005 ; Boudouresque *et al.*, 2006 ; Romero *et al.*, 2007)	Diminution / Turbidity	No	All	Rapid acquisition. If evaluation on basis of photographic data, then possibility of comparison over time period & less variability due to manipulator. Applicable to whole bathymetric tranche of seagrass distribution. . Can be estimated over large surface areas based on aerial photos or sonograms (side-scan sonar)	Strong seasonal & bathymetric variability (e.g. for Po coverage of 100 % at upper limit at 40 % for lower limit for healthy meadow *in* Boudouresque *et al.*, 2006). Multiples methods used do not always allow comparisons to be made of the results obtained as observation surface areas are very diverse & coverage is fractal. (Romero, comm. pers.). Sampling plan must be adapted to include spatial variability.

1 - Descriptor	2 – measuring method	3.expected response/factors of degradation	4 – destruc. Charac.	5 – target species	6 – Interest	7 – Limits
Percentage of plagiotropic rhizomes (in %)	Counting of plagiotropic rhizomes in a given surface area (which can be represented by a quadrat)	Increase/mechanical effects (anchoring, fishing gear)	No	Cn, Po	Easy, rapid & inexpensive parameter in shallow depths (0 to 20 m).interpretation scale available for Po (Charbonnel *et al*., 2000 *in* Boudouresque *et al*., 2006)	
Presence of inter-mat channels & dead mats	Highly precise mapping of site (Cf. Part I of present document, permanent square) &/or in situ observations Percentage of dead mats & live meadow can be used as a perturbation index. (CI = L/(L+D) ; CI : index of conservation, L : meadow surface area , D :surface area dead mats ; Moreno *et al*., 2001 *in* Boudouresque *et al*., 2006).	Increase/mechanical effects anchoring, fishing gear	No	Po	Easy-to-use parameter. Possible to quantify surfaces areas in view of mapping techniques used	Dead mats are natural components intrinsic to some types of seagrasses (e.g. striped meadows) & do not reflect systematically a regression of seagrasses in response to anthropogenic pressures. (Boudouresque *et al*., 2006)

Tab.7: Synthesis of main descriptors (1) used for monitoring marine magnoliophyta – next.

1 - Descriptor	2 – measuring method	3-expected response/factors of degradation	4 – dest. charact er	5 target species	6 – Interest	7 – Limits
plant information						
Foliar surface area (cm².bundle), & other phenological characteristic s	Counting & measuring the length & width of different types of leaf bundles. (Po : Giraud, 1979 ; Cn : Orfanidis *et al*. 2010)	Foliar surface area (Po) - Diminution / Overgrazing & anthropogenic impacts. Length of leaves. (Po & Cn) – Augmentation / nutriments enhancemen	Yes	All	Easy-to-measure & inexpensive parameter. Possible to measure length of adult leaves type 1 or 2 (most external leaves) in situ & this avoids destruction of plant. ; Lopez Y Royo *et al*., 2010b)	Strong seasonal variability. Strong individual variability so necessary to measure an adequate number of bundles.
Necrosis on leaves (in %)	Percentage of leaves with necrosis, through observation in lab. (Romero *et al*., 2007)	Augmentation / More contaminants	yes	Po	Easy-to-measure & inexpensive parameter	Necrosis very rare in some sectors of the Mediterranean (e.g. Corsica littoral)
State of apex	Percentage of leaves with broken apex	Augmentation / overgrazing	No	Po	Easy-to-measure & inexpensive parameter.	Of little use in case of strong hydrodynamism & on old leaves
Foliar production (in mg dry weight. bundle.$^{-1}$, .yr^{-1})	With Po: possibility, thanks to lepidochronology, to ascertain number of leaves produced in a year, at present or in the past. (Pergent, 1990). Other species, measuring leaves through markings or by using the relationship length/foliar growth of bases/ (Zm; Gaeckle *et al*., 2006).	Diminution / en nutrients deficit, increase in interspecific competition	yes& No (Zm)	Tall	For Po lepidochronology makes it possible to work over whole bathymetric tranche & interpretation scale is available (Pergent *et al*., 2008). For Zm the relationship length of bases & foliar growth makes it possible to have in situ non destructive measuring.	For other species parameter takes long to acquire & necessitates monthly monitoring or at least for 4 seasons. (Gaeckle *et al*., 2006).

