PROJECT

FINAL PUBLISHABLE SUMMARY REPORT

Grant Agreement number: 282977

Project acronym: MEDINA

Project title: Marine Ecosystem Dynamics and Indicators for North Africa

Funding Scheme: FP7-CP-FP-SICA

Date of latest version of Annex I against which the assessment will be made: 29/09/2014

Period covered: from 01/10/2011 to 31/12/2014

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1. Executive Summary

The MEDINA EU funded project started on October 1st 2011 and ended on December 31st 2014. The main aims of MEDINA were: 1) enhancing the capacities of Algeria, Egypt, Libya, Morocco and Tunisia, Libya to monitor and assess their Mediterranean marine coastal ecosystems; 2) contributing to populate the GEOSS (Global Earth Observation System of Systems) Common Infrastructure (GCI) in terms of assessment tools and results.

MEDINA achieved the first goal by focusing on a well defined and concrete target, namely developing tools and methodological approaches for supporting the implementation of the main policy for the protection of the Mediterranean marine coastal ecosystems, i.e. the UNEP-MAP Ecosystem Approach, EcAp, endorsed by all Contracting Parties of the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention). The backbone of EcAp is the execution of an Integrated Monitoring and Assessment Programme (IMAP) concerning coastal and marine ecosystems, to be repeated every 6 years.The first IMAP is currently being designed and will start in 2016. The full implementation of the EcAp in North African countries is challenging, not because of the lack of local Scientific&Technical knowledge but, rather, due to the large investment required and, in some instances, to the fragmentation and overlapping of mandates among different monitoring agencies. Therefore, the need of designing cost-effective monitoring programmes, on one side, and of setting up an interoperable infrastructure for archiving and sharing the collected data is felt even more acutely in the region, compared with EU Mediterranean countries.

In MEDINA, we identified a subset of EcAp Ecological Objectives and indicators which could be estimated in a cost-effective way by combining field data, remotely sensed Earth Observation, namely satellite data, and simulation models. Subsequently, we developed and applied at the regional scale, among others:

a methodology for the identification of Drivers&Pressures, based on the use of satellite images;

an integrative methodology for the assessment of eutrophication at the regional scale, which is based on both the output of a 3D regional biogeochemical model and the spatial distribution of Chlorophyll a, as derived from satellite data;

a model for assessing the potential distribution of *Posidonia oceanica* meadows, one of the most important Mediterranean habitat, based on satellite data.

We also developed and tested tools for water masses classification, scenario analysis, ecosystem assessment and monitoring optimization at a local scale, which were applied to five selected pilot cases, namely the Bay of Bejaia (Algeria), Lake Burullus (Egypt), the Gulf of Syrte (Libya), the Lagoon of Nador (Morocco) and the Gulf of Gabés (Tunisia).

As regards the second objective, the MEDINA Consortium developed and populated an interoperable Spatial Data Infrastructure, named MeI (MEDINA-e-Infrastructure, www.medinageoportal.eu) which was brokered and made fully accessible from the GEO portal, thus contributing to the GCI. The MeI includes a Catalogue and a Viewer, which allows end-users to access a set of maps, at regional and local scale, showing the main results of MEDINA, i.e. the spatial distribution of indicators of pressure and status as well as that of important variables characterizing ecosystem dynamics, either simulated or estimated from satellite data. The viewer has a split-screen tool, which allows users to compare two indicators, and a time slider, which can be used for getting further insight into the dynamics of selected variables. Ten workshops (seven in North Africa) were organized during the project lifetime for: i) enhancing S&T exchanges among partners ii) involving stake-holders and end-users; iii) connecting with the GEO community at large.

2. A summary description of project context and objectives

Coastal and marine ecosystems in the Mediterranean deliver extremely valuable ecosystem services including fisheries and aquaculture resources, tourism, waste assimilation, coastal stabilization and erosion prevention, carbon sequestration, etc…: according to (UNEP/MAP/BP, 2010) Mediterranean ecosystem service benefits may exceed 26.128 million Euros annually. However, the main conclusions of the first Mediterranean-wide Integrated Assessment suggest that such a valuable natural capital is currently being dissipated, as the functioning of coastal and marine ecosystems is severely threatened by:

- **Coastal development and sprawl**, driven by urban and touristic development, leading to fragmentation, degradationand loss of habitats and landscapes, including the destabilization and erosion of the shoreline.
- **Chemical contamination** of sediments and biota caused by pollution from urbanisation, industry, anti-foulants, and atmospheric transport.
- **Eutrophication** caused by human-mediated input of nutrients into marine waters is a source of concern, especially in coastal areas near large rivers and/or cities
- The increase in the presence of **Marine litter**, concentrated especially in bays and shallow areas, is increasingly regarded as a matter of concern across the Mediterranean.
- The impact of **Marine noise** on biota, especially marine mammals and fish due to intense maritime traffic, particularly in the Western Mediterranean, and offshore exploration.
- The increase in the number of **Invasive non-indigenous species**, particularly in the easternmost reaches of the Mediterranean. Documented impacts on natural diversity include predation, alteration of the food web, niche competition, and modification of habitats, leading to a variety of impacts on
- fishing, aquaculture, shipping, human health, and tourism.
- **Fish stocks over-exploitation** beyond sustainable limits and increase in **Aquaculture,** which may lead to an increase in nutrient and organic matter pollution and the introduction of non-indigenous species, if not properly managed.
- **Sea-floor integrity** is affected mainly by bottom fishing, but also by dredging and offshore installations.
- Changes in **hydrographic conditions** caused by local disruption of circulation patterns by human-made structures, changes in freshwater fluxes to the sea, brine release from desalination

plants, or climate change influence both nearshore and offshore areas.

As a result, the abundance of large predator species has decreased and it has been estimated that, on average, the trophic level in fishery catches has gone down by one level in the last 50 years, a clear sign of stress of the **marine food webs**, which could be one of the causes of the recent increase in jellyfish numbers. Ultimately, the cumulative effects of the pressures affecting the Mediterranean coastal and marine environment is causing a decrease in **biodiversity.**

The protection of Mediterranean coastal marine ecosystems requires a long term regional strategy and concerted actions, for harmonizing and focusing towards common goals the measures taken by individual countries. This was realized as early as 40 years ago, when sixteen countries bordering the Mediterranean and the European Union launched the Mediterranean Action Plan (MAP), which was the first Regional Sea plan to be of the United Nation Environmental Programme (UNEP). This action was soon followed in 1976 by the adoption of the “Convention for the Protection of the Mediterranean Sea against Pollution” (Barcelona Convention), which came into force in 1978. The Barcelona Convention was subsequently amended and renamed “Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean” in order to take into account a more comprehensive and ecosystem-based approach towards the protection of the environment which was emerging in the last two decades of the last century. The amended Barcelona Convention came into force in 2004 and includes seven Protocols addressing specific aspects of environmental protection. At present, 21 countries bordering the Mediterranean and the European Union are Contracting Parties to the Barcelona Convention, including Algeria, Egypt, Libya, Morocco and Tunisia.

In 2008 Contracting Parties fully endorsed the "Ecosystem Approach", hereafter EcAp, to the management of human activities in the Mediterranean (see the 2008 Decision IG.17/6 and the 2012 Decision IG.20/4). The EcAp aims at achieving 11 "Ecological Objectives", EOs, which were endorsed by Contracting Parties in February 2012. The backbone of EcAp is the execution of an Integrated Monitoring and Assessment Programme (IMAP) concerning coastal and marine ecosystems, to be repeated every 6 years: the results will provide the scientific basis for designing the programmes of measures, to be undertaken for achieving the vision which characterizes the EcAp, i.e. "A healthy Mediterranean with marine and coastal ecosystems that are productive and biologically diverse for the benefit of present and future generations".

Within the European Union, concerted actions for the protection of coastal and marine ecosystems are being undertaken by Member States through the implementation of the Marine Strategy Framework Directive (Directive 2008/56/EC MSFD), which is also based on an ecosystem perspective and on 11 Qualitative Descriptors: these largely overlaps with the 11 EOs. A six year cycle of monitoring/assessment/measure is also to be implemented.

Both approaches fully recognize the importance of observation networks and monitoring of coastal marine ecosystem as key elements for tailoring management responses that effectively address the site-specific levels of pressure to the underlying conditions of ecosystems. Continuous observation (monitoring) and assessment of the marine environment is needed and motivated by ecological and environmental considerations, but also by economic and social imperatives, as it provides a scientific basis for taking the most appropriate measures to improve the quality of the environment and for checking their effectiveness, in agreement with the adaptive approach to sustainable management of natural resources.

To this regard, is has to be underlined that the collection of large and comprehensive data sets is not the ultimate goal of monitoring programmes, as the end point of the 6 year cycle is to deliver useful information to decision makers, as a main driver for actions to be undertaken. To this purpose, data should be properly archived and, if necessary, made available for further processing. Data sharing and interoperability, in fact, are emerging as key issues in many areas, including that of environmental management and protection, since science based responses to global challenges require strong interdisciplinarity. GEO, Group on Earth Observation, is an intergovernmental organization, launched in response to calls for action by the 2002 World Summit on Sustainable Development, Earth Observation Summits, and by the G8 (Group of Eight) leading industrialized countries. GEO, established in 2005, has designed and carried a ten year long implementation plan, with the main aim of building GEOSS, the Global Earth Observation System of Systems, as an integrating public infrastructure, interconnecting a diverse, growing array of Earth observing instruments and information systems for monitoring and forecasting changes in the global environment. GEOSS aims at collecting environmental data from different sources and making them globally available, thus facilitating data access to scientists and stake-holder. Data and metadata are accessed through the GEOSS Common Infrastructure (GCI), which allows the user of Earth observations to access, search and use the data, information, tools and services available through the Global Earth Observation System of Systems. The infrastructure consists of four main elements: 1) The GEO Portal, which provides the direct web interface through which the user accesses GEOSS and searches for information and services; 2) the GEOSS Clearinghouse, which is the engine that drives the entire system; 3) The GEOSS Components and Services Registry, which is similar to a library catalogue; 4) The GEOSS Standards and Interoperability Registry, which enables contributors to GEOSS to configure their systems so that they can share information with other systems. As such, GEOSS has been recognized also by UNEP-MAP as the right framework for sharing environmental data concerning the status of Mediterranean ecosystems.

In this context, the MEDINA project, launched in October 2011, was designed to enhance the capacity of Northern African countries, namely Algeria, Egypt, Libya, Morocco and Tunisia, of monitoring and assessing their coastal marine ecosystems, including fish stocks resources. As said above, the establishment of long term cost-effective monitoring programmes is a prerequisite for implementing environmental policies, conventions and protocols and is, in fact, mandatory in the coming years, as all these countries are contracting parties of the Barcelona Convention. Furthermore, as these countries share many of the environmental issues listed above, MEDINA was called to promote data sharing and interoperability in the context of GEOSS as a mean of increasing the capacity to deal with the main threats to North African marine ecosystems at a regional level.

The two main objectives of MEDINA therefore are:

1. To contribute to the implementation of permanent and cost-effective monitoring&assessment programmes of the status of coastal marine ecosystems in North African Countries (Morocco, Algeria, Tunisia, Libya and Egypt), enhancing the monitoring capacity in the region and identifying as well major risks due to climate change, as support to the elaboration of adaptation strategies for their mitigation.
2. To ensure the exploitation of the GEOSS GCI capabilities at the maximum extent possible in providing the appropriate infrastructure for fusion of satellite EO and conventional environmental monitoring data.

These general objectives were broken down into two sets of specific objectives, listed below.

Objective 1:

- ✓ To assess the existing capacity for marine and coastal ecosystem monitoring in the region of interest;
- ✓ To apply technology and scientific transfer from EU Countries.
- ✓ To identify relevant historical and updated data sets, including satellite EO, in-situ monitoring networks, airborne and ground survey information;
- ✓ To identify major drivers and pressures
- ✓ To identify critical areas where the ecosystem may face further deterioration, due to unsustainable management of human activities, including fishery and provide this information to relevant national or regional administrations
- ✓ To develop tools, namely integrative assessment methodologies and simulation models, for supporting the design of cost-effective monitoring&assessment programmes
- ✓ To assess the status of North African coastal marine ecosystems at a regional scale.
- ✓ To apply tools at a local scale to five specific areas, which are representative of region-wide issues, called Pilot Cases
- ✓ To identify risks and impact due to global change. To propose risk mitigation and adaptation strategies.
- ✓ To feedback MEDINA scientific contribution within the EU regulatory framework, thus contributing to the implementation of MSFD and WFD..

Objective 2:

- ✓ To lower the present entry level barrier to the GCI in North African countries.
- ✓ To ensure the interoperability of data, metadata and services developed during the project lifetime via the use of recommended standards.
- ✓ To ensure technological use cases derived from the thematic pilot case studies are implemented;
- ✓ To closely cooperate with relevant Science and Technology GEO Tasks, Capacity Building GEO Tasks (building national and regional capacity; developing and encouraging the use of Open Source Software; building regional networks for ecosystems);
- ✓ To contribute to future GEO AIP -x efforts, and to the implementation of the GEOSS data sharing principles;
- ✓ To ensure the availability and usability of MEDINA's products during and after the project end.
- ✓ To issue international cooperation for data and services sharing with existing EU efforts

The above objectives were achieved by partitioning the project activities among 6 well connected Work-Packages, besides the mandatory Coordination WP1.

The state-of-the art of monitoring agencies and programmes in the region was analysed in WP2, and, on this basis, five areas, one in each country, were selected as Pilot Cases, representing typical ecosystems and issues of concern in the region. The Pilot Cases, which were chosen in close collaboration with North African partners are: the Bay of Bejaia (Algeria), Lake Burullus (Egypt) the Gulf of Syrte (Libya), the Lagoon of Nador (Morocco), the Gulf of Gabès (Tunisia).

In agreement with the GEOSS Common Infrastructure (GCI) approach, MEDINA built on existing capacities within the region of interest and expertise within the Consortium and assembled them in a dedicated spatial data infrastructure, namely the MEDINA e-Infrastructure (MeI), which applied the GCI standards and data sharing principles. The MeI was developed in WP3 and progressively populated with indicators, model output and data produced in WP4 and WP5.

Tools, namely: 1) indicators of pressure and ecosystem status derived from remotely sensed Earth Observation and 2) simulation models for scenario analysis and for establishing cause-effect relationships among Drivers/Pressure and ecosystem status were developed in WP4. At the local scale, these tools were applied to the investigation of site specific issues concerning Pilot Cases. At the regional scale, they provided input data to the integrative methodologies for assessing the status of marine coastal ecosystems which were developed in WP5. Assessing ecosystem status at the regional scale is a very challenging task, because regional sets of field data are still lacking or very difficult to access, as was shown by the results of the gap analysis carried out in WP2. To this regard, in MEDINA, we decided to maximize our contribution to the implementation of the UNEP-MAP EcAp by carefully selecting a subset of EOs and indicators which could be assessed by using the expertise and data provided by the MEDINA Consortium. Accordingly, in WP5 integrative methodologies for assessing the ecosystem status at the EO level were developed. This strategy allowed us to reach the first general objective, by demonstrating how the tools developed in WP4 could be effectively used for optimizing the design of monitoring programmes and minimizing their costs, by complementing field data with satellite data and simulation models.

The plan to extend to the region in point monitoring&assessment capacity, therefore, relied on a scientific and technology transfer approach, starting from the solid European experience in Mediterranean coasts management and active participation across GEO activities. However, the project aimed also at involving external users, including international and regional policy-makers and stakeholders, scientists and selected GEO Communities of Practice. This goal was achieved by means of a wide range of Capacity building activities, which were carried in WP6, and dissemination events, pertaining WP7. Such events included 3 Training Sessions for S&T transfer to North African partners, 7 workshops held in North Africa, three of them with participatory sessions, for involving local end-users and stakeholders and one final workshop, in which the results of the project were discussed with relevant GEO Tasks, such as Blue Planet, and the impact of the project framed into the forthcoming AfriGEOSS activities.

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3. A description of the main S&T results/foregrounds

The present section includes a short introduction concerning preliminary activities aimed at defining the State-of-the Art of monitoring, and three parts, addressing:

1) MEDINA results at the local scale;
2) MEDINA results at the regional scale;
3) MEDINA contribution to GEOSS-GCI.

