MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

A set of guidelines to support the development of management plans

MMMPA

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A set of guidelines to support the development of management plans

With the participation of:

Edited by MMMPA Supervisory Board

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FOREWORD

With the aim to address some of the complex needs of Marine Protected Areas (MPAs) management, the results of the "Monitoring Mediterranean Marine Protected Area" project (MMMPA) are here synthesized in a series of timely and original guidelines.

These guidelines provide support for Marine Protected Area (MPA) managers with multiple objectives.

Monitoring and evaluation systems are needed to ensure that the goals and objectives of MPAs are achieved. Monitoring systems vary regarding what they measure, who performs the measuring, where, when and how measures are made. They must be carefully designed and must include good baseline data, robust indicators and possibly control sites. The monitoring systems depend on the characteristics of the MPA. In many cases, the financial resources to adequately structure and achieve the goals are not available. A priority is represented by the need to record changes in the ecology of the MPA, asking for the evaluation of the cascade effects of changes on the local communities.

Considering the management discrepancy between the existing Mediterranean MPAs, it is urgent to define strategies and converge upon concrete monitoring priorities. Indeed, one of the main issues faced by Mediterranean MPA managers relates to ensuring a continuous, long-term basic monitoring of specific indicators. The lack of shared and standardized methodologies for the monitoring of Mediterranean MPAs, both regarding environmental and socio-economic aspects, transforms what should be an institutional task into a real practical challenge.

The MMMPA project merged 'traditional' monitoring techniques (e.g., visual census, video/photosampling, genetic tools, assessment of trophic status) with approaches from emerging interdisciplinary fields (e.g., underwater georeferred biocartography, genetic connectivity, biogeochemistry, trophic chains and holistic socio-economic approaches). Building upon this "contamination", the present guidelines can be grouped according to four main topics: habitat assessment (*Gianni and Mangialajo, this issue.; Mateos-Molina et al., this issue; Markantonatou et al., this issue; Zapata et al., this issue*), ecosystem functioning (*Arevalo et al., this issue; Cabana et al., this issue; Prato et al. this issue*), genetic connectivity (*Marti-Puig et al., this issue*), and social sciences (*Hogg et al., this issue; Young et al., this issue; Markantonatou et al., this issue*). More in detail, for what concerns habitat assessment there is a focus on algal forests, on the coralligenous habitat and on the importance to monitor changes in terrestrial landscapes, as well. The monitoring of ecosystem functioning is approached considering coastal high trophic level predators pathways as well as lagoon habitats. Genetic connectivity is addressed for both pelagic and benthic species. Finally, as sustainability is one of the main scope of MPAs, which relates to understanding and managing human behaviour and the use made of natural resources, social components must be at the forefront of MPA monitoring strategies. Three guidelines have therefore been specifically built to address social aspects.

Guidelines have a common general structure. Each document includes:

1. An introduction highlighting why managers should take the specific topic into account.
2. A section about the methodologies that should be applied to implement the monitoring in the most cost-effective way.
3. A case study provided as an example.
4. A section containing general conclusions.

Ready-to-use, visual infographic versions of the guidelines are presented to facilitate uptake and use.

The realization of these guidelines would not have been possible without the cooperation of all the partners associated to the MMMPA network. Their generous contribution, in terms of time and knowledge, was essential to support the studies on all the different topics carried out during the project. Moreover, MPAs, by hosting the researchers during their training secondments, allowed not only the completion of effective research but also permitted true management experience of each study case.

In particular we are indebted to:

- Reserva Marina de Cabo de Palos e Islas Hormigas
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- Area Marina Protetta di Tavolara – Punta Coda Cavallo
- Area Marina Protetta Isola di Ustica
- Area Marina Protetta Isole Tremiti
- Management Agency of Messolonghi-Aetoliko lagoons, estuaries of Acheloos, Evinos and Echinades islands
- Studio Associato GAIA
- OceanScan Marine Systems & Tecnology, Lda
- Med Ingegneria srl
- National Oceanography Centre (NOC), Natural Environment Research Council (NERC)
- NOAA - National Ocean Service National Centers for Coastal Ocean Science

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LARGE BROWN ALGÆ FORESTS

MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

GUIDELINES FOR THE CONSERVATION, MONITORING AND RESTORATION OF CYSTOSEIRA FORESTS IN THE MEDITERRANEAN SEA

Fabrizio Gianni[1,2] and Luisa Mangialajo[1,2]

In this document we propose guidelines with simple and replicable methods that may be applied by MPA managers in order to evaluate the distribution and status of marine forests, and, eventually, restore them.

Why focus on marine forests?

In the Mediterranean Sea, marine forests of large-brown seaweeds are mostly formed by the genus *Cystoseira* and *Sargassum* (order Fucales), distributed from the surface up to several meters depth *(Ballesteros, 1992)*. Most of the species belonging to these genus are ecosystem engineers, because they create unique habitats offering substrate, food and shelter to other algae and a large amount of invertebrates and fish *(Ballesteros et al., 1998)*. Based on their ecology and zonation, we can differentiate species forming belts in the very shallow infralittoral fringe, forests in rock-pools (photophilous species thriving in rock-pools), shallow subtidal forests (photophilous species thriving in the upper infralittoral zone) and deep forests (sciaphilous forests thriving in the circalittoral zone) **(Fig. 1)**.

However, loss of Mediterranean forests has been observed in many coastal areas. Coastal urbanization, marine pollution and outbreak of herbivores (i.e. sea urchins and herbivorous fish) are some of the most important factors affecting marine forests *(for a review see Mineur et al., 2015)*. For this reason, almost all Mediterranean *Cystoseira* and *Sargassum* species are listed in two European Conventions *(Barcelona Convention, 1976 and Bern Convention, 1979)*, but very few tangible focused actions have been carried out so far for their conservation, monitoring and management, especially as concern the assessment of marine forests distribution or the establishment of marine protected areas (MPAs). An exception is the cartography of *Cystoseira* belts in the infralittoral fringe performed to assess the ecological status of coastal waters using the CARLIT index, under the Water Framework Directive (WFD) 2000/60/EU *(Ballesteros et al., 2007, Mangialajo et al., 2007)*. This index is applied in the North-Western Mediterranean and in the Adriatic Sea, but it is often performed only on limited stretches of the rocky coastlines. In addition, most of the marine forests distribution in the subtidal zone is still largely unknown, also because the cartography needed for the institution of the Natura 2000 sites only reports 'photophilous algae on rocky bottom', without any distinction among deserts of encrusting corallinales, turf-forming algae, shrubs of erect algae or forests of large-brown seaweeds.

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Therefore, it is extremely important to increase our knowledge on marine forests, updating maps on their distribution, following their evolution over time and, if necessary, considering restoration *(Gianni et al., 2013)*. These actions are particularly important in MPAs, in order to give the managers the tools necessary to conserve existing marine forests or the restoration of damaged ones, allow the survival of many other associated organisms, including some species of fish, and detect impacts that may affect rocky-bottom communities.

Here we propose some guidelines with simple and replicable methods that may be applied by scientists/MPA managers in order to evaluate the distribution and status of marine forests.

Monitor *Cystoseira* forests is important because:

- They produce oxygen.
- They are reproductive and nursery habitats.
- They export organic matter to other systems.
- You can early detect impacts affecting rocky bottoms communities.

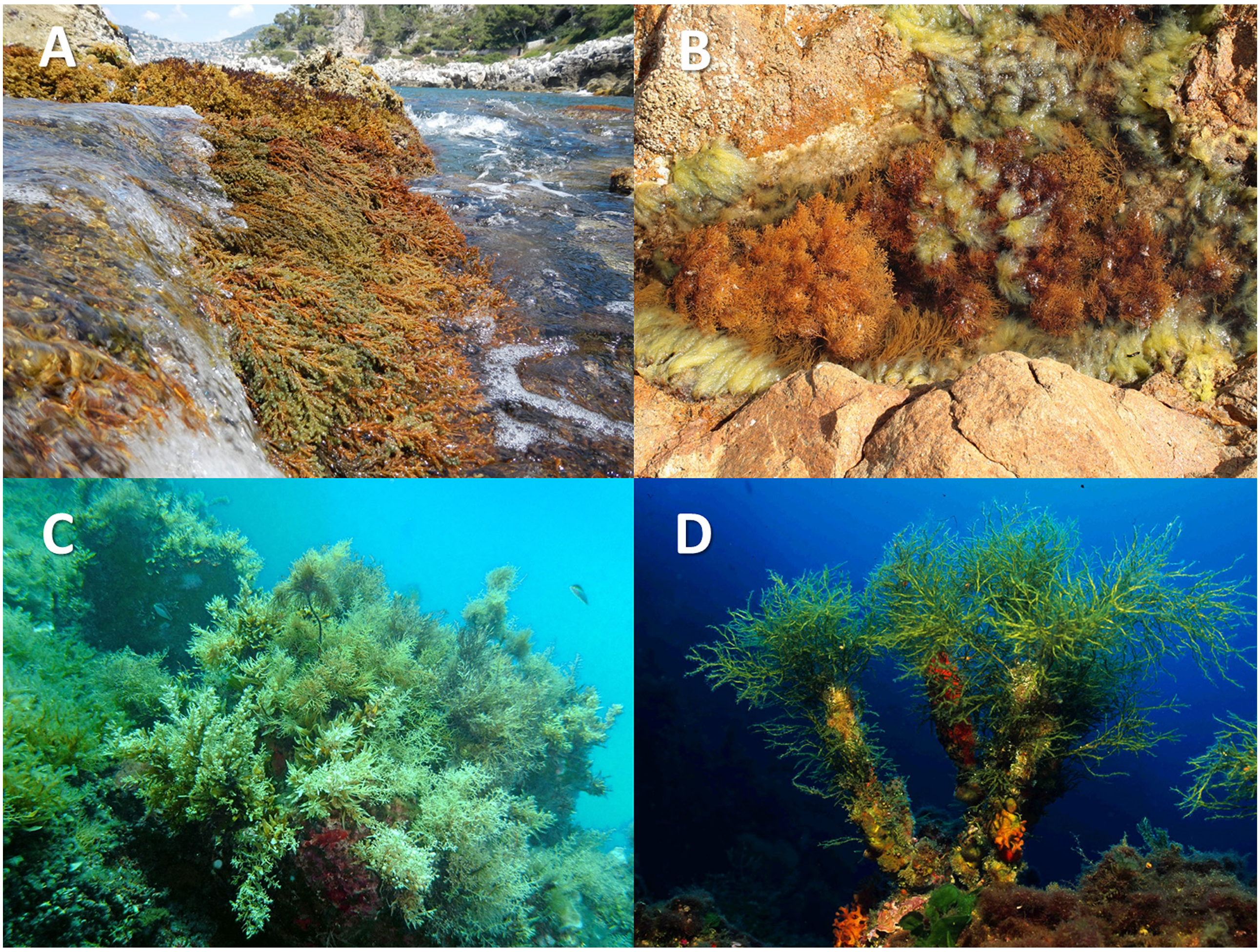

Figure 1. *Cystoseira* forests in the infralittoral fringe (A), in rock-pools (B), in the infralittoral zone (C) and in the circalittoral zone (D). (Photos A: Gianni, F.; B: Parisi, L.; C: Mangialajo, L.; D: Ballesteros, E.).

Cystoseira species should become a conservation priority in the future context of Mediterranean Sea management

How to conserve, monitor and, eventually, restore marine forests

In order to conserve, monitor and, if required, restore marine forests, we suggest following a few steps allowing to plan the adequate actions. These steps can be performed by trained MPA staff, because they are easy to apply and involve low-cost techniques. At the beginning of the monitoring/restoration process, experts can help to train MPA staff and with the identification of some species.

Are marine forests present in the area?

In order to enhance conservation of marine forests the first gap to fill is the lack of knowledge on their distribution in MPAs. In some cases, information on Fucales distribution in the target areas is already available from past surveys, so that a literature search should be performed first. Expert judgment can be useful in this phase. Then, a detailed cartography has to be carried out in order to have information on *Cystoseira* presence and distribution in MPAs. The presence and distribution of very shallow species (species forming belts and the forests in rock-pools) can be evaluated by a small pneumatic boat/kayak and/or snorkelling. Scuba diving is generally used for both shallow and deep subtidal species, but progress has been made with the use of remote control engines (cameras, ROVs).

It is recommended to map the entire surface of the protected area, in order to have complete information on the rocky-bottom communities present in the MPA and address future management actions in the best way. During surveys, it is essential to georeference data on species distribution, using a GPS tracker or detailed orthophoto maps for very shallow species. This procedure will permit to create georeferenced and detailed maps in GIS environment that could be used by MPA managers as baseline maps in order to evaluate marine forests evolution over time and manage potentially impacts affecting these important habitats.

What is the conservation status of marine forests?

Once marine forests distribution is available, their conservation status should be assessed with non-destructive techniques.

The status of *Cystoseira* belts in the infralittoral fringe can be evaluated with linear transects as for the CARLIT index calculation *(Ballesteros et al., 2007 , Nickolić et al., 2013)*. The coastline is mapped and *Cystoseira* abundance is visually estimated and associated to a value corresponding to three categories (1: isolated individuals; 2: dense and numerous populations; 3: algal forests forming almost continuous or continuous belts). The survey is carried out by two operators, proceeding very close to the coast in kayak or by a small pneumatic boat. Transects can be coupled to replicated quadrats (20 × 20 cm) randomly placed into *Cystoseira* belts in order to estimate the percentage of coverage. This last method can be also applied to monitor the status of Fucales in rock-pools and potentially may be coupled to an assessment based on Braun-Blanquet abundance classes.

Cystoseira populations of the infralittoral and circalittoral zones are assessed with transects performed by a team of scuba divers *(Perkol-Finkel and Airoldi, 2010)*. We suggest to do a rough estimation of the forests covering the rocky bottom by using 25 m transects. Along each transect, changes in rocky bottom communities/habitats (e.g. *Cystoseira* canopies, mosaic of different species, seagrass meadows, turfs, barren grounds, etc.) are recorded at a small scale of variability (20-50 cm). If *Cystoseira* canopies are present, randomly quadrats (50 × 50 cm side) can be performed inside the forests to assess the status: the density of individuals and the height of the axes is estimated for species with a single axis (monopodial species), while the percentage of coverage and/or the number of axes and/or the maximal height is estimated for species with multiple axes at the base (sympodial species). Estimation of biomass can be obtained by applying conversion factors to some features of the individuals (e.g. axis length for the monopodial species, coverage, etc.). If sea-urchins barren grounds are present, it is important to note them and eventually assess the density of individuals based on size classes.

Is an action necessary to protect marine forests?

In case *Cystoseira* stands are in regression or are lost, the first step is to investigate the causes of such decline and, whenever possible, manage the sources of the impact that threatens or generated the loss of the forests (e.g. water discharge, herbivores overgrazing).

If a restoration action is deemed necessary to enhance *Cystoseira* recovery, we suggest to choose a non-destructive forestation method. However, being the restoration of marine forests still at an experimental stage, it may be necessary at the beginning of these actions a collaboration with experts. Several approaches are available, depending on the species and the environmental conditions *(see Gianni et al., 2013 for details)*. The most easy-to apply methods are the installation of fertile receptacles in the target areas or the interception of embryos, but more sophisticated methods, such as the culture of embryos/juveniles in laboratory can be planned.

Based on the scientific literature *(see Gianni et al., 2013 for a review)* and following the results of the studies we performed (see below), it appears important to set up herbivores exclusions to avoid high grazing rates at least in the first phases of the restoration.

Regular monitoring of marine forest

All forests thriving in the MPA (healthy, suffering or recently restored) should be regularly monitored, in order to detect any human impact at the first stages of development (e.g. proliferations of herbivores) or assess the success of the restoration action.

In the case of healthy forests, the same techniques proposed for the assessment of their conservation status should be applied. In the case of monitoring following a restoration action, different variables can be measured, like density and mortality of recruits or adults and/or fertility of the individuals. If possible such variables should be compared to healthy forests in order to understand when the restored forest matches the features of the natural ones and can be considered self-sustaining.

We suggest to monitor *Cystoseira* forests once a year during spring (the season of maximal growth of the primary branches). All these methods are cheap and can be coupled to other monitoring activities performed by the MPA staff in order to reduce the costs.

A flow-chart, proposed in a recent review on marine forests *(Gianni et al., 2013)*, resumes hypothetical conservation, monitoring and non-destructive restoration actions to undertake, and highlighting the paramount role that MPAs should play for the protection of marine forests **(Fig. 2)**.

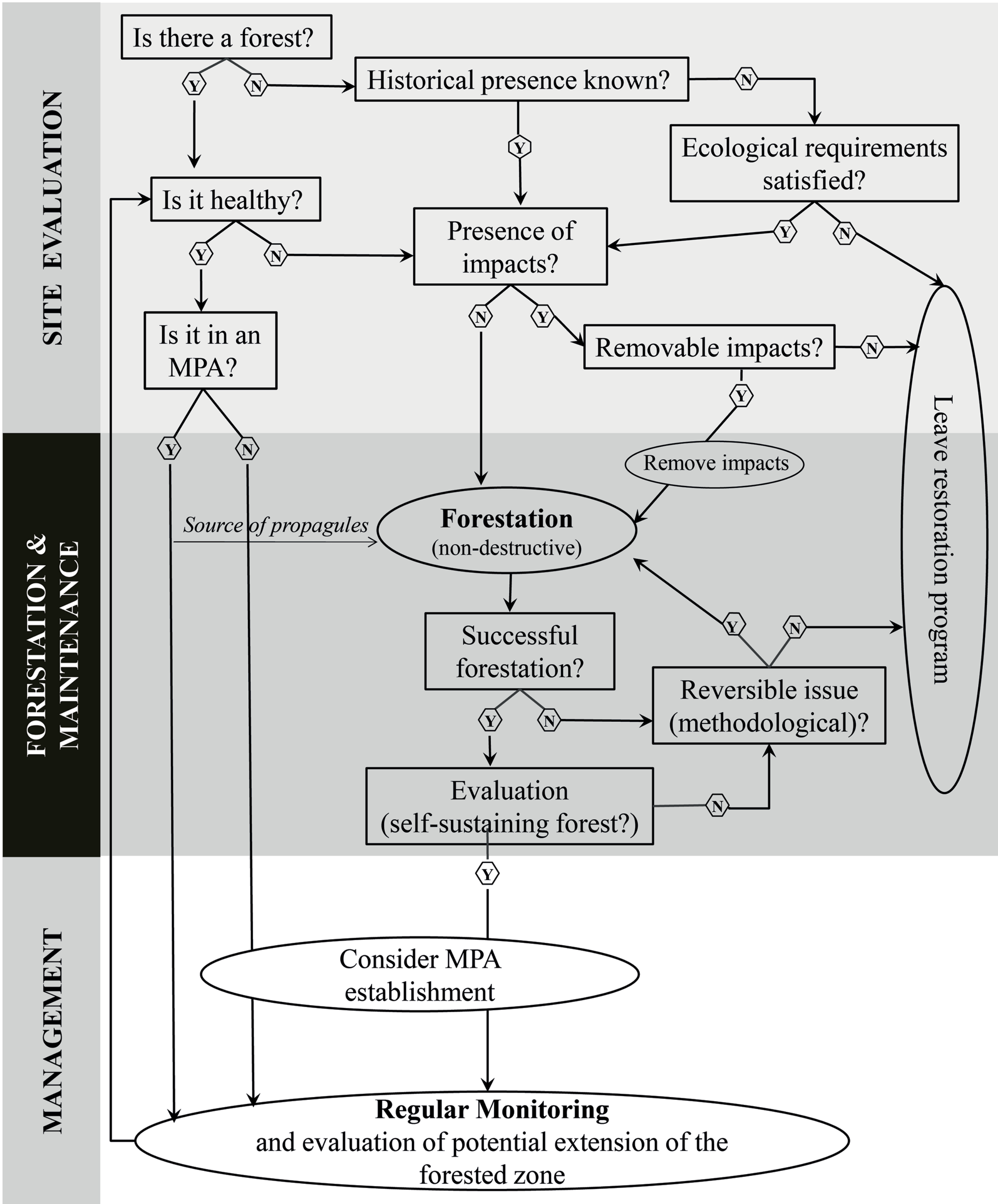

Figure 2. Conservation, monitoring and forestation of *Cystoseira* species in the Mediterranean Sea should follow some practical steps to be successful *(modified by Gianni et al., (2013))*.

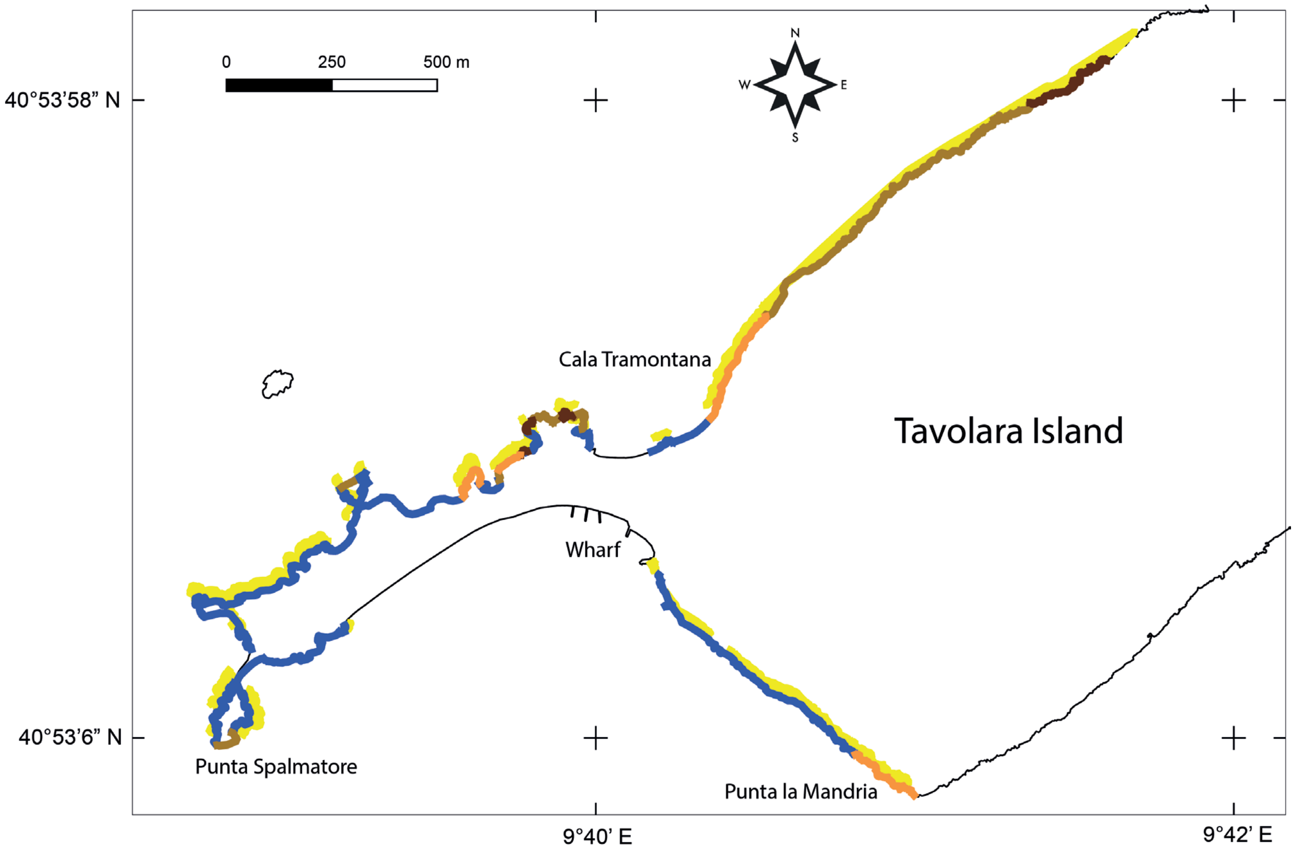

Figure 3. A stretch of coast of Tavolara Punta Coda Cavallo MPA in Italy, showing the distribution of *Cystoseira compressa* (in yellow) and *Cystoseira amentacea* (orange lines: isolated individuals; light brown lines: dense and numerous groups; dark brown lines: algal belts almost continuous or continuous; blue lines: absence).

Practical applications and examples

In the framework of the Programme ITN-MMMPA (International Training Network on Monitoring Mediterranean Marine Protected Areas), we assessed shallow marine forests distribution in three Mediterranean MPAs: Portofino, Tavolara-Punta Coda Cavallo and Ustica island (Italy) in spring/summer 2013 – 2014. Information on historical distribution of Fucales in these MPAs was, firstly, collected by searching in the scientific literature and asking the MPA managers. The research revealed a general lack of knowledge on marine forests distribution and highlighted the necessity to do a cartography in such MPAs. Intertidal macroalgal communities were surveyed applying a simplified CARLIT method (as described above), while Fucales in rock-pools and in the upper-infralittoral zone were assessed by snorkelling.

For instance, in Tavolara-Punta Coda Cavallo MPA, *Cystoseira* and *Sargassum* are well represented: we observed up to eleven taxa including new species, never described in the MPA. Overall, up to 90% of the surveyed coastline is covered by Fucales. *Cystoseira* forests of the infralittoral fringe are characterized by almost continuous belts and density of the canopies is mostly linked to the physical features of the coast (e.g. wave exposure, morphology). Upper-infralittoral forests are also abundant and continuous along the coasts of the MPA, formed by a mosaic of different species.

Finally, data were georeferenced in GIS maps **(Fig. 3)** that will be provided to the managers in order to inform them on the presence of Fucales in their MPAs and support decisions. The surveys conducted in this study represent a starting point for future monitoring of Fucales and for checking their evolution in these three MPAs.

Concerning ecological restoration research, several experiments were carried out in the French Riviera with the aim to improve *Cystoseira* restoration techniques. Our studies showed that herbivorous fish, very likely *Sarpa salpa*, were the main herbivores able to reduce the restoration success of *Cystoseira amentacea* in the infralittoral fringe of artificial structures. Such results were confirmed by experiments in tanks. Subsequently, the effect of fish grazing was also quantified on natural *Cystoseira* populations, highlighting an important loss of growth and reproductive potential.

Our studies demonstrated that herbivorous fish are highly responsible to reduce the success of *Cystoseira* restoration and severely graze on natural populations. Likely, their role in regulating very shallow macroalgal assemblages has been overlooked so far. Even if we cannot state it with the current knowledge, *Sarpa salpa* population in the Mediterranean Sea has probably increased in the last decades due to the overfishing of its predators, and in particular in MPAs *(Prado et al., 2008)*. We suggest that future conservation and restoration actions of marine forests, also in MPAs, take into account herbivorous fish exclusion or regulation by means of devices to protect forests, including *Sarpa salpa* in target fishing species and favouring the recovery of top-predators.

Conclusions

In the future context of Mediterranean Sea management, ecologically relevant and sensitive species, as *Cystoseira*, should become a conservation priority. The awareness on the importance of marine forests of large-brown seaweeds should be raised and cartographies should be performed, especially in MPAs where information is scarce, but also in non-protected sensitive areas where *Cystoseira* forests are still healthy and deserve attention. Then, on the base of a complete and detailed habitat mapping of marine vegetation, a regular monitoring of such forests should be included in MPA management plans in order to evaluate first signs of regression due to local human impacts and/or ecological dynamics. Restoration plans can be considered to enhance *Cystoseira* recovery when necessary and if all the conditions for a successful restoration are guaranteed. However, the conservation of the existing pristine forests has always to be considered as priority, since it is the most effective tool for conservation and it represents the only way for preserving older marine forests that are still present in some remote zones of the Mediterranean Sea.

References

Ballesteros, E., 1992. *Els vegetals i la zonació litoral: espècies, comunitats i factors que influeixen en la seva distribució. Institut d'Estudis Catalans. Vol. 101.*

Ballesteros, E., Sala, E., Garrabou, J., Zabala, M., 1998. *Community structure and frond size distribution of a deep water stand of Cystoseira spinosa (Phaeophyta) in the northwestern Mediterranean. European Journal of Phycology. 33 (2), 121-128.*

Ballesteros, E., Torras, X., Pinedo, S., García, M., Mangialajo, L., De Torres, M., 2007. *A new methodology based on littoral community cartography dominated by macroalgae for the implementation of the European Water Framework Directive. Marine Pollution Bulletin. 55, 172-180.*

Gianni, F., Bartolini, F., Airoldi, L., Ballesteros, E., Francour, P., Guidetti, P., Meinesz, A., Thibaut, T., Mangialajo, L., 2013. *Conservation and restoration of marine forests in the Mediterranean Sea and the potential role of Marine Protected Areas. Advances in Oceanography & Limnology. 4 (2), 83-101.*

Mangialajo, L., Ruggieri, N., Asnaghi, V., Chiantore, M., Povero, P., & Cattaneo-Vietti, R. (2007). *Ecological status in the Ligurian Sea: The effect of coastline urbanisation and the importance of proper reference sites. Marine Pollution Bulletin, 55(1), 30-41.*

Mineur, F., Arenas, F., Assis, J., Davies, A.J., Engelen, A.H., Fernandes, F., Malta, E., Thibaut, T., Van Nguyen, T., Vaz-Pinto, F., Vranken, S., Serrão, E.A., De Clerck, O., 2015. *European seaweeds under pressure: Consequences for communities and ecosystem functioning. Journal of Sea Research. 98, 91-108.*

Nikoli V., Žuljevi A., Mangialajo L., Antoli B., Kušpili G., Ballesteros E., 2013. *Cartography of littoral rocky-shore communities (CARLIT) as a tool for ecological quality assessment of coastal waters in the Eastern Adriatic Sea. Ecological Indicators, 34: 87-93.*

Perkol-Finkel, S., Airoldi, L., 2010. *Loss and recovery potential of marine habitats: an experimental study of factors maintaining resilience in subtidal algal forests at the Adriatic Sea. PLoS one. 5 (5), e10791.*

Prado, P., Farina, S., Tomas, F., Romero, J., Alcoverro, T., 2008. *Marine protection and meadow size alter fish herbivory in seagrass ecosystems. Marine Ecology Progress Series. 371, 11-21.*

MONITORING CYSTOSEIRA FORESTS

Monitoring and restoration of Cystoseira forests in Marine Protected Areas of the Mediterranean Sea

WHY MONITOR IT?

- oxygen producers
- reproductive and nursery habitats
- they export organic matter

HOW TO MONITOR IT?

1 ARE THERE ALGAE FORESTS?

LITERATURE SEARCH
for prior available information

DETAILED CARTOGRAPHY
expanding on found literature

PUT DATA INTO GIS
for automated proccessing

2 WHAT IS ITS CONSERVATION STATUS?

FORESTS FORMING BELTS AT THE WATER SURFACE LEVEL
CARLIT method + quadrats for density/coverage

SUBTIDAL FORESTS
Line transects + quadrats for density/coverage

ENVIRONMENTAL VARIABLES
human impacts, sea urchins density, substrate morphology, etc.

3 IS THERE ACTION REQUIRED?

INVESTIGATE CAUSES OF REGRESSION
e.g. water discharge, herbivores overgrazing

NON-DESTRUCTIVE FORESTATION
from installing fertile receptacles to laboratory cultures

HERBIVORE EXCLUSION
to avoid high grazing rates

4 FURTHER MONITORING

YEARLY MONITORING
Preferably in spring

SAME METHODS AS INITIAL ASSESSMENT

WHAT TO EXPECT

Detailed cartography of marine forests in the MPA → Health status of marine forests → Need for impacts management and/or forests restoration

LAND COVER CHANGES

MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

ASSESSMENT OF LAND COVER CHANGES TO DETERMINE POTENTIAL IMPACTS ON WATER QUALITY IN COASTAL MARINE PROTECTED AREAS

Daniel Mateos-Molina[1,2], Marco Palma[2], Idelfonso Ruiz-Valentin[3], Panos Panagos[4], José A. García-Charton[1], Massimo Ponti[5]

Land cover changes have a strong influence on sediment delivery to coastal waters, being a well-recognized threat to near shore marine habitats. This guideline provides managers with a powerful tool to detect potential runoff increases and make better and preventive coastal-land management decisions.

Why assess land cover change

Changes in land cover can increase the runoff of sediments, pollutants and nutrients into coastal waters *(Syvitski et al., 2005)*, having negative effects on benthic habitats due to increased water turbidity and siltation, and declines in water quality. In particular, increased turbidity is a major threat to seagrass meadows *(Erftemeijer and Lewis, 2006)*, while increased siltation may have dramatic effects on subtidal macroalgal assemblages *(Airoldi and Virgilio, 1998)*.

In the last decades, land-cover in coastal areas of the Mediterranean Sea has been vastly altered by land development policies *(Falcucci et al. 2006)* affecting MPAs success. Therefore the necessity of integrated approaches far beyond the MPA boundaries and better understanding of the potential impact of land cover changes in coastal ecosystems is critical to improve marine and coastal ecosystem-based management, and current management plans.

It is important to monitor land cover change because:

- Changes in land cover can increase the runoff of sediments into coastal waters
- It is crucial for actual, preventive and effective land and coastal management decisions
- The necessity of integrated approaches far beyond the MPA boundaries

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How to monitor land cover change

Geographic Information Systems (GIS) provide the opportunity to integrate the data collected and produce spatial results. In our approach the basin is to be delineated with high resolution Digital Elevation Model (DEM) data *(European Union open access data)*. The quality of the DEM will define the precision of the flow direction, flow accumulation, outflows and delineation of the basins. Aerial photographs should be used to detect possible human alterations to the natural flow regimes of rivers at the outflows.

