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D4.2 Report, accompanying database and supporting materials on LEAC Methodology and how to apply it in CASES

Pegaso Project
People for Ecosystem based Governance in Assessing Sustainable development of Ocean and coast

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SEVENTH FRAMEWORK PROGRAMME

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Contents

Acronyms and abbreviations

A

ACRI: ACRI Etudes et Conseil

AFRIPOP: African Population Projet

AL: Algae

AREA-ED: *Association de Réflexion, d'Échanges et d'Actions pour l'Environnement et le Développement* (Association for Reflection and Action on the Environment and Development - Algeria)

AWMPFD: Area Weighted Mean Patch Fractal Dimension

AWMSI: Area Weighted Mean Shape Index

B

BBN: Bayesian Belief Network

BSC: Black Sea Commission (Commission on the Protection of the Black Sea against Pollution)

BSC-PS: Black Sea Commission (Commission on the Protection of the Black Sea against Pollution) Permanent Secretariat

C

C: Coralligenous communities

CA: Class Area

CAMP(s): Coastal Area Management Programme(s)

CASE(S): Collaborative Application Site(s)

CBD: Convention on Biological Diversity (Article 17)

Cd: Cymodocea

CD: Dense Cymodocea meadows

CDA: Dispersed coralligenous communities

CIM: Cumulative Impact Mapping

CLC: Corine Land Cover

COCONET: Towards COast to COast NETworks of marine protected areas (from the shore to the high and deep sea), coupled with sea-based wind energy potential

CORINE: Coordination of Information on the Environment

CPMR: Conference of Peripheral Maritime Regions

CVC: Climate Variability and Change

D

DDNI: Danube Delta National Institute for Research and Development (Romania)

DG MARE: Directorate-General for Maritime Affairs and Fisheries

DIEC: Data and Information Exchange Coordinator

DLT: Dominant Landcover Types

DMSP-OLS: Defence Meteorological Satellite Program - Operational Linescan System

DoW: Description of Work

DPSIR: Drivers Pressures State Impacts Responses

DRR: Disaster Risk Reduction

DSS: Decision Support System

E

EC: European Commission

EcAp: Ecosystem Approach

ED: Edge Density

EEA: European Environment Agency

EIA: Environmental Impact Assessment

EMODnet: European Marine Observation and Data Network

ESRI: Environmental Systems Research Institute

ETC-SIA: European Topic Centre for Spatial Information and Analysis

ETRS 1989 - LAEA: European Terrestrial Reference System 1989 - Lambert Azimuthal Equal Area Coordinate Reference System

EU: European Union

EUC: End User Committee

EUNIS: European Union Nature Information System

EUROSION: European initiative for sustainable coastal erosion management

EUSAIR: EU Strategy for the Adriatic and Ionian Region

EUSEAMAP: Modelling seabed habitats across Europe

F

FP7: Seventh Framework Programme

G

GEBCO: General Bathymetric Chart of the Oceans

GEF: Global Environment Facility

GES: Good Environmental Status

GFCM: General Fisheries Commission for the Mediterranean

GIS: Geographical Information System

GlobCover: Global Land Cover Map

GlobeCorine: Global Land Uses / Land Cover Map

GWP: Global Water Partnership

H

HCMR: Hellenic Centre for Marine Research (Greece)

HFA: Hyogo Framework for Action

I

ICZM: Integrated Coastal Zone Management

IFREMER: Institut Français de Recherche pour l'Exploitation de la Mer (French Research Institute for Exploration of the Sea - France)

IMIS: Integrated Marine Information System

IMP: Integrated Marine/Maritime Policy

INSPIRE: Infrastructure for Spatial Information in Europe Directive

IOC: Intergovernmental Oceanographic Commission

IOE: Institute of the Environment (UOB-University of Balamand)

IRA: Integrated Regional Assessment

IRA: Integrated Regional Assessment

IRBM: Integrated River Basin Management

J

JRC: Commission of the European Communities – Directorate General Joint Research Centre

L

LEAC/SEAC: Land/Sea Ecosystem Accounts

LEAC: Land and Ecosystem Accounting

M

MAP: Mediterranean Action Plan (UNEP/MAP)

MEBM: Marine Ecosystem-Based Management

MEDCOAST: Mediterranean Coastal Foundation (Turkey)

MedICIP: Mediterranean Integrated Climate Information Platform

MedPS: Median Patch Size

MedSeA: European Mediterranean Sea Acidification in a changing climate initiative

MedWet: The Mediterranean Wetlands Initiative

MHI: Marine Hydrophysical Institute - Ukrainian National Academy of Sciences (Ukraine)

MmCC: Mixed meadows of Cymodocea and Caulerpa

MNN: Mean Neighbour Metric

MODIS: Moderate-Resolution Imaging Spectroradiometer

MPAR: Mean Perimeter:Area Index

MPE: Mean Patch Edge

MPFD or MFRACT: Mean Patch Fractal Dimension

MPS: Mean Patch Size

MSFD: Marine Strategy Framework Directive

MSI: Mean Shape Index

MSP: Maritime Spatial Planning

MSSD: Mediterranean Strategy for Sustainable Development

N

NAFO: Northwest Atlantic Fishing Organisation

NARSS: National Authority for Remote Sensing and Space Sciences (Egypt)

NDVI: Normalized Difference Vegetation Index

NFP(s): National Focal Point(s)

NGOs: Non-Governmental Organisations

NIOF: National Institute of Oceanography and Fisheries (Egypt)

NPP: Net Primary Production

NumP: Number of Patches

O

OGC: Open Geospatial Consortium

P

P: Continuous Posidonia meadows

PAP/RAC: Priority Action Programme / Regional Activity Centre

Pc: Precoralligenous communities

PCA: Principal Components Analysis

Pch: Precoralligenous communities on hard bottoms

Pd: Degraded Posidonia meadows

Pe: Posidonia with erosion channels

PI: Isolated Posidonia

PLC: PEGASO Land Cover

PMA: Pollution Monitoring and Assessment

Pr: Posidonia growing in rocky areas

PSSD: Patch Size Standard Deviation

R

RAC: Regional Activity Centre

RACSPA: Regional Activity Centre for Specially Protected Areas

RSC: Regional Sea Convention

RTD: Research and Technical Development

S

SAP: Strategic Action Plan

SCA: Stakeholder and Conflict Analysis

SCUFN: Sub-Committee on Undersea Feature Names

SDI: Spatial Data Infrastructure

SEA: Strategic Environmental Assessment

SEAC: Sea ecosystem accounting

SEEA: System of Integrated Environmental and Economic Accounts

SEMCs: Southern and Eastern Mediterranean Countries

SNA: Standard National Accounting

SPA/BD: Specially Protected Areas / Biological Diversity Protocol

SRTM: Shuttle Radar Topography Mission

STATISTICA: Statistical System (software)

T

TDV: Tour du Valat Foundation (France)

TE: Total Edge

U

UAB: Universitat Autònoma de Barcelona (Autonomous University of Barcelona - Spain)

UfM: Union for the Mediterranean

UM5a: University Mohammed V – Rabat Agdal (Morocco)

UNECE: United Nations Economic Commission for Europe

UNEP: United Nations Environment Programme

UNESCO: United Nations Educational Scientific and Cultural Organisation

UNIGE: University of Geneva (Switzerland)

UNIVE: Universita Ca'Foscari Di Venezia (Ca'Foscari University of Venice - Italy)

UNOTT: University of Nottingham (United Kingdom)

UNSD: United Nations Statistical Divison

UOB: University of Balamand

UPO: Universidad Pablo de Olavide de Sevilla (Pablo de Olavide University of Sevilla - Spain)

V

VIC(s): Virtual Conference(s)

VLIZ: *Vlaams Instituut voor de Zee* (Flanders Marine Institute - Belgium)

W

WAVES: Wealth Accounting and the Valuation of Ecosystem Services

WMIIE: Western Mediterranean Impact Index on Ecosystems

WMS: Web Map Server

WP(s): Work Package(s)

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1. Introduction

1.1. The need for useful tools to make ICZM decisions

The Mediterranean and Black Sea Basins have, and continue to suffer severe environmental degradation. In many areas this has led to unsustainable trends which have impacted economic activities and human well being. The pressures, which include urban growth and sprawl, intensification of maritime activities, degradation of natural and semi-natural areas, and loss of terrestrial and marine biodiversity, have been exacerbated by the lack of integrated spatial planning and common agreed management approaches. In the future these pressures are likely to increase, with further human development and the impacts and acceleration of climate change. However, these two Basins remain of great interest and importance in terms of their natural resources (endemic fauna and flora, unique cultural landscapes) and human opportunity (maritime activities, including tourism, fishery, aquaculture and agriculture). Both seas represent a vital resource upon which many millions of people depend on both economically and culturally, and continue to provide a wide range of ecosystem services that are essential to the health of local and regional environment and to support integrated management of coastal and marine ecosystems in a sustainable way.

If the pressures leading to environmental degradation are to be overcome, and more sustainable development trends established, then a more integrated framework for policy and management, based on the ecosystem approach is required (see PEGASO DEL2.1). In terms of developing such an integrated approach to policy and management important progress has been made with the launch of the Integrated Coastal Zone Management Protocol for the Mediterranean Sea in January 2008. This was the result of many years of effort supported by the Convention of Barcelona, the EU Commission, and the Mediterranean countries. The ICZM Protocol offers, for the first time in the Mediterranean, an opportunity to work in a new way, and a model that can be used as a basis for solving similar problems elsewhere, such as in the Black Sea.

Mitigating the threats affecting both seas will mean that policy advisors and managers must overcome the problems of working with complex, multi-scale organisational systems, involving high levels of uncertainty which cannot always be resolved by traditional forms of science. Experience suggests that even though a number of analytical and monitoring tools have been produced by scientists to answer the needs of end users, they have often not been used because they have proved to be complicated and yielded inadequate, non practical results (see Kumar Singh et al., 2008). It is now acknowledged that what is needed is a new, trans-disciplinary way of co-working, between scientists and end users.

The PEGASO project has therefore been designed to bring the science and end-user communities relevant to the Mediterranean and Black Sea Basins together, to develop collaboratively a robust, relevant and easy to use set of sustainability tools. For this reason the PEGASO project is organised around the ICZM Governance platform, the heart of the project, made by the PEGASO partners, 18 end users of the Mediterranean representing countries, regions, NGOs and economic sectors, 6 end users from the Black sea, representing countries, and the 10 collaborative field work laboratories (the CASES). Moreover since November 2011 all the National Focal Points of the ICZM Protocol are part of the PEGASO end users Governance Platform. PEGASO has animated and promoted collaborative work among the governance platform participants with two main purposes: (1) to built together a common shared knowledge on ecosystems and geography, main resources, socio economic statistics, current and emergent threats, etc in the two basins, (2) to facilitate well discussed knowledge based priority decisions and agreed recommendations for the sustainable development of coast and sea, framed in an ecosystem based ICZM renewed concept.

1.2. The PEGASO context

The task of building a common shared knowledge for the coastal zone and the sea cuts across a number of science and policy areas. As a result, those engaged in this action (the PEGASO ICZM Governance Platform) have to draw on, and take account of a range of different types of information. However, PEGASO found that knowledge and techniques were fragmented and difficult to access and apply.

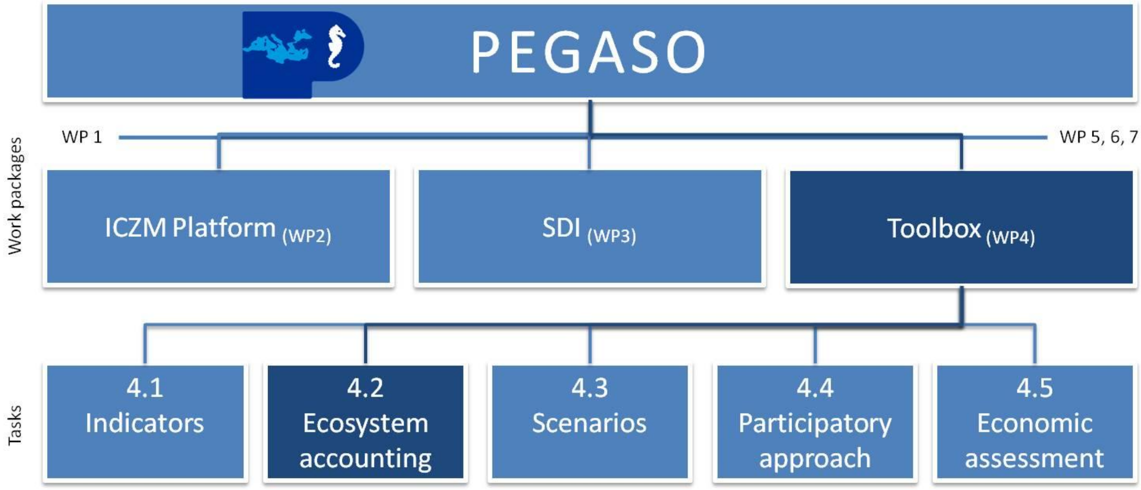

Figure 1.1: PEGASO general organization, work packages and tasks.

For robust and credible decisions to be made, the PEGASO ICZM Governance platform created bridges between the science and end-user communities so that decision makers gained access to relevant data, were supported in the interpretations they make, and able to transform these data into information that effectively supports the judgements they make.

The WP4, lead by IFREMER, is therefore designed to provide the technical and scientific organisation and support needed to build a common shared knowledge , a basis to make integrated assessments and well based decisions for the Mediterranean and Black Sea Basins, in an ecosystem based ICZM framework including catchments, coast and sea.

In keeping with the broad philosophy that has shaped the PEGASO project, the aim was to building on, and refine existing scientific achievements, and to create, in a co-working process with the Governance Platform, a suite of tools and techniques that can be used by decision makers, stakeholders, NGOs and the citizen themselves, ultimately supporting end-users in their future work.

We recognise that it is not a single approach, as it has been based on a continued interactive work between scientists and decision makers at different scales. Following the principles of the post-modern science which involves users from the beginning to build a commom knowledge, in a process of tool and models validation, in a participatory way, which allowed for the identification of uncertainties, getting ownership of the methods and results, and empowering them to combine the results of applying the various tools according to the specifics needs of the task they face. Thus the WP provides a flexible and integrated suite of tools that can be used in different problem contexts, and so overcome the problem that knowledge and information resources are fragmented.

Five key thematic areas are covered in the WP, namely: indicator construction (T4.1); coastal land and marine ecosystem accounting (T4.2); scenarios (T4.3); participatory processes and methods (T4.4); and, economic and social valuation techniques (T4.5). Although each is the focus of a separate sub-work package (task), all of them have a common general work plan.

The testing and development work that will take place in relation to the tools and techniques developed in WP4 also forms part of the capacity building processes embedded in PEGASO. In order to test the tools, they need to be documented, and the end-users in the consortium have received training in their application. The experience developed through the case applications in WP6 has also been used as part of the dissemination process. A set body of training materials is an important part of the legacy of the project. WP7 has taken benefit with the outputs of the WP4 in providing materials for dissemination.

1.3. Aim of the deliverable 4.2

This deliverable aims to present concepts, methods and results of the Task 4.2 on "Coastal land and marine ecosystem accounting", whose responsibility is shared between UAB and UNOTT.

Land and Ecosystem ACcounts (LEAC) are used to characterise change in the terrestrial environment. They are an effective set of tools that can be used to systematically describe the processes by which land based resources are transformed over time, and as a framework for spatially explicit indicator development and policy appraisal. The work undertaken in this task has been very innovative as it has explored the way to extend the accounting methodologies into the coastal zone for the whole Mediterranean and Black Sea basins far beyond Corine Land Cover (CLC) geographical coverage. CLC has been done at different times (1980, 1990, 2000 and 2006), with a number of countries that has grown over time, from 8 countries covered in 1980 to 27 countries in 2006. Interested countries are mainly EU countries, including Mediterranean partners. Only the last CLC 2006 version includes Turkey.

In light of this previous work, the PEGASO team has had to build a new method for the entire coverage of the Mediterranean and the Black Sea, consistent with a simplified CLC classification, but using new data for land (e.g. GlobCover 2006 V2. MODIS; night light, etc), making a full coverage of land cover in both basins at two dates (2000 and 2011), making it possible to compare stocks at the two dates and to measure changes and flows (eg. artificialisation trends, loss of natural areas, etc). Taking into account that this work is an innovative exploration of a land cover map, consistant for the two basins, and allowing comparisons, we acknowledge some errors, and did already an important effort for validating the method and its results with the PEGASO Governance Platform and through a number of misision in the CASES. One of the main lessons learned is that our PEGASO land cover (LC) will need more detailed validation work in the post-PEGASO phase, using high resolution remote sensing data in the areas with potential errors and local expert knowledge to have a final updated and high quality data set for the two basins. Once the methodology is consolidated, therefore, it will be easy to repeat the exercise every 2 or 5 years.

This exercise has been completed with an exploratoy work to measure natural capital in a spatial frame. It has been also an innovative and exploratory work only possible for European countries as it takes main data from CBD Article 17. However, the work has an important value as a first step that gives methodological key for enlarging it to the whole basin.As a proxy of natural capital, the protected areas were found relevant for the whole basin; therefore a mapping of these areas has been performed.

The objective of the task was to develop accounts not only at the coast but also in the marine realm, linking land and sea in a unique continued mapping.
The PEGASO team faced great dificulties to perform such a product due to limited data.

The marine realm cannot be mapped in the same way as land, due to the dynamics of the non-static, 3-dimensional realm. Only the habitats and communities of the sea floor, are fixed. But no full monitoring data exist for a specific year. We used EUSEAMAP where a mapping of the sea bottom communities (following EUNIS classification) has been achieved. So far it is only available for the Western Mediterranean, and the map is derived from some existing monitored data and models. These models are based on the probability to find a certain habitat type depending upon bathimetry, light penetration, strength of currents and waves on the bottom, etc. So it is not the same than a land cover map, and it is a one shot product, not easily reproduceable in future years as it embeds a high uncertainty in the habitats limits (stocks) and trends.

Spatially explicit data on marine (benthic and pelagic) habitat and species distribution and changes at basin large scale are currently not available for the Mediterranean and Black Sea Basins. Moreover the relation between habitat changes (e.g. replacement of forest by urban reas) is not as direct in the marine environment where habitat changes are mostly driven by environmental and oceanographic parameters and anthropic activities difficult to map accurately in a concrete time frame (e.g. bottom trawling).

To be on the secure side, it was decided to look at the human activities and global pressures that cause those changes by using the cumulative impact methodology on coastal and marine ecosystems developed by

Halpern (Halpern et al, 2007) at the global scale and by Korpinen at regional scale (the Baltic Sea). This approach allowed us to map the coastal and marine ecosystems, and the cumulative pressures exerted on these ecosystems, habitats and species. EUSEAMAP and other existing monitoring data were used and, through expert judgement, a pressure index and impact map and statistics on the coastal and marine ecosystems in the Western Mediterranean could be to produce (WMIIE).

In addition, for continuing the exploration of stocks and trends on marine ecosistem, exploring a Sea Ecosystem ACcount (SEAC), we decided to work on the most relevant ecosystems of the Mediterranean, looking at different metrics to measure the status and trends and assess the health of coastal and marine habitats.

If the three methods have been developed separately, they can be integrated in coastal and sea accounts in different ways. The hierarchical classification frameworks presently employed in LEAC have facilitated a multi-scale approach to the production of statistical data on land cover stocks and changes for different parts (analytical units) of the coastal zones. The results on pressures and impacts on the ecosystems (WMIIE) have been also processed in a statistical way, by spatial units, using the same grid. Finally the SEAC results, even though at much more local scale, are also planned to be integrated in a statistical data base. All three data bases are currently incorporated into the Spatial Data Infrastructure (SDI, WP3) of PEGASO that is accessible throught the web.

In addition, LEAC results at the coast helped to map land pressures in coastal and marine ecosystems for the WMIIE. This methodology to draw pressure index and impact index of coastal and marine ecosystems allows at the same time to model the potential impact of multiple stressors in the marine environment and to create direct links between land and sea by calculating land based pressures as a function of coastal and watershed land cover maps. As such, it does not provide directly marine ecosystem accounts, but an estimation of where changes in quality and quantity of marine habitats and species may occur and which are the causes of those changes both from land and sea. The work on the spatial arrangement and interactions of coastal and marine habitats, that uses metrics from landscape analysis for marine ecosystems, opened the way to assess the seascape qualitaively and quantitalively, , while producing results that are comparable to the terrestrial landscape. Currently, little is known about the ecological processes and services of coastal and marine ecosystems. It is therefore very challenging to develop useful methods to aim at ecosystem accounts for the sea. Both explorative studies, even if they are limited in coverage by data availability, can be considered as important methodological milestones towards an innovative Sea Ecosystem Accounts (SEAC), related as much as possible at current scientific developments, with LEAC.

The work has supported the Task 4.1 to critically evaluate the role that accounting methodologies can play in providing operationally effective indicators. It has also provided a good knowledge base to develop foresight and scanario exercises with the Governance Platform at regional and in different CASES (Task 4.3), through participatory methods (Task 4.4) , providing also an important input for the socio-economic valuation (Task 4.5). This work is key to explore how accounts can be used as a framework for modelling current and plausible futures with stakeholders, and assess marginal change in values for the stocks of natural assets, the consequences of pressures and impacts on them, the benefit flows associated with them, both on land and at sea, and the identification of main stressors.

1.4. Collaborative work with the ICZM Governance platform and, on request, with other institutions.

Ecosystem based approaches such as the Integrated Coastal Management (ICZM) Protocol (and also other policies such as Integrated Marine Policy (IMP), Marine Strategy Framework Directive,(MSFD) and Marine Spatial Planning (MSP) are greatly facilitated by spatially explicit information such as ecosystem accounts which inform policymakers on environmental and natural resource availability, use, depletion, and degradation over time and help identify the drivers of change. With this vision and in order to help the implementation of ICZM Protocol at different scale, PEGASO's task 4.2 has developed a methodology allowing accounts of ecosystems and human based pressures in the Mediterranean and Black Sea coasts and, at the scale of the

West Mediterranean for the account of human and climatic pressures and impacts on ecosystems in the coastal marine realms.

This work (concept, method, results and validation needs) has been discussed many times along the 4 years of the PEGASO project, and since the kick off meeting, with the ICZM Governance Platform, valuing its limits and its potential (CASE meeting in Alexandria, Decembre 2013, General PEGASO meetings in the Danube Delta July 2011 and Rabat, March 2013), ERAM meeting in Alexandria, October 2010). It has also been presented at different Coastal Days (in Algeria, September 2011, in Split (Croatia) in September 2012, in Rimini in September 2013 to the National Focus Points of the ICZM Protocol and other national stakeholders).

Presentations and discussions on LEAC/SEAC have been enlarged to UNEP-MAP National Focal Points (Convention of Barcelona). A UNEP-MAP/GEF meeting took place in Dubrovnik in October 2011 where PEGASO products were presented in an ad-hoc session to National Focus Points of the UNEP-MAP. MEDPartership/GEF has invited the PEGASO coordinator to its steering Committee in Istanbul in May 2012, to present LEAC/SEAC method to discuss its usefulness to address climate variability. UNEP-MAP has invited the Coordinator of PEGASO to its EcAp meetings and the meetings of the Commission for the Sustainable Development of the Mediterranean where LEAC/SEAC has been presented and discussed with its National Focal Points. Side events have also been orgnised to present PEGASO Governance Platform and tools at the UNEP-MAP COP 17 in Paris, February 2012, and the COP 18 in Istanbul, December 2013.

LEAC/SEAC methods and results have been also presented to the Adriatic-Ionian Commission, upon request of the Commission to use this method in the Marine Strategy (Portoroz, February 2011 and September 2012) and meeting with EU in Istanbul, May 2012 to work on the Adriatic Strategy (EUSAIR).

Results have been used in different PEGASO LEAC/SEAC and envisioning workshops, in a collaborative work with the PEGASO ICZM Governance Platform (at Mediterranean regional scale Arles, November 2012; Rabat, March 2013 and Rimini, September 2013), at the Black Sea regional scale in Istanbul, December 2012. Envisioning Workshops and foresight exercises have been done, using LEAC/SEAC results in the North Lebanon CASE (June 2013) and in the Dalyan CASE (Turkey), November 2013. In the two CASES work is ongoing with local and national stakeholders and will finish in December 2013.
In total PEGASO has co-worked with more than 700 stakeholders in the Mediterranean and the Black Sea.

Capacity Building Workshops have been organised to work with PEGASO Tools (incl. LEAC/SEAC) in November and Decenber 2013: Algeria and French speaking Magreb, Georgia CASE, Greece CASE with focus on aquaculture and MSP, and finally in Egypt CASE, with focus on Nile Delta sustainable future.

Moreover, presentation of the LEAC/SEAC have been done in the two International MEDCOAST meetings in Rhodes, October 2011) and Marmaris (October 2013).

The methodology has been presented and discussed in different worshops with the EEA, at the ETC-SIA in Malaga (April 2011 and April 2012), in LEAC/SEAC Workshop in Copenhagen, at the EEA (SEEA meeting in May 2011; EEA Sea and Fish Accounting in February 2012, and at EEA ICZM/MSP EU working group meeting in September 2012).

Presentation of LEAC/SEAC have been also performed on demand of the EU or other EU projects (e.g. MSFD Mini-seminar by the Marine Strategy coordination Group, Brussels, 22 February 2012; MEDSEA stakeholders meeting, Rome, March 2012; Meeting of the FP7 working on the Mediterranean and the Black Sea, Athens, 13-14 June 2013, etc).

Internal meetings have taken place timely organised at UAB-Barcelone, IOC_UNESCO, Paris, JRC- Ispra and UNNOT- Nottingham to coordinate the work. Many skype conferences have been also used for team collaboration.

1.5. Organisation of the Deliverable 4.2

Chapter 1 of this deliverable is an introduction where the PEGASO context is presented, where the explanation of how the three different parts of the work process fit together in an innovative exploratory work on ecosystem accounting, and how this work has been shared with the PEGASO ICZM Governance Platform and enlarged to other stakeholders.

Chapter 2 is dedicated to, "Land and Ecosystem Accounting in the coastal zones of the Mediterranean and Black Sea basins", where coastal accounts are presented with its methodology and data. It contains an important part on the testing and validation of the results and on how ICZM applications have been derived from LEAC with resulting assessments, lessons learned and recommendations.

Chapter 3 focuses on the Western Mediterranean Impact Index on Ecosystems (the WMIIE), which explain the method and process of work, the construction of the cumulative index on pressures and impact, the expert Surrey and the results, with a concluding part on data gaps and next stops to be achieved.

In chapter 4, a framework for Sea Ecosystem Accounting (SEAC) is given. The application of spatial pattern metrics to produce baseline ecosystem accounts for is explained and the application of this tool is demonstrated through two case studies.

The purpose of Chapter 5 is to discuss the different results and their integration in an accounting exercise, with lessons learned and recommendations.

Chapter 6 links the accounts (LEAC/SEAC) with the other tasks developed in WP4

Finally Chapter 7 is dedicated to the main conclusions of the work.

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Land and Ecosystem Accounting in the coastal zones of the Mediterranean and Black Sea Basins

By University of Nottingham (Emil Ivanov, Roy Haines-Young and Marion Potschin)

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SEVENTH FRAMEWORK PROGRAMME

Executive Summary

Land and ecosystem accounts provide the user with a picture of the ecological status of an area, or region, so that management decisions can be made. Such accounts are designed to provide key indicators or metrics that characterise the integrity of the ecosystems being considered. In this work we show how they have been developed for the Mediterranean and Black Sea Basins. Accounting methods are fundamentally data driven and application focussed. In this report we describe what data resources are available for land cover, biodiversity and ecosystem productivity, and for land cover how they can be processed to make a consistent set of accounts for the two sea basins. We also describe the work that has been done to test the robustness of these accounts and how they can be used to support decision making at the regional and CASE scales. We recommend that (1) accounting methods are taken forward in conjunction with the wider indicators that PEGASO has initiated, and that appropriate institutional mechanism for maintaining these sources of information are considered as part of the Business Plan that is now being developed as a legacy of the Project; and, (2) that wherever possible accounting methods are considered in any future work programme undertaken by the Platform to make periodic regional assessments and analysis at the CASE scale, so that the outcomes and benefits of such work are fed back to the wider community.

2.1 Introduction

In this section we set out the background to and results for the work on land and ecosystem accounting that was done in PEGASO. Throughout, the aim has been to build on the experience that has been build up on Europe, and extend the concept and methods to the whole of the Mediterranean and Black Sea Basins. In **section 2** we describe the history of the concepts and the accounting approach. **Section 3** reviews methods, data sources and results. **Section 4** describes the accounts themselves and **section 5** describes the way the outputs were tested and then **section 6** moves on to look at some applications. In the final **section 7** of this Part of the deliverable we look at the lessons learned and make recommendations for future work on land and ecosystem accounts.

2.2 Review of ecosystem accounting

2.2.1 History of Accounting

Accounts, whether they be financial or environmental are primarily decision support tools. They are designed to provide the user with a picture of the financial or material status of an organisation or system, so that management decisions can be made. In terms of what makes a good set of accounts, therefore, the most important thing is that they track the *key indicators* or *metrics* that characterise the integrity of the organisation or system being considered. They are therefore fundamentally *data driven and application focussed*. In a financial context these metrics might be profit and loss, costs and expenditures. In an environmental context, they might be measures of the stock of resources and how they are dissipated or restored over time.

In this part of our report we focus on environmental accounts. They are a tool that is especially important in the context of ICZM, which is primarily concerned with the governance of the coastal zone. A key ingredient of ‘good governance’ (see Deliverable 2.1C, Haines-Young et al., 2013) is reliable information presented in a way that enables users to make evidence-based judgements. Environmental accounts therefore provide part of the platform on which effective ICZM can be built. By way of introduction we outline the history and wider interest in the idea of environmental accounts, so that the contribution of the work done in PEGASO can be more easily seen.

The need to develop and apply systems of economic-environmental accounting has been widely recognised by the international community. Much of the interest over the last two years can be traced to ‘Rio’ and Agenda 21, which emphasised the need for reform of national systems of economic accounting. The aim was to ensure that the value of environmental services and resources as well as the impacts of economic activities are expressed clearly when calculating our national wealth. Agenda 21 expressed the challenge as follows:

> *A first step towards the integration of sustainability into economic management is the establishment of better measurement of the crucial role of the environment as a source of natural capital and as a sink for by-products generated during the production of man-made capital and other human activities. As sustainable development encompasses social, economic and environmental dimensions, it is also important that national accounting procedures are not restricted to measuring the production of goods and services that are conventionally remunerated… A programme to develop national systems of integrated environmental and economic accounting in all countries is proposed* (United Nations Conference on Environment and Development 1992, Chapter 8).

Since that time, an international programme of development has been led by the United Nations Statistical Division (UNSD) and its 'London Group', to devise a System of Integrated Environmental and Economic Accounts, known as SEEA. These efforts have most recently culminated in the publication of a revised standard for the 'Central Framework' in May 2012. Work on the additional portions of the SEEA, and particularly those that are of interest in the context of PEGASO and ICZM, are covered in the work done for the second volume on 'Experimental Ecosystem Accounts and Applications and Extensions' (SEEA, 2012).
Although accounting concepts are well understood, the challenge for the environmental accounting community is to find a suitable set of metrics that can be used to characterise ecosystems. Edens and Hein (2013) have recently set out some of the challenges, which include definition of ecosystem services in the context of accounting, their allocation to institutional sectors, the treatment of degradation and rehabilitation, and valuing ecosystem services consistent with 'Standard National Accounting' (SNA) principles. In this work we focus particularly on problems of degradation and rehabilitation of ecosystems and ecosystem function in the coastal zone, approached from the perspective of land cover.

A key player in taking this kind of work forward in Europe has been the European Environment Agency (EEA), which through the developing of its Land and Ecosystem ACccounts (LEAC) has shown how spatially explicit accounts for land cover can now routinely be prepared (EEA, 2006). The methods grew out of work carried out in the mid-1990s by a UNECE task force on physical environmental accounts (see UNECE, 1995, Parker et al. 1996, and Haines-Young, 1996), which sought to describe the relationship between the stock of land and the associated uses as a set of linked tables. Building on this experience EEA (2011) has described how the concept of land accounts can be embedded in a more comprehensive set of 'Simplified Ecosystem Capital Accounts' which aim to construct balance sheets for assets and liabilities that describe the status of our natural capital in physical and monetary terms. It is suggested that these balance sheets can be used to estimate the magnitude of ecological debt in physical and monetary terms so that while conventional metrics such as GPD remain unchanged in accounting terms a more informed judgement can be made of what it tells us by supplementing it with appropriate adjusted new aggregate measured derived from the ecosystem accounts.
The construction and implementation of ecosystem capital accounts, and how we use them as part of more comprehensive wealth account systems is still a long term goal. Many technical and institutional barriers remain to implementing such approaches, not least relating to the way these would operate and influence decision making at different spatial and temporal scales. A project such as PEGASO cannot, by itself, overcome many of these issues. Nevertheless, it has sought to make a contribution to these important debates by exploring how land cover information can be used to represent the stock and change of key elements of natural capital in the coastal zones of the Mediterranean and Black Sea Basins, and how species data can be used alongside that of land cover to understand the pressures on biodiversity. A particular contribution is the exploration of how concepts that have mainly been developed for the terrestrial environment can be transferred to the coastal and marine sectors so that a more holistic picture of the fate of natural capital in all these environments can be established.
In terms of the overall development of environmental accounting approaches we are now firmly in a phase of experimentation and piloting, prior to the implementation of the basic concepts. In addition to the testing that will be stimulated by the publication of Volume II of SEEA, the WAVES1 Initiative being led by the World Bank will

trigger further interest. The latter seeks to work with central banks and ministries of finance and planning across the world to integrate natural resources into development planning through environmental accounting. Thus for PEGASO the focus throughout has been to develop *practical*, *operational* procedures that are *relevant* to the needs of the ICZM 'end-user' community across the two sea basins.

2.2.2 Approaches to Environmental Accounting

Current approaches to integrated environmental and economic accounting generally regard environmental accounts as taking the form of a series of 'satellite' tables that sit alongside the economic accounts, and which can be used to better interpret changes in a broader measure of wealth. The approach has a number of advantages, not least that the accounting measures can be expressed in *physical* rather than monetary units. Thus environmental accounts can be used directly to describe the physical changes ('flows') of materials and energy, and hence the extent to which more sustainable patterns of consumption and production are being achieved. This might, for example, be done using some efficiency metric that expresses the 'decoupling' of economic growth from impact or dependency on natural resource systems. Alternatively, physical accounts can also be used as the basis of estimating the expenditures needed to manage, restore or protect the environment, and hence the defensive costs that society has to bear given the pressures it puts on natural capital. In keeping with this general philosophy, the accounts developed in PEGASO have also approached the problem of characterising the natural capital in the coastal zone in physical terms.