The project initially aimed at increasing the level of knowledge on the existing monitoring systems in the North African countries, in order to assess their capacity to be compliant towards the implementation of the UNEP-MAP EcAp. Therefore, a preliminary inventory phase was carried in MEDINA WP2. North African current national monitoring capacities, in terms of legal framework, agencies with monitoring mandates, and current monitoring programmes were identified. Furthermore a preliminary gap analysis was performed, with the aim of highlighting the main challenges which are connected with the implementation of the Integrated Monitoring and Assessment Programme. Our analysis showed that national legal frameworks are adequate but that monitoring agencies often have overlapping mandates and, as a result, monitoring activities are fragmented and data often are not collected and processed at a central level. Therefore, data accessibility to stake-holders, potential end-users, scientists, NGOs and general public is often limited and data sharing principles have yet to become a common policy. Furthermore, monitoring programmes often lack temporal continuity, which makes it difficult to detect trends and, therefore, assess the benefits of undertaken measure

3.1. MEDINA results at local scale (Pilot Cases)

Based on the above findings, five Pilot Cases were selected, taking into account:

1) Their representativeness at regional level, in terms of ecosystem typology and environmental issues;
2) Their social and economic importance;
3) The availability of environmental data;

As a result, MEDINA activities, at local scale, were focused on the following areas, shown in Fig. 1:

- The Bay of Bejaia (Algeria)
- Lake Burullus (Egypt)
- Gulf of Syrte (Libya)
- The Lagoon of Nador, Morocco
- The Gulf of Gabés (Tunisia)

The main issues investigated in each Pilot Case and the tools developed in MEDINA for investigating the dynamics of coastal marine ecosystems and supporting the design of cost-effective monitoring programmes at the scale of Pilot cases are listed in Table 1. These tools were developed in WP4, led by PML team, except for a urban metabolism study, which was carried out in WP5. In this section, the results are presented with reference to each Pilot Case.

Fig. 1. Geographical distribution of the MEDINA Pilot Cases.

Table 1. *Specific issues concerning Pilot Cases and tools adapted/developed in MEDINA WP4 for their investigation.*

Issues	Algeria: Bay of Bejaia	Egypt: Lake Burullus	Libya: Gulf of Sirte	Morocco: Nador Lagoon	Tunisia: Gulf of Gabes
Coastal erosion	Geostatistical methods applied to the output of a high-resolution wave model			Geostatistical methods applied to the output of a high-resolution wave model	
Nutrients enrichment and eutrophication		- Eutrophication Indicators - Biogeochemical box model		- Eutrophication indicators - High resolution biogeochemical model	- Eutrophication indicators
Fishery decline				- Time series analysis of catches - Food web model - Front analysis from EO	
Sustainable aquaculture	EIA and Food web model	EIA and Food web model			
Conservation of *Posidonia o.* meadows	Habitat Suitability model		Habitat Suitability model		Habitat Suitability model
Impact of coastal urbanization				Urban metabolism indicators	

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3.1.1 Bay of Bejaia (Algeria)

The bay of Bejaia, located on the Algeria coastline (4° 55'E and 35° 45'N), about 200 Km eastward of Algier, is very important for the Algerian economy, being the third industrial district in Eastern Algeria. Furthermore, the presence of several historical sites as well as of a variety of different landscapes, ranging high cliffs, to rocky shore, beaches and wetlands, makes it an ideal location for developing touristic infrastructure. To this regard, it is important to note that it is planned to set up a Marine Protected Area at Gouraya, at the western limit of the bay.

Two issues were investigated namely: 1) The dynamics of coastal erosion; 2) The potential for developing mariculture in the area.

Coastal erosion is severely affecting the touristic industry in Bejaia: in some areas, the shoreline receded by up to 8 meters in the last forty years. The vulnerability to erosion due to wave mechanical stress on the seabed was estimated using the model SWAN for propagating to the coast offshore wave data (source http://www.ncep.noaa.gov/) A ten year long time series of bi-daily data was processed, in order to estimate significant statistical indexes, such as: 1) the 90th percentile of wave heights; 2) the 90th percentile of waves-induced stress on the sea-bottom; 3) the 90th percentile of wave induced currents: 4) the mean duration of storms; 5) the average time between storms. These statistics were subsequently post-processed in order to estimate erosion/accretion rates. Results are summarized in Fig. 2, which presents, on the left hand side, the median value of such potential and on the right hand side the one corresponding to 90th percentile wave induced stress. These maps, which do not require any in situ input data, except for the bathymetry, are very relevant to scientists and stakeholders for planning a correct and cost-effective sampling strategy. Fig. 2 clearly indicates potential of sediment transport towards the East, close to Bejaia city, with some westward transport (green colours). In this case study, these results have confirmed the large erosion rate offshore the airport, which tends to indicate that the observed sand depletion immediately at the East of airport could be due to a significant decrease of the sediment stock offshore that could not feed anymore the longshore sediment transport eastward. However, to turn "potential transport" into actual transport rate, information about the sediment grain size are needed and a proper sediment transport model should be put in place.

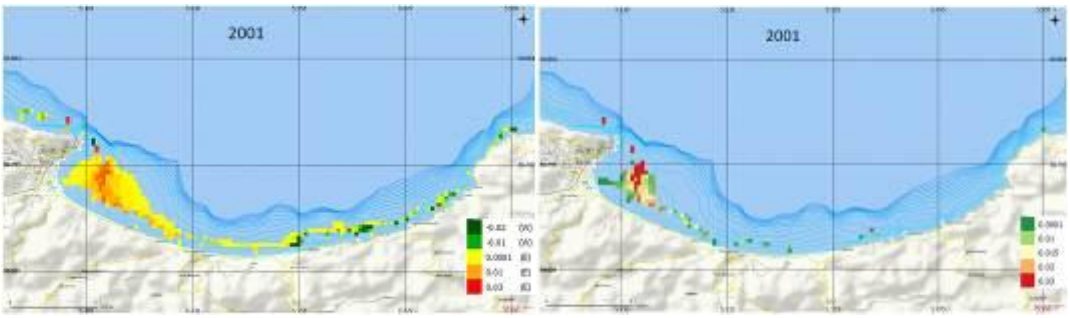

Fig.2 Erosion potential for longshore sedimentary transport at Bejaia based on the median value of wave stress on bottom, left and 90th percentile, right ; (W) - greenish colours correspond to sedimentary transport towards the West, while (E) and others colours corresponds to transport towards the East.

The Algerian Ministery of Fishery is planning to develop marine aquaculture in Algeria, either land-based and in cages at sea, and identified a set of candidate areas for establishing new farms, among which the Bay of Bejaia. A key step for the sustainable and profitable management of cage culture is the selection of suitable farming sites, which, at the same time, minimizes the environmental impact and guarantee an optimal growth rate. In MEDINA we designed and applied to a site selection methodology aimed at optimizing the allocation of space for seabass/seabream cage culture in Bejaia Wilaya. The conceptual model of the methodology is shown in Fig. 3. procedure is based on a multi-criteria analysis, combining information from satellite data, wave statistics, data provided by operational oceanographic model and the output of an integrated model, FiCiM (see also the Exploitable Foreground section). The model allows one to estimate, on the one side, the biomass yield, as a function of husbandry practices and water temperature and, on the other, the impact of uneaten feed and fish feces on the seabed, in terms of organic enrichment of surface sediment.

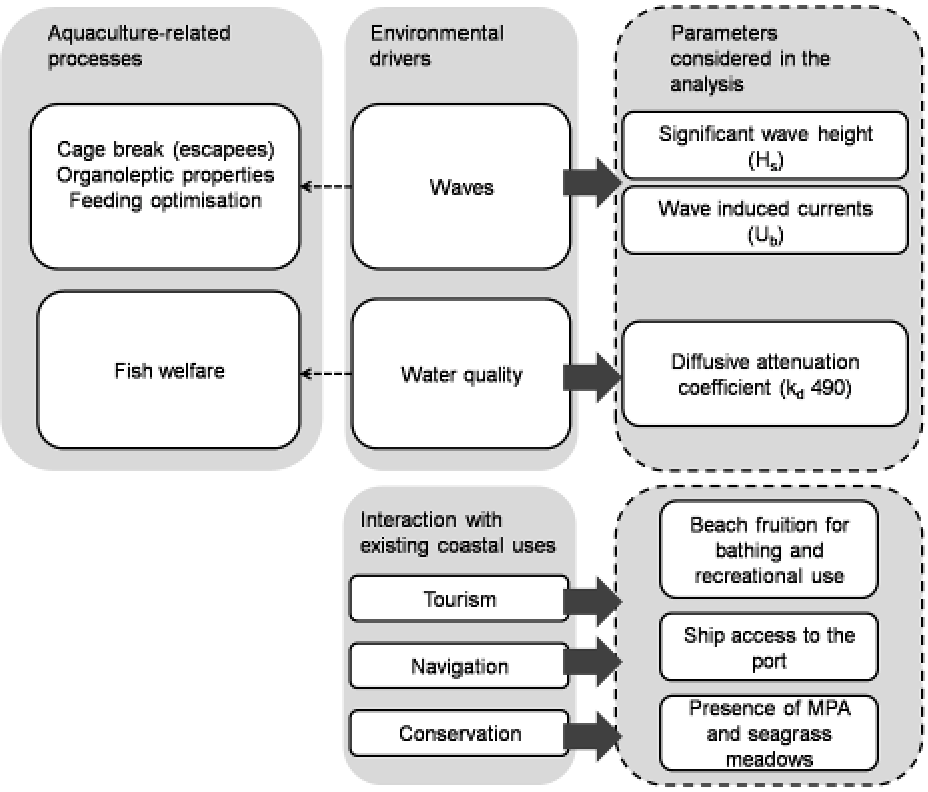

Fig. 3.From left to right: Aquaculture processes affected by environmental drivers and parameters used for quantifying such interactions.

As a result, one gets both a preliminary estimation of potential revenues and of the “footprint” of a farm, in terms of sediment pollution. This, according to our knowledge, new methodology does not require the collection of “in situ” data, at least at a screening level and, therefore, appears to be suitable for an extensive application in data poor areas, such as the North African coastline. Aquaculture site-selection application in Bejaia allowed the identification of the most suitable sites to deploy new fish farm installation (floating cages), combining the quality of a site from the aquaculture use perspective with the conservation of endangered benthic habitats (*Posidonia oceanica* meadows), under the spatial restrictions imposed by existing activities (tourism). This result goes in the direction of defining site selection methodologies complying with the principles of the Ecosystem Approach to Aquaculture (EAA). The results of the methodology are illustrated in Fig.4.

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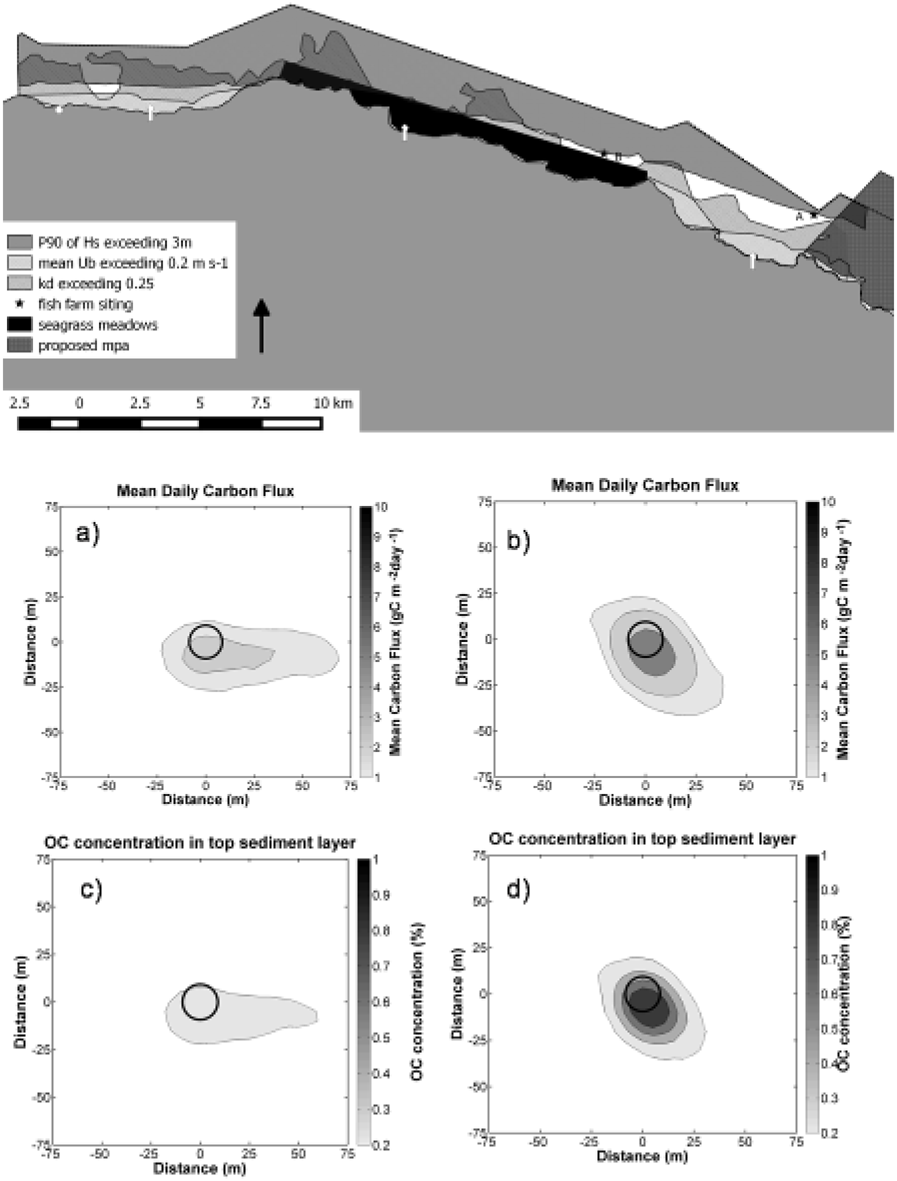

Fig. 4. Indicators of environmental interaction of the farm at the selected sites: C fluxes and TOC concentrations in superficial sediment (a,c: site B; b,d: site A).

3.1.2 Lake Burullus (Egypt)

Lake Burullus, in Kafr el-Sheikh Governorate east of Rosetta, is the second largest lake on the Nile delta. The lake is very important from the economic point of view, since it provides about 20% of the total Egyptian fish production. Furthermore, the lake ecosystems show a high biodiversity. For this reason, it is included in the network of Egyptian Protected Areas, managed by the Egyptian Environmental Affairs Agency (EEAA). It is registered as a Ramsar site and indicated by Bird Life International as an Important Bird Area (IBA). Fishery and aquaculture coexist in the Lake but the increasing pressure from semi-intensive aquaculture is exacerbating the conflicts between these two activities and is also leading to decrease in the free-access surface of the Lake. The Lake is surrounded by fertile land and receives relevant amounts of Nitrogen and Phosphorus, which contribute to its eutrophication.

As depicted in Fig. 5, the potential impact of fish farming on the Lake water quality and ecosystem functioning was investigated by combining a set of tools, namely: 1) a biogechemical box-model, for understanding how loads of Nitrogen and Phosphorus affect the Lake primary production, 2) the

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model FiCIM, (used also in the Bejaia PC) for estimating the local direct impact of fish cages; 3) a food web model, for a preliminary analysis of the effect of fish farming on the functioning of the Lake ecosystem.

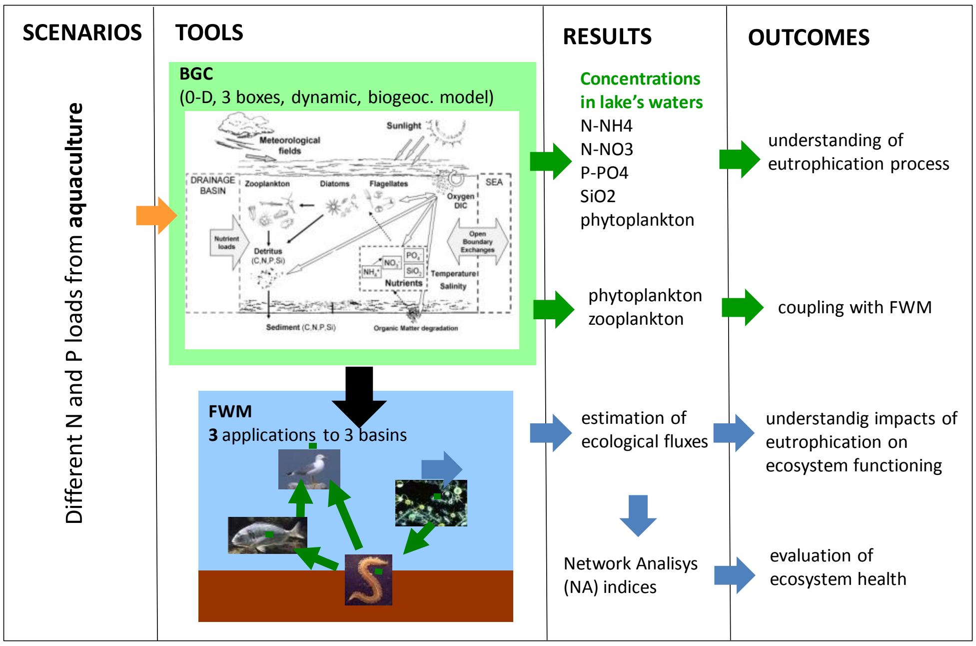

Fig. 5. Methodological approach for studying the eutrophication and the potential impact of fish farming in Burullus lake.