Tab.7: Synthesis of main descriptors (1) used for monitoring marine magnoliophyta – next.

1 - Descriptor	2 – measuring method	3 –expected response/factors of degradation	4 – dest. character	5 target species	6 – Interest	7 – Limits
Production of rhizomes (in mg dry weight. bundle.-1, .yr-1)	With Po: possibility,thanks to lepidochronology, to ascertain rate of growth or biomass per year.	Augmentation / Accumulation of sediments due to littoral developments	Yes	Po	Parameter independent of season	Interpretation sometimes difficult as rhizome production increase can be observed in reference sites in the absence of anthropogenic impact.
Recession or burying of rhizomes	Measuring degree of recession or burying of rhizomes measured (value in mm) or percentage of buried or receded bundles on a given surface area	Augmentation in burying / Accumulation of sediments due to littoral developments urban effluent discharge ,presence of marine farms and dredging rejects, Recession increase / Deficit in sediments due to littoral developments	No	Tall	Recession or burying easy to measure in situ, non destructive & inexpensive Parameter independent of the season	

Tab.7: Synthesis of main descriptors (1) used for monitoring marine magnoliophytes – next.

1 - Descriptor	2 – mesuring method	3 –expected response / factors of dégradation	4 – destruct. Charact	5 target species	6 – Interest	7 – Limits
Epiphytes of leaves (in mg dry weight bundle.-1 or % dry weight bundle.-1).	Several measurements possible : evaluation of biomass (µg bundle-1, after scraping, drying & weighing), of nitrogen content (in % dry weight ; measure using simple analyser CHN ; Romero *et al*., 2007)	Augmentation / Increase in nutrients contribution of rivers, (Fernandez-Torquemada *et al*., 2008)	yes	All	Easy-to-measure & inexpensive parameter (biomass). Interpretation scale available (Morri, 1991 in Pergent-Martini *et al*., 2005)	Parameters with strong seasonal & spatial variations. Parameters necessitating specific analytical equipment (nitrogen content)
Physiological or cellular information						
Nitrogen & phosphorus content of plant plant plant phosphorus (in % dry weight)	Dosage through mass spectrometry & plasma torch in different plant tissue after acid mineralisation (e.g. rhizomes of Po ; Romero *et al*., 2007)	Augmentation / Nutrient increase	yes	all	Short response time to environmental changes	Very expensive parameter, necessitating analytical equipment & specific competence
carbohydrates content(in % dry weight)	Dosage through spectrophotometry after alcohol extraction in different plant tissues (e.g. rhizomes of Po ; Alcoverro *et al*., 1999, 2001b *in* Romero *et al*., 2007)	Diminution / anthropogenic Impact	yes	all	Short response time to environmental changes	Expensive parameter necessitating analytical equipment and specific competence

Tab.7 : Synthesis of main descriptors (1) used for monitoring marine magnoliophytes – next.

1 - Descriptor	2 – measuring method	3–expected response/factors of dégradation	4 – destr. Charact	5 target species	6 – Interest	7 – Limits
Trace metal content (in µg.g-1)	Dosage through spectrometry in different plant tissues after acid minéralisation (Salivas-Decaux, 2009).	Augmentation / More metallic contaminants	yes	all	Short response time to environmental changes	Expensive parameter necessitating analytical equipment & specific competence
Nitrogen isotopic relationship (□$^{□}$N in ‰)	Dosage through mass spectrometer in different plant tissues after acid mineralisation (e.g. rhizomes of Po ; Romero *et al*., 2007)	Augmentation / Increase in nutrients from marine farms & urban effluents Diminution / Increase in nutriments from fertilizers	yes	Po	Short response time to environmental changes	Very expensive parameter necessitating analytical equipment & specific competence
Sulphur isotopic relationship (□^{34}S in ‰)	Dosage through mass spectrometer in different plant tissues (e.g. rhizomes of Po ; Romero *et al*., 2007)	Diminution / anthropogenic Impact	yes	Po	Short response time to environmental changes	Very expensive parameter necessitating analytical equipment & specific competence

b) What monitoring system?