Later, we used a simplified Revised Universal Soil Loss Equation (RUSLE) model to assess the potential change on basin's sediment delivery driven by the land cover changes in areas surrounding MPAs. The combination of RUSLE model and sediment delivery ratio (SDR) methodology was used in this study to compare the estimations of sediment delivery yield at the outflow of each basin over time. This research is "low cost" because the cost is the time expended to collect the open access information available from European Commission data portals such as European Soil Data Centre (ESDAC). Later, data analysis and modelling can be done by a person with intermediate GIS knowledge.

Key stages in the assessment of the consequences of land cover changes at regional levels:

1. Define study area and collect data from regional and European agencies.
2. Organize data in GIS.
3. Delineate the basins and identify outflow points.
4. Run RUSLE model and sediment delivery at the outflow point.
5. Compare results between years and identify what kind of land cover has changed to provoke this change.
6. Identify basins with increases in sediment delivery at the outflow.

Detection of changes on sediment deliveries is a “low cost” approach based on open access data, crucial for making effective coastal-land management decisions.

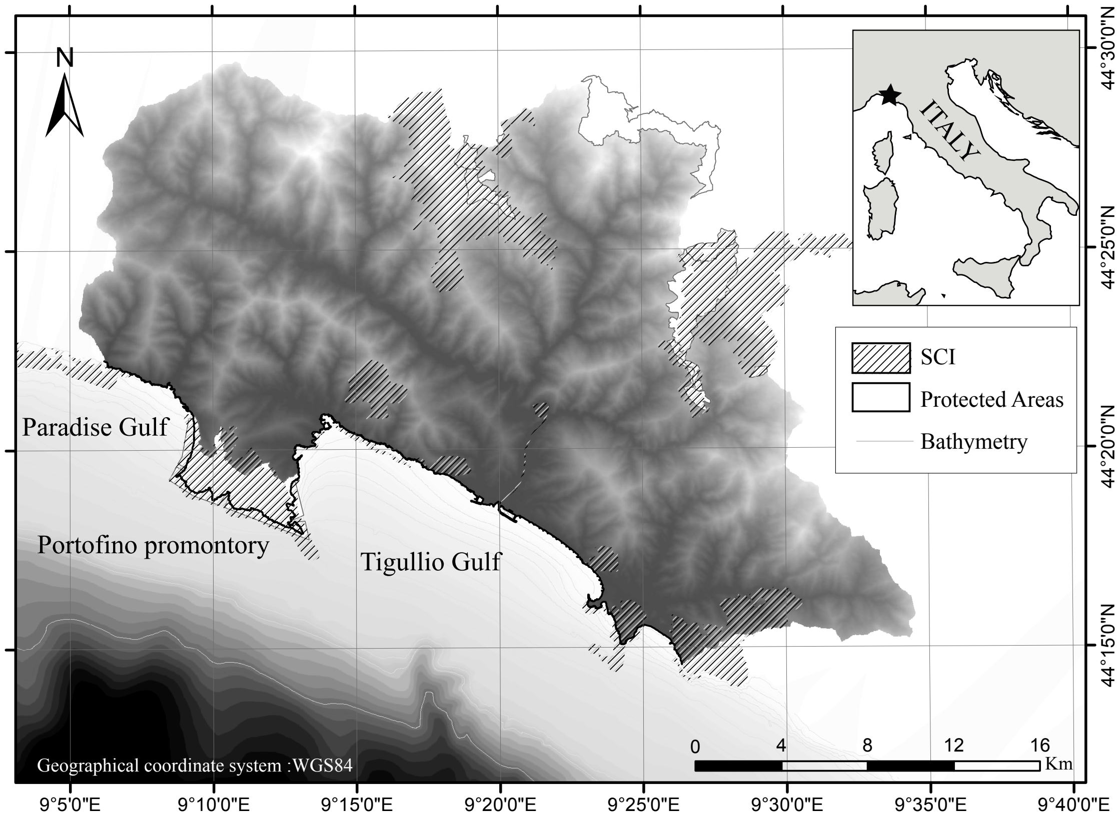

Figure 1. Study area, including bathymetry and digital elevation model.

Portofino MPA: a case study

The study area extends 75 km of coastline, from the Paradiso Gulf to Manara Cape, along the Ligurian Sea (northwestern Mediterranean Sea), and includes 58,919 ha of water catchment area. The stretch of coastline shared with the catchment area includes the Portofino national Marine Protected Area (Portofino MPA, 67 and 5 marine Sites of Community Importance *(SCIs, European Habitats Directive, 92/43/EEC)* **(Fig. 1)**. *Posidonia oceanica* meadows extend for about 296 ha along the coasts of the Paradiso and Tigullio Gulfs, while coralligenous habitats extend for about 51 ha in front of the Manara Cape and Portofino Promontory.

The whole coastal area of the study has an important role in the regional economy as it is extensively used for beach and nautical tourism, SCUBA diving, and fisheries, among others *(Italian National Institute of statistics, ISTAT, 2007)*. The inland area is characterized by a mountainous territory with steep seaward slopes, which increases the quantity of terrigenous material draining to the Ligurian Sea shelf *(Vietti et al., 2010)*

Conclusions

The potential changes in sediment delivery and soil erosion risk due to land cover changes were estimated for sixteen basins along 75 km of coastline, from the Paradiso Gulf to Manara Cape. Some basins showed dramatic changes in their potential sediment delivery yield to coastal waters in the last two decades because of land cover changes. The strongest changes happened individually in two different basins in the periods 1990-2000 and 2006-2012 meanwhile the period 2000-2006 showed several changes in several basins with less estimated change **(Fig. 2)**.

The use of land cover changes as a proxy of potential sediment delivery changes at the outflows and the assessment of the erosion risk at regional scale are a crucial source of knowledge for:1) the early monitoring and detection of changes in the coastal biodiversity; 2) actual, preventive and effective land and coastal management decisions.

This study suggests that a holistic ecosystem-based approach to understand the complexity of land-sea interactions is crucial.

Preventive measures like forest conservation or good agricultural practices (e.g. terraces/stonewalls, grass margins, contour farming) should be incorporated in land management plans, giving priority to basins that threaten most sensitive marine habitats or, at least, considering this aspect, among others, into well integrated environmental policies, going beyond the classical application of integrated coastal zone management.

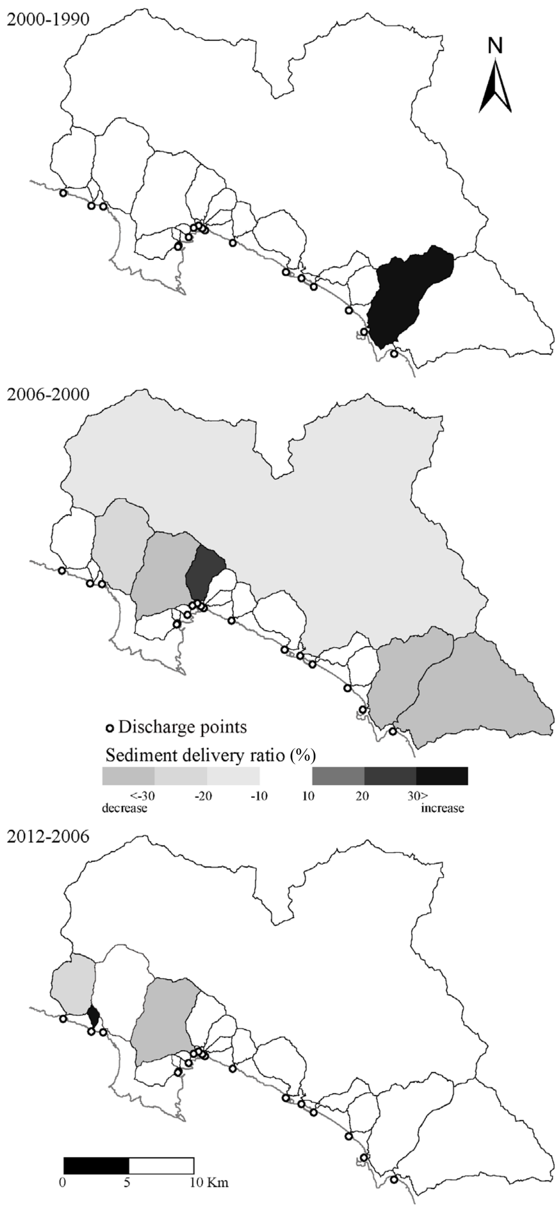

Figure 2. Potential sediment delivery changes by basin in different periods of time.

References

Airoldi, L., Virgilio, M., 1998. *Responses of 240 turf-forming algae to spatial variations in the deposition of sediments.* Marine Ecology Progress Series. 165, 271–282. doi:10.3354/meps165271

Erftemeijer, P.L. a, Lewis, R.R.R., 2006. *Environmental impacts of dredging on seagrasses: a review.* Marine Pollution Bulletin. 52, 1553–72. doi:10.1016/j.marpolbul.2006.09.006

Falcucci, A., Maiorano, L., Boitani, L., 2006. *Changes in land-use/land-cover patterns in Italy and their implications for biodiversity conservation.*Landscape Ecology 22, 617–631. doi:10.1007/s10980-006-9056-4

Syvitski, J.P.M., Vörösmarty, C.J., Kettner, A.J., Green, P., 2005. *Impact of humans on the flux of terrestrial sediment to the global coastal ocean.* Science 308, 376–80. doi:10.1126/science.1109454

Vietti, R., Albertelli, G., Aliani, S., S.Bava, Bavestrello, G., Cecchi, L. Benedetti, Bianchia, C.N., Bozzoa, E., Capelloa, M., Castellanoa, M., Cerranoa, C., Chiantorea, M., Corradia, N., Cocito, S., Cutroneoa, L., G. Diviacco, Fabianoa, M., Faimali, M., Ferraria, M., Gasparini, G.P., M. Locritani, Mangialajoa, L., Marina, V., Morenoa, M., Morria, C., Relinia, L.O., L.Panej, Paolia, C., Petrilloa, M., P.Poveroa, Pronzatoa, R., Relinia, G., Santangeloe, G., Tuccia, S., Tunesik, L., M.Vacchik, P.Vassalloa, L.V. j and M.W., 2010. *The Ligurian Sea: present status, problems and perspectives.* Chemical Ecology. 26, 319–340.

MONITORING LAND COVER CHANGES

Assessment to determine potential impacts on water quality in coastal marine protected areas

WHY MONITOR IT?

Land cover changes can cause increased sediment runoff

Crucial information for effective MPA management decisions.

Allows for integrated, far reaching policies.

HOW TO MONITOR IT?

1

DEFINE AREA AND COLLECT DATA

Collect relevant data from regional and european agencies.

2

ORGANIZE DATA IN GIS

Input all data into GIS for analysis

3

DELINEATE WATERSHEDS

Identify the outflow points in the study area.

4

RUN RUSLE MODEL

Run the RUSLE equations on sediment delivery at the outflow point.

5

COMPARE RESULTS BETWEEN YEARS

Identify what kind of land cover has changed to provoke this change.

6

IDENTIFY DELIVERY INCREASES

Identify basins with potential increases in sediment delivery at the outflow.

WHAT TO EXPECT

Monitor land cover changes to identify outflows with potential sediment delivery changes

Early detection of changes in coastal biodiversity

Effective land and coastal management decisions

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FISHING IMPACT

MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

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GUIDELINES FOR MONITORING PRESSURE AND IMPACTS FROM SMALL SCALE AND RECREATIONAL FISHING ACTIVITY IN MEDITERRANEAN MARINE PROTECTED AREAS

Vasiliki Markantonatou[1], Michele Marconi[1], Carlo Cerrano[1]

Developing reliable, transparent and robust monitoring strategies to provide high-resolution of fishing activity distribution is a key challenge in marine resource management.

Why monitor fishing activity in Marine Protected Areas

Monitoring and management of small scale and recreational fisheries is one of the most important challenges that MPAs have to encounter from a socio-economical, cultural and ecological point of view. Fishing activity is considered a significant threat due to the exploitation of fish stocks. Intensive fishing may alter the habitats' health status directly through mechanical destruction and abrasion, or indirectly from the re-suspension of sediments and lost fishing gear *(Bo et al., 2014; Gilman, 2015)*. Spatial and temporal allocation of fishing effort is fundamental for understanding the impacts from the activity on vulnerable habitats and seafloor integrity *(Markantonatou et al., 2014)*. The present monitoring guidelines mainly focus on the fishing effort perspective and the capacity that this information may provide to address sound management decisions. Prato et al. *(2015)* provide complementary information on management response regarding the fishing catch.

It is important to monitor fishing activity because:

- Secures long-term, sustainable fisheries from an ecological and socio-economic point of view
- Assists managers and policy makers to mitigate impacts on vulnerable habitats, sustain fish stocks and protect ecosystem goods, functions and services
- Assures sustainable exploitation and equal distribution of marine resources in a transparent and efficient way

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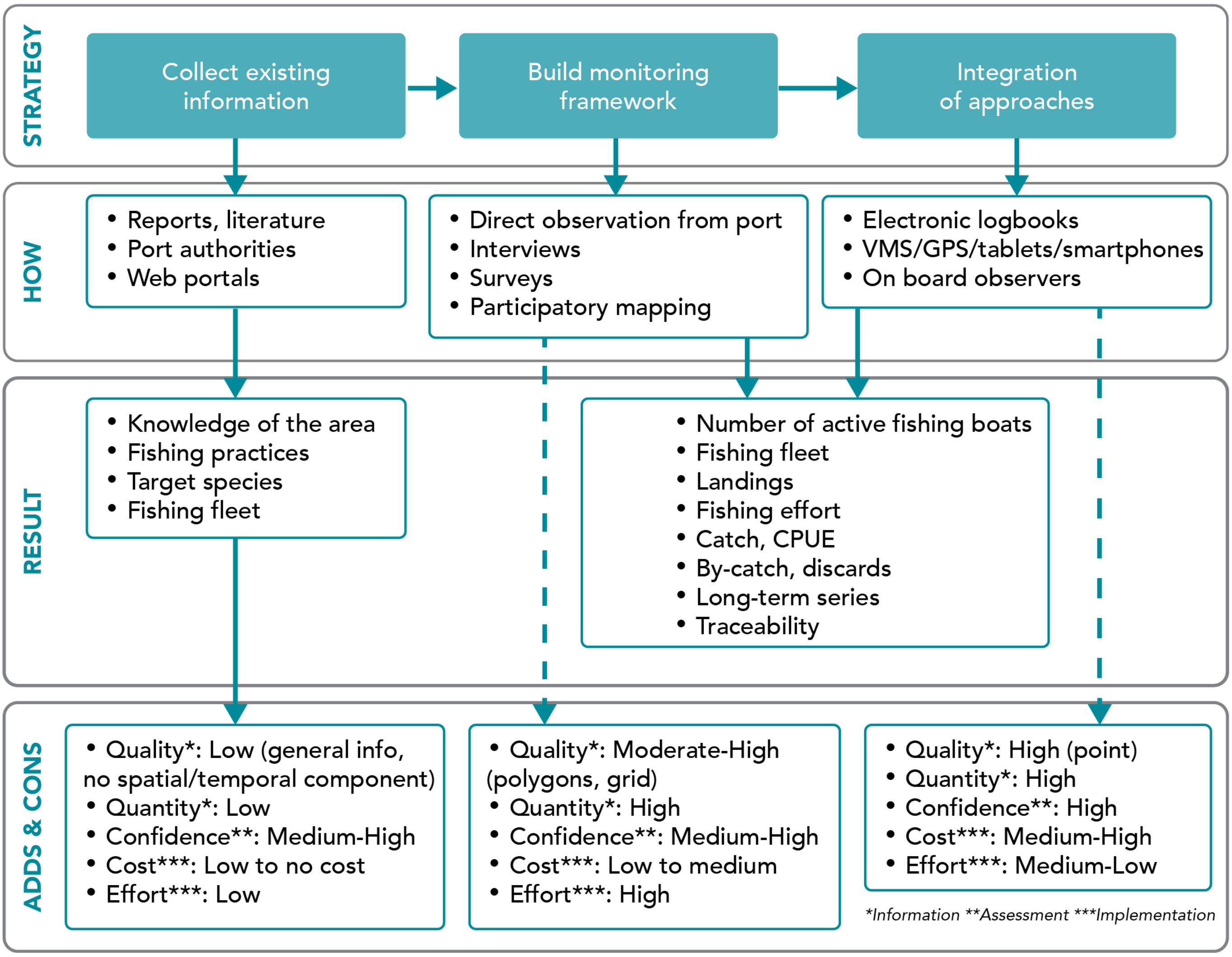


Figure 1. Monitoring frameworks, sources of information, advantages and disadvantages of each monitoring strategy.

Preparation of monitoring framework:

Define the boundaries of study area and create a grid of equally distributed cells (for no point data) as spatial units of reference. In order to monitor fishing activity, geo-referenced layers of bathymetry and habitat distribution should be available. There are several different methods to monitor fishing activity **(Fig. 1)**. The selection of the approach highly depends on the MPA capacity (e.g. staff, budget, trust-bond relationships with fishers and relevant port authorities etc.). The adoption of more than one monitoring strategy, for instance logbooks (systematic monitoring) and interviews and/or questionnaires (once per year, or more frequently), is suggested in order to ensure efficient monitoring data in terms of quantity and quality.

Monitoring of fishing activity:

Fishing activity may be allocated based on integration of heterogeneous data if spatial scale is carefully selected. We present a cost-efficient and flexible monitoring protocol **(Table 1)** that may ensure successful spatial allocation of fishing activity. Trained MPA staff and students, expertised researchers and relevant port authorities may collect field information through the establishment of agreements or collaborations in research projects.

Data can also be collected through advanced web tools (e.g. SeaSketch[1], OceanMapTool[2]), mobile apps (e.g. DONIA[3]) or administered real-time GPS location data transmitted through satellites (AIS, VMS) such as Marine Traffic[4], although the cost increases tremendously considering the provi-

This is a generic framework for long-term monitoring that integrates powerful analysis and visualization, providing a holistic assessment and scientific advice towards ecosystem based fisheries management.

Fishing activity	Access to information	Outcome
Fisherman & boat name Port registered License number Distance from coast (license) Boat characteristics (length, LFT, GRT, engine power, engine type)	EU Fleet Database (http://ec.europa.eu/fisheries/fleet) Coastguard Port authorities	Authorized maximum distance from coast; mapping information when spatial information is absent Fleet description Introduction of non-synthetic compounds (gasoline, oil etc.)
Number of personnel Salary of personnel Nationality of personnel Total expenses per year (license, fuel, personnel, gears etc.)	Interviews Coastguard Port & fishing authorities	Labour market Socio-economic, cost-benefit analysis
Fishing ground (area, depth, distance from coast, substrate type, habitat type)	Indicate on map all fishing grounds Use GPS (coordinates of position of net - start and end point of net deployment)#	Fishing grounds Mapping accuracy
Fishing gear(s)*/techniques**	Indicate gears in every fishing ground Show a list of fishing practices**	Gear footprints
Gear features	Net height and length, material* Line length, number and size of hooks, bait (lines) Number of traps, type, surface, bait	Mapping accuracy Wear resistance Force of gear practice & retrieval Invasive species (bait)
Months per year	Indicate in every fishing ground per gear, or provide % from total in every area	Fishing effort (per month, per season, per year) Fishing effort (days, trips, hours)
Days per month		
Fishing trips per day		
Number of gears/ hauls per trip		
Hours of gear active Date & time of gear deployment & retrieval#		
Additional questions -Dimension of mesh size, hooks, traps etc. -Main catch (target species, number individuals, aver. kg/month) - Bait used -By catch, discards (species, number individuals, aver. size) -Trace of catch (restaurants, local market, direct selling, personal consumption) - Cost (fuels, gears, licenses etc.)	Indicate per fishing ground Collect information on prices from fishermen and restaurants, market	Catch (Aver. kg/year, CPUE) Mapping of species Evaluation of fish population status Trophic food web (see Prato et al., 2015) Socio-economic, cost-benefit analysis

Asterisks refer specifically to artisanal (*) or recreational fishing (**), while # refers particularly to on board observers or logbook information.

sion of smartphones or tablets and Internet access (*Markantonatou et al., 2013*). Moreover, the average age of fishermen in several Mediterranean countries hinders the use of high technology unless proper training is offered.

In any case new technologies for fisheries data collection advance in providing accurate spatial data and locating violations (e.g. Global fishing Watch)[5].

Mapping fishing activity (ArcGIS software):

Bathymetry is a prerequisite layer for mapping fishing. It can be easily created through interpolation in ArcGIS using bathymetric lines and known depth points. Management and local regulations of the wider area are also necessary to set spatial rules (e.g. fishing closures). Information such as areas' acronyms, distance from coast, habitat and substrate type may increase mapping accuracy. Other tools may be useful in the case of information gaps, such as Google Earth for recreational

fishing assists in the identification of areas with access from coast, authorized distance from coast *(Giakoumi et al., 2013; Mazor et al., 2014)*, common depth technique is practiced *(Markantonatou et al., 2014)*.
In the case of point information (e.g. GPS, VMS/AIS[6], boat observers), the spatial deviation equal to 10% of the gear length ('buffer') should be drawn around the location of gear deployment accounting for uncertainty of fixed nets location (Stelzenmüller et al., 2008). In the case of fishing from coast, distance from coast is considered more accurate for mapping than depth *(Markantonatou et al., 2014)*. Confidence levels are defined by assessing the quality and quantity of information following the precautionary principle.

Fishing effort per gear expressed as total number of hours per temporal unit (e.g. season or year) is suggested as the most appropriate indicator in order to characterize fishing pressure on benthic habitats and sea bottom **(Fig. 2)**.

Trends from past information may provide an additional indicator to inform decisions regarding the emergence of management response. Identification of metiérs may also take place in this phase using spatial analysis tools *(e.g. Tzanatos et al., 2013)*.

Pressure assessment:

Overlaying in ArcGIS the habitat map and fishing effort may identify areas that receive different levels of fishing activity. Vulnerable habitats receiving the highest fishing pressure may be defined as the ones receiving 90% of the total effort occurring for a specific fishing gear, as suggested by the Data Collection Framework (DCF) of the Common Fishery Policy *(EC, 2008; EC, 2008)*.

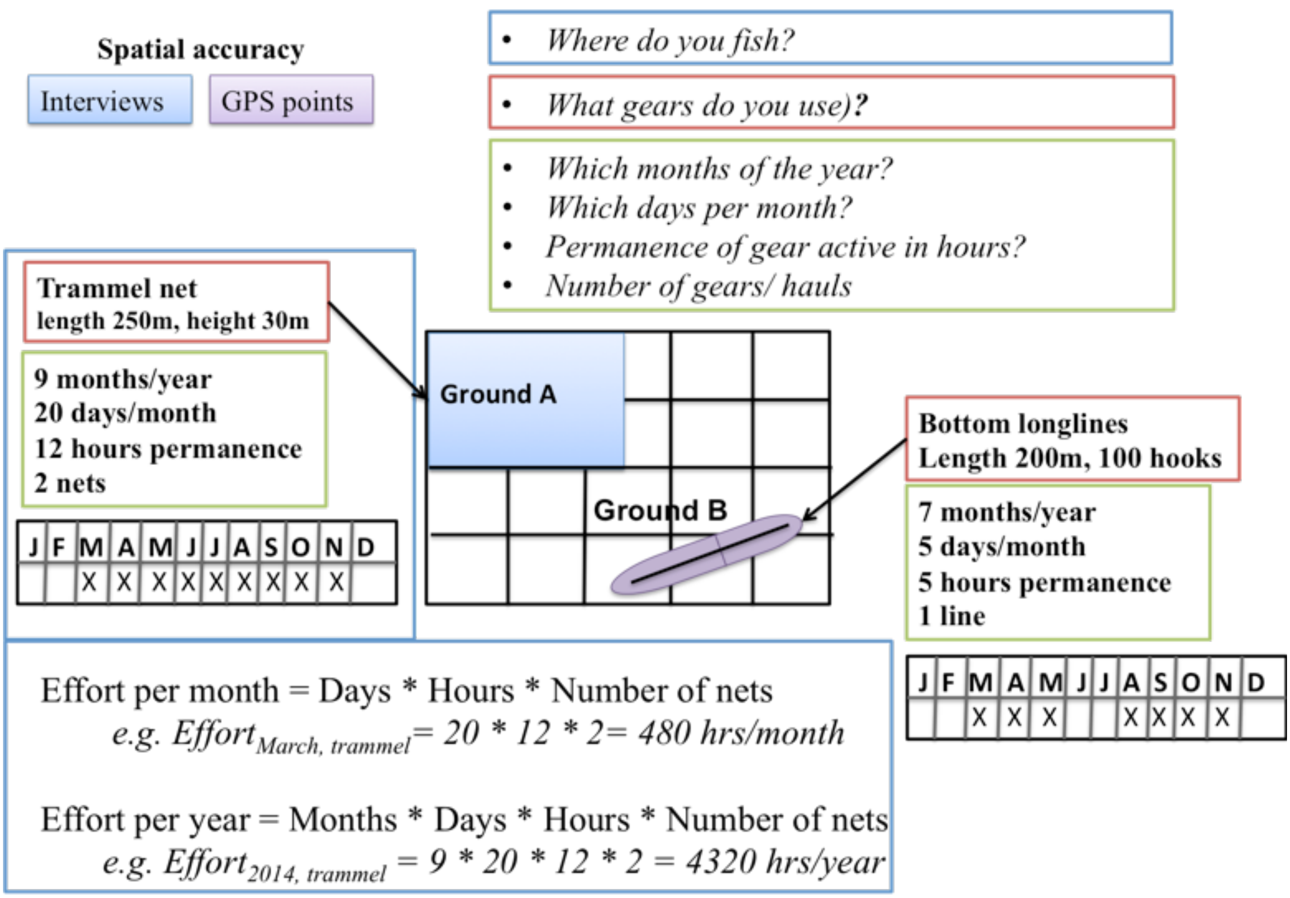


Figure 2. Example of minimum information necessary for spatial allocation of fishing activity. The difference in quality of information between area (interviews) vs. point information (e.g. GPS, VMS, boat observers) is also depicted.

3

Capacity of geo-referenced fishing effort:

(I) Risk assessment: the potential risk of degradation or loss of a vulnerable habitat considering the different level of impacts from fishing practices and the vulnerability of the habitat *(amongst others Knights et al., 2015; Robinson et al., 2013)*.

(II) Verification of information, such as species distribution modelling, by catch and lost fishing gear *(e.g. Markantonatou et al., in prep.)*.

(III) Bio-economic modelling finding optimal harvesting policy in combination with no-take MPAs, or exploring the implications for effort allocation *(e.g. Briscoe et al. 2014; Torres et al., 2015)*.

(IV) Cumulative impact assessments *(Halpern et al., 2007)*.

(V) Stock assessments and trophic food web modelling regarding the catch information *(e.g. Prato et al., in prep.)*.

(VI) Marine Spatial Planning and Systematic conservation planning: designing of MPAs and zoning plans with the least opportunity cost, examination of conservation targets reached *(Marxan and Marxan with Zones software, Ball et al., 2009; Watts et al., 2009)*.

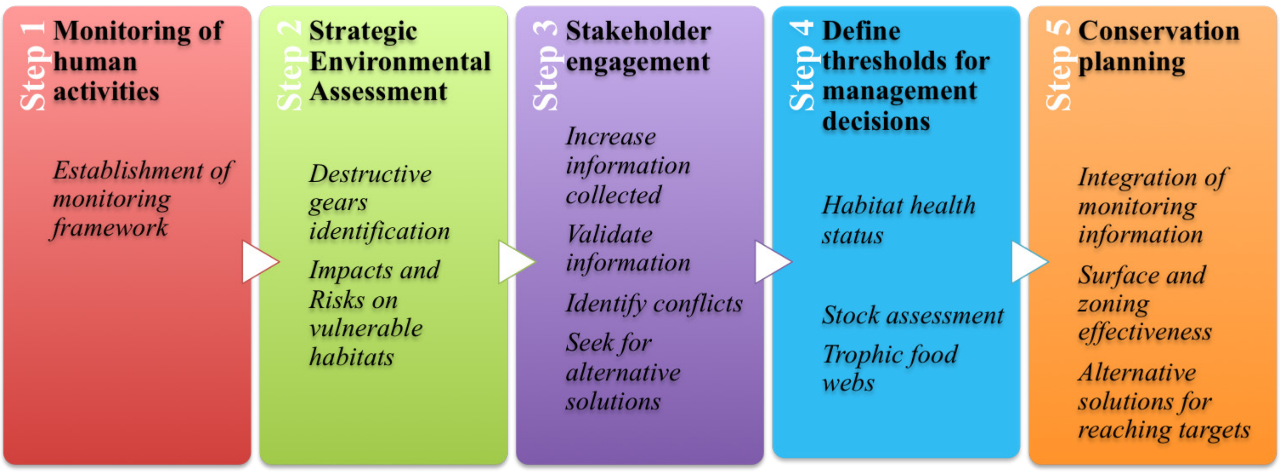


Figure 3. Holistic framework for informing management decisions regarding fishing activity in MPAs.

Monitoring fishing activity in Portofino MPA (Ligurian Sea, Italy)

Monitoring and mapping fishing effort:

The MPA has been divided into 18 smaller management units. Information obtained by fishing diaries, boat observers and interviews mapping of 27 small-scale and 113 recreational fishermen that use tools potentially harmful for benthic habitats (period 2012-2014) was integrated and mapped in ArcGIS 10.2 as described above (*Markantonatou et al., 2014 and references therein*). Spatial accuracy of fishing activity was increased using interpolated bathymetry, common depth of each fishing practice, habitat and substrate type *(Diviacco and Coppo, 2006)*, Google Earth, participatory maps and acronyms of areas. Fishing effort was calculated in terms of total hours per year.

Spatial and temporal allocation of fishing effort:

Artisanal fishing is rather limited but locally intensive on vulnerable habitats. The use of artisanal gears is highly seasonal with gillnets, combined nets and fishing cephalopods mostly employed during autumn. During spring and summer, use of trammel nets and longlines is increased. On the contrary, recreational activity is assessed as high with an increasing trend recorded since 2008 *(Cappanera et al., 2012)*. October was the most popular month for recreational fishing.

Pressure assessment:

The coralligenous habitats are used as an example to describe the pressure assessment on vulnerable habitats present in a MPA. The analysis showed that the coralligenous habitats receiving maximum fishing activity are located at depths between 40-60m, with special reference to depths of 30-40 m at the southeastern part (management units 6- 11; Fig. 4). Recreational fishing with rod and bottom trolling, and professional gillnets and trammel nets mainly affect these areas. These results are verified by the multiple reports of human impacts and climate change they are subject to, such as lost fishing gear, necrosis and massive mortality events reported on these habitats (*Cattaneo-Vietti, R., personal communication; Cerrano et al., 2000; Vezzulli et al., 2013*).