Food Web Models (FWM) describe quantitatively energy and matter fluxes at the community level and, based on these fluxes, providing useful insights concerning the food web structure. The inverse methodology applied in this study and in that concerning the Lagoon of Nador allows one to estimate fluxes from under-determined systems of mass-balance equations, taking into account eco-physiological constraints derived either from the literature or site specific data/local knowledge. The subsequent Ecological Network Analysis (ENA) provides a set of indicators of ecosystem functioning.

The results of the application of the FWM to Lake Burullus show that primary producers and, in particular, phytobenthos account for a significant portion of the overall net production of the system. Benthic fauna and nekton provide a comparable quota of the remaining production. The most important sources of food for the system are benthic vegetation and detritus. Macrozoobenthos compartments consume most part of the energy flowing through the system. The ecosystem is efficient in energy assimilation: respiration and defecation play minor roles. The fraction of energy extracted as fish catches, which were estimated on the basis of literature data, does not appear to be relevant, as the ecosystem is still extremely productive.

As regards the potential impact of aquaculture, the role of its discharges in the eutrophication process of Burullus lake has not yet been well documented but it is expected not to be negligible within overall nutrient balance of the lake. In fact, fishponds (*hoshas*) occupy relevant extension around and within the lake, namely about 34000 ha in 2011. Based on semi-intensive aquaculture practices, a relevant contribution in terms of nutrient loadings to the lake is expected, due to pre-stocking organic fertilization and to the largely adopted feeding practices during the stocking period. In this preliminary study, we considered three different scenarios:

no aquaculture: only nutrients loads, namely Nitrogen and Phosphorus, from drains and agricultural run-off were considered ;

present scenario: the contribution of aquaculture to N and P loads was estimated on the basis of the fishpond extension recorded in 2011 and of the current fish production

future scenario of <u>further expansion of aquaculture</u> activities, based on a working hypothesis of extension of fishponds area up to 150% of the current one

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The results are summarized in Fig. 6, which shows two of the main indexes of ecosystem functioning based on ENA. The total system throughput (TST), corresponding to the sum of all energy flows in the ecosystem and indicating its activity, increases with the increased nutrient loads. It is interesting to note that this is particularly true in the case of the central basin, which is shown to be the most ecologically active area of the lake in terms of quantity of energy flowing through the ecosystem. This basin seems to be characterized by a well structured food web, better adapting to eutrophication conditions. Under an eutrophication gradient the ecosystem of the central basin is not only growing in size (increasing its TST) but it increases also its degree of organization of energy fluxes, as shown by Ascendency (ASC) values, representing a combined measure of system structure organization and system size. The decrease in ASC, of eastern and central basins, even if small in value, suggests these sub-basins are characterized by food webs more sensible to stress due to eutrophication.

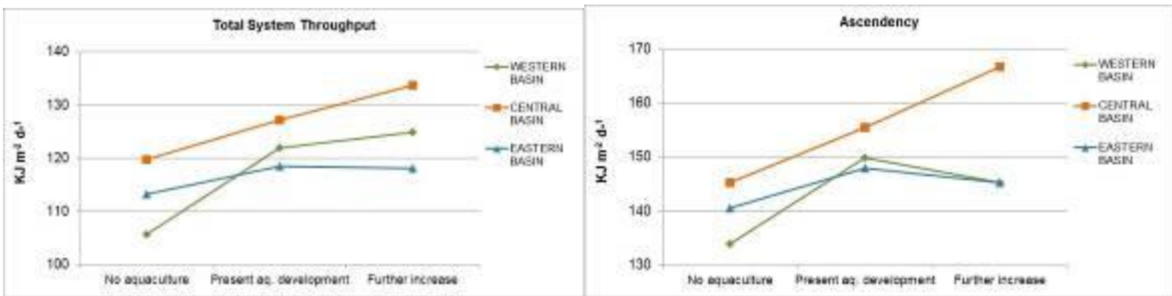

Fig. 6. Total System Throughput and Ascendency for the three scenarios.

3.1.3 Gulf of Syrte (Libya)

The gulf of Syrte located in the Eastern basin of the Mediterranean Sea, along the northern coast of Lybia and delimited by a line joining the promontory of Boreum (now Ras Teyonas) at East side to the promontory of Cephalae (Ras Kasr Hamet) at West. Information concerning ecosystem status and its dynamic are currently lacking: in view of implementing a monitoring programme aimed at collecting a basic data sets of field data, in MEDINA we undertook an exploratory analysis, based on monthly data harvested on the web services implemented in the Environmental Marine Information System (EMIS *http://emis.jrc.ec.europa.eu/*). The analysis aimed at identifying areas where biogeochimical and physical parameters are homogeneous and is referred to as bioregionalization or ecoregionalization in the literature. This is a key step towards the ecosystem based management of marine resources and the implementation of both the UNEP-MAP EcAp and the EU MSFD, since, in both cases, the assessment of ecosystem status at the level of “water body” is required. The ecoregionalization procedure was carried out using a multivariate regression tree method, (MRT) which can integrate spatial and temporal characteristics of the predictors. Starting with all the data represented by a single node at the top of the tree, the tree grows by repeated binary splitting of the data. Splits are chosen to maximize the homogeneity of the resulting two nodes. The terminal nodes (i.e., unsplit nodes) are also called the leaves of the tree. The tree is then “pruned back” to the desired size, according to the scope of the analysis. The MRT was applied to 7 variables, namely: Bathymetry, Chlorophyll a concentration, Water transparency, Colored dissolved organic matter, Suspended particulate matter concentration, Eddy kinetic energy, Wind stress, Sea Surface Temperature. A climatology was built for each parameter over the period 2003-2012.

The analysis was carried out using the free software environment for statistical computing and graphics “R”, in order to ensure its transparency and reproducibility. The open-source tool purposely developed in MEDINA is freely available at *https://github.com/ldbk/EMISR* and could be used for the ecoregionalization of other coastal areas: in MEDINA is was also applied to the Egyptian coastal waters. The results are summarized in Fig. 7, which presents the partitioning obtained using the ecoregionalization methodology, and Fig. 8, which shows the average seasonal evolution in each region. The partition distinguishes coastal regions (*16*, *17*, *12*, *11* and *8*) vs pelagic regions (*15*, *09*,

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06 and *07*). The western part of the gulf of Syrte is more fragmented with the smallest regions (*16*, *15* and *17*): the environmental parameters are more variable in this area. As one can, the methodology allows one to identify the most productive part of the Gulf, region 16 and 17, as well as those most affected by wind stress, 8 and 11, between June and September.

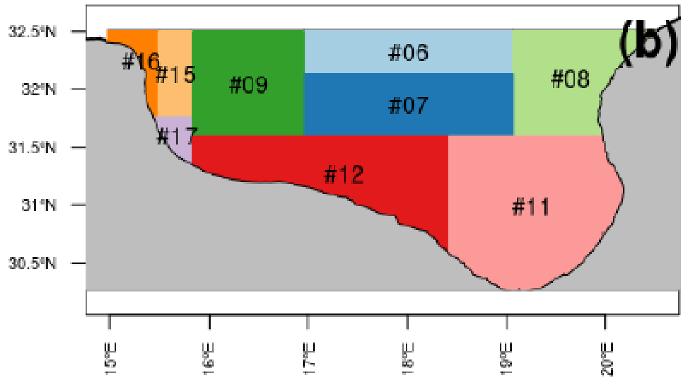

Fig. 7. Results of the ecoregionalization for the Gulf of Syrte.

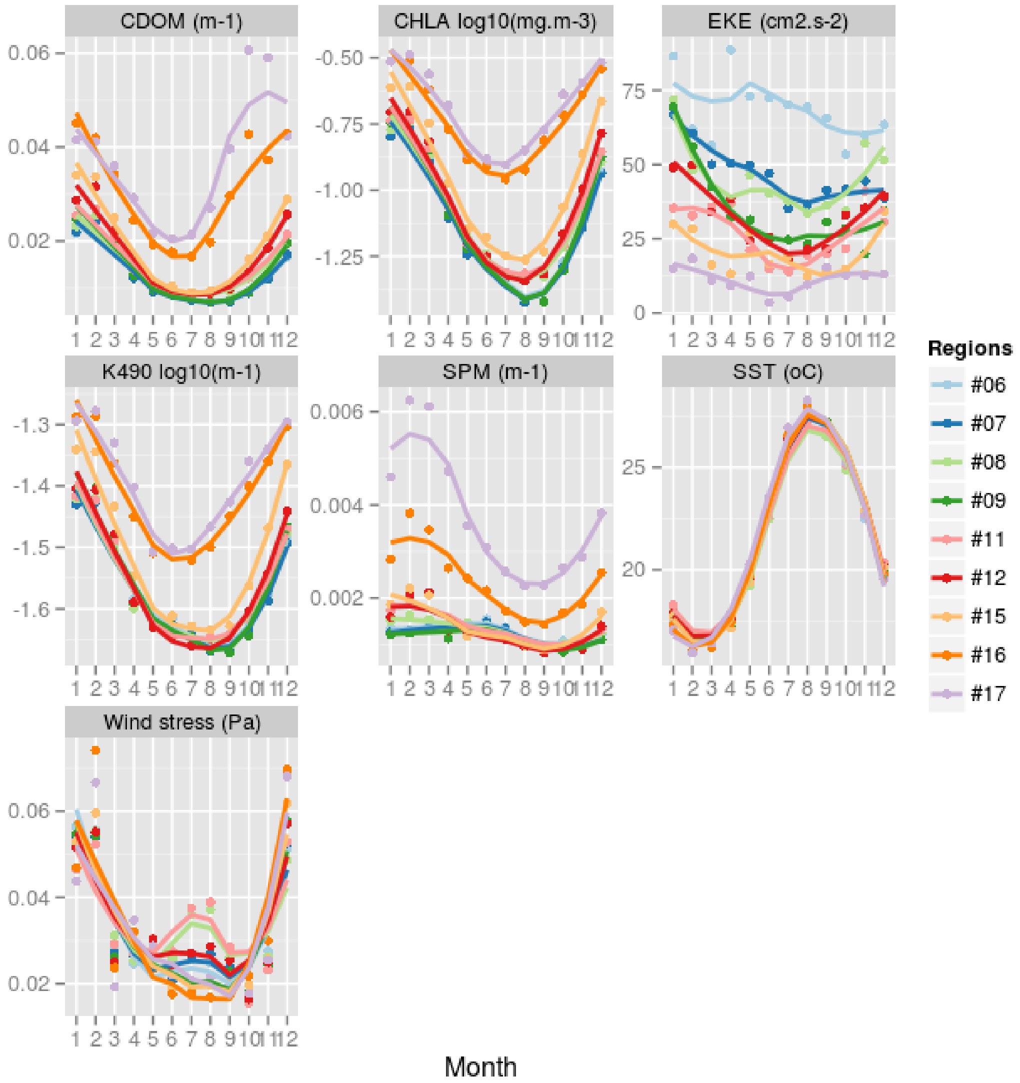

Fig. 8. Seasonal evolution of the oceanographic variables used for the ecoregionalization.

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3.1.4 Lagoon of Nador (Morocco)

The Lagoon of Nador, also called Sabkha Bou Areg or Mar Chica, is located in the northeastern part of Morocco on the Mediterranean coast. It is the second largest lagoon complex of northern Africa (115 km^2), the largest lagoon in Morocco and the only one located along its Mediterranean coast. The Lagoon of Nador is a complex and delicate ecosystem, which is threatened by several anthropic pressures, whose effect on the ecosystem could also be exacerbated by climate changes. Artisanal fishery has always been one of the main activities in the Lagoon, but, recently, tourism has become one of the main economical assets of the area. To this regard, the Moroccan government has planned the construction of touristic infrastructure, which may affect the lagoon ecosystem and the traditional activities in the area.

As shown in Table 1, four issues were investigated, namely: 1) nutrient enrichment and eutrophication; 2) Ecosystem functioning and fishery decline; 3) Impact of coastal urbanization; 4) coastal erosion. The main results are summarized below.

Nutrient enrichment and eutrophication

The dynamic of primary production and the potential of developing signs of eutrophication in this ecosystem were investigated by developing a high resolution model of the lagoon of Nador for simulating the evolution of physical, (e.g. temperature, salinity and currents) and bio-geo-chemical variables (e.g. chlorophyll a and nutrients) inside the lagoon and in the adjacent coastal waters.

The objectives of the application of the high-resolution biogeochemical model of the Nador Lagoon were:

1) To support the understanding of the eutrophication processes, in relation to both the hydrodynamic circulation and the seasonal dynamic of Nitrogen and Phosphorus loads;
2) To provide model outputs and information useful for further analysis aimed at designing an integrated monitoring strategy in the Nador Lagoon.

As regards the first objective, it is worth noting that the opening of a new inlet with armed breakwaters in 2011 could have led to significant changes to the hydrodynamic circulation and, therefore, to the dynamics of the Lagoon ecosystem, as the results of this study suggests.

The high resolution model was developed by coupling the unstructured grid model FVCOM, for simulating in detail the hydrodynamic circulation, and the ERSEM biogeochemical module, which simulates the dynamics of macronutrients, namely Nitrogen, Phosphorus and Silica, that of Dissolved Oxygen and of the lower trophic levels. An example of the results can be seen in Fig. 9, which shows the spatial distribution of the annual means of Salinity, Nitrate, Dissolved Oxygen and Chlorophyll a. The simulation is representative of the last decade, being referred to the year 2006.

As one can see, the lagoon exports Nitrate to the sea, as indicated by the decreasing border-to-inlet gradients in figure 9b: the average values of nitrate are higher at the borders of the North and South basins, where streams discharge freshwater into the lagoon, as indicated by the lower salinity (9a). Dissolved Inorganic Nitrogen, mainly Nitrate, fuels the phytoplankton proliferation: in fact, chlorophyll a concentration shows a clear spatial gradient, being higher on the edges of the Lagoon (9d). Overall, phytoplankton growth seems to be limited by the concentration of Dissolved Inorganic Phosphorus (not shown in Fig. 9). Dissolved oxygen has evident decreasing gradients from the inlet towards the inner parts of the lagoon (9c). This suggests an important effect of the inflow of oxygenated seawaters on the average distribution of this indicator. The positive correlation of oxygen with salinity supports this statement.

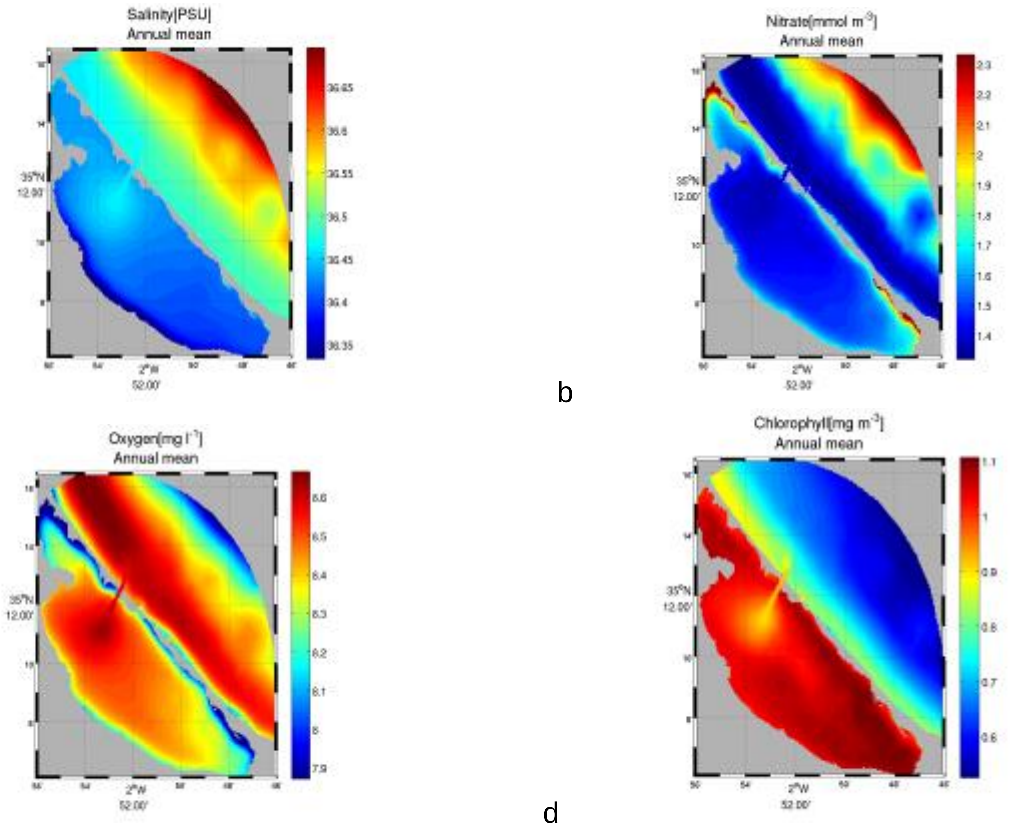

Fig. 9. Maps of the annual averages of Salinity, Nitrate, Oxygen and Chlorophyll a, estimated by model simulation concerning the year 2006.