Setting up a monitoring system means starting with the data acquisition phase. The observations and sampling during the acquisition phases or data validations of the cartographical surveys, could also constitute the outline of a monitoring system (Kenny *et al.,* 2003) even if it is not just limited to that and cartography could also constitute a monitoring tool (Tab.7; Boudouresque *et al*., 2006).

On a regional geographical level today there are two main types of monitoring systems: the marine magnoliophyta monitoring system (SeagrassNet) which was established on a worldwide level at the beginning of the year 2000 and which covers all the species of marine magnoliophytes (Short et al 2002 and the “Posidonia” monitoring network initiated in the Mediterranean at the beginning of the 1980s (Boudouresque *et al*., 2006) and which is specific to the *Posidonia oceanica* species but which can be adapted to other Mediterranean species and to the genus Posidonia in general. The Posidonia monitoring system is used today, with a degree of variability from one country to another and even from one region to another within the same State (Buia *et al.*, 2004; Boudouresque *et al.*, 2006, Romero et al 2007; Fernandez-Torquemada *et al.,* 2008; Lopez y Royo, 2010a) in at least nine Mediterranean countries and in over 350 sites. After the work carried out within the framework of the Interreg IIIB MEDOCC programme “coherence, development, harmonization and validation of evaluation methods of the quality of the littoral environment by monitoring the *Posidonia oceanica* meadows, and the “MedPosidonia” programme set up by RAC/SPA, an updated and standardized approach for the P. monitoring network has been tested and validated (UNEP-MAP-RAC/SPA). The main differences between these two great systems are:

- Within the framework of SeagrassNet, monitoring is done along the three permanent transects, parallel to the coast and positioned respectively (i) in the most superficial part of the meadow, (ii) in the deepest part and (iii) at an intermediate depth between these two positions. The descriptors chosen (Short *et al.*, 2002; Tab.8) are measured on precise and fixed points along each of the transects every three months.

- Within the framework of the “Posidonia” monitoring system, the measurements are taken (i) at the fixed markers placed along the lower limit of the meadow, (ii) at a portion of the upper limit and (iii) at an intermediate fixed depth of -15 m. The descriptors (Tab. 8) are measured only every three years if after visual control there are no changes in the geographical position of the limits.

If the SeagrassNet makes it possible to compare the data obtained in the Mediterranean with the data obtained in other regions of the world, as it has a world coverage of over 80 sites distributed in 26 countries (www.seagrassnet.org), it is not that suitable for large-size species (Posidonia genus) and for meadows whose lower limit is beyond 25 m depth and which was set up only for one site in the Mediterranean (Pergent *et al.,* 2007).

The descriptors measured basically provide information on the state of health of the meadow concerned. The “Posidonia” monitoring system, in view of the multiplicity of descriptors identified (Tab. 7), makes it possible to compare the different meadows in the Mediterranean and also to evaluate the plant’s vitality and the quality of the environment in which it grows (so that the plant is then used as a global bio-indicator). Monitoring also becomes less of a constraint as the observations can be spaced out over a period of time.

Tab.8: Nature of parameters measured within the framework of the SeagrassNet, Corsica P. Monitoring Network (RSP Corse) (Pergent *et al*., 2007) and the MedPosidonia programme (Pergent *et al*., 2009).

Parameters	SeagrassNet	P. Monit. Network (RSP)	MedPosidonia
Light	X	-	-
Temperature	X	-	X
Salinity	X	-	-
Lower limit	Depth	depth, type and cartography	depth, type, cartography
Upper limite	Profondeur	depth, type and cartography	Cartography
Density	12 measurement along transect	Measurement at each of 11 markers	Measurement at each of 11 markers
% plagiotropic rhizomes	-	Measurement at each of 11 markers	Measurement at each of 11 markers
Receding	-	Measurement at each of 11 markers	Measurement at each of 11 markers
Cover	12 measures along transect	Along markers using (50m) vidéo	Measurement along each of 11 markers
Phenological analysis	12 measures along transect	on 20 bundles	on 20 bundles
lépidochronological analysis	-	on 10 bundles	on 10 bundles
State of apex	-	On 20 bundles	on 20 bundles
Biomass (g. poids sec)	Feuilles	-	-
Necromass	Rhizome & scales	-	-
Granulometry of sédiment	-	1 measurement	1 measurement
% organic material of sédiment	-	1 measurement	1 measurement
Trace-metal content	-	-	Ag & Hg