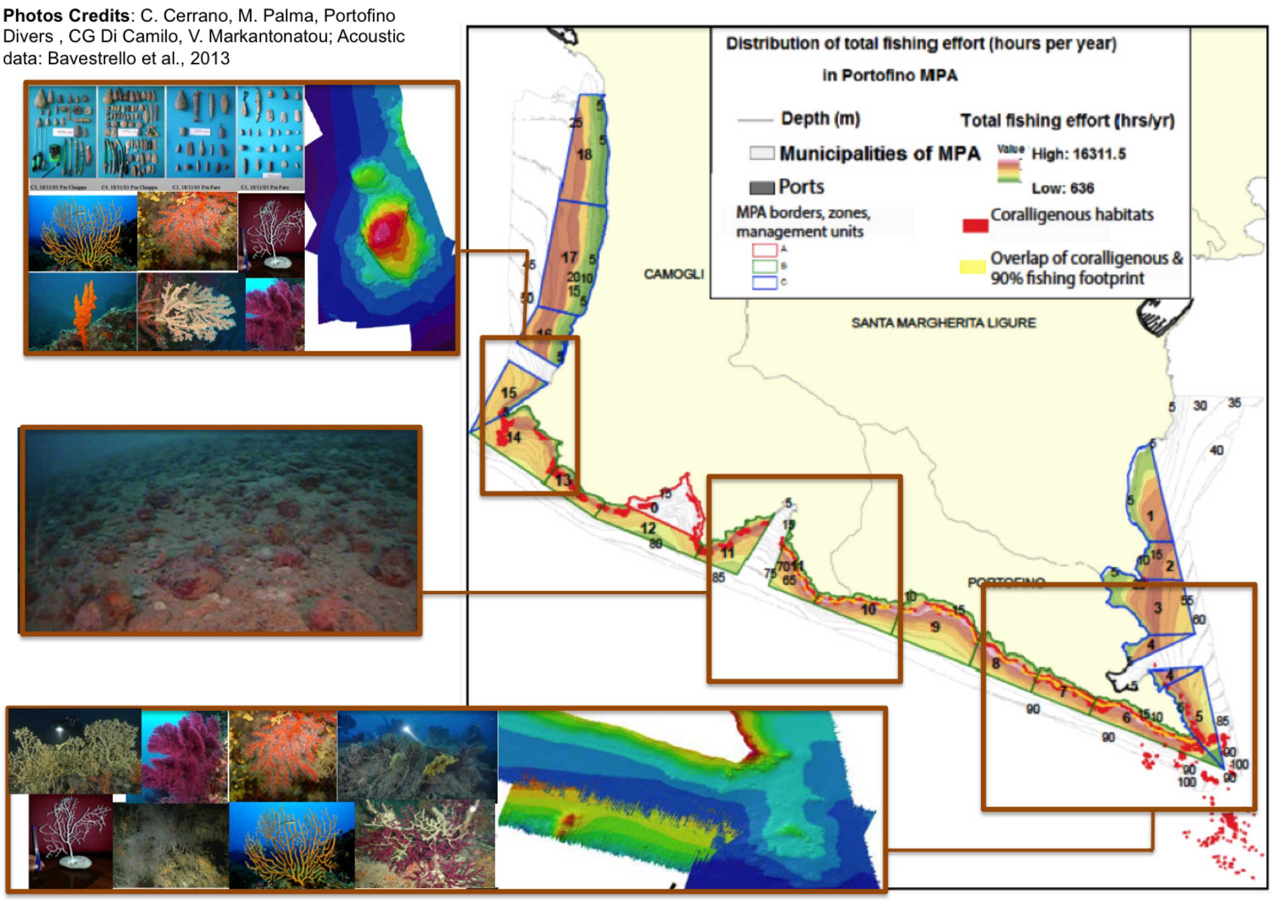


Figure 4. Total fishing effort (hours per year) of fishing practices potentially harmful for benthic habitats in Portofino MPA. Photos present the most characteristic species of the habitat and severe pressures that are subject to. Red colour depicts the distribution of coralligenous communities, while yellow shows the coralligenous receiving the maximum fishing effort (90% of total effort). From Markantonatou et al., 2014

Management recommendations for Portofino MPA

- Discrimination of destructive gears in monitoring and provision of accurate data is an essential element to taking action *(Markantonatou et al., 2014)*.
- Special care should be made regarding the southeastern part towards more strict regulations in order to limit destructive fishing practices in this area. In particular, the use of bottom longlines (directly target grouper) comes in contrast with to the MPA's regulation regarding maximum catch and prohibition of fishing for *Epinephelous emarginatus.*
- In the case of anomalous warm waters during the summer period, spatial and temporal closures from September is recommended. This action is expected to limit the likelihood of a mass mortality events on coralligenous habitats, facilitated where organisms already presents injuries.
- Adoption of online tools, VMS/AIS and consistent on-board observers may additionally increase monitoring efficiency *(Markantonatou et al., 2013)*.
- Although currently divers collect lost fishing gears, consistent action should be implemented along with labelling of nets *(Markantonatou et al., in prep.)*.
- Regular meetings, awareness and trust-bonded relations with fishermen are expected to improve the quality of monitoring and reporting of lost gears.
- Regular surveillance will assist in eliminating illegal fishing and could be combined with monitoring, especially in the case of recreational fishing.
- Outcomes regarding holistic management decisions should be treated with caution, since the complete framework suggested in Fig. 3 has been partially applied.

Conclusions

Understanding the spatial and temporal patterns of fishing effort is fundamental for the sound conservation of fish stocks, habitats and seafloor integrity, identification of conflicts and cumulative impacts in resource management.

The present study provides a straightforward approach for monitoring and mapping spatial and temporal patterns of artisanal and recreational fishing activity. Simple spatial indicators and analyses are suggested in order to describe fishing pressure and identify areas that receive the greatest fishing effort. The approach integrates information originating from a range of monitoring strategies that may be adopted depending on the capacity of MPA management performance, and incorporates uncertainty regarding available information following the precautionary principle.

This is a generic framework for long-term monitoring that integrates powerful analysis and visualization, which may provide a holistic assessment and scientific advice towards ecosystem-based fisheries management. The guidelines correspond to a wide range of EU Directives, such as the Common Fishery Policy, the Marine Strategy Framework Directive and the Directive of Marine Spatial Planning, that promote the good environmental status of habitats and seafloor integrity and sustainable exploitation of marine resources. We suggest spatial pressure indicators, such as fishing effort, as useful and comprehensive tools that are easily communicated regarding fishing footprint on vulnerable habitats. They respond rapidly to ecosystem changes from human activities and management actions, can be monitored and measured precisely, and therefore may inform effective decisions *(Piet and Hintzen, 2012)*.

Our framework combines relatively low cost methods that can be progressively evolved along with the MPA management capacity, and is applicable to other ecosystems at any location. Long term monitoring and geo-referenced information regarding the species distribution and the health status of habitats may improve the quality of this analysis in order to assess the risk to and recovery of ecosystems from artisanal and recreational fishing activities on a scale relevant to support conservation objectives. This approach could also trigger an important participatory pathway, exploitable with different stakeholders.

Finally the importance of local responsibility and surveillance in the area is highlighted as an important component to achieve win-win outcomes.

References

Ball, I.R., Possingham, H.P., Watts, M., 2009. *Marxan and relatives: software for spatial conservation prioritisation, in: Moilanen, A., Wilson, K.A., Possingham, H.P. (Eds.), Spatial Conservation Prioritisation: Quantitative Methods and Computational Tools. Oxford, UK, pp. 185–195.*

Bo, M., Bava, S., Canese, S., Angiolillo, M., Cattaneo-Vietti, R., Bavestrello, G., 2014. *Fishing impact on deep Mediterranean rocky habitats as revealed by ROV investigation. BIOLOGICAL CONSERVATION 171, 167–176. doi:10.1016/j.biocon.2014.01.011*

Briscoe, D.K., Hiatt, S., Lewison, R., Hines, E., 2014. *Modeling habitat and bycatch risk for dugongs in Sabah, Malaysia. Endang. Species. Res. 24, 237–247. doi:10.3354/esr00600*

Cappanera, V., Venturini, S., Campodonico, P., Blini, V., Ortenzi, C., 2012. *Valutazione dell'impatto antropico sul sistema costiero, con particolare riferimento alla pressione antropica all'interno dell'Area Marina Protetta del Promontorio di Portofino. Portofino MPA.*

Cerrano, C., Bavestrello, G., Bianchi, C.N., Cattaneo-vietti, R., Bava, S., Morganti, C., Morri, C., Picco, P., Sara, G., Schiaparelli, S., Siccardi, A., Sponga, F., 2000. *A catastrophic massmortality episode of gorgonians and other organisms in the Ligurian Sea (Northwestern Mediterranean), summer 1999. Ecology Letters 3, 284–293. doi:10.1046/j.1461-0248.2000.00152.x*

Diviacco, G., Coppo, S., 2006. *Atlante degli habitat marini della Liguria. Centro Stampa Offset, Genova.*

E.C., 2008a. *Commission Decision of 6 November 2008 adopting a multiannual Community programme pursuant to Council Regulation (EC) No 199/2008 establishing a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy (2008/949/EC). O.J.E.U., L346.*

EC, 2008b. *Commission Regulation (EC) No 665/2008 of 14 July 2008 laying down detailed rules for the application of Council Regulation (EC) No 199/2008 concerning the establishment of a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy, O.J.E.U., L186.*

Giakoumi, S., Sini, M., Gerovasileiou, V., Mazor, T., Beher, J., Possingham, H.P., Abdulla, A., Çinar, M.E., Dendrinos, P., Gucu, A.C., Karamanlidis, A.A., Rodic, P., Panayotidis, P., Taskin, E., Jaklin, A., Voultsiadou, E., Webster, C., Zenetos, A., KATSANEVAKIS, S., 2013. *Ecoregion-Based Conservation Planning in the Mediterranean: Dealing with Large-Scale Heterogeneity. PLoS ONE 8, e76449. doi:10.1371/journal.pone.0076449*

Gilman, E., 2015. *Status of international monitoring and management of abandoned, lost and discarded fishing gear and ghost fishing. Marine Policy 60, 225–239. doi:10.1016/j.marpol.2015.06.016*

Halpern, B.S., Selkoe, K.A., Micheli, F., Kappel, C.V., 2007. *Evaluating and Ranking the Vulnerability of Global Marine Ecosystems to Anthropogenic Threats. Conservation Biology 21, 1301–1315. doi:10.1111/j.1523-1739.2007.00752.x*

Knights, A.M., Piet, G.J., Jongbloed, R.H., Tamis, J.E., White, L., Akoglu, E., Boicenco, L., Churilova, T., Kryvenko, O., Fleming-Lehtinen, V., Leppanen, J.-M., Galil, B.S., Goodsir, F., Goren, M., Margonski, P., Moncheva, S., Oguz, T., Papadopoulou, K.N., Setälä, O., Smith, C.J., Stefanova, K., Timofte, F., Robinson, L.A., 2015. *An exposure-effect approach for evaluating ecosystem-wide risks from human activities. ICES J. Mar. Sci. 72, 1105–1115. doi:10.1093/icesjms/fsu245*

Markantonatou, V., Marconi, M., Cappanera, V., Campodonico, P., Bavestrello, A., Cattaneo-Vietti, R., Papadopoulou, N., Smith, C., Cerrano, C., 2014. *Spatial allocation of fishing activity on coralligenous habitats in Portofino MPA (Liguria, Italy), in: Bouafif, C., Langar, H., Ouerghi, A. (Eds.). Presented at the UNEP/MAP- RAC/SPA, Proceedings of the second Mediterranean Symposium on the conservation of Coralligenous and other Calcareous Bio-Concretions. Portorož, Slovenia, 29-30 October 2014, Portorož, Slovenia, pp. 118–123.*

Markantonatou, V., Marconi, M., Cerrano, C. *Susceptibility assessment of seafloor to lost fishing gear in data poor areas. In prep*

Markantonatou, V., Meidinger, M., Sano, M., Oikonomou, E., di Carlo, G., Palma, M., Ponti, M., Cerrano, C., 2013. *Stakeholder participation and the use of web technology for MPA management. Advances in Oceanography and Limnology 4, 260–276. doi:10.1080/19475721.2013.851117*

Mazor, T., Giakoumi, S., Kark, S., Possingham, H.P., 2014. *Large-scale conservation planning in a multinational marine environment: cost matters. Ecological Applications 24, 1115–1130. doi:10.1890/13-1249.1*

Piet, G.J., Hintzen, N.T., 2012. Indicators of fishing pressure and seafloor integrity. ICES J. Mar. Sci. 69, 1850–1858. doi:10.1093/icesjms/fss162

3

Prato, G., Gascuel, D., Francour, P., 2015. *Guidelines for monitoring trophic relationships and ecosystem functioning in Mediterranean MPAs. MMMPA Deliverable.*

Prato, G., Barrier, C., Francour, P., Cappanera, V., Markantonatou, V., Cappanera, V., Guidetti, P., Cattaneo-Vietti, R., Mangialajo, L., Gascuel, D. A trophic modelling approach to assess artisanal and recreational fisheries impacts and conflicts in MPAs, In prep

Robinson, L.A., White, L., Culhane, F., Knights, A.M., 2013. *ODEMM Pressure Assessment Userguide V.2.*

Stelzenmüller, V., Rogers, S.I., Mills, C.M., 2008. *Spatio-temporal patterns of fishing pressure on UK marine landscapes, and their implications for spatial planning and management. ICES J. Mar. Sci. 65, 1081–1091. doi:10.1093/icesjms/fsn073*

Tzanatos, E., Castro, J., Forcada, A., Mati-Skoko, S., Gaspar, M., Koutsikopoulos, C., 2013. *A Métier-Sustainability-Index (MSI25) to evaluate fisheries components: assessment of cases from data-poor fisheries from southern Europe. ICES J. Mar. Sci. 70, 78–98. doi:10.1093/icesjms/fss161*

Torres, L.G., Sutton, P.J.H., Thompson, D.R., Delord, K., Weimerskirch, H., Sagar, P.M., Sommer, E., Dilley, B.J., Ryan, P.G., Phillips, R.A., 2015. *Poor Transferability of Species Distribution Models for a Pelagic Predator, the Grey Petrel, Indicates Contrasting Habitat Preferences across Ocean Basins. PLoS ONE 10, e0120014. doi:10.1371/journal.pone.0120014*

Vezzulli, L., Pezzati, E., Huete-Stauffer, C., Pruzzo, C., Cerrano, C., 2013. *16SrDNA Pyrosequencing of the Mediterranean Gorgonian Paramuricea clavata Reveals a Link among Alterations in Bacterial Holobiont Members, Anthropogenic Influence and Disease Outbreaks. PLoS ONE 8, e67745. doi:10.1371/journal.pone.0067745*

Watts, M.E., Ball, I.R., Stewart, R.S., Klein, C.J., 2009. *Marxan with Zones: software for optimal conservation based land-and sea-use zoning. Environmental Modelling and Software 24, 1513–1521. doi:10.1016/j.envsoft.2009.06.005*

[1] **www.seasketch.org, McClintock lab, University of California Santa Barbara**

[2] **www.ecotrust.org**

[3] **www.donia.fr, Andromède Océanologie**

[4] **www.marinetraffic.org**

[5] **http://globalfishingwatch.org, Oceana**

[6] **Vessel Monitoring Systems (VMS) and Automatic Identification System (AIS)**

MONITORING
FISHING PRESSURE ON BENTHIC HABITATS

Pressure assessment from small scale and recreational fishing in Mediterranean Marine Protected Areas

WHY MONITOR IT?

- Overexploitation of resources
- Habitat degradation and biodiversity loss
- Need to balance ecological and socio-economic sustainability

HOW TO MONITOR IT?

1 PREPARE MONITORING NETWORK

- Boundaries and grid
- Bathymetry
- Seafloor topography and sediments
- Habitat distribution

2 MONITOR FISHING ACTIVITY

- Profile
- Fishing costs
- Fishing grounds
- Fishing gear
- Frequency

3 MAPPING OF FISHING ACTIVITY AND PRESSURE ASSESSMENT

- Data verification
- Add data to GIS
- Calculate and map fishing effort
- Pressure assessment: Spatial overlap of pressures with habitats (footprint) - % habitat impacted

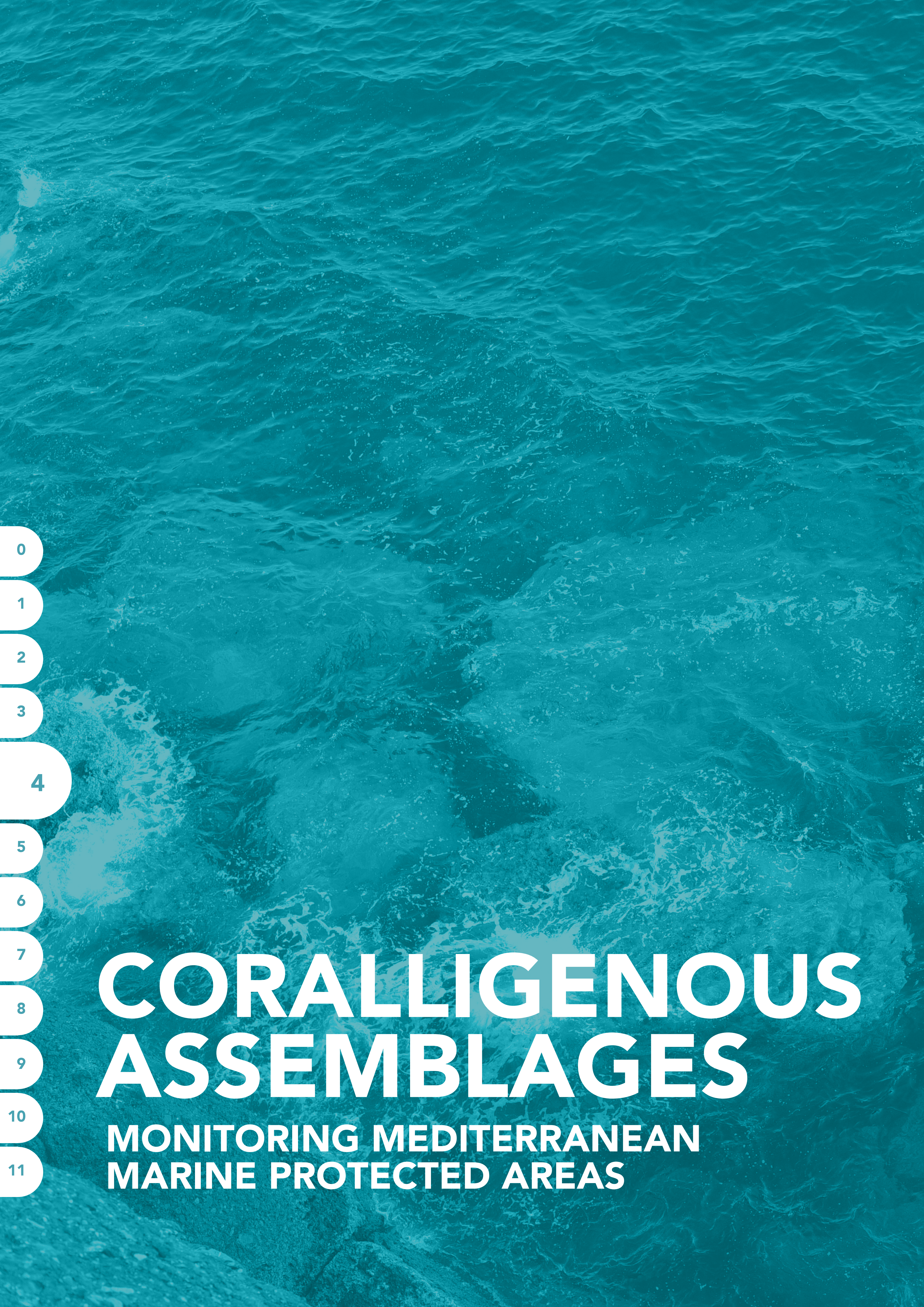
4 FURTHER ANALYSIS AND DATA CAPACITY

- Risk assessment
- Bioeconomic model
- Stock assessment and food web modelling
- Conservation planning

5 INTEGRATE RESULTS AND INFORM MPA MANAGEMENT

WHAT TO EXPECT?

- Identification of areas that are likely to be impacted by fishing activity
- Fishing activity in balance with Good Environmental Status of habitats
- Capacity to further inform MPA management holistically under several different aspects



CORALLIGENOUS ASSEMBLAGES

MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

GUIDELINES FOR MONITORING MEASURES OF CORALLIGENOUS ASSEMBLAGES WITHIN A MANAGEMENT CONTEXT

Paula Andrea Zapata Ramírez [1], Michele Marconi [1] and Carlo Cerrano [1]

This document provides a methodological framework for the implementation of monitoring measures for coralligenous assemblages with the aim to provide statistically sound data for management purposes. The method is based on existing standard monitoring assessment currently used in marine benthic habitats.

Why is it important to monitor coralligenous environments?

Coralligenous habitats provide several essential ecological, economic and cultural services and their sustainable management and exploitation is one of the most important concerns of the last decade throughout the Mediterranean basin. Their importance has been also recognised under different international, European and national conservation frameworks (e.g. Habitats Directive; European Water Framework Directive) and as protected habitats in the EC Regulation No. 1967/2006 concerning management measures for the sustainable exploitation of fishery resources. Despite their importance, however, there are missing consensual methodologies for their monitoring and little is known about their distribution and status. This situation could be related to the difficulties associated with their exploration, their spatial heterogeneity and the lack of technical and financial capacity to collect and use the data.

Consequently, governmental bodies are increasingly obliged to implement and establish monitoring programs and protocols for the assessment with which achieve or maintain a Good Environmental Status (GES) by 2020. Therefore, Marine Strategy Framework Directive (MSFD) offers a crucial opportunity to Member States to build and standardise novel innovative methodological assessments and to incorporate a cost-benefit analysis, based on today's state-of-the-art technological developments into current monitoring practices.

Faced with the challenge of implementing MSFD goals, policymakers are tackled with the problem of 'the need to know versus the need to act'. Effective implementation of the MSFD directives relies on a comprehensive geospatial framework with which to understand the processes that determine the observed distribution patterns of habitat/species in marine ecosystems as a starting point. This information should contain spatially continuous and broad scale data on the distribution of both biological and physical resources and their interaction, with which to make informed and ecologically relevant decisions. Several pressures can be responsible of structural changes in the coralligenous habitats and the present approaches are at the moment the most effective to monitor them.

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How remote sensing, habitat mapping and distribution modelling tools are useful for coralligenous management?

Remote sensing (RS) and Habitat Mapping (HM) techniques are now fundamental tools for the monitoring and management of marine ecosystems *(Brown et al., 2011; Buhl-Mortensen et al., 2015)*. These approaches offer repeatable, quantitative assessments and have the potential to provide a broad-scale synoptic view over spatially extensive areas, providing temporal data that may be used to assess events in community dynamics *(Zapata-Ramirez et al., 2013)* and in long term monitoring practices. Additionally to the HM practice and results, the implementation of Distribution Modelling (DM) procedures have resulted in an increased availability of environmental data *(Brown et al., 2012; Reiss et al., 2015)* with which to explore the relationships between abiotic and biotic patterns, allowing the predicted distributions to be mapped across an entire region. From this perspective, the integration of RS, HM and DM methods can be used as a management tool, providing information on:

(I) the exploration of possible effects of climate change on benthic species distribution patterns *(Elith et al., 2011; Reiss et al., 2015)*, (II) to assess habitat distributions in areas that, due to their complexity, are difficult to study and therefore have limited data availability *(Fourcade et al., 2014; García-Alegre et al., 2014)*, (III) to estimate the most suitable areas for a species and infer probability of presence in regions where no systematic surveys are available *(Martin et al., 2014)*, (IV) to illustrate how human impacts interact with their distribution *(Bandelj et al., 2009; Martínez et al., 2012; Zapata-Ramirez et al., submitted)* and (V) to identify optimal sites for restoration initiative *(Elsäßer et al., 2013; Valle et al., 2015)*. As a result, the integration of these techniques have proved to be a cost-effective and productive endeavour to achieve management objectives and to provide coherent maps of distributions of species and habitats, ecological goods, and services with which to assess the status *(Piroddi et al., 2015)* of MPAs.

Consequently, our aim is to offer an easy and understandable guideline with which to identify and recommend the most appropriate RS techniques, HM and DM tools and data that should be used to address coralligenous management questions. We present a framework with simple steps useful to build a strong baseline exploitable also to forecast future conditions and evaluate management actions of these habitats. The method is based on current standard monitoring assessment used in similar benthic habitats such as “reefs” (e.g. European Projects: HERMES, HERMIONE, CoralFish, SEDCoral, MAREMAP, MESH, MAREANO program, CODEMAP) as described in the European Habitats Directive (92/43/EEC). They have proven to be a cost-efficient and widely applied internationally-recognized method which provide relevant information for management purposes. As a result, the guideline for coralligenous assemblages management presented here, are likely to be applicable in a variety of other benthic habitat contexts where management actions are needed.

How to do it

Step by Step Graphic Guide

Figure 1 summarises the basic steps of the methodological process fordata collection and processing based in RS, HM and DM techniques.

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The integration of remote sensing and habitat mapping have proved to be a cost-effective way to help achieve MPA management objectives and to provide coherent maps of species and habitat distributions, ecological goods, and services with which to assess the status of MPAs.

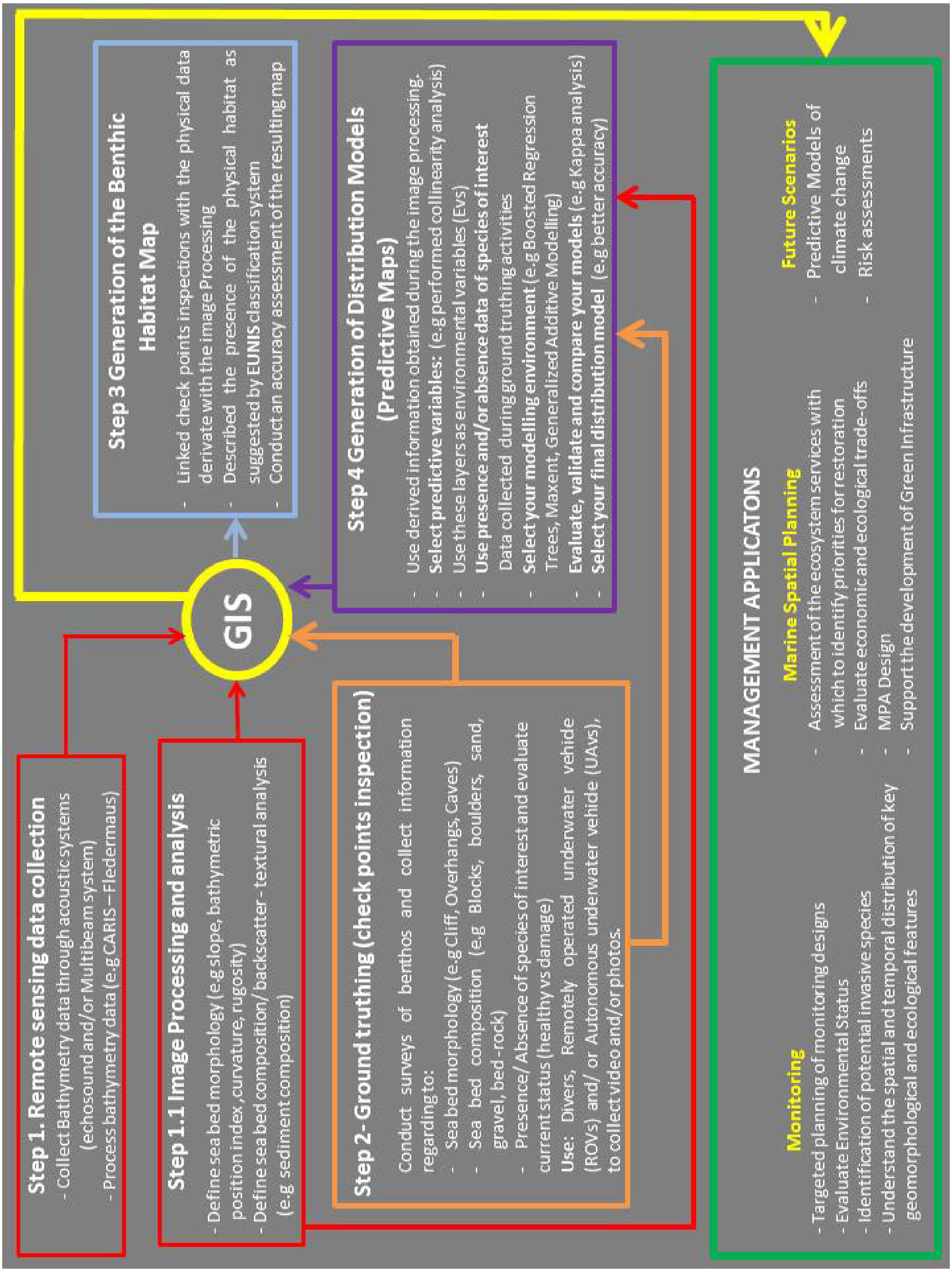

Figure 1. Key Step by Step Graphic Guide.

Costs

The resource requirements vary significantly between different monitoring methods and the general expenses could be between medium to high. Time and cost, therefore, need to be considered across six main categories **(Table 1)**:

ACTIVITY	MEDIUM COST	HIGH COST
Set-up costs (e.g. hardware and software requirements)	ArcGIs 10.2 The R Project for Statistical Computing (Open source)	CARIS HIPS and SIPS Hypack Fledermaus - QPS Computers
Cost of acoustic acquisition	Single beam: low resolution	Multibeam: high resolution
Image acquisition	Divers with High resolution cameras / low resolution camera such as Go-Pro	AUVs – ROVs with high resolution cameras
Geo-Positional System	Divers connected with GPS in the surface	Ultra-Short Base line transponder (USBL system)
Field survey costs	The cost of this category will depend of the number of sampling days	The cost of this category will depend of the number of sampling days.
The time required for image processing, derivation of habitat classes and modelling	The cost of this category will depend on the amount of models and the expertise level of the researchers	The cost of this category will depend on the amount of models and the expertise level of researchers

Table 1: Common Resources Required and Estimated Cost.

What are the benefits of the implementation of this methodological framework on management implications?

The methodological framework here presented will help to provide recommendations to managers and policymakers about how to best protect coralligenous resources, how to create or redefine different zones or levels of protections at MPA's and how to forecast future changes due to global warming and/or anthropogenic activities.

We believe that the implementation of these recommended guidelines are timely and in alignment with the MSFD objectives and could strengthen management efficiency to make the best decisions at local scale that also could take into consideration the broader regional contacts and in that way, help to achieve or maintain the GES of coralligenous habitats by 2020.

Monitoring coralligenous habitats is important for managers because:

- Helps evaluate current status
- Helps understand the spatial and temporal distributions of key geomorphical and ecological features
- Identifies priorities and develops the most adequate management strategies for coralligenous habitats
- Models the prediction of habitat type, based on physical information within different habitat areas and water depths
- Identificates potential invasive species
- Evaluates economic and ecological trade-offs
- Assesment of the ecosystem services with wich to identify proirities for restoration
- Allows for targeted planning of monitoring designs
- Helps calculate current and potential future stressors
- Serves risk assessment
- Predicts outcomes of alternative management choices
- Improves MPA design
- Supports the development of Green infrastructure
- Evaluates success of management action to achieve MSFD targets and future conditions to accomplish or maintain a GES

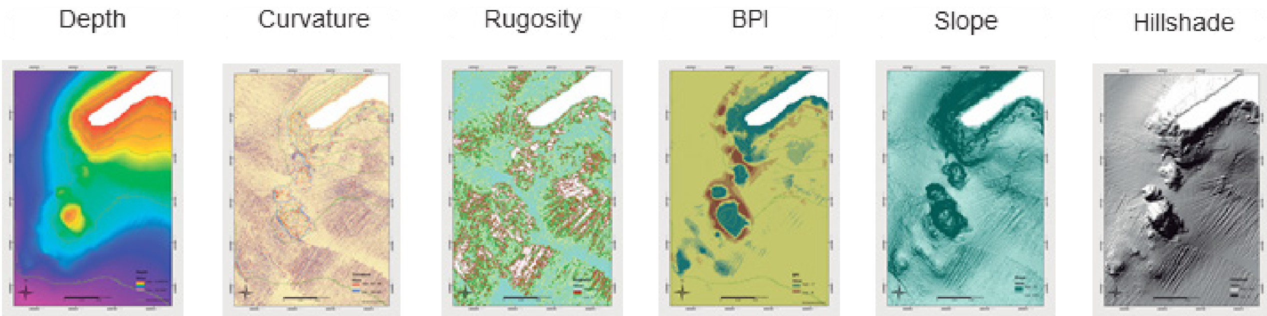

Figure 2. Multibeam derived products at Portofino MPA.

Skills and Training

It is essential that those who commission surveys and monitoring for the coralligenous ensure that the habitat survey team has the required ecological and technological expertise. Regardless of the skill levels of field surveyors, some training for the methodological framework here presented will often be required, as survey objectives and methods can vary considerably. In the absence of widely recognized training in RS, HM and DM, at least for the implementation of the first step here presented can be challenging. Therefore, expert knowledge will be compulsory and essential to assist the succesful implementation of the methodological framework with which to obtain the baseline distribution maps. However and due to the fact that MPA managers often operate on a limited budget, consideration should also be given to establishing collaborations with research centers, universities or other government agencies which may have better technical, building capacity and resources to produce higher quality tested models and maps.

Once these baseline maps are produced, they will provide simplistic and comprehensive inputs, easy to be exploited by managers and stakeholders providing clarity and coordination among plans, useful to implement monitoring actions and with which to make informed management decisions and increase social awareness towards conservation needs.

Portofino MPA case study

The methodological framework here presented was developed and tested at Portofino MPA, here we provide the main maps and models produced in the study case.

Bathymetric data was provided by the Ligurian Region, the data was collected in 2010. This data creates an extremely accurate digital representation of seafloor topography. The spatial analysis functions of a GIS allow the extraction of several derived products from bathymetric data, such as slope, bathymetric position index (BPI), curvature, hillshade and rugosity **(Fig. 2)**.

Through a set of standard algorithms based on image classification and segmentation process, these derived products, and the relationships between them, can be examined to classify the benthic landscape **(Fig. 3)**. In general terms, pixels with close proximity and having similar spectral characteristics are grouped together into segments that exhibit certain shapes, spectral, and spatial characteristics that are grouped to classify the area of interest (AOI).