The model was then used for investigating the effects of the opening of the new inlet on the dynamics of dissolved nutrients and primary production in the Lagoon of Nador, The inlet includes two breakwaters and is deeper (6 m instead of 3) and wider (300 m instead of 250) than the old one of Bokhana, which was located 1.5 Km southward. This intervention was aimed at increasing the water exchange between the sea and the lagoon, restoring the quality of the natural environment and facilitating the navigation. A one year long simulation was carried out with the old bathymetry and the old inlet, in order to simulate the hydrodynamics and biogeochemistry before the opening of the new one. The model was forced by the same forcing functions and boundary data used for the 2006 simulation, in order to compare the results, which are summarized in Fig. 10 and 11. As one can see in Fig. 10, the model indicates that the new channel has increased the water exchange with the Mediterranean Sea: on this basis, one can expect a marked effect also on the distribution of biogeochemical variables. The comparison between this simulation and the one concerning the present situation is presented in Fig. 11 for Salinity, Nitrate, Chlorophyll a and Dissolved Oxygen. The model suggests that salinity, and Dissolved Oxygen could have increased, due to the increased circulation of marine waters, Nitrate and phytoplankton concentrations, could have decreased, due to an increased outflow of nutrients and phytoplankton towards the Mediterranean.

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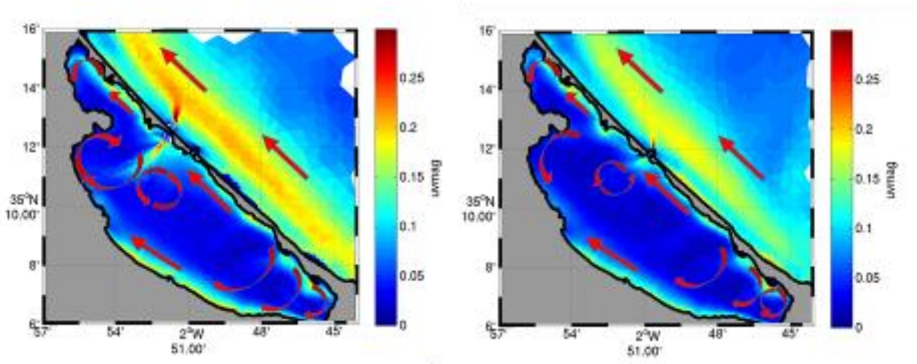

Fig. 10. High-resolution modelled 15-day average surface current speeds for new (left) and old (right) inlet, showing an increase in the water circulation in the present situation.

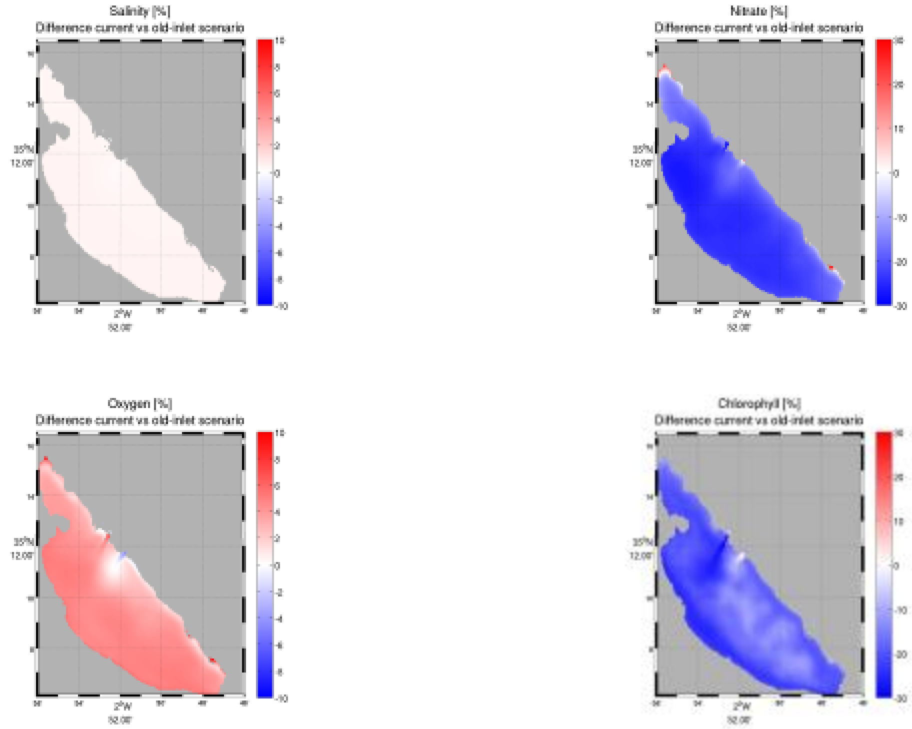

Fig. 11. Maps of the percentages differences between the annual averages of Salinity, Nitrate, Dissolved Oxygen and Chlorophyll a computed in two scenario simulations. The "current" scenario, see Fig. 9, concerns the bathymetry that represents the lagoon inlet opened in 2011, the "old-inlet" scenario includes the Bokhana inlet that was closed in 2011. Note the different scales of the maps of salinity and oxygen.

As was remarked in the previous section of this report, field data in the North African regions are scarce and difficult to access. The results here presented were partially validated on the basis of available data (see Deliverable D4.3) and strongly suggest that a proper monitoring programme should be set up in order to understand how the trophic state of the Lagoon could evolve. In order to address this issue, the model was also used for suggesting where sampling stations could be located for optimizing the sampling effort. The approach for the identification of optimal spatial distribution and temporal frequency of in situ monitoring was successfully applied in the framework of several European Commission research projects (e.g. FP5 ODON, FP6 ECOOP, FP7 OPEC). The method (Fu et al., 2011) is based on the iterative computation of maps of fraction of variance explained by different monitoring networks we tested. These test networks can be characterized by different numbers and location of monitoring stations, as well as by different frequencies of

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measurement. The objective is to identify a monitoring network that could explain large part of the variability of the monitored variables. Ideally, the identification of the optimal network should be carried out by using real in situ data. However, this would require large amounts of in situ time series collected at high frequency and at high spatial resolution. Such amounts of data are rarely available in practice, due to budget and technical issues. Thus, the method is usually applied using proxy of in situ data, such as biogeochemical model outputs, as was done in this case, or satellite data, as was done for the Gulf of Gabes, see next subsection. Typically, these proxy data are available at a low cost and at spatial resolutions and temporal frequencies that allow one to test several alternative monitoring networks.

The following variables were selected as targets of the proposed monitoring activity: Salinity, Temperature, Nitrate, Dissolved oxygen and Chlorophyll a. These variables are also included in most scientific and policy recommendations for the surveillance of marine ecosystem eutrophication (see e.g. OSPAR, 2005). The variance explained by alternative monitoring network was computed on the basis of the estimates provided by the "current scenario" simulation of the high-resolution biogeochemical model (see Fig. 9). The optimal monitoring network identified in our analysis is presented in Fig. 12, which shows the location of the two selected monitoring sites, and the variance explained by daily time series of indicators collected at those sites for two of the above variables. These sites should ideally monitored by automated multiparametric sensors. The first monitoring station is located at the inlet of the lagoon. This site allows one to survey efficiently mass and energy that are exchanged between lagoon and Mediterranean Sea. The second station is located in the southern part of the lagoon, where local biogeochemical dynamics (e.g. primary production, remineralisation) are the major drivers of the ecosystem indicators. The spatial-temporal variability explained by the daily sampling is higher than 80% for all the indicators, in large part of the lagoon. Chlorophyll, i.e. phytoplankton, resulted the most challenging indicator to monitor, as the lowest values of explained variance suggests.

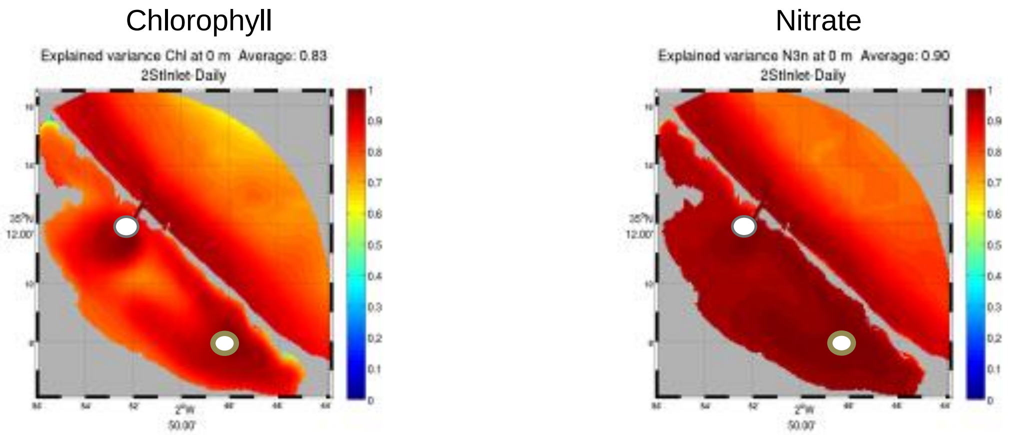

Fig. 12. Location of the monitoring stations of the identified monitoring network in the Nador lagoon (white circles). The maps show the estimated fraction of variance explained by daily sampling of the indicators by ideal automated multiparametric sensors.

<u>Ecosystem functioning and fishery decline</u>

Artisanal fishery is a traditional activity in the Lagoon of Nador and the whole Mediterranean coast of Morocco which is still important from the economic point of view. A decrease in fish catches in the last decade was allegedly reported by fishermen, in particular for the Lagoon of Nador, even though available data do not allow one to support this claim. However, as we saw, changes in the hydrodynamic circulation can significantly affect the dynamic of low trophic levels and, therefore, the whole ecosystem functioning. In the last years, such changes, could have been worked in synergy with a reduction in the Nitrogen and Phosphorus loads, thus leading to a decrease in its productivity. In order the enhance our understanding of the evolution of the Lagoon ecosystem in the last decades, we developed a FWM, see the section concerning Lake Burullus, by combining literature

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data, the results of the biogeochemical model and field data collected in the framework of MEDINA, thanks to the collaboration with the INRH (Institute National de Recherche Halieutiquee), Nador Department. The methodological approach is illustrated in Fig. 13.

As shown in Fig. 14, FWM models were applied to two data sets, which are representative of the ecosystems status in the 1980ies (Past scenario) and in the past decade (present scenario). In fact, the analysis of literature data and local knowledge of INRH personnel suggested that the ecological conditions of the Lagoon have markedly changed from a status characterized by the presence of seagrass meadows and macroalgae in the 1980ies to the current situation, in which these communities occupy only the edges of the Lagoon. The application of the model required also the collection of field data concerning the benthic community, which was carried out in collaboration with the INRH personnel in September 2013: these data indicate a marked decline in macrozoobenthos biomass, compared with the 1980ies.

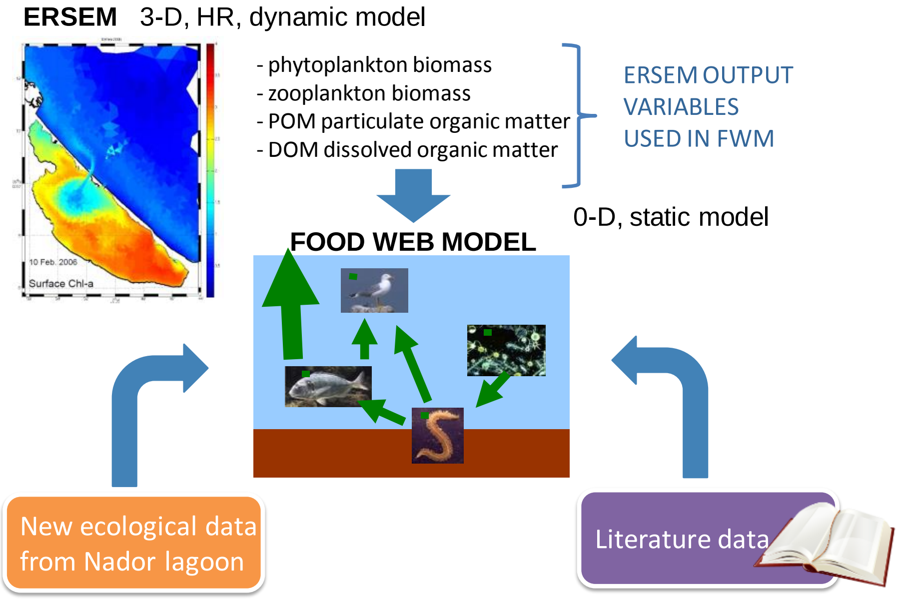

Fig. 13. Methodological approach to the application of FWM to the Lagoon of Nador.

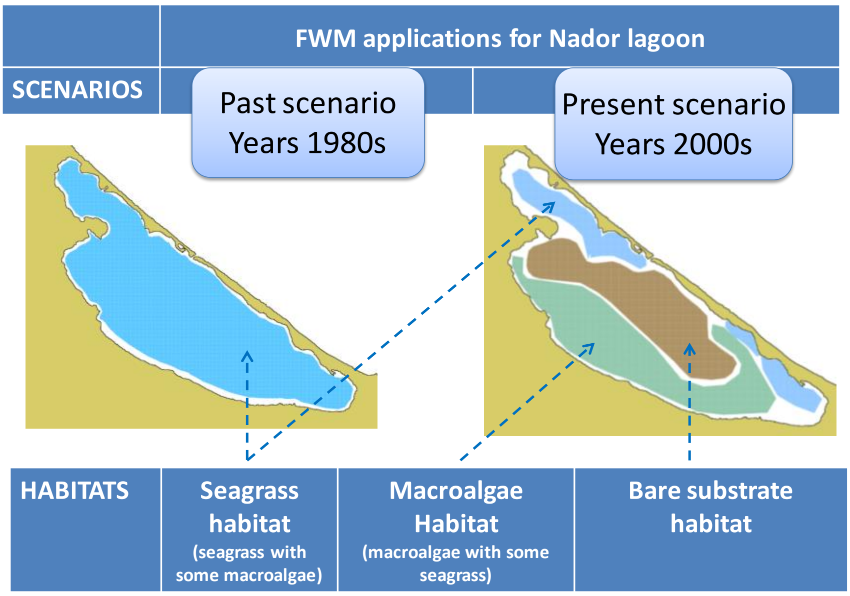

Fig. 14. Temporal scenarios and habitats considered to set up the Food Web Model applications to the Nador lagoon.

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The comparison of the FWM model outputs concerning the two scenarios indicates:

- an increase in the overall net production of the ecosystem;
- a sharp decrease of the role of *macrozoobenthos* component and an increase in the herbivorous nekton;
- a relevant increase in of *piscivorous birds in controlling the food web;*
- the need of introducing an external energy source for supporting the food web concerning the present scenarios:

Furthermore, the results of the Ecological Network Analysis suggest that the Lagoon, very likely, was affected by eutrophication during the last two decades, which may have cause also the recession of the seagrass meadows. At present, the ecosystem seems in a transitional phase, in which the energy produced is not channeled through the food web in the optimal way for supporting the fish species targeted by the artisanal fishery. The situation could rapidly evolve, as most impacts of eutrophication are reversible, but it certainly require monitoring of the ecosystem compartments, as is pointed out in the “impact” section of this report.