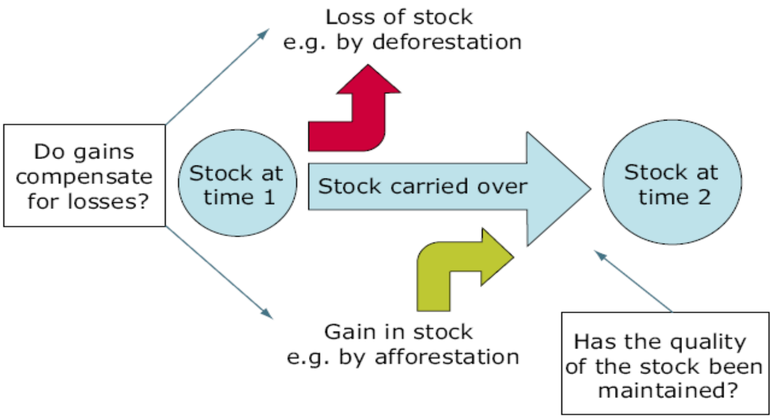

Figure 2.1: Environmental Accounting Model (after EEA, 2006; Haines-Young, 2009)

The overall methodology is best explained by reference to accounts for land cover (see Figure 2.1). If land cover changes over time, then the process can be documented by tracking the stocks of different types of land cover. In the case of wetlands, for example, there may be losses to the initial stock through drainage or conversion; while there might also be gains through restoration and natural succession. These stocks and flows can be recorded in an accounts which shows the opening and closing stocks for each type of resource and the 'flows' into and out of this stock that have been recorded. Although the simple mode shown in Figure 2.1 only deals with wetlands, it can clearly be applied to all the different types of land cover in an area and the processes of change that relate to them, and in this way a complete set of accounts set up. Despite its simplicity, however, the model does illustrate the valuable role that the accounting approach plays in policy and management debates. Thus observing the changes in stock or quantity of a particular type of land cover (measures in area units), such as wetland, we may ask whether the gains actually compensate the losses that

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1 Wealth Accounting and the Valuation of Ecosystem Services; see http://www.wavespartnership.org/waves/

were experienced over the same time period. Questions about compensation are fundamental to the issues associated with strong and weak notions of sustainability. Alternatively, we might be concerned as to whether the *quality* of the stock carried over from time 1 to time 2 has been maintained in terms of the benefits it provides to people or the support it offers to wider ecosystem functions. Maintaining the functional integrity (or condition) of natural capital stocks is also fundamental to planning for sustainability.

Ideally environmental accounts should therefore help users to understand changes in the quantity and quality of key stocks or resources. For land cover, we are well-placed in terms of monitoring changes in the area of different land cover types, but less well off in terms of measuring the functional status of these different resource categories. Limitations arise both from the difficulty of measuring ecological condition over wide areas, and of understanding precisely how condition relates to the benefits that people derive from natural capital via ecosystem services. Although the status of biodiversity is of interest in its own right, for the work undertaken in PEGASO we have also used accounts relating changes in the abundance, range and conservation prospect as a proxy of the overall condition of natural capital.

The model shown in Figure 2.1 is a simplification of the environmental accounting approaches currently being developed in Europe. For example, the EEA's ecosystem accounting framework (Weber, 2007) attempts to describe changes from both natural and human actions as they impact on primary ecosystem functions, such as productivity, biomass storage, habitat provision, water cycle and other aspects of environmental regulation. Energy and matter are incorporated in various forms within the ecosystem, such as biomass, habitats, soil organic carbon, all of which are essential for maintaining biodiversity and associated biophysical processes and ultimately the contribution that ecosystem make to human well-being though ecosystem services. Estimates of changes in the stock of natural capital are then made on the basis of the differences between the gains and losses of matter or energy per unit area.

The conceptual layout for these 'capital' accounts is shown in Figure 2.2. The rigor that the accounting approach brings to such calculations is that if the data are of sufficient quality, and no essential components are left un-accounted, then the account can be 'closed', meaning that the balance can be estimated, with the stocks and flows on the two sides of equation below showing the same amount of the accounted measures.

		natural	human	
year 1		flow A (+)	flow C (+)	
	Opening stock	flow B (-)	flow D (-)	Closing stock
year 2		flow A (+)	flow C (+)	
	Opening stock	flow B (-)	flow D (-)	Closing stock
year 3		flow A (+)	flow C (+)	
	Opening stock	flow B (-)	flow D (-)	Closing stock

Opening stock, yr1 + flows, yr1 (A, B) = closing stock, yr1 - flows, yr1 (C, D)

Figure 2.2: The concept of flow accounts

For accounts to be constructed we need to identify the resource stocks that are of interest, and the time period over which the accounts will be constructed. A further consideration is the 'accounting unit' that will be used to report the information. In PEGASO, we have followed the approach developed by the EEA in their land accounting work, which has been based on constructing an 'accounting grid' at 1km x 1km resolution for the whole of Europe. The grid is used to record land cover and any other associated attributes for each grid cell (such as where it sites in the different tiers of administration, or its biophysical characteristics such as altitude), as well as information relating to the species and habitats found at that location. The data for each 'accounting cell' can then be aggregated, for reporting purposes and accounts generated for any larger spatial unit. In this way spatially explicit accounts can be generated and the key stocks and changes associated with them mapped.

For a brief overview on the methodology and approach of the Land and Ecosystem Accounting (LEAC) a fact sheet was produced, which is now also included in the PEGASO WIKI and can be downloaded at: http://www.pegasoproject.eu/wiki/Application_of_LEAC_in_PEGASO.

2.3 Building the PEGASO Land Accounting Framework

In PEGASO the European accounting grid has been extended to the entire coastal zones of both the Mediterranean and Black Sea Basins. For the purposes of making land accounts **'coastal zone' has then been defined as the areas within 50km of the coastline.** The accounting grid also extends across the near shore and marine parts of the study area so that both land and sea accounts can be constructed where data are available.

The relevance and practicality of the accounting approach proposed for Europe by the EEA (2011) was considered as the basis of the work done in PEGASO. Two criteria were important. First the availability of suitable data for all or the major parts of the study area. Second the interest that the PEGASO end-user community had in developing the different accounting themes.

Conceptually, the EEA approach suggests that environmental accounts should span six major thematic areas: land, water, biomass, biodiversity, abiotic interactions and biotic interactions. In an initial phase of the work in PEGASO we looked at the availability of data for each of these areas (see Internal deliverable ID4.2.3 Ivanov et al., 2012a), and noted those where progress might be limited by lack of information. It should be noted that even in Europe the EEA have found that significant data deficiencies exist that hinder implementation of their approach. We found a similar picture in PEGASO, especially given the requirement to extend the work to coastal and marine waters.

Throughout the work in PEGASO the focus has been on developing a methodology that is *operational* in the sense that the methods are both fully reproducible and the datasets likely to be available in the future so that updating and hence maintenance of the accounts is possible. To assist in this process, the kinds of criteria used for the selection of national and international statistics was reviewed and adapted for the purposes of PEGASO. Table 2.1 shows the criteria suggested by the FAO, and how they were applied in PEGASO to the section of data. In applying these criteria particular attention was paid to the issue of data quality. Not only was the question of whether stocks and flows in the different thematic areas could be properly defined and quantified with the available data, but also their reliability was investigated by testing the estimates using them with a number of independent sources, where these were available.

Table 2.1: Criteria used to select data sources for building environmental accounts

	FASTAT example (FAO, 2005)	PEGASO LEAC
Spatial coverage	Global coverage	Mediterranean and Black Sea coastal areas (at least 50 km from coastline)
Data production	Regular, committed sustainable data collection activities by the countries	Committed partners (contributions to SDI)
Temporal coverage	Time-series data	At least two points in time (years 2000 and 2011
Quality assessment	Data quality assessment performed	Data quality assessment performed
Metadata for users	Statistical metadata available	Statistical metadata available
Data release	Data is edited and validated	Data is edited and validated

The results of the outcome of our review of data sources for PEGASO is summarised Table 2.2. The row for the 'accounting inputs' shows that there is potentially good coverage for land and some characteristics of coastal waters, as well as biodiversity, providing a way could be found to make the data consistent across the two sea Basins (this was achieved through the 'PEGASO Land Cover Product' (PLC) shown in the Table). It also appeared that there was the possibility of characterising ecosystem productivity, at least for the European area. The poor coverage of data for water, and biotic and abiotic interactions meant that these were eliminated from the work programme at an early stage. The other rows in Table 2.2 show where independent data were available that would allow us to test the accounts, or where in the absence of empirical measurements meant that model-based studies might be the only way of assessing ecosystem change. The latter mainly related to the extension of the accounting framework into marine space, using the outputs from the coastal protection analysis done by Liquete et al. (2013) and the eutrophication modelling done by Druon et al. (2004). Both are potentially capable of providing spatially explicit mapping of a range of indicators than can be used either to characterise aspects of the protection regulation service provided by coastal ecosystems or the threats to coastal zones from pollution. Details of this work and the potential it offers are provided in Internal Deliverable ID 4.2.4 (Ivanov et al., 2012b).

Table 2.2: Data sources for PEGASO environmental accounts

Themes	Space		Biodiversity		Water		Productivity/ biomass		Abiotic interactions		Biotic interactions	
	Land	Sea	Land	Sea	Land	Sea	Land	Sea	Land	Sea	Land	Sea
Accounting inputs	PLC CORINE LC Nile delta LC (NARSS)	CORINE LC (coastal waters)	Art. 17 Protect. Species Protect. areas	Art. 17 Prot. Species EMODNet (VLIZ) Prot. areas	AQUA-STAT (FAO)		Bio-C (EEA)	FishStat (FAO) EMIS (JRC)	FATE (JRC)			
Testing phase	PLC/ CORINE: IRA PLC /CORINE: cases		Protect. areas Art. 17									
Modelling						PSA, OXYRISK (JRC)			Coastal protection (JRC)			

Table 2.3: The PEGASO accounting matrix

PEGASO Accounting Matrix					
	Biophysical accounts		Ecosystem services accounts	Socio-economic accounts	
	Ecosystem conditions/capital	Human use of ecosystem capital/human impacts	Ecosystem services	Economic valuation	Maintenance of natural capital (investment/ restoration)
Land	Land cover/use	Land use (ex. urban sprawl/intensification of agriculture)	Provision of living space, recreation etc.	Wealth generated through real estate; incomes from mass tourism / restoration costs	
Biodiversity	Habitats and biodiversity	Protected areas, Homogenization, fragmentation	Resilience, regulatory services, tourism support etc.	Incomes from eco-tourism and mass tourism	Protected areas, conservation success
Biomass/ productivity	a) NPP (NDVI) and biomass b) chlorophyll-a	Timber, livestock, crops harvest; fisheries; aquaculture	Food and materials provision Food provision		

In parallel with the review and evaluation of potential data sources, we also consulted the PEGASO end-users and Case partners to find out which accounting themes would be especially valuable in their ICZM work. The consultation process followed the interactive procedure for account construction described in PEGASO Internal Deliverable ID4.2.2 (Ivanov et al. 2012c). Land cover change in the coastal zone was identified as important by many, followed by biodiversity. Less interest was identified for ecosystem productivity. As a result of this process it was decided to carry each of these themes forward, but to place most emphasis on the construction of land cover accounts for the two sea Basins. Table 2.3 provides an overview of the 'accounting matrix' that was developed as a result of the consultation process. It identifies the kind of biophysical account in the three thematic areas that were taken forward in PEGASO, and shows how they might link to the wider analysis of ecosystem services and socio-economic accounting. In the sections that follow we describe in more detail how the accounts for land cover, biodiversity and productivity were constructed.

2.3.1 Data sources for Land Accounts

For the construction of land accounts in PEGASO an extension of CORINE Land Cover methods used in Europe was extended over the Mediterranean and Black Sea Basins. The basis for the work was the classification of remotely-sensed MODIS multispectral imagery. European CORINE land cover data was used to calibrate a supervised maximum likelihood classification algorithm that was applied to these data. Other ancillary data were also used in the classification process.

The suitability of different data sources were examined in a pilot phase of the work (Ivanov et al., 2012c). In the case of GlobCover2 and GlobCORINE3 the mapping for 2005 and 2009 did not follow the same classification procedure as CORINE and so this prevented reliable change detection, or the extraction of 'flows' in the accounting sense. As an alternative MODIS[4] land cover data at 250m resolution was considered. These data are available for the whole globe and have been freely accessible since 2000. A range of products are available, including classified land cover maps, vegetation indices and multispectral reflectance data at 250 m, on a 14 day repeat cycle. The land cover data are published annually at a resolution of 500m but they are not suitable for multi-temporal analysis because the changes observed between years are more influenced by variations in precipitation variations and its influence on vegetation phenology rather than land use changes. As

2 http://due.esrin.esa.int/globcover/
3 http://dup.esrin.esa.int/prjs/prjs114.php
4 MODIS land products can be accessed and downloaded from NASA's data centre: http://reverb.echo.nasa.gov/reverb/#utf8=%E2%9C%93&spatial_map=satellite&spatial_type=rectangle

a result, the pilot work in PEGASO looked at the possibility of using the MODIS multi-spectral data to construct CORINE-compatible product.

CORINE[5] is a standardised land cover inventory for the EU and EEA associated countries, available for 1990, 2000 and 2006 at a spatial resolution of 100m. The data sources use to prepare CORINE have better thematic and spatial resolution than MODIS, and so in order to extend the CORINE approach across the two Sea basin other ancillary data were used to provide additional contextual information for the supervised classifier, namely:

- The DMSP-OLS Night-time Lights Time Series[6] was used to help identify urban areas and artificial surfaces. The data on nightlight intensity are available at 1km resolution for the entire globe; the images are composites of cloud-free scenes using all available smooth resolution data acquired during each calendar year since 1992.
- The SRTM 90m Digital Elevation Data (DEM) from NASA, at 90m resolution at the equator, were used to better separate classes by topographic context. For the current application the DTM were resampled at 250 m resolution, and along with altitude, were used to calculate slope and aspect.

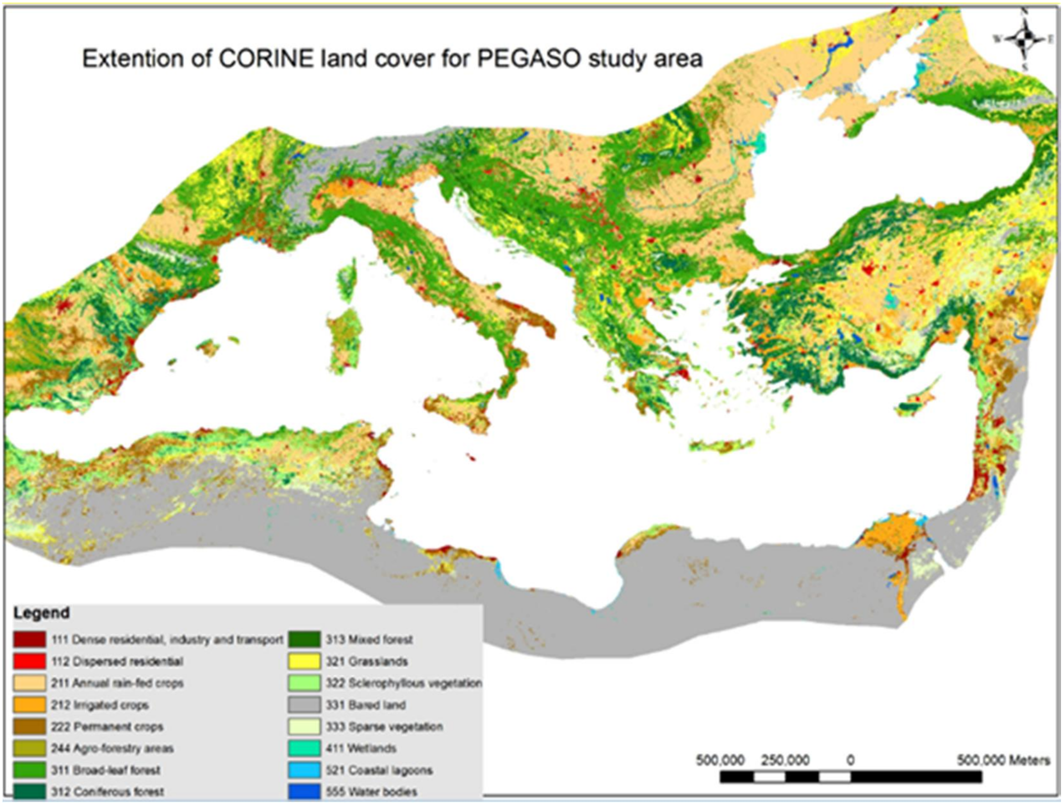


Figure 2.3: The extent of the PEGASO land cover product

A detailed account of the image classification methods used is provided by Ivanov et al. (2013a). The CORINE nomenclature was modified by merging some classes and excluding others to ensure separability using the

5 CORINE Land cover can be downloaded from EEA's data centre: http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-raster-2
6 http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html

MODIS multispectral and other inputs at 250 m spatial resolution. For example all the classes characterised by continuous hard or paved surface were merged in a single class '111', while the class of discontinuous urban land, including open spaces (agriculture, parks, green areas) is kept separate '112'. The procedure enabled a European CORINE land cover type product, to be extended over the African and Near-east Mediterranean areas and East European temperate areas. Land cover classifications were made for the years 2000 and 2011. Example output is shown in Figure 2.3. The classification used for the resulting 'PEGASO land cover product' is shown in Table 2.4.

Table 2.4: PEGASO land cover nomenclature

Land cover Level 1		Level 2	Land cover Level 3	
Urban and artificial cover	1	1	111	Dense residential, industry and transport
Urban and artificial cover	1	1	112	Dispersed residential
Agricultural land	2	21	211	Annual rain-fed crops
Agricultural land	2	21	212	Irrigated crops
Agricultural land	2	22	222	Permanent crops (orchards, vineyards, olives)
Agricultural land	2	22	244	Agro-forestry areas
Forest and semi-natural cover	3	31	311	Broad-leaf forest
Forest and semi-natural cover	3	31	312	Coniferous forest
Forest and semi-natural cover	3	31	313	Mixed forest
Forest and semi-natural cover	3	32	321	Grasslands (merged with pastures)
Forest and semi-natural cover	3	33	322	Sclerophyllous vegetation
Forest and semi-natural cover	3	34	333	Sparse vegetation
Forest and semi-natural cover	3	34	331	Bared land (beaches, rocks)
Wetlands	4	4	411	Inland marshes and salt marshes
Water	5	5	521	Coastal lagoons
Water	5	5	555	Water bodies (rivers, lakes)

2.3.2 Data sources for biodiversity accounts

At present the construction of biodiversity accounts is experimental, not least because of the lack of consistent data across the two sea basins. Methods for using species and habitat data to construct biodiversity account, even where they are available, are not fully established. Thus the work undertaken in PEGASO was designed to explore what kinds of approach might be feasible in an operational context at least the European part of the study area.

For the implementation of the biodiversity accounts it was decided to explore the information available for a subset of around 1000 species of plants, mammals, amphibians, reptiles and arthropods, that were included in the Annexes of the Habitat Directive (Council Directive 92/43/EEC). These data have been generated by a policy processes that focussed on deriving information on species having European conservation importance. Although progress can be made using these sources, data availability and data quality are identified as the main constraints for constructing a complete set of accounts. A major challenge has been to extract and harmonise the available data, and report them spatially so that comparable results could be published across all the European countries for at least two time periods.

The work on species has focussed on three elements:

- the number of species of European conservation importance present in a given area; this is representative for the time when the countries carried out their assessments for the period 2001 - 2006;
- the prevailing trend of the population sizes of the species present in a given area, which indicates whether the conservation status of the species improved or worsened since their designation in the 1990s; and,
- the species' prevailing future prospects, which can be used, help to assess whether the current trend in conservation success may continue or change in the near future.

All of the data are part of the so-called 'Article 17' assessment database, which has been generated by reports from the EU member states and harmonized by the European Topic Centre on Biodiversity. For the purposes of the PEGASO project a new method of down-scaling these data was developed (Ivanov et al., 2012d). It involved using the European CORINE Land Cover data described above, to distribute the species records spatially in those locations to which they are most likely to apply. An example of the outputs generated by these methods using the Article 17 species data is shown in Figure 2.4. Although we are interested in the coastal zones on the Mediterranean, maps for the whole of Europe have been provided in order to better establish the plausibility of the results using this novel methodology.

Clearly we are currently limited to making species accounts to the European part of the study area. In the future it is likely that other species data can be to extend the mapping to other areas in North Africa and the Black Sea. These other data sources include: the IUCN red-list species and the Protocol for Specially Protected Areas and Biological Diversity in the Mediterranean. The latter identifies species of Mediterranean conservation importance (Annex II: List of Endangered or Threatened Species) and commits the countries that have signed the Barcelona Convention to fulfill monitor and report their of conservation status, in a similar way as done for the European Article 17 Habitats Directive.

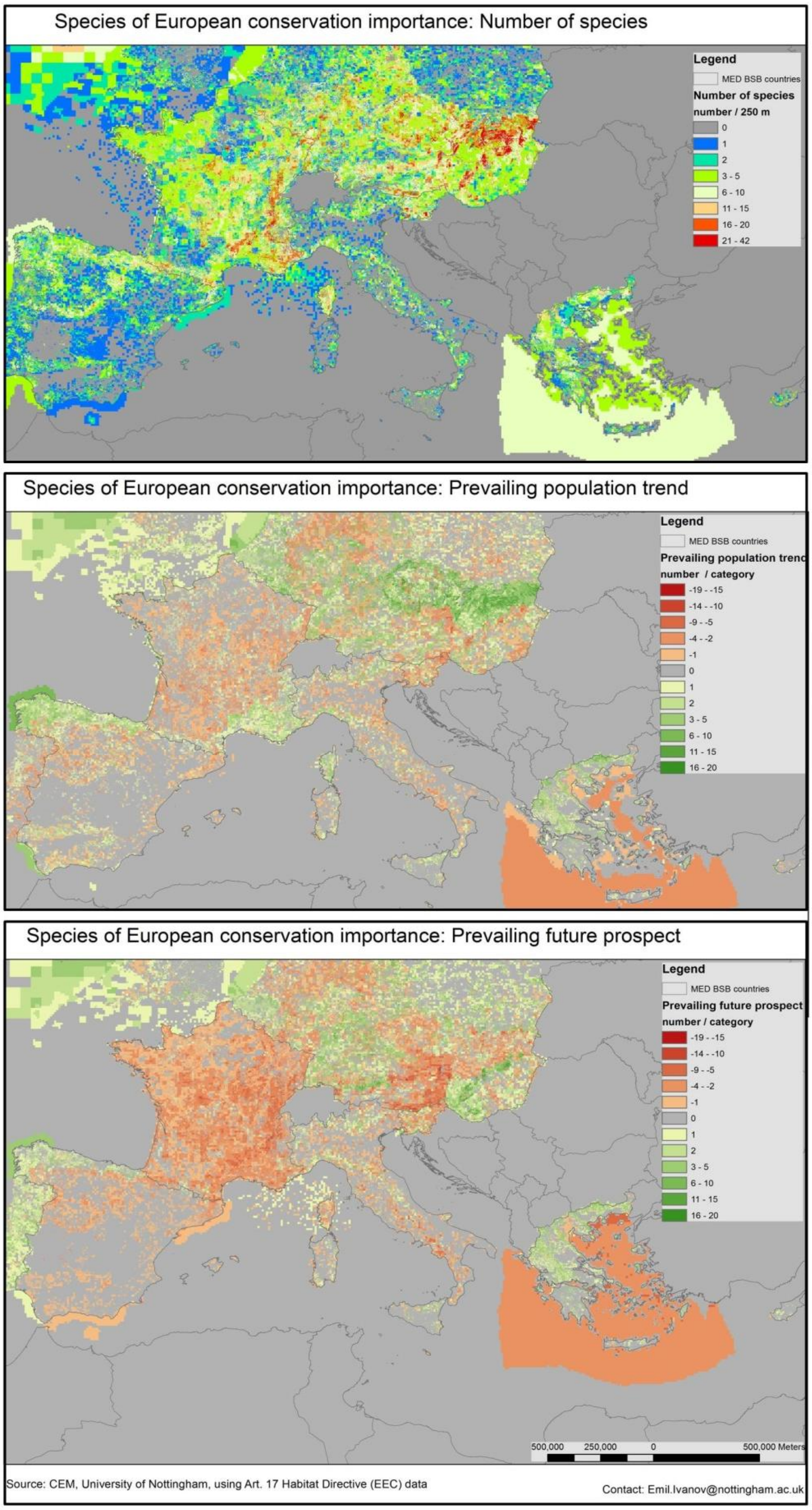


Figure 2.4: Biodiversity accounts based on Article 17 data

2.3.3. Data sources for carbon accounts

Carbon accounts are designed to assess ecosystem primary production and its changes resulting from to human use and impacts. The work reported here follows that being undertaken by the EEA in Europe, namely to find a way of mapping of the relations between ecosystems biomass production (carbon fixation, ecosystem vigour) and the human use of biomass for food, fibre, materials. By assessing each of these elements separately a set of indexes can be constructed to represent the relationships between the human uses and the ecosystem parameters. Such carbon accounts can then be used to assess whether countries (or other administrative units) are overusing their own, or other countries resources, to identify which ecosystems are under threat of degradation and where they are located.

Therefore the carbon accounting model used for the present study is based on the estimation of three parameters (Ivanov et al., 2012b):

- **Carbon resource** (or annual carbon stock), which is the annual sum of carbon sequestered as a result of Net Primary Production (NPP);
- **Carbon storage**, which is the multi-annual sum of carbon stored in woody plant material and soils; and,
- **Carbon use**: annual sum of carbon removed from the ecosystems in the form of crop harvest, timber extraction and grazed biomass by domestic livestock

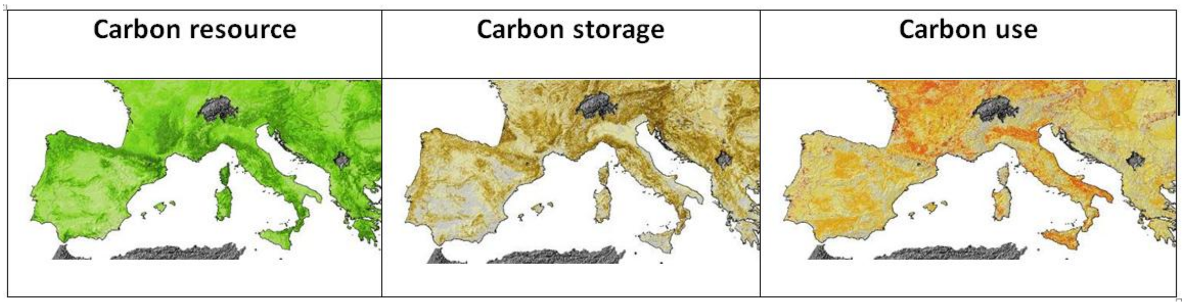


Figure 2.5: Components of the carbon accounting model estimated for year 2000

These parameters were measured and mapped across the [European Part of the] PEGASO accounting grid using the GEOSUCCESS NPP product and Spot-vegetation NDVI. CORINE land cover and national statistics on crops, timber and livestock from FAO were used to estimate carbon removals. All parameters were measures as tons of carbon per km^2 and per year (where relevant). Only exchanges related to living processes are considered at this stage, carbon sequestration in the ocean or processes related to fossil fuels were not considered.

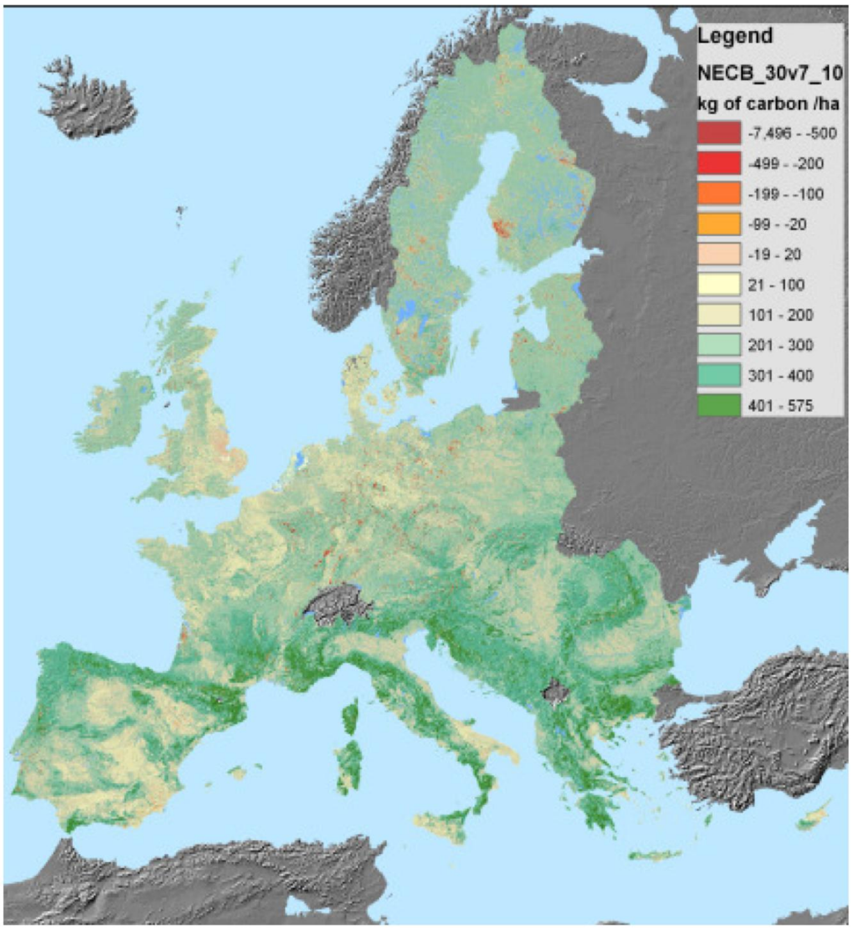


Figure 2.6: Carbon balance for Europe

On the basis of the analysis of the three separate elements, an aggregated index for carbon balance can be estimated (Figure 2.6); this is the difference between carbon stocks (annual and multiannual) and carbon use. The index can be used to assess whether the annual resources produced by the ecosystems, as well as the multi-annual stock accumulations are used sustainably by people, e.g. when the balance is positive; and the reverse – assess if the ecosystems might be under risk of continuous degradation indicated by multi-annual trends of negative carbon balance.

As in the case of the productivity and biodiversity accounts the outputs are currently restricted to the European part of the PEGASO study area. However, with the new PEGASO Land Cover product, the mapping of biodiversity and carbon can potentially be extended over the whole Mediterranean and Black Sea Basins.

2.4 The PEGASO Coastal Accounts

2.4.1 The LEAC Database

An integrated LEAC database for PEGASO was constructed using the accounting inputs described in Section 2.3. The backbone of the data resource is the data for land cover for the years 2000 and 2011, the accounting units of land administrative divisions, buffers defining different widths of the coastal strip (i.e. 1km, 10km and 50km) and the boundaries of the PEGASO case study areas.

Table 2.5: Land cover nomenclature used for LEAC database

1	Urban and artificial covers
21	Intensive agriculture
22	Mixed and extensive agriculture
31	Forest
32	Grassland
33	Shrubland
34	Desert and sparse vegetation
4	Wetlands
5	Water

For the purpose of constructing the database the land cover was transformed from discrete classes at 250 m x 250 m to number of hectares within 1 km x 1 km grid, at level 2 of the PEGASO land cover nomenclature, shown in Table 2.5. Nine maps were produced in this way, each of them presenting the variability of the class as a continuous variable, in the form of the number of hectares from 0 to 100 (the total area of the grid-cell). The information was extracted to points located at the centroid of each cell and these were assigned unique reference number from the original accounting grid. This allowed the processing of the entire coastal zone of the two basins for the 50k coastal strip. The resulting database consisted of over a million of records. Spatial processing techniques were used to assign to each point further attribute data relating to its location in relation to country, administrative region and distance from coast. The integrated database was then used to extract stocks and flows of land accounts for different accounting units.

For the purposes of extracting data on the changes in land cover (i.e. the flows or stock changes represented in the accounts) the approach as used by the EEA to construct land cover accounts was applied. Overlaying the nine land cover maps described above, for two points in time (2000 and 2011), allowed a total of 81 potential land cover transitions between classes to be identified. Following the EEA method, these were reviewed and only the plausible transitions retained for mapping purposes.

Table 2.6: Data sources by theme in PEGASO accounting framework

Theme		Dataset	Source	Link
Space	Land	PLC	UNOTT - PEGASO SDI	http://pegasosdi.uab.es/catalog/srv/en/main.home
		CORINE LC	EEA	http://www.eea.europa.eu/themes/landuse/interactive/clc-download
		Nile delta land cover	NARSS - PEGASO SDI	
	Sea	CORINE LC (coastal waters)	EEA	http://www.eea.europa.eu/themes/landuse/interactive/clc-download
Biodiversity	Land	Art. 17	UNOTT - PEGASO SDI	http://pegasosdi.uab.es/catalog/srv/en/main.home
		Protected species	IUCN	http://www.iucnredlist.org/technical-documents/spatial-data
		Protected areas	WDPA	http://www.wdpa.org/
	Sea	Art. 17	UNOTT - PEGASO SDI	http://pegasosdi.uab.es/catalog/srv/en/main.home
		Protected species	IUCN	http://www.iucnredlist.org/technical-documents/spatial-data
		Protected areas	WDPA	http://www.wdpa.org/
		EMODNet	VLIZ	http://bio.emodnet.eu/portal
Water	Land	AQUA-STAT	FAO	http://www.fao.org/nr/water/aquastat/main/index.stm
	Sea (quality)			
Productivity and biomass	Land	Bio-C	EEA	
	Sea	EMIS	JRC	http://emis.jrc.ec.europa.eu/
		FishStat	FAO	http://www.fao.org/fishery/en
Abiotic interactions	Land	FATE	JRC	http://fate-gis.jrc.ec.europa.eu
	Sea			
Biotic interactions	Land			
	Sea			

After the checking the reliability of the accounts (see Section 2.5, below) all the accounting inputs and outputs were transferred to the 'PEGASO SDI' both as maps and in the form of pivot tables. Table 2.6 summarises all the data sources across all the accounting themes in this work, and indicates which is stored on the PEGASO SDI and which are available from other sources.

2.4.2 Land cover stock accounts

Stock accounts for the nine land categories, estimated for years 2000 and 2011 at level 2 in the PEGASO nomenclature are shown in Table 7. The data are disaggregated by continent and the 1, 10 and 50 km coastal buffer strips. All data are shown in terms of per cent cover. The stock accounts show the dominance of urban cover in the near coast zone, especially in Asia and the Near East. Agricultural lands and shrublands occupy highest share in Europe, while forests are the most extensive in Asia. The high figure of 8.4% wetlands on the European coasts reflects the existence of extensive wetlands on the north Black Sea coast. The figure on water bodies is also very high in the first 1km, because this includes coastal sea waters; the 10 and 50km buffer only includes freshwater. The second buffer, spanning 10 km from the coastline, shows high forest cover (circa 50%) for the Asian part of the Mediterranean and the Black Sea. In Europe over one third of the land cover is devoted to agriculture. A similar picture is found in the buffer strip beyond 10km. The dominance of deserts and shrubland is a particular feature of all zones in Africa.

Table 2.7: Stocks of land types in the Mediterranean and Black sea coastal, 2011

Coastal buffer	Region	Land cover (%cover)								
		Urban land	Intensive Agriculture	Mixed agriculture	Forest	Grassland	Shrubland	Desert, sparse vegetation	Wetland	Water
0-1km	Africa	16.4	7.4	8.0	3.6	1.0	12.2	31.0	3.3	17.0
	Asia	22.3	15.4	7.1	23.5	0.5	14.0	6.2	2.5	8.5
	Europe	14.7	15.3	11.3	12.1	6.2	18.8	5.5	8.4	7.7
1-10km	Africa	8.3	10.2	19.3	7.1	1.3	13.7	36.4	0.8	2.9
	Asia	7.6	20.5	6.6	47.2	0.6	11.1	4.0	0.5	1.8
	Europe	6.6	27.4	16.9	23.7	4.0	14.8	2.0	2.7	2.0
10-50km	Africa	1.1	13.6	15.9	4.3	2.6	10.8	50.8	0.2	0.7
	Asia	3.4	18.8	4.4	46.1	5.5	9.2	11.8	0.2	0.6
	Europe	2.7	32.7	10.9	34.6	5.6	8.7	3.4	0.7	0.7

The stock accounts reveal consistently larger areas of urban land in year 2011 than 2000, throughout the study region. Intensive agriculture areas were larger in year 2000 on the European and Asian coast, and smaller on the African. Forest stock increased in most of the coastal areas, except the 50 km zone of the Asian and European coast. Desert and sparse vegetation areas have slightly diminished in general. Wetlands and water bodies cannot be well compared for the first km zone, due to the impossibility to distinguish coastal sea waters, however while the stocks of wetlands seem very stable, there is certain decrease of water bodies surfaces on the 1 km and 10 km coastal zones. These changes of stocks of water resources need further investigation as sustained water provision is a key issue for the Mediterranean region.