Other, intermediate techniques between these two methods (permanent transects with seasonal monitoring, acoustic data) can be used in particular situations like the monitoring of lagoon environments (Pasqualini *et al.*, 2006) or for the study of “relic” meadows (Descamp *et al.,* 2009).

It needs to be stressed that:

- In addition to the chosen technique, the measured parameters (Tab. 7 & 8) determine the nature of the monitoring (e.g. monitoring of chemical contamination of the environment, discharge into the sea from a treatment plant, general evaluation of a meadow’s state of health);

- No matter what parameters are chosen, particular attention must be paid to the validity of the measurements made (acquisition protocol, precision of the measurements, reproducibility, whether parameters correspond to expected monitoring data; Lopez Y Royo *et al.*, 2010a).

c) How to interpret monitoring data?

Monitoring data can be interpreted on the basis of what experts say or by comparing the measured data with the data available in the literature, either directly or through scales. The multiplication of studies on *Posidonia oceanica* (over 1000 publications indexed in the Web of Science) means that in the last few decades a growing number of interpretation scales have been set up of the most widely used parameters for monitoring this species (e.g. Giraud, 1977; Meinesz & Laurent, 1978; Pergent *et al.*, 1995b; Pergent-Martini *et al.,* 1999; Montefalcone *et al.,* 2006; Salivas-Decaux *et al.*, in press; Tab. 7).

The implementation of the Water Framework Directive in the European countries has led to:

- An adaptation of some of the scales (rating), (e.g. density *in* Pergent-Martini *et al.,* 1999) with the creation of five classes (bad, poor, moderate, good and high: Annex 3);

- The setting up of synthetic indices to provide, on the basis of a panel of different parameters, (Buia *et al.,* 2004, Pergent *et al.* 2007, Romero *et al.,* 2007, Fernandez-Torquemada *et al.,* 2008, Gobert *et al.,* 2009, Lopez Y Royo *et al.,* 2009, Montefalcone 2009) a global evaluation of the quality of the water masses based on the "marine magnoliophyta" biological quality factor. This panel or range must be based on an adequate number of parameters to avoid evaluation errors but not too many to avoid excessive costs in terms of acquisition time and the budget required. (Fernandez-Torquemada *et al.,* 2008).
  In the present state of knowledge it is difficult to opt for one or other of these synthetic indices as it has not been possible to compare them all on one single site.

Intercalibration trials between the POMI (Romero *et al.,* 2007) and POSID indices (Pergent *et al.,* 2008) have shown that there is a coherence in the classification order of the five sites studied (the Corsican sites had a higher classification than the Catalonia sites). Applying the BIPO index to 9 Mediterranean sites yields an identical classification of the Catalonia sites like the classification obtained with the POMI index (Lopez Y Royo *et al.,* 2010c). Finally, using both the POSID and BIPO indices within the framework of the "MedPosidonia" programme also yielded a similar classification of the meadows studied (Pergent *et al.,* 2009).

The POMI (Romero *et al.,* 2007) and POSID (Pergent *et al.,* 2007) indices are of interest as they are based on several parameters (respectively 14 and 8) which include different levels of organisation (of the population on a cellular level) and therefore response times which can be quite rapid and which yield information on the meadow and the mats, the plant structure and the impact of human activities through an increase in nutrients and the accumulation of trace-metals.

The BIPO index is based only on non-destructive parameters (Lopez Y Royo *et al.,* 2010b) and is particularly well suited for the monitoring of species or protected areas.