As we saw, the opening of the new inlet has increased exchanges with the open sea: in principle, this could also have enhanced the flow of pelagic species, which both enter occasionally the Lagoon or reside in this ecosystem for part of their life cycle. Therefore, in keeping with the MEDINA objective, we undertook an analysis of the influence of the hydrodynamic circulation in the Alboran on fish landings. In fact, coastal front structures could affect fish catches, as they may determine changes in forage and spawning areas, as well as shifts in the timing of spawning. This objective was pursued by testing the presence of correlations among indicators characterizing front activity and landings of pelagic target species from the three major Mediterranean Moroccan harbors: M’diq, Al Hoceima and Nador. Monthly landing data concerning the years 2007-2013 were kindly provided by ONP (Office National des Peches, http://www.onp.co.ma/) and were partitioned in 5 functional groups (demersals, flat fishes, large pelagics, small pelagics, sardines). The following front activity indicators were selected: front density: (combination of their thermal gradient and persistence), front gradient density, distance among fronts, front side, which indicates weather the zone is located on the cold or warm side of the closest major front, sea surface temperature. We investigated significant correlations among the indicators of frontal activity and landings data, which were log transformed. Sea surface temperature was significantly correlated with all the considered indicators, and was therefore introduced in the model as a confounder. The results of the analysis show that correlations were significant for all the indicators at all the time lags in AL Hoceima and M'diq, with some notable exception: front side in M'diq seems to have a minor influence on landings, with respect to Al Hoceima. The sign of correlation is different for different functional groups of landings, with an inversion among sardines and small pelagic fish. The same general pattern is repeated in the case of Nador also for Sardines, although, in this latter case, Large Pelagic landings show no correlations with the font indicators considered, correlations which are limited also in the case of Small Pelagics. These preliminary results show that the Alboran Sea circulation can play a role in determining significant variation and, therefore, could also affect fish landings in the Lagoon of Nador. Unfortunately, it was not possible to test this hypothesis, as well as those suggested by the FWM, due to lack of specific landing data for the Lagoon and data aimed at charactering its nektonic community. This gap in knowledge should be closed, in order to increase the effectiveness of fishery management measures.

Impact of coastal urbanization

As underlined in the context&objective section coastal urban sprawl and unregulated urbanization is one of the main threat to Mediterranean ecosystem. Besides leading to fragmentation, degradation and loss of habitats and landscapes, including the destabilization and erosion of the shoreline, urban settlement also represents non-negligible point-like sources of macronutrients, namely Nitrogen and Phosphorus. As was seen in the previous section, excessive loads of Nitrogen and Phosphorus may cause the eutrophication of coastal water bodies, with severe consequences on ecosystem functioning. The role of cities as potential hot-spots of land based pollution is, in

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particular, relevant in the North African coastline, where the population of coastal cities is increasing and, in some instances, proper Waste Water Treatment Plant are lacking.

In order to study the importance of coastal cities as sources of Dissolved Nitrogen and Phosphorus for coastal waters, in MEDINA we undertook a pioneering study of the “urban metabolism” of the Gran Nador urban region. The study aimed at obtaining a better understanding of the flows and stocks of N and P concerning this urban system and the potential impacts and implications of urban lifestyles on N and P emissions to coastal waters. To this regard, , the flows of nitrogen (N) and phosphorus (P) related to food consumption and waste disposal were investigated. The Grand Nador area is enduring an intensive industrialization accompanied by excessive, rapid and disorderly urbanization, most of which is localized on the edges of the Lagoon. At present, the region is experiencing significant economic transformations owing to the Moroccan Royal Initiative for the Development of the Oriental region that translates into the development of major infrastructural and sectorial projects. The analysis was carried out using the Substance Flow Analysis (SFA) methodology, which is based on the conservation of matter and energy and provides information about the key stocks and flows of a specific substances, about possible imbalances in the stocks and flows, and about unsustainable use of resources.

The methodology was applied to the year 2010 and concerns the total N and P flows/stocks: further work would be needed to relate the emissions to dissolved Nitrogen and Phosphorus entering the Lagoon. N and P flows related to food consumption were estimated on the basis of FAO statistics, adjusted on the basis of the ration between urban and rural population in the study area, and on specific conversion factors. Food is either eaten or disposed of as food waste, resulting in the outflow of nutrients as either solid waste or/and wastewater and sewage sludge. These outflows were estimated on the basis of available data on per capita municipal solid waste (MSW) generation, estimated organic waste fraction, rate of MSW collection and disposal, urban and rural connection rate to sewer network, as well as, data on water quality and treatment plant.

The results are summarized in Fig. 15, which shows the estimates of the stocks and flows: as one can see, according to our calculations, approximately up to 1.211t of N and 323,5t of P are lost annually to the aquatic system and thus ultimately delivered into the Lagoon. Nitrogen total outputs are lower than total inputs, the difference attributable to N atmospheric emissions from the WWTP and the non-controlled landfill (emissions not calculated due to lack of data). With regard to phosphorus, total outputs are slightly greater than total inputs; this small difference might be due to already acknowledged problems with data uncertainty, result of the use of literature based estimates rather than detailed in-situ measurements of some parameters and the necessary assumptions in estimating model components.

Despite the shortcomings associated with the lack of in-situ accurate data, this study which, to the best of our knowledge, if the first SFA studies on Moroccan societal systems, already illustrates the linearity of the outflows and thus the openness of the urban system resulting in losses of both N and P to water, air and soil (landfill). The major linear outputs of food nitrogen and phosphorus occurred as wastewater products discharged directly into the Lagoon of Nador or either in the streams flowing into the Lagoon.

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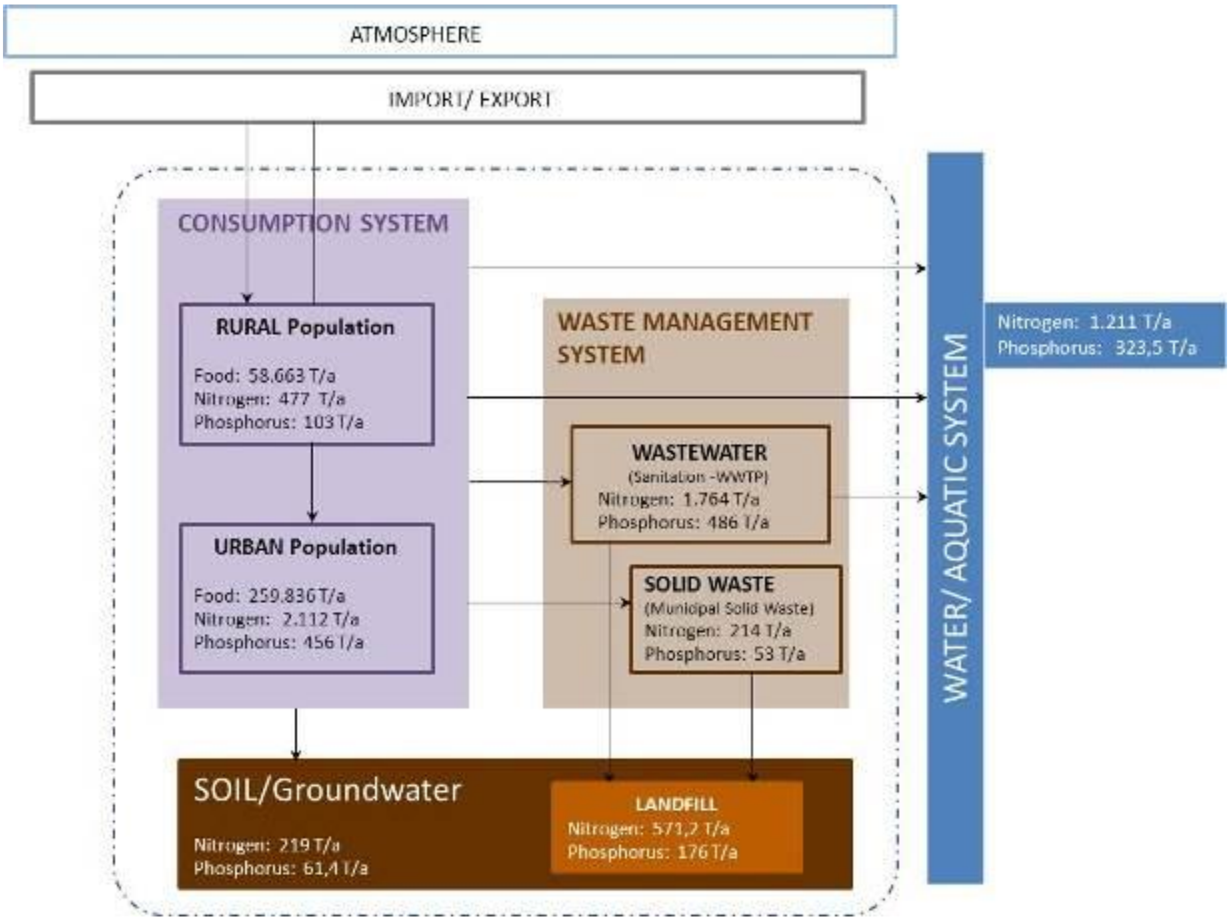

Fig. 15. Nitrogen and Phosphorus nutrient flows from urban and rural populations of Grand Nador.

Coastal erosion

The vulnerability to erosion nearby the Lagoon sand bars was estimated by means of the SWAN model, as described in the subsection concerning the Bay of Bejaia. The results are summarized in Fig. 16, similar to Fig. 2, which shows, on the top panel, two statistical indexes, namely the median and 90 percentile of significant wave height, and on the lower one the potential for erosion, based on the median and 90th percentile wave pressure.

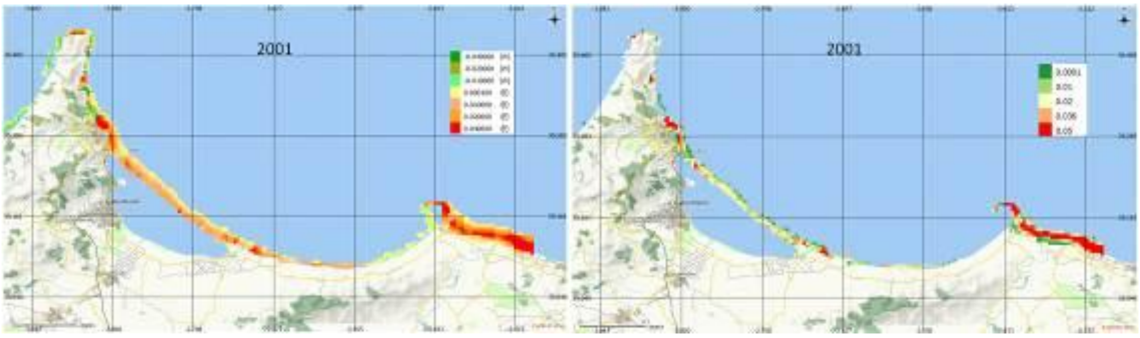

Fig. 16. Erosion potential for longshore sedimentary transport at Nador, based on the median value of wave stress on bottom, left and 90th percentile, right ; (W) - greenish colours correspond to sedimentary transport towards the West, while (E) and others colours corresponds to transport towards the East.

3.1.5 Gulf of Gabés (Tunisia)

The Gulf of Gabès is located in Tunisia, at the junction of the eastern and the western basins. One of its main characteristics is the tidal amplitude (maximum of 2 meters), one of the highest in the Mediterranean. The Gulf presents specific topo/bathymetric (large continental shelf) features, which amplify the tidal excursion, making it one of the highest of the Mediterranean (maximum of 2 meters). These physical features favour the reproduction and growth of a large number of marine species and the very slow bottom slope creates the condition for the presence of large *Posidonia oceanica* meadows. In fact, the Gulf of Gabès, was the most important seagrass area across the Mediterranean and one of the largest in the world. *Posidonia* meadows are a perfect spawning ground for all marine organisms and a nursery for juvenile fish. However, the intense fishing activities involving trawling operations, on the one hand, has markedly depleted fish resources and severely damaged the meadows of *Posidonia oceanica*. On the other hand, the very large release of phosphogypse by GCT (Groupe Chimique Tunisien) in the Gulf since 1952 until now (up to 12.000t / day) has considerably damaged the natural ecosystem. The result of these pressures is a deterioration of the functioning of the whole ecosystem, which led to the proliferation of harmful invasive species such as algal bloom and associated jellyfish, which took advantage of empty ecological niches. Loss of seagrass meadows also implies losses in associated ecosystem services.

Therefore, we investigated, as main issue, the dynamic of *Posidonia oceanica* meadows in the Gulf, in connection with that of eutrophication. To this aim, in MEDINA we developed a Species Distribution Model for *Posidonia oceanica* (PoDM), in order to investigate the causes of the decrease in the coverage of seagrass meadows, and to provide a preliminary estimation of the lost ecosystem services and address the issue of their potential restoration. The model was subsequently applied to the whole North African coastline, as shown in the next section. PoDM is a statistical model which relates the probability of presence of *P. oceanica* to a set of environmental variables, such as: water depth; transparency; dissolved coloured organic matter, salinity, SST, bottom slope, euphotic depth, wave relative exposure index. The model was specifically designed for its application to areas where in situ data are lacking: therefore, most input data can be derived from remotely sensed Earth Observation or modelling. Ecosystem Services (ESS) can be defined as the contributions of ecosystem structure and function, in combination with other inputs, to human well-being. The functions of the *P. oceanica* meadows, and the consequent ESS provision, can be conceptually divided into trophic, structural or combined. A set of eight ESS were identified: seafood (provisioning ESS), lifecycle maintenance, genepool protection, waste treatment, climate regulation, disturbance prevention and erosion prevention (habitat and regulating ESS), recreation and leisure and information for cognitive development (cultural ESS).

ESS can be characterized in terms of supply and demand: the potential to supply ESS is based on the functioning of an ecosystem. However, this potential is converted into real ESS only if there is a demand for these services from the society. This can be transposed to a spatial dimension by introducing the concepts of “service providing area”(SPA), i.e. the spatial units where the service is sourced, and “service benefiting area” (SBA), i.e. the spatial units where the service is needed or readily used or consumed. These two types of area do not necessarily need to coincide in order to have the actual ESS provision, but can be linked by “service connecting areas” (SCA), whose spatial characteristics depend on the ESS. Therefore, the ESS provision potentially occurs where the SPA or the SCA overlap the SBA.

The results are summarized in Fig, 17, which compares the predicted probability of presence of *Posidonia oceanica* with the observed one in a recent survey and Fig. 18, which shows, as an example, the increase in coastal protection from erosion due to the presence of *P. oceanica*. Other EES were taken into consideration: see MEDINA deliverables for details. As one can see in Fig. 17, a large portion of the coastal area presents suitable stable conditions for *P. oceanica,* matching quite well with the observations. The comparison of the observed distribution, on the right, with the potential one, on the left, allows one to identify: 1) areas where *Posidonia* meadows were reported in the past as present, but showing unsuitable environmental conditions (e.g. the inner part of the Gulf, close to the city of Gabes or the area surrounding the Kerkennah island) and 2) areas where the species has never been reported but present favourable conditions, like the large areas north-east of Kerkennah island. The former type of areas is important, and should be a priority for monitoring programmes, as could represent either areas where meadows already disappeared, or areas where the species is still present in sub-optimal conditions (i.e. priority for management actions aimed at restoring suitable conditions). In contrast, the latter type could represent areas where *Posidonia* meadows are already expanding or where the species could potentially settle (i.e. areas eligible as transplantation receiver).

In the case of Gabés, besides applying the SWAN model (see Deliverable D4.3 for results), the vulnerability to coastal erosion was also assessed using the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs tool) Coastal Vulnerability model, developed by the Natural Capital Project. Two scenarios were explored: one with no seagrass meadows and one with the predicted *P. oceanica* meadows, that was used to provide an estimation of how much seagrasses are likely to meet the *disturbance prevention and erosion prevention* ESS demand. As one can see in Fig. 18, the presence of seagrass meadows brings down the risk of erosion to the lowest level for a large fraction of the costaline.