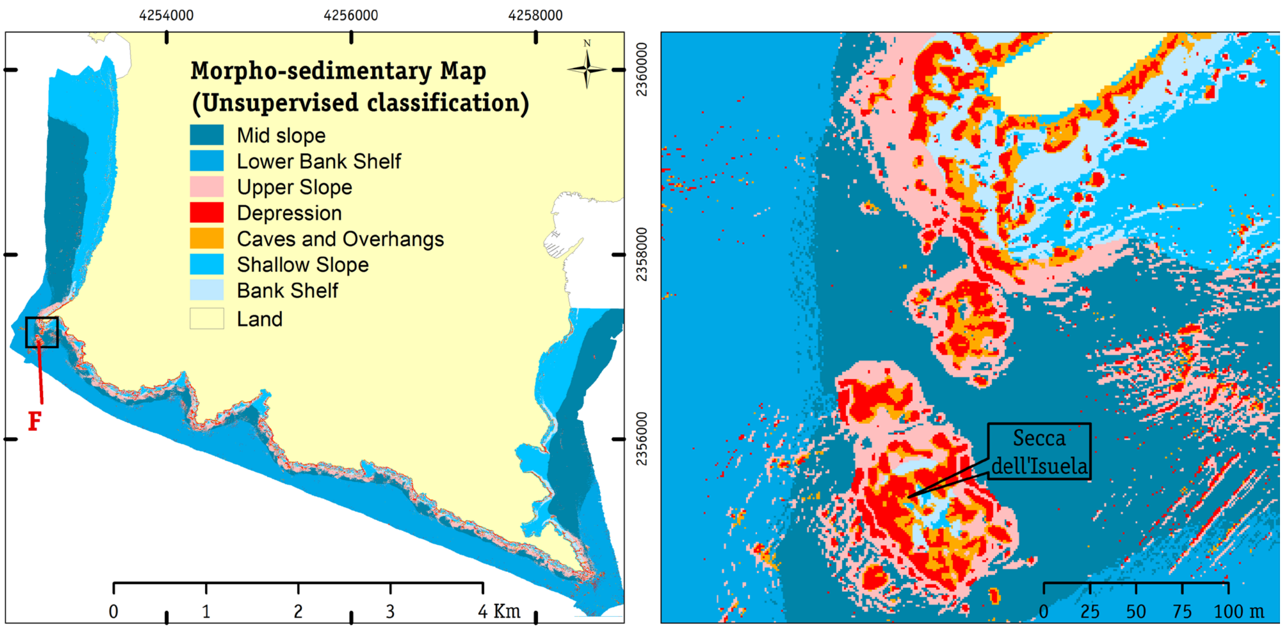

Figure 3. Portofino Habitat Map. On the left, a general map displaying the results of the entire MPA. On the right, the figure shows a close up of the study area recognized as "Isuela", a stack formation along the cliff (Zapata-Ramirez et al., submitted).

Portofino MPA habitat Map

The map (Fig. 3) show a rough estimation of the different seabed zones within the study area and with respect to the topography and kind of sediment distribution, providing an indication of where to find different habitat types during ground truthing activities.

Ground truthing verification

We selected *in situ* transects that crossed areas that were spectrally separated in the classification map (Fig. 3) and in order to produce an integrated, georeferenced dataset. We accounted the accessibility from land that could help guarantee future monitoring activities as well as potentially more impacted areas. Once in the field, we recorded ground-truth variables as sea floor indicators and based on a combination of the main sediment types, the presence absence of the geomorphological features resulted from the image classification process and the presence of the benthic habitats as suggested by EUNIS classification system.

The figures below shows two conceptual models: (Fig. 4) the morpho-sedimentary structures and facies-biotic associations at "Isuela" and (Fig. 5) the schematic representation of caves and overhangs at "Altare".

Spatial and quantitative analyses were applied to this dataset in order to characterize the morphology and distribution of coralligenous assemblages at the selected transects. An integration of the ground truthing and the classification map was conducted. Then training and ground validation field data collection and the map were refined and tested.

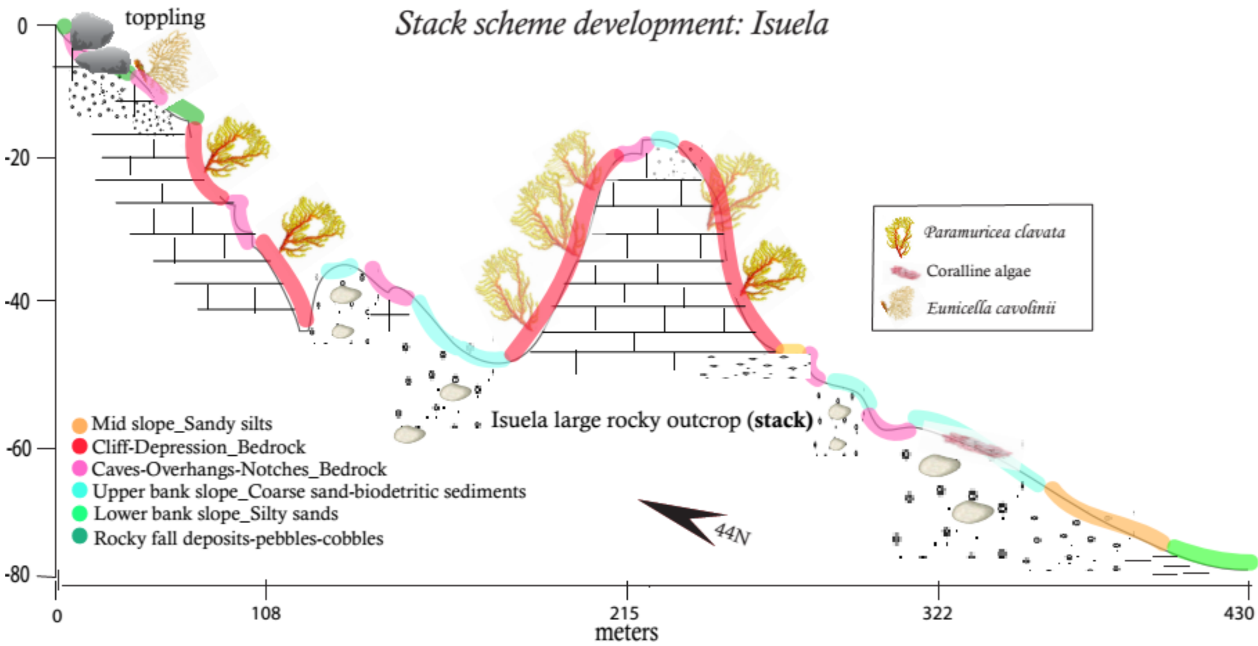

Figure 4. The schematic diagrams show the main coralligenous assemblage at "Isuela "and their relation with the morphology of the seabed, the water depth and the sediment grain size.

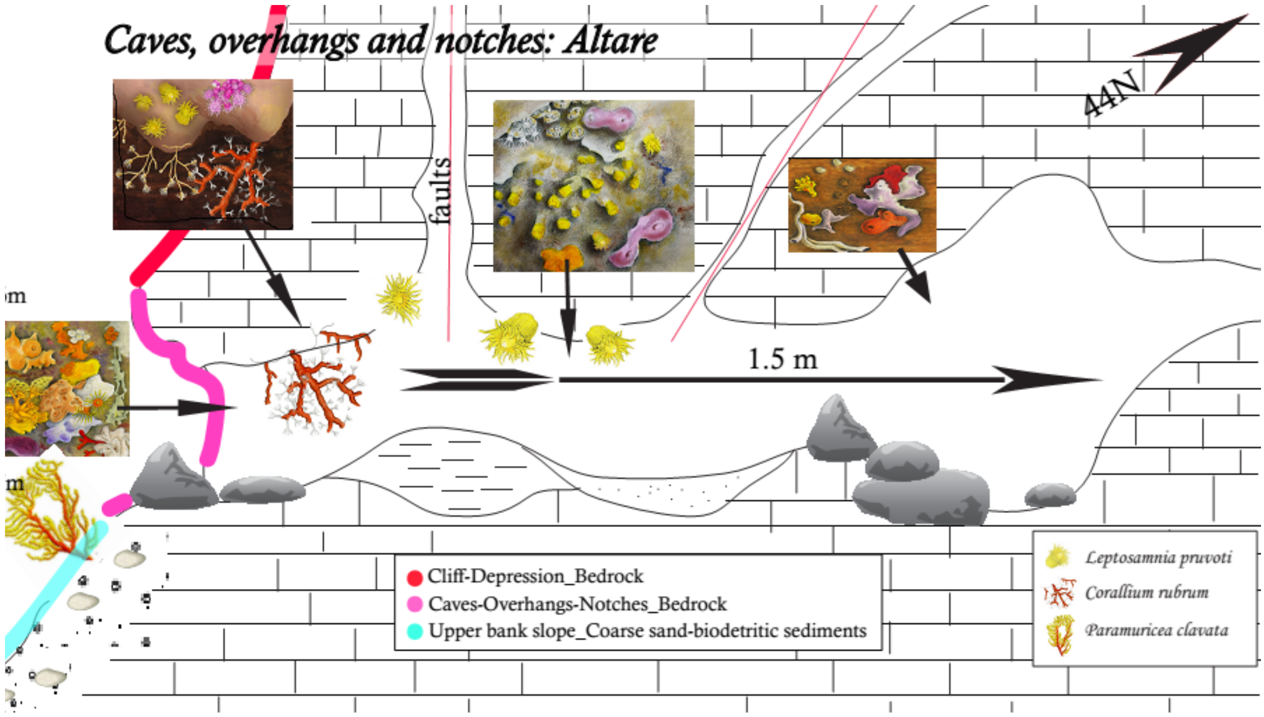

Figure 5. The schematic diagram show the coralligenous assemblages associated with the morphology of the seabed, in particular with rims where several overhangs between 18-40m depth occur at "Altare".

Final Habitat Map Product released with known accuracy results

As coralligenous occurs at the circalitoral zone *(Peres and Picard, 1964; Laborel, 1987)*, we cut the shallow area (-0 to -20m) of the habitat map classification. Finally, total surface area considered for the habitat map and distribution models were 5.45 Km2, of which 2.57 Km2 fall within the MPA.

Accuracy of assessment of the classification map **(Fig. 6)** produced an overall accuracy of 76.40%. The classification of the habitat map and the spatial analyses shows that coralligenous preferentially grow on steep slopes/ cliff depressions **(Fig. 4)**, while on caves and overhangs structures, semi dark communities such as the red coral develop **(Fig. 5)**.

Due to the proximity between coralligenous and cave environments at Portofino MPA, we consider that *Corallium rubrum* **(Fig. 5)** should be also included among the aspects of coralligenous assemblages. These species develop in the same sites, hence the integration for monitoring activities between the two habitats and their connections to management strategies, protection and conservation would be more effective.

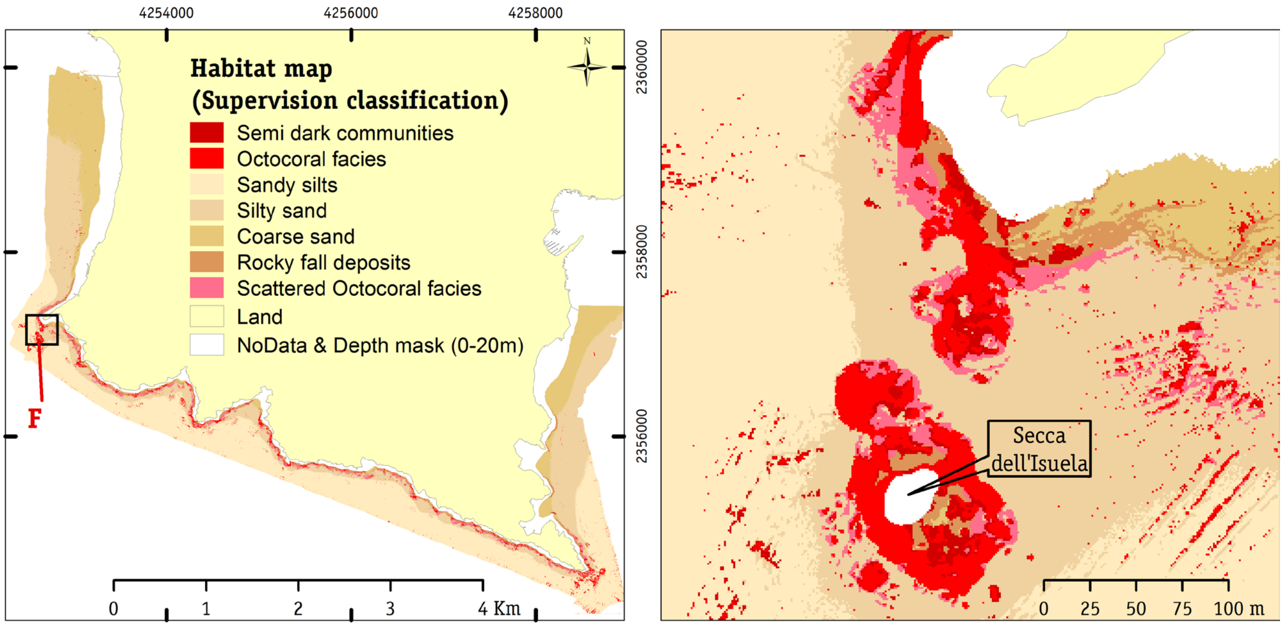

Figure 6. Final Habitat Map Product released with known accuracy of Portofino MPA. On the left, a general map displaying the results of the entire study area and on the right, a zoom in one of the sampling sites ("Isuela") (Zapata-Ramirez et al., submitted).

Distribution Models

There is now a variety of Distribution Modelling (DM) techniques based on presence-absence or presence-only data and the list of available methods to select is growing continuously *(Reiss et al., 2015)*. As a result, a key decision should be to choose the most appropriate method to use to model the interest habitat. Methods which tend to under predict distribution patterns might be useful for species protection applications such as MPAs, as a consequence, here we presented two possible solutions that performs equally well and describe the distribution in a similar way in Portofino MPA.

Presence only algorithm approach:

- The maximum entropy model (Maxent) **(Fig. 7)**

The final model has a mean AUC (area under the curve): 0.97 and narrow confidence which indicate a good model. The model indicate Slope (> 53.2 %) as the most important variable of contribution for the model prediction follow by Rugosity (19.4%) and Bathymetric Position Index (BPI) (17%).

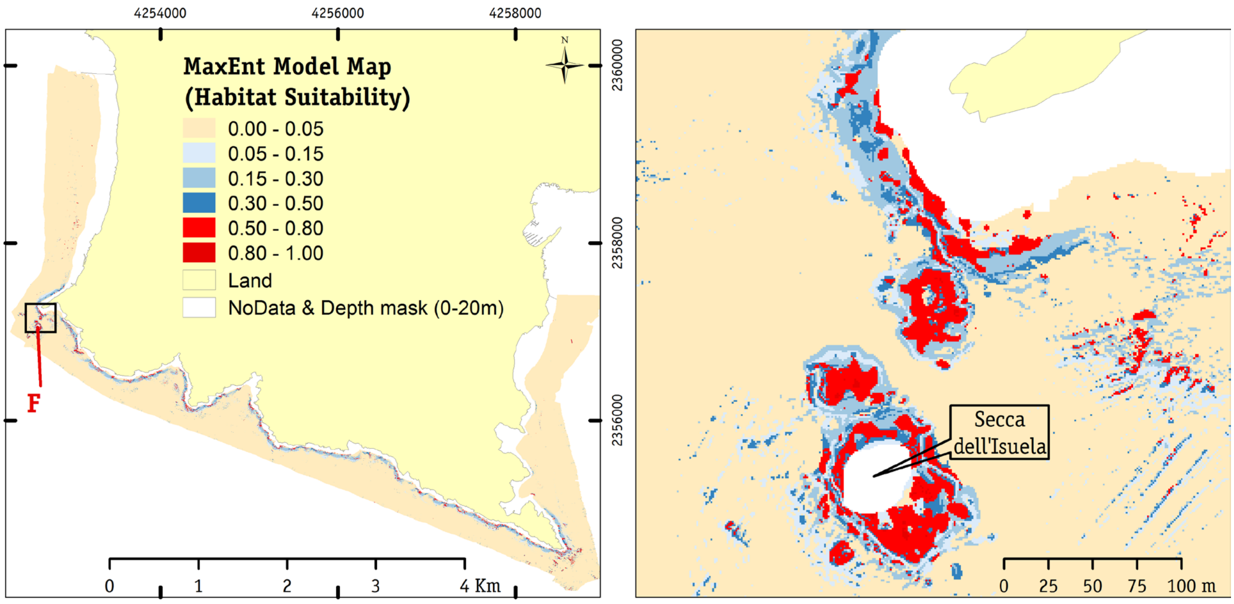

Figure 7. Distribution model (MaxEnt) revealing the predicted occurrence of the coralligenous assemblages located at Portofino MPA. On the left, a general map displaying the results of the entire study area and on the right, a zoom in one of the sampling sites ("Secca dell' Isuela"). Pink background indicates that coralligenous is not present (probability < 0.05), blue shades indicate low probability (< 0.50) and red high probability of presence (> 0.50). (Zapata-Ramirez et al., submitted).

Presence – absence algorithm

- Boosted Regression Trees (BTR) also called stochastic gradient boosting.

A final model (Fig. 8) selected using 10 fold cross validation utilized 9950 trees for the same area, Isuela, achieve an excellent (AUC 0.98) prediction. As in Maxent prediction model, Slope contributed the most (> 66.7 %) to the prediction, but in this case followed by Curvature (15%) and Depth (14%).

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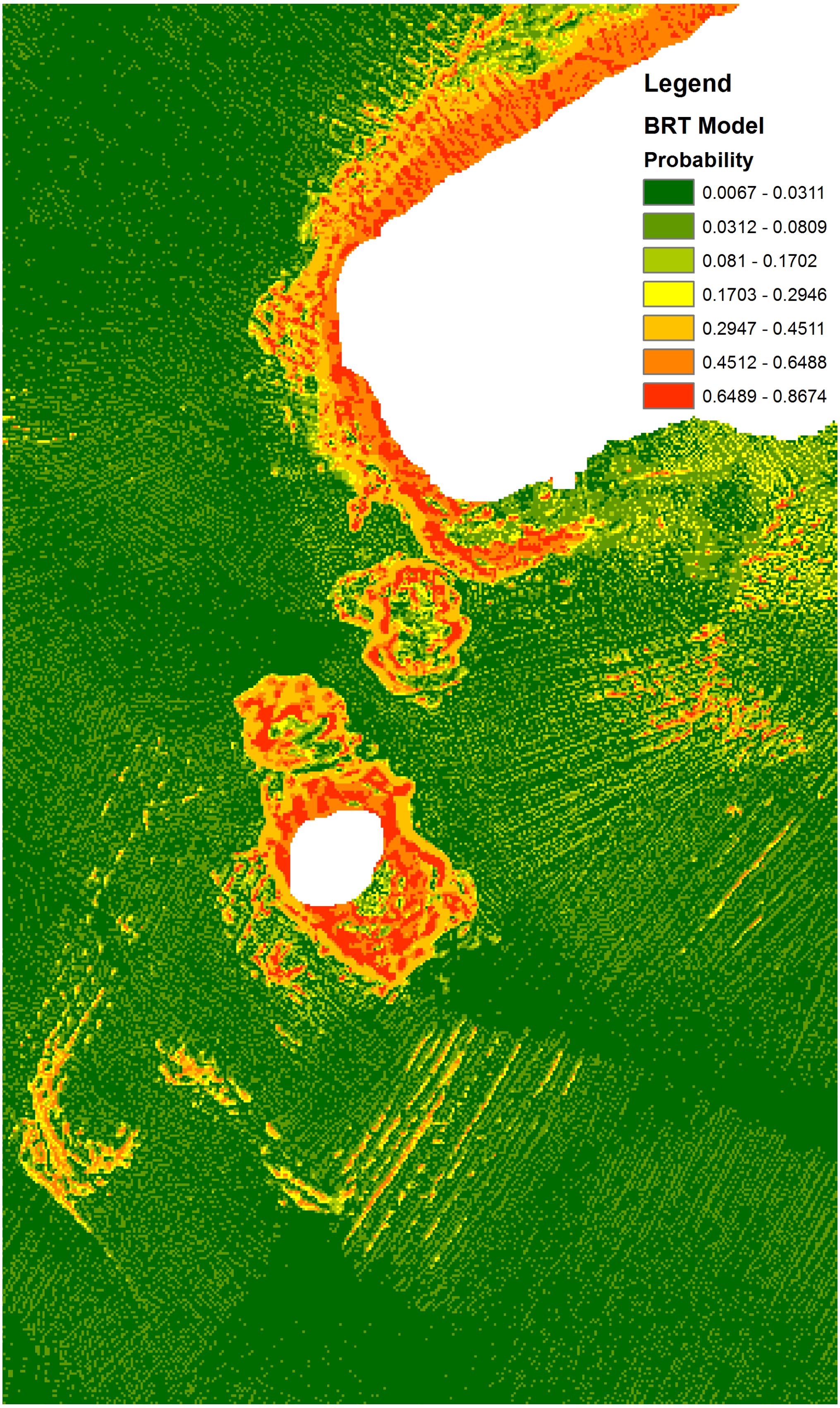


Figure 8. BRT Distribution model showing the presence of coralligenous assemblages at "Isuela".

References

Bandelj, V., Curiel, D., Lek, S., Rismondo, A and Solidoro, C., 2009. *Modelling spatial distribution of hard bottom benthic communities and their functional response to environmental parameters. Ecological Modelling 220, 2838–2850. DOI: 10.1016/j.ecolmodel.2009.04.024.*

Brown, C.J., Smith, S.J., Lawton, P and Anderson, J.T., 2011. *Benthic habitat mapping: A review of progress towards improved understanding of the spatial ecology of the seafloor using acoustic techniques, Estuarine Coastal Shelf Sci. 92-3, 502–520. DOI:10.1016/j.ecss.2011.02.007.*

Brown, C.J., Sameoto, J.A and Smith, S.J., 2012. *Multiple methods, maps, and management applications: Purpose made seafloor maps in support of ocean management. Journal of Sea Research 72, 1–13. DOI:10.1016/j.seares.2012.04.009.*

Buhl-Mortensen, L., Buhl-Mortensen, P., Dolan, M.J.F and Gonzalez-Mirelis, G., 2015. *Habitat mapping as a tool for conservation and sustainable use of marine resources: Some perspectives from the MAREANO Programme, Norway. Journal of Sea Research, SEARES-01309; Vol 100, 46-61.DOI:10.1016/j.seares.2014.10.014.*

Elith, J., Phillips, S.J., Hastie, T., Dudik, M., Chee, Y.E and Yates, C.J., 2011. *A statistical explanation of MaxEnt for ecologists. Diversity and Distributions, 17, 43-47. DOI: 10.1111/j.1472-4642.2010.00725.x.*

Elsäßer, B., Fariñas-Franco, J.M., Wilson, C.D., Kregting, L and Roberts, D., 2013. *Identifying optimal sites for natural recovery and restoration of impacted biogenic habitats in a special area of conservation using hydrodynamic and habitat suitability modelling. Journal of Sea Research 77 , 11–21. DOI: 10.1016/j.seares.2012.12.006.*

Fourcade, Y., Engler, J.O, Rodder., D and Secondi, J., 2014. *Mapping Species Distributions with MAXENT Using a Geographically Biased Sample of Presence Data: A Performance Assessment of Methods for Correcting Sampling Bias. PLoS ONE 9(5): e97122. DOI:10.1371/journal.pone.0097122.*

García-Alegre, A., Sánchez, F., Gómez-Ballesteros, M., Hinz, H., Serrano and Parra, S., 2014. *Modelling and mapping the local distribution of representative species on the Le Danois Bank, El Cachucho Marine Protected Area (Cantabrian Sea), Deep-Sea Research II. 106, 151–164. DOI: .org/10.1016/j.dsr2.2013.12.012.*

Laborel, J., 1987. *Marine biogenic constructions in the Mediterranean: a review. Scientific Reports Port-Cros National Park, 13, 97-126.*

Martin, C.S., Giannoulaki, M., De Leo, F., Scardi, M., Salomidi, M., Knitweiss, L., Pace, M. L., Garofalo G., Gristina, M., Ballesteros E., Bavestrello, G., Belluscio, A., Cebrian, E., Gerakaris V., Pergent, G and Pergent-Martini, C., 2014. *Coralligenous and maërl habitats: predictive modelling to identify their spatial distributions across the Mediterranean Sea. Scientific Reports., 4, 50-73 DOI: 10.1038/srep05073.*

Martínez, B., Viejo, R.M., Carreno, F and Aranda, S.C., 2012. *Habitat distribution models for intertidal seaweeds: responses to climatic and non-climatic drivers. Journal of Biogeography, 39, 1877–1890. DOI:10.1111/j.1365-2699.2012.02741.*

Piroddi, C., Teixeira, H., Lynam, C.P., Smith, C., Alvarez, M.C., Mazik, K., Andonegi, E., Churilova, T., Tedesco, L., Chifflet, M., Chust, G., Galparsoro, I., Garcia, A.C., Kämäri, M., Kryvenko, O., Lassallei, G., Neville, S., Niquil, N., Papadopoulou, N., Rossberg, A.G., Suslin, V and Uyarra, M.C., 2015. *Using ecological models to assess ecosystem status in support of the European Marine Strategy Framework Directive. Ecological Indicators, 58, 175–191. DOI:10.1016/j.ecolind.2015.05.037.*

Peres, J. and Picard, J., 1964. *Nouveau manuel de bionomie benthique de la Mer Méditerranée. Recueil des Travaux de la Station Marine d'Endoume, 31 (47), 1-137.*

Reiss, H., Birchenough, S., Borja, A., Buhl-Mortensen, L., Craeymeersch, J., Dannheim, J., Darr, A., Galparsoro, I., Gogina, M.,Neumann, H., Populus, J., Rengstorf, A. M., Valle, M., van Hoey, G., Zettler, M. L., and Degraer, S., 2015. *Benthos distribution modelling and its relevance for marine ecosystem management. – ICES Journal of Marine Science, 72: 297–315. DOI:10.1093/icesjms/fsu107.*

Valle, M; Garmendia, J.M; Chust, G; Franco, J and Borja, A., 2015. *Increasing the chance of a successful restoration of Zostera noltii meadows. Aquatic Botany 127, 12-19. DOI:10.1016/j.aquabot.2015.07.002.*

Zapata-Ramírez P.A., Blanchon, P., Olioso, A., Hernandez-Nunez, H., Sobrino, J.A., 2013. *Accuracy of IKONOS for mapping benthic coral-reef habitats: A case study from the Puerto Morelos Reef National Park, Mexico, International Journal Remote Sensing 34 (9-10), 3671-3687. DOI: 10.1080/01431161.2012.716922.*

Zapata-Ramirez, P.A; Huete-Stauffer, C; Scaradozzi, D; Marconi, M and Cerrano, C., *Submitted. Mapping and modelling the distribution of coralligenous and cave environments, a multi approach to assess the Good Environmental Status (GES) at Portofino MPA. Submitted to Marine Environmental Research.*

Zapata-Ramirez, P.A., Gianni, Fabrizio and Marconi, M., *Submitted. Modelling the distribution of rocky intertidal communities and their relationship with the geomorphological expression and anthropogenic pressures at Portofino MPA. Submitted to Ecological Indicators.*

European Projects :

CODEMAP: http://www.codemap.eu/

CoralFish: http://www.eu-fp7-coralfish.net/

HERMES: http://www.eu-hermes.net/

HERMIONE: http://www.eu-hermione.net/

MAREANO: http://mareano.no/en/about_mareano

MAREMAP: http://www.maremap.ac.uk/index.html

MESH: http://www.emodnet-seabedhabitats.eu/default.aspx?page=2003

SEDCoral: http://archive.noc.ac.uk/SEDCORAL/SEDCoral_results_Darwin.html

http://archive.noc.ac.uk/SEDCORAL/SEDCoral_results_Darwin.html

MONITORING
CORALLIGENOUS ASSEMBLAGES

Establishing global standards for appropriate and efficient monitoring methods

WHY MONITOR IT?

- essential ecological, economic and cultural role
- increasingly recognized and regulated
- need to establish up to date monitoring protocols

HOW TO MONITOR IT?

1 REMOTE SENSING
bathymetry collection and processing

2 IMAGE PROCESSING
define sea bed morphology and composition

3 GROUND TRUTHING
inspect checkpoint for truthing and population data

4 PUT DATA INTO GEO. INFORMATION SYSTEM
for automated proccessing

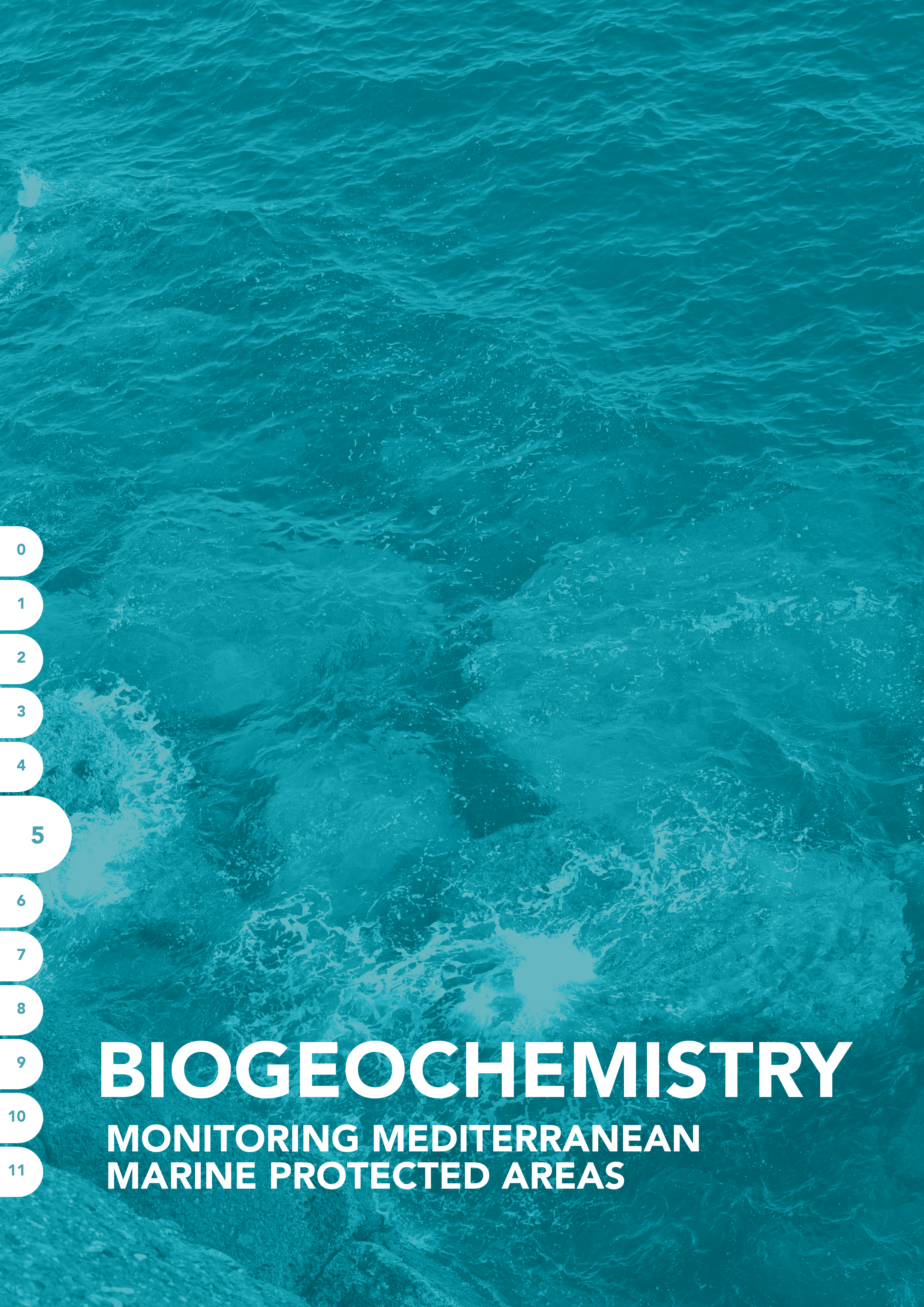
5 BENTHIC HABITAT MAP
compile map with collected data according to EUNIS system

6 DISTRIBUTION MODEL
fine tune, compare and validate models for better accuracy

7 APPLY FINDINGS
improve monitoring efforts, future risk assessment and MPA design

WHAT TO EXPECT

- improved monitoring of environmental status
- effective marine spatial planning and MPA design
- better predictive modeling and risk assessment



BIOGEOCHEMISTRY

MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

GUIDELINES FOR THE EFFECTIVE MANAGEMENT OF LAGOONS ON THE BASIS OF BIOGEOCHEMISTRY

Elizabeth Arévalo[1], Juan Severino Pino Ibánhez[2], Sokratis Papaspyrou[3], Artemis Nicolaidou[1]

Coastal lagoons are very important water bodies. Here we explain which variables are more important on the basis of biogeochemistry and how to measure them in order to implement a monitoring system in these ecosystems.

Why monitor coastal lagoon through biogeochemistry?

Coastal lagoons are defined as shallow water bodies separated from the ocean by a barrier, connected to it at least by one or more restricted inlets. They are important on account of their biological, geological, physical and chemical characteristics. Coastal lagoons are commonly highly productive ecosystems and support a variety of essential habitats for many fish, shellfish, birds and plant species. Furthermore, coastal lagoons act as modulators of anthropogenic pressure over the coastal zone and play an important role on the global circulation of elements like carbon or nitrogen. Coastal lagoons also support important economic, commercial, recreational and touristic activities, while they form important ecosystems for food supply through aquaculture or fishing.

Monitoring coastal lagoon biogeochemistry is important because:

- Biogeochemistry helps us to understand how organic matter and nutrients go from one form to another and to learn how and why the environmental problems arise (contamination, eutrophication).
- Knowing the biogeochemistry of the area, you know the functioning of the ecosystem, so it is much easier to make decisions about which habitats/parts of the lagoon you should protect.

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How to monitor coastal lagoons

Before starting to monitor a coastal lagoon its main habitats should be identified and the major threats established. The latter include eutrophication, loss of marine vegetation (mainly sea grasses), overfishing, and invasion of alien species. Eutrophication is the most important, as it may lead to dystrophic crises and deaths of fish and shellfish. Lagoons are naturally eutrophic but nutrient concentrations may be enhanced by anthropogenic activities both in the lagoons themselves and in the surrounding areas.