2.4.3 Land cover flow accounts

The flexibility of the LEAC database can be illustrated by the way more detailed accounts can be constructed using these data. As noted above, the areas of land occupied by forest represent an important asset in the Mediterranean and Black coastal zones, especially on the European and Asian parts. Complete forest 'flow accounts' for these areas can be extracted from the LEAC database for the period 2000-2011. Instead of using a tabular method to display the accounts, the results are shown in graphical terms in Figures 2.7 and 2.8.

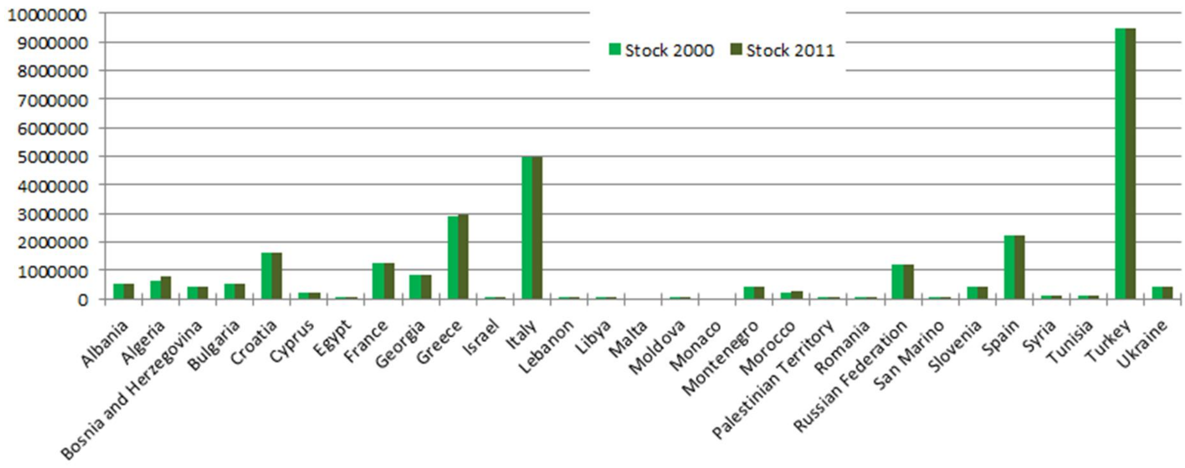


Figure 2.7: Forest stock [ha] in the 50km wide coastal zones (Mediterranean and Black Sea countries)

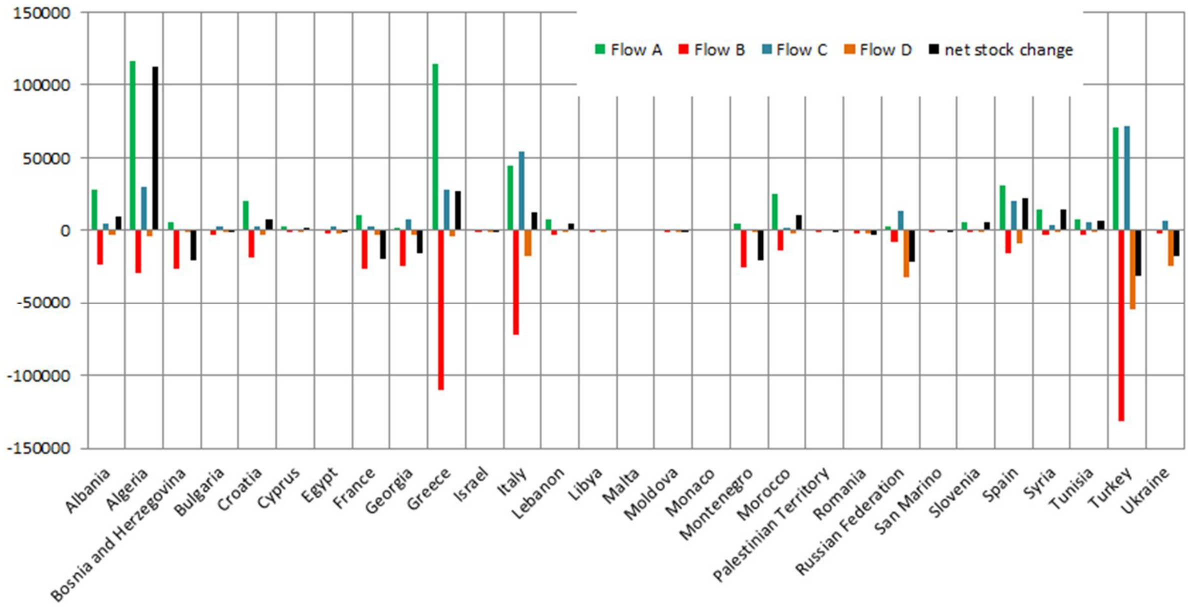


Figure 2.8: Forest flows [ha] in the 50km wide coastal zones (Mediterranean and Black Sea countries)

Figure 2.7 shows the 2000 opening and 2011 closing stock of forest by country. The flows (Figure 2.8) were estimated according to the accounting model described above. Flow A is the gain in forested land, which occurred on ‘natural’ land types, such as grasslands, shrublands, sparse vegetation and wetlands. These transitions can be considered mostly ‘natural’, following spontaneous processes, such as forest expansion and secondary succession, even if afforestation can take place on natural lands too. Flow B, is the opposite; that is loss of forest. This flow is also considered mostly ‘natural’. Such transitions often occur as a result of fires, storms etc. Flow C, registers new forests which were established on previously agricultural or urban land. In this case, it can be assumed that the transition follows an element of human decisions. The new forest may be results of deliberate forest plantations or spontaneous secondary succession on croplands, but following land abandonment. Flow D registers forest loss where either cropland or urban land was established.

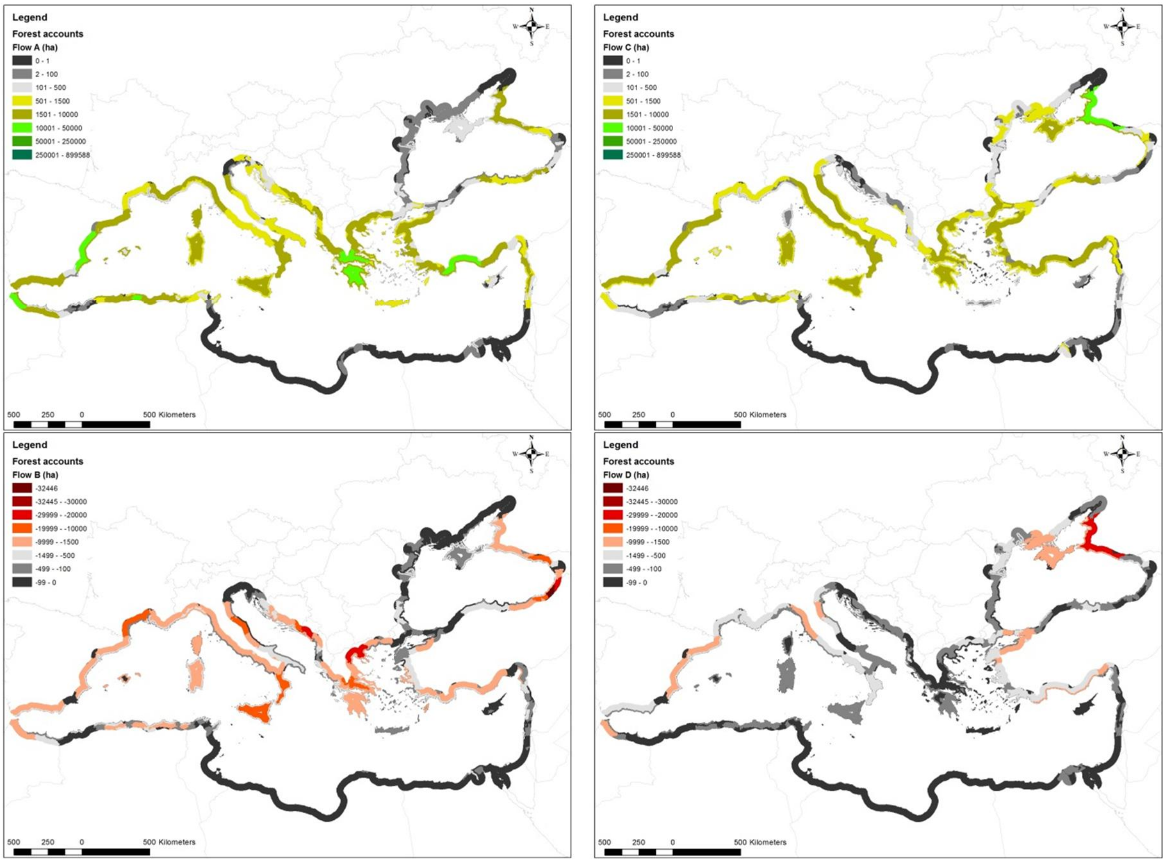


Figure 2.9: Forest flows [ha] in the 50km wide coastal zones shown per administrative unit and buffer zone

Figure 2.9 illustrates how the accounts data for forest can be mapped using the LEAC database. The maps show the data on the four types of flow discussed above for the 50km coastal buffer. The largest areas of forest lost due to natural factors (flow type B) are to be found in the Greek region of Macedonia and the highest areas due to human factors (flow type D) – on the Russian Black sea coast. The areas of gains, indicate that also highest rate of afforestation occurred on the Russian coast, and suggest quite intensive land use changes.

2.4.4 Local scale accounts

The flexibility of the LEAC database can be further illustrated by the way data can be prepared for a specific local-scale area of interest, such as one of the PEGASO Case Study Areas. The example selected to show this is the Nile Delta (Figure 2.10).

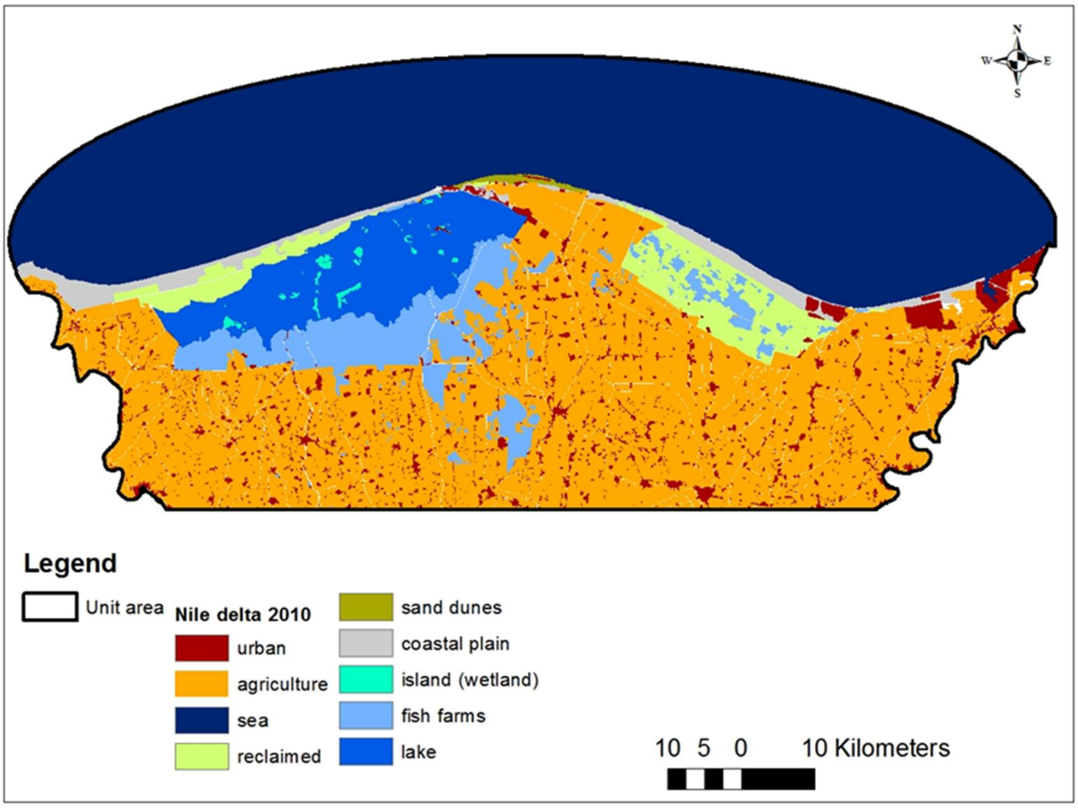


Figure 2.10: Land cover stock for the Nile Delta, 2010

The accounts were produced using NARSS data at very high spatial resolution, rather than from the sources used to develop the PEGASO Land Cover Product. However, in order to provide consistency with the broad scale analysis, these local data have been classified using the PEGASO Land Cover nomenclature. The analysis therefore illustrates how more detailed locally specific accounts can be prepared in a way that is compatible with the broader scale information that is available across the entire study area. As we will also see in section 5, such data can also be used to test the accuracy of these coarser scale analyses.

Using the PEGASO nomenclature, the stock of different cover types in 2010 for the Nile Delta in 2010 is shown in Figure 2.10. The accounts (Table 2.8) demonstrate very intensive land transformations in the Nile Delta, probably more so than anywhere else in PEGASO study area. There has been a massive increase of infrastructure. Fish farms area have increased by 15%, and natural coastal habitats (coastal plains and dunes) areas decreased by a quarter within seven year period. It has to be emphasized, that according to the regional land cover maps there has been also very intensive transformation around the Nile Delta in the surrounding desert and coastal areas. These transformations include high rates of urbanization and infrastructure development, as well as new irrigated areas for croplands.

Table 2.8: Nile delta land cover change accounts, 2002-2010

Land types	**Stock 2002**	**Stock 2010**	**Net change**	**Per cent change**
Canals	1458.6 km	2363.0 km	904.4 km	62.0
Roads	2727.4 km	3506.9 km	779.5 km	28.6
Agriculture	2759.1 km^2	2673.7 km^2	-85.4 km^2	-3.1
Fish Farms	357.2 km^2	412.9 km^2	55.7 km^2	15.6
Lake	465.0 km^2	438.5 km^2	-26.5 km^2	-5.7
Reclaimed	290.6 km^2	264.8 km^2	-25.8 km^2	-8.9
Coastal plain	208.7 km^2	155.8 km^2	-52.9 km^2	-25.4
Sand dunes	16.5 km^2	12.8 km^2	-3.7 km^2	-22.3
Urban	272.3 km^2	280.0 km^2	7.6 km^2	2.8

2.5 Testing the accounts

Having constructed the accounting database described above, its robustness was examined to assess the spatial and quantitative accuracy of the accounts on natural and urban areas, using independent and high resolution reference data sources. The accuracy was judged on the bases of linear correlation coefficients (R2) estimated between the reference data and the evaluated data (either CORINE or PEGASO version). For this purpose all the three datasets had to be processed to express the quantities of area estimates (in hectares) in comparable way. This was done by converting the discrete classes into continuous quantitative measure expressing number of hectares of either natural or urban land per one km grid cell. Consequently, the numbers of hectares were 'sampled' for around 500,000 centroid points. Each centroid represented each of the 1km cells, and could be linked with different spatial reporting units. The geographical units considered were countries, buffers around the coast and dominant land types. The correlations were analysed by comparing the average values for these spatial units.

The evaluation was made at two levels: (a) the 'regional', covering the entire 50 km coastal zone for the EU countries in which the three sources overlap completely in terms of areal coverage (Figure 2.11). It includes all the EU and associated countries; and, (b) the CASEs scale, for which the equivalent sources could be applied at local levels. The CASEs considered (Figure 2.12) were Bouches-du-Rhone, North Adriatic, Cyclades, Danube Delta and Nile Delta. The reference data used for the two themes, natural and urban land originates from different sources and needed separate processing procedures to derive comparable results.

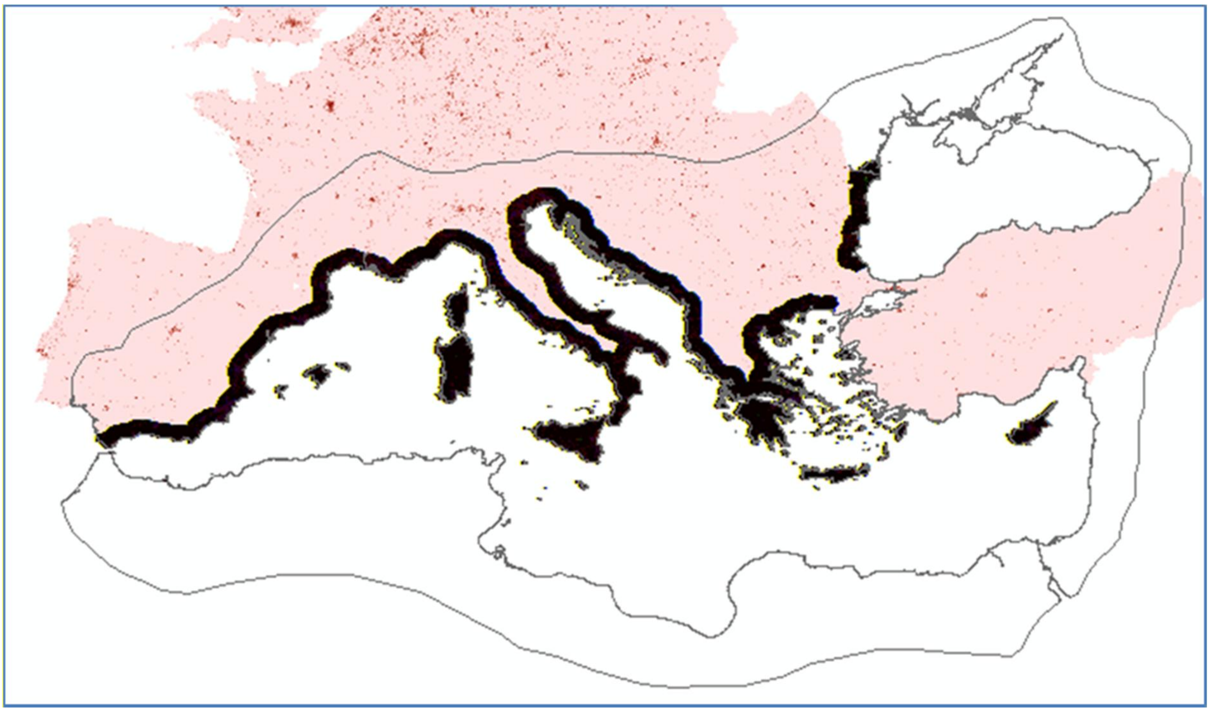


Figure 2.11: Evaluation data extent at regional level. The black dots are the 1km centroids of the grid-cells used to 'sample' the three data inputs for evaluation

Figure 2.12: Evaluation data extents at CASEs level

2.5.1 Evaluation of the accounts on natural areas

For natural areas, the accounts from PEGASO and CORINE land cover were compared with the JRC product of forest cover in year 2000. The JRC map was produced at 25m spatial resolution using LANDSAT imagery (see Ivanov et al., 2013b). For the evaluation purposes, the input from PEGASO and CORINE had to be processed and harmonised to match the semantic definitions of the JRC product. In this regard, the natural areas of forests and shrublands were grouped to express the total coverage of woody vegetation from PEGASO and CORINE Land cover, which was then compared to the JRC Forest areas map. The three products were compared after being converted to area coverage registering number of hectares woody vegetation per 1km grid cell. At regional level, the average number of hectares of woody vegetation of the coasts per country is shown in Table 2.9.

Table 2.9: Forested areas from JRC, PEGASO and CORINE land cover per country

	mean JRC forest	mean PLC forest	mean CLC forest
Albania	18.44	52.00	46.54
Bosnia and Herzegovina	24.70	70.18	63.35
Bulgaria	32.75	35.89	34.12
Croatia	42.64	71.66	59.62
Cyprus	11.05	44.12	37.11
France	33.83	54.85	50.25
Greece	14.46	52.74	43.83
Italy	23.52	35.38	30.07
Malta	0.49	0.37	12.17

Montenegro	40.50	76.96	62.24
Romania	4.11	6.91	9.09
Slovenia	79.65	85.92	72.12
Spain	20.47	53.51	40.43

The average per country were analysed considering the JRC as the 'most precise' estimate. In comparison to it, PEGASO land cover averages are generally higher than the other two sources which imply an over-estimation of woody vegetation in the latter. The correlation coefficient for CLC is slightly higher, as shown on the Figure 2.13. Similar coefficients are estimated when considering the much higher spatial variation when comparing the averages per coastal accounting units (defined by intersecting the three buffers around the coast and the administrative divisions).

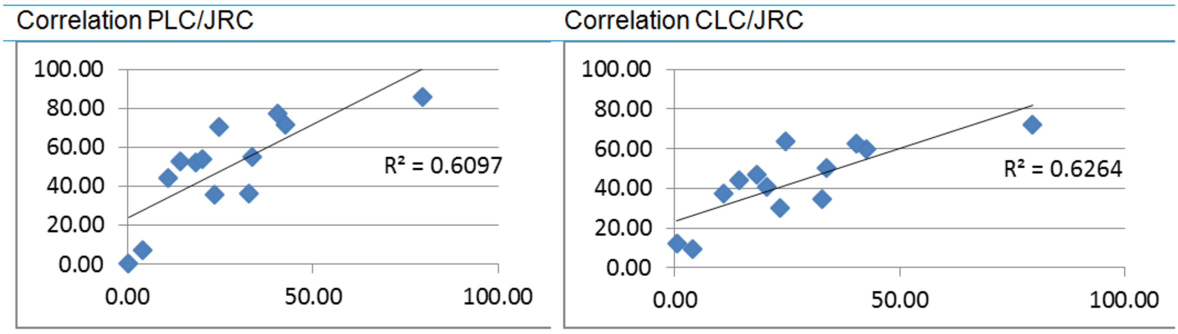


Figure 2.13: Scatterplots and linear correlation coefficients for woody vegetation from PEGASO land cover (PLC, left) and CORINE land cover (CLC, right) against average for country from JRC data

At the CASEs level, the same reference data for applied for the four EU cases and another product was applied for the Nile Delta case. It is the land cover map developed by NARSS at very high spatial resolution, specifically for the purposes of PEGASO. The average areas per case and buffer from coast are shown in Table 2.10. The correlations (Figure 2.14) for woody/natural vegetation for these five cases are rather low for the two sources (R2=0.22 for PEGASO land cover and R2=0.39 for CORINE land cover). The two sources show quite similar averages for most units. Therefore, it can be confirmed that more accurate data sources are needed to analyse natural areas at case level. Higher correlations were registered, however when analysing the spatial variation as averaged per case and dominant land type, as shown on Figure 2.15. A possible reason, for obtaining higher correlation when considering DLT, rather than coastal buffers could be that much of the land within the first coastal buffer, of 1km may be affected by differences in the coast definition and detection by the three sources. In the case of PEGASO land cover, it was observed that most mountainous coasts facing west are obscured by 'shadowing' effects.

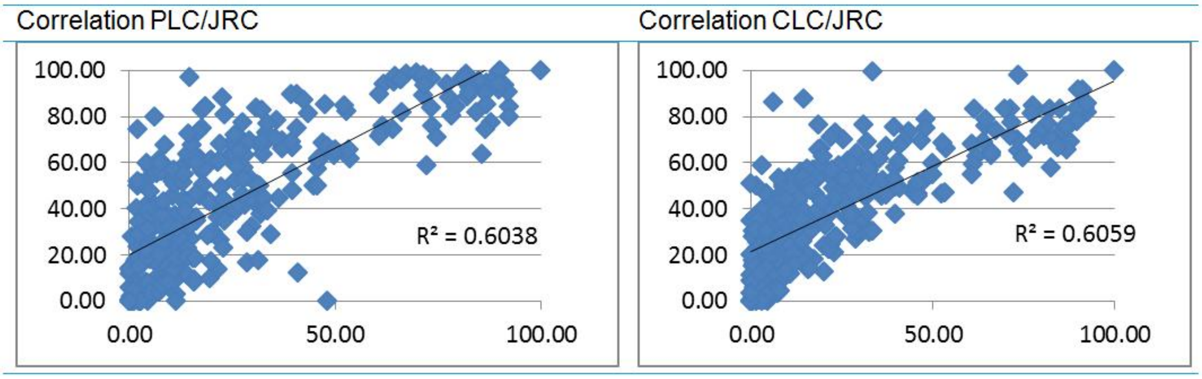


Figure 2.14: Scatterplots and linear correlation coefficients for woody vegetation from PEGASO land cover (PLC, left) and CORINE land cover (CLC, right) for average areas per ecosystem accounting unit estimated from JRC data

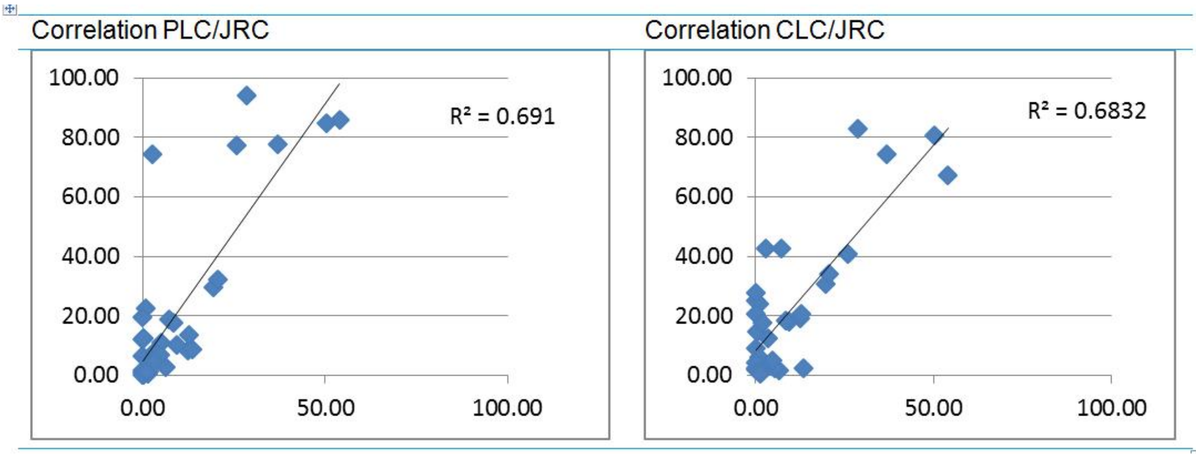


Figure 2.15: Scatterplots and linear correlation coefficients for woody/natural vegetation from PEGASO land cover (left) and CORINE land cover (right) per DLT and CASEs

Table 2.10: Forested areas and difference between CORINE, PEGASO and JRC forest map for the 5 CASEs

cases	buffers	mean JRC forest	mean PLC forest	mean CLC forest
	10000	13.14	20.40	22.18
Bouches-du-Rhone	50000	28.44	42.05	41.59
	1000	0.91	27.68	24.72
Cyclades	10000	3.69	57.05	37.51
	1000	0.93	3.75	13.05
Danube Delta	10000	1.70	3.52	6.09

	50000	6.38	10.12	11.79
	1000	4.09	3.01	3.60
	10000	2.67	1.81	1.86
North Adriatic	50000	1.64	3.06	1.37
Nile delta	all	3.35	4.45	

2.5.2 Evaluation of accounts on urban areas

Urban areas from PEGASO and CORINE Land cover were compared to high resolution map of per cent sealed soil (downloaded from EEA7 website), representing artificialized surfaced in year 2006. Artificial cover was consequently considered equivalent to urban land cover and the corresponding classes from CORINE and PEGASO land cover, grouped at level 1. The artificial cover was mapped at 20m spatial resolution using SPOT imagery. For the purpose of comparing the three sources, the area coverage was sampled in the same way as for woody vegetation, and in addition a temporal adjustment had to be done for the PEGASO land cover product. The adjustment was done by estimating the difference between 2000 and 2011, deriving the annual rate of change, and applying 6-year increment to the value in year 2000. The mean area of urban cover per country and buffer zone is shown in Table 2.11.

Table 2.11: Urban areas from CORINE, PEGASO and EEA soil sealing map per country and buffer zones

country	**buffer**	**mean EEA sealed soil**	**mean PLC urban**	**mean CLC urban**
Albania	1000	3.03	4.64	8.27
Albania	10000	1.64	1.94	6.67
Albania	50000	0.76	1.67	3.31
Bosnia and Herzegovina	1000	6.64	3.82	7.64
Bosnia and Herzegovina	10000	0.69	0.55	0.79
Bosnia and Herzegovina	50000	1.19	1.55	1.38
Bulgaria	1000	11.72	13.86	21.64
Bulgaria	10000	3.09	3.86	6.69
Bulgaria	50000	1.12	1.68	4.24
Croatia	1000	4.98	4.73	8.03
Croatia	10000	2.30	1.82	2.90
Croatia	50000	0.93	0.44	1.09

7 http://www.eea.europa.eu/data-and-maps/explore-interactive-maps/european-soil-sealing-v2

Cyprus	1000	6.58	13.35	16.37
Cyprus	10000	3.65	6.27	8.62
Cyprus	50000	3.05	5.06	6.76
France	1000	11.13	17.96	22.44
France	10000	5.73	10.91	10.39
France	50000	2.08	3.88	4.34
Greece	1000	2.79	6.81	
Greece	10000	1.68	4.62	
Greece	50000	1.01	1.28	
Italy	1000	11.21	20.20	20.13
Italy	10000	4.12	9.22	6.28
Italy	50000	1.91	3.78	3.44
Malta	1000	10.27	56.04	18.94
Malta	10000	14.74	85.63	30.54
Montenegro	1000	7.66	5.12	15.25
Montenegro	10000	1.29	0.43	1.35
Montenegro	50000	1.17	1.75	1.60
Romania	1000	4.90	3.41	10.12
Romania	10000	1.85	3.07	4.22
Romania	50000	1.26	1.15	4.70
Slovenia	1000	20.66	31.75	23.69
Slovenia	10000	4.47	8.89	3.66
Slovenia	50000	1.29	1.41	1.39
Spain	1000	14.67	22.38	25.63
Spain	10000	6.63	11.58	8.95
Spain	50000	2.04	4.75	3.08

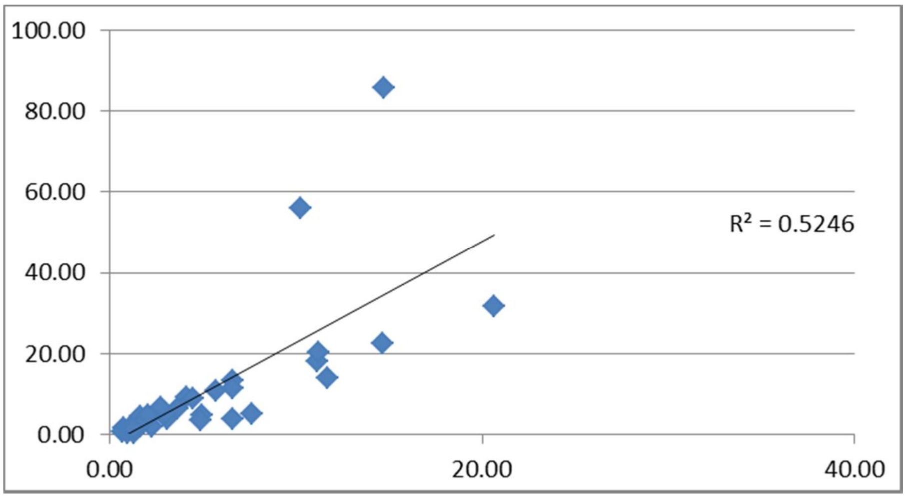


Figure 2.16: Scatterplot of mean urban area coverage/country & buffer zone from PEGASO land cover

The mean values from the three sources show lowest values from the highest precision source, the EEA's sealed soil; higher averages from the PEGASO land cover and generally highest from CORINE land cover, which implies that CORINE estimates are mostly exaggerated. The correlation coefficients (Figure 2.16), however, shows that CORINE's estimates (R^2 = 0.87) with the reference source are higher than PEGASO estimates (R^2=0.53). On the scatterplot several distinct outliers can be observed, which show exceptionally high of urban land in PEGASO land cover, e.g. for Malta. If these outliers are cleared the correlation coefficients will be R^2 = 0.89 for PEGASO land cover and R^2 = 0.86 for CORINE land cover. At the level of coastal accounting units, CORINE preserves very high correlation while PEGASO land cover diminishes.

Table 2.12: Mean coverage of urban/artificialized areas from CORINE, PEGASO and EEA soil sealing map per case and buffer zones

Case	buffer	mean EEA sealed soil	mean PLC urban	mean CLC urban
Bouches-du-Rhone	1000	15.77	26.45	24.80
	10000	8.62	21.29	15.00
	50000	4.55	15.05	8.98
Cyclades	1000	1.32	5.23	
	10000	0.58	3.66	
Danube Delta	1000	4.27	2.60	9.07
	10000	1.84	3.08	4.17
	50000	1.36	1.34	4.77
North Adriatic	1000	6.04	15.54	13.46
	10000	3.53	11.42	8.10
	50000	4.19	11.03	9.06

Nile delta	all	3.80	2.00	

At CASEs level, average coverage of urban area is shown for the coastal stripes of the cases in Table 2.12. At CASEs level the average coverage of urban land is exaggerated by the two sources, as shown on regional level. However for the French and Italian cases, the exaggeration is higher for PEGASO land cover. The correlation coefficients (Figure 2.17) are very high for CORINE land cover, but also high for the PEGASO product.

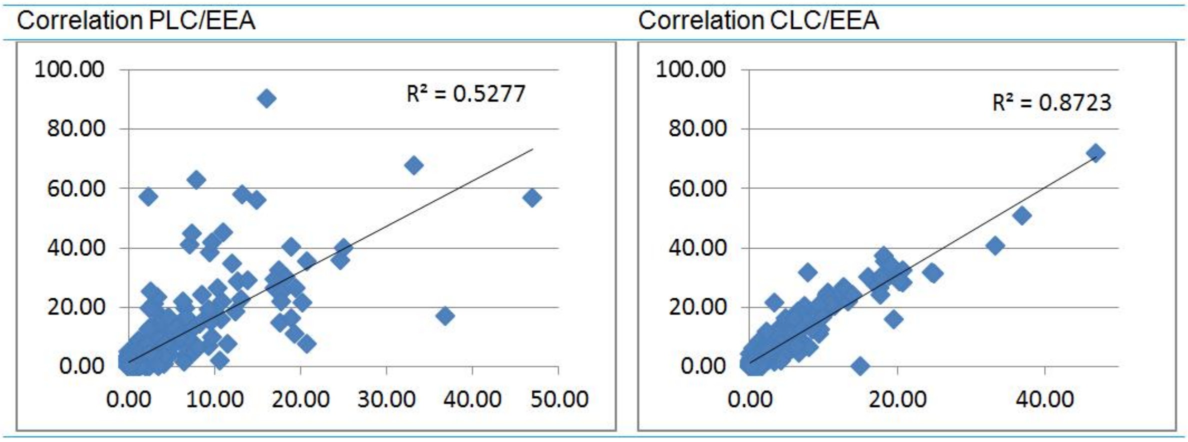


Figure 2.17: Scatterplots and linear correlation coefficients for urban/artificialized land from PEGASO land cover (left) and CORINE land cover (right) for average areas per ecosystem accounting unit

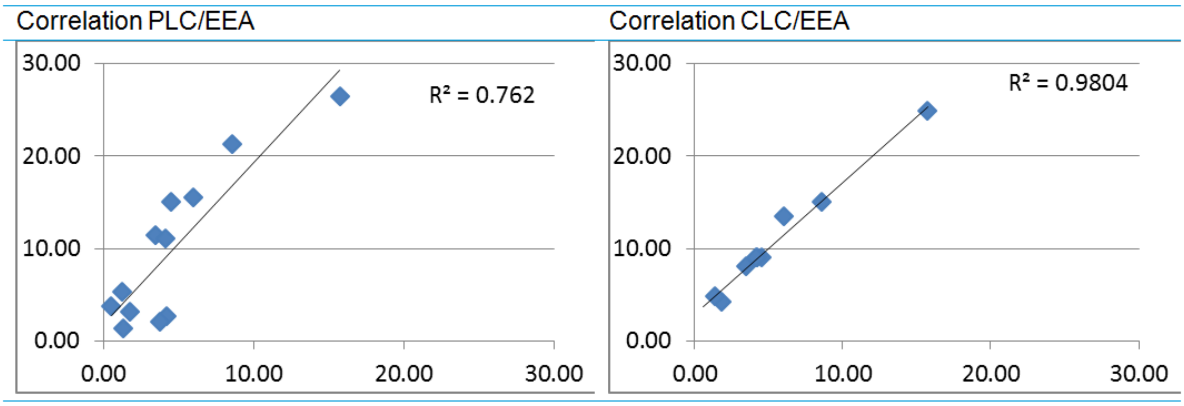


Figure 2.18: Scatterplot and correlation coefficients for cases with three coastal buffers

The correlation coefficient for PEGASO land cover increases to R2 = 0.83 when estimated for averages per DLT, possibly due to the same effects commented above, for woody and natural vegetation (Figure 2.18).