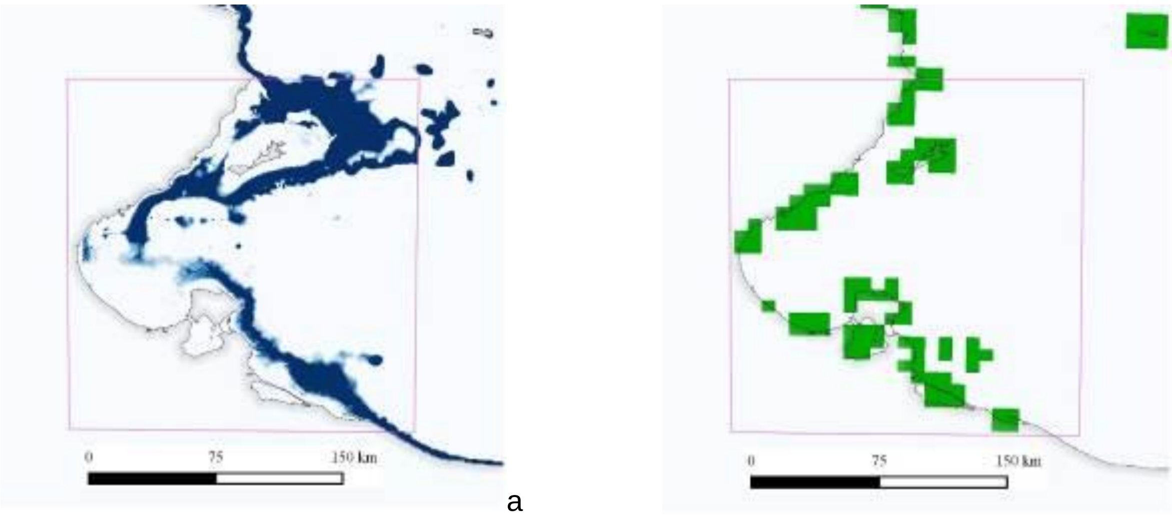

Fig. 17. Probability of presence of *Posidonia oceanica* (left) compared with the actual distribution, based on a survey carried out in 2013

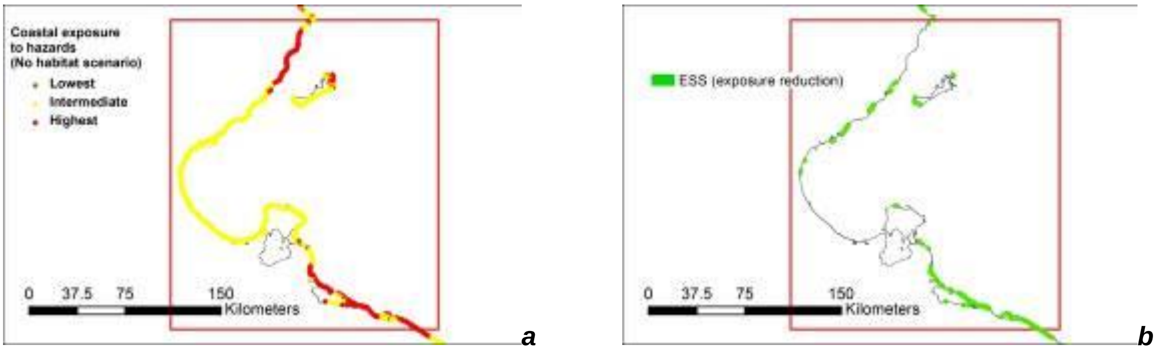

Fig. 18. Coastal exposure to erosion in the absence of seagrass meadows (left) and with the presence predicted by the PoDM model (right): coastal segments which shifted to a lower exposure level are marked in green.

Water transparency is a key factor for the presence of *P. oceanica* meadows. High phytoplankton concentrations, due to eutrophication, can markedly decrease it, leading to the disappearance of the Submerged Aquatic Vegetation (SAV). This could be one of the causes of the rapid decrease in the seagrass coverage in Gabes. Therefore, it could be relevant to establish a permanent monitoring network for monitoring the symptoms of eutrophication in the Gulf. To this regard, we applied also to the Gulf of Gabés the methodology for determining the optimal allocation of monitoring stations

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outlined in the description of the Nador Pilot Case. A minimum number of four stations was identified, as the best compromise between information provided by a weekly sampling and associated costs: the location of the stations are displayed in Fig. 19. We estimated that this monitoring network is capable to estimate up to 90% of the variability of chlorophyll, along the coast and in large off-shore areas. We note that the Northern, station included between the coast and the inland, can explain a relatively low fraction of chlorophyll variance. This result can be due to the lower reliability of the satellite data in this area, as a consequence of sediment disturbances. However, we recommend monitoring this site impacted by the nearby industrial area of Sfax.

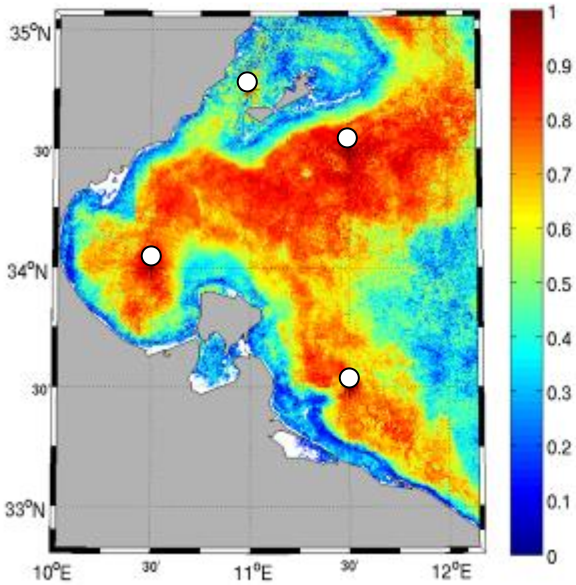

Fig. 19. The map shows the recommended location of four stations for monitoring the chlorophyll indicator in the Gulf of Gabes. The values in the map represent the fraction of the variance of chlorophyll that can be explained by monitoring chlorophyll weekly by, e.g., moorings or routine cruises.

3.2. MEDINA results at regional scale

Assessing the status of North African coastal marine ecosystem at a regional scale proved to be a very challenging task for two reasons:

Well established integrative methodologies for ecosystem assessment are still lacking, with respect of the majority of the indicators identified either in the UNEP-MAP EcAp or the EU MSFD;

No regional data base is available: field data, whenever available, are scattered both in space and time and difficult to compare, in the absence of well-established regional protocols for data collection, sample analysis and data archiving.

In MEDINA WP5, led by UAB, we took the challenge up-front and focused on a well-defined and concrete target, namely developing tools and methodological approaches for supporting the implementation of the main policy for the protection of the Mediterranean marine coastal ecosystems, i.e. the UNEP-MAP, EcAp, endorsed by all Contracting Parties of the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention). The backbone of EcAp is the execution of an Integrated Monitoring and Assessment Programme (IMAP) concerning coastal and marine ecosystems, to be repeated every 6 years.The first IMAP is currently being designed and will start in 2016. The full implementation of the EcAp in North African countries is challenging, not because of the lack of local Scientific&Technical knowledge but, rather, due to the large investment required and, in some instances, to the fragmentation and/or overlapping of mandates among different monitoring agencies. Therefore, the need of designing cost-effective monitoring programmes, on one side, and of setting up an

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interoperable infrastructure for archiving and sharing the collected data is felt even more acutely in the region, compared with EU Mediterranean countries.

In order to reach the above target, we first identified a subset of EcAp Ecological Objectives and indicators which could be estimated in a cost-effective way by combining remotely sensed Earth Observation, namely satellite data, and simulation models: these data could have been produced by the MEDINA Consortium. This first step required a collective effort, which involved all MEDINA participants and was finalized in WP5, leading to the definition of a set of fact-sheets for each one of selected indicators. Each fact sheet provide information about: policy relevance, type of indicator, (based on the DPSIR conceptual model), data sources, methodology for calculating the indicator, and assessment of data quality, based on expert judgement of the Consortium (See Deliverable 5.1 for details).

Subsequently, in WP5, we developed and applied at the regional scale:

- A methodology for the estimation of Drivers&Pressures;
- An integrative methodology for the assessment of EO 5-eutrophication;
- An integrative methodology for the assessment of EO8-coastal ecosystem;
- An assessment of EcAp indicator 1.4.1 “Potential/observed distributional range of certain coastal and marine habitats listed under SPA protocol”, pertaining to EO1-Biodiversity, concerning the distribution of *Posidonia oceanica* meadows, one of the most important Mediterranean habitat.

The application of the above methodologies was performed at the level of Off-shore and, whenever possible, Coastal Water bodies, which were previously identified on the basis of a set of criteria, including the delimitation of each country Exclusive Economic Zone, the partitioning in eco-region, wave exposure, depth and coastline typology, as a surrogate of the seabed substratum. As a result, we identified seven Off-shore water bodies and nine typologies of Coastal ones.

The results are described in detail in Deliverable D5.2 and are summarized below.

Estimation of Drivers&Pressures

The assessment of land-based pressures at a regional scale was based on LUSI methodology (Land Use Simplification Index), which provides proxies of diffuse pollutants loads, based on land use and population data. This choice was motivated by the lack of regional quantitative data concerning pollutant loads from human activities (e.g. industrial or municipal sources). LUSI is based on quantitative evaluation of the main coastal land uses that could have an influence on coastal marine ecosystems. As such, LUSI is a tool for investigating the link between human induced pressures and ecosystem status, integrating information concerning: 1) land use categories in the coastal zone, i.e. urban, irrigated land, etc…; 2) riverine influence; 3) coastal morphology, as a proxy of water residence time. This index was adopted, among others, by the European Commission and tested in Valencia (Spain). Five drivers were used in the LUSI application to the North African coastline, namely: Urban Morphology, Population in littoral cities, Agriculture, Ports, and Rivers. The results were summarized in five maps, one for each country, such as the one concerning Algeria, presented in Fig. 20. As one can see, the index suggests the presence of hot-spots of pressures: in these areas, monitoring activities should be intensified, if a risk-based approach to monitoring is adopted.

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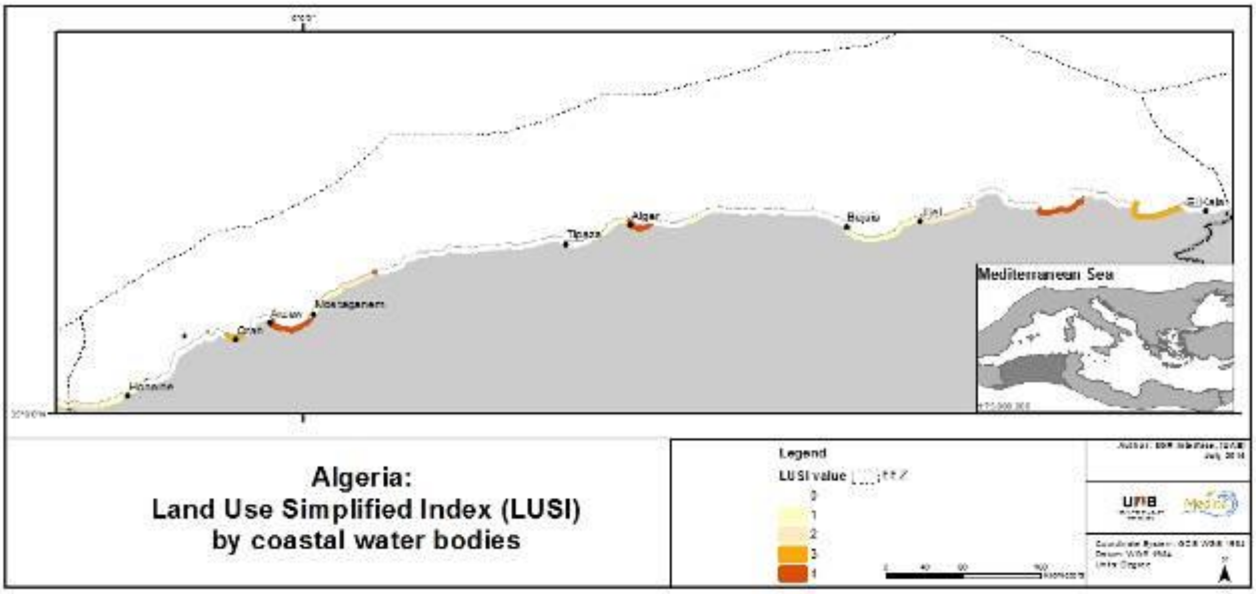

Fig. 20 . LUSI applied to the Algerian coast

<u>Integrative assessment of ecosystem status for EO 5-eutrophication</u>

Nutrient enrichment, in particular dissolved inorganic forms of Nitrogen and Phosphorus, can induce excessive growth of primary producers, with severe consequences on the status of coastal marine ecosystems. Conceptual and mathematical models of eutrophication processes are well established and led to specify the EcAp Operational Objectives and Indicators listed in Table 3.

Tab. 3. Operational Objectives and Indicators defined by the UNEP/MAP-EcAp for Ecological Objective 5 (Eutrophication).

Ecological Objective (EO)	Operational Objectives (OO)	Indicators
Human-induced eutrophication	5.1 Nutrients	5.1.1 Concentration of key nutrients in the water column
		5.1.2 Nutrient ratios (silica. nitrogen and phosphorus), where appropriate
	5.2 Direct effects	5.2.1 Chlorophyll-a concentration in the water column
		5.2.2 Water transparency where relevant
		5.2.3 Number and location of major events of nuisance/toxic algal blooms
	5.3Indirect effects	5.3.1 Dissolved oxygen near the bottom

Indicators 5.1.1, 5.1.2 and 5.3.1 were estimated on the basis of the output of a regional biogeochemical model developed in WP4. Indicator 5.2.1 was estimated as the 90th percentile of the surface Chl-a concentration, measured monthly for a period of at least 5 years through Ocean Colour satellite data. Indicator 5.2.2. was also estimated from Ocean Colour as a yearly average diffuse attenuation coefficient at 490nm, based on a reanalysis of monthly data collected in the decade 2003-2012.

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The assessment of the ecological status concerned only Off-shore water bodies, as satellite data does not yet provide reliable estimates of Chlorophyll a in near-shore waters. Assessment results were aggregated for each water body, starting from the indicator level up to the Operational Objective (OO) and, eventually, the Ecological Objective (EO) one. The aggregation method was based on dimensionless Ecological Quality Ratios (EQR), as suggested by the literature and recent practice in relation to the implementation of the EU WFD. The calculation of EQRs required the estimation of reference conditions of each WB and of thresholds of "acceptable" deviation from the reference: water bodies trespassing the thresholds were classified as non-complying with the Good Ecological Status, i.e. Non-GES. Reference conditions and thresholds were determined by combining the results of an exploratory analysis of the statistical distribution of the data with expert judgment. Thresholds were tentatively determined based on the literature and expert judgement. The methodology is presented in detail in Deliverable D5.2. As an example of the results, in Fig. 21 we show the classification obtained for the two indicators derived from ocean colour, namely surface Chla-a concentration and light attenuation coefficient. We believe that the methodology developed in MEDINA is scientifically sound. However, the results of the classification should be taken with great care, being sensitive to the choice of reference conditions, of thresholds and, of course, to the input data. To this regard, data collected during the forthcoming EcAp Integrated Monitoring & Assessment Programme would be crucial for validating the approach here proposed and improving the accuracy of the results.

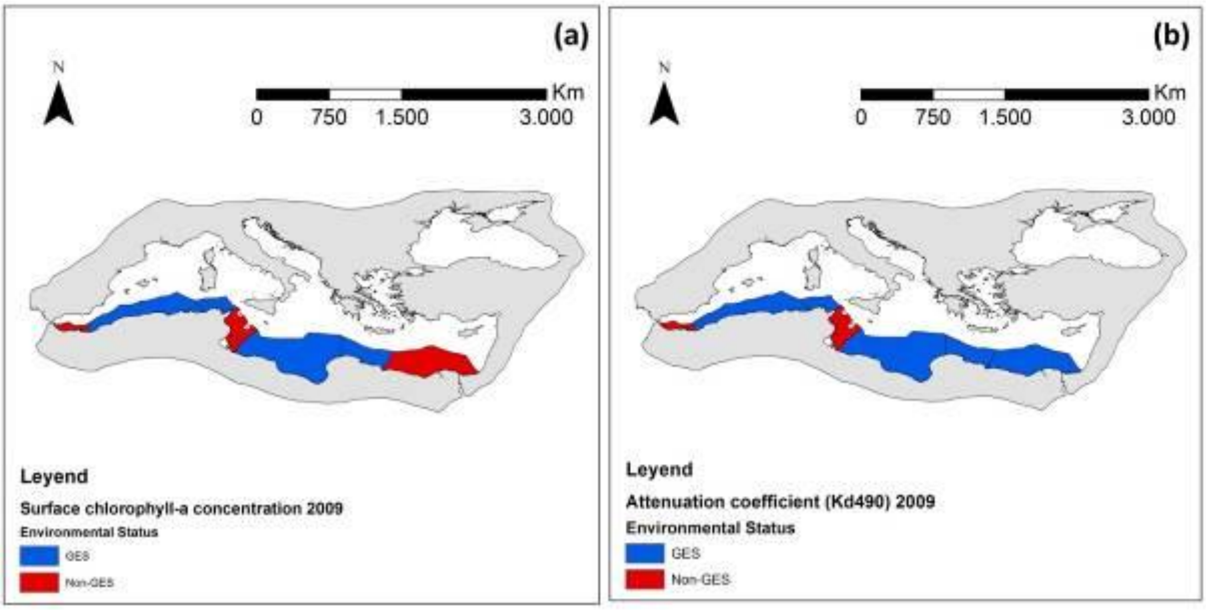

Fig. 21. Environmental Status classification for the (a) 90th percentile of chlorophyll-a concentration and for the (b) average attenuation coefficient, for Offshore Water Bodies.