Conclusion

The approaches proposed for mapping and for monitoring marine magnoliophyta meadows are therefore similar (Fig. 14 & 15) and can be divided into three stages:

- Planning
- Implementation and data acquisition
- Analysis, data interpretation and archiving

Steps to be taken for mapping marine magnoliophyta meadows

Initial Planning

Definition of mapping objectives (e.g. heritage inventory, impact study, knowledge, monitoring over a period of time)

Determination of surface area to be mapped and the necessary precision

Identification of tools to be used and the survey strategy

Evaluation of requirements (necessary means such as human, material and financial resources)

Survey data per se

Acquisition of the necessary data with complementary tools: optical methods and/or random observation for the superficial tranche (0 to -15 m), acoustic methods and/or random observations for the lower tranche (beyond -15 m).

Validation of acquired data with geo-located in situ observations which are numerous enough and distributed appropriately (e.g. with the necessary precision, heterogeneity of habitats).

Accurate archiving of data (what data, why, by whom, how and where?)

Data processing and interpretation

Data processing and classification (e.g. reference list of Mediterranean marine habitats)

Data interpretation (e.g. direct interpretation, according to what the experts say, or statistical modeling on the basis of available observations).

Preparation of map using standardized representations.

Evaluation of reliability of results (e.g. quality of the bibliographical data used, suitable surveying techniques, % of the surface area really inventoried in relationship to the mapped area, precision of positioning, heterogeneity of habitat….).

Fig. 14: Synthesis of the approach proposed for cartography

Steps to be taken for setting up a monitoring system for marine magnoliophyta meadows

Initial planning

Definition of monitoring objectives (e.g. control within the framework of developments in the environment, monitoring for regulatory purposes, monitoring over a period of time of trends for heritage and conservation reasons.

Locating sites to be monitored

Identifying parameters to be taken into account by targeting different levels of organization (e.g. population, individual, and cell) and setting up a sampling strategy.

Evaluation of requirements (necessary human, material and financial resources).

Setting up the monitoring system

Positioning of structures to ensure monitoring over time (e.g. fixed markers, buoys, transects…).

Acquisition of parameters chosen at the initial phase and establishing a reference report or initial report for each of the monitored sites.

Regular return visits to the sites in line with the monitoring strategy and enhance the chosen parameters.

Data processing and interpretation

Measurements made in situ to be analyzed and archived
Data interpretation (.e.g. according to the experts, direct interpretation through comparison with data from the literature or through the interpretation grids or existing indices).

Checking that the results obtained respond to the monitoring objectives (reliability and reproducibility of the results, valid interpretations and coherence with the observations made).

Fig. 15: Synthesis of approach proposed for monitoring.

There are no ideal methods for mapping or universal parameters for the monitoring of marine magnoliophyta meadows but rather a great diversity of efficient and complementary tools. They must be chosen depending on the objectives in mind and the species present and the local context.

As for cartography, an integration into a Geo-referenced Information System which can be freely consulted (like MedGIS implemented by RAC/SPA), is to be recommended and should be encouraged, so that the data acquired becomes available to the wider public and can be of benefit to the maximum number of users.

As for effective monitoring, this should be done over a period of time even if it means limiting the number of sites being monitored and the number of parameters. The parameters should be adequate enough to avoid errors of interpretation but sufficiently reduced in numbers to ensure permanent monitoring. The nature of the parameter is less important than reproducibility, reliability and the precision of the method used for its acquisition.

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Annex 1 – Keynote presentation at the Round table, organized by RAC/SPA in Hvar (September 2009)

Context

3rd Mediterranean Symposium on marine vegetation (Marseille 2007)

Creation of a tool-box for studying seagrasses

Proposition of guidelines for the mapping and the monitoring

Questionnary

Mapping

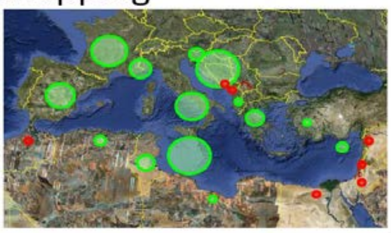
- How the situation is?
- Are there methods?
- For each, is it necessary to propose a standardization?
- Are they relevant for all the Mediterranean species?
- Are they applicable in each mediterranean countries?
- Avantages and limits?

Monitoring

- How the situation is?
- Are there methods?
- For each, is it necessary to propose a standardization?
- Are they relevant for all the Mediterranean species?
- Are they applicable in each mediterranean countries?
- Avantages and limits?