2.5.3 Testing the accounts: Implications for the Accounting Database

According to the evaluation results, both sources of accounting inputs CORINE land cover and PEGASO land cover compare well with independent and high precision reference data on forested and artificialized land in Europe. PEGASO land cover is more appropriate for assessments at wide regional level across the entire Mediterranean and Black Sea basins, while CORINE land cover performs better at higher spatial detail level. Both sources, show deficiencies of accuracy when assessed at local, CASEs level, although to a lesser extent for urban/artificialized areas. Clearly where more precise or customised land cover data are available, as in the Nile, it would be more appropriate to use these data sources for local applications. However, the existence of the PEGASO land cover product offers the possibly of comparing local trends and patterns with other areas using a consistent reference source. Thus also the data sources used for testing the accounting outputs were identified as separate elements in Table 2.2, all form part of the overall, integrated accounting resource made available by the Project.

2.6 Using Land and Ecosystem Accounts: Building ICZM Applications

As noted above, the focus of the accounting work in PEGASO has been to build practical applications that can support decision making in the coastal zones. We therefore now turn to the results from this work, which first cover the accounting input to the PEGASO Integrated Regional Assessment (IRA). In the second part of this section we look at more local types of application at the scale of three of the PEGASO Cases.

2.6.1 Accounting and the Integrated Regional Assessment[8]

The work done in support of the PEGASO IRA included:

- Application of land-cover and protected areas accounts to assess progress towards preservation of natural capital, and;
- Application of land accounts to assess to track progress towards balanced urban development in Mediterranean and Black-Sea coastal areas.

Two sources of land accounting inputs, covering a 50km wide coastal stripe of the Mediterranean and the Black Sea were used, the CORINE land cover and PEGASO Land Cover Product. The land cover data held in the LEAC database were extracted into a set of accounting units defined by intersecting administrative divisions (source: World administrative divisions) and the 1km, 10km and 50km buffers around the coastline of the two sea basins. In this way accounts for urban, natural and protected areas were prepared for various spatial units, namely: countries; countries and coastal buffer divisions; and units defined by the intersection of administrative divisions and the coastal buffers. The mapping and other data are available on the PEGASO SDI.

8 For full details see Santoro and Barbière (2013) (eds): *Report on the Mediterranean and Black Sea Basin Integrated Regional Assessment.* Deliverable D5.2. EU FP7 Project PEGASO Grant agreement nº: 244170

2.6.2 Urban sprawl assessment at the basin scale

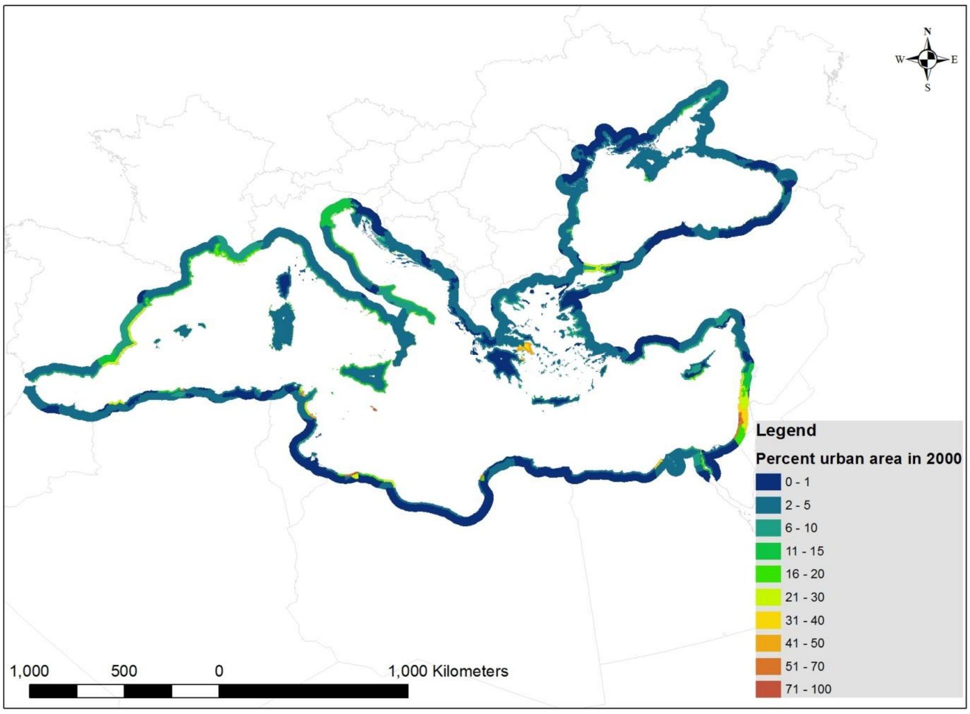


Figure 2.19: Map of proportion of urban areas from total are of coastal accounting units, estimated from PEGASO Land Cover in year 2000

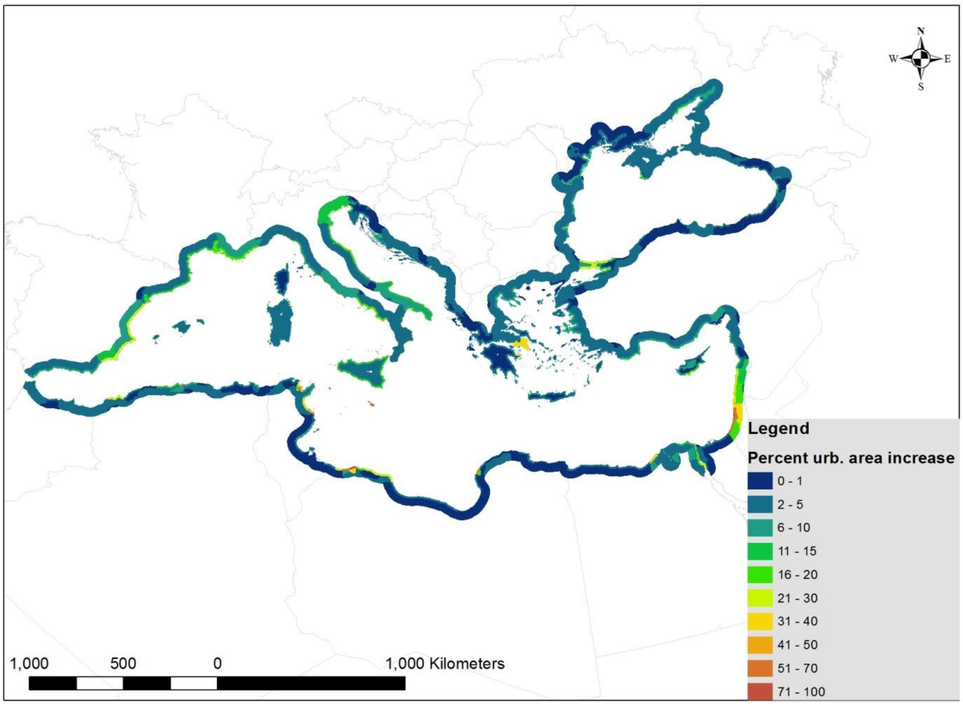


Figure 2.20: Map of proportional change in urban areas from total unit area between 2000 and 2011 from PEGASO land cover, per coastal accounting unit

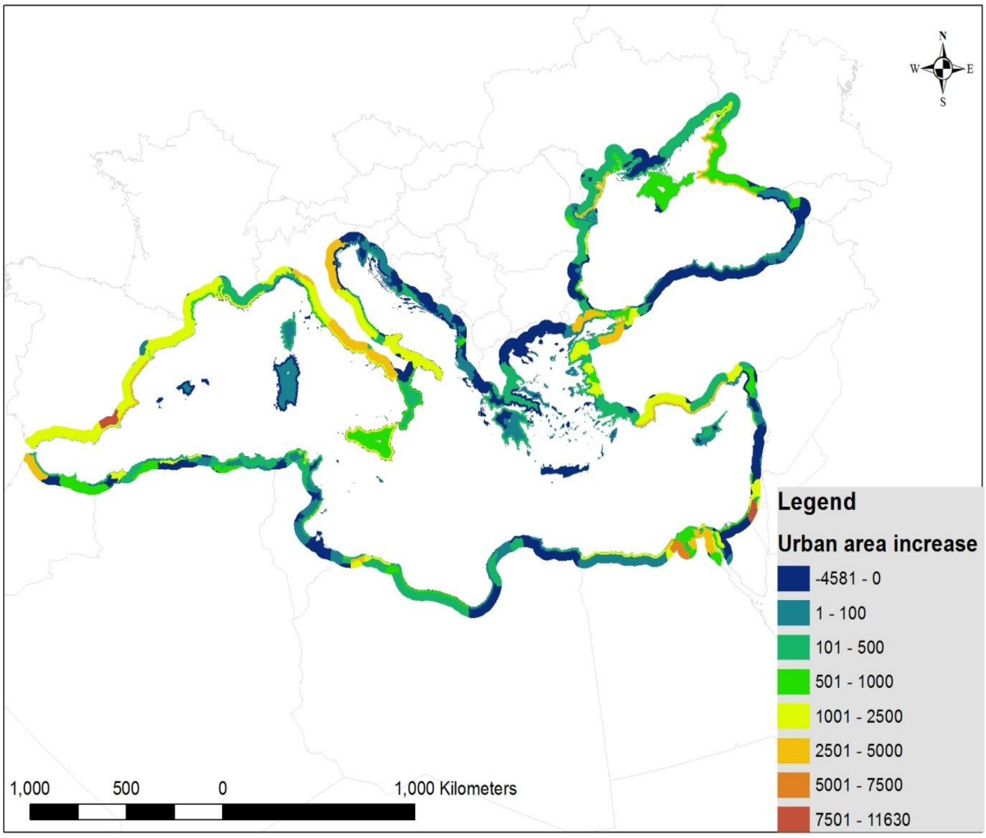


Figure 2.21: Number of hectares increase in urban areas between 2000 and 2011 from PEGASO land cover, per coastal accounting unit

The extent of the area of urbanized land within the 50km coastal strips of the countries was assessed in four categories:

- Highly urbanized, above 25%
- Intermediate, between 3% and 25%
- Low, between 1 and 3%
- Very low, below 1%.

Change between 2000 and 2011was categorised as follows:

- Increase, exceeding 1.5% can be considered high
- Increase between 0.5 and 1.5% intermediate
- Increase between 0.1 and 0.5% is low
- Decrease between -0.1 and -0.5% is low
- Decrease between -0.5 and -1.5% – intermediate

The accounting outputs were extracted from the integrated database, using pivot tables, and linked to the coastal ecosystem accounting units. Examples of the mapped output are shown in Figures 2.19, 2.20 and 2.21. The first of these figures shows the stock of urban land in 2000. The high percentages of urbanized land on the

Spanish and French coasts are apparent, along with the developed areas of Athens and Istanbul, and the Near-East Mediterranean coast. These data provide a baseline against which change can be measured for the different divisions and buffer strips. Figure 2.20 shows the change data for the administrative districts in the 50km coastal buffer, and highlights that in percentage terms it is highest on south and east Mediterranean coasts. Figure 2.21 shows the same data expressed as total numbers of hectares of urban area increase. Clearer patterns are to be seen in this map product, with marked increases in the north Mediterranean countries. High absolute rates of increase can also be observed in the north and west Black Sea Basin.

In the context of the PEGASO, these data were used to show that the different regions across the Mediterranean and Black sea coastal have had different trajectories in terms of urban land cover. Generally the northwest Mediterranean coast has been more extensively developed and at an earlier stage. Consequently, more development has taken place in the hinterland of the coastal zone during the last decade. In the south, developments have occurred more intensively during land decade but mostly in the vicinity of existing urban centres. The most densely and intensively developed coast is in the Near-eastern countries, namely Israel and Lebanon. In the Black Sea, rates of coastal development have been rather higher within the first kilometre of the coastal zone, compared to further inland.

2.6.3 Natural capital assessment at basin scale

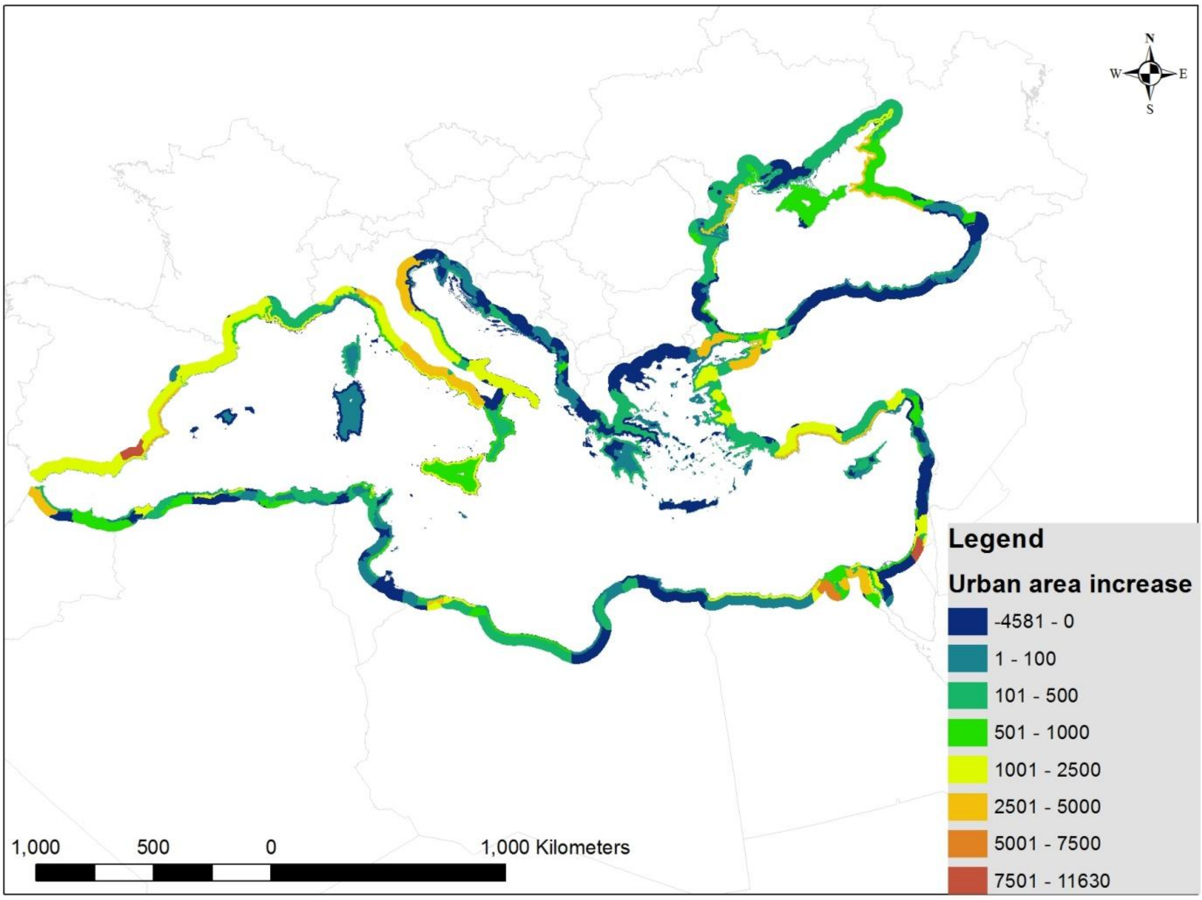


Figure 2.22: Map of natural area accounts from PEGASO land cover in year 2000, estimated as a proportion of the total area the coastal accounting unit

The accounts for natural capital were based on the areas of forests and open surfaces, wetlands and water surfaces (i.e. classes 3, 4 and 5 from level 1 of PEGASO and CORINE land cover classifications). The areas of these 'natural areas' within the 50 km coastal stripes of the countries are assessed in four categories:

- High, above 60%
- Intermediate, between 30% and 60%
- Low, between 15 and 30%
- Critically low, below 15 %.

The temporal changes in natural areas were assessed as follows:

- Increase, exceeding 2.5 % can be considered high
- Increase between 1 and 2.5% intermediate
- Increase between 0.1 and 1% is low
- Decrease between -0.1 and -1% is low
- Decrease between -1 and -2.5 – intermediate
- Decrease of more than -2.5, is high.

The accounting outputs were prepared in the same way as for the urban areas and linked to the coastal accounting units as before. Figure 2.22 shows the share of natural areas in the coastal zone across the two sea basins. While overall the African coast of the Mediterranean stands out for having high levels of natural cover, the lower proportional cover along the north shore of the Black Sea is especially apparent. However, a more detailed comparison across the three coastal buffer strips indicates that coastal areas of the Black sea countries contain higher percentages of natural land compared to the hinterland (e.g. in Bulgaria, Romania, Ukraine and also in Algeria). Several of the Mediterranean countries (e.g. Spain, France, Israel and Italy) tend to show the opposite, that is a lower share of natural land closer to the coast line. Figure 2.23 shows the changes in natural cover between 2000 and 2011. From these data it is evident that there has been an increase of natural areas in the north Mediterranean (except Andalucía), and decrease in the south (except Algeria). The highest rate of natural area increase is to be found for the 10 km coastal zone of the Italian Adriatic area, and in parts of Spain, Greece, Bulgaria and Turkey.

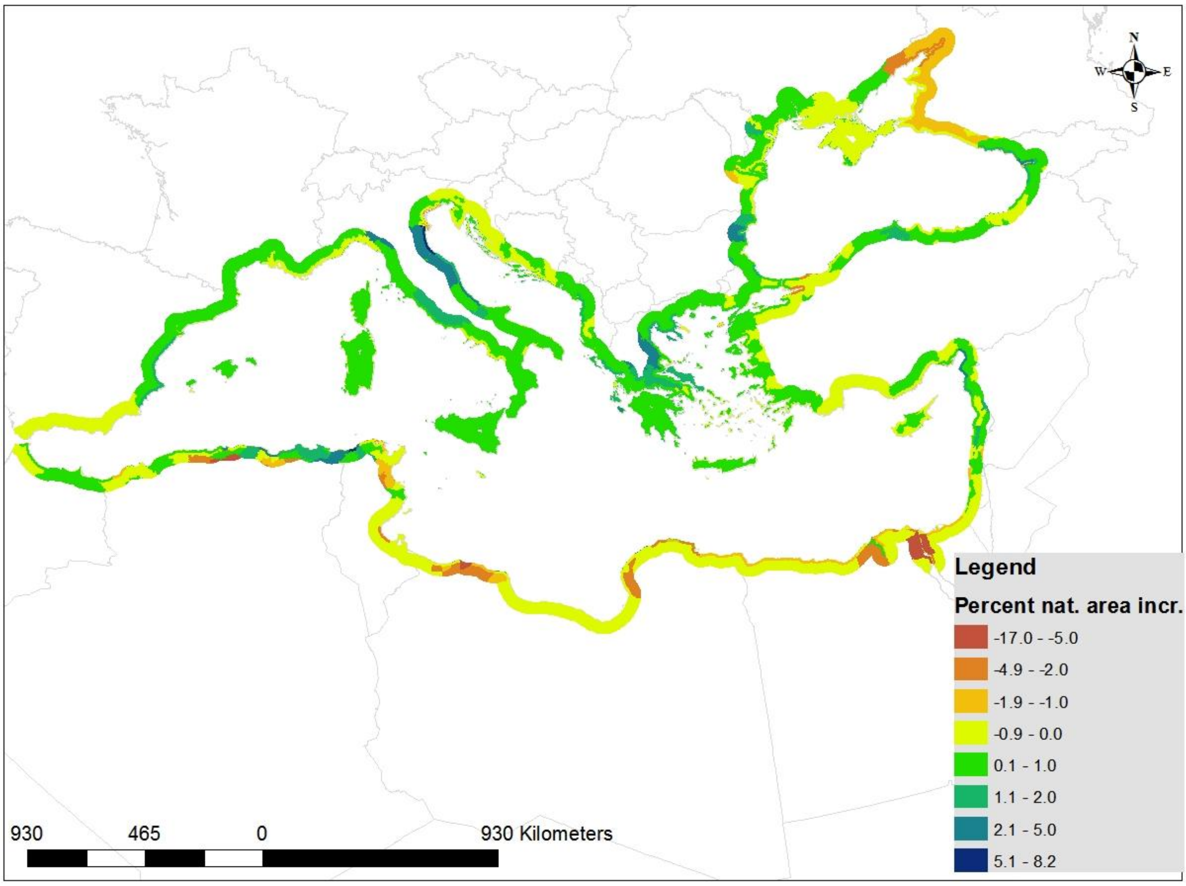


Figure 2.23: Map of temporal change of natural areas from PEGASO Land cover (between 2000 and 2011), expressed as a proportion of total unit area of the coastal accounting unit

As a complement to the estimates of cover of natural areas, the proportional areas within a protected zone were also estimated by country and buffer strip, using the data from the *World Database of Protected Areas*9 (Figure 2.24). The northern countries, especially the ones part of the EU have relatively high proportion of their coast within a protected area, while certain countries from the south Mediterranean do not appear to have any. It is important to note that this situation could be due the difficulty of collecting data for these countries for inclusion in the global source used for this assessment.

9 http://www.wdpa.org/

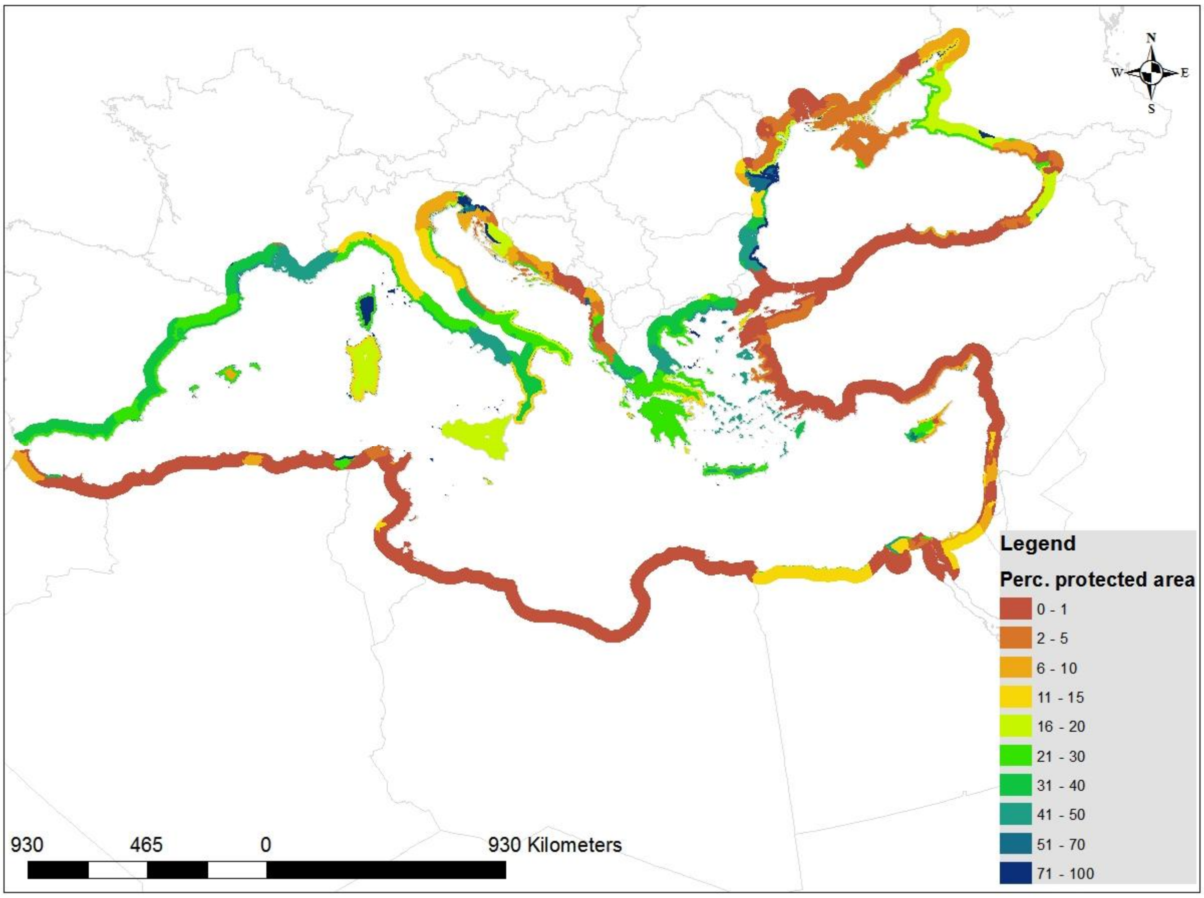
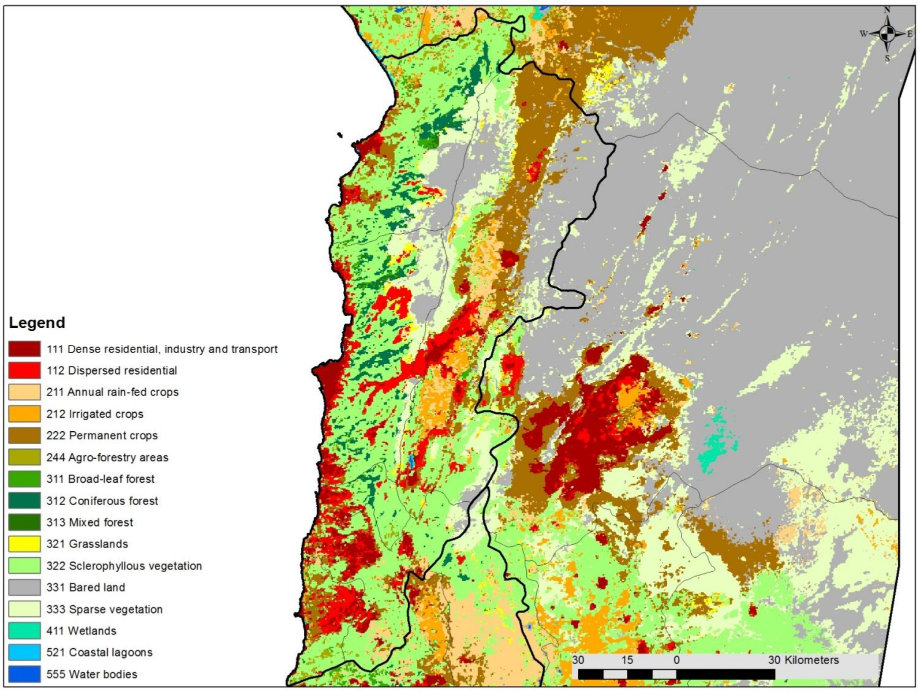


Figure 2.24: Proportion of protected areas for three coastal buffers per country

2.6.4 Case-scale applications

Urban area in 2011 and net change since 2000									
		1 km buffer			10 km buffer			50 km buffer	
	area unit (ha)	area urban (ha)	%	area unit (ha)	area urban (ha)	%	area unit (ha)	area urban (ha)	%
Lebanon	18100	11456.25	63.29	188900	44456.25	23.53	708400	77762.50	10.98
	net change (ha)	1756.25	9.70		-4200	-2.22		-4581.25	-0.65



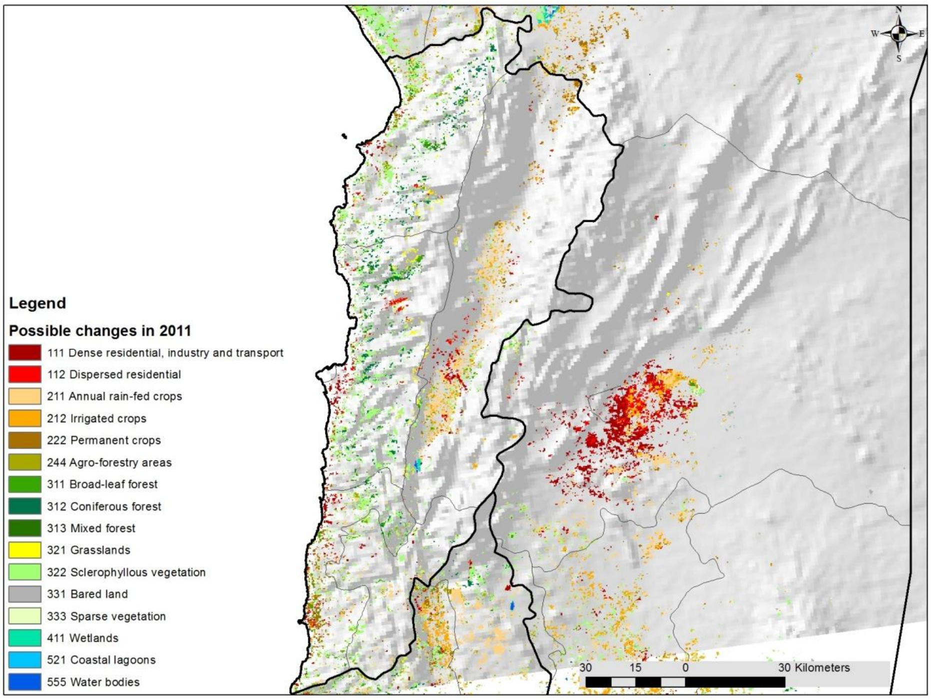


Figure 2.25: Lebanon accounts from PEGASO Land Cover

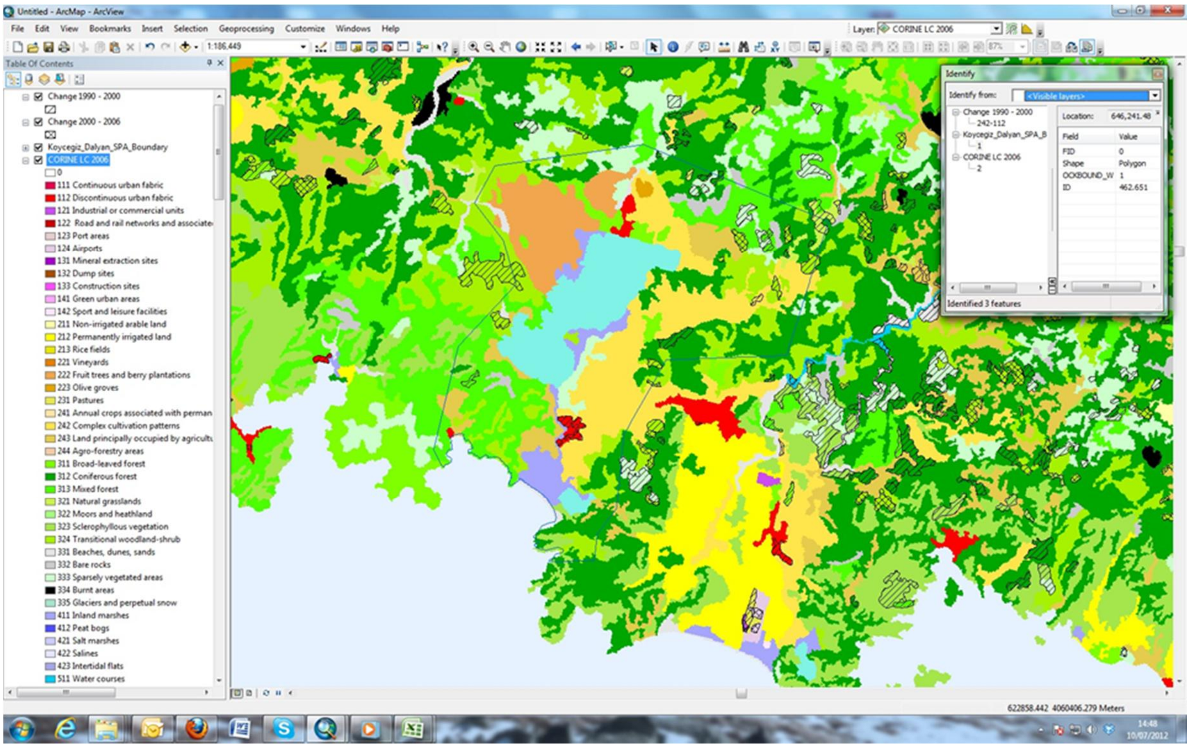


Figure 2.26: Koycegiz-Dalyan SPA site – fast growth of housing developments in Dalyan. Source: Cinar Muhendislik (2007)

Table 2.13: Areas to be submerged in Cyclades according to three scenarios of sea level rise, mapped by the Hellenic Centre for Marine Research

		sea level rise		
		1m	60 cm	30 cm
		area (ha)	area (ha)	area (ha)
111	Continuous urban fabric	21.6	15.0	9.3
112	Discontinuous urban fabric	69.0	42.6	25.7
123	Port areas	1.1	0.6	0.3
131	Mineral extraction sites	9.2	6.9	5.1
133	Construction sites	0.7	0.2	0.0
142	Sport and leisure facilities	10.4	7.1	3.8
211	Non-irrigated arable land	61.5	44.1	29.0
221	Vineyards	3.5	2.1	1.0
222	Fruit trees and berry plantations	10.9	9.6	8.6
223	Olive groves	4.5	1.5	0.1

242	Complex cultivation patterns	652.9	550.8	469.8
243	Land principally occupied by agriculture, with significant areas of natural vegetation	237.4	170.3	110.1
321	Natural grasslands	245.0	170.0	108.7
323	Sclerophyllous vegetation	174.4	123.2	80.8
324	Transitional woodland-shrub	0.1	0.1	0.0
331	Beaches, dunes, sands	10.2	8.1	5.3
333	Sparsely vegetated areas	6.9	6.0	3.5
334	Burnt areas	0.1	0.0	0.0
422	Salines	11.5	6.9	3.4
	Total submerged area (ha)	**1530.7**	**1164.9**	**864.6**

Table 2.14: Land accounts for Bouches du Rhone case

Class of interest	1990		2000		2006	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Urban areas	15225	8.78	15828	9.13	15978	9.21
Agricultural land	50082	28.88	49621	28.61	49481	28.53
Natural or semi-natural land	101363	58.45	96755	55.79	96691	55.75
Transport infrastructures	715	0.41	743	0.43	743	0.43
Industries, mines, dumps	5155	2.97	5174	2.98	5228	3.01
Ports	885	0.51	802	0.46	802	0.46

Table 2.15: Types of land conversion considered in the Bouches du Rhone case discussions with stakeholders

Types of conversion
Conversion of agricultural land to urban area
Conversion of natural or semi-natural land to urban area
Conversion of natural or semi-natural land to agricultural land
Conversion of agricultural land to industrial area
Conversion of natural or semi-natural land to industrial area
Conversion of agricultural land to transport infrastructure
Conversion of natural or semi-natural land to transport infrastructure
Conversion of agricultural land to ports
Conversion of natural or semi-natural land to ports

Accounts from PEGASO Land Cover Product and CORINE mapping extracted for all the PEGASO Cases and following discussion within the consortium were considered in detail for four of them. In summary using these data sources it was found that for:

- The Case area in the Lebanon, between 2000-2011, there has been a loss of urban land in the 10 and 50 km buffers from the coast, and increase of nearly 10 % in the first. (Figure 2.25). The increase in the first kilometre zone could be visually confirmed by very high resolution analysis of land cover change on the Lebanese coast during the period 1998 – 2010 (IOE-UOB, 2012).
- The Turkish Case area there was significant urban sprawl near the protected site within the study area in the period 1990 – 2000, but after this change was more limited and mainly related to forest degradation (Figure 2.26). There has been fast growth of housing developments in the town of Dalyan. The resident population increased from 2200 people in 1986 to nearly 5000 at present. There are many summer houses as well and these are occupied for a fraction of a year. This is certainly not tremendous urban sprawl, but rather fast increase. The more important problem however is housing developments outside the towns (around villages and over agricultural land) that are less controllable (personal communication Özhan, 2013).
- The Greek Case in the Cyclades, significant areas of natural, agricultural and developed land would be vulnerable to loss as a result of sea level rise (Table 2.13). Different types of land to be flooded could be accounted by overlaying the CORINE LC maps for year 2000 with the coastal areas which would be submerged with 1 m sea level rise (largest area, in total 1530,7 ha), 60 cm and 30 cm (smallest area, 864.6 ha). The largest share of land at risk is occupied by 'complex cultivation patterns', grasslands and sclerophyllous vegetation. Developed land to be submerged amounts to 112 ha with 1 m rise, 72.4 ha with 60 cm and 44 ha with 30 cm. Of particular concern is the possible loss of some of the most valued beaches (according to personal communications with Conides and Klaoudatos, 2012). The CORINE class of 'Beaches, dunes, sands' indicates 10.2 ha to be submerged with 1 m sea rise, 8.1 ha in case of 60 cm rise and 5.3 ha with 30 cm.
- The Bouches du Rhone Case there was a loss of natural capital for the study area, with the proportion of natural surfaces falling from 58.45% to 55.75% between 1990 and 2006. These data were discussed extensively with local stakeholders in order to validate the patterns of loss detected in the accounts (Table 2.14). Particular interest was associated with the types of conversion listed in Table 2.15. It was concluded that the loss of natural areas is probably due to a sharp increase of the artificialization of the territory during the same period in some coastal zones. Urbanized areas increased from 8.78% to 9.21% and industrial areas increased from 2.97% to 3.01%. Changes were also seen through the conversion of natural habitats into agricultural areas.