Measuring nutrients in the water is a good indicator of its environmental quality, while measuring Chromophoric Dissolved Organic Matter will quantify any pressures and define their origin. Environmental quality in the lagoons should also be monitored in the sediment, since biogeochemical processes taking place in the sediment play an important role in the functioning of the whole ecosystem. Sediments act as an effective reservoir of nutrients which can be released under certain circumstances.

Here are some guidelines for monitoring water and sediment quality in lagoons.

Water quality:

- Nutrients should be analyzed in the water of the lagoon as well as in the water of the main tributaries discharging into it.

· Sampling points should be fixed every $5 km^2$, with at least one sampling point in every different habitat of the lagoon and in every tributary.

· Sampling should be carried out at least once per season to follow evolution of nutrients over the year.

· Water samples must be filtered and kept in the freezer until analysis. For filtering Hydrophilic poly-ether-sulfone (PES) membranes (Rhizon Soil Moisture Samplers, 10cm length, 0.1 um average pore size; Rhizosphere, The Netherlands) are highly recommended as an easy, cheap and quick tool.

· Analysis of Dissolved Inorganic Nitrogen ($DIN = NO_3^- + NO_2^- + NH_4^+$) and Dissolved Inorganic Phosphorus (DIP) is carried out.

Limits of eutrophication: $NO_x^- > 1.19$ µM; $NH_4^+ > 2.2$µM; DIP > 0.68 µM.

- Chromophoric Organic matter should be measured in the same samples as above by Excitation-Emission-Matrix (EEM) fluorescence spectroscopy.

Sediment quality:

· A minimum of three cores should be taken in each habitat of the lagoon to 5 cm depth approximately.

· Each corer must be cut into surface and bottom layers. From each layer pore-water must be extracted and analyzed as above.

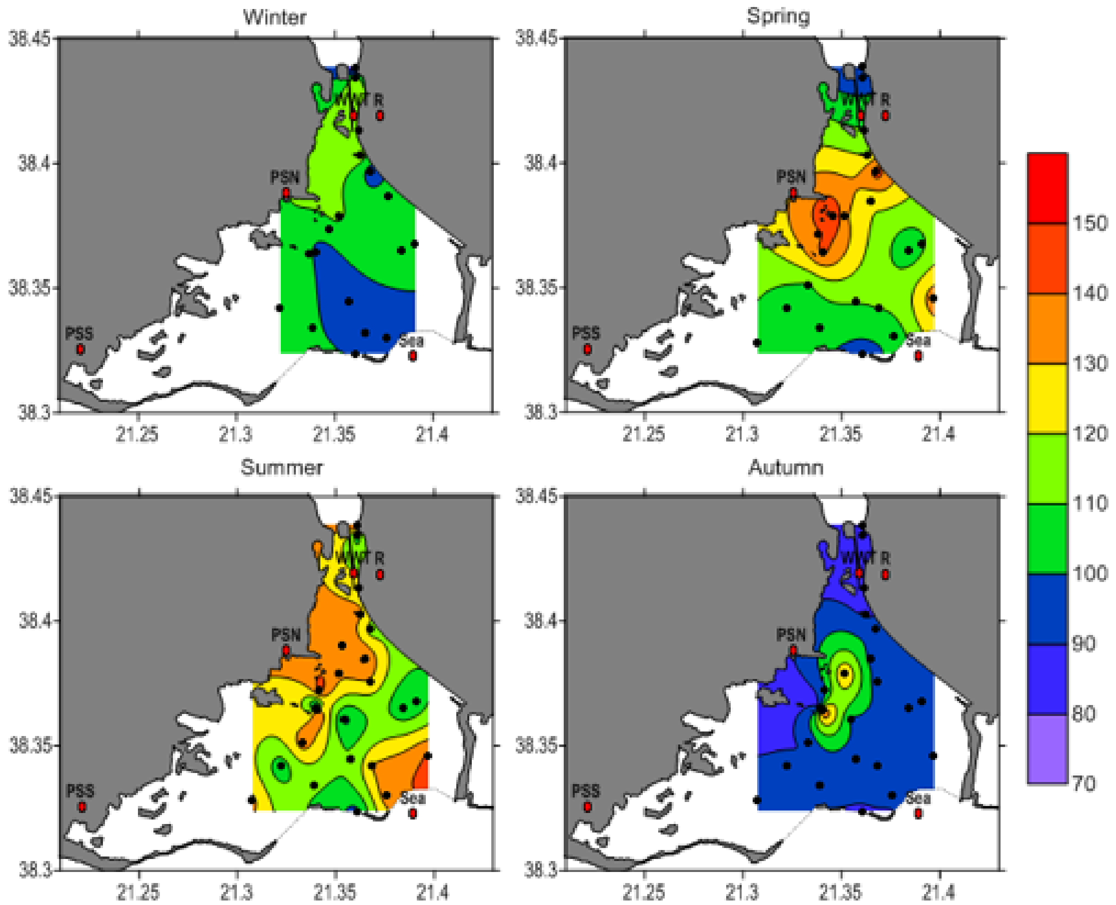
· Sediment samples from each layer should be kept frozen for protein and carbohydrate analysis. Their ratio provides information on the trophic status of the ecosystem.

Biogeochemical transformations are the basis for the functioning of the ecosystem. Any alterations or perturbations of it will have cascading effects on the entire ecosystem.

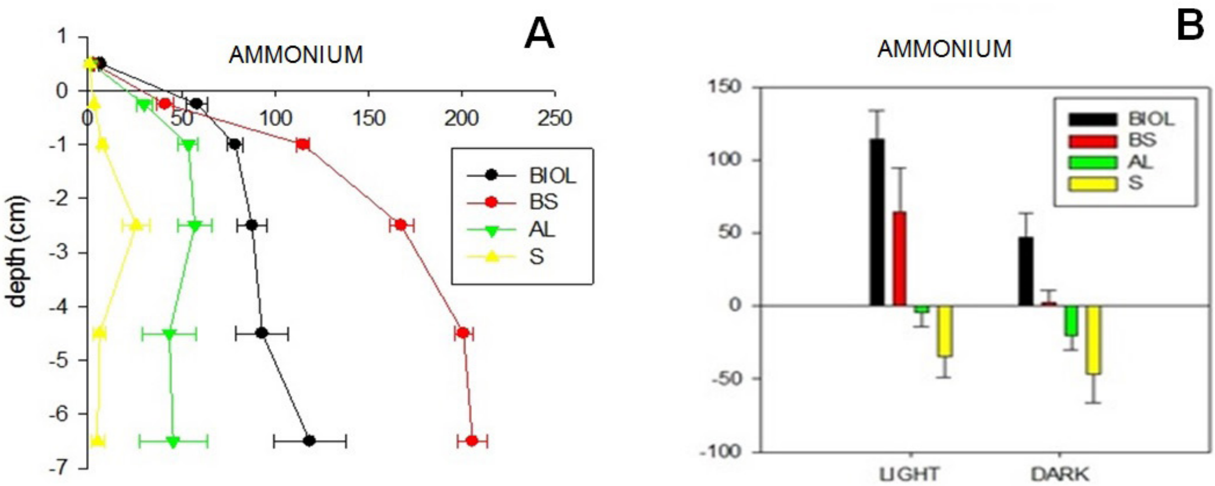
Messolonghi coastal lagoon: a case study

Messolonghi lagoon (Patraikos Gulf, W Greece), has a surface area of 15000ha. Four main habitats can be distinguished: bare sediment (BS), bare sediment receiving water from a wastewater treatment plant (BIOL), sea grass (S) and algae (AL).

Apart from the procedures described above, fluxes between water and sediment, as well as the influence of infauna on these fluxes were also studied.



Seasonal distribution of Oxygen in the water of Messolonghi.



Porewater profiles (A) and fluxes of ammonium (B) in the four habitats of Messolonghi lagoon.

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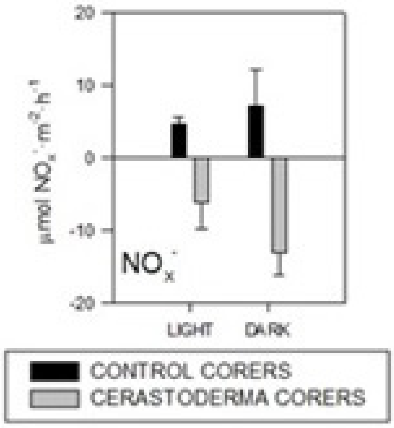
Our results clearly show that the habitats colonized by algae and seagrass are uptaking ammonium from the overlying water. Bare sediment is a large reservoir of ammonium which, under certain conditions, may be released back to the water causing eutrophication. Similar results were obtained for other nutrients.

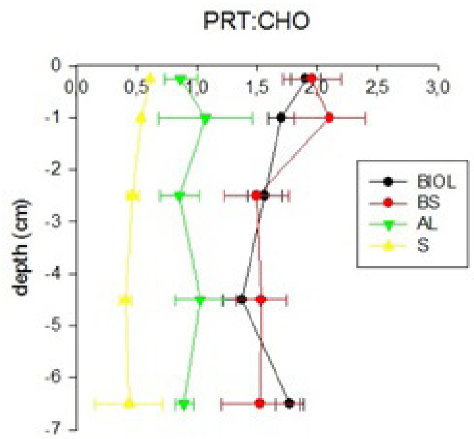
The burrowing activity of bivalves increases the oxygenation of the sediment and enhances the microbiological activity of the area. This results in the consumption and reduction of nutrients from the overlying water.

Ratios higher than 1 suggest eutrophic conditions *(Vezzuli et al., 2010)*. The graph indicates the importance of seagrass and algae in the lagoon ecosystem.

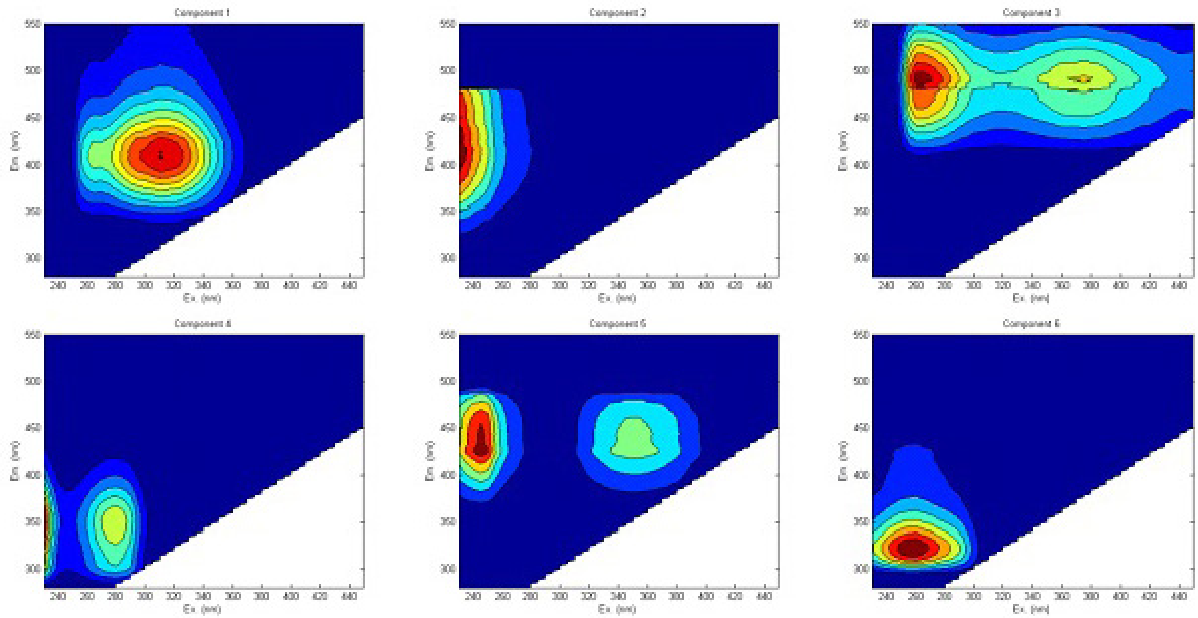
The spectra of the six fluorophores found in Messolonghi lagoon allow the separation of dissolved organic matter in two different groups; humic-like components, with more complex fluorophores and protein-like components, which are more labile and bioavailable. The humic-like component can differentiate between terrestrial compounds (anthropogenic inputs) and marine compounds (dependent of marine microbial sources), enabling the clarification of the pollution sources.



Fluxes of nitrates in the presence of the bivalve *Cerastoderma glaucum* and in controls.



Ratio of proteins: carbohydrates in the four habitats.



EEM spectra of six fluorophores components identified by PARAFAC modeling

Hydrophilic poly-ether-sulfone (PES) membranes were used here for the first time in lagoon sediments. They were originally developed for use in soil. They have been successfully applied to sample intertidal sand pore water with some precautions *(banhez et al., 2014)*. Rhizon membranes are versatile, low cost and reusable (cost ~7 E per membrane).

The chemical analyses were carried out using standard chemistry laboratory facilities. The cost per sample is estimated to approximately 250 E.

For analysing CDOM samples, an Excitation-Emission-Matrix fluorescence spectroscopy is required. The difficulties for its use are: the cost of the equipment (around 30000 E) and the complexity of the data analysis. However, the equipment can be shared by different companies, agencies, universities, etc. and no reagents are required except distilled water. Most importantly, the information obtained on the main sources of pollution is very valuable and makes this analysis worthwhile.

Conclusions

Eutrophication, one of the main problems threatening the sensitive coastal lagoon ecosystems, may be monitored by measuring nutrients in the water.

It is highly recommended, however, that sediment characteristics are also monitored, since they provide important information on the functioning of the ecosystems. These include nutrients in the pore water and proteins and carbohydrates in the sediment.

The study of the Chromophoric Dissolved Organic matter is very useful in tracing the sources of pollution in the lagoons and an effort should be made to use it, despite the cost of obtaining the equipment.

Sea grasses, algae and filter feeding bivalves are important in maintaining the good environmental conditions in the lagoons.

References

Vezzulli, L., and Fabiano, M., 2006. Sediment biochemical and microbial variables for the evaluation of trophic status along the Italian and Albanian continental shelves. Journal of the Marine Biological Association of the United Kingdom, 86, 27-37.

Ibánhez, J.S.P., and Rocha,C., 2014. Porewater Sampling for NH4+ with Rhizon Soil Moisture Samplers (SMS): Potential Artifacts induced by NH4+ Sorption. Freshwater Science, 33, 1195-1203.

MONITORING

WATER AND LAND BIOCHEMISTRY

Studying biochemical and trophic status for the better management of lagoon MPAs

WHY MONITOR IT?

- Lagoons act as coastal pollution modulators
- Allows detection of early signs of eutrophication
- Deeper insight into ecosystem interactions

HOW TO MONITOR IT?

1 IDENTIFY THREATS

- eutrophication
- loss of marine vegetation
- overfishing
- invasion by alien species

2 MONITOR INDICATORS

IN WATER

SAMPLING EVERY 5KM²
Both lagoon waters and tributaries

FILTER AND FREEZE
Filter using PES membranes and freeze until analysis

DIN AND DNP LEVELS
Measure dissolved inorganic Nitrogen and Phosphorus

CHROMOPHORIC ORGANIC MATTER
measure with EEM flourescence spectroscopy

IN SEDIMENT

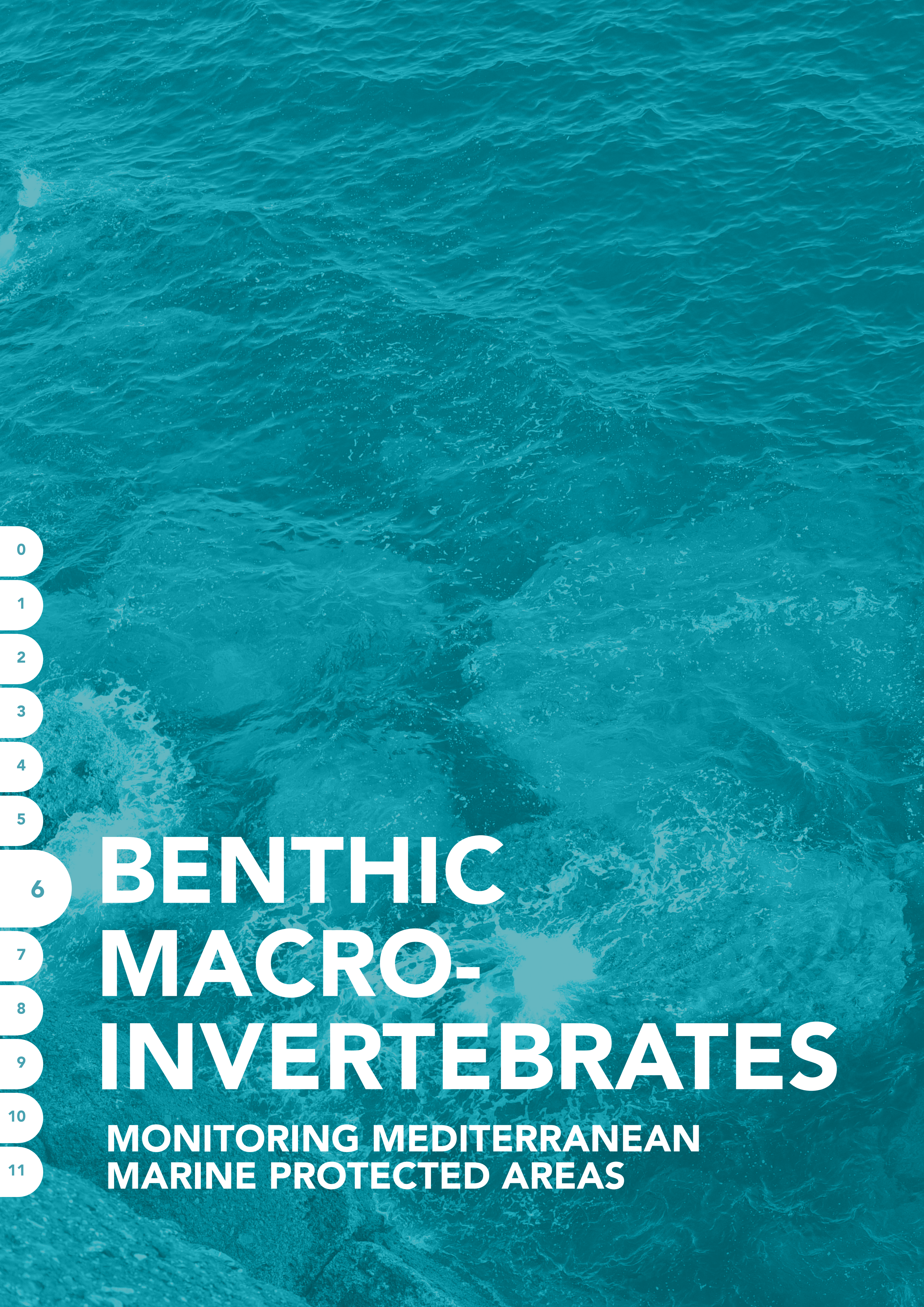
3 CORES PER HABITAT
5cm depth, then cut into surface and bottom layers

PORE WATER ANALYSIS
separate and filter from surface layer and bottom layer

SAMPLE FREEZING
surface and bottom layers frozen for protein and carbo-hydrate measurement

WHAT TO EXPECT

- Early detection of high nutrient level input in the water (eutrophication prevention)
- Detection of anthropogenic input
- Deeper insight into ecosystem functioning



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BENTHIC MACRO-INVERTEBRATES

MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

MONITORING GUIDELINES FOR MEDITERRANEAN COASTAL LAGOONS

The use of benthic macroinvertebrate communities as biological quality indicators

David Cabana[1,2], Kalliopi Sigala[1,2], Artemis Nicolaidou[2] & Sofia Reizopoulou[1]

Benthic ecosystems play a critical role in relation to the goods and services that marine and coastal ecosystems provide. Benthic macroinvertebrate communities have been proven to be reliable proxies to evaluate Ecological Quality Status of benthic ecosystems.

Why monitor benthic macroinvertebrate communities

Coastal lagoons are sheltered and shallow transitional water bodies where continental and coastal waters meet. Commonly, these ecosystems are extremely dynamic and typically highly productive playing a key role in the buffering of pollution loads transported by continental drainages into the sea. Therefore, coastal lagoons normally are organically enriched areas, both as a result of river input and recycling of materials within the system. Mediterranean coastal lagoons differ from each other according to their size, salinity and tidal ranges, exposure, mixing characteristics and depth.

Those transitional ecosystems commonly enclose a wide variety of habitats which sustain a high biodiversity that might be adapted to the natural sources of variation. Due to their geomorphological conditions, human activities such as industry discharge, sewage treatment plants, fisheries, tourism etc can cause long term irreversible damage to coastal lagoons.

Benthic macroinvertebrate fauna are small organisms comprising sizes between 0.5mm and few centimetres which live on and under the sediment, algae and aquatic plants. The community of macroinvertebrates, among others, frequently include polychaetes, crustaceans and molluscs which play a key role in the maintenance of a balanced lagoonal food chain. As benthos die, they decay, leaving behind nutrients that are reused by aquatic plants and other animals in the food chain.

Human activities that disturb the natural processes in transitional and coastal waters can highly impact on the species and abundance of benthic macroinvertebrates thus the equilibrium of the food chain. Due to their sessile, sedentary and relatively long life span macroinvertebrate species are highly sensitive to changes in the aquatic environment and are proved to be good indicators of natural and anthropogenic driven variations in coastal ecosystems (*Pearson and Rosenberg. 1978*).

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How to monitor benthic macroinvertebrate communities

The assessment of the benthic condition is one of the evaluation criteria in the Water Framework Directive. Under this directive two different macroinvertebrate related metrics; i.e. Bentix *(Simboura and Zenetos, 2002)* and M-AMBI *(Borja et al., 2004; Muxika et al., 2007)* based on sensitive taxa, abundance and diversity have been developed and intercalibrated for Mediterranean transitional water bodies. To provide homogeneous results among the European countries the Good Ecological Status reference conditions and threshold values for these indices have been intercalibrated for transitional water bodies in a European context. Furthermore metrics based on macroinvertebrates body size as the ISD *(Reizopoulou and Nicolaidou, 2007a)* and ISS *(Basset et al., 2012)* have been proved also to be a consistent assessment instrument able to offer complementary ecological information. The use of one or a combination of these metrics can be used to provide the Ecological Quality Status of the waterbody and the status of the macroinvertebrate community in three simple steps.

Ecological Quality Status assessment

1. Sampling
2. Taxonomic identification and organism measurement
3. Index application and final assesment

An assessment procedure for determining the condition of soft-sediment benthic habitats requires to; (1) define the water body typology (2) define the reference conditions and (3) establish monitoring and ecological quality classification systems for the purpose of assessing the ecological status and to determine the level of human impact on the water body.

The selection and standardization of optimal and cost-effective measures such as spatial and temporal coverage, targeted habitats, sampling effort, sample and mesh size will optimize the sampling and further assessment *(Tillin et al., 2008)*. Unstudied lagoons would require a pilot study to better know the local conditions and better design the sampling grid. For this, an earlier analysis of hydrological and ecological data (e.g. fresh water inflows, rivers, communication with the sea, depth, waterways and currents) is recommended. Moreover the use of Geographic Information System (GIS) to enable the adequate substrate and habitat mapping may help to detect habitat variability and spatial coverage *(Diaz et al., 2004)*.

Benthic macroinvertebrates are important to be monitored because

- They cannot escape from pollution
- Some groups are intolerant to pollution and others very tolerant
- They might show the cumulative impacts linked to pollution
- They play a key role in the waterbody food chain

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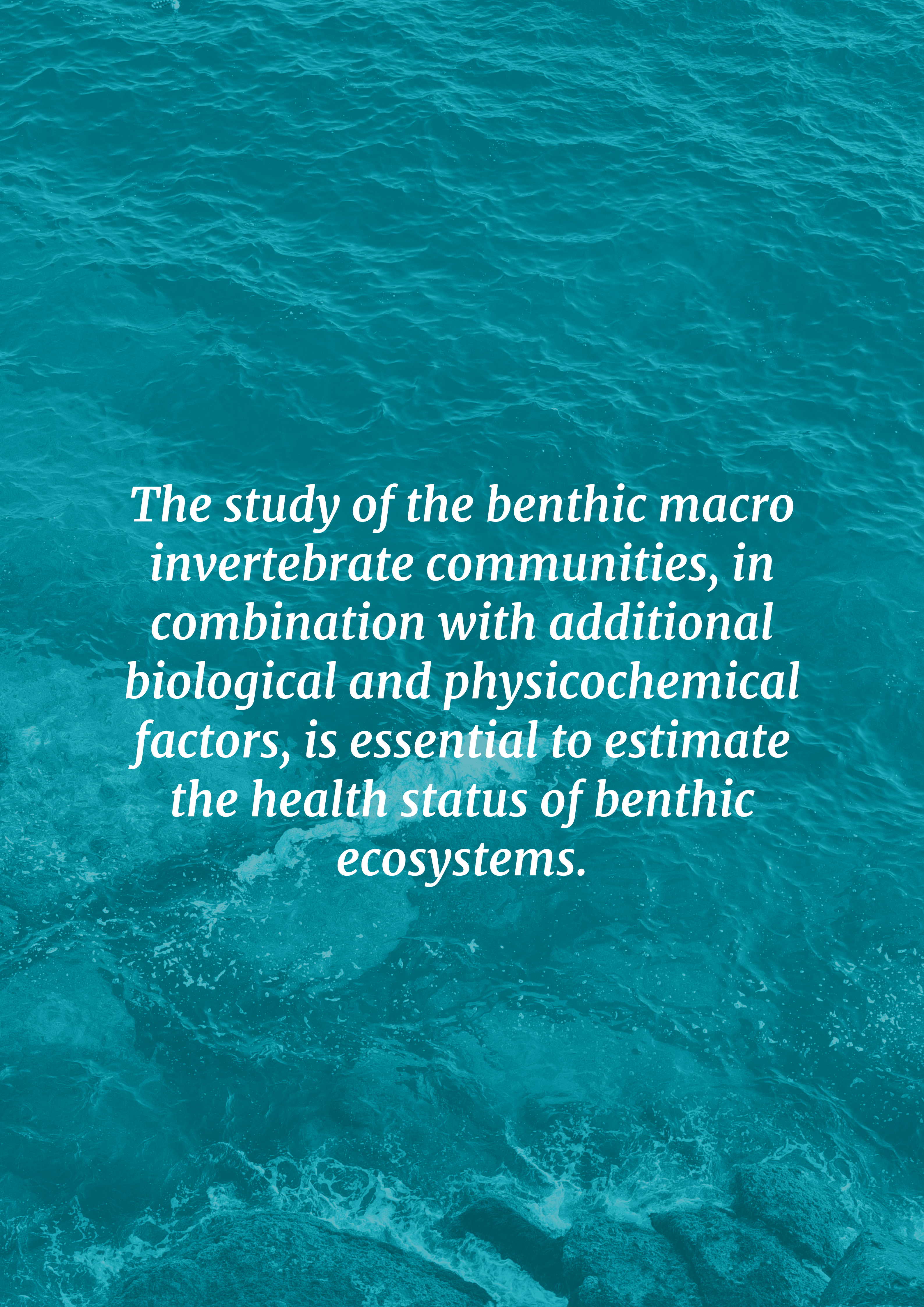

The study of the benthic macro invertebrate communities, in combination with additional biological and physicochemical factors, is essential to estimate the health status of benthic ecosystems.

IN THE FIELD CONSIDERATIONS

Spatial coverage

Sampling strategy needs to fulfil the spatial natural variability of these ecosystems. A multi-habitat approach that targets vegetated and bare bottoms is recommended. Furthermore transects that sweep from the inner to the outer part of the lagoon might be recommended in closed and semi closed lagoons.

Temporal coverage

Given the seasonal variation of benthic assemblages it is recommended to avoid direct comparisons between samples collected during different seasons The standardization of field sampling protocols, (e.g. periodicity of the sampling) enabling direct comparisons across studies is highly recommended.

Sample size and replicates

Samples must cover the same sediment surface and be large enough to represent communities at the site adequately, but not so large that they are too time-consuming to process. The most common sample size by quantitative bottom studies used historically in Mediterranean coastal lagoons goes from 0.03 to 0.1 m2. For statistical comparisons, three to five replicates per sampling point are recommended.

Mesh size

By convention, the term macroinvertebrates refers to invertebrates retained by a 0.5 to 1 mm net or sieve. The use of a 0.5 mm mesh net is suggested. Samplers using 0.5 mm mesh will be less prone to miss small specimens due to the small body size on lagoonal conditions *(Reizopoulou and Nicolaidou, 2007b).*

Messolonghi coastal lagoon: a case study

We investigated the Ecological Quality Status of a set of 7 sampling stations present in Messolonghi lagoon (Western Greece) along a confinement gradient and covering the main lagoonal benthic habitats. A point of interest (location M8) was sampled in the vicinity of a sewage treatment plant outflow

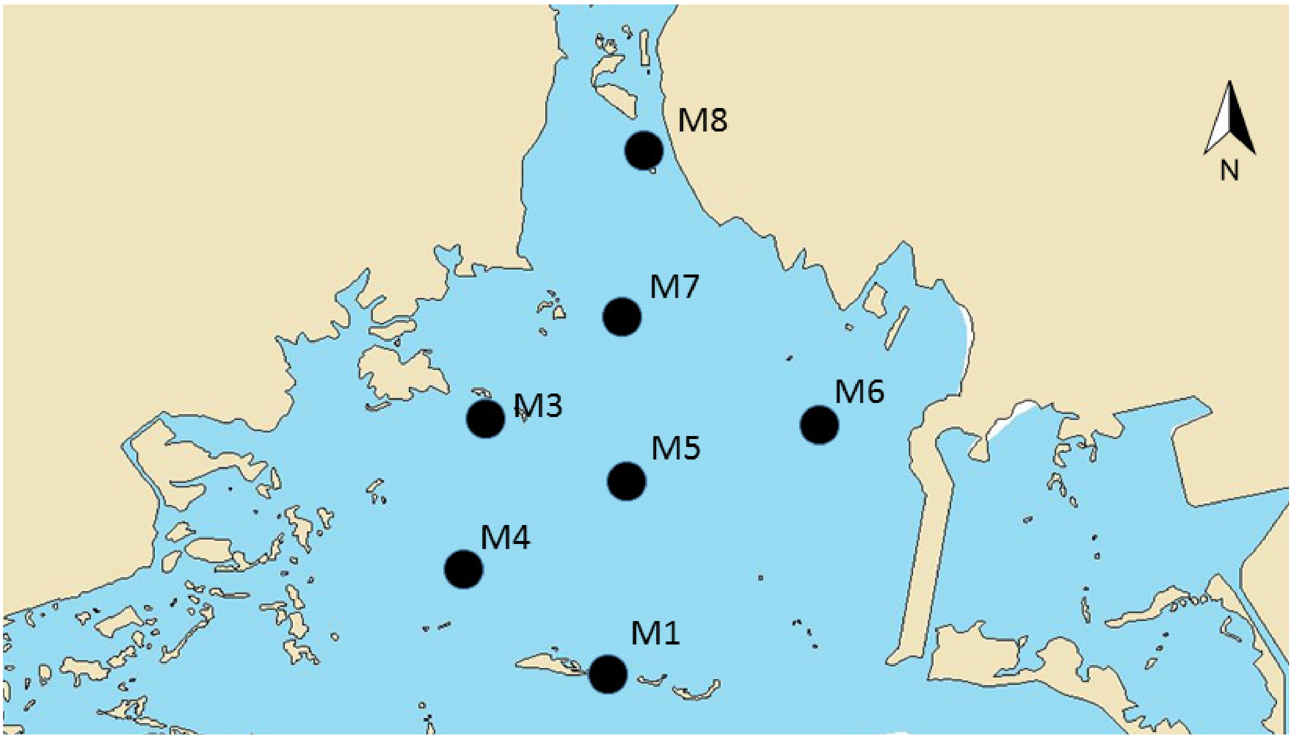

Figure 1; Sampling locations for the Ecological Quality Status assessment in Messolonghi lagoon.

At each site five samples of surface sediments were collected with a box corer of (0.03m2). At each sampling point physicochemical factors (temperature, dissolved oxygen, salinity, sediment granulometry and organic carbon) were also measured and analysed **(Fig. 2)**. The samples for macroinvertebrates identification were washed in a 0.5 mm square mesh sieve. The retained material was fixed with 4% buffered formalin stained with Rose Bengal for further benthic macroinvertebrates and phytal composition analysis. For each replicate benthic macroinvertebrates were sorted and identified to the lowest possible taxonomic level (commonly species level), counted and length measured.

For the Ecological Quality Status assessment we have applied M-AMBI *(http://ambi.azti.es/)* biotic index under the reference conditions established in *(Simboura and Reizopoulou, 2008)* i.e.; Shannon diversity (H')=4, Species richness (S)=50 and AMBI=0.

Final results of M-AMBI went from 0.44 to 1.03 **(Table 1)**. The location M8 located in the vicinity of the sewage treatment plant for the municipality of Aetoliko displayed the lowest M-AMBI value (0.44) and the location M3 which is dominated by a *Valonia aegagropila* habitat displayed the highest (1.03).