Mapping

Present situation ?



Main methods used

MESH

http://www.ifremer.fr/posidonia/

http://www.searchmesh.net/

Is standardization useful or required ?

Monitoring

Present situation ?

Existing methods

SeagrassNet

Descriptors of Posidonia oceanica meadows: Use and application. C. Pergent-Martini a, V. Leoni a,*, V. Pasqualini a, G.D. Ardizzone b, E. Balestri c, R. Bedini d, A. Belluscio b, T. Belsher e, J. Borg f, C.F. Boudouresque g, S. Boumaza h, J.M. Bouquegneau i, M.C. Buia j, S. Calvo k, J. Cebrian l, E. Charbonnel g, F. Cinelli c, A. Cossu m, G. Di Maida k, B. Dural n, P. Francour o, S. Gobert i, G. Lepoint i, A. Meinesz o, H. Molenaar o, H.M. Mansour p, P. Panayotidis q, A. Peirano r, G. Pergent a, L. Piazzi c, M. Pirrotta k, G. Relini s, J. Romero t, J.L. Sanchez-Lizaso u, R. Semroud h, P. Shembri f, A. Shili v, A. Tomasello k, B. Velimirov w

→ Is a Mediterranean Monitoring System possible ?

Annex 2 – Summary of the Round table, organized by RAC/SPA in Hvar (September 2009)

« Standardization of methods for mapping and monitoring seagrasses in the Mediterranean region»

Chairs: Christine Pergent-Martini & Aslam Djellouli
Rapporteur: Cecilia Lopez y Royo

The context

The RAC/SPA is responsible at regional level of the implementation of the conservation Action Plan of the Mediterranean marine vegetation. During the 3rd Mediterranean Symposium on marine vegetation, in Marseille, in March 2007, a general request was formulated: the development of a common tool-box for monitoring seagrass.
The RAC/SPA therefore proposes to develop, together, guidelines for the development of this common toolbox to map and monitor seagrasses at Mediterranean level.

For this purpose, and in the context of this round table, a basic questionnaire has been prepared:

Mapping
- How the situation is?
- Are there methods?
- For each, is it necessary to propose a standardization?
- Are they relevant for all the Mediterranean species?
- Are they applicable in each mediterranean countries?
- Avantages and limits?

Monitoring
- How the situation is?
- Are there methods?
- For each, is it necessary to propose a standardization?
- Are they relevant for all the Mediterranean species?
- Are they applicable in each mediterranean countries?
- Avantages and limits?

Discussion

Mapping

The present situation has been illustrated in Christine Pergent Martini's presentation (morning session). There is certain coverage in N Mediterranean, however is this sufficient?

A variety of methods have been adopted to map seagrass beds, which mainly include satellite images, aerial photography, Side Scan Sonars, ROVs, field measures, etc.

Concerning standardization of mapping methods, two research projects have approached the subject:

- An Interreg project, which compares the different mapping methods in terms of aim, cost and reliability.
- The MESH programme, which developed guidelines on the ability in Europe to map seagrass, however information on the Mediterranean is scarce.

The issue of cost of mapping entire coastlines was raised. In this context, the reduction of areas to be mapped is inevitable, however it is essential to keep in mind the importance of following a rationale in the selection of areas (i.e. reference sites vs impacted sites).

In addition, although financial limitations are an important issue, these do not prevent laboratories and research institutes to agree on a common tool-box of methods.

No additional comments were made concerning mapping methods.

Monitoring

The present situation has been illustrated in different presentations during the morning session. Operational *P.oceanica* monitoring networks result in a good coverage of the NW Mediterranean,and have been developed in certain areas of the southern and eastern Mediterranean. However there are important geographical gaps, in which it would be interesting to develop additional monitoring networks.

Methods to monitor seagrass, in particular *P. oceanica*, are numerous and varied. A published paper clearly summarises the different descriptors and methods adopted around the Mediterranean (Pergent-Martini *et al*., 2005).
Considering this variety of methods, is it possible to develop a common toolbox of methods and to develop a Mediterranean monitoring network?