2.7 Discussion, Lessons Learned and Recommendations

Environmental accounting concepts and the data needed to operationalise them are developing rapidly. In this part of PEGASO we have examined how they can usefully be designed to support ICZM. As has been highlighted elsewhere in the Project (Haines-Young and Potschin, 2011; Haines-Young et al., 2013), ICZM is mainly a governance issue, and can only be taken forward by developing appropriate *institutional structures* and *practices*.

In terms of the institutional structures needed to take ecosystem accounting in the coastal zones forward, international initiatives such as SEEA will clearly stimulate work at the national scale. However, the results of these new international standards and requirements will only be available in the long term, and coastal issues will be but one aspect of a much broader ranges of analyses. Thus focussed thematic initiatives such as PEGASO remain essential. The major challenge for such work is ensuring its perennity. The current accounting work in support of the IRA has shown that it is possible to implement an operational system for land accounting across the two sea basins, and that these data are capable of providing information relevant that is relevant for monitoring progress towards the goals of balanced development and protection of natural capital in the coastal zone. A key task for the ICZM governance platform that PEGASO seeks to establish is how to ensure that the data series for land cover that we have established is maintained.

The consistency in measurement that the broad scale PEGASO Land Cover product provides is the basis for a number of ICZM indicators. These will be a useful way of monitoring progress towards sustainable development across the two Basins. ***We therefore recommend that they are taken forward in conjunction with the wider indicators that PEGASO has initiated (Deliverable D4.1), and that appropriate institutional mechanism for maintaining these sources of information are considered as part of the Business Plan that is now being developed as a legacy of the Project (deliverable D2.4B).***

While new institutional structures are needed to ensure the perenity of the accounting methods described here, it is also important to note that one of the key lessons learned from his work namely that the accounts have to be relevant to decision making practice. Throughout the work that we have undertaken in PEGASO we have been aware of the tension between what is theoretically and practically possible in terms of generating environmental accounts and what is useful to those making decisions. We found that although the idea of environmental indicators and mapping was familiar to our CASE partners and end-users, the concept of environmental accounting was new to many of them. Thus while, through our work, some new capacity has been built in terms of understanding, much more remains to be done. The need to stimulate a faster rate of uptake of accounting concepts was one of the major lessons that we have drawn from the work that we have undertaken.

There are, given the range of data now available, opportunities to develop new consistent strategic accounting products across the two Basins for biodiversity and ecosystem productivity. Moreover, given the accounts that are now available and operational, there are opportunities to look more closely at how they can be used in decision making practice at the more local, case-scale. **We recommend that both avenues are actively explored through the activities that will be coordinated through the ICZM Governance Platform.** Two priorities suggest themselves:

- Initiating further work with the case partners who have shown an interest in the current accounting work, to show how the data these accounts provides can be used in support of ‘evidence-based decision making’. If other potential users are to be convinced about the utility of accounting methods then we urgently need some ‘best-practice’ examples that can demonstrate the added value of the accounting approach. ***We therefore further recommend that wherever possible accounting methods are considered in any future work programme developed at the CASE level as a result of their involvement in the PEGASO project, and that the outcomes and benefits of such work are fed back to the wider community through the Governance Platform.***
- Initiating the development of accounts at the broad, strategic scale, to stimulate interest across the two sea basins as a result of comparative analyses such as those done in the PEGASO Integrated Regional Assessment. A key lesson to be taken from the PEGASO Project is that the construction of accounts is not an end in itself. Rather to be useful such data need to be interpreted and the implications discussed and considered. One of the key functions of the ICZM Governance Platform being developed through PEGASO will be to provide this kind of strategic and comparative view. The Integrated Regional Assessment is a kind of ‘state of the environment report’ for the coastal zones of the Mediterranean and Black Sea Basins, and in the future the range of new issues could be considered, and the assessment extended to include reference to new accounting themes such as biodiversity and ecosystem productivity. The ability to map these data, along with land cover and land cover change, will enable people working at the CASE scale to see how their locality sits within the ‘wider picture’. More importantly, such strategic mapping supported by the Governance Platform will enable decision makers to identify those areas undergoing the most rapid and potentially damaging change, or where policy interventions are having a beneficial effect. ***We therefore further recommend that accounting methods are used actively as part of the ICZM Governance Platform that is being put in place through PEGASO, and that the outputs are used to make period assessments of the state of the environment across the two sea***

basins. The availability of such strategic analyses will both help with additional capacity building and stimulate uptake of accounting methods at local scales.

Land and Ecosystem Accounting (LEAC) is one of the many tools that decision makers require to assist them in managing our coastal zones in a sustainable way. These tools therefore need to be integrated with the other tools being explored through PEGASO and seen as part of a broader menu of techniques and methods that are available to the user community (see deliverable D4.6 for more details). The integration and extension of these methods with those more applicable to the marine space is especially important. It is to these issues that the remaining parts of the report are now devoted.

2.8 References

Cinar Muhendislik (2007) Koycegiz - Dalyan Specially Protected Area - Investigations on the biological wealth and preparation of the management plan, Final Report, Prepared for the Agency for Specially Protected Areas, 498 pages + annexes, December 2007 (In Turkish)

Druon, J-N., Schrimpf, W., Dobricic, S. and A. Stips (2004): Comparative assessment of large-scale marine eutrophication: North Sea area and Adriatic Sea as case studies. *Marine Ecology Progress Series* **272**: 1-23.

Edens, B. and L. Hein (2013): Towards a consistent approach for ecosystem accounting. *Ecological Economics* **90**: 41-52.

EEA (2006): *Land accounts for Europe 1990–2000: Towards integrated land and ecosystem accounting*. European Environmental Agency, EEA Report 11/2006.

EEA (2010): *Ecosystem Accounting and the Cost of Biodiversity Losses: The Case of Coastal Mediterranean Wetlands.* Edited by Haines-Young, R.; Potschin, M.; Kumar, P. and J.L. Weber. European Environmental Agency, EEA Technical Report No3/2010.

EEA (2011): *An experimental framework for ecosystem capital accounting in Europe*. European Environmental Agency, EEA Technical Report TR13/2011, Copenhagen (Author: Jean-Louis Weber).

Haines-Young, R. (1999): Environmental accounts for land cover: Their contribution to state of the environment reporting. *Transactions of the Institute of British Geographers* **24**: 441-456.

Haines-Young, R. and M. Potschin (2011): Integrated Coastal Zone Management and the Ecosystem Approach. PEGASO Deliverable D2.1, September 2011, 11 pp. CEM Working Paper No 7. Available under: http://www.nottingham.ac.uk/CEM/WorkingPapers.html

Haines-Young, R.; Potschin, M.; Škaričić, Z.; Shipman, B.; Petit, S.; Breton, F.; Ariza, E. and Y. Henocque (2013): Common conceptual framework for the implementation of ICZM based on the review of current issues. Deliverable D2.1C. EU FP7 Project PEGASO Grant agreement nº: 244170.

Ivanov, E.; Haines-Young R., Potschin, M.; Liquete, C.; Stips, A.; Morisseau F. and N. De Hauwere (2012a): LEAC Data Base. ID4.2.3, V3.0 (Dec 2012), 30pp. EU FP7 Project PEGASO Grant agreement nº: 244170.

Ivanov, E.; Haines-Young, R.; Potschin, M.; Liquete, C.; Morisseau, F. and A. Stips (2012b): Development of Spatial Indicator and modelling. ID4.2.4 Modelling Framework Report. V2.0 (December 2012), 24 pp. EU FP7 Project PEGASO Grant agreement nº: 244170.

Ivanov, E.; Nowell, M. and F. Morisseau (2012c): Revised report on LEAC methodology for coast and marine accounts (Deliverable ID4.2.2). With contributions from F. Beton and R. Haines-Young. EU FP7 Project PEGASO Grant agreement nº: 244170.

Ivanov, E.D.; Weber, J.L.; Spyropoulou, R. and R. Haines-Young (2012d): *Developing an accounting method for species of European conservation importance.* CEM Working Paper No 11_Version.2.0, 12 pp. available from: http://www.nottingham.ac.uk/cem/WorkingPapers.html

Ivanov, E.; Haines-Young, R. and M. Potschin (2013a): Applications of LEAC in PEGASO: An Overview. CEM Working Paper No 12, 11pp. available from: http://www.nottingham.ac.uk/ cem/WorkingPapers.html

Ivanov, E.; Haines-Young, R. and M. Potschin (2103b): Report on Application and Testing of Accounting Tools for IZCM (Deliverable D4.2A). EU FP7 Project PEGASO Grant agreement nº: 244170.

Liquete, C.; Zulian, G.; Delgado, I.; Stips, A. and J. Maes (2013): Assessment of coastal protection as an ecosystem service in Europe. *Ecological Indicators* 30: 205-217.

Parker J.; Steurer A.; Uhel R. and J.-L. Weber (1996): *A general model for land cover and land use accounting.* Invited Paper drafted from the report of the UN-ECE Task Force on Physical Environmental Accounting — Special Conference on Environmental Accounting in Theory and Practice, Tokyo, March 5–8, 1996.

SEEA (2012): *System of Environmental-Economic Accounting: Central Framework.* http://unstats.un.org/unsd/envaccounting/White_cover.pdf

UN-ECE (1995) Conference of European Statisticians Task Force: Physical environmental accounting: land use/land cover; nutrients and the environment. Etudes et travaux, IFEN, Orléans, France.

IOE-UOB (2012) Situational Analysis of the current land use of the coastal zone, particularly in terms of socio-economic activities. Final report: Environmental Resources Monitoring in Lebanon - ERML

Weber, J.-L. (2007): Implementation of land and ecosystem accounts at the European Environment Agency. *Ecological Economics* 61: 695–707.

Western Mediterranean Impact Index on Ecosystem[10]

By Universitat Autònoma de Barcelona (François Morisseau)

Table of content

[10] If you use or refer to any part of this Part please quote as: François Morisseau (2013): West Mediterranean Impact Index on Ecosystems. In: Breton, F; Ivanov, E.; Morisseau, F. and M. Nowell (Eds.) Report, accompanying database and supporting materials on LEAC Methodology and how to apply in CASES. Deliverable 4.2. EU FP7 Project PEGASO Grant agreement nº:244170.

Executive Summary

Understanding where multiple pressures are occurring, their principal source and how they impact marine and coastal ecosystems is essential to support these strategies and is a requirement of the developing marine policies (Marine Strategy Framework Directive (MSFD), EcAp MAP). At present, an integrated qualitative and quantitative understanding of the relationship between pressures and impacts in the marine environment is far from being achieved. In 2007, Halpern et al. provided a way to predict ecosystem response to pressures using expert knowledge. Using this methodology and its developments in more recent studies, a cumulative impact map is being created by Pegaso for the Western Mediterranean Sea (Spain, France, Italy, Morocco, and Algeria). Not only will this approach be consistent and comparable across all marine regions and sub-regions, but it will also enhance the cross-boundary cooperation between EU and non-EU countries assessing the availability of harmonized data for this area. This study will provide a framework to extend the capacity of implementing the cumulative impact index methodology to the rest of the Mediterranean and Black Sea as necessary datasets become available. The cumulative impact map will be an integrative component of the Pegaso toolbox which includes tools such as ecosystem accounts, indicators, scenarios, participatory methods and economic valuation.

3.1 Introduction

Building accounts is an exercise that is strongly data driven. As said in the first part of this report, quantitative data on the quantity and quality of marine habitats/species stocks and flows over time are very scarce (e.g.for benthic habitats) or difficult to use given the high variability of the marine environment (e.g. for pelagic habitats).

Even if we have no exact knowledge of the evolution of stocks and quality of the ecosystems in the marine environment, it is possible to try to anticipate where changes in quality and quantity are most likely to occur by providing spatial explicit assessment of human activities and related pressures.

This kind of assessments are actually explicitly required by ecosystem based framework currently applied in the Mediterranean (Marine strategy framework directive and Ecosystem Approach (EcAp) from Mediterranean Action Plan initiative) as a base for understanding environmental status and fixing targets.

There is a recent effort to estimate and map in a transparent and systematic way the potential impact of pressures on each ecosystem. Halpern et al.(2008), applying a method eliciting expert judgments on the vulnerability of ecosystems to anthropogenic threats, gave one of the first spatial visualization of cumulative impact (from land-sea) at global level and was followed by other papers at smaller scale with refined data (Korpinen et al., 2012; Andersen and Stock, 2012).

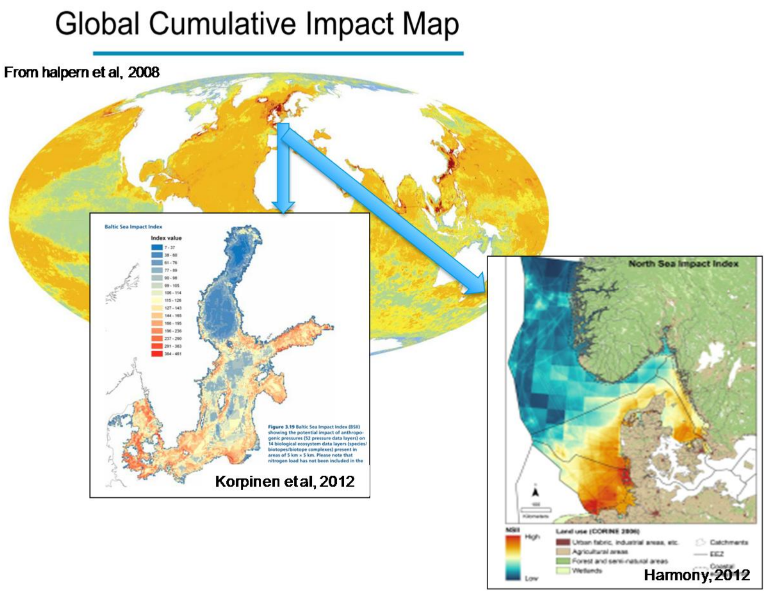


Figure 3.1: Example of work done on cumulative impact using similar methodologies. A: A Global Map of Human Impact on Marine Ecosystems (Halpern et al., 2008); B: Human pressures and their potential impact on the Baltic Sea ecosystem (Korpinen et al., 2012); C: North Sea Impact Index (Andersen and Stock, 2012).

In the framework of the European FP7 project PEGASO (www.pegasoproject.eu), this methodology has been applied to the Western Mediterranean sea with the underlying objectives of:

- Showing where and with which intensity human activities are potentially causing impact on Mediterranean ecosystems;
- Assessing spatial explicit data availability on anthropogenic and ecosystem features for the Mediterranean Sea;
- Obtaining through the expert survey, the vulnerability of Mediterranean ecosystems to anthropogenic and global changes threats; and,
- Proposing a tool to decision makers that allows integrating data from different stressors and ecosystems characterizing their interactions.

3.2 Methods

3.2.1 General framework

The cumulative[11] impact index is based on the model developed by Halpern et al. (2007, 2008) and later developments (Selkoe et al., 2009: Ban et al., 2010, Korpinen et al., 2012, Andersen and Stock, 2012). This methodology is used to evaluate in a systematic way the potential impact of anthropogenic pressures here after called "**stressors**" on different marine ecosystems. **Human uses and land-based pollution** data are considered as proxies for stressors and **Expert judgment** allows estimating the cumulative impact they have on **Ecosystem components for each** 1km^2 as showed in the figure above.

In other words, basing us on the DPSIR framework, the **Drivers** (coastal population, maritime traffic) cause **Pressures** (nutrient inputs, pollution, etc) that depend directly on the intensity and location of the Drivers.

[12] An important underlying hypothesis of these studies and of the present one is that pressures effects act in a cumulative way. It has been showed by number of studies (Crain et al, 2008) that it is not always the case. However, given the actual state of knowledge on the effect of multiple stressors in the marine environment, this hypothesis has been retained.

Those **Pressures** cause **Impacts** on ecosystems that depend on the vulnerability of the ecosystem to the pressure and the intensity of this last.

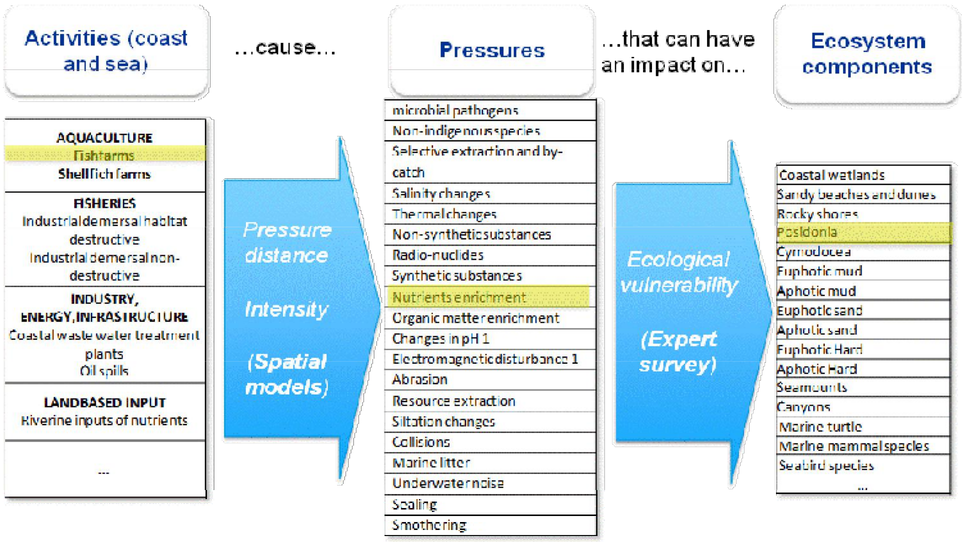


Figure 3.2: Conceptual framework for the impact index development.

Following methodology of Halpern et al. (2008), predictive cumulative impact score are calculated for each cell as follows:

$$I_c = \sum_{i=1}^{n} \sum_{j=1}^{m} P_i * E_j * \mu_{i,j}$$

For each 1km^2 cell: P_i is the log-transformed and normalised value of a pressure *i*, E_j is the surface of ecosystem *j* present in the 1km^2 cell (0 to 1) and $\mu_{i,j}$ is the vulnerability of the ecosystem *j* to pressure *i*.
All the impact score of each pressure over each ecosystem are then added together to create the final cumulative impact index.
The resulting map with impact index value is indicative of the predictive cumulative impact of these stressors on present ecosystems for each 1km^2 cells.

The development of a cumulative impact Index consists in 3 main parallel steps (as showed in figure 3.3) described below:

- **Expert survey**: Gathering expert opinion on the vulnerability of Mediterranean coastal and marine ecosystem components to anthropogenic activities.
- **Spatial data gathering and processing:** Selection gathering and development when necessary a spatial explicit datasets on pressures and ecosystems in the Mediterranean Sea.
- **Index calculation**: Calculation of the cumulative impact index and associated products.

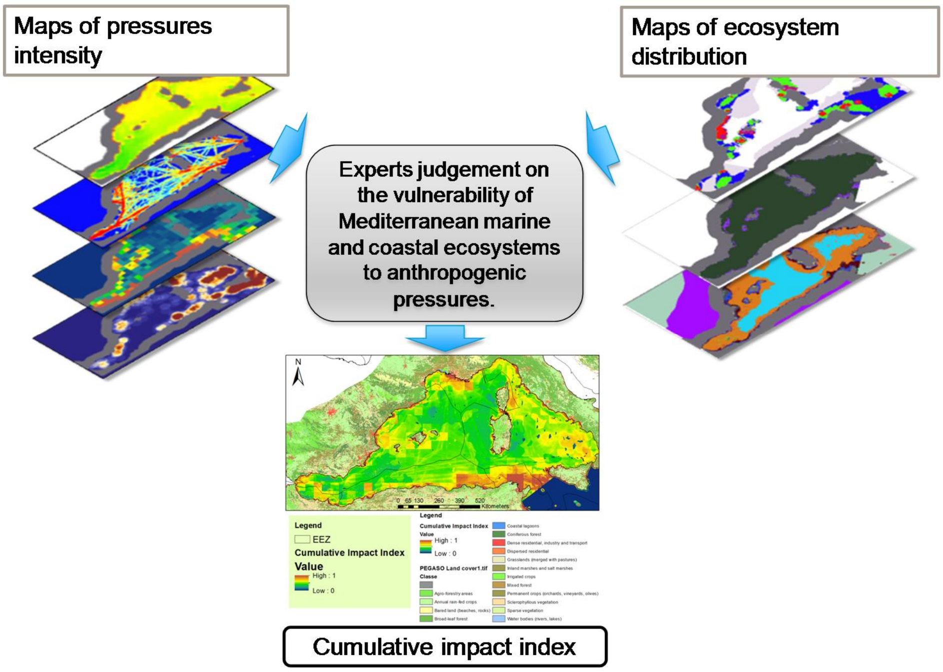


Figure3.3: Schematic representation of the main steps for building the Western Mediterranean Cumulative Impact Index on ecosystems.

3.2.2 Expert Survey

One of the key points to map the impact of multiple human related stressors on multiple ecosystems is to find methods to quantify and compare the responses of different ecosystems to any given stressor.
These methods should be based ideally on field experiments (with few exceptions) and large-scale, long-term coordinated monitoring programs based on robust experimental designs (Claudet and Fraschetti, 2010). However, as shown by the same authors, even if some studies exist, there is still a lack of quantitative information about how marine ecosystems react to human pressures.
Because of this lack, expert opinion is needed to quantify and compare the effect of human based stressors on different ecosystems.
Halpern et al, in 2007, presented a method for eliciting expert judgments on the vulnerability of coastal and marine ecosystems to anthropogenic threats. This method, by asking individually experts to rate on a defined scale the specific vulnerability of one ecosystem to different threats allows defining ecosystems vulnerability in a transparent, quantitative and repeatable way so that results would be easy to update in the future when new data become available.
Following this method, we developed a specific survey for Mediterranean ecosystems that experts could fill in directly in internet. The free open source application **Limesurvey** has been used as support to build this survey.
We selected 350 experts of the different Mediterranean marine ecosystems (e.g. posidonia, deep sea corals, etc…) by publications mainly in scientific journals and environmental reports. We then contacted them by phone and mail asking them to fill in the survey and explaining its goal.
We also contacted other scientific Mediterranean project working on our thematic like COCONET (http://www.coconet-fp7.eu) as they regroup already a number of Mediterranean experts and represent a good platform for the diffusion of this kind of survey.

It is easier for experts working on one specific ecosystem, to define the vulnerability of this ecosystem to several human activities and it is the same for people working specifically on one human activity and its effects. In order to facilitate the work of peolpe from both expertises, we designed 2 different questionnaires that can be fill in either by human stressor (choosing a specific **HUMAN STRESSOR** (e.g. aquaculture) and rating how it could affect the different ecosystem components) or by ecosystem component (choosing a specific **ECOSYSTEM COMPONENT** (e.g. seagrass) and then rating its vulnerability to different human stressors). The chosen approach was indifferent to the final result.

When entering the questionnaire, experts were asked about personal information. Then they were asked:

1) To select the ecosystem component or human stressor that best fit with their knowledge in a list of 25 ecosystem components (see table 3.2) or 28 human activities (see table 3.3)
2) To rate the vulnerability of the ecosystem component to each human human activity listed in the questionnaire or rate the sensibility of each ecosystem component listed in the survey to one human stressor.

The definition of the vulnerability used in the questionnaire is based on the definition admited by Teck et al, 2010, Halpern et al, 2008, Metzger et al. 2005, Millennium Ecosystem Assessment 2005, which defined it as a function of exposure, sensitivity, and resilience to stressors.

As showed in the figure 3.4, experts were asked to rate the **vulnerability** based on 4 factors detailed in the questionnaire with the following definition:

Impact distance: The maximum distance from the location of the activity, the pressure will occur. This impact distance is scored on the following scale (Local, 1km, 5km, 10km, >50km).

Functional impact: The level at which the pressure will cause an impact from individual to the entire population or at community level. The functional impact is scored on this scale (No impact, No impact, Individuals, Population, Entire community).

Resistance: The resistance is the average tendency of the ecosystem component to resist the pressure considered. This resistance is scored on the following scale (No impact, High, Medium, Low).

Recovery time: The recovery time is the average time it takes to the component of the ecosystem to recover after the activity/pressure ceased. The recovery is rated on the following scale (No impact, <1 year, 1-10 years, 10-100 years, >100 years).

Confidence: Expert was asked to rate the general confidence they have in their judgment. Confidence was rated on the following scale (Very high, High, Medium, Low, don't know).

As showed in the figure 3.4, before to judge the vulnerability of one ecosystem to one stressor (e.g. cage aquaculture system), experts were asked to identify the main pressure by which the stressor will affect the ecosystem. This intermediary step has been introduced by Andersen, and Stock, 2012 because one human activity can result in several pressures that can spread over different distances affecting differently each kind of ecosystem. For example aquaculture would affect surrounding benthic ecosystem mainly by nutrient and organic matter enrichment whereas it would affect dolphins and seabirds by changing their comportment and spreading pathogens.

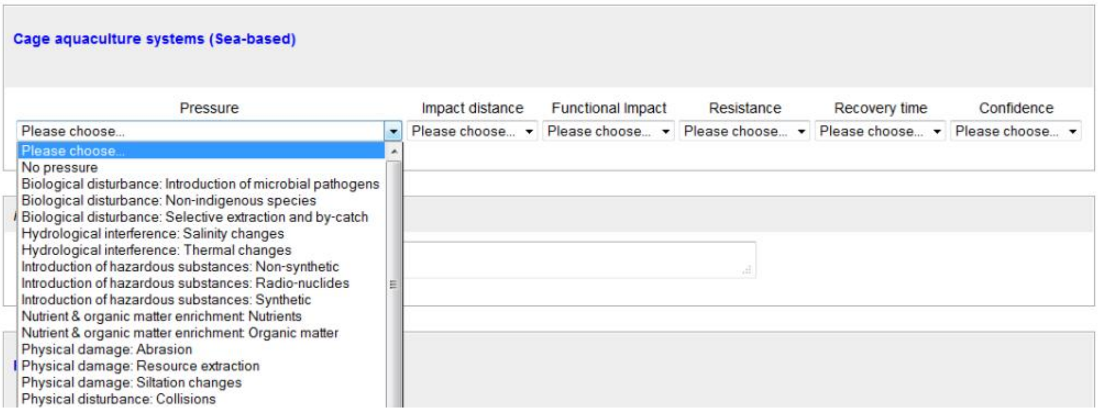


Figure 3.4: Example of the online survey for the activity “Cage Aquaculture (sea-based)” as presented in the online survey.

This additional information allows to explicit the link between the human activity and the impact they cause on ecosystems and improve the spatial representation and quantification of pressures and potential impacts.
Moreover, this information allows the creation of spatial explicit accounts of pressures, as required by the Marine Strategy Framework Directive. In order to be coherent with this policy, the list of pressures used in the expert survey has been defined by using the marine strategy pressures types as shown in the table 3.1.

Table 3.1: Pressure types as used in the expert survey. Most of the pressures have been taken directly from the Marine Strategy Framework Directive.

Pressure	**Description of the pressure following the MSFD**
Biological disturbance: Introduction of microbial pathogens	Introduction of microbial pathogens
Biological disturbance: Non-indigenous species	The biological disturbance derived from introduction of non-indigenous species, and in particular those which become invasive.
Biological disturbance: Selective extraction and by-catch	Selective extraction of species, including incidental non-target catches (e.g. by commercial and recreational fishing).
Hydrological interference: Salinity changes	Significant changes in salinity regime (e.g. by constructions impeding water movements, water abstraction).
Hydrological interference: Thermal changes	Significant changes in thermal regime (e.g. by outfalls from power stations)
Introduction of hazardous substances: Non-synthetic	Introduction of non-synthetic substances and compounds (e.g. heavy metals, hydrocarbons, resulting, for example, from pollution by ships and oil, gas and mineral exploration and exploitation, atmospheric deposition, riverine inputs)
Introduction of hazardous substances: Radio-nuclides	Introduction of radio-nuclides

Introduction of hazardous substances: Synthetic	Introduction of synthetic compounds (e.g. priority substances under Directive 2000/60/EC which are relevant for the marine environment such as pesticides, anti-foulants, pharmaceuticals, resulting, for example, from losses from diffuse sources, pollution by ships, atmospheric deposition and biologically active substances)
Nutrient & organic matter enrichment: Nutrients	Inputs of fertilizers and other nitrogen and phosphorus-rich substances (e.g. from point and diffuse sources, including agriculture, aquaculture, atmospheric deposition)
Nutrient & organic matter enrichment: Organic matter	Inputs of organic matter (e.g. sewers, mariculture, riverine inputs)
Physical damage: Abrasion	Abrasion (e.g. impact on the seabed of commercial fishing, boating, anchoring)
Physical damage: Resource extraction	Selective extraction (e.g. exploration and exploitation of living and non-living resources on seabed and subsoil)
Physical damage: Siltation changes	Changes in siltation (e.g. by outfalls, increased run-off, dredging/disposal of dredge spoil),
Physical disturbance: Other, e.g. collisions 2	Collision (e.g collision between ships and marine mammals)
Physical disturbance: Marine litter	Marine litter
Physical disturbance: Noise	Underwater noise (e.g. from shipping, underwater acoustic equipment)
Physical loss: Sealing	Sealing (e.g. by permanent constructions)
Physical loss: Smothering	Smothering (e.g. by man-made structures, disposal of dredge spoil)
Others: Changes in pH	Changes in water pH
Others: Changes in turbidity	Changes in turbidity of water column
Others: Changes in UV radiation	Changes in UV radiation

-Calculation of the vulnerability

All the answers resulting from the questionnaires were placed in an excel list with 9 columns: Expert name / ecosystem component / Stressor / Pressure /vulnerability scores (impact distance(0-4), functional impact(0-3), resistance(0-3), recovery time(0-4)) and confidence (0-4).

We then rescaled “functional impact” and “resistance” values to range from 0 to 4 (multiplied by 4/3), so all vulnerability measures were comparable.

From the cleaned answers, we conserved a specific combination **stressors-main pressure** only when it has been cited more than 4 times across any ecosystems. Any combination cited less than 4 times or with any missing information was systematically eliminated.

In Halpern et al, 2007, the vulnerability was calculated as the arithmetic mean of the 4 vulnerability scores (impact distance, functional impact, resistance, recovery time).

In this study, pressure layers are spatially explicit and include already the “impact distance” in their calculation (pressures spreading has been calculated using the impact distance defined by the experts). In this situation, including the impact distance in the vulnerability scores would give an overweight to this factor overestimating the impact of large scale pressure such as climate change and underestimating the effects of localized pressures such as abrasion.

Therefore it was decided to exclude the impact distance from the calculation of the vulnerability. For each expert answer, the vulnerability has been calculated as the arithmetic mean of the functional impact, resistance and recovery time.

The final vulnerability score for one combination **ecosystem component-stressor-main pressure** has been calculated as the arithmetic mean of the vulnerability scores given all the experts for this combination. Because of our system where one activity can cause several pressures over one or more ecosystem, we end up with a table where there were no answers for some specific combinations. In those cases we set the vulnerability to 0 if one or more experts have indicated that the activity cause "no pressure" on the considered ecosystem or let the ranking blank in the contrary case.

3.2.3 Spatial data processing

3.2.3.1 Ecosystem components

-Selection and data gap analysis

One of the main steps of mapping the risk of impact of human activities on ecosystems is to select and gather relevant information on ecosystem components.

Habitats and species selected for this study have been identified on the basis of guidance document for the implementation of the EcAp MAP and the Marine Strategy Framework Directive, the goal being to maximize the potential usefulness of the results for the application of those strategies. These documents have been produced to help countries to select priority habitats and species to be monitored in the Mediterranean by defining:

- Three species groups (Marine mammals, birds and reptiles) selected from the Annex II of the SPA/BD Protocol.

- A list of habitats that achieves representativeness across broad categories of habitat types which could include (from shallow to deep): biocoenosis of infralittoral algae (facies with vermetids or trottoir), hard beds associated with photophilic algae, meadows of the sea grass Posidonia oceanica, hard beds associated with Coralligenous biocenosis and semi dark caves, biocoenosis of shelf-edge detritic bottoms (facies with Leptometra phalangium), biocoenosis of deep-sea corals, seeps and biocoenosis of bathyal muds (facies with Isidella elongata).

On the basis of those documents, it was decided to include in this study:

- 5 types of coastal ecosystems coherent with the corine land cover (EUNIS) classification.
- 2 types of seagrass meadows (Posidonia Oceanica and Cymodocea Nodosa)
- 2 specific seabed ecosystems (Submarine canyons and Seamounts)
- 9 benthic habitats and biocenosis classified following the EUSEAMAP[12] classification (coherent both with EUNIS and SPABD classification).
- *Seabirds*[13]
- *4 marine mammal species*[14]
- *2 turtle species*[15]

-Habitat classification

The distribution of benthic habitat used in this study is based mainly on the EUSEAMAP (Cameron, A. and Askew, N. 2011) which is a predictive seabed habitat map (EUNIS level 4) for the Western Mediterranean Sea. Two other works on cumulative impacts have already been developed using the EUSEAMAP results (Korpinen et al, 2012; Andersen and Stock, 2012) respectively in the Baltic Sea and in the North Sea. Both projects have

[12] http://jncc.defra.gov.uk/page-5040
[13] Not include in the final map due to a lack of data
[14] Not include in the final map due to a lack of data
[15] Not include in the final map due to a lack of data

used a generic habitat classification defined by substrate type and light availability (Aphotic/Photic mud, sand or hard bottom) instead of the original EUSEAMAP classification.
As for those studies we had to define a new classification in order to reduce the original number of classes propsed in the EUSEAMP in order to reduce the high number of habitat-pressure combinations (20 habitats×22pressures originally). We had the choice either to fusion some clases of the EUNIS nivel 4 classification based on their response to pressures, either to use the same kind of generic classification used in the Baltic and North Sea Studies.
This kind of generic classification has the advantage to be more realistic in the sense that when experts will judge the vulnerability of the habitat, they will take into account only the measured parameters defining this habitat (light availability and sediment type) whereas with the EUSEAMAP classification, they will judge the vulnerability of an habitat which is a prediction and may not be present in the reality.