Integrative assessment of EO8-coastal ecosystem

As an intermediate step towards the implementation of the monitoring of the full set of 56 indicators pertaining the EcAp, Contracting Parties as agreed on a core subset of "Common Indicators" , to be monitored in the forthcoming IMAP, due to start in 2016. One important indicator concern the EO8, namely indicator 8.1.4 "Length of coastline subject to physical disturbance due to the influence of manmade structures". As there is no Descriptor matching this EO in the MSFD, its estimation and the subsequent classification of the status of coastal areas as GES or Non-GES is extremely challenging. Therefore, in MEDINA we undertook a pioneering study, given also the relevance of this indicator for Southern Mediterranean coastal areas, which are being severely threatened by urban sprawling and the construction of ports, touristic and industrial infrastructures. The indicator 8.1.4 was estimated as the percentage of coastline occupied by man-made structure over its total

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length, for each given administrative spatial unit, i.e. each “wilaya” or “governatorate”. Subsequently, units which exceeds 15% were tentatively classified as “Non-GES”, based on literature suggestions.

The type of man-made structures considered are listed in Tab. 4. These structures can be easily detected from remote sensing imagery: Very High Resolution (VHR) satellite images would provide the most accurate information but the costs involved are still quite high. Therefore, in MEDINA we estimated the presence of manmade structures by an accurate visual interpretation and digitalization of Bing imagery together with Google Earth.

Tab. 4 - Coastal manmade structures causing physical disturbance in sediment dynamics

1	Hard coastal defence (excluding soft techniques e.g. beach nourishment),
2	Ports and marinas
3	Land claim
4	Impervious surface in the hinterland (100 meters from the coastline).

The results are summarized in the map presented in Fig. 22, which shows the percentage of manmade structure occupying the coastline per each administrative unit, i.e. each “wilaya” or governatorate, for the whole region.

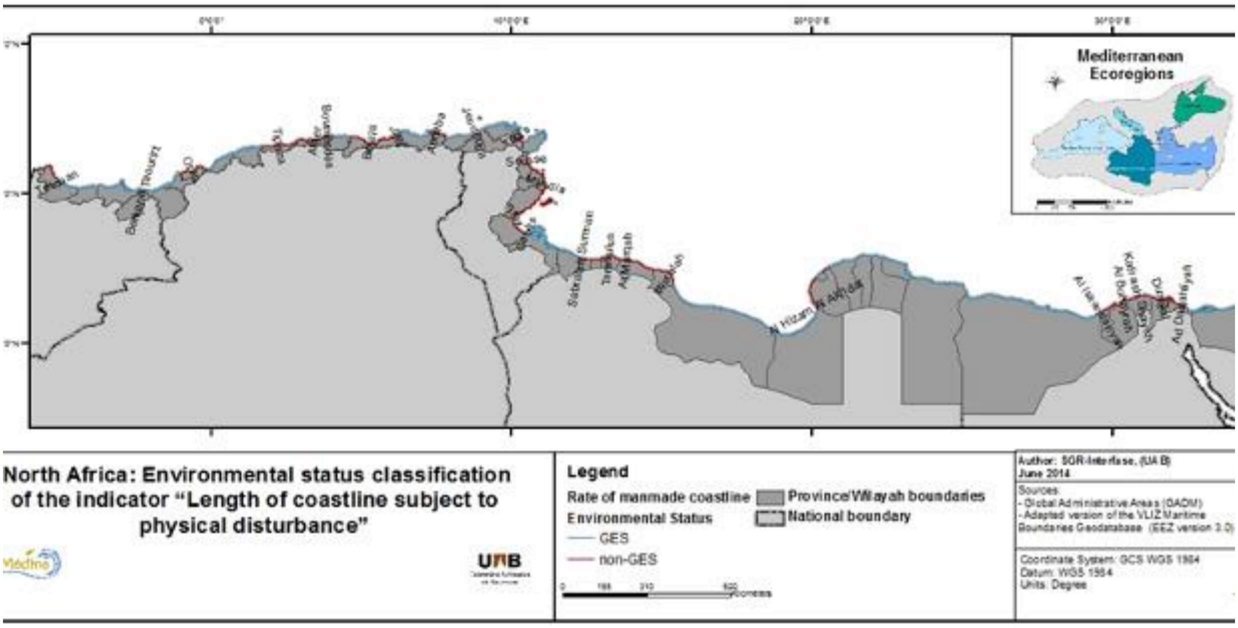

Fig. 22. Indicator 8.1.4: results of the classification for the whole North African coast.

Assessment of a specific indicator pertaining to EO1-Biodiversity

The United Nations Convention on Biological Diversity defined biodiversity as the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Protection of Mediterranean biodiversity is at the core of the EcAp: as a result, four Operational Objectives and eight indicators are associated with the first EO, namely “Biological diversity is maintained or enhanced. The quality and occurrence of coastal and marine habitats and the distribution and abundance of coastal and marine species are in line with prevailing physiographic, hydrographic”. Standard methodologies and guidelines exist for the assessment and monitoring of some indicators relevant for Ecological Objectives of GES, such as EO9 Contaminants or EO5 Eutrophication but are not yet established for the indicators related to EO1. In order to partially fill this gap, in MEDINA we investigated the possibility of characterizing the spatial distribution of an important habitat, namely *Posidonia oceanica* one, by means of a species distribution model. This contribution could prove useful in estimating indicators 1.4.1.and "Potential/observed distributional range of certain coastal and marine habitats listed under SPA protocol" for this species.

Due to the lack of a sufficiently detailed regional data set concerning the presence of seagrass meadows, this indicator was calculated at a local scale for several sites along the North African coasts were data concerning the spatial distribution of *P. oceanica* were available. The potential distributional range of the habitat was estimated using thePoDM described in section 1.5: the indicator is obtained by dividing the total area covered by seagrass meadows by that estimated from the output, in terms of probability of presence of *P. oceanica* versus absence. Therefore, it is a dimensionless quantity and can be used as EQR. The GES/Non GES threshold was tentatively set to 0.75, i.e at least 75% of the potential area should be occupied by *Posidonia* meadows in order to reach GES. The results, presented in detail in Deliverable 5.2, were summarized in maps such as the one presented in Fig. 23, which, from left to right, presents the observed distribution, the probability of presence and the indicator, with GES marked in blue.

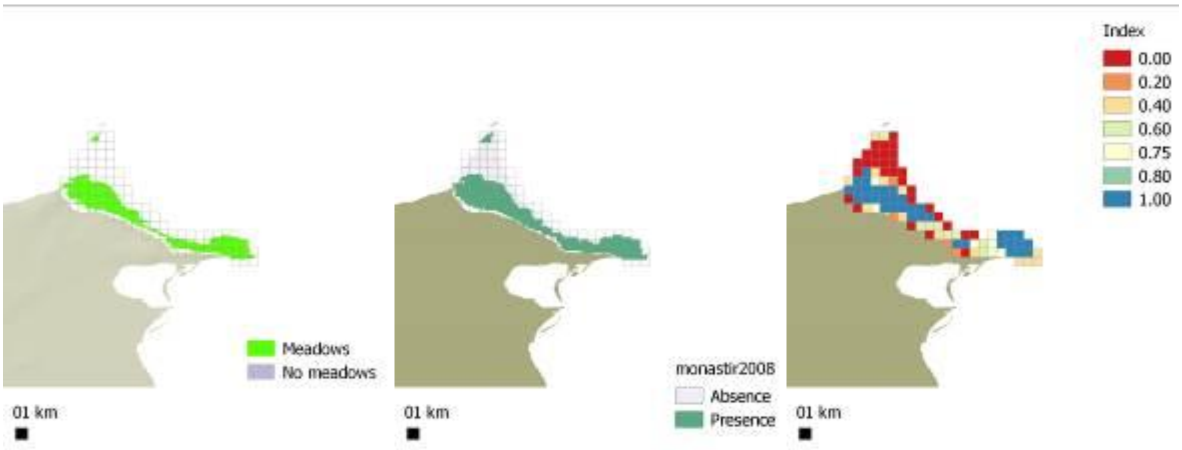

Fig. 23. From left to right: observed distribution, probability of presence and indicator, with GES marked in blue.

3.3. MEDINA contribution to GEOSS-GCI

The activities concerning MEDINA contribution to GEOSS and GCI were carried out mainly in WP3, led by UPO team. The main objective of this WP was the construction of an interoperable Spatial Data Infrastructure, named Medina-e-Infrastructure, MeI hereafter, fully compliant with the INSPIRE Directive and fully accessible from the GEOSS portal. In keeping with the inspiring principles of GEOSS, the MeI is hosted by a free access portal www.medinageoportal.eu, which is the main doorway for stake-holders and end-users to exploit the results of the project. In fact, The MeI based on a compound of OGC Web Services which provides access to the indicators, tools, models and other relevant cartographic information produced within MEDINA.

Therefore, the MeI played a double role in MEDINA: on the one hand, it allowed us to test technological solutions for interoperability, i.e. the Data Access Brokering approach, and, on the other, it greatly facilitated the involvement of stakeholders and end-users. The latter had immediate access to useful high-level information, i.e. spatial distribution of ecosystem status indicators, both at the local and regional scale. The structure of the MeI is displayed in Fig. 24. The main components are: 1) a data catalogue,2) a searching tool 3) a map viewer.

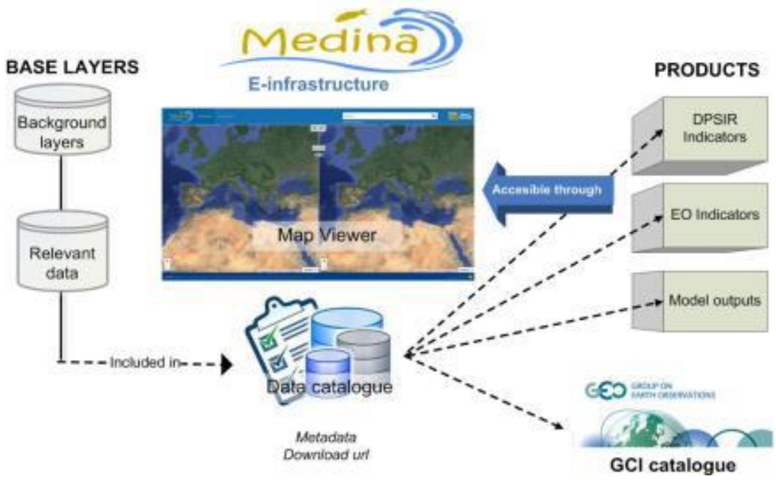

Fig. 24. Structure and conceptual model of the Medina e-Infrastructure

The **MeI Catalogue** include ten categories, organized in subsections: namely:

- **"***Top rated***"**, where the most relevant results achieved during the project can be accessed;
- **"***General***"**, which stores useful cartographic data, a group of three subcategories that includes all indicators developed at regional scale ("Earth Observations", "Modelling outputs" and "Ecological Objectives and DPSIR indicators");
- *Pilot Cases* where maps concerning the main results summarized in section 1.1 of this report are displayed.

Users can access the corresponding metadata, which comply with INSPIRE specifications, through a **"***view metadata***"** link located besides each indicator.

An *ad hoc* **searching tool** was develop and included in the MEDINA map viewer application: this tool exploits the connection between MeI and GEOSS Catalogues which was established in compliance with one of the most relevant objectives of the project. In this way, end-users can search for indicators and environmental variables within both catalogues, thus enabling the full exploitation of the resources made available by the CGI.

A great deal of effort was invested in visualizing the MEDINA products as interoperable maps through the **MeI Map Viewer,** which allows end users to access to nearly 400 maps concerning Pressure and Status indicators and relevant variables, both at regional and local scale, in compliance with the second main objective of MEDINA. Further information is provided by a set of maps from Google Corporation®, which were added for better referencing of geographic areas of interest (e.g. countries and cities concerning Pilot Cases) . The Map Viewer includes several tools, such as those listed below.

- Split screen for indicators comparison.
- A tool to synchronise/desynchronise indicators.
- A zooming tool.
- A tool to change layers transparency, a legend box, a specific tool to apply zoom to layers already loaded in the viewer and, finally, a *bin* icon to remove selected layers.
- A time slider, for visualising the evolution of the spatial distribution of some indicators, such as monthly time series of Chl-a, temperature anomaly, sea surface temperature, Dissolve organic Carbon).
- A calendar tool, which has the same functionality of the time slider but was developed for analysing the short-term temporal evolution of variables and indicators at the local scale of Pilot Cases, such as those resulting from the application of the high-resolution model (see section 1.1) to the Lagoon of Nador (Morocco).

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- ➢ A query tool, for improving the comparison of indicator values between different periods of time, which allows one to to retrieve the real pixel(s) value(s) at a given location.
- ➢ A tool for measuring distances between different locations.

An example of the usefulness of split screen tool is given in Fig. 25, which shows the comparison between the spatial distribution of Euphotic Depth and the probability of presence of Posidonia oceanica, estimated using the PoDM model presented in section 1.5.

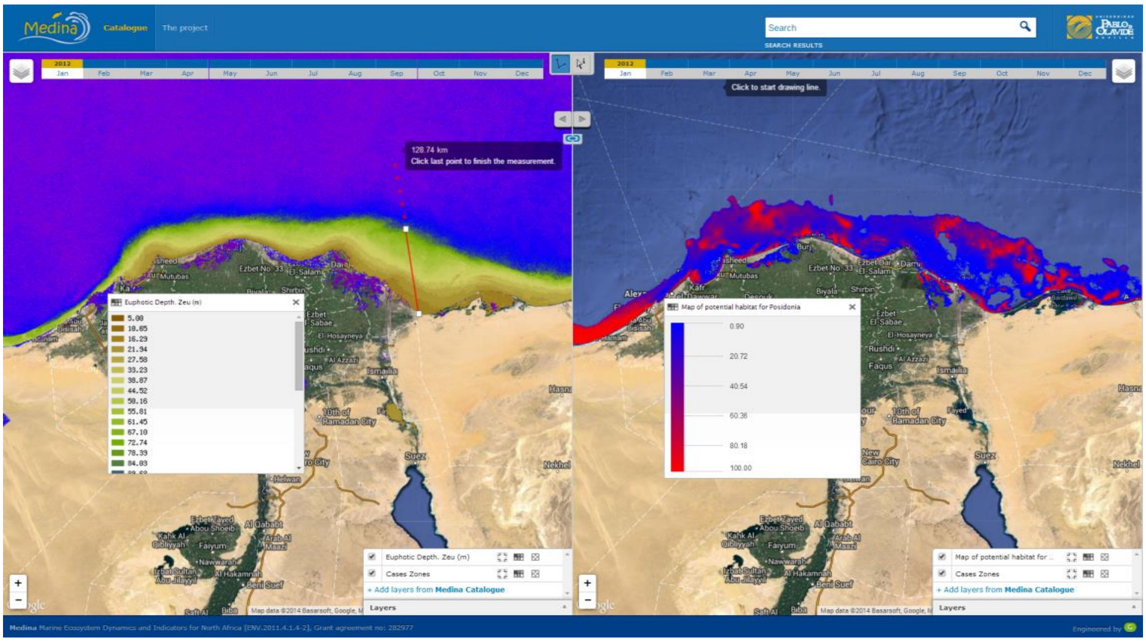

Fig. 25 Comparison of Euphotic Depth (Zeu, in meters) and Presence of P. oceanica in Nile Delta.

The population of the MeI catalogue was a cooperative effort of the whole MEDINA Consortium, which, led to the selection of high-quality products, that were identified as the most useful for stakeholders and end-users engaged in monitoring&assessment of North African coastal marine ecosystems. The process required <u>three stages</u>. During the <u>first one</u>, partners engaged in the production of data were supported by UPO team in the task of delivering indicators in a fully compatible structure for the MeI and the GCI principles. This result was achieved through a Technical meeting and the distribution of a set of documents, providing detailed information on format requirements and metadata creation. <u>The second stage</u> was focused on the integration of all spatial products provided by the indicators producers (PML, UAB, UNIVE and ACRI-EC Institutions). At present, the MeI allows one to access a total of **395 maps** corresponding to **80 indicators**, grouped into 37 indicators from DPSIR and Ecological Objectives, 10 indicators from Earth Observations and 33 indicators from Modelling, are stored and available in the MeI. ***All these indicators and variables were transformed into Web Map Service (WMS)*** following OGC Standards as well as the INSPIRE EU Directive and the GEOSS principles. This step was key to assure the full interoperability among the MeI and GEOSS-GCI, as well as providing access to all products by end-users through any desktop GIS applications. Furthermore, all components and services created for the regional scale (Mediterranean basin) and local pilot cases involved in MEDINA were registered in the GCI. Technical details concerning the interoperability among MEDINA e-Infrastructure/ and the GEOSS GCI are provided in Deliverable D3.3.

The final version of the MeI was presented to the Consortium and Egyptian stake-holders/end-users during the final meeting held in Alexandria, Egypt. Overall, it constitutes a powerful and user-friendly tool that successfully supports stakeholders and end-users in ongoing monitoring and assessment of coastal and marine ecosystem, assuring compliance with the second main objective of MEDINA, as shown in detail in Deliverable D3.4.