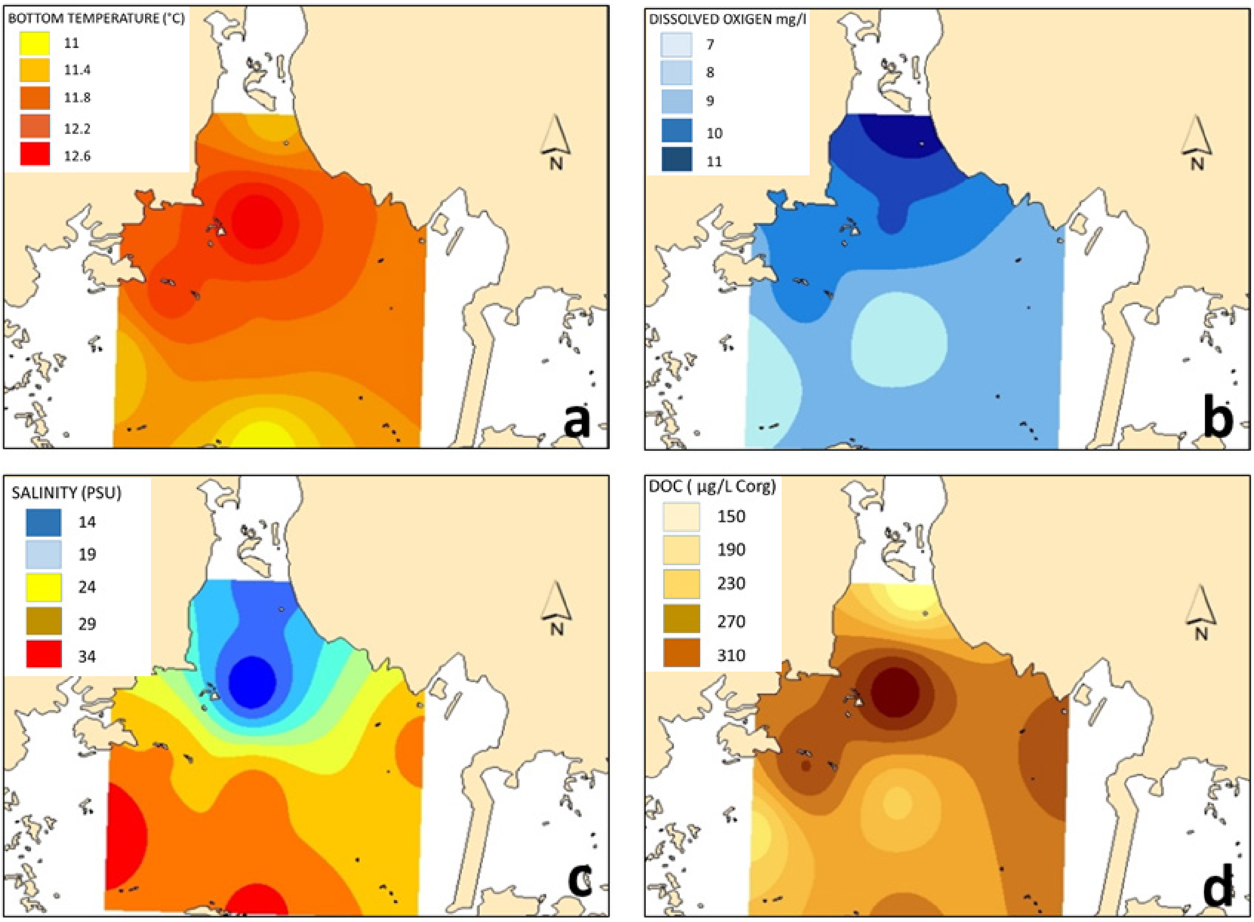

Figure 2; a)bottom temperature, b) dissolved oxygen, c) salinity and d) dissolved organic carbon during the sampling in January 2013.

6

STATION	M-AMBI
M1	0.60784
M3	1.0
M4	0.85653
M5	0.97301
M6	0.99557
M7	0.64579
M8	0.4469

Table 1, M-AMBI results for the 7 sampled locations in Messolonghi lagoon in January 2013.

For the final EcoQ we applied the Ecological Quality Ratio Boundaries that have been intercalibrated for the transitional waters in the Mediterranean basin **(Table 2)**.

Final results of EcoQ during January 2013 give values from Moderate to high. The location M1 and M8 display a moderate EcoQ. The EcoQ in M8 might be linked to the vicinity to the Aetoliko sewage treatment plant outflow. The stressed conditions in M1 might be a confluence of natural and anthropogenic pressures due to the very shallow waters and a high transit of small motor boats due to the extensive artisanal fisheries activity in this side of the lagoon.

Boundary	Status
0.83	High
0.62	Good
0.41	Moderate
0.2	Poor

Table 2. M-AMBI Ecological Quality Ratio boundary values used for the final assessment.

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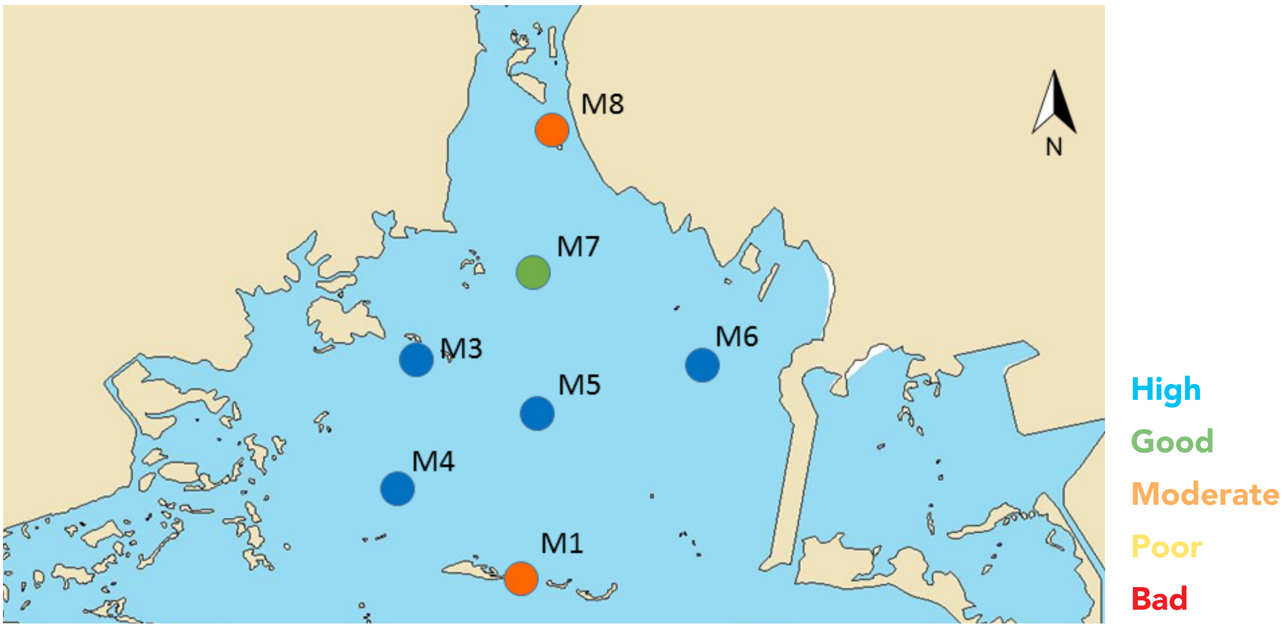

Figure 3; Ecological Quality Status for the 7 sampled locations during January 2013 in Messolonghi lagoon.

Conclusions

The goal of this work was to define the Ecological Quality Status of 7 locations across the main benthic habitat present in Messolonghi Lagoon (i.e. bare sediment, *Valonia Aegagropila, Rytiphlaea tinctoria, and Cymodocea nodosa*). A point of interest (M8) was also taken, linked to a sewage treatment plant was taken in consideration in this study. Good Ecological Status across the main habitats and locations has been recorded. The results of this study point out the moderate status of 2 different locations, one in the most inner part of the lagoon (M8) and dominated by bare sediment and the other in the southern sampled point (M1). Regarding the results obtained in this piece of work the average status of the benthic communities of the lagoon is good but pressures over M8 and M1 might be addressed in order to rise the Ecological Quality Status of the area.

References

Basset, A., Barbone, E., Borja, A., Brucet, S., Pinna, M., Quintana, X.D., Reizopoulou, S., Rosati, I., Simboura, N., 2012. *A benthic macroinvertebrate size spectra index for implementing the Water Framework Directive in coastal lagoons in Mediterranean and Black Sea ecoregions. Ecology Indicators 12, 72-83.*

Borja, A., Franco, J., Valencia, V., Bald, J., Muxika, I., Jesús Belzunce, M.a., Solaun, O., 2004. *Implementation of the European water framework directive from the Basque country (northern Spain): a methodological approach. Marine Pollution Bulletin 48, 209-218.*

Diaz, R.J., Solan, M., Valente, R.M., 2004. *A review of approaches for classifying benthic habitats and evaluating habitat quality. Journal of Environmental Management 73, 165-181.*

Muxika, I., Borja, A., Bald, J., 2007. *Using historical data, expert judgement and multivariate analysis in assessing reference conditions and benthic ecological status, according to the European Water Framework Directive. Marine Pollution Bulletin 55, 16-29.*

Pearson, T.H., Rosenberg, R., 1978. *Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology Annual Review 16, 229-311.*

Reizopoulou, S., Nicolaidou, A., 2007a. *The growth of the bivalve Abra segmentum (Recluz , 1843) in two Mediterranean lagoons. 4, 1-8.*

Reizopoulou, S., Nicolaidou, A., 2007b. *Index of size distribution (ISD): a method of quality assessment for coastal lagoons. Hydrobiologia 577, 141-149.*

Simboura, N., Reizopoulou, S., 2008. *An intercalibration of classification metrics of benthic macroinvertebrates in coastal and transitional ecosystems of the Eastern Mediterranean ecoregion (Greece). Marine Pollution Bulletin 56, 116-126.*

Simboura, N., Zenetos, A., 2002. *Benthic indicators to use in Ecological Quality classification of Mediterranean soft bottom marine ecosystem, including a new biotic index. Mediterr. Marine Science, 77-112.*

Tillin, H.M., Rogers, S., Frid, C.L.J., 2008. *Approaches to classifying benthic habitat quality. Marine Policy 32, 455-464.*

MONITORING
BENTHIC MACROINVERTEBRATES

Using macroinvertebrates to assess the Ecological Quality Status of benthic habitats in coastal lagoon ecosystems

WHY MONITOR IT?

- vital role in food chain
- provide geographical information on pollution
- show cumulated impact of pollution

HOW TO MONITOR IT?

1. **DEFINE WATER BODY TYPOLOGY**
   to be subject to analysis
2. **DEFINE REFERENCE CONDITIONS**
   for measuring human impact
3. **ESTABLISH MONITORING AND CLASSIFICATION SYSTEMS**
   Bentix and M-AMBI

Sampling considerations

- spatial coverage
- temporal coverage
- sample size
- mesh size

4. **PILOT STUDY**
   For previously unstudied lagoons
5. **COLLECT AND PRESERVE SAMPLES**
6. **IDENTIFY AND INDEX SPECIES**
7. **IMPORT DATA INTO GEOGRAPHIC INFORMATION SYSTEM**
8. **ASSESS RESULTS**
9. **INTEGRATE RESULTS INTO MPA DESIGN**

WHAT TO EXPECT

- Detect pressures and impacts acting upon the benthic habitats
- Ecological Quality Status ready to integrate with other environmental indicators
- Scientific contribution for coastal management planning and decision-making

HIGH TROPHIC LEVEL PREDATORS AND TROPHIC INTERACTIONS

MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

GUIDELINES FOR MONITORING HIGH TROPHIC LEVEL PREDATORS AND TROPHIC INTERACTIONS IN MEDITERRANEAN MPAS

Giulia Prato [1], Didier Gascuel [2], Patrice Francour [1]

High trophic level predators play an important functional role in marine ecosystems, ensuring the persistence of complex food webs that increase ecosystem resistance to human impacts.

Why monitor high trophic level predators and trophic interactions?

Centuries of selective fishing on high trophic level predators (HTLP) caused a gradual simplification of Mediterranean food-webs, which are nowadays mostly controlled by smaller and lower trophic level species *(Sala et al. 2004)*. The depletion of HTLP affected the overall stability of Mediterranean ecosystem and reduced its resilience to human impacts *(Coll et al. 2008)*.

The protection from fishing within MPAs allowed to trigger a recovery in HTLP abundance and biomass, but long time frames are needed in order to re-establish lost trophic interactions and ecosystem functions *(Babcock et al. 2010, Guidetti et al. 2014)*. Moreover, Mediterranean MPAs often direct monitoring efforts to some species of recognised ecological importance such as fish (e.g. sea breams) and sea urchins *(Guidetti 2007)*, but other functional groups can also play keystone roles and are often understudied *(Sala 2004)*. Long-term monitoring of both HTLP and trophic interactions is thus essential to assess if MPAs are effectively promoting an overall ecosystem recovery, to evaluate potential indirect effects of management actions and to adapt management consequently.

Monitoring HTLP and trophic interactions in MPAs is essential to

- Preserve food web complexity and ecosystem functioning, and thus the provision of ecosystem services.
- Understand and assess the direct and indirect human impacts on the food web (professional and recreational fishing, climate change, invasive species, etc.) and thus manage accordingly.
- Identify keystone species that shall be monitored in priority.
- Unravel and prevent potential trophic cascades which can severely impact ecosystem conditions.

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How to monitor high trophic level predators and trophic interactions?

Trophic interactions and ecosystem functioning can be unravelled through the modelling software Ecopath with Ecosim (EwE) and Ecotroph (ET) *(Christensen & Pauly 1992, Gascuel et al. 2009)* **(Fig.1)**. Such tools, widely applied in the context of the ecosystem approach for the management of marine resources at large ecosystem scales, had limited although promising application at the small scale of Mediterranean coastal MPAs *(Albouy et al. 2010,Valls et al 2012)* due to the often lacking or dispersed data. A standard model structure together with the identification of key groups for which local biomass data is needed in priority, can largely simplify the process of model construction *(Prato et al. 2014)*. Data prerequisites for model building are biomass, production and consumption rates, diets and fisheries catches for all the functional groups in the ecosystem. While vital rates and diet can be indirectly derived (literature, empirical equations), local biomass data and fishery catches are essential. This data often exists for well-studied MPAs, but is generally dispersed among several institutions. Effort shall thus be directed to collecting and standardising such data.

When biomass data are lacking, they should be collected in priority for those functional groups that play an important role in the ecosystem and significantly impact the model structure. In order of importance: high trophic level predators (HTLP) (including several fish groups), primary producers, cephalopods, decapods and macrofauna *(Prato et al. 2014)* (Fig.2). Monitoring programs targeting these groups could be coupled to other regular programs like monitoring for the reserve effect. For HTLP , we suggest to use underwater visual census transects of 35 x 20 meters, proven to record higher biomasses and species richness than standard 25x5 m transects used in regular reserve effect monitoring *(Prato, in prep)*. A monitoring program with different sized transects adapted to fish mobility (35x20 for HTL, 25x5m for necto-benthic,10x1 m for crypto-benthic fish) allows, besides model building, to assesses the recovery of HTL predators within the MPA and the reserve effect.

Once data are available, the model can be developed in relatively short time frames (1 month max) by a specialist in the domain. Outputs of an EwE-ET model allow to identify priority targets for monitoring (keystone species and species subject to the strongest fishing pressure), compute indices of food web complexity and ecosystem maturity useful for comparisons over time, and quantify the impact of fishing activities and of potential management actions on the whole food-web (Fig.2). Food-web models also allow to bring to light data gaps or inconsistencies in local data, thus they can re-direct monitoring, in a feed-back loop that shall be accordingly translated into adaptive management (i.e fill data gaps, increase data quality for keystone groups,or re-evaluate ecosystem impacts through an updated model after management actions have been taken) **(Fig.2).**

The EwE-ET software is free and available online. Data collection can be integrated within the regular MPA activities, both by gathering and standardising dispersed data, by ensuring that research projects within MPA boundaries to provide, when possible, biomass estimations on the studied group, and finally by expanding existing monitoring activities to key but lesser studied groups (for example invertebrates, see www.pisco.org monitoring programs). An estimation of the total data collection costs to build a model for a case study with no existing data or monitoring programs (145 ha, with typical Mediterranean habitats, warm season) totals 47 700 € (assuming the price of a scientific operator at 500 € /dive, and including 27 500 € for field work , 16 000 € for the specialist analysis of macrofaunal samples and 4200 € for data analysis and model development by a specialist). MPA staff can also receive formal training (approx. 400 €, 3-days course) to become proficient in EwE modelling. If no data at all is available, it is advisable to invest initially in fish monitoring, primary producers, cephalopods and decapods, since macrofauna sampling is the least-cost effective process. If the MPA is provided with the necessary scientific diving skills and material and if model development is integrated to the regular monitoring activities of the MPA, the cost is reduced to computer work (4200 €).

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A truly effective ecosystem based management must account for trophic interactions to understand and manage human impacts on marine ecosystems.

Figure 1. Ecopath with Ecosim software.

Portofino MPA case study

A standard model structure was developed for the Port Cros MPA and applied to the Portofino and Cap Roux MPAs. In Portofino, data gathering from existing literature on the area allowed to obtain local biomass estimates for 60% of the 32 functional groups in the area. Keystone species analysis on the balanced model identified the HTLP groups (including *Seriola dumerili, Sphyraena viridensis, Dentex dentex, Dicentrarchus labrax, Conger conger, Muraena helena*), the Large scorpionfish group (including *Labrus merula, Labrus viridis, Scorpaena scrofa, Sciaena umbra, Pagrus pagrus*), the small dusky grouper (*Epinephelus marginatus*) and cephalopods as keystone functional groups in the ecosystem **(Fig.2)**. HTLP and Large scorpionfish were also strongly impacted by local artisanal and recreational fishing, being thus “sentinel species” combining high ecological importance and high fishing pressure in the ecosystem. They should thus be prioritised for monitoring, together with cephalopods.

Simulation of the unexploited state of the ecosystem, shows that there is potential for an increase of 50% in the biomass of HTLP, if all fisheries are forbidden and of 24% if only recreational fishing is stopped **(Fig.2)**. Forbidding recreational fishing would also significantly benefit artisanal fisheries catches, releasing HTLP and thus increasing the mean TL of artisanal catches **(Fig.2)**. Reducing recreational fishing would thus allow to pursue both the MPÀs conservation and sustainable socio-economic development objectives. MPAs should direct more efforts in quantifying artisanal and fisheries catches to increase reliability of model results.

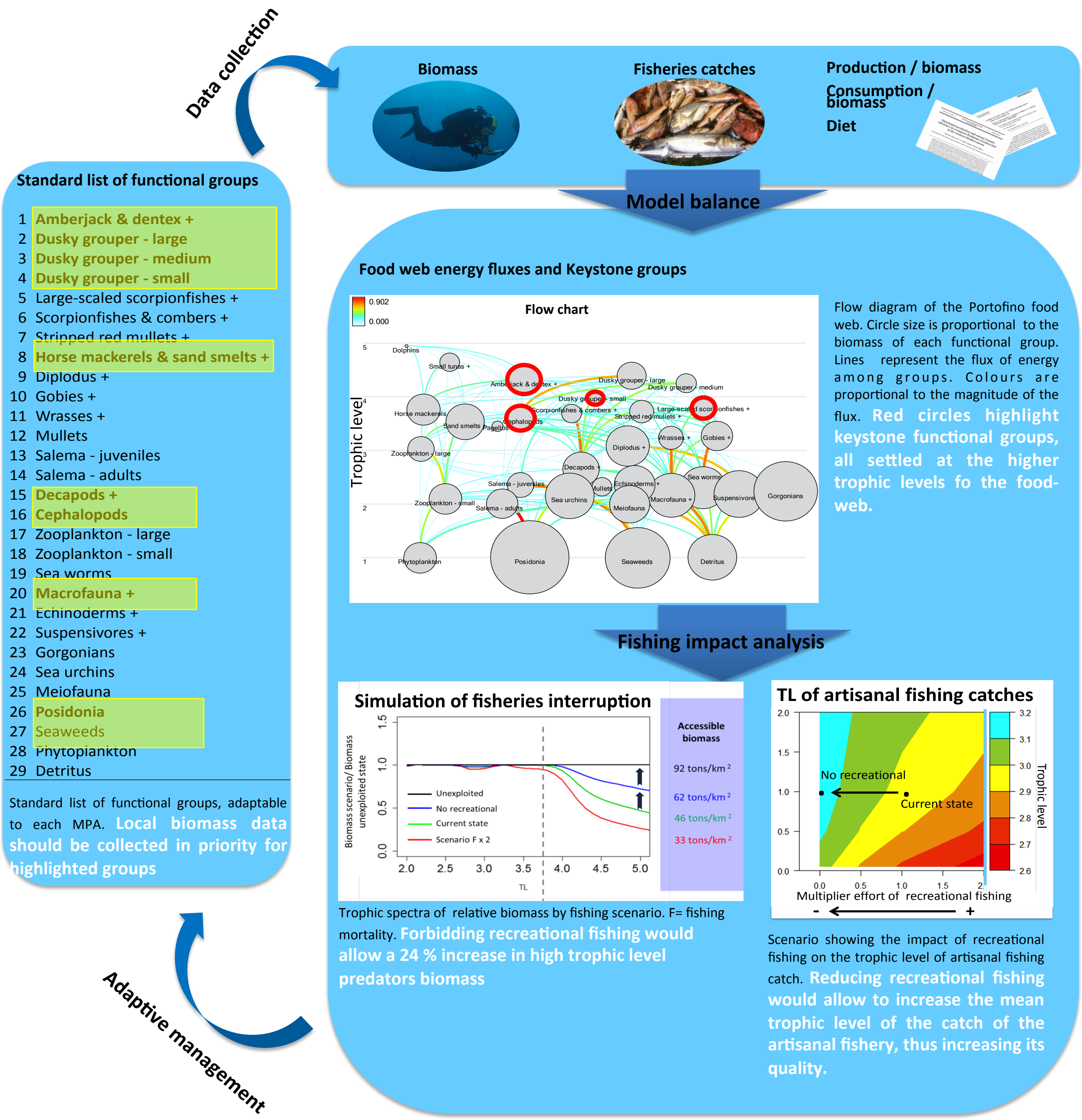

Figure 2. Monitoring keystone species at the Portofino Marine Protected Area.

Conclusions

EwE - ET trophic modelling software provides a standard framework for organising existing ecological data into a coherent picture of ecosystem functioning for the MPA, allowing the monitoring of trophic interactions over time. This approach has high potential as a tool to advise management in Mediterranean MPAs. Trophic modelling can build upon monitoring data to develop ecosystem based indicators, such as food-web indicators, as also required by the Marine Strategy Framework Directive, in order to achieve the Good Environmental Status (Heymans et al. 2014). In this view, trophic models of MPAs could be very useful to define targets for indicators and to provide reference values corresponding to different conservation targets. "Sentinel species", i.e keystone species combining high ecological importance and high fishing pressure in the ecosystem under study, can be identified and prioritised for monitoring and can be a reference for the definition of management actions that deserve to be taken (e.g. to calculate the reduction of fishing mortality needed to attain predefined conservation objectives) and for the assessment of their efficiency.

Trophic-level based indicators centred on the proportion of apex and/or high trophic level predators in the ecosystem can also be developed as a proxy for the good functioning of the whole food web, and ecosystem-specific targets can be proposed for each indicator.

Overall, the approach should be seen as an incentive for establishing long-term monitoring programs, since once a model is available, it can be updated yearly with low effort and costs, allowing to assess the evolution of the protected food-web over time. Data gaps can be identified to direct monitoring efforts, and once time series of biomass and catch data are available, spatio-temporal simulations can be performed to evaluate potential impact of several management actions (extension or modification of MPA borders, alternative fishing scenarios and many more).

References

Albouy, C., Mouillot, D., Rocklin, D., Culioli, J., Le Loc'h, F., 2010. *Simulation of the combined effects of artisanal and recreational fisheries on a Mediterranean MPA ecosystem using a trophic model. Marine Ecology Progress Series 412, 207–221. doi:10.3354/meps08679.*

Babcock, R.C., Shears, N.T., Alcala, A.C., Barrett, N.S., Edgar, G.J., Lafferty, K.D., McClanahan, T.R., Russ, G.R., 2010. *Decadal trends in marine reserves reveal differential rates of change in direct and indirect effects. PNAS 107, 18256–18261. doi:10.1073/pnas.0908012107.*

Coll, M., Lotze, H.K., Romanuk, T.N., 2008. *Structural degradation in Mediterranean Sea food webs: testing ecological hypotheses using stochastic and mass-balance modelling. Ecosystems 11, 939–960.*

Guidetti, P., Baiata, P., Ballesteros, E., Di Franco, A., Hereu, B., Macpherson, E., Micheli, F., Pais, A., Panzalis, P., Rosenberg, A.A., Zabala, M., Sala, E., 2014. *Large-Scale Assessment of Mediterranean Marine Protected Areas Effects on Fish Assemblages. PLoS ONE 9, e91841. doi:10.1371/journal.pone.0091841.*

Christensen, V., Pauly, D., 1992. *Ecopath II—a software for balancing steady-state ecosystem models and calculating network characteristics. Ecological modelling 61, 169–185.*

Gascuel, D., Pauly, D., 2009. *EcoTroph: modelling marine ecosystem functioning and impact of fishing. Ecological Modelling 220, 2885–2898.*

Guidetti, P., 2007. *Predator diversity and density affect levels of predation upon strongly interactive species in temperate rocky reefs. Oecologia 154, 513–520.*

Heymans, J.J., Coll, M., Libralato, S., Morissette, L., Christensen, V., 2014. *Global Patterns in Ecological Indicators of Marine Food Webs: A Modelling Approach. PLoS ONE 9, e95845. doi:10.1371/journal.pone.0095845.*

Prato, G., Gascuel, D., Valls, A., Francour, P., 2014. *Balancing complexity and feasibility in Mediterranean coastal food-web models: uncertainty and constraints. Marine Ecology Progress Series 512, 71–88.*

Sala, E., 2004. *The past and present topology and structure of Mediterranean subtidal rocky-shore food webs. Ecosystems 7, 333–340.*

Valls, A., Gascuel, D., Guénette, S., Francour, P., 2012. *Modeling trophic interactions to assess the effects of a marine protected area: case study in the NW Mediterranean Sea. Marine Ecology Progress Series 456, 201–214.*

MONITORING
HIGH TROPHIC LEVEL PREDATORS AND TROPHIC INTERACTIONS

Studying the food web to manage direct and indirect human impacts on the ecosystem

WHY MONITOR IT?

- Preservation of the food web complexity
- Understanding of human impact on the MPA
- Identifying keystone species
- Prevention of trophic cascades

HOW TO MONITOR IT?

1 SOFTWARE TOOLS
Use Ecopath+Ecosim (EwE) and Ecotroph (ET) for modeling

2 DEFINE FUNCTIONAL GROUPS AND INPUT VARIABLES
e.g. biomass, production and consumption rates, diet, fishery catches

3 COLLECT INPUT VARIABLES

BIOMASS
from visual census using fish mobility adapted transects

FISHING CATCHES
from surveys of professional and recreational fishing

VITAL RATES
from empirical equations

DIET
from literature

4 MODEL BUILDING AND BALANCING
Identifying data gaps,priority monitoring targets and assessing fishing impact with EwE and ET

5 INTEGRATE DATA COLLECTION INTO MPA ACTIVITIES
for consistent monitoring

WHAT TO EXPECT

- Identification of keystone species for informed monitoring
- Food-web indicators for definition of ecosystem-specific conservation targets
- Quantification of ecosystem carrying capacity
- Holistic advice for professional and recreational fisheries management

GENETIC CONNECTIVITY

MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

GENETIC CONNECTIVITY AND DIVERSITY AS A TOOL TO ASSESS THE EFFECTIVENESS OF MARINE PROTECTED AREAS

Patricia Marti-Puig [1]*, Antonio Calò [2]*, Federica Costantini [1], Adriana Villamor [1], Marco Abbiati [1], Massimo Ponti[1], José A. García-Charton [2]

This document provides the methodological framework for the assessment and monitoring of species genetic connectivity in the MPA context. The methodologies suggested, used in combination with other tools, can help the establishment of new MPAs and the monitoring of MPA effectiveness over time.

Why monitor genetic connectivity and diversity

The design and management of Marine Protected Areas (MPAs) and MPA networks should consider spatial patterns of species distribution and connectivity among populations *(Green et al., 2014)*. Connectivity is the exchange of individuals among populations through the passive transport and/or active movement of individuals at whatever life stage (i.e. gametes, larvae, juveniles, sub-adults and adults) *(Cowen and Sponaugle, 2009)*. Beside its importance in MPA design, connectivity is a fundamental aspect to consider when evaluating the status of existing MPAs and their ability to participate in an effective network, since well-connected and highly diverse populations are more resilient to environmental changes and less subjected to face local extinctions *(Kaplan et al., 2009; Planes S, 2009)* **(Fig. 1)**.

From this perspective, the investigation of connectivity patterns can be used as a management tool, providing information on: (1) the portion of individuals coming from protected populations retained within MPA borders, allowing assessment of the level of self-sustainment of populations living inside the MPA; (2) the amount of individuals exported from protected populations toward unprotected areas, that gives an estimate of the ability of a MPA to supply outer unprotected locations; (3) the strength and direction of the connections between a MPA and the other MPAs that indicates if a MPA is acting as a 'source' and/or 'sink' of propagules (i.e. eggs and larvae). All this information can help managers assess the status of their MPAs, and to address specific management issues in order to improve and/or maintain MPA health and effectiveness.

Monitoring genetic connectivity in MPAs is important because allows to:

- Assess the level of self-sustainability of populations living inside the MPA.
- Estimate the ability of an MPA to supply outer fished locations.
- Know if a MPA is acting as a 'source' and/or 'sink' of propagules.

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Figure 1: Effect of connectivity and genetic diversity on the resilience of local populations.

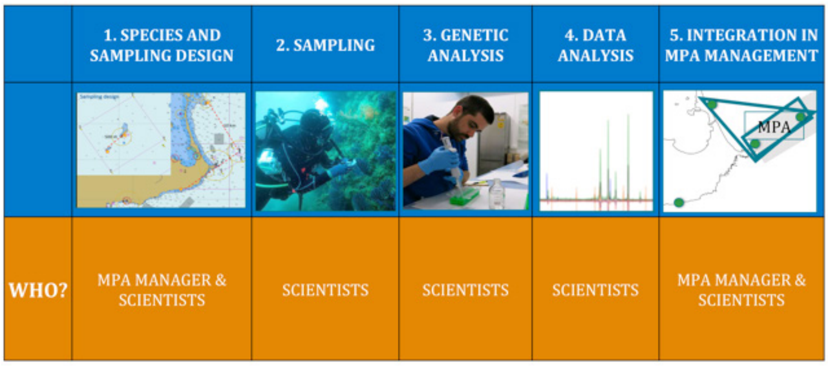


Figure 2: Schematic standard approach for gathering data on genetic connectivity and integrate them for the development of marine conservation strategies.

How to monitor genetic connectivity and diversity

Different methods can be used to assess connectivity patterns between populations of marine organisms: e.g. biophysical larval dispersal models, genetic analyses, chemical analysis of carbonatic structures (such as fish otoliths). Each method has its advantages and disadvantages and none are flawless for assessing connectivity patterns *(Calò et al., 2013, Jones et al., 2009)*. However, in the context of MPA monitoring, genetic tools could be preferable as they permit assessment of connectivity patterns at different temporal and spatial scales, and are possibly non-lethal, allowing their application on endangered species and focal species *(Calò et al., 2013, Marti-Puig et al., 2013)*. Moreover, they can be used to investigate diversity and connectivity patterns in a huge variety of marine organisms with standard approaches equally valid for all animal or plant taxa.

A general approach for the monitoring of connectivity patterns should take into account the characteristics of the monitored MPA but also a series of aspects that would allow us to have a representative sampling design (Fig. 2). From this perspective, the number of sampling sites should be defined depending on the geographic extension of the study area. The distance among sites would depend on the MPA size, the geomorphological and environmental characteristics, and the target species *(Marti-Puig et al., 2013)*. A replicated design with selection of two or more site inside and outside the MPA in order to evaluate MPA effectiveness. Specifically, for genetic analysis, at each site, 20-30 individuals per species should be collected , for instance, within an area of approximately 100 m², separated from 1-10 m apart in the case of sessile individuals or sampling from different shoals in the case of fishes, in order to avoid clones or collection of closely related specimens *(Bell, 2008, Costantini et al., 2007)*. A small amount of tissue is enough for genetic analysis, which usually can be extracted without harming or killing the individual. Samples should be preserved in 90% ethanol and maintained at 4 °C until processing. Cost per unit area would depend on the species selected for the monitoring, and the type of analysis needed. Samples could be extracted and sent to a sequence facility with a relatively low cost (DNA sequencing cost around 200€ for 96 samples). Moreover, nowadays genetics is evolving very fast, and cheaper and faster analysis such as next generation sequencing are available *(Csencsics et al., 2010)*.

Since connectivity patterns differ among species *(Coleman et al., 2011)*, several species should be selected to better address MPA management issues *(Marti-Puig et al., 2013)*, as well as, additional information, such as oceanographic current data and demographic data, should be integrated in connectivity studies, in order to better interpret the results.