Finally it has been decided to keep the EUSEAMAP/SPABD/EUNIS classification for 2 main reasons: a) It should be easier for expert to judge the vulnerability of historically studied habitats with a classification already used in the litterature; and b) the obtained vulnerability will be usable if and where monitoring based data on benthic habitats become available.
The detailed list of habitats considered in this study is available in table3.2.

Table 3.2: Ecosystem component datasets considered in this study (type, availability and origin).

Ecosystem component	Data origin/public availability (In blue when publicly available)	Type of data
Littoral		
Sandy beaches and dunes	Annexe 2	Analysis of Earth observation product (line with presence/absence)
Rocky shores	Annexe 2	Analysis of Earth observation product (line with presence/absence)
Coastal wetlands (Salt marches, Salines, Intertidal flats)	Annexe 2	Analysis of Earth observation product (presence/absence)
Estuaries	Annexe 2	Analysis of Earth observation product (line with presence/absence)
Coastal lagoons	Annexe 2	Analysis of Earth observation product (presence/absence)
Seagrass beds		
Posidonia Oceanica	EUSEAMAP/RACSPA Annexe 2	Compilation all the cartographic information available for this habitat type
Cymodocea nodosa	EUSEAMAP	Compilation all the cartographic information available for this habitat type
Specific deep water seabed ecosystems		
Canyons	Harris and Whiteway, 2012	Interpretation of the ETOPO1 bathymetric grid
Seamounts	RACSPA	
Broad-scale benthic habitats and their communities		
Infralittoral sand and coarse sediments	EUSEAMAP	Modelisation based on physical and morphosedimentary parameters
Infralittoral mud and sandy mud	EUSEAMAP	Modelisation based on physical and morphosedimentary parameters
Infralittoral rock and other hard substrata	EUSEAMAP	Modelisation based on physical and morphosedimentary parameters
Coralligenous and shelf edge rock	EUSEAMAP	Modelisation based on physical and

		morphosedimentary parameters
Mediterranean biocenosis of coastal detritic bottom	EUSEAMAP	Modelisation based on physical and morphosedimentary parameters
Mediterranean communities of muddy and shelf edge detritic bottoms	EUSEAMAP	Modelisation based on physical and morphosedimentary parameters
Mediterranean communities of coastal terrigenous muds	EUSEAMAP	Modelisation based on physical and morphosedimentary parameters
Bathyal hard beds and rocks	EUSEAMAP	Modelisation based on physical and morphosedimentary parameters
Abyssal and bathyal muds, sands and mixed substrata	EUSEAMAP	Modelisation based on physical and morphosedimentary parameters
Seabirds		
Seabirds	RACSPA	Compilation of seabird data and expert knowledge
Marine mammal species		
Monk seal (Monachus monachus)	Giulia Mo and Manel Gazo, personal communication	Compilation of field observations
Fin whale (Balaenoptera physalus)	Druon et al, 2013	Modelisation based on biogeochemical parameters
Sperm whale (Physeter macrocephalus)	No data available for the project	
Dolphin species (Mediterranean sea residents: Stenella coeruleoalba, Delphinus delphis, Tursiops truncates, etc..)	No data available for the project	
Turtles		
Loggerhead turtle (Caretta caretta)	No data available for the project	
Green turtle (Chelonia mydas)	No data available for the project	

-Data harmonisation

In total it was possible to gather data for 22 ecosystem components. Those datasets have been provided in different resolutions and formats (point, line, polygon, raster). There were all projected using the spatial projection ETRS_1989_LAEA and then rasterised at 100m following the PEGASO GRID.
Data on terrestrial, coastal and marine habitats have been all assembled on the same map at 100m resolution ensuring and removing when necessary data overlaps between land and sea datasets (figure 3.6).
Data on canyons (Harris and Whiteway, 2012), Seamounts (RACSPA), Seagrass beds of north African coast (RACSPA) and littoral habitats (Corine land cover, EUROSION and Dataset develop by the Universitat Autònoma de Barcelona) was combined together in order to produce the habitat map used in this study.

As the final resolution of the WMIIE is 1km^2, we combined the 100m^2 resolution map with the 1km^2 PEGASO grid(1km^2 cells INSPIRE compliant). As such, we conserved for each cell of the Grid the information on the surface of each ecosystem present in the cell as showed in the figure 3.7.

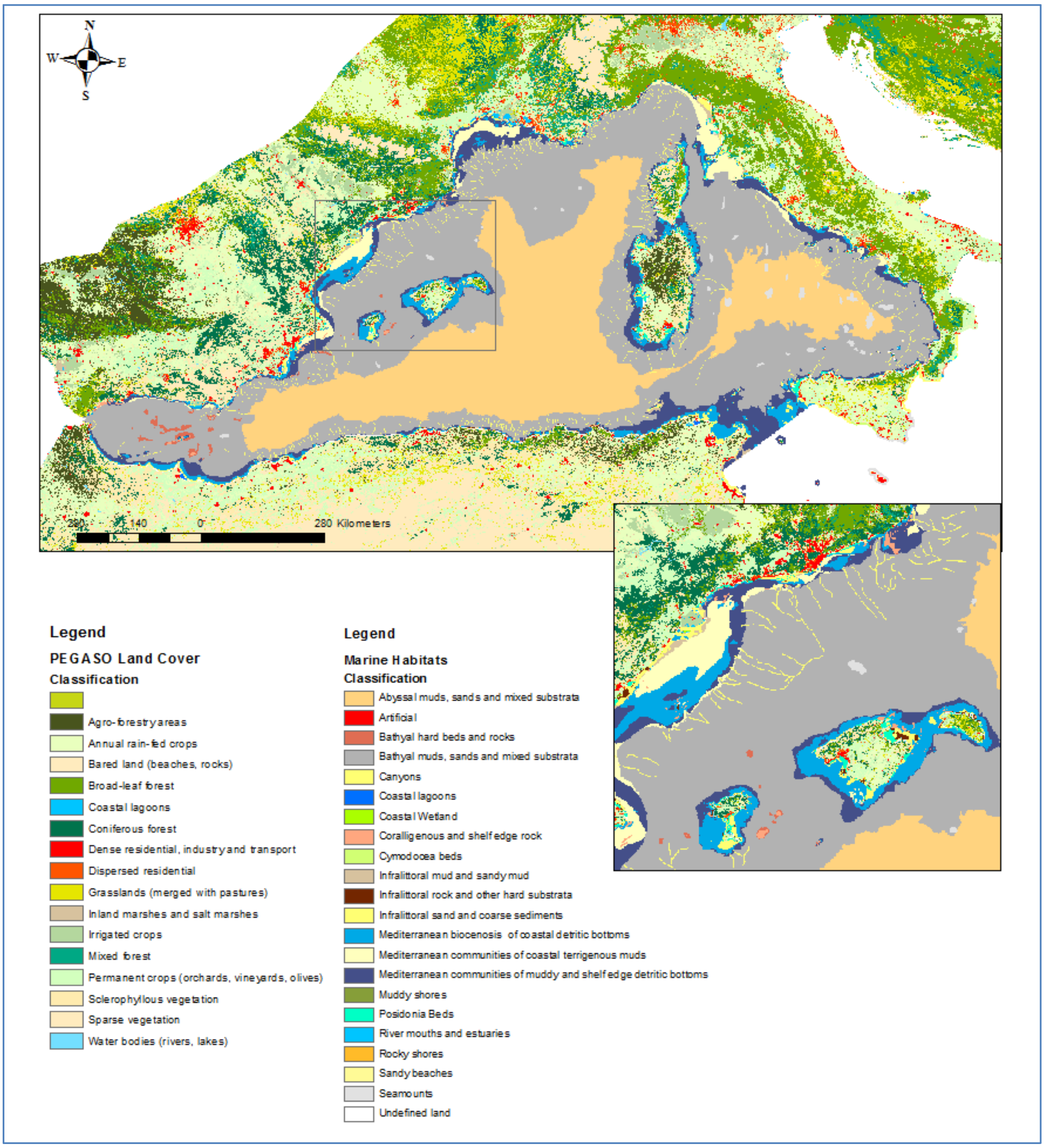


Figure 3.5: Map of the benthic ecosystems as defined in this study (PEGASO Land Cover has been used for the terrestrial part)

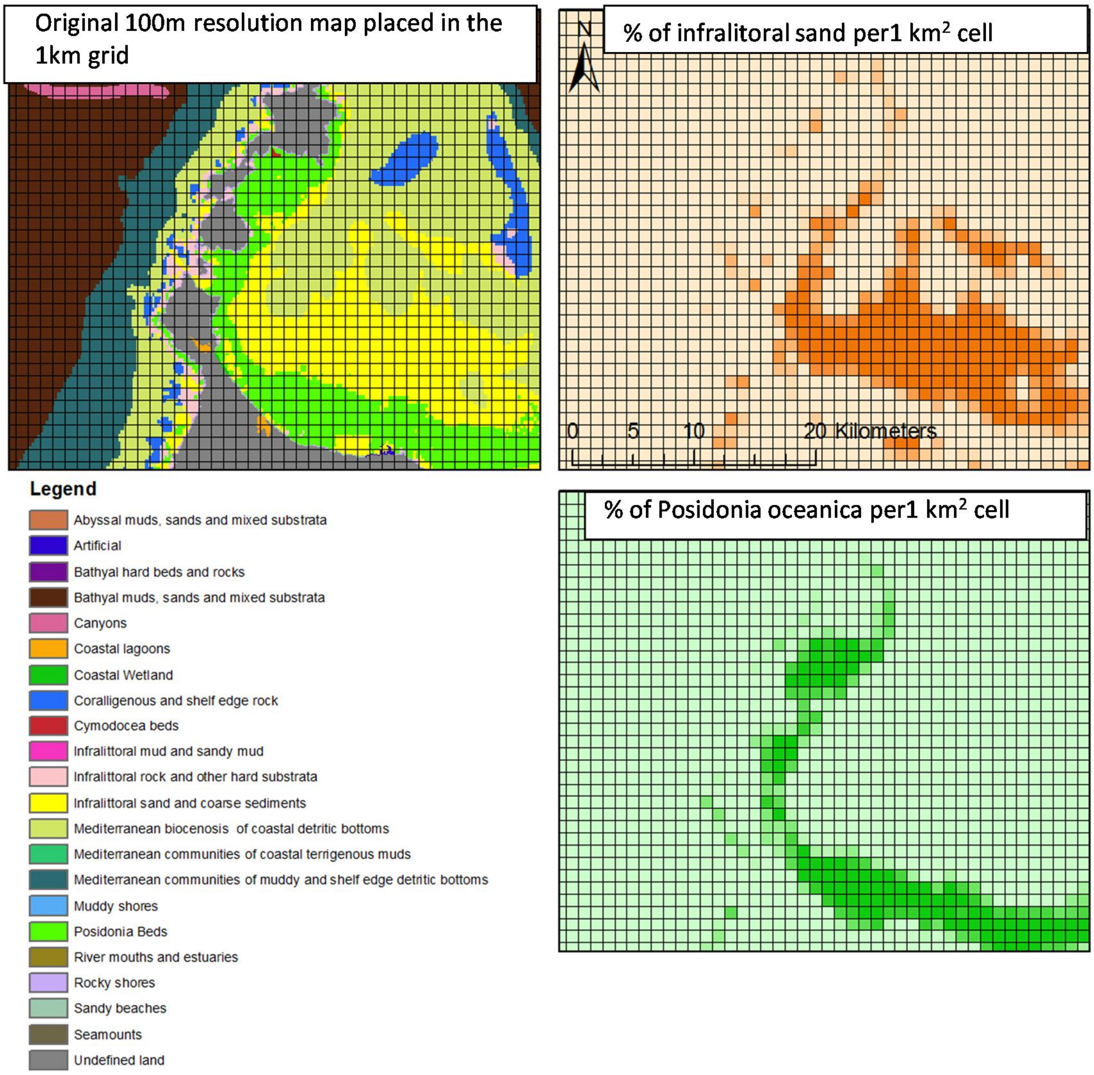


Figure 3.6: Original map at 100m resolution and final result with the proportion of habitat in each 1km grid cell for the habitats infralittoral sand and Posidonia Oceanica.

3.2.3.2 Human activities

-Selection and harmonization of data

The coastal area is affected by a multitude of stressors resulting from land and sea-based human activities.
A significant amount of data is required to represent in a spatial explicit way the intensity of those stressors and activities and surrounding ecosystems
Therefore, an important challenge of applying this methodology was to select the activities/stressors that should be included and then to find data that are harmonised for the study area (Time scale, resolution, coverage).
Human activities/stressors to be included in this study have been selected by using recent published literature (scientific journal, UNEPMAP reports, European Environmental Agency reports). 31 human activities and stressors relevant for the Mediterranean have been identified.

Spatial explicit datasets have been search for those activities/stressors by using relevant scientific literature, online search of ongoing and past projects as well as relevant databases and contacts with Mediterranean and European Governmental and nongovernmental organizations.

We were able to find datasets with acceptable quality for 22 of those activities and stressors (table 3.3).

The different datasets have been projected using the spatial projection ETRS_1989_LAEA and then gridded at 1km using the PEGASO grid (1km^2 cells INSPIRE compliant).

Table 3.3: Human activities and stressors datasets availability and origin.

Human activity/stressor	Data origin/public availability (In blue when publicly available)	Type of data
Land based and atmospheric inputs		
Riverine inputs of nutrients	Halpern et al, 2008	Modelisation by catchement (based on land use and fertilisers inputs): intensity per unit of surface
Atmospheric deposition of nutrient	Kanakidou et al, 2012	Modelisation: quantity per year per unit of surface
Riverine inputs of heavy metals	Halpern et al, 2008	Modelisation by catchement (based on land use): intensity per unit of surface
Atmospheric deposition of heavy metals	Ilyn et al, 2012	Modelisation: quantity per year per unit of surface
Riverine input of organic matter	No data available for the project	
Riverine input of synthetic coumpounds	Halpern et al, 2008	Modelisation by catchement based on (land use and pesticides input): intensity per unit of surface
Turbidity change	PEGASO product (ACRI)	Analysis of Earth Observation product: Intensity of change per unit of surface
Fish farming		
Cage aquaculture systems	No data available for the project	
Pond aquaculture systems	No data available for the project	
Fisheries		
Pelagic, low-bycatch	Reg Watson, personal communication and Halpern et al, 2008	Spatial disaggregation of FAO catch data per area
Pelagic, high bycatch	Reg Watson, personal communication and Halpern et al, 2008	Spatial disaggregation of FAO catch data per area
Demersal, destructive	Reg Watson, personal communication and Halpern et al, 2008	Spatial disaggregation of FAO catch data per area
Demersal, non destructive low bycatch	Reg Watson, personal communication and Halpern et al, 2008	Spatial disaggregation of FAO catch data per area
Demersal non destructive high bycatch	Reg Watson, personal communication and Halpern et al, 2008	Spatial disaggregation of FAO catch data per area
Artisanal	Halpern et al, 2008	Modelisation based on socio economic indicators and distance to ports
Industry, energy, population and		

infrastructure		
Oil rigs (operational)	No data available for the project	
Cables and pipelines	www.sigcables.com http://www.cablemap.info/	Maps of cables distribution (presence/absence)
Desalination plants	No data available for the project	
Coastal population density	Europe: EEA: Gallego F.J., 2010 North Africa: Afripop Project (Linard et al, 2010)	Number of habitant per unit of surface
Coastal waste water treatment plants	No data available for the project	
Marine litter	Lebreton et al, 2012	Modelisation of current quantity of marine debris per unit of surface for 30 years input
Coastal engineering (harbors, dams, dikes...)	EUROSION project MEDINA project	Presence/absence of artificial structures on the coastline
Oil spills	Cinirella et al, 2012 http://sdi.iia.cnr.it/	Analysis of Earth Observation product. Number of observed event per unit of time per unit of surface.
Shipping and transport		
Passenger shipping (Ferries)	David March (SOCIB), personnal communication	Collection and analysis of AIS data: Number of boat per unit of time per unit of surface
Commercial shipping	David March (SOCIB), personnal communication	Collection and analysis of AIS data: Number of boat per unit of time per unit of surface
Major ports	World Port Index from Maritime Safety Association: http://msi.nga.mil/NGAPortal/MSI.portal	Point data
Invasive species	Halpern et al, 2008	Modelisation based on maritime traffic intensity and origine.
Climate change		
Ocean acidification	Halpern et al, 2008	Analysis of Earth Observation product: Intensity of change per unit of surface
Ocean warming	Halpern et al, 2008	Analysis of Earth Observation product: Intensity of change per unit of surface
Increased UV radiation	Halpern et al, 2008	Analysis of Earth Observation product: Intensity of change per unit of surface
Sea level rise	No data available for the project	

-Spatial models

One human activity can result in several pressures that can spread over different distances affecting differently each kind of ecosystem. For example the activity maritime traffic could affect marine mammals by 2 different pressures: Collision and underwater noise, which have a different spatial impact (local in the case of collision and several kilometers in the case of underwater noise). Therefore our model should take into account those differences in the way pressures can spread and affect differently one or several species/habitats.

Taking exemple on the work developped by Anderson and Stock, 2012, it was decided to differentiate the human activity/stressors from the pressure it generates on each ecosystem.
In some cases, the pressure distribution was already modelled explicitly in the dataset (e.g. atmospheric deposition of nutrient and pollutant, oil spills density).

In other cases we used simple functions to model the spreading of the pressure intensity from the activity (e.g. the intensity distribution of the pressure underwater noise has been derived from shipping density)
The maximum distance at which a significant pressure can spread from one activity has been defined using the “impact distance” defined by the expert for each combination activity stressor (see table 3.4)
We used the median “impact distance” for each combination activity-main pressure over any ecosystem. Only combinations with more than 4 answers have been conserved.
The pressure intensity has been then distributed using a decay function inversely proportional to the Euclidian distance from the activity. We assumed that the pressure intensity is highest where the activity occurs and decay to O at the maximum impact distance defined by the experts.

All the pressure layers used in this study have been log transformed (log(x+1)) and rescaled from 0 to 1 in order to be comparable. We obtained in total 46 pressure layers.
The list of human activities and related spatial models used is detailed in the table 3.4.

Table 3.4: the 22 human activities/stressors and associated pressures as defined by the expert survey with associated spatial model (explicit model or median distance and number of respondents)

Activity/pressure	Impact distance (MEDIAN)	Number of experts
Artisanal		
Biological disturbance: Selective extraction and by-catch	Explicit spatial model	
Physical damage: Abrasion, smothering, sealing, ressource extraction	Explicit spatial model	
Cables and pipelines		
Physical damage: Abrasion, smothering, sealing, ressource extraction	Local	22
Physical damage: Siltation changes	Local	4
Physical disturbance: Collisions	Local	5
Coastal engineering (harbors, dams, dikes,...)		
Others: Changes in turbidity	1km	4
Physical damage: Abrasion, smothering, sealing, ressource extraction	5km	13
Physical damage: Siltation changes	5km	15
Coastal population (density)		
Nutrient & organic matter enrichment: Nutrients	10km	11
Nutrient & organic matter enrichment: Organic matter	5km	12
Physical disturbance: Marine litter	10km	10
Commercial shipping		
Introduction of hazardous substances: Non-synthetic	50km	4
Introduction of hazardous substances: Synthetic	50km	4
Physical damage: Abrasion, smothering, sealing, ressource extraction	50km	4
Physical disturbance: Collisions	Local	8
Physical disturbance: Marine litter	10km	5
Physical disturbance: Noise	10km	9
Demersal, destructive		
Biological disturbance: Selective extraction and by-catch	Explicit spatial model	
Physical damage: Abrasion, smothering, sealing, ressource extraction	Explicit spatial model	
Demersal, non destructive, high bycatch		
Biological disturbance: Selective extraction and by-catch	Explicit spatial model	
Physical damage: Abrasion, smothering, sealing, ressource extraction	Explicit spatial model	
Demersal, non destructive, low bycatch		
Biological disturbance: Selective extraction and by-catch	Explicit spatial model	
Physical damage: Abrasion, smothering, sealing, ressource extraction	Explicit spatial model	
Increased UV radiation		
Others: Changes in UV radiation	Explicit spatial model	
Invasive species		
Biological disturbance: Non-indigenous species	Explicit spatial model	
Major ports		
Introduction of hazardous substances: Synthetic	5km	5

Physical damage: Abrasion, smothering, sealing, ressource extraction	5km	5
Physical damage: Siltation changes	10km	8
Physical disturbance: Noise	10km	7
Marine litter		
Physical disturbance: Marine litter	Explicit spatial model	
Ocean acidification		
Others: Changes in pH	Explicit spatial model	
Ocean warming		
Hydrological interference: Thermal changes	Explicit spatial model	
Oil spills		
Introduction of hazardous substances: Non-synthetic	Explicit spatial model	
Introduction of hazardous substances: Synthetic	Explicit spatial model	
Physical damage: Abrasion, smothering, sealing, ressource extraction	Explicit spatial model	
Passenger shipping (ferries)		
Physical disturbance: Collisions	Local	10
Physical disturbance: Marine litter	5km	6
Physical disturbance: Noise	1km	7
Pelagic, high bycatch		
Biological disturbance: Selective extraction and by-catch	Explicit spatial model	
Physical damage: Abrasion, smothering, sealing, ressource extraction	Explicit spatial model	
Pelagic, low-bycatch		
Biological disturbance: Selective extraction and by-catch	Explicit spatial model	
Physical damage: Abrasion, smothering, sealing, ressource extraction	Explicit spatial model	
Riverine input and atmospheric deposition of heavy metals		
Introduction of hazardous substances: Non-synthetic	Explicit spatial model	
Riverine input and atmospheric deposition of nutrients		
Nutrient & organic matter enrichment: Nutrients	Explicit spatial model	
Riverine input of synthetic compounds		
Introduction of hazardous substances: Synthetic	Explicit spatial model	
Turbidity changes		
Others: Changes in turbidity	Explicit spatial model	

3.3 Cumulative indexes construction

3.3.1 Western Mediteranean Pressure Index

Basing us on previous work done by Andersen and Stock, 2012 and Korpinen et al, 2012, we developed a Western mediterranean pressure index.

This index is the result of the sum of the intenstiy of the 22 human activities/stressor layers considering the maximum distance at which each activity can generate any pressure on any ecosystem. For example, for the activity “commercial shipping”, we used the maximum pressure distance defined by the expert “50 km”.

The resulting 22 layers have been simply added following the equation:

$$I_c = \sum_{i=1}^{22} P_i$$

For each 1km^2 grid cells, the intensity I_c of the pressure index is the sum of the intensities P_i of the 22 human activity/stressors defined in the study.
This index allows to see where many pressures are occurring at the same time with high intensity. This index is not ecosystem-related. Pressures are displayed with the same intensity whether or not there are spatially overlappin any sensitive ecosystem.

3.3.2 Western Mediterranean Impact Index

The western mediteraneanImpact Index represents the intensity of the risk of impact of all the human related pressures over all the ecosystems considered.
In this Index all the pressures (and their specific impact distance) related to each human activity/stressor are considered.
For example for the potential impact of the human activity “passenger shipping”, we considered the 3 pressures and related spatial model: “Physical disturbance: Collisions”, “Physical disturbance: Marine litter”, “Physical disturbance: Noise”, and the specific sensibility of each ecosystem to those pressures.
The index is calculated this way:

$$I_c = \sum_{i=1}^{22} \sum_{q=1}^{n} \sum_{j=1}^{m} (S_i, P_q) * E_j * \mu_{q,j}$$

For each 1km2 cell: S_i is the Human activity/stressor, P_q are the log-transformed and normalised value of the pressures *q* related to the stressor i , E_j is the surface of ecosystem j present in the 1km^2 cell (0 to 1) and $\mu_{q,j}$ is the vulnerability of the ecosystem j to pressure *q*.
All the impact score of each pressure over each ecosystem are then added together to create the final cumulative impact index.

3.4 Results

3.4.1 Expert Survey

In total 350 surveys were send and we get back completed questionnaires for 111 of them which give us a response rate of 31.7 % slightly inferior to the response rate of 37% obtained by Halpern et al in 2007.
Most of the experts have opted to answer the questionnaire by the ecosystem entry (77%) whereas only 23% have opted to answer the questionnaire by the human activity entry. This is logical given that we selected experts mostly by published scientific literature that is generally more focused on ecosystems than on human activities.
From the 111 experts that answered the questionnaire, 56% came from academic institutions, 25% from government agencies, 10% from NGOs and 9% from other kind of institutions.
Some ecosystems or human activities have been chosen by experts more than others. In average, 3 questionnaires have been filled in for each ecosystem but more questionnaires have been filled in for posidonia (10 questionnaires), rocky shores and coastal lagoons (6 questionnaires). As said before, fewer questionnaires have been filled in for the entry human activity. In average less than 1 questionnaire has been filled in for each activity (there were no answers for some activities), the exeption being demersal destructive fisheries (6 experts) and aquaculture (4 experts).
When rating vulnerability, experts had the possibility to make comments and provide references supporting their judgement.
It was possible to indentify 5 main types of comments:

- Refences: more than 90 scientfic papers or projects have been cited by respondents to support their judgement.

- For some combinations stressor-ecosystems, experts have indicated that there is currently a lack of knowledge or no information concerning the response of the ecosystem components to the the stressors. These comments were found only for three ecosystem components: Abyssal and bathyal muds, sands and mixed substrata; Bathyal hard beds and rocks; Canyons.

- Some experts have indicated besides the main one asked in the survey, 1 or more pressures related to the effect of one human activity on one ecosystem component. In some case they have indicated additional pressures which were not available in our survey (for example: entanglement for seabirds).

- Numbers of experts have indicated their difficulties considering the current state of knowledge to renseign quantitatively all or some specific factors of the vulnerability. This comment was specifiqualy found for the rating of the recovery time.

- There was also number of comments related to the impossibility of some interactions stressors-ecosystems because of existing local or national legislations or natural factors such as distance.

In total we get vulnerability scores for 3009 combinations ecosystem component-stressor-main pressure. From these answers we removed 789 combinations for which the main pressure has not been indicated or one or more vulnerability factors have not been rated by the expert. The vulnerability factors which were most often missing were the recovery time (70 blanks) followed by the resistance (26 blanks).

We calculated for each human activity, the average vulnerability across all ecosystems. The results of the survey identified Riverine input of synthetic compounds, Riverine input and atmospheric deposition of heavy metals, Oil spills, Ocean warming, Ocean acidification, Riverine input and atmospheric deposition of nutrients, Riverine input of organic matter and Demersal, destructive fishing as the activities to which the ecosystems considered in the survey are most vulnerable ((i.e., highest 30% of vulnerability scores, see table 3.5). For comparison, the 7 global highest threats identified by Hapern et al, 2007 was increasing sea temperature, demersal destructive fishing, coastal development, point-source and nonpoint-source organic pollution, increasing sediment input, hypoxia, and direct human impact.
Similarly, we calculated for each ecosystem the average vulnerability to all human activities/strtessor. Experts considered that the 30% most vulnerable benthic ecosystem components was Estuaries, Infralittoral rock and other hard substrata, Posidonia oceanica, Rocky shores, Infralittoral sand and coarse sediments, Mediterranean biocenosis of coastal detritic bottom and canyons.
When looking at the vulnerability by ecosystems, it appears for example that coastal wetlands was considered more sensible to Cables and pipelines, Coastal engineering (harbors, dams, dikes,...), Coastal population (density) and major ports.
Coralligenous and shelf edge rock was considered to be more sensibles to ocean acidification Demersal, destructive, Oil rigs (operational) and Oil spills whereas experts considered that Posidonia oceanica was more sensible to Major ports, Coastal engineering (harbors, dams, dikes,...), Turbidity changes and Demersal, destructive fishing.

It has to be remembered that those scores represent only the intrinsic vulnerability of the ecosystem wether the activity occurs or not. They shoudn't be interpreted as a risk of impact.

For each human stressor, we identify the relative importance of each vulnerability factor in the final vulnerability score (see table 3.5). Between the 3 factors, the "functional impact" had the highest value for all human activities. Expert considered that in general the recovery time is a less impacting factor of the vulnerability than the resistance. The only 2 stressors for which the recovery time was rated highest than the resistance were "Riverine input and atmospheric deposition of heavy metals" and "ocean warming".

Table 3.5: Mean vulnerability and vulnerability factors for all ecosystems.

Human activity/stressor	**Functional impact (0:No impact, 4:Entire community)**	**Resistance (0:No impact, 4:low resistance)**	**Recovery (0: No impact, 4: >100 years)**	**Confidence (0: Don't know, 5: Very high)**	**Vulnerability**
Riverine input of synthetic compounds	2,40	2,37	1,91	2,85	2,22
Riverine input and atmospheric deposition of heavy metals	2,77	1,66	2,17	3,13	2,20
Oil spills	2,53	2,18	1,77	3,30	2,16
Ocean warming	2,36	1,96	2,00	2,81	2,11
Ocean acidification	2,11	1,83	1,79	2,50	1,91
Riverine input and atmospheric deposition of nutrients	2,56	1,77	1,33	2,89	1,88
Riverine input of organic matter	2,35	1,80	1,32	3,27	1,82
Demersal, destructive	2,03	1,96	1,41	3,21	1,80
Invasive species	1,70	1,49	1,41	2,81	1,53
Desalination plants	1,88	1,58	0,98	3,17	1,48
Turbidity changes	1,86	1,48	0,96	2,99	1,44
Marine litter	1,35	1,57	1,31	3,33	1,41
Demersal, non destructive, high bycatch	1,44	1,49	1,14	3,14	1,36
Increased UV radiation	1,22	1,35	1,18	2,39	1,25
Artisanal	1,28	1,32	0,96	3,22	1,19
Coastal waste water treatment plants	1,47	1,22	0,83	2,92	1,18
Coastal engineering (harbors, dams, dikes,...)	1,32	1,18	0,99	3,06	1,17
Coastal population (density)	1,39	1,09	1,01	2,80	1,16
Demersal, non destructive, low bycatch	1,08	1,16	0,84	3,04	1,03
Oil rigs (operational)	1,07	1,01	0,83	2,96	0,97
Cables and pipelines	0,77	0,96	0,71	2,85	0,81
Major ports	0,81	0,77	0,67	3,03	0,75
Pelagic, high bycatch	0,78	0,79	0,64	4,07	0,74
Cage aquaculture systems (Sea-based)	0,92	0,75	0,51	3,61	0,73
Pelagic, low-bycatch	0,57	0,80	0,55	2,83	0,64
Pond aquaculture (land-based)	0,75	0,64	0,41	3,42	0,60
Passenger shipping (ferries)	0,43	0,52	0,39	2,92	0,45
Commercial shipping	0,42	0,40	0,35	2,77	0,39
Average	1,49	1,32	1,09	3,05	1,30

3.4.2 Western Mediterranean pressure index

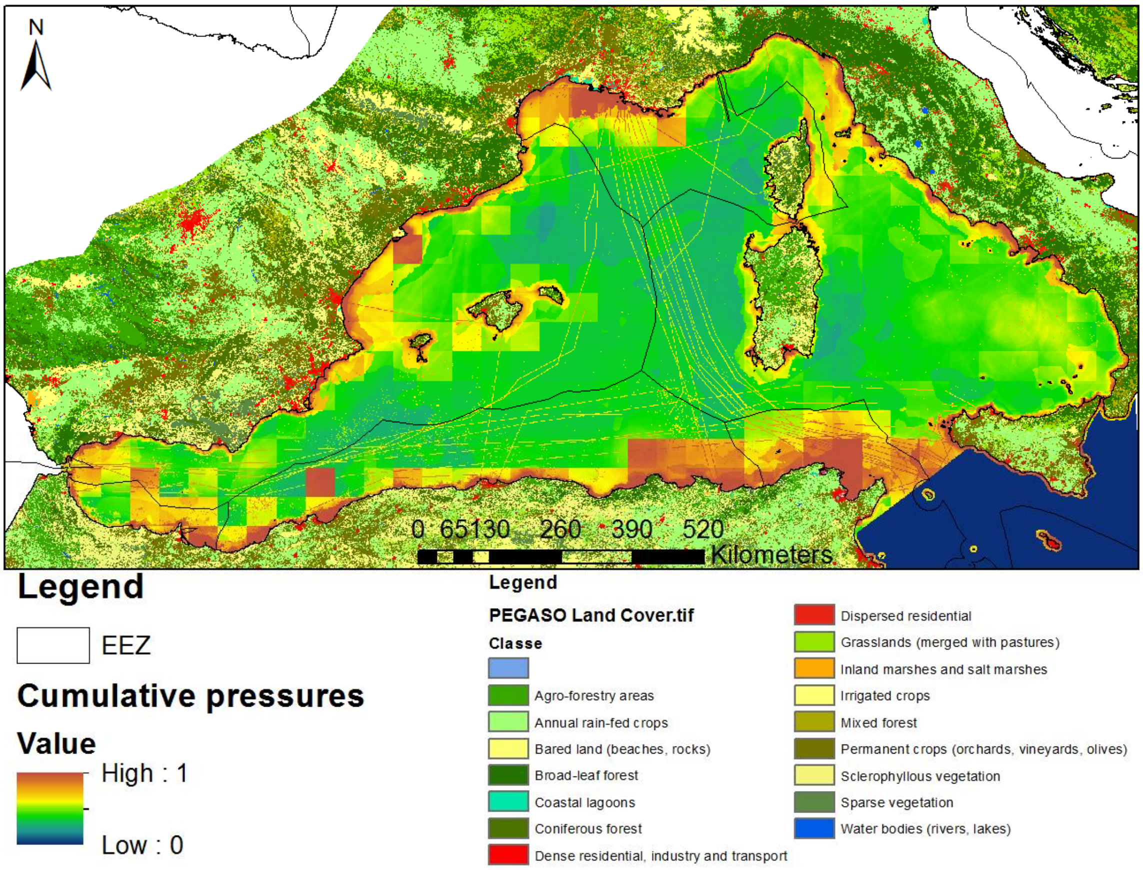


Figure 3.7: Cumulative pressure index for the Western Mediterranean Sea.

The cumulative pressure index is the result of the addition of all the pressure layers.It allows seeing where many pressures are occurring at the same time with high intensity. This index is not ecosystem-related, which means that pressures are displayed with the same intensity whether or not there are overlapping with any sensitive ecosystem.

This index can be desegregated by spatial area to look for example at the respective influence of each pressure in the total pressures intensity by pixel or for a given area.

The figure 3.8 and 3.9 show the results of analysing the percentage of influence of land based pressures in the first 20 kilometres near the coast. The figure 3.10 shows the respective influence of Ocean based, Fisheries and land based stressors in the 20 first kilometres from the coast.

A higher proportion of land based pressure [16]is visible in France, Spain and Italy. This result is logical given that most of the land based pressures have been modelised on the basis of urbanized area and/or population

[16] Defined as the addition of the following layers: Coastal engineering, Coastal population, Marine litter, Riverine inputs and atmospherique deposition of nutrients, riverine inputs of synthetic compounds.

density which present highest rate in European coasts. For North African countries, the influence of fisheries[17] and land based pressures are still comparable whereas ocean based pressures [18]are generally less important.