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4. The potential impact and the main dissemination activities and exploitation of results

In our point of view, MEDINA has the potential for effectively contributing to “an enhanced monitoring and management system of the North African Mediterranean coastline with the uptake of the information and services provided by the network of responsible regional and local authorities”, as requested by the call.

Accordingly, impacts of MEDINA are presented in the following three subsections.

1) Impacts at the local scale of Pilot Cases;
2) Impacts on the implementation of the main regional policy, i.e. the UNEP-MAP EcAp and its backbone, namely the Integrated Monitoring and Assessment Programme, due to start in 2016. These impacts will also concern EU policies, given the strong similarity between the EcAp and the MSFD and the need of harmonizing their implementation in EU Mediterranean countries.
3) Impacts on the exploitation of the GEOSS GCI capabilities in the region, with particular reference to interoperability and data sharing.

In order to ensure that MEDINA would have lasting impacts on the three areas listed above, a structured programme of Capacity Building activities was carefully planned and carried out in WP6, led by UAE-FPL, throughout the project life time. To this regard, we organized eleven Capacity Building Workshop, as summarized in Table 5 (see Deliverable 6.2 for details). Eight of them were held in North Africa, in order to maximize the participation of local stakeholders and end-users, who were also involved in participatory sessions (see Deliverable 5.3 for details). These workshops provided the opportunity of presenting the results of the project and showing the potential use of the MeI. To this regard, we developed training material for facilitating end-users engagement, such as a user-guide, video tutorials, available through the media television of the University Pablo de Olavide (Seville, Spain) and a publication on “MEDINA e-Infrastructure System of Systems and its pilot implementation” which was distributed to NA partners and all interested stakeholders.

Tab. 5. Summary of Capacity building workshops held in MEDINA

Where and when	Who	Main Topics
Tangier (Morocco) May 28th-30th 2012	Partners and invited experts	Selection of indicators for coastal and marine ecosystem assessment
Rome (Italy) Feb 7th-8th 2013	Partners and invited experts	GEO and GEOSS in the context of the implementation of UNEP-MAP EcAp and MSFD
Plymouth (UK) April 8th-	Partners and invited experts	Modelling tools for supporting monitoring&assessment
Rabat (Morocco) Sept. 30th 2013	Partners and local stakeholders	The implementation of UNEP-MAP EcAp: contribution from MEDINA.
Alexandria (Egypt), December 9-11 2013*	Partners and local stakeholders	Participatory scenario analysis: foreseeable future of aquaculture in Egypt
Nador (Morocco) June 1st-2nd 2014	Partners, invited experts and local stakeholders	Participatory scenario analysis: foreseeable futures for the Lagoon of Nador
Rabat (Morocco) June 1st-2nd 2014	Partners, local stakeholders and end-users	MEDINA contribution to the enhancement of monitoring and assessment in Morocco.
Djerba (Tunisia) June 10th-11th	Partners, local stakeholders and end-users	MEDINA contribution to the enhancement of monitoring and assessment in the Gulf of Gabes and Tunisia.
Bejaia (Algeria) June 18th	Partners, local stakeholders and end-users	MEDINA contribution to the enhancement of monitoring and assessment in the Gulf of Bejaia. Participatory session: foreseeable futures for the Bay of Bejaia

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Alexandria (Egypt) Sept. 8th 2014	Partners, local stakeholders and end-users	The contribution of MEDINA to the enhancement of monitoring assessment of Nile Delta Lakes.
Brussel (Belgium) Dec. 11th 2014	Partners, EU Commission, GEO-GEOSS (Blue Planet and AfriGEOSS), Copernicus, UNEP-MAP, other EU projects involved in CB for fostering GEOSS.	The contribution of MEDINA to GEO-GEOSS Tasks and Communities of Practise.

*The workshop was organized in collaboration with the FP7 project "PEGASO".

4.1 Impacts at the local scale of Pilot Cases

Specific issues concerning each Pilot Case were dealt with by means of purposely developed models, reanalysis of satellite data or a mix of the two, as shown in detail in the previous section and summarized below.

- An integrated model for Environmental Impact Assessment of finfish farms was used in combination with the reanalysis of ocean colour data and data provided by MyOcean for setting up a cost-effective procedure for site selection, which was applied to the Bay of Bejaia (Algeria).
- A biogeochemical box-model and a food web model were developed and coupled for assessing the impact of semi-intensive aquaculture in Lake Burullus (Egypt).
- A reanalysis methodology, aimed at classifying coastal waters mainly on the basis of satellite data, was developed and applied to the Gulf of Syrte (Libya)
- A high resolution biogeochemical model, including hydrodynamic transport, was developed for the Lagoon of Nador (Morocco) and coupled with a food web model for investigating the potential effects on ecosystem functioning of the opening of a new, wider inlet in 2011;
- An innovative approach, based on a "urban metabolism" methodology, allowed the estimation of Nitrogen and Phosphorus urban loads to the Lagoon of Nador (Morocco).
- A Species Distribution model was developed, for understanding the causes of the negative trends of the coverage of *Posidonia oceanica* meadows in the Gulf of Gabés (Tunisia).
- SWAN model was used for a preliminary assessment of vulnerability to erosion at Gabés, Nador and Bejaia,

Besides providing sound scientific results, these tools produced a wealth of results and indicators, which can be used <u>for establishing causal links between specific pressures and impacts.</u> This is a fundamental step for the design of comprehensive, cost-effective monitoring programmes, since:

- the choice of variables to be monitored must be consistent with the main issues affecting a given water body;
- it is of paramount importance to adopt a systemic view and DPSIR approach to monitoring&assessment, i.e. to include in the programme the monitoring of Pressures, for example loads of nutrients potentially causing eutrophication or of other pollutants.

In this framework, these tools:

- when applied at a <u>screening level</u> <u>at an early stage in the designing the programme</u>, can help in addressing the selection of variables, as well as that of the location of sampling stations and sampling frequencies.
- after proper validation, based on the collected data in monitoring programmes and ancillary information, they could support decision makers to take appropriate <u>programmes of measures</u>, aimed at achieving the Good Ecological Status, in keeping with the main objectives of the EcAp.

Therefore, <u>models or less formal methodologies for linking Pressure to State and Impacts should be regarded as a true, mandatory, component of any monitoring programme</u>, without which the risk of investing large amount of money for getting in return little usable information runs very high.

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To this regard, we would like to offer concrete examples of the impact that MEDINA is already having on the planning of monitoring activities at some Pilot Cases. The most comprehensive study in MEDINA concerned the Lagoon of Nador (Morocco), where, in spite of the importance of the site, no systematic monitoring in presently being carried out. The results presented in the previous section suggest that the ecosystems is rapidly evolving, probably on the way of recovering from a status of acute eutrophication, as a consequence of depollution interventions and the opening of the new inlet. However, its productivity seems presently lower than in the past and local fishermen claim that their catches and revenues are decreasing. The coastal morphology of the Lagoon is also going to change, due to the construction of more touristic infrastructure. In this situation, in the local workshop, we showed the evidence provided by the case study and exchanged ideas with local stake-holders and decision makers, who realized the need of gaining a deeper understanding of what is happening. As a concrete result of this interactive process, the MEDINA local partner, UAE-FPL, was able to prepare an hypothesis of a well structured monitoring programme, which was proposed to the attention of local agencies, such as the Environmental Observatory for the Lagoon of Nador, (Observatoire de la Lagune the Nador), ,the INRH Department of Nador and local Authorities. (See also Deliverable D6.2).

At Bejaia (Algeria), where no systematic monitoring in presently being carried out, results presented and discussed in the MEDINA workshop put in evidence the need of designing and implementing a comprehensive monitoring programme including:

- yearly surveys concerning the quality of sediment, in terms of organic micropollutants and heavy metals, in the area surrounding the port
- determination of land based pollution, by monitoring discharge rate and contaminants at the outlet of Wadi Soummam
- monthly or by-monthly sampling of physico-chemical parameters, including chlorophyll a and macronutrients along the coast, with transects in the area facing the discharge of Wadi Soummam;
- characterization of the hydrodynamic in the area, by means of current-meters and buoy, as a first step for developing a sediment-transport model and for improving the accuracy of the site selection methodology applied for sustainable aquaculture.
- mapping of areas colonized by seagrasses, in order to combine this information with the output of the above site selection methodology, thus minimizing the impact of to-be-established fish farms.

In general, the work performed at Pilot Cases and the associated Capacity Building activities increased in local stakeholders the awareness that a better and sustainable management of their coastal marine ecosystems depends crucially on the establishing of long-term monitoring programmes. Furthermore, the sharing of experiences among Pilot Cases brought to the attention the issue of data sharing and, hence, proper data archiving and interoperability, as one of the key for closing the gap that still limits the adoption of best practices in monitoring planning and execution. To this regard, the MeI could be regarded as a prototype of an interactive portal, where potential end-users could find out how issues concerning their own environment were successfully dealt with in other sites and which tools were used.

4.2 Impacts on the implementation of UNEP-MAP EcAp and MSFD

The results summarized in the previous section showed that we succeeded in providing integrative methodologies for ecosystem assessment which, in our point of view, could markedly contribute both to the implementation of the EcAp in the region and its harmonization with the MSFD. The need of harmonizing the two approaches is clearly expressed, at all levels, by the institutions actually involved in the implementation of these policies. It has to be said that our effort was severely constrained by:

- the lack of regional datasets;

- the difficulty in accessing field data, from national and local data bases, concerning both the status of coastal marine ecosystem and the main pressure.

In order to overcome these difficulties, we took a pragmatic point of view and decided to focus on the development of scientifically sound methodologies, which could rely mainly on mathematical modelling and satellite data, in order to show their potential use in supplementing/complementing field data. Furthermore, by relying mainly on the expertise of the Consortium, we demonstrated how this methodologies could actually be applied for classifying water bodies as GES-Non GES, from the level of EcAp indicators up to that of Ecological Objective. For these reason, the actual results of the assessment in terms of GES-Non GES are to be taken as very preliminary "educated guesses", as they were obtained on the basis of remotely sensed data and model output which could not be validated against field data. Nevertheless, we claim that a similar "exercise" has not been carried out before for the whole North African region and the range of EcAP indicators and EOs dealt with in MEDINA. Therefore, we are confident that the suggested methodologies can be regarded as good candidates for carrying out the next integrated assessment, once the first Integrated Monitoring Programme will be completed and, as such, should be carefully evaluated, in particular, by the UNEP-MAP EcAp Coordinating Group and the National Focal Points in NA countries. In summary, MEDINA provided the following contributions.

a) Alternative methodologies for classifying water masses based, on the one hand, on physical features, such as bathymetry, waves exposure and coastal morphology and on the other, on multivariate analysis of satellite data: these methods could possibly be combined for a preliminary identification of water bodies, as a preliminary step to the assessment.

b) An integrated index of Pressure, LUSI, which was adapted to the NA coastal region and mapped.

c) An integrative methodology for the assessment of the GES concerning the EO5 "Human induced Eutrophication" , which was fully developed and applied up to the EO level to the whole region for off-shore waters: input data were provided by the regional biogeochemical model GCOMS and the reanalysis of satellite data;

d) A methodology for assessing the indicator 1.4.1. "Potential/observed distributional range of certain coastal and marine habitats listed under SPA protocol", pertaining to EO1-Biodiversity, for *Posidonia oceanica*, based on the ratio between observed coverage and the one predicted using a spatially explicit Specie Distribution Model.

e) A cost-effective method for a preliminary estimation of one of the most important and less investigated Common Indicators, namely 8.1.4 "Length of coastline subject to physical disturbance due to the influence of manmade structures", pertaining to EO8 – Coastal Ecosystems: this indicator was estimated and mapped for each given administrative spatial unit along the NA coastline, based on the processing of Bing imagery together with Google Earth.

f) A tentative approach to the estimation of the indicator *3.1.2* 'Total effort by operational unit', pertaining to EO3-Fishery, based on FAOCOPEMED data, which was applied to the coasts of Tunisia, Algeria and Morocco: results, not summarized in the previous section, are provided as maps in Deliverable D5.2.

g) Insights on the potential use of MEDINA tools for estimating challenging EOs, such as EO4-Food webs: to this regard, food web models and indexes derived from Ecological Network Analysis seems promising tools for estimating EO4 indicators at ecosystem level.

Even though assessment tools should be continuously adapted when new scientific knowledge and data becomes available, such as, for example, those which are going to be provided through Copernicus by ESA Sentinel missions, we feel that the above methodologies represent a sound starting point, consistent with the information presently available and the EcAp vision.

In order to maximize the exploitation and uptake of the results in the context of the UNEP-MAP EcAp, during the project life time, the Consortium made any possible effort for liaising with UNEP-

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MAP personnel engaged in the implementation of the IMAP in MEDINA. In particular, UAB presented MEDINA preliminary results at the UNEP-MAP Integrated Correspondence Groups of GES and Targets Meeting held in Athens the 17th -18th February 2014 and UNEP-MAP representatives were invited at the last MEDINA workshop in Brussel, were the final results were presented and discussed.

In conclusion, we believe that the results achieved in MEDINA could potentially be exploited for developing well-structured monitoring strategies in North Africa but, as shown in more detail in Deliverable D5.4, some gaps need also to be closed, in particular:

- more effort is required to coordinate the collection of data and their post-processing by means of appropriate tools , in order to provide decision makers the required information to take proper measures;
- data sharing principled should be adopted by all UNEP-MAP Contracting Parties;
- the use of remotely sensed Earth Observation and models is still limited: to this regard, more capacity building activities in the area may help in closing the gap.

4.3 Impacts on the exploitation of GEOSS/GCI in the region

The concluding remarks of the previous subsection leads to consider a crucial objective of MEDINA, i.e. the increase in the visibility of GEO and in the level of contribution and, on the other hand, exploitation of the resources offered by the GEOSS GCI.

In order to reach this objective and ensuring a lasting impact of the project, in MEDINA we:

a) Developed an interoperable Spatial Data Infrastructure, the MeI, www.medinageoportal.eu, fully accessible from the GEO portal;
b) Developed and populated the MEDINA Catalogue, thus contributing to the population of GEOSS GCI and to the transfer of MEDINA methodologies to other regions, in the framework of the GEO Task Blue Planet.
c) The main results of the project, in terms of spatial distributions of DPSIR indicators and important variables which characterize the dynamics of marine ecosystems in the region, can be searched either from the GEOSS portal or the MeI porta and visualized on the MeI viewer;

Overall, the project outcomes and the MeI were positively assessed in MEDINA workshops held in North Africa: feedback from local end-users and stakeholders are reported in detail in Deliverable D6.2. In general, the workshops succeeded in increasing the awareness on:

- the importance of Earth Observation in ecosystem monitoring&assessment;
- the need of increasing the exploitation of remotely sensed data;
- the opportunities created by an open data sharing policy.

However, a full scale exploitation of the GEOSS/GCI has still to be achieved and in our point of view, would require the following actions:

Well targeted Capacity building activities, based on practical demonstrations and “success stories”, in order to show the potential use of GEOSS resources;

Concomitant actions, on the GEOSS side, aimed at facilitating the registration of products to scientists who are not ICT experts: to this regard, we may dare to suggest that also the adoption of a less cryptic jargon, more accessible to a wider scientific audience, could be considered.

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4.4 Main dissemination activities

Two project web sites have been established and operated throughout the project lifespan. One was focused on an overall information on MEDINA, communicating on the project activities with a general dissemination purpose, available in English and French languages. The second one was related to the MEDINA E-Infrastrucure (MeI), a full SDI, constructed as a compound of web services (OGC standards), that allows end users to visualize, query maps and analyse coastal data. Five video have been produced and broadcasted throug web channels: three of them were related to general project contents, while two are focused on two of the selected Pilot Cases (Lake Burullus - Egypt, the Lagoon of Nador –Morocco). Moreover, few tutorials on how to use the MEI geoportal have been produced.

Dissemination activities were carried out together with the capacity building workshops performed in North African countries: visibility through local newspapers and media were ensured. Also, at the Final Conference in Alexandria media were informed and involved in raising interest on the project activities and results.

Dissemination tools were produced by the project: leaflets targeted to specific events, particularly for GEO, two newsletters, one factsheets, as well as logo, banners for specific events and posters.

Scientific and educational articles have been produced, as well as a project comprehensive final publication, in English and French languages. This study describes some of the most promising achievements of the MEDINA project and it is based on the experiences gained, with the purpose of disseminating the fieldwork.

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5. The address of the project public website, if applicable as well as relevant contact details

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- NIOF - National Institute for Oceanography and Fisheries (ET)
- IUCN - Union International pour la Conservation de la Nature et de ses ressources (CH)
- CNL - Commissariat National du Littoral (DZ)
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The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n° 282977