Connectivity studies are fundamental for the establishment of new MPAs and the monitoring of existing ones, as they provide information on the spatial scale to consider to effectively protect marine populations.

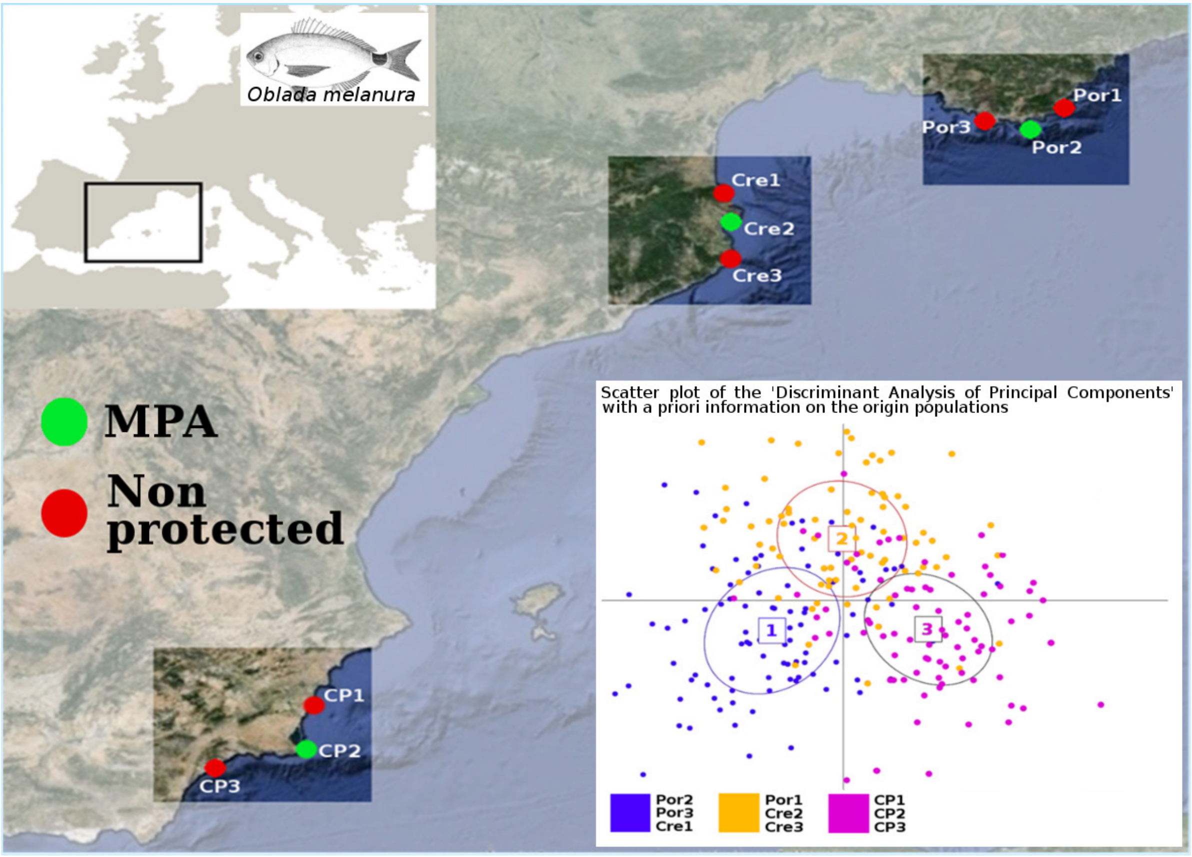


Figure 3: Study area and species. Right-down: Scatterplot from 'Discriminant Analysis of Principal Components'.

A case study on fishes: the saddled sea bream (Calò et al, 2016)

The saddled sea bream (*Oblada melanura*) is an economically important species, widely distributed in Mediterranean coastal ecosystems. Although generally protected within Mediterranean MPAs, population genetic patterns of this species are currently unknown in the Western Mediterranean Sea. With this aim, the genetic structure of the saddled sea bream and the level of genetic connectivity between protected and unprotected populations was investigated, using a set of 11 microsatellite loci. Spatial patterns of population differentiation were assessed locally (50-100 km) and regionally (500-1000 km), considering three MPAs of the Western Mediterranean Sea. All values of population differentiation (F_{ST} and Jost's D) were non-significant after Bonferroni correction, indicating that, at a relatively local spatial scale, protected populations were in general well connected with non-protected ones. On the other hand, at the regional scale, statistical analyses (i.e. discriminant analysis of principal components, AMOVA and STRUCTURE) revealed the presence of a subtle population structure that reflects the main oceanographic features (currents and barriers) of the study area **(Fig. 3)**.

This genetic pattern (population divergence in presence of high gene flow) could be a consequence of different processes acting at different spatial and temporal scales among which species dispersal capacity, the presence of admixed populations or large population size could play a major role. These results may have important implications for the conservation biology and fisheries management of saddled sea bream like other coastal fish, as spatial variability in connectivity patterns may promote long-term stability of fish populations. From this perspective, multi-scale patterns of genetic connectivity should be taken into account when future MPAs will be established in the western Mediterranean Sea, implementing the existing network.

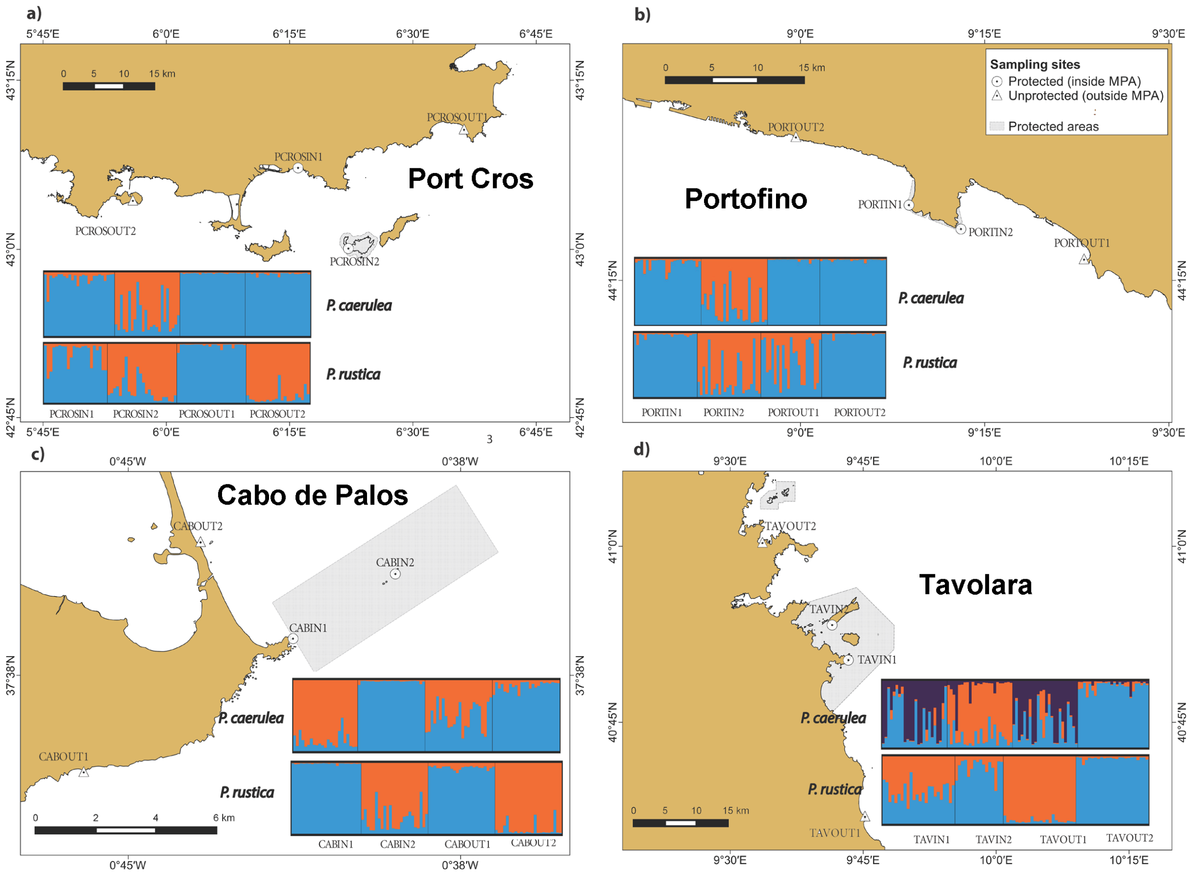


Figure 4: Possible results obtained by genetic analysis that will help to understand the populations structure and connectivity patterns.

A case study on intertidal invertebrates: the limpets

Limpets have a key ecological role in structuring rocky intertidal assemblages. Therefore their conservation is essential to protect these communities. Genetic variability and population connectivity of two widely distributed limpets (*Patella caerulea* and *P. rustica*) were analysed inside and outside four MPAs in the western Mediterranean Sea using mitochondrial and microsatellite markers. No effect of protection on genetic variability was observed in either species (Fig. 4).

Mitochondrial marker reveals for both species limited genetic structure among MPAs in the north-western Mediterranean. Within each location, different patterns of genetic structure and connectivity were observed depending on the species and local hydrodynamic features (Fig. 4). These and future genetic connectivity studies will help to MPA managers for the design of MPAs in order to enhance connectivity and genetic diversity that will increase the resilience of marine populations.

Conclusions

MPA design and monitoring based on connectivity assessment should take into account:

1) The knowledge of the biology and ecology of the model species, including:

- Life history traits, habitat preferences and behaviour
- Larval dispersal capability and movement characteristics
- Population genetic background

2) The environmental features in the area, including:

- Information on hydrodynamic patterns
- Information of the habitat characteristics

References

Bell, J.J., 2008. *Connectivity between island Marine Protected Areas and the mainland. Biol. Conserv. 141, 2807-2820.*

Calò, A., Félix-Hackradt, F.C., Garcia, J., Hackradt, C.W., Rocklin, D., Treviño Otón, J., García-Charton, J.A., 2013. *A review of methods to assess connectivity and dispersal between fish populations in the Mediterranean Sea. Advances in Oceanographic and Limnology 4, 150-175.*

Calò A., Muñoz I., Pérez-Ruzafa Á., Vergara-Chen C., García-Charton, J.A., 2016. *Spatial genetic structure in the saddled sea bream (Oblada melanura [Linnaeus, 1758]) suggests multi-scaled patterns of connectivity between protected and unprotected areas in the Western Mediterranean Sea. Fisheries Research 176: 30-38.*

Coleman, M.A., Chambers, J., Knott, N.A., Malcolm, H.A., Harasti, D., Jordan, A., Kelaher, B.P., 2011. *Connectivity within and among a network of temperate marine reserves. PloS one 6, e20168.*

Costantini, F., Fauvelot, C., Abbiati, M., 2007. *Genetic structuring of the temperate gorgonian coral (Corallium rubrum) across the western Mediterranean Sea revealed by microsatellites and nuclear sequences. Molecular Ecology 16, 5168-5182.*

Cowen, R.K., Sponaugle, S., 2009. *Larval dispersal and marine population connectivity. Annual Review of Marine Science 1, 443-466.*

Csencsics, D., Brodbeck, S., Holderegger, R., 2010. *Cost-effective, species-specific microsatellite development for the endangered dwarf bulrush (Typha minima) using next-generation sequencing technology.Journal of Heredity 101, 789-793.*

Green, A.L., Maypa, A.P., Almany, G.R., Rhodes, K.L., Weeks, R., Abesamis, R.A., Gleason, M.G., Mumby, P.J., White, A.T., 2014. *Larval dispersal and movement patterns of coral reef fishes, and implications for marine reserve network design. Biological Reviews.*

Jones, G., Almany, G., Russ, G., Sale, P., Steneck, R., Van Oppen, M., Willis, B., 2009. *Larval retention and connectivity among populations of corals and reef fishes: history, advances and challenges. Coral Reefs 28, 307-325.*

Kaplan, D.M., Botsford, L.W., O'Farrell, M.R., Gaines, S.D., Jorgensen, S., 2009. *Model-based assessment of persistence in proposed marine protected area designs. Ecological Applications 19, 433-448.*

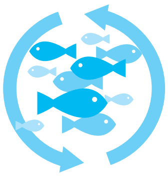
Marti-Puig, P., Costantini, F., Rugiu, L., Ponti, M., Abbiati, M., 2013. *Patterns of genetic connectivity in invertebrates of temperate MPA networks. Advances in Oceanographic and Limnology. 4, 138-149.*

Planes S, J.G., Thorrold SR 2009. *Larval dispersal connects fish populations in a network of marine protected areas. Proceedings of the National Academy of Sciences 105, 5693-5697.*

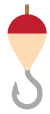
MONITORING
GENETIC CONNECTIVITY AND DIVERSITY

Assessment to determine the effectiveness of Marine Protected Areas

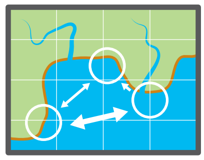
WHY MONITOR IT?



MPAs self-sustainability



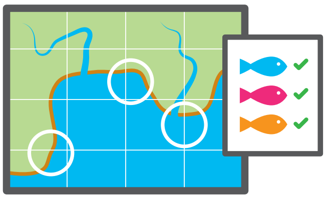
Information about the MPA supply capacity



Strength and direction of connections between MPAs

HOW TO MONITOR IT?

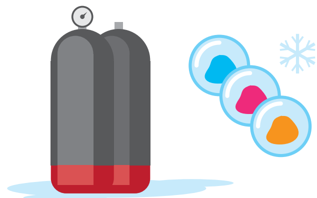
1



SELECT SPECIES AND SAMPLING DESIGN

done by managers and scientists

2



COLLECT AND PRESERVE TISSUE SAMPLES

done by scientists

3

PERFORM COMPARATIVE GENETIC ANALISYS

done by scientists

4

INDEX AND INTERPRET RESULTS

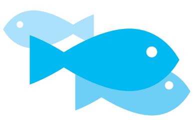
done by scientists

5

INTEGRATE RESULTS INTO MPA DESIGN

done by scientists and MPA managers

WHAT TO EXPECT



Selection of commercially important species

Genetic data acquisition and analysis

Integration with complementary methods for assessing connectivity patterns

0 1 2 3 4 5 6 7 8 9 10 11

9 SOCIAL RESEARCH

MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

SET OF GUIDELINES FOR SOCIAL SCIENCE RESEARCH IN MPAS

Katie Hogg [1], Sarah Young [1], María Semitiel-García [1], Pedro Noguera-Méndez [1]

Social rather than physical factors are the primary determinants of MPA success (Pomeroy et al., 2004).

So why don't we monitor human behaviour with the same vigour we monitor fish and corals?

Why monitor the human dimension?

MPAs are designed for a variety of purposes including conservation of biodiversity, management of fisheries, protection of endangered species, establishment of marine parks for tourists and local residents and protection of cultural resources. In all cases the MPA objectives ultimately stem from human needs, attitudes and desires, whether this be to increase the number of fish, support traditional livelihoods or protect sensitive habitats. In order to better understand the human dimension of MPAs it is necessary to acknowledge that MPAs are not without complexity and controversy.

Essentially an MPA is a socially constructed set of rules that govern human interactions within a specified area, for example who may do what, where and when. As MPAs involve some restriction of human uses, they can generate debate and concern among those directly affected. We are beginning to understand the ecology of these systems, yet we lack key information on the social, cultural and economic aspects of MPAs. This gap in information hinders MPA managers' ability to make science-based decisions that include the human environment as well as the natural environment.

It has been highlighted that the inability to adequately address the human dimension of MPAs is perhaps the greatest factor impeding their broader and effective use in marine conservation *(Wahle and Lyons, 2003)*. It is therefore important to systematically assess the human dimensions of MPAs and evaluate the outcomes of management actions. One such example could be to measure the perceived societal satisfaction with management. In addition, the data collection process (surveys, interviews, meetings) can be designed and conducted in such a way that it has the potential to build relationships between administrators and users, generating social capital, which helps anticipate potential problems and reduce conflict.

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Social research in MPAs is important because:

- MPAs have a human dimension that is currently overlooked
- Failure to address the human dimension is the biggest factor impeding MPA success
- In order to form sound science based decisions and achieve adaptive management the human as well as the natural environment must be fully understood

How to monitor the human dimension

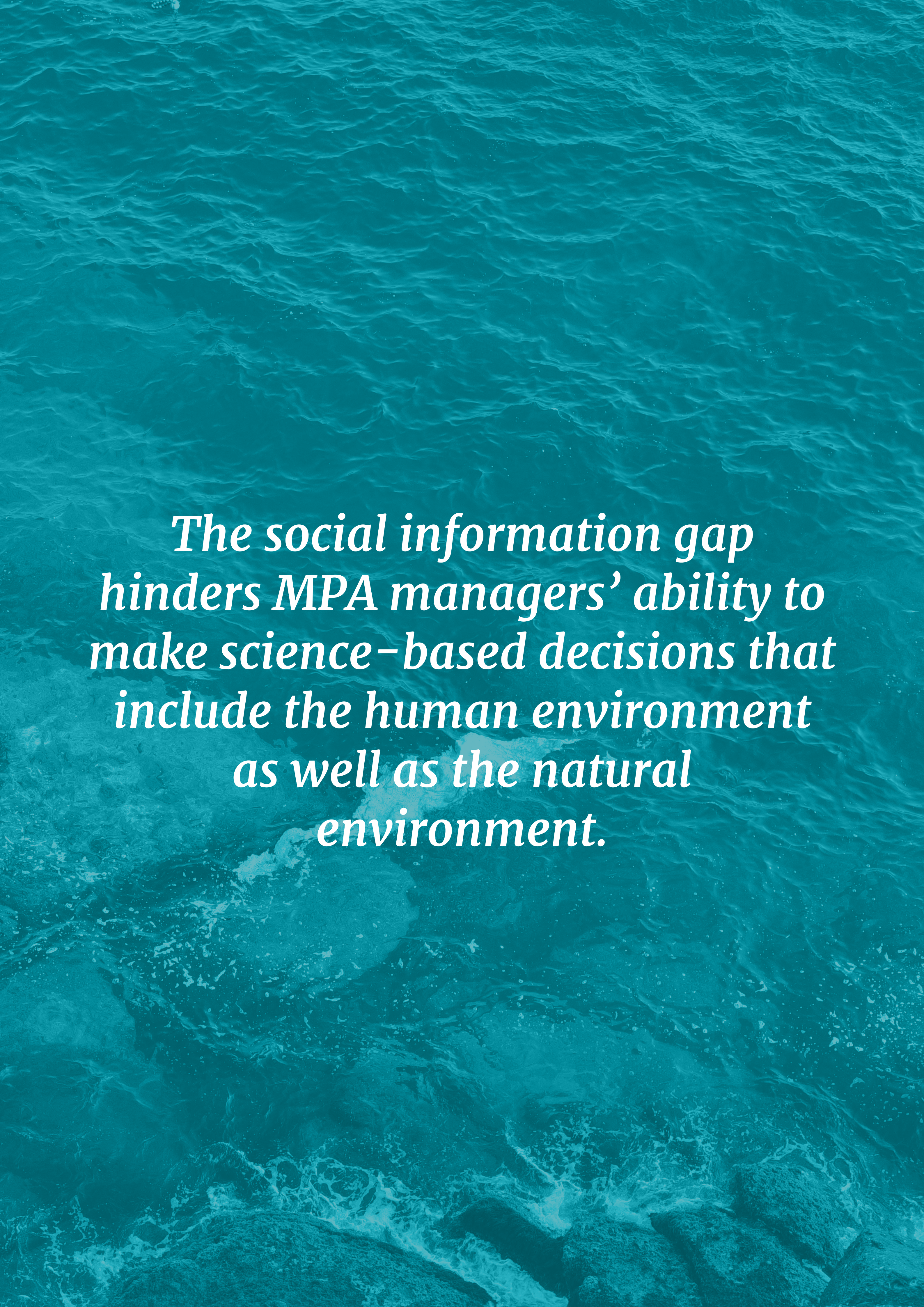
MPAs have a lifecycle that can generally be divided into phases: planning, implementation management, evaluation and baseline and monitoring. In general these phases overlap and repeat through cycles of evaluation and adaptive management. MPA policy and management decisions always involve trade-offs between the natural and human environment. Therefore both must be understood before decisions are made. Many excellent introductory texts exist providing guidance on social research *(Beebe, 2001; Tashakkori and Teddlie, 2003; Teddlie and Tashakkori, 2009; Wahle and Lyons, 2003)*, indicators *(Bunce et al., 2002; Pomeroy et al., 2004)*, data collection methods *(Bryman, 2012; Dilman et al., 2008)* and integrating social and biological data *(Manfredo et al., 2014)*.

In **Table 1** six priority themes and subtopics for social science research needed to strengthen the planning, management and evaluation of MPAs are presented (adapted from *(Wahle and Lyons, 2003)*. The table illustrates the applicability of each theme to specific stages of a generalised MPA life cycle (H=high, M=Medium, L= Low). The table also indicates using the same general scale for the characteristics of the different research topics in terms of complexity, cost and duration. The table is not an exhaustive list, but rather to be used by MPA managers to prioritise efforts and resources as it highlights the importance and applicability of different social science research topics relevant to MPAs.

The best social science tools and methods to use will depend on information needed, time, resources (money and manpower), and context. In **Table 2** some common research methods are provided which may be appropriate to each phase of the MPA lifecycle. This table is adapted from Wahle and Lyons *(2003)*, it is not a prescriptive list, but can be considered a first step for managers to understand what methods are commonly used and when certain methods could be appropriate. It is worth noting that often a combination of methods is more appropriate and/or necessary taking into consideration the sociocultural context and political realities of that particular location.

It is recommended that MPA managers consult or work directly with an expert in social research methodologies who can provide support and advice on sample sizes, question design, data analysis techniques and suitable ways to engage the group of interest (survey, interviews, workshops, participant observation, oral histories, focus groups). The time and expense for each assessment varies widely depending on the method, the number of stakeholder groups involved and the number of questions you ask. **Table 3** provides a general guide of the resources often required and a very simplified estimate for costs, as stated above the costs will vary greatly regarding where, when and how the data will be collected and what manpower/expertise you already have in the MPA.

In all cases of social research good research practice and behaviour must be followed. Much can be gained from designing participatory research projects in collaboration with the group of interest. Furthermore, it is necessary to include data validation processes and feedback into the project design. Please consult the good research ethics guidelines included in this booklet for more information.



The social information gap hinders MPA managers' ability to make science-based decisions that include the human environment as well as the natural environment.

Table 1: Priority Social Science Research Themes and Topics.

Theme	Topic	MPA Process			Characteristics		
		Planning	Management	Evaluation	Complexity	Cost	Duration
Governance, Institutions and Processes	Jurisdictional Structure	H	L	M	M	M	M
	Public Participation and Stewardship	H	M	M	M	H	M
	MPA Process	H	M	M	H	M	H
	Institutional Analysis	H	L	H	L	M	M
Use Patterns	Baseline data on Human Ecology of Use	H	H	M	M	H	H
	Political Ecology of MPA- Related Use Patterns	H	M	M	M	M	M
	Historical Ecology of MPA- Related Use Patterns	H	M	M	M	H	M
Attitudes, Perceptions and Beliefs	Baseline data	H	L	M	M	H	H
	Traditional and Local Ecological Knowledge	H	H	M	H	M	H
	Uncertainty and Attribution	M	H	M	M	M	M
	Aesthetics	H	M	L	M	M	L
	Environmental Ethics	M	M	L	L	M	L
	Satisfaction	L	H	H	M	M	L
Economics of MPAs	Baseline Information	H	M	H	M	H	H
	Cost Benefit Analysis	H	M	L	M	M	L
	Environmental Variability	H	L	M	H	H	M
	Non-Market Values	H	M	M	H	H	M
Communities	Socioeconomic Conditions	H	M	H	H	M	M
	Capacity and Skills	M	M	M	M	H	M
	Information Flow and Use	H	M	L	M	L	L
	Management Structures and Processes	H	M	H	L	M	L
	Lessons Learned	H	L	H	L	M	M
Cultural Heritage and Resources	Characterisation	H	M	M	M	M	M
	Protection	H	M	M	H	H	H
	Information Resources	H	H	H	M	H	H

Table 2: Common Research Methods and Usefulness in the MPA Lifecycle.

Common Research Methods and Approaches	MPA Process		
	Planning	Management	Evaluation
Focus Groups	✓	✓	✓
Survey Research		✓	✓
Socio-Economic Impact Assessment	✓		✓
Rapid Assessment	✓	✓	
Ethnography	✓	✓	
Contingent Valuation	✓		✓
Predictive Modelling	✓		
Content Analysis		✓	✓
Cost Benefit Analysis	✓	✓	
Comparative Research		✓	✓
Historical Research	✓		
Secondary Data Analysis		✓	✓
Case Study Research	✓	✓	

Table 3: Common Resources Required and Estimated Cost.

Common Resources	Cost		
	High	Medium	Low
Man Power: project manager, experts, field assistants	✓	✓	
Social Science Training: interview techniques, data analysis, facilitation	✓	✓	
Logistical Expenses: accommodation, travel, translation		✓	
Equipment: camera, dictaphones, notepads, flip charts, pens, computer			✓
Office costs: printing, photocopying and other office related costs			✓
Workshops, Focus groups, Meetings: rental of public paces, refreshments		✓	✓
Feedback & Data Validation			✓
Software for Data Analysis: qualitative data analysis software e.g. Nvivo		✓	✓

Case study: Cabo de Palos Islas Hormigas MPA

MMMPA conducted a social research investigation in Cabo de Palos Islas Hormigas MPA, Spain. The process followed is outlined in **Figure 1**, with a generalised timeframe provided for each phase. This figure provides a basic guide that could be useful to MPA managers to follow. The diagram presents a series of steps in a linear order, however it is not always this direct. In reality, new information, or the discovery of an overlooked stakeholder group can create new requirements. It is therefore necessary to continuously assess results, consider the implications for other steps in the process and change plans accordingly.

As recommended a mixture of social research methods were applied in Cabo de Palos: semi-structured interviews with resource users (e.g. fishers and divers), key informant interviews, social network analysis, focus groups, workshops, data validation/feedback meetings. The main fieldwork period took 6 weeks with follow-up and validity checks the following year. In terms of manpower, there was a research coordinator and project manager assisted by 4 volunteer research assistants. Interviews were conducted with 127 individuals constituting a representative sample of resource users (85%), and all identified key informants. Questions included in the semi-structured interviews were designed to collect perceptions on: MPA use, social acceptance of the MPA, stewardship, level of participation in MPA decision-making, institution analysis, overall satisfaction with MPA management and community well-being. The interviews lasted 30-60 minutes.

Three community meetings were held - one with fishers, a second with divers and a third with all stakeholders, including the MPA administration. The meetings offered the opportunity to conduct participatory data analysis and validation, to gather additional data and to provide feedback. Several participatory exercises were used during these meetings. For example, in one exercise participants were asked to prioritize their concerns related to the MPA that had been revealed through semi-structured interviews. The exercise involved an open discussion and an activity involving voting with stickers to prioritise these issues in terms of importance and urgency **(Fig. 2)**. Managers can use this information to see if their perception of problems and priorities match users and therefore if their management initiatives will receive support. It also provides baseline information against which to monitor future changes. Another exercise required different user groups to list the institutions they believed were involved in the MPAs management, and then place them on a bullseye designed to symbolise distance in terms of accessibility **(Fig. 3)**. In this case the administration bodies were considered to be the most inaccessible reflecting the low level of participation perceived by stakeholders in decision-making. These findings are useful for managers, allowing them to reflect on their role and responsibility, i.e. to be accountable, and also offer the opportunity for possible solutions to be revealed such as creating a local level management unit that would help bridge this gap.

The full set of data provides a rich understanding of the human environment in Cabo de Palos. In what follows a few highlights are provided. The data has been particularly useful to reveal how perceptions of regulatory burden can contribute to differences in overall satisfaction with the MPA. This has important implications for managers when deciding which activities are to be permitted, as particular attention should be paid to ensure regulations are distributed equitably between users groups. The results have also revealed the relative level of participation of different stakeholders within decision-making. The results revealed that fishers, for example, are marginalised reducing the legitimacy of decisions made. Using social network analysis in this case has offered insight for MPA managers, uncovering possible strategies to strengthen relationships and the role of fishers in the governance structure. Another particular relevant result revealed by the analysis is that the benefits yielded from protection might not benefit those expected. For example, in this case the objective of the MPA is to benefit the fishing community, however the perceived ‘winner’ was the dive community. This has contributed to increased conflict between the two groups and an overall dissatisfaction with the MPA and its management by the fishing sector and wider community that are increasingly affected by overcrowding associated with the dive industry. This emphasises the importance of continual monitoring to understand what outcomes the MPA is having on the human environment.

Over the length of the project the biggest expenses/costs were researcher training, time, field-site accommodation, provision of refreshments during the focus group meetings, and transcription and translation of interviews. Data were analysed using Social Network Analysis software (UCINET and Gephi) and NVivo10 software, which involves thematic coding of the interview transcripts. NVivo software is relatively costly, however, there are free open source qualitative data software's available.

Figure 1: Example research process followed for MMMPA work in Cabo de Palos.

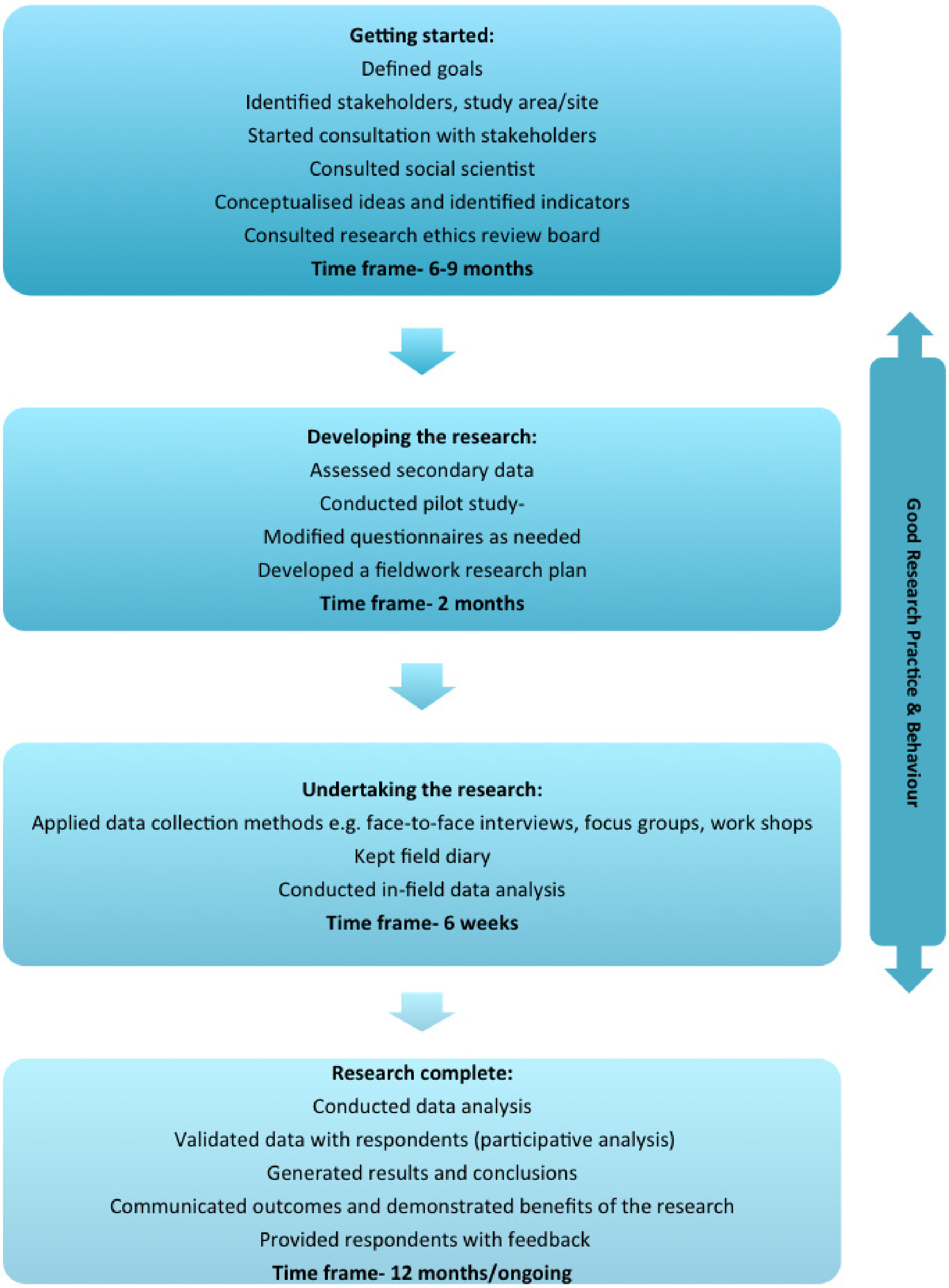


Figure 2: Participatory activity involving prioritising problems.