This result is coherent with the results of the LEAC methodology showing higher percentages of urbanisation in the European coasts and relatively logical given that the calculation of land based stressors is based on land use.

-Characterizing the pressure index

The western Mediterranean pressure index is the result of the simple addition of the intensity of the pressure (maximum potential impact distance) generated by each activity (22 activities considered in this study). As such this product has the following characteristics:

- Relatively easy to understand: high intensity areas corresponding to the overlap of high number of activities with relatively high intensities.
- Does not include the uncertainty related to the ecosystem localisation or identification and the calculation of their sensitivity (expert based).
- The quality of the product depends mostly of the quality of each pressure layer.
- It is easy to update when new data become available.
- It is not reactive to the absence or presence of ecosystems and their specific vulnerability.

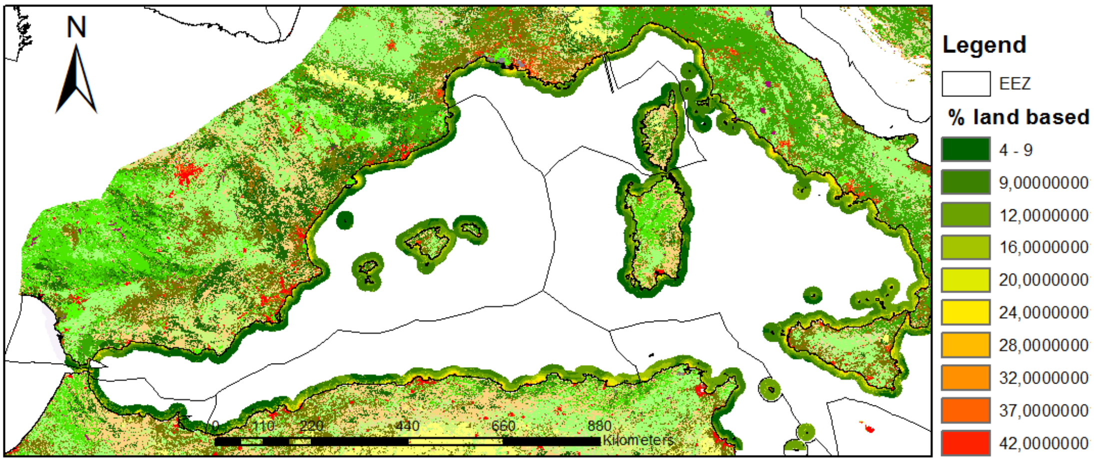


Figure 3.8: Percentage by cell of influence of land based pressure in the first 20 km from the coast.

[17] Defined as the addition of the following layers: Artisanal ; Demersal destructive ; Demersal Non destructive, high bycatch ; Demersal Non destructive, low bycatch ; Pelagic high bycatch ; Pelagic low bycatch fisheries.

[18] Defined as the addition of the following layers: cables and pipelines ; commercial shipping ; Major ports ; Invasive species ; Oil spills ; Passenger shipping ; turbidity changes.

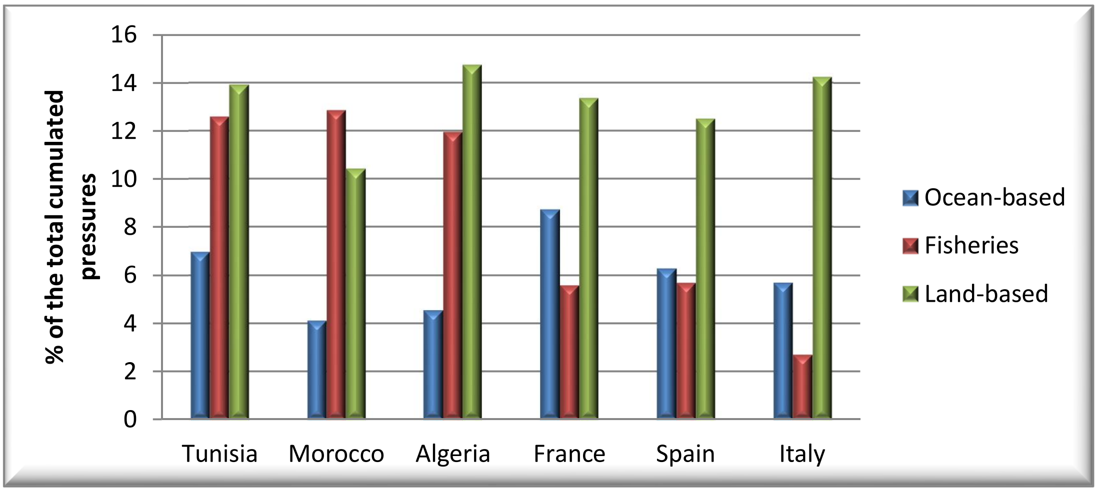


Figure 3.9: Percentage of influence of land based pressures, fisheries and ocean based pressures for the first 20 kilometres of Tunisia, Morocco, Algeria, Spain and France.

3.4.3 Western Mediterranean impact index

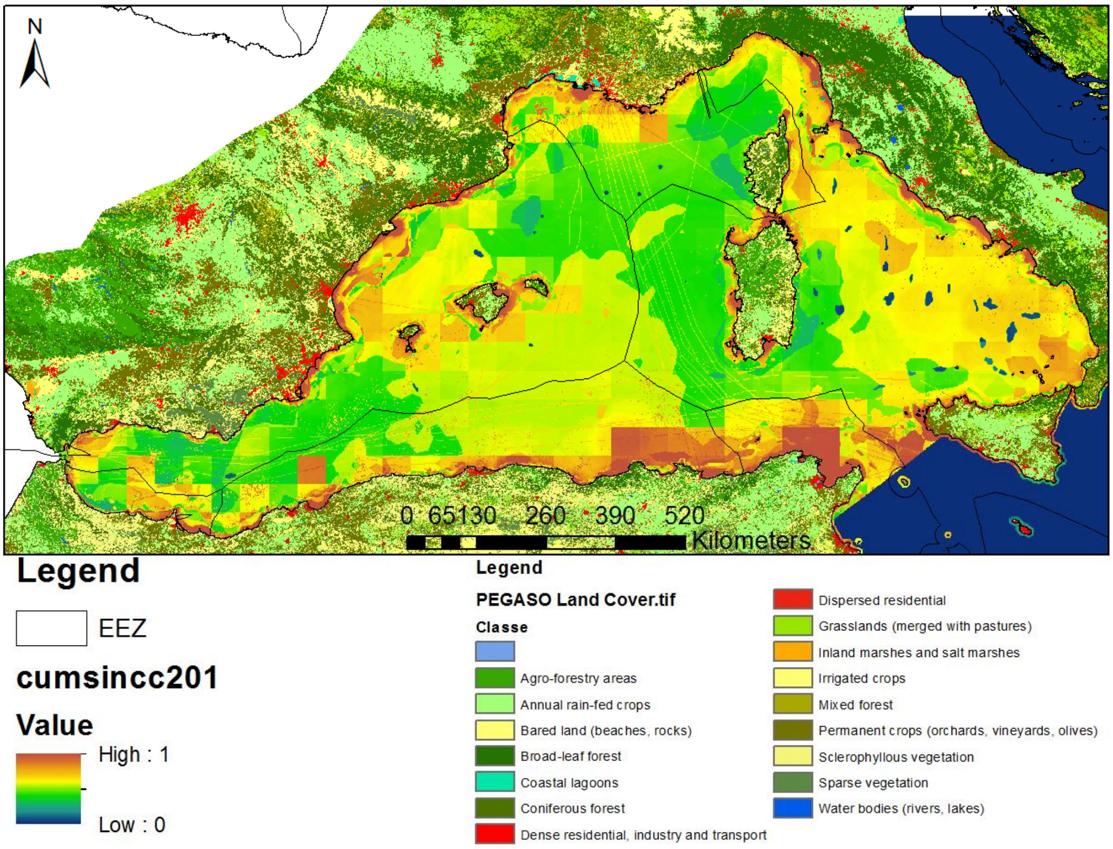


Figure 3.10: Western Mediterranean Cumulative pressure Index without climate change related stressors.

-The cumulative impact index

The cumulative impact index represents the “modelised” or “potential impact” of the pressures over underlying ecosystem components. The displayed impact intensity in a grid cell depends both on the intensity of the pressure and the specific vulnerability of the underlying ecosystem. As showed in the figure 3.11, when analyzing the overall impact of climate change related stressors, they displayed a very high impact compared with the other stressors. This was also the case in Halpern et al, 2008 and is due to the fact that those stressors are present everywhere with relatively high intensity (even if we removed the impact distance in the vulnerability score).

It was finaly chosen to not include climate change related stressors in the final map (figure 3.11) because the effect of those stressors was predominant and masked the other ones (figure 3.12).

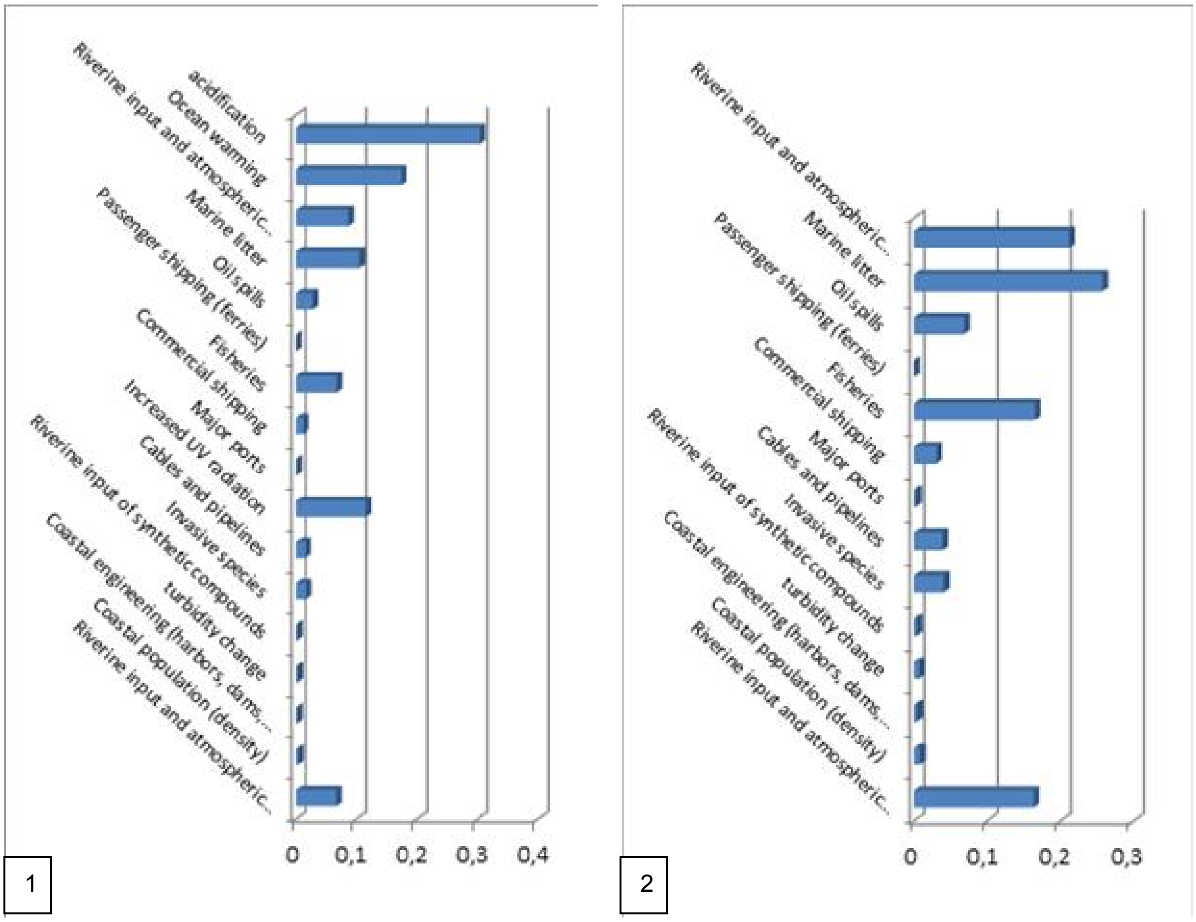


Figure 3.11: (1) Relative risk of impact impact of anthropogenic stressors in the Western Mediterranean Sea including Climate change related stressors, (2) Relative risk of impact of anthropogenic stressors in the Western Mediterranean Sea without Climate change related stressors.

The figure 3.13 shows the index disaggregated in ocean based impact (A), Land Based impact (B) and fisheries impact (C) without considering climate change related stressors.

In the ocean based layer, the high intensities near the coast are related to the presence of major ports and associated maritime traffic.

In the land based layer, the medium high intensities at the north of Algeria yellow areas and in the Tyrrhenian Sea are mostly the results of the marine litter accumulation layer (30 years accumulation model).

In the layer of fisheries, we can see that impact is mostly concentrated over the continental platform and more concentrated in the North African coast.

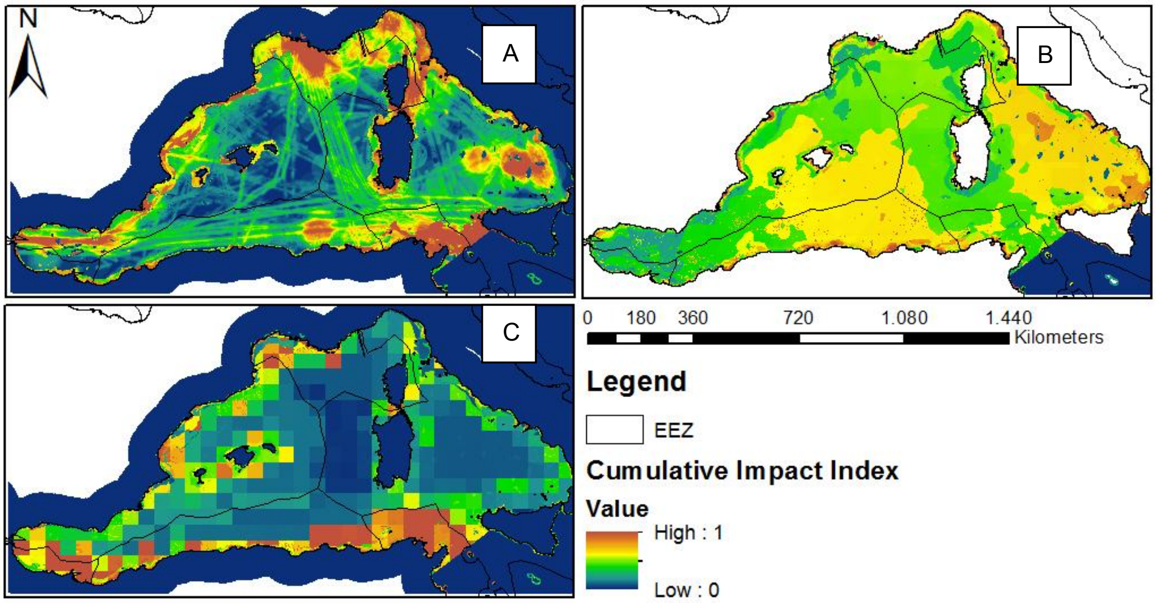


Figure 3.12: Cumulative Impact Index disaggregated in ocean based impact (A), Land Based impact (B) and fisheries impact (C).

-Disaggregation by ecosystem

As the cumulative impact index is ecosystem-related, it can be disaggregated by ecosystems. We can calculate the cumulated impact of all the pressures over one specific ecosystem or the relative influence of each pressure over this ecosystem.

The result of the cumulative impact of all pressure over Posidonia Oceanica has been calculated for the 3 countries that have the most complete maps for this ecosystem (Spain, France, Italy). Results are showed in figure 3.13.

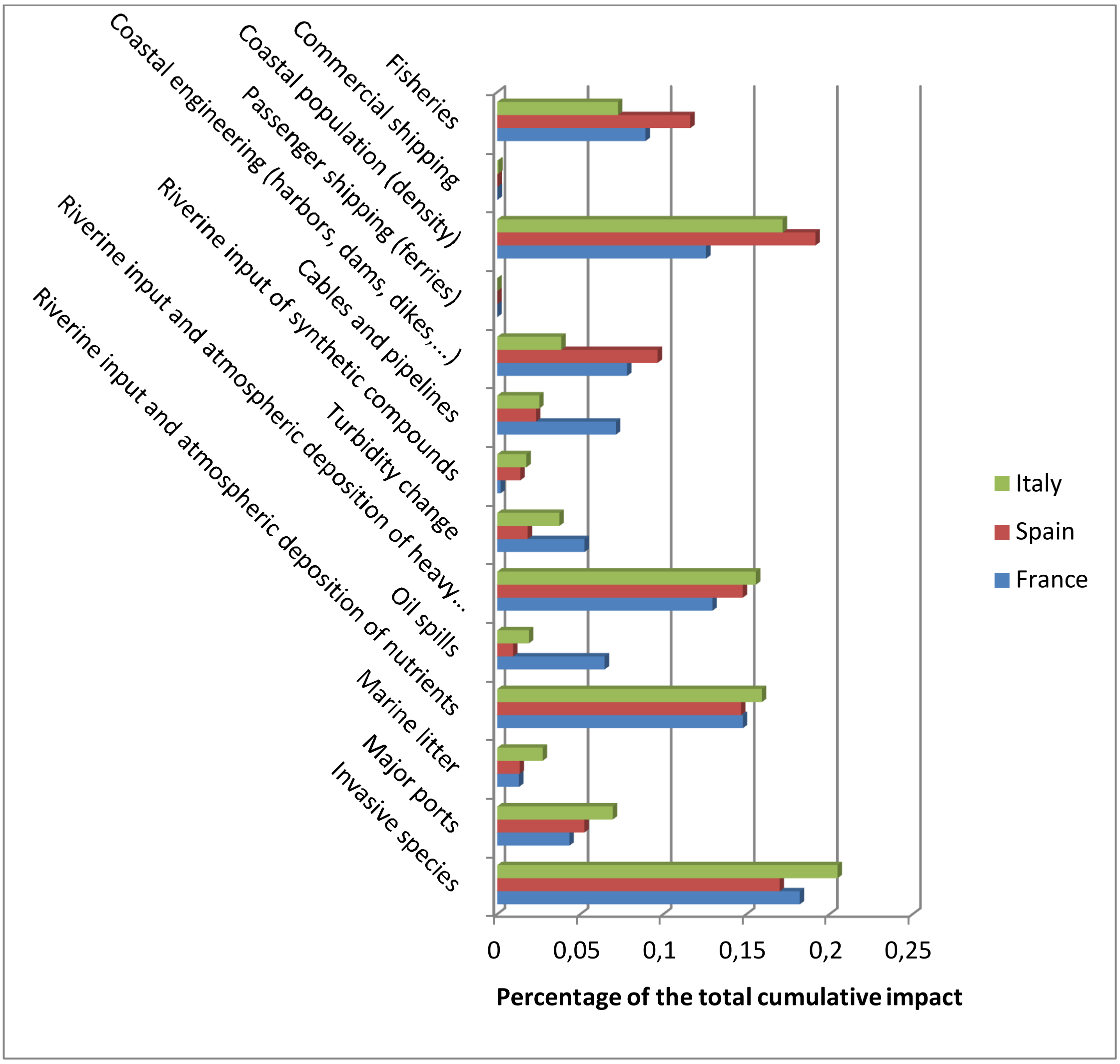


Figure 3.13: Relative potential impact of anthropogenic stressors on Posidonia for the Western Mediterranean Sea excluding climate change related stressors.

-Characterizing the Cumulative Impact Index

The Western Mediterranean Impact Index is the result of the addition of the potential impact of each pressure on each ecosystem. It takes into account all the pressures generated by each activity (e.g. the activity maritime traffic generates 6 different pressures, see table 3.4) and the potential effect they have on each ecosystem by considering their sensibility. As such the Western Mediterranean has the following characteristics:

- The impact index is reactive to the ecosystem presence or absence:
  - It offers therefore more possibilities of disaggregation (e.g. Total cumulative impact by ecosystem/Relative impact of each activity over 1 ecosystem, etc…)
  - At the same time, its interpretation is more difficult (e.g. presence of high impact areas with low pressure intensity or the contrary).
  - It includes the uncertainty associated with ecosystem localization and sensitivity scores calculation.

- It is easy to upgrade when new information become available on ecosystem, activities or their interactions.

3.5 Discussion, Lessons Learned and Recommendations

Understanding how multiple stressors can impact marine ecosystem is still in its infancy and uncertainty remains very high. However waiting for the ideal conditions to understand pressures/status relationships is a luxury that marine ecosystems and their managers can hardly afford (Parravicini et al., 2010).

Conscious of that, the goal of this exercise is not to provide a realistic prediction of where and with which intensity Mediterranean ecosystems are impacted by human activities but to provide a dynamic approach that help stakeholders and decision makers to participate, formulate and visualize the link between human activities and the potential impact they have on surrounding ecosystems. At the same time, the efforts developed to concretise this exercice have already highlighted a certain number of important issues in the Mediterranean without entering in the results:

Data availability and access:

Pressures
Spatial explicit measurements of pressure (e.g. underwater noise or acidification) don't exist in most of the cases and would be very costly to develop in the futur. The only pressure explicit datasets are the one derived from satellite imagery (turbidity change, oil spills).
In this exercice and the previous ones, they have been replaced by modelisation (sometimes very simple) of the pressures based on the activities that generate them. This approximation has however the important advantage to explicit and make the pressures directly reactive the the activities that cause them. This is an important point because monitoring activities is generally less costly than monitoring pressures and because management generally occurs at the level of activities. Moroever the quantification and the realism of the driver-pressure estimation could be easily and greatly improved if well chosen monitoring based data become available.
Data for land based driver (land use, population, coastline artificialisation) was relatively easy to collect. It was not possible to obtain any spatial explicit dataset on fisheries for any area of the Mediterranean and we used therefore a global datasets obtained from a modelisation (Watson et al, 2005, 2006) which is the best product currently available. It was impossible to obtain any dataset on Maritime traffic, oil spills or submarine cables from any of the Mediterranean institution in charge of those questions and those datasets have been finally gently provided by other scientists.

Ecosystems
The existence of the present work is mainly due to the availability of the EUSEAMAP which is the first harmonized map of the benthic habitat distribution in the western Mediterranean sea. However those datasets are the result of a modelisation which imply that (1) we are not sure of their presence (2) we can not see their evolution over time. We obtain also relatively easily datasets on remarquable ecosystems such as canyons and seamounts. It was also relatively easy to obtain coastal ecosystems data. Data on seabird distribution was provided by the RACSPA but we choosed to not use them for this work. We also obtained data on Sperm Whale, probability of presence and Monk Seal sightings but we was not able to use them in this work.

Scientific knowledge: Operational knowledge on how one or multiple pressures affect marine ecosystem is still in its infancy. There is an extended literature on the biological functioning of some Mediterranean ecosystem but even for the most studied like Posidonia Oceanica, experts have important difficulties to quantify the link between pressures and impact.This knowledge gap seems to grow up when going deeper into the sea where we have still very little knowledge of the effects of anthropogenic activities.

Ground truthing:
With the implementation of policies such as the Water Strategy Framework directive and the Marine Stategy Framework Directive, more and more spatial explicit information become available on the status of marine habitats. The comparison of the present work future improved impact indexes with better human activities datasets with these newly available data could provide interesting insides on the existence of correlation between the impact indexes and the measured status of certain benthic ecosystems.

The present work and the resulting WMIIE has not the goal to be a one shot frozen picture but at the contrary to:

- Provide a tool for the integration of on-going scientific work and results on ecosystem distribution and sensibility to anthropogenic pressures.
- Stimulate discussion for people from different background by integrating and linking data both from the environmental, industrial and commercial sectors that are generally separated.
- Show explicitly where are (e.g. regions, country) and which are (e.g. activities, ecosystems) data gaps if we want to improve the realism and have a regional representation of human activities and the ecosystems they could impact.

Moreover, management and planning generally occur at the level of human activities (e.g. Maritime traffic) rather than stressors (e.g. Pollution by boats), (Ban et al, 2010).

This framework, by allowing quantifying both the impact of pressures and the localization and intensity of drivers that cause them could provide new highlights on the activities that need management at basin scale and could help the reflection on management actions at this scale.

3.6 References

Andersen, J.H., A. Stock (eds.), M. Mannerla, L. Meski, S. Heinänen and M. Vinther. 2012. Human uses, pressures and impacts in the eastern North Sea. DCE - National Centre for Environment and Energy), Aarhus University, Denmark. 139 pp. – DCE Technical Report No. ##

Ban, N.C., Alidina, H.M., Ardron, J.A., 2010. Cumulative impact mapping: advances, relevance and limitations to marine management and conservation, using Canada's Pacific waters as a case study. Marine Policy 34, 876–886.

Cameron, A. and Askew, N. (eds.). 2011. EUSEAMAP - Preparatory Action for development and assessment of a European broad-scale seabed habitat map final report. Available at http://jncc.gov.uk/euseamap

Cinnirella, S., March, D., O'Higgins, T., Murciano, C., Sardà, R., Albaigés, J., Pirrone, N., 2012. A multidisciplinary Spatial Data Infrastructure for the Mediterranean to support implementation of the Marine Strategy Framework Directive. International Journal of Spatial Data Infrastructures Research 7, 300-322.

Claudet J, Fraschetti F 2010. Human-driven impacts on marine habitats: A regional metaanalysis in the Mediterranean Sea. Biological Conservation 143(9): 2195-220

Crain, C. M., K. Kroeker, and B. S. Halpern. 2008. Interactive and cumulative effects of multiple human stressors in marine systems. Ecology Letters 11:1304–1315.

Druon J.N, Vaes Tom, 2013. Mapping of potential risk of ship strike with fin whales in the Western Mediterranean Sea. A scientific and technical review using the potential habitat of fin whales and the effective vessel density. JRC Publication N°: JRC79841
http://publications.jrc.ec.europa.eu/repository/handle/111111111/27790

Gallego F.J., 2009, A population density grid of the European Union, Submitted to Population and Environment.

Halpern, B.S., Selkoe, K.A., Micheli, F., Kappel, C.V., 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conservation Biology 21, 1301–1315.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F.,Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R., Watson, R., 2008. A global map of human impact on marine ecosystems. Science 319, 948–952.

Harris, T., Whiteway. T,.(2011) Global distribution of large submarine canyons: Geomorphic differences between active and passive continental margins, Marine Geology 285 69–86.

Kanakidou, M., Duce, R.A., Prospero, J., Baker, A.R., Benitez-Nelson, C., Dentener, F.J., Hunter, K.A., Liss, P.S., Mahowald, N., Okin, G., Sarin, M., Tsigaridis, K., Uematsu, M., Zamora, L.M., Zhu, T., 2012. Atmospheric fluxes of organic N and P to the global ocean. Global Biogeochemical Cycles, 10.10.1029/2011GB004277

Korpinen, S.Meski, L., Andersen, h., J., Laamanen, M. Human pressures and their potential impact on the Baltic Sea ecosystem.2012.Ecological Indicators, Volume 15, Issue 1, April 2012, Pages 105-114, ISSN 1470-160X, 10.1016/j.ecolind.2011.09.023.

Lebreton, L.C.-M., Greer, S.D., Borrero, J.C., 2012. Numerical modeling of floating debris in the world's oceans. Mar. Pollut. Bull. 64, 653–661. http://dx.doi.org/ 10.1016/j.marpolbul.2011.10.027.

Lenôtre N., Thierry P., Batkowski D. and Vermeersch F.(2004)–EUROSION project. The Coastal Erosion Layer WP 2.6 BRGM/PC-52864-FR, 45 p., 8 fig., 3 app

Linard, C., Gilbert, M. and Tatem A.J., 2010, Assessing the use of global land cover data for guiding large area population distribution modelling, *Geojournal,* doi:10.1007/s10708-010-9364-8

Linard, C., Gilbert, M., Snow, R.W., Noor, A.M. and Tatem, A.J., 2012, Population distribution, settlement patterns and accessibility across Africa in 2010, *PLoS ONE*, 7(2): e31743.

O.Travnikov, Ilyin I., O.Rozovskaya, M.Varygina, W.Aas, H.T.Uggerud, K. Mareckova, and R. Wankmueller, 2012. Long-term Changes of Heavy Metal Transboundary Pollution of the Environment (1990-2010). EMEP Status Report 2/2012.

Selkoe, K.A., Halpern, B.S., Ebert, C.M., Franklin, E.C., Selig, E.R., Casey, K.S., Bruno, J., Toonen, R.J., 2009. A map of human impacts to a pristine coral reef ecosystem, the Papahanaumokuakea Marine National Monument. Coral Reeefs 28, 635-650.

UNEP-MAP-RAC/SPA. 2009. State of knowledge on the geographical distribution of marine magnoliophyta meadows in the Mediterranean. By Leonardini, R., Pergent, G. and Boudouresque C. F., GIS POSIDONIE. UNEP(DEC)/MED WG. 331/Inf.5

UNEP-MAP-RAC/SPA. 2010. Report presenting a georeferenced compilation on bird important areas in the Mediterranean open seas. By Requena, S. and Carboneras, C. Ed. RAC/SPA, Tunis: 39pp.

UNEP-MAP-RAC/SPA. 2010. Technical report on the geographical information system developed for Mediterranean open seas. By Requena, S. Ed. RAC/SPA, Tunis: 50pp.

Van Drecht, G., A. F. Bouwman, J. Harrison, and J. M. Knoop (2009), Global nitrogen and phosphate in urban wastewater for the period 1970 to 2050, Global Biogeochem. Cycles, 23, GB0A03, doi:10.1029/2009GB003458.

Watson, RA and Kitchingman, A and Gelchu, A and Pauly, D, 2004.Mapping global fisheries: Sharpening our focus, *Fish and Fisheries*, **5** (2) pp. 168-177. ISSN 1467-2960.

Watson, RA and Revenga, C and Kura, Y,2006. Fishing gear associated with global marine catches. I. Database development, *Fisheries Research*, **79** (1-2) pp. 97-102. ISSN 0165-7836.

Watson, RA and Revenga, C and Kura, Y,2006.Fishing gear associated with global marine catches. II. Trends in trawling and dredging, *Fisheries Research*, **79** (1-2) pp. 103-111. ISSN 0165-7836.

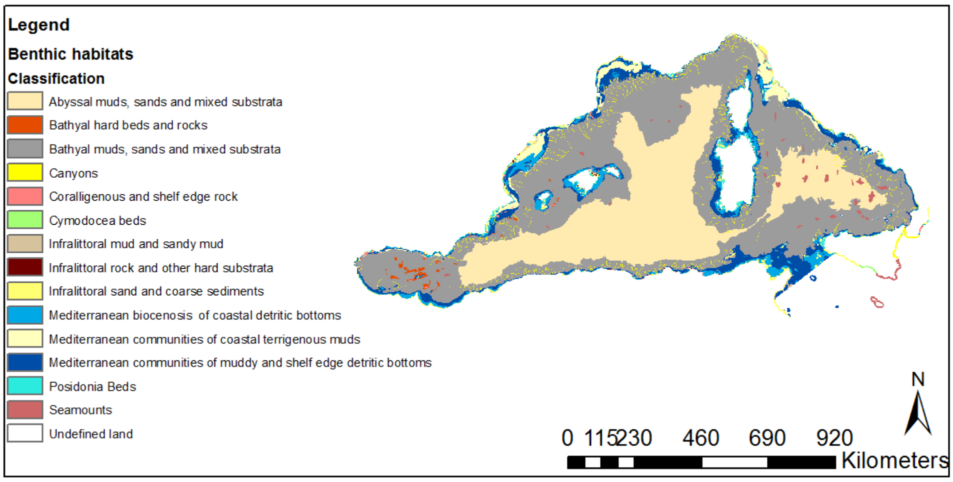
3.7 Annexes of chapter 3

Annex 1: Benthic habitat classification used in this study and its correspondance Barcelona Convention and Eunis classification.

Classification used in this survey	Barcelona convention name	EUNIS classification (Euseamap)	EUSEAmap Zone (defined by slope angle)
Posidonia Beds	Posidonia Beds	Posidonia Beds	Infralittoral
Cymodocea beds	Cymodocea beds	Cymodocea beds	Infralittoral
Infralittoral sand and coarse sediments	Fine sands with more or less mud	Infralittoral Fine Sand	Infralittoral
	Coarse sands with more or less mud	Infralittoral Coarse sediments	Infralittoral
Infralittoral mud and sandy mud	*No corresponding Barcelona Convention habitat type*	Infralittoral sandy mud	Infralittoral
		Inralittoral mud	Infralittoral
Infralittoral rock and other hard substrata	Infralittoral rock and other hard substrata	Infralittoral rock and other hard substrata	Infralittoral
Coralligenous and shelf edge rock	Coralligenous biocenosis	Mediterranean coralligenous communities moderately exposed to hydrodynamic action	Upper Circa
	Biocenosis of shelf-edge rock	Faunal communities on deep moderate energy circalittoral rock	Deep Circa
Mediterranean biocenosis of coastal detritic bottoms	Biocenosis of the coastal detritic bottom	Mediterranean animal communities of coastal detritic bottoms	Upper Circa
Mediterranean communities of muddy and shelf edge detritic bottoms	Biocenosis of the muddy detritic bottom	Mediterranean communities of muddy detritic bottoms	Upper Circa
	Biocenosis of shelf-edge detritic bottom	Mediterranean communities of shelf-edge detritic bottoms	Deep Circa
Mediterranean communities of coastal terrigenous muds	Biocenosis of coastal terrigenous muds	Mediterranean communities of coastal terrigenous muds	Circa
Bathyal muds, sands and mixed substrata	Biocenosis of bathyal muds	Mediterranean communities of bathyal muds	Bathyal
	Facies of sandy muds with Thenea muricata	Facies of sandy muds with *Thenea muricata*	Bathyal
	No corresponding Barcelona Convention habitat type	Deep sea muddy sand	Bathyal
	No corresponding Barcelona Convention habitat type	deep sea mixed substrata	Bathyal
	Sands	Deep-sea sand	Bathyal
Bathyal hard beds and rocks	Deep-sea rock and artificial hard substrata (Bathyal)	Deep-sea rock and artificial hard substrata	Bathyal
Abyssal muds, sands and mixed substrata	Communities of abyssal muds	Communities of abyssal muds	Abyssal
	No corresponding Barcelona Convention habitat type	Deep sea sand	Abyssal
	No corresponding Barcelona Convention habitat type	deep sea mixed substrata	Abyssal
	No corresponding Barcelona Convention habitat type	Deep sea muddy sand	Abyssal

Annex 2: Spatial explicit layers created for this study.

Benthic habitats



Data sources

- EUSEAMAP (http://jncc.defra.gov.uk/page-5040)
- Seagrass North African Coast (UNEP-MAP-RAC/SPA. 2009)
- Seamounts (UNEP-MAP-RAC/SPA. 2010)
- Submarine Canyons (Harris and Whiteway, 2012)

Methodology

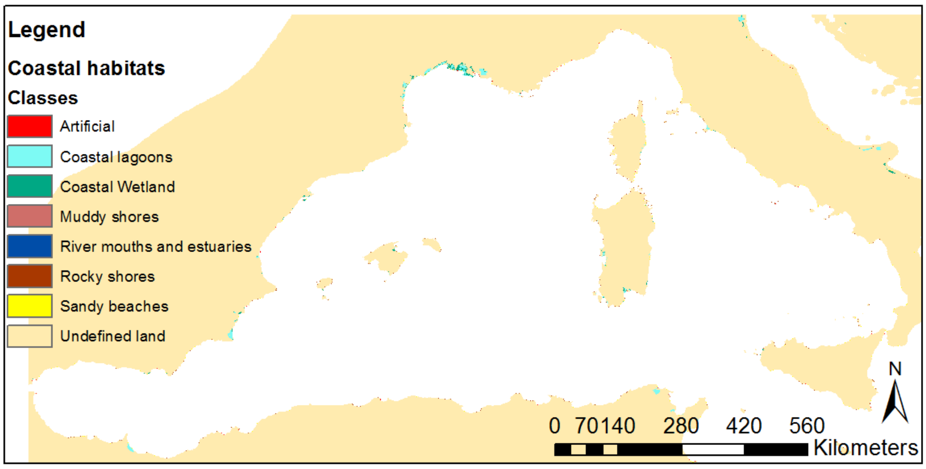
The distribution of benthic habitat used in this study is based on the EUSEAMAP (Cameron, A. and Askew, N. 2011) which is a predictive seabed habitat map (EUNIS level 4) for the Western Mediterranean Sea.
As the EUSEAMAP didn't include seagrass bed data for the North African coast, we include for this coast the data obtained from the RACSPA.
The original classification (23 classes) has been simplified to 12 classes as showed in the annex 1.
Two specific deep water seabed ecosystems (canyons and seamounts) have been added to this map respectively based on Harris and Whiteway, 2012 and the RACSPA.
All data sets was assembled in Shape format and then transformed in raster at 100m resolution.