In terms of standardisation of methods to measure desciptors, two aspects have to be considered:

- The definition of a descriptor and,
- The method to measure this descriptor.

Is it necessary to adopt a unique definition of common descriptors (e.g. cover)? A single common definition for each descriptor would be in line with the Mediterranean regional approach. However it is difficult to reach given different labs’ expertise and habits.
Is it necessary to standardize methods to measure descriptors? A strong request was expressed by managers, for experts to reach standardization at least for the most commonly used descriptors.

The issue of number and type of descriptors to be used in a monitoring programme was also raised. The choice of descriptors has to clearly correspond to the objectives of the monitoring programme, in terms of type of information required, timeframe, etc. Ideally the common toolbox of methods should contain protocols for a certain number of descriptors. Therefore, all or part of this toolbox will be included in the monitoring network (in relation to its objectives).

In addition, the experimental design with which you measure these parameters is essential too. The adoption of an inadequate experimental design could lead to data interpretation errors.

Proposals

- Fred Short: to create a hierarchy of parameters. A hierarchy of parameters that can be measured by all, according to the information they provide. This would allow to request financial support step by step, as well as to report results in a visible way to managers.

  However, the parameters included in the hierarchy should have a clearly defined protocol.
- As a clearly defined protocol has been defined for the MedPosidonia programme, can’t this protocol be used as the basis to discuss the development of the common toolbox of methods to map and monitor seagrass in the Mediterranean?

Conclusions

The protocol of the MedPosidonia programme and the SeagrassNet manual that are available online (RAC/SPA and SeagrassNet websites) could be used to build this common tool-box.

Christine Pergent-Martini is available to discuss this protocol further with all the scientific community.

Annex 3 – Grids of interpretation into five classes of few descriptors of *Posidonia oceanica* meadow

Meadow structure

Type of lower limit (UNEP-MAP-RAC/SPA, 2009b)

	High	Good	Moderate	Poor	Bad
L. inf.	Progressive	Sharp C+	Sharp C-	Sparse	Regressive

Type de limite	**Main Chatacteristics**
Progressive	Plagiotropic rhizome beyond the limit
Sharp – High cover (C+)	Sharp limit with cover above than 25%
Sharp – Poor cover (C-)	Sharp limit with cover lower than 25%
Sparse	Shoot density lower than 100 shoots/m^{-2}, cover lower than 15%
Regressive	Dead matte beyond the limit

Depth of the lower limit (in m; UNEP-MAP-RAC/SPA, 2009b)

	High	Good	Moderate	Poor	Bad
Lower limit	> 34.2	34.2 to 30.4	30.4 to 26.6	26.6 to 22.8	< 22.8

Leaf cover (in percentage; UNEP-MAP-RAC/SPA, 2009b)

	High	Good	Moderate	Poor	Bad
L. inf.	> 35%	35% to 25%	25% to 15%	15% to 5%8	< 5%

Shoot density (number of shoots per m²)