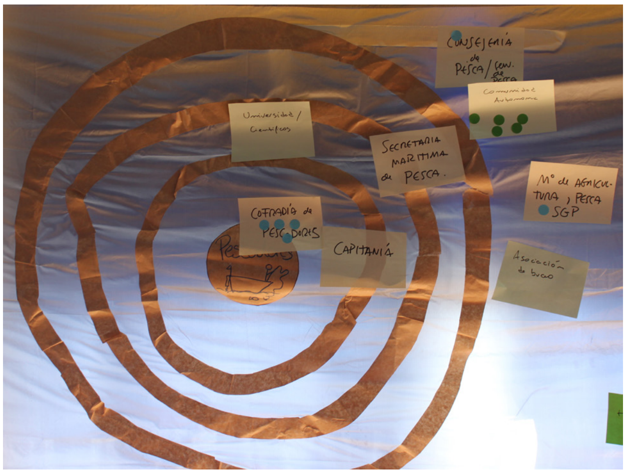


Figure 3: Participatory activity involving mapping accessibility to actors involved in MPA decision making.

Conclusions

Marine protected areas exist to help meet societal demands e.g. healthy fish stocks, recreational opportunities, conservation values, community well-being and sustainable development aspirations. However, they also incur costs, both to user communities and taxpayers who fund enforcement and management. It is therefore essential that social impacts are monitored to ensure MPAs achieve their objectives and provide value for money. In order to make sound science-based decisions the human environment must be fully understood. Using participatory techniques to monitor changes in satisfaction with MPA management provides useful evaluation data and at the same time opportunities for administrators and stakeholders to interact and build trust in the management process.

References

Beebe, J., 2001. *Rapid Assessment Process. Rowman Altamira.*

Bryman, A., 2012. *Social Research Methods, 4 ed. Oxford University Press, NY.*

Bunce, L., Townsley, P., Pomeroy, R., Pollnac, R., 2002. *Socioeconomic manual for coral reef management.*

Dilman, D.A., Smyth, J.D., Christian, L.M., 2008. *Internet, Mail, and Mixed-Mode Surveys: the Tailored Design Method. John Wiley & Sons.*

Manfredo, M.J., Vaske, J.J., Rechkemmer, A., Duke, E.A., 2014. *Understanding Society and Natural Resources. Springer.*

Pomeroy, R.S., Parks, J.E., Watson, L.M., 2004. *How is your MPA doing?: a guidebook of natural and social indicators for evaluating marine protected area management effectiveness. IUCN, Gland Switzerland and Cambride UK.*

Tashakkori, A., Teddlie, C., 2003. *Handbook of Mixed Methods in Social & Behavioral Research. SAGE Publications, Incorporated.*

Teddlie, C., Tashakkori, A., 2009. *Foundations of Mixed Methods Research. SAGE Publications, Incorporated.*

Wahle, C., Lyons, S., 2003. *Social Science Research Strategy For Marine Protected Areas. National Marine Protected Areas Centre, NOAA 1–52.*

MONITORING
HUMAN BEHAVIOR

Researching the human dimension of MPAs to ensure effective conservation policies

WHY MONITOR IT?

- Fundamental impact on MPA success
- Constantly overlooked
- Has to be understood for adequate management

HOW TO MONITOR IT?

GOALS AND INDICATORS
Define goal of study and indicators to measure
Costs

TARGET POPULATION
ID stakeholders you want to study
Costs

SECONDARY DATA
Assess what has been done before
Costs

PILOT STUDY
Test if the questions are understandable
Costs

DATA COLLECTION
Select suitable methods e.g. face-to-face interviews, focus groups
Costs

DATA MANAGEMENT & ANALYSIS
Transcribe interviews & conduct thematic & quantitative analysis
Costs

VALIDATE DATA
Have participants confirm findings & improve understanding of them
Costs

FEEDBACK FINDINGS
To promote transparency, trust, respect and as a thank you!
Costs

WHAT TO EXPECT

- Understanding of outcomes of management actions
- Improved relationships with stakeholders
- Social data gap filled to support more effective decisions

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STAKEHOLDER ENGAGEMENT

MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

GUIDELINES FOR INCREASING INFORMATION FLOW AND STAKEHOLDER ENGAGEMENT IN MARINE PROTECTED AREAS

Vasiliki Markantonatou[1], Pedro Noguera-Méndez[2], María Semitiel-García[2],
Katie Hogg[2], Marcello Sano[3]

*There is an increasing understanding that the complexity of most ecosystems is matched by equally complex social settings.
Early involvement and active participation of stakeholders is a prerequisite strategy that accrues numerous benefits to natural resource management.*

Why promote stakeholder engagement?

Stakeholder engagement promotes transparency and cooperation in decision-making, enhances mutual understanding and assists in the mitigation of conflicts and exploration of possible solutions on the use of marine resources *(Pomeroy and Douvere, 2008)*. However, participation is a complicated and difficult process involving expensive and time-consuming procedures, that often results in a limited audience and restricted engagement potential *(Reed et al., 2008)*. The heterogeneity of groups and the emergence of personal interests may pose conflicts or power inequalities capable of influencing perceptions and decreasing the efficiency of policy interventions *(Prell et al., 2009)*. Managers need to involve diverse groups that represent all users' perspectives and interests in a participatory approach that is in line with existing local plans affecting the area at a broader scale *(Tempesta and Otero, 2013)*. However, successful selection of actors in the engagement process is not straightforward.

It is important to integrate stakeholder engagement because it:

- Creates opportunities to adapt to changing conditions and explicitly incorporates changing values and priorities.
- Facilitates social learning, mutual understanding and joint action for sharing a common vision and achieving conservation targets.
- Increases transparency in decisions, promotes trust, assists in compliance with agreed solutions.
- Monitoring of stakeholder engagement itself may provide feedback for improvement of the process.

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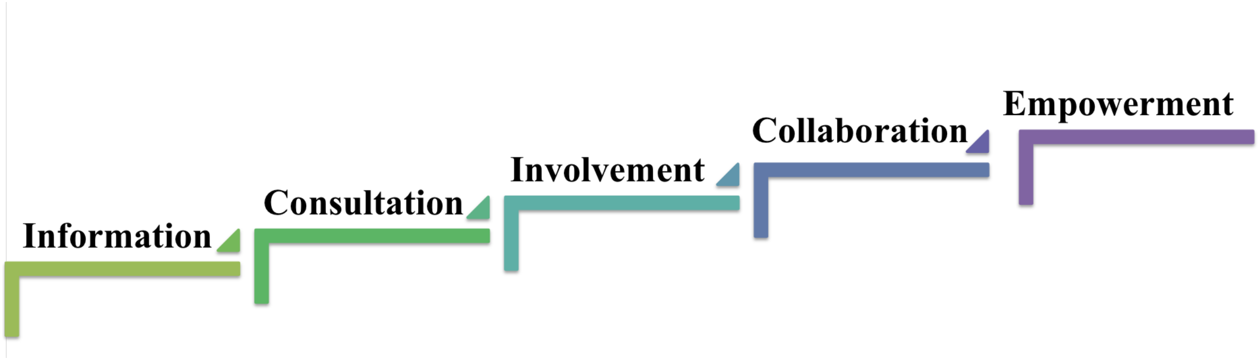

Figure 1. The participation ladder for stakeholder engagement ranging from simple information provision to more interactive participation strategies that empower stakeholders in resource management decisions (amended from Pomeroy and Douvere, 2008)

How to monitor stakeholder engagement

Social networks in MPAs develop through interactions between people and organizations that are linked to natural resources *(Crona et al., 2011)*. A social network consists of actors (or nodes) holding relationships (ties) with each other. Relationships may differ in their interpersonal strength depending on the frequency and quality of communication between actors *(Valente, 2012)*. Strong ties are characterized by trust-bonded relationships of frequent interaction, while weak ties are less frequent but hold more diverse opinions and are considered valuable for accessing or disseminating new ideas across a network *(Granovetter, 1973)*.

Stakeholder Analysis (SA) helps to identify, characterize and prioritize stakeholders, and may indicate conflicting actors that may hamper the engagement process *(Reed et al., 2008)*. Typically in SA a list of all actors linked to the MPA's management is composed ('roster'). Each actor can nominate missing actors in the list ('snowballing sampling') and characterize his relations to all others included in the roster (Fig. 2). The survey will be finalized when no new names appear in the list. At this point the stakeholder list is completed.

Descriptive information (attributes) may also be collected to provide further exploration of stakeholders and their social network. Although this information may be collected through face-to-face interviews, the use of online surveys is a much cheaper and effective approach to reach a wide range of actors in a short time and low effort *(Borgatti et al., 2013)*.

Exploration of the social network perspective may provide guidance for the enhancement of communication, trust and collective learning, and minimize the effort and risks of management success.

1 Identify main activities in the MPA, review legal framework

Identification of stakeholder categories
Legal framework of decision making
State of the art for the area and past experiences of actors

Costs

2 Conduct semi-structured interviews with key informant stakeholders
Inform acturs about the aims of the study (telephone calls, email)

Who are the most important stakeholders in the MPA?
Which sector do they represent?
What are the conflicts between stakeholders?
Primary stakeholder list (roster)
Identification of possible challenges and conflicts between actors in the area

Costs

3 Conduct online survey

Include your roster - Snowballing sampling
Who should be added or removed from the list?
Allow to add missing stakeholders and update roster based on responses.

What is your relationship with each of the stakeholders in the list?
(question may be adapted according to the context and necessities of the study)
0=no relationship; 1=communication 1-2 times per year; 2= ommunication of monthly, weekly or daily basis

What is your current and desired level of participation in the MPA management?

Which tools do you use or you are willing to use in order to communicate with the other stakeholders?
- Personal communication (e.g. round tables, workshops, public events)
- Cyber communication (e.g. email, social media, online questionnaires)

Finalize stakeholder list by including all relevant stakeholders that are influenced or may be influenced by decisions. Collect relational information, perceptions of current and desired level of participation (who to involve and when). Identify preferences on communication means.

Costs

4 Send reminders if necessary (emails, telephone calls)

Increase response of the survey

Costs

5 Social network analysis

Individual (node), groups, nework level
Apply indicators in social networks considering all ties and only strong ties

Does the network have the capacity to support efficient information flow?
Who are the actors that may act as potential receiver and transmitter of information?
Who are the actors that bring isolated parts of the network together?
Does the structure of the network promote or hinder collaboration in natural resource governance?

Costs

6 Provide feedback to participants (report, workshop)

Promotes transparency, collaboration and information flow

Costs

Figure 2. Step by step approach for applying SA and SNA.

A pre-notification of stakeholders via email or telephone that states clearly the scope, consequences and ethics of the study is fundamental. Moreover, reminders may be necessary to be sent during the online survey in order to secure the response of all stakeholders. Finally, it is essential to provide feedback to all participants in the form of a short report at the end of the study (please refer to the good research ethics guidelines within this document for further information).

Social Network Analysis (SNA) complements SA and moves one step further by elucidating relationships among actors developed within a social network. The analysis provides a deep understanding of how the position of actors and the structure of the network may promote or hinder collaboration in natural resource governance *(Bodin and Crona, 2009)*. By applying different measures at the level of nodes, subgroups and network may be applied **(Table 1)**, it allows the identification of central actors with strategic position for receiving or disseminating information (or access to resources) that flows within the network in a short time, due to their multiple contacts *(Borgatti and Everett, 2006; Wasserman and Faust, 1994)*.

Table 1 Suggested indicators that may facilitate the identification of important actors with the capacity to promote information flow and access to resources in natural resource management.

Indicator	Level of response	Definition	Outcome	References
InDegree centrality	Individual actors (nodes)	The number of ties received by an actor	Identify actors with capacity to act as potential receiver of information Reveals prominent and trusted leaders	Wasserman & Faust, 1994
OutDegree centrality		The number of ties given by an actor	Identify actors with capacity to act as potential transmitter of information	Wasserman & Faust, 1994
Betweenness centrality		The times that an actor rests between two others that are not themselves directly connected to others or are completely disconnected	Identify actors that bridge isolated fragments of network ("brokers") Reveals actors that expand the network	Freeman, 1978
Closenness centrality		The inverse of farness, which is in turn the sum of the distances to all other actors	Identify actors with capacity to receive information rapidly	Freeman, 1978
Density	Subgroups and network	The proportion of all possible links present in a network	Shared understanding of the system	Wasserman & Faust, 1994
Centralization		The extent a network is dominated by single actors	Capacity of network to support information flow between stakeholders	
Coreness	Network structure	The strength of actor membership in the core group by measuring the degree of how close the position of each actor is to the core, using the correlation measure of fit of the core-periphery model	Understand the way information flows in the network Identify highly connected actors that keep the network cohesive Reveals actors with capacity to acts as super-spreaders of information	Borgatti & Everett, 1999; Semitiel-García & Noguera-Méndez, 2012

Stakeholder engagement workshop conducted in Portofino MPA

Enhancing information flow and participation in Portofino MPA (Ligurian Sea, Italy)

We have applied SA and SNA in the Portofino MPA to identify central stakeholders with the capacity to act as communication hubs in the identified social network, and explored the presence of core-periphery network structure that may boost information flow and increase participation *(Markantonatou et al., 2016)*. Conducted at a time when Portofino MPA was considering whether or not to initiate MPA expansion, the reserve that is expected to stimulate oppositions, this case study is of particular interest and relevance as it adds value and recommendations that can support participation and information flow between stakeholders.

After conducting semi-structured interviews and the compilation of a preliminary stakeholder list, an online survey was administered in April 2013. Two rounds of telephone calls and three e-mail notifications were sent to participants to increase the response rate, which reached 82.1% at the end of the survey. The complete stakeholder list included 56 actors related to Portofino MPA management, in which 49 actors were identified initially from the interviews and 7 from the snowballing sampling.

Results showed that the Portofino MPA's social network has an adequate capacity to efficiently support information and knowledge flow between stakeholders. When considering only strong ties the social network is characterized by poor representation of stakeholder categories and limited trust between stakeholders, suggesting possible risks for the collaboration among subgroups and joined action in natural resource management (Fig. 3). On the contrary the network of all ties is more cohesive and seems to operate as a unity with dense communication channels that allow information to reach all actors *(Carlsson and Berkes, 2005)*. This highlights the role of weak ties in promoting deliberation and assuring a higher network capacity for long-term planning *(Bodin and crona, 2009)*.

A core-periphery structure characterizes the Portofino MPA's social network **(Fig. 3)**. The core, compiled by academy[1], administration[2], professional fishing[3], diving[4] and education[5], represents the most central stakeholders that pull together the system acting as central communication hubs in Portofino MPA's social network.

These core actors combine central characteristics of trusted leaders and brokers with a great potential to promote the initiative of Portofino MPA enlargement. However, tourism and recreational sectors are predominant user categories that are currently less involved and therefore are located closer to the margins of the network (middling or low coreness values). This had important implications for the access to information and resources. Moreover, the fact that the core relies on a few strongly linked actors makes the system vulnerable if these actors are not cooperative or were to become inactive *(Bodin and Crona, 2009)*.

Outcomes show that all stakeholders desire to participate more actively and take responsibilities in the MPA management, while most of them are familiar with online communication tools. Existing relationships should be strengthened in order to improve participation and boost information flow in Portofino MPA's social network. This provides an important opportunity for the managers of Portofino MPA to create key conditions by combining personal and web technologies for achieving successful stakeholder engagement and sound conservation planning *(Markantonatou et al., 2013)*. The fact that Portofino represents a typical case of an MPA where decisions usually stimulate opposition from users makes this methodology and results applicable to MPAs of similar context.

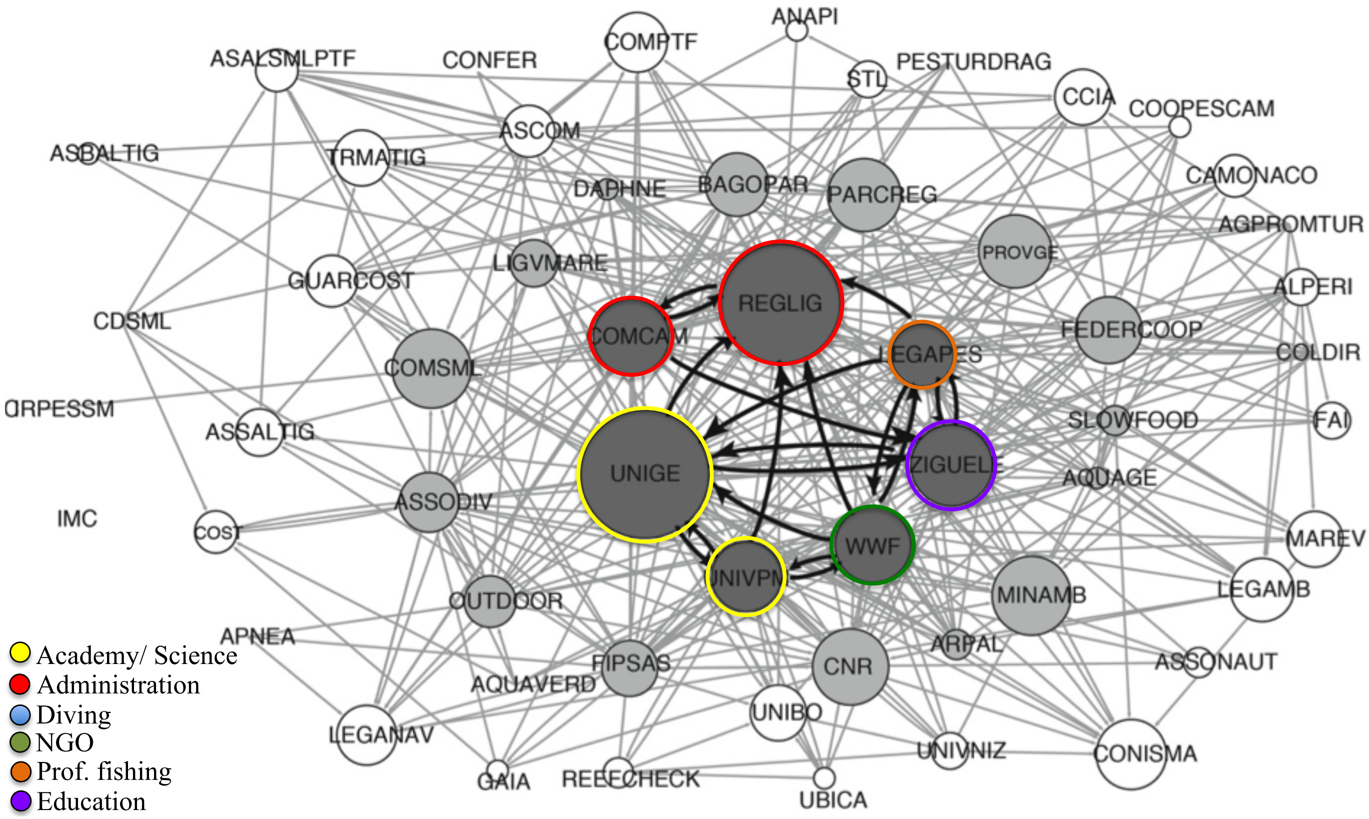

Figure 3: Social network of Portofino MPA accounting (a) only strong ties and (b) all ties. Size of nodes represents in-degree centrality; the colour of nodes indicates the core (dark grey), semi-periphery (light grey) and periphery (white). Bold arrows indicate the strong ties within the core. From Markantonatou et al. (2016).

Management suggestions

Support the core actors to promote the conservation initiative, to collect information and lead change by using their power, prominence and widespread contacts.

Integrate peripheral actors in MPA management in order to support information to flow more readily and to add adaptiveness into the network. Strengthen weak ties in order to support the central hubs to widespread information and balance power disparities of core members to control information or circulate exclusively between them.

Create technological environments that integrate e-mail notifications, social media characteristics and dynamic mapping services, that combined with more traditional communication approaches aid to increase stakeholder interaction for the future decision-making process.

Conclusions

Many conservation initiatives have failed because they pay inadequate attention to the preferences, interests and characteristics of stakeholders *(Prell et al., 2009)*. The capacity of network perspective in exploring the social conditions and their implications in marine resource management has been very recently recognized. SA and SNA are complementary methodologies that provide information and guidance for fostering communication, trust and collective learning in natural resource management by minimizing the effort and risks of management success *(Bodin and Crona, 2009)*.

The suggested guidelines imply a simple and low cost methodology for conservation managers and planners to explore alternative forms of dynamic stakeholder participation and collaborative management. The method incorporates typical engagement barriers, such as restrictions of time, budgetary constraints and availability of stakeholders to participate with their physical presence. However, cost may vary greatly depending on the geographical distance between stakeholders, the selection of communication strategies and tools, and stakeholders' willingness to participate. It may secure representativeness and explicitly include powerful but also remote and marginalized actors in the MPA management for sound governance performance and co-management of resources.

References

Borgatti, S.P., Everett, M.G., Johnson, J.C., 2013. *Analyzing social networks. SAGE Publications, first ed. London.*

Borgatti, S.P., Everett, M.G., 2006. *A graph-theoretic perspective on centrality. Social Networks 28, 466–484.*

Bodin, Ö., Crona, B.I., 2009. *The role of social networks in natural resource governance: what relational patterns make a difference? Global Environmental Change 19, 366–374.*

Crona, B., Ernstson, H., Prell, C., Reed, M. and Hubacek, K., 2011. *Combining social network approaches with social theories to improve understanding of resource governance, in: Ö. Bodin and C. Prell (Eds) Social networks and natural resource management: uncovering the social fabric in environmental governance. Cambridge University Press, Cambridge, pp. 44-71.*

Freeman, L.C., 1978. *Centrality in social networks conceptual clarification. Social Networks 1, 215–239.*

Granovetter, M., 1973. *The strength of weak ties. American Journal of Sociology 78, 1360–1380.*

Markantonatou, V., Meidinger, M., Sano, M., Oikonomou, E., di Carlo, G., Palma, M., Ponti, M., Cerrano, C., 2013. *Stakeholder participation and the use of web technology for MPA management. Advances in Oceanography and Limnology 4, 260–276.*

Markantonatou V, Noguera P, Semitiel-Garcia M, Hogg, K, Sano M, 2016. *Social networks and information flow: building the ground for collaborative marine conservation planning in Portofino Marine Protected Area (MPA). Journal of Ocean and Coastal Management, 120: 29-38.*

Pomeroy, R., Douvere, F., 2008. *The engagement of stakeholders in the marine spatial planning process. Marine Policy 32, 816–822.*

Prell, C., Hubacek, K., Reed, M.S., 2009. *Stakeholder analysis and social network analysis in natural resource management. Society and Natural Resources 22, 501–518.*

Reed, M.S., 2008. *Stakeholder participation for environmental management: a literature review. Biological Conservation 141, 2417–2431.*

Semitiel-García, M., Noguera-Méndez, P., 2012. *The structure of inter-industry systems and the diffusion of innovations: the case of Spain. Technological Forecasting and Social Change 79, 1548–1567.*

Tempesta M., Otero M. 2013. *Guide for quick evaluation of management in Mediterranean MPAs. WWF Italy, IUCN. 68 pp.*

Valente, T.W., 2012. *Network interventions. Science 337, 49–53.*

Wasserman, S., Faust, K., 1994. *Social network analysis: methods and applications, second ed. Cambridge University Press, New York and Cambridge.*

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[4] Assodiving association (ASSODIV)

[5] Ziguele association

MONITORING
STAKEHOLDER ENGAGEMENT

Researching the human dimension of MPAs for assuring effective conservation policies

WHY MONITOR IT?

- Promotes transparency and trust
- Mitigates possible conflicts
- Facilitates adaptive, co-management of resources

HOW TO MONITOR IT?

1. **IDENTIFY MAIN ACTIVITIES IN MPA**
   Identify stakeholders, legal framework, area's past, culture, values
   Costs

2. **INTERVIEW STAKEHOLDERS**
   Review primary roster. Check for sectors, conflicts
   Costs

3. **ONLINE SURVEYS**
   Compile primary roster, identify past and current conflicts
   Costs

4. **SEND REMINDERS**
   Increase rate of survey
   Costs

5. **SOCIAL NETWORK ANALYSIS**
   Identify central actors, improve stakeholder engagement and information flow
   Costs

6. **PROVIDE FEEDBACK**
   Promote transparency and trust, increase system's adaptiveness
   Costs

WHAT TO EXPECT?

- Increased information flow, mutual understanding and development of common solutions
- Mitigation of conflicts and the power of dominant stakeholders, opportunity for equal access to resources
- Transparent decision making, adaptive co-management of resources and compliance

ETHICAL GUIDELINES

MONITORING MEDITERRANEAN MARINE PROTECTED AREAS

ETHICAL GUIDELINES AND GOOD PRACTICE FOR SOCIAL RESEARCH

Sarah Young[1], Katie Hogg [1], Pedro Noguera-Méndez [1], María Semitiel-García [1]

When conducting any type of research we have an obligation to ensure we follow good research practice and apply high ethical standards to our research. In what follows a guideline is provided that outlines norms for conducting social research aiding MPA managers to achieve good research practice.

Why are research ethics important?

As researchers we have an obligation to apply high ethical standards, to act with integrity and to strive for consistency of thought and action. This is particularly true for social scientists, whose 'subjects' are people. Ethics refers to the well-founded standards of right and wrong that prescribe what humans ought to do, usually in terms of rights, obligations, benefits to society, fairness, or specific virtues. In research ethical norms:

Given the importance of ethics for the conduct of research, many research institutions, professional associations, and government agencies have adopted specific codes, rules and policies relating to research ethics. These rules help protect both the organization and the researcher against potential legal implications of neglecting to address important ethical issues of participants. As researchers no matter what the type of research we have an obligation to apply high ethical standards to our work. We must honestly report data, results, methods and procedures and publication status. We must not fabricate, falsify, or misrepresent data. In these guidelines we outline norms for conducting social research addressing concerns such as: informed consent, confidentiality, respondent burden and feedback.

Ethical norms in research are important because they:

- Promote the aims of research, such as knowledge, truth and avoidance of error .
- Promote the values that are essential to collaborative work, such as trust, accountability, mutual respect and fairness.
- Help ensure researchers can be held accountable to the public.
- Help build public support for research .
- Promote a variety of other important moral and social values, such as social responsibility, human rights, animal welfare, compliance with the law, health and safety *(Resnik, 2011)*.

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Ethical principles and good practice in social research

The following outlines best practices for conducting social research widely accepted within the scientific community that should be followed when conducting social research.

Institutional Review Boards

In many countries/research institutions it is necessary for social research projects to be verified by an institutional review board, also known as independent ethics committee (IEC), ethical review board (ERB), or research ethics board (REB). The purpose of the review process is to assure, both in advance and by periodic review, that the appropriate steps are taken to protect the rights and welfare of the people participating in the study. Even if ethical review is not compulsory it is good practise to include the following elements in a research proposal:

- Purpose of study
- Sponsor
- Definition of population under study
- Description of the sampling frame and survey design
- Sample sizes, eligibility criteria and response rates
- Method, location, dates, personnel
- Benefits and risks to subjects from participation
- Procedures for use of audio/video or photographic images
- Description of how the data will be analysed
- Description of any weighting and estimation procedures used for calculating results
- Expected major findings
- Description of the expected precision of the findings including estimates of sampling error

Research Objectives

'Research in Action' calls for scientists to work in the public domain addressing issues of societal concern. It focuses on how the scientific method can be used to identify solutions to practical questions that are tied up with economic and policy matters. Often research questions and problem definition are conducted in collaboration with the wider community. As a modern scientist it is important that you think about how your research addresses societal needs and the impact it may have on your study population.

Investigator training

Writing valid and reliable questions for surveys and interviews and knowing how to analyse the data is a skill that requires training and practice. If you don't know the difference between a Guttman and a Likert scale seek advice on measurement theory. In a similar vein, inexperienced interviewers tend to introduce bias into interviews through body language, question annunciation and the way in which responses are recorded. So equip yourself and any staff/volunteers with basic training to perform scientifically rigorous research.

Voluntary participation and harmlessness

Subjects in a research project must be aware that their participation in the study is voluntary, that they have the freedom to withdraw from the study at any time without any unfavourable circumstances, and that they are not harmed as a result of their participation or non-participation in the project.

As researchers we have an obligation to apply high ethical standards, to act with integrity and to strive for consistency of thought and action.

Informed consent

Informed consent is an essential part of conducting social research. This may be in the fashion of a pre-prepared, signed consent form, an obligatory check box on an Internet survey or an audio/ video recorded verbal consent prior to interview. For subjects under 18 consent must be obtained from a parent or guardian. In each case the participant needs to be given:

- A brief description of the study.
- Clear identification of the research firm affiliation.
- A description of the role of the respondent in the study, including the expected duration of the respondent's participation.
- An explanation of how the respondent was selected for the study.
- A clear indication that participation is voluntary and that the information provided will be held confidential to the extent allowed by law.
- Contact information for a study investigator or other research team member whom respondents can contact.

Anonymity and confidentiality are principles that must be followed

Anonymity implies that the researcher or readers of the final report or paper cannot identify a given response with a specific respondent.

In some circumstances such as face-to-face interviews anonymity is not possible. Under such circumstances, subjects must be granted confidentiality, in which the researcher can identify a person's response but promises not to divulge the persons ID in any report, paper or public forum.

Common practice is to separate personally identifiable information (PII) from the respondent data. PII minimally includes name, address, phone number and identification number.

Pilot study

A survey instrument should be tested on a pilot sample of members of the target population, or a population that is very similar to the target population. This is a necessary step in the research process as it allows researchers to identify whether the questions are understandable (validity) and whether the meaning of questions is the same for all respondents (reliability). Responses to the pilot study should be used to fine-tune and validate the layout of the questionnaire. Necessary changes should be made to improve overall response rate, and to ensure that high quality data is collected.

Respondent burden

Respondent burden must be considered when deciding the length of the questionnaire, question ordering, survey design and interviewer training. Making sure each question in the survey maps to a specific research goal and the need for information is balanced against the effort that is required to complete additional questions can reduce this. Respondents can become tired of the survey task and as a result the quality of the data they provide deteriorates. If you are asking questions about private, sensitive (illegal activity) or embarrassing subjects implement techniques to minimise unease.

Survey fatigue

In addition to respondent burden, there is also potential individuals and communities that are regularly targeted for research purposes, i.e. those viewed as an interesting case study, become frustrated with the lack of coordination between researchers and lack of feedback. The manner in which research is conducted can shape a community's views positively or negatively on research topics, research institutions, and funders of the research. Considerable care must be given when designing research projects to know what research has been conducted previously and with which target populations. In many cases the data required could already be available and acquired from other researchers.

Feedback

A fundamental element of good research practice is providing respondents with feedback. Professional social science organizations generally agree that researchers should report findings to benefit the widest possible community (not solely through scientific publications). It is good practise to make available as much of the study's methods, results, and raw data as possible, within the bounds of protecting participants' confidentiality, in order to permit others to evaluate the study and to replicate the findings.

Providing feedback directly to participations acknowledges the respondent's time and energy and builds trust in the research process.

Record keeping

It is useful to maintain a copy of the following documents:

- Scripts, letters, fact sheet and any other materials provided to respondents for them to make an informed decision about participation.
- Proof of consent (signed forms, recorded copies of oral consent).
- Confidentiality procedures and protocols.
- Pledge of confidentiality signed by staff members.
- Ethic review board submission and approval.

References and key sources of information

Resnik, D.B., 2011. *What is ethics in research & why is it important. National Institute of Environmental Health Sciences.*

National Committees for Research Ethics in Norway (**NESH**)**, 2006.** *Guidelines for Research Ethics in the Social Sciences, Law and The Humanities.* *https://graduateschool.nd.edu/assets/21765/guidelinesresearchethicsinthesocialscienceslawhumanities.pdf*

European Society for Market Research (ESOMAR)*, and the* **International Statistical Institute (ISI)***, have also developed ethical codes and guidelines for their members.*

American Psychological Association. *Ethical Principles of Psychologists.*

American Anthropological Association. *Statements on Ethics and Professional Responsibility.*

World Medical Association. *Nuremberg Code and the Declaration of Helsinki.*

FOLLOWING RESEARCH ETHICS

Ethical guidelines and good practice to ensure sound social research

WHY GOOD ETHICS?

Promote trust and mutual respect

Researchers are accountable to public

Promote social and moral values

HOW TO FOLLOW?

INSTITUTIONAL REVIEW BOARDS
Have research reviewed by an ethics board

RESEARCH OBJECTIVES
Consider how research addresses societal needs

INVESTIGATOR TRAINING
Ensure team has adequate training and knowledge

VOLUNTARY PARTICIPATION
Ensure participants understand they can withdraw from study

INFORMED CONSENT
Prepare consent forms for each participant

ANONYMITY & CONFIDENTIALITY
Ensure that participants ID is protected

PILOT STUDY
Conduct pilot and refine study as required

RESPONDENT BURDEN
Ask only the essential questions

SURVEY FATIGUE
Be aware if your target population has been surveyed before

FEEDBACK
Make as much of the study as possible available to the wider public

WHAT TO EXPECT

Compliance with the law and moral and social values

Confidence in research validity and security

Improved public support and interest

Monitoring and evaluation systems are needed to ensure that the goals and objectives of MPAs are achieved. Monitoring systems vary regarding what they measure, who performs the measuring, where, when and how measures are made. They must be carefully designed and must include good baseline data, robust indicators and possibly control sites. The monitoring systems depend on the characteristics of the MPA. In many cases, the financial resources to adequately structure and achieve the goals are not available. A priority is represented by the need to record changes in the ecology of the MPA, asking for the evaluation of the cascade effects of changes on the local communities.

Edited by MMMPA Supervisory Board

SEVENTH FRAMEWORK PROGRAMME

MARIE CURIE ACTIONS