Profondeur (en m)	High		Good			Moderate			Poor			Bad	
1	>	1133	1133	to	930	930	to	727	727	to	524	<	524
2	>	1067	1067	to	863	863	to	659	659	to	456	<	456
3	>	1005	1005	to	808	808	to	612	612	to	415	<	415
4	>	947	947	to	757	757	to	567	567	to	377	<	377
5	>	892	892	to	709	709	to	526	526	to	343	<	343
6	>	841	841	to	665	665	to	489	489	to	312	<	312
7	>	792	792	to	623	623	to	454	454	to	284	<	284
8	>	746	746	to	584	584	to	421	421	to	259	<	259
9	>	703	703	to	547	547	to	391	391	to	235	<	235
10	>	662	662	to	513	513	to	364	364	to	214	<	214
11	>	624	624	to	481	481	to	338	338	to	195	<	195
12	>	588	588	to	451	451	to	314	314	to	177	<	177
13	>	554	554	to	423	423	to	292	292	to	161	<	161
14	>	522	522	to	397	397	to	272	272	to	147	<	147
15	>	492	492	to	372	372	to	253	253	to	134	<	134
16	>	463	463	to	349	349	to	236	236	to	122	<	122
17	>	436	436	to	328	328	to	219	219	to	111	<	111
18	>	411	411	to	308	308	to	204	204	to	101	<	101
19	>	387	387	to	289	289	to	190	190	to	92	<	92
20	>	365	365	to	271	271	to	177	177	to	83	<	83
21	>	344	344	to	255	255	to	165	165	to	76	<	76
22	>	324	324	to	239	239	to	154	154	to	69	<	69
23	>	305	305	to	224	224	to	144	144	to	63	<	63
24	>	288	288	to	211	211	to	134	134	to	57	<	57
25	>	271	271	to	198	198	to	125	125	to	52	<	52
26	>	255	255	to	186	186	to	117	117	to	47	<	47
27	>	240	240	to	175	175	to	109	109	to	43	<	43
28	>	227	227	to	164	164	to	102	102	to	39	<	39
29	>	213	213	to	154	154	to	95	95	to	36	<	36
30	>	201	201	to	145	145	to	89	89	to	32	<	32
31	>	189	189	to	136	136	to	83	83	to	30	<	30
32	>	179	179	to	128	128	to	77	77	to	27	<	27
33	>	168	168	to	120	120	to	72	72	to	24	<	24
34	>	158	158	to	113	113	to	68	68	to	22	<	22
35	>	149	149	to	106	106	to	63	<	63			
36	>	141	141	to	100	100	to	59	<	59			
37	>	133	133	to	94	94	to	55	<	55			
38	>	125	125	to	88	88	to	52	<	52			
39	>	118	118	to	83	83	to	48	<	48			
40	>	111	111	to	78	78	to	45	<	45			

Plagiotropic rhizome (in percentage ; UNEP-MAP-RAC/SPA, 2009b)

	High	Good	Moderate	Poor	Bad
Lower. limit	> 70%	70% to 30%	< 30%		

Plant Structure

Foliar surface (in cm² per shoot), between June and July (UNEP-MAP-RAC/SPA, 2009b)

	High	Good	Moderate	Poor	Bad
-15 m	> 362	362 to 292	292 to 221	221 to 150	< 150

Number of leaves produced by year (UNEP-MAP-RAC/SPA, 2009b)

	High	Good	Moderate	Poor	Bad
-15 m	> 8.0	8.0 to 7.5	7.5 to 7.0	7.0 to 6.5	< 6.5

Rhizome elongation (in mm per year; UNEP-MAP-RAC/SPA, 2009b)

	High	Good	Moderate	Poor	Bad
-15 m	> 11	11 to 8	8 to 5	5 to 2	< 2

Environment eutrophication

Nitrogen concentration in adult leaves (in percentage, between June and July; UNEP-MAP-RAC/SPA, 2009b)

	High	Good	Moderate	Poor	Bad
-15 m	< 1.9%	1.9% to 2.4%	2.4% to 3.0%	3.0% to 3.5%	> 3.5%

Organic matter in the sediment (in percentage, fraction 0.063 mm; (UNEP-MAP-RAC/SPA, 2009b)

	High	Good	Moderate	Poor	Bad
-15 m	< 2.5%	2.5% to 3.5%	3.5% to 4.6%	4.6% to 5.6%	> 5.6%

Environment contamination (Salivas-Decaux, 2009)

Argent Concentration (mg per g DW), blade of adult leaves, between June and July

	High	Good	Moderate	Poor	Bad
-15 m	< 0.08	0.08 to 0.22	0.23 to 0.36	0.37 to 0.45	> 0.45

Cadmium Concentration (mg per g DW), blade of adult leaves, between June and July

	High	Good	Moderate	Poor	Bad
-15 m	< 1.88	1.88 to 2.01	2.02 to 2.44	2.45 to 2.84	> 2.84

Mercury Concentration (mg per g DW), blade of adult leaves, between June and July

	High	Good	Moderate	Poor	Bad
-15 m	< 0.051	0.051 to 0.064	0.065 to 0.075	0.075 to 0.088	> 0.088

Plomb Concentration (mg per g DW), blade of adult leaves, between June and July

	High	Good	Moderate	Poor	Bad
-15 m	< 1.17	1.17 to 1.43	1.44 to 1.80	1.81 to 3.23	> 3.23