Data quality

Strength and weaknesses of data:
Benthic Habitats obtained from the EUSEAMAP (exculding seagrass beds) are the result of a modelisation and include therefore uncertainties related to the supporting data and modelisation process. However an important work have been done to explicit and quantify this uncertainty (Cameron, A. and Askew, N. 2011) . The seagrass beds compiled by EUSEAMAP for the european coasts are considered to be usable to evaluate Sites of Community Importance distribution nationally. For the North African coast, the seagrass dataset represents the currently available information which is neither representative neither actualised.
Uncertainty associeted with the characterisation of submarine canyon is described in Harris and Whiteway, 2012. Seamounts dataset is based on GEBCO Sub-Committee on Undersea Feature Names (SCUFN).

Spatial resolution	Spatial coverage	Time period covered
Native EUSEAMAP resolution: 250m	Western Mediterranean Sea	North African coast Seagrass:1950-2008 Canyons: Date of publication is 2012 Seamounts: Date of publication is 2010 EUSEAMAP: Date of publication is 2011

Coastal habitats



Data sources

- Europe: EUROSION (Lenôtre et al, 2004), Corine Land Cover 2006.
- North African coast: Google Earth/Bing

Methodology

For European coast, EUROSION results and Corine Land Cover (CLC) have been combined together to obtain the 7 classes of coastal ecosystems. For North African coasts, a layer has been created specifically for the project. This layer has been produce by a visual interpretation and digitalization of Bing and Google Earth imagery. Coastal segments have been identified according to 5 main morpho-sedimentology typologies (coherent with EUROSION project classification), obtaining a continuous succession of segments that distinguish: rocky coasts; sandy beaches; Muddy shores; ports and shoreline with defense structures; river mouths (> 100 meters width). Main coastal lagoons have been then added based on the PEGASO Land Cover.

Data quality

Strength and weaknesses of data:

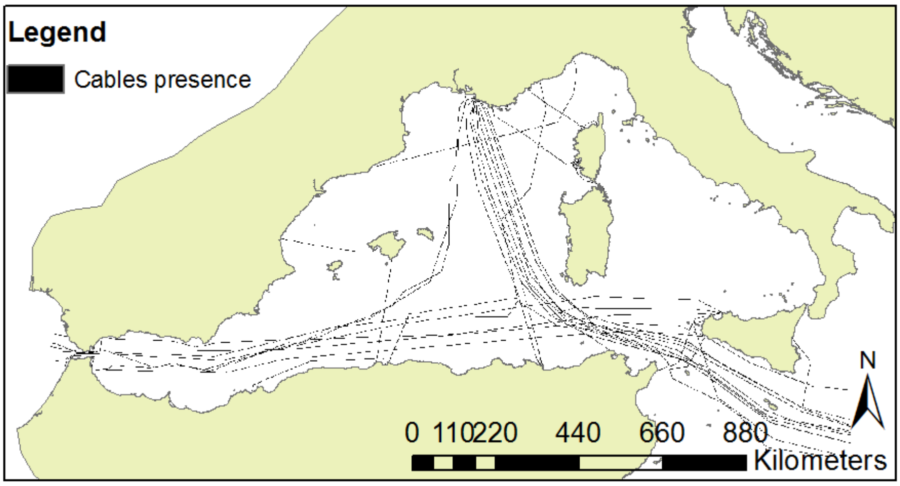
Eurosion and CLC are accurate product with number of ground truth validations but coastline can evoluate quickly and more recent datasets would have been preferable.

The main strength of this data is the accuracy reached thanks to the visual interpretation of the Google Earth imagery, especially relevant taking into account the regional coverage of the dataset (7440 km of coastline). Noted that the native resolution of the Google Earth imagery used is higher than the final output (100m). Moreover, it is a data comparable from one country to another (same methodology, nomenclatures, reference period, etc.) and in accordance with standards laid down by previous initiatives (e.g. CORINE Land Cover and Eurosion project).

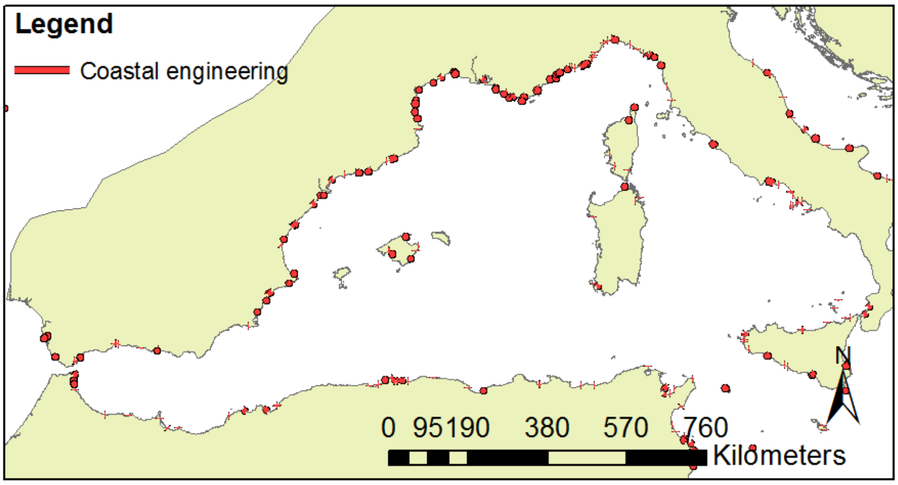
This data set has not been validated by fieldwork and some uncertainties remain in the interpretation due to the variability of the imagery quality (resolution, influence of atmospheric conditions).

Spatial resolution	Spatial coverage	Time period covered
100m	Europe(CLC, EUROSION) NORTH AFRICA (Morocco to Egypt)	EUROSION:2004 Corine Land Cover: 2006 North African Coastline:2003-2013

pegasoproject.eu

Cables and Pipelines		
		
Data sources • www.sigcables.com • http://www.cablemap.info/		
Methodology The 2 datasets were joined in Shape format and then rasterized at 100m resolution.		
Data quality Strength and weaknesses of data: The exact localisation of submarine cable is generally not publicly available. The localisation of cables as used in this study are approximative and should be taken as an indication of the overall presence abscence of submarine cables in a certain area. Moroever given the difficulty of access to the information, it was impossible to assess the level of representativity of this map (number of cables/function of cables).		
Spatial resolution N/A	**Spatial coverage** Western Mediterranean	**Time period covered** N/A

Coastal engineering (harbors, dams, dikes,...)



Data sources

- Eurosion
- North African coast: Google Earth/Bing

Methodology

Artificial coastline areas have been extracted from EUROSION for Europe and from the layer specifically created for the project for the North African coast (ports and shoreline with defense structures), (See the annex on Coastal habitats for the exact methodology). In this study, we differentiate coastal engineering and major ports because they cause different pressures. All the major ports areas present in the Major ports dataset have been therefore removed from the coastal engineering dataset.

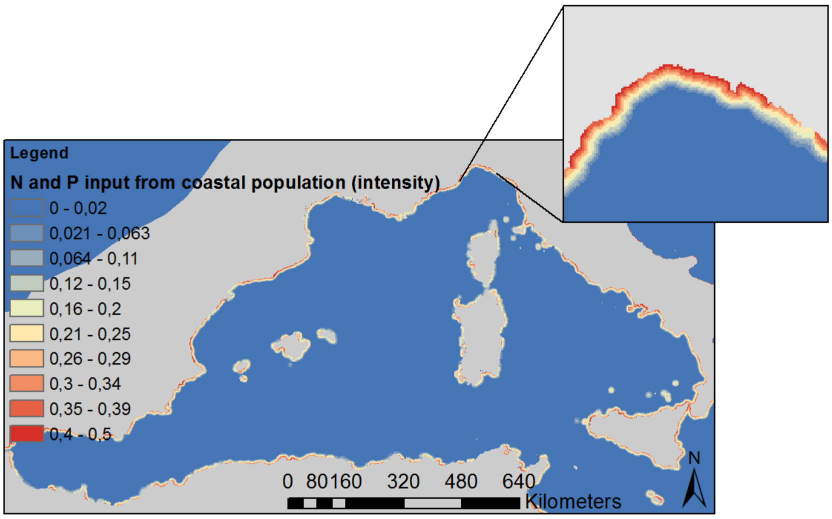
Data quality

Strength and weaknesses of data:

EUROSION dataset have been validated but is already old for this kind of stduy whereas the dataset developped for this studdy is relatively recent (depending on satellite imagery) but has not been validated by fieldwork and some uncertainties remain in the interpretation due to the variability of the imagery quality (resolution, influence of atmospheric conditions).

Spatial resolution	Spatial coverage	Time period covered
100m	Europe(EUROSION) NORTH AFRICA (Morocco to Egypt)	EUROSION:2004 North African Coastline:2003-2013

Coastal population (density): Nutrient & organic matter enrichment: Nutrients



Data sources

- North African population: AFRIPOP (Linard et al, 2010)
- European population: European Environmental Agency (Gallego F.J., 2009)

Methodology

Treated and untreated waste water from coastal urban areas contribute significantly to N and P budgets in coastal waters related consequences of this increase (harmfull algal blooms, eutrophication, anoxia, etc….).
By using together the spatialised population density by watersheds in the coastal area and the production of N&P per habitant, we can make an estimation of the quantity of N&P rejected in each watershed and then in coastal waters for Mediterranean coasts. For defining the population density, we used in Europe the Population density disaggregated with Corine land cover 2000 at 100m produced by Gallego F.J., 2010 and the Population density disaggregated at 100m produced by the AFRIPOP project for North African countries (Linard et al, 2010).
We calculated N and P output per person using the method defined by Van Drecht et al, 2009 that predicted the emission and the degree of treatment of N and P in urban waste water for 9 regions of the World including Europe and Africa using the formula:

$$E_{SW}^{N} = E_{hum}^{N} D(1 - R^{N})$$

Where E_{SW}^{N} is the N emission that reaches surface water after treatment (kg person^{-1} a^{-1}), E_{hum}^{N} is the N emission by humans (kg person^{-1} a^{-1}), D is the fraction of the total population connected to sewage system, R^{N} is the efficiency of the N removal by the waste water treatment plant. The total P emission to surface water was calculated as:

$$E_{SW}^{P} = \left(E_{hum}^{P} + E_{Ldet}^{P} + \frac{E_{Dde}^{P}}{D}\right) D\,(1 - R^{P})$$

Where E_{SW}^{P} is the P emission that reaches surface water after treatment (kg person^{-1} a^{-1}), E_{hum}^{P} is the P emission by humans (kg person^{-1} a^{-1}), E_{Ldet}^{P} is the P emission from laundry detergents (kg person^{-1} a^{-1}), E_{Dde}^{P} is the P emission from dishwasher detergents (kg person^{-1} a^{-1}), R^{P} is the efficiency of the P removal by the waste water treatment plant. E_{Dde}^{P} is calculated for the population connected to sewerage systems. Dividing by D results in a value that applies to the total population.
Those equations account uniquely for waters entering the sewage system and not for water reject directly in the environment. As we want to consider total waste water, we used the equations:

$E_{SW}^{Ntot} = E_{hum}^{N}((1 - D) + D(1 - R^{N}))$

$$E_{SW}^{Ptot} = \left(E_{hum}^{P} + E_{Ldet}^{P} + \frac{E_{Dde}^{P}}{D}\right)\left(D\,(1 - R^{P}) + \,(1 - D)\right)(E_{hum}^{P} + E_{Ldet}^{P})$$

Using the values defined Van Drecht et al, the E_{SW}^{Ntot} and E_{SW}^{Ptot} are for Europe and North Africa:

Europe:

$E_{SW}^{Ntot} = 5.7\left((1 - 0.79) + 0.79(1 - 0.5)\right)$ =3.45 kg per person per year

E_{SW}^{Ptot}= $(1 + 0.2)\left(0.79\,(1 - 0.59) + \,(1 - 0.79)\right)(1.02)$ =0.59 kg per person per year

North Africa:

$E_{SW}^{Ntot} = 3.5\left((1 - 0.14) + 0.14(1 - 0.05)\right)$ =3.48 kg per person per year

E_{SW}^{Ptot}= $(0.6)\left(0.14\,(1 - 0.05) + \,(1 - 0.14)\right)(0.6)$ =0.59 kg per person per year

Mapping

The number of people per catchment has been mapped at 100m resolution, multiplied by the value of E_{SW}^{Ntot} and E_{SW}^{Ptot} and aggregated to the catchment pour point. However this method gives an overweight to large catchment that present higher total population due to their larger surface even if far away from the sea.

In order to account for this phenomenon and give and higher weight to coastal cities that reject waste water (treated or untreated) directly into the sea, we divided the total N per catchment per the surface of the catchment.

As such, small coastal catchments with high population density have more weight comparatively to large catchments with high total population.

The spreading of the pollution was modelised using a decay function inversely proportional to the Euclidian distance from the poor point with a maximum diffusion of 10km in accordance with the impact distance defined by the expert survey.

Data quality

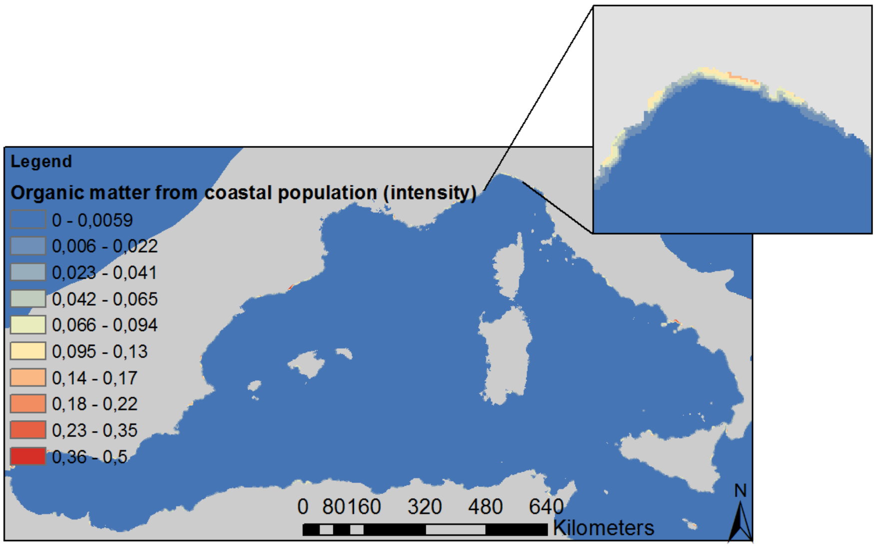
Strength and weaknesses of data:

Some monitoring based data on coastal waste water treatment plant have been published by the UNEP MAP for the mediterranean. However no monitoring based data was available for our area of study. Therfore we had to make important hypothesis to modelise the nutrient inputs by coastal population. This model could be greatly improved by making correlation with monitoring based data.

We used the best data availble on population density disagregated at 100m for both North and South realm of the Mediterranean. The estimation of N and P input is a modelisation based on very coarse regional estimation of N and P rejected by habitant and treated by waste water treatment that could be greatly improved wit monitoring based data.

Spatial resolution	Spatial coverage	Time period covered
100m	Western Mediterranean Sea	Van Drecht et al, 2009:2000 Population:2000-2010

Coastal population (density): Nutrient & organic matter enrichment: Organic matter



Data sources

- North African population: AFRIPOP (Linard et al, 2010)
- European population: European Environmental Agency (Gallego F.J., 2009)

Methodology

We considered that organic matter from coastal population was directly proportional to N and P inputs generated by treated and untreated waste water. The methodology applied is the same as for N and P but the maximum spreading distance has been reduce to 5km in accordance with the results of the expert survey.

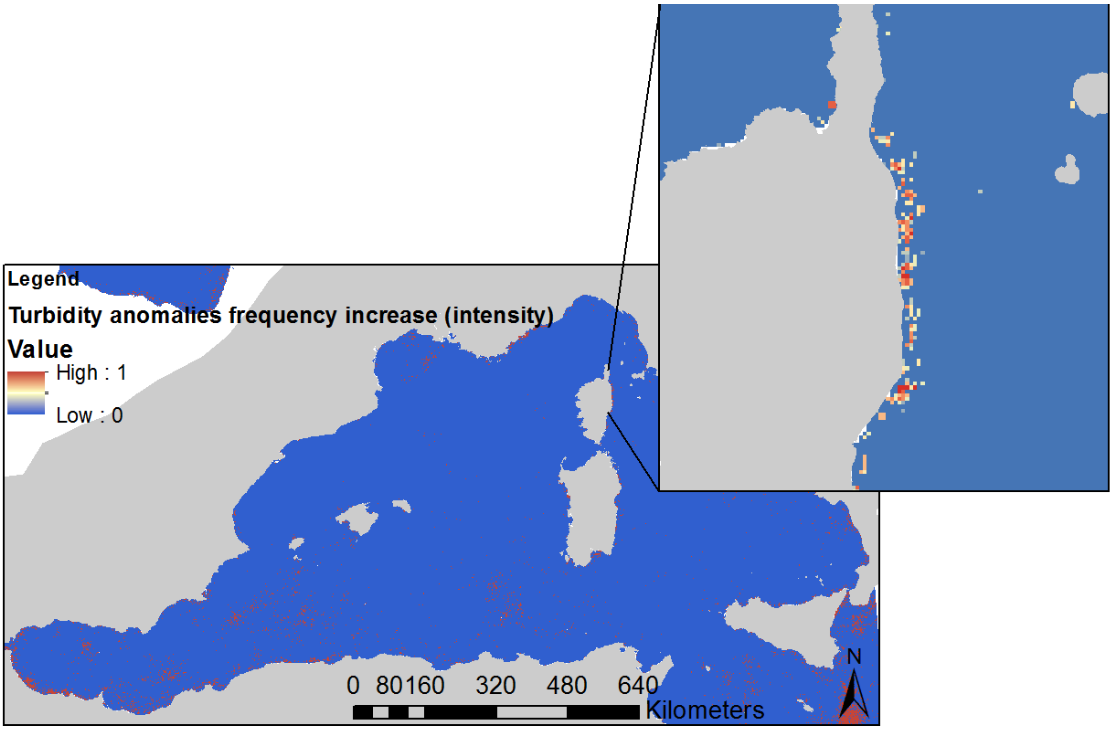
Data quality

Strength and weaknesses of data:

Some monitoring based data on coastal waste water treatment plant have been published by the UNEP MAP for the mediterranean. However no monitoring based data was available for our area of study. Therfore we had to make important hypothesis to modelise the nutrient inputs by coastal population. This model could be greatly improved by making correlation with monitoring based data.

We used the best data availble on population density disagregated at 100m for both North and South realm of the Mediterranean. The estimation of N and P input is a modelisation based on very coarse regional estimation of N and P rejected by habitant and treated by waste water treatment that could be greatly improved wit monitoring based data.

Spatial resolution	Spatial coverage	Time period covered
100m	Western Mediterranean Sea	Van Drecht et al:2000 Population:2000-2010

Turbidity Change		
		
Data sources • ACRI • Meris 1km		
Methodology Potential for impact on light-dependent ecosystems in response to changes water column turbidity can be approximated by the frequency of turbidity anomalies, where the turbidity exceeds a threshold value like the long-term mean. Using Meris data at 1km, we calculated for each pixel the “natural value or threshold” defined by the monthly P50 (2003-2011) plus the monthly sigma (sigma=0.5*(P84-P16)). For each month, the monthly mean has been compared to the “natural value” (monthly P50 (2003-2011)+Sigma). The same has been done for each month of the year in order to count the number of anomaly (Na) per year (between 0 and 12) for the period 2003-2011. We then defined for each pixel the slope of change (positive increase of the number of anomalies per year for the period 2003-2011) and the related Mann-Kendall coefficient. We then conserved only the pixel for which the Mann-Kendall coefficient was above 1 and used the intensity of the slope as an approximation of the intensity of the pressure. This dataset is a first step through the spatial explicit quantification of the pressure caused by turbidity changes in the Mediterranean sea. It could be improved by considering also the duration of turbidity events and increasing the resolution and the time series used.		
Data quality **Strength and weaknesses of data:** This dataset is a first step through the spatial explicit quantification of the pressure caused by turbidity changes in the Mediterranean sea. It could be improved by considering also the duration of turbidity events and increasing the resolution and the time series used.		
Spatial resolution 1km	**Spatial coverage** Western Mediterranean Sea	**Time period covered** 2003-2011

Sea ecosystem accounting (SEAC)

By Universitat Autònoma de Barcelona (Megan Sarah Nowell)

Table of Contents

Executive summary

Until shockingly recently, we believed that there was nothing we could do that would impact the ecosystem processes and functioning of the marine environment. In return for our ignorance, we are now faced with collapsing fisheries, coastal wastelands, eutrophication, swarms of jellyfish and global warming. While science endeavours to understand the complexity of the <5% of the oceans and seas that have been explored, marine management agencies are tasked with dealing with the consequences of anthropogenic activities and making decisions based on very little scientific knowledge. What is needed is a time efficient method of tracking changes in coastal and marine ecosystems and linking those changes to human activities. This information is required at the seascape scale so that appropriate responses can be taken and adaptive management implemented. The emerging field of seascape ecology has the potential to address this need through tools that characterize the structure of seascapes, thereby providing information on the seascape stocks and flows for sea ecosystem accounting and effective management.

This section of the deliverable reports on the use and application of seascape ecology tools as a first step toward creating physical sea ecosystem accounts. A framework for sea ecosystem accounting is presented along with two case studies demonstrating the use of spatial pattern metrics to describe the stocks and flows of typical Mediterranean seascapes. This tool has the potential to be applied in any seascape where digital benthic habitat maps are available and at multiple spatial and temporal scales.

4.1. Context

The ecosystem goods and services provided by coastal seascapes have been suggested to have the highest economic value of all natural ecosystems (Costanza, 1999). Due to the proximity to the densely populated coastal zone, these seascapes are one of the most heavily utilised and impacted environments globally (Gray, 1997; Lotze et al., 2006). Increased pressure on coastal ecosystems has resulted in habitat degradation, fragmentation and destruction (Gray, 1997). This is especially true of the coastal zone of the Mediterranean Sea which has historically been one of the most densely populated regions on Earth (Airoldi et al., 2008). Quantifying the changes in the coastal zone is of the utmost importance. To assist in this goal, ecosystem accounting is a tool used to reflect on the critical stock and flows of natural capital by describing the changes in the quality and quantity of ecosystems (stocks) and the services and benefits (flows) from them (EEA, 2010). Understanding the ecological consequences of the changes in stocks and flows is essential for effective management and planning of the coastal environment (Böstrom et al., 2011; Pittman et al., 2011; Wedding et al., 2011).

Driven by a ‘spatial data revolution,’ the emerging field of seascape ecology introduces a novel approach to sea ecosystem accounting by quantifying coastal habitat structure. Seascape ecology tools, such as spatial pattern metrics, quantify seascape structure and can be used as a consistent and efficient means of assessing and monitoring coastal stocks. Seascape ecology explores the ecological consequences of the spatial configuration, composition and complexity of habitat patches. These aspects of the seascape structure influence the ecological processes and functioning of coastal zones, which are termed flows in ecosystem accounting.

The availability of spatial data online, such as that provided by PEGASO's Spatial Data Infrastructure (SDI) provides coastal managers and decision-makers with an unprecedented source of information for optimizing decisions and management responses. Spatial metrics harness this opportunity by translating spatial data into ecologically relevant and meaningful information at multiple spatial and temporal scales. This powerful management tool has a range of applications that include spatially explicit indicator development (T4.1), ecosystem accounting (T4.2), scenarios (T4.3), economic assessment (T4.5) and policy appraisal, among others. In this deliverable we demonstrate the application of seascape ecology techniques as a first step towards sea ecosystem accounting (T4.2).

4.2. A framework for sea ecosystem accounting

4.2.1. What is ecosystem accounting

As described in Chapter 2 of this deliverable, ecosystem accounts are used to characterise change in the environment by systematically describing the processes by which resources are transformed over time. Ecosystem accounts aim to report or record the state of natural resources and ecosystem components in terms of quality (e.g. seascape composition); quantity (e.g. spatial configuration) and changes in quality and quantity in time and space. The quantity and quality features are termed and accounted as physical 'stocks', while the change features are accounted as 'flows.'

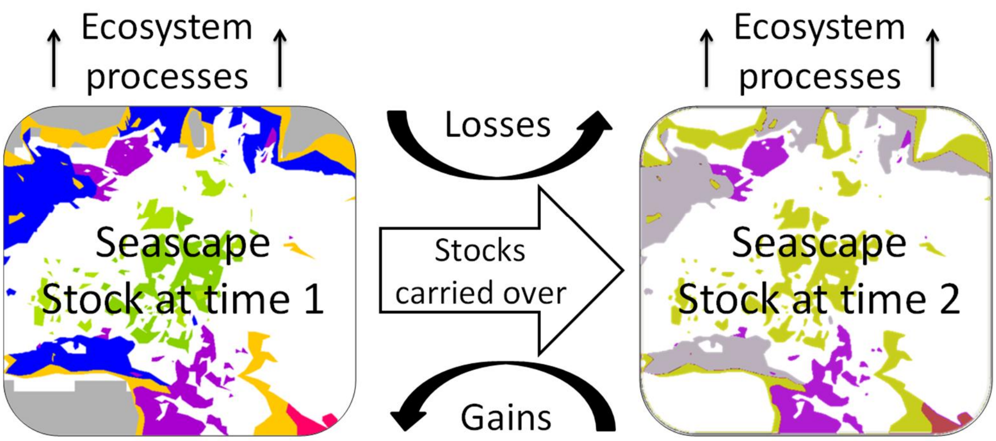


Figure 4.1: Traditional ecosystem accounts explore the changes in the quality and quantity of stocks and flows over time.

Stocks are ecosystem assets that consist of fixed characteristics such as the benthic habitats, as well as variable characteristics, for example ecosystem services, species richness or habitat diversity. As an input for ecosystem accounts, stocks should be spatially explicit, harmonized and comparable across scales. Flows, on the other hand, are the services within or between ecosystems and to people (ecosystem services). Human activities alter the balance between the gains and losses thereby causing changes in the quantity and quality of stocks over time. These changes influence ecosystem processes and functioning of the seascape (Nowell et al., 2011).

The ecological functioning of marine and coastal ecosystems is poorly understood making it challenging to quantify the flows needed to construct sea ecosystem accounts. As seascape structure is inherently linked to ecological processes, it could be used as a proxy for flows. Furthermore, seascape structure is derived from spatial benthic habitat data, which are stocks. What this means is that measuring changes in seascape structure using seascape ecology techniques could provide information on the changes in the quality and quantity of both stocks and flows. In other words, seascape ecology provides a quantitative and repeatable method of physical ecosystem accounting (Figure 4.2).

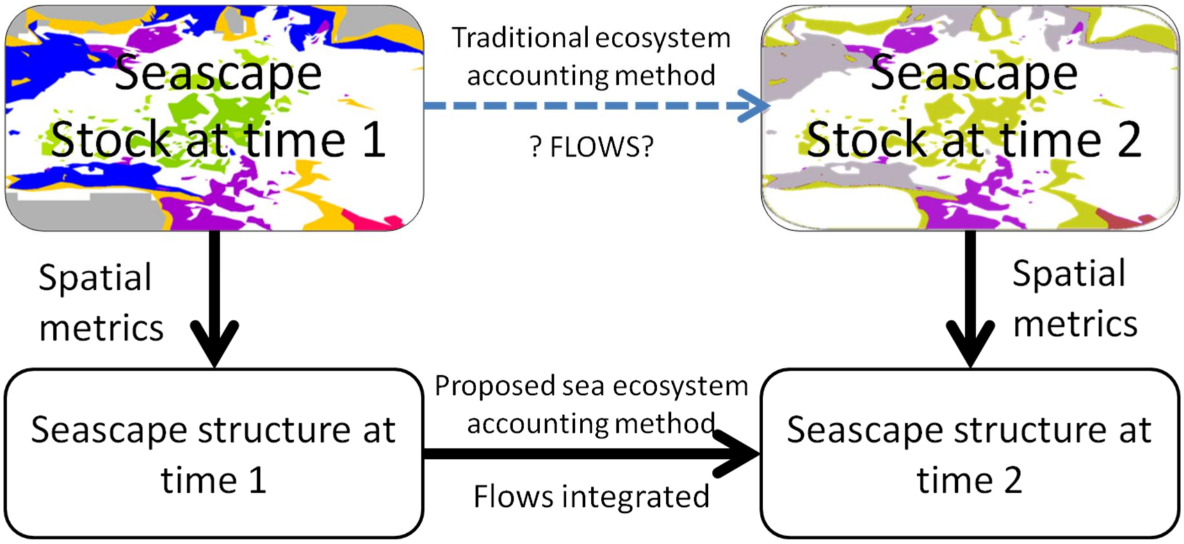


Figure 4.2: We propose using seascape ecology techniques for sea ecosystem accounting. These techniques quantify seascape structure which provides valuable information on the quality and quantity of both stocks and flows.

4.2.2. Seascape ecology

The seascape ecology approach has been derived from the theoretical and analytical framework of landscape ecology, which seeks to understand how ecological functioning is related to the spatial geometry of the environment. The application of landscape ecology concepts and techniques to the seascape has been explored for coastal environments with particular success in shallow-water benthic ecosystems (Böstrom et al., 2011). This highly interdisciplinary approach allows for a better understanding of the multi-scale (both temporal and spatial) relationships between spatial patterns and ecological processes (Böstrom et al., 2011; Wedding et al., 2011).

Landscape and seascape structure can be quantified using spatial geometry tools such as spatial pattern metrics. Spatial metrics are usually formulas or algorithms that are used to quantify: (a) the landscape/seascape composition such as the abundance and diversity of habitats, (b) the spatial configuration, which is the spatial arrangement of habitat patches in the mosaic, and (c) the patch shape complexity including the fractal dimension (Wedding et al., 2011). These metrics can be linked to the ecological processes of the seascape. For example, fish assemblage attributes and density were predicted based on seascape structure by

Pittman et al. (2007). Similarly, Meynecke et al. found ecological linkages between nearshore fisheries and geomorphic coastal features using spatial metrics (2008). In addition to linking spatial geometry to ecological variables, the quantification of seascape structure can provide seascape managers and decision-makers with a consistent method for baseline characterization, monitoring changes and comparing seascapes across scales (Wedding et al., 2011).

4.2.3. Spatial pattern metrics

A wealth of spatial metrics are available to measure landscape and seascape composition, configuration and complexity. These metrics provide extensive information about the structure of the area in question, and may often overlap with each other. It is therefore desirable to use the smallest number of independent metrics that quantify seascape structure (Cushman et al., 2008). While the components may vary based on the objective of the study, the basic spatial pattern metrics recommended for seascape structural quantification are given in figure 4.3. The stocks are represented by the composition metrics, namely the class area (CA) and the proportion of the study area covered by class. Further information about the layout of these stocks in given by the configuration metrics: the number of patches (NumP), mean patch size (MPS), median patch size (MedPS) and the standard deviation of patch size (PSSD). The flows on the other hand, are determined by patch complexity metrics such as the mean shape index (MSI), mean patch fractal dimension (MPFD) and the mean perimeter:area index (MPAR). The connectivity of the patches also influences ecosystem services and is measured using the mean nearest neighbour metric (MNN). Changes in these structural components determine changes in the quality and quantity of the stocks and flows.

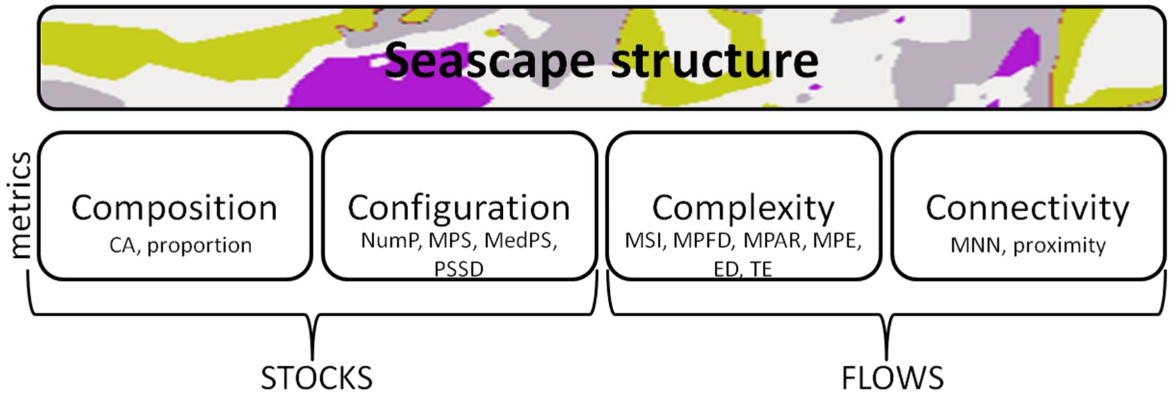


Figure 4.3: Spatial metrics provide information on both the stocks and flows of the seascape.

4.2.4. Sea ecosystem accounts

Sea ecosystem accounts have the same input requirements as land ecosystem accounts, such as LEAC (Table 4.1). Like LEAC, sea ecosystem accounts can be physical or monetary. In this section, a basic framework for physical ecosystem accounts is described.

Accounting units are selected based on the area of interest, the objective and scale of the study, and the availability of data. These accounting units may cover administrative boundaries, habitats of interest, marine protected areas, regional seas, etc. Digital benthic habitat maps are then acquired for the accounting units. These maps can be at any scale, provided that the same scale is used for all accounting units. Generally, ecosystem accounts require more than one spatial dataset so that changes over time can be assessed. A single snapshot (or baseline) of the area of interest may also be accounted for, however this information gains significance when monitored over time. The gains and losses of the stock can be measured using spatial metrics to quantify the changes in the seascape structure (see case study 1) (Nowell et al., 2013a). Similarly, the flows are also measured using this tool. Information on the pressures driving the changes in stocks and flows can be correlated to specific components of the seascape structure using multivariate statistics (this is demonstrated in case study 2)(Nowell et al., 2013b). Correlations with additional variables can be identified using the same technique.

Ecosystem account inputs	Data	Spatial metrics
Accounting units	Area of interest (ex. Seascape, administrative units, EEZ, regional sea, etc.)	/
Land cover/land use	Benthic habitat map	CA, Proportion
Gains and losses	Seascape structure (time series data)	NumP, MPS, MedPS, PSSD
Land cover flows	Seascape structure (time series data)	MSI, MPFD/MFRACT, MPAR, MNN, MPE, TE, ED, Proximity
Pressures	T4.1 Indicators	/
Additional inputs	Environmental variables Species data Chlorophyll-a Etc.	/

Table 4.1: The inputs for sea ecosystem accounts. The following metrics can be used to measure changes in the stocks and flows of the seascape: class area (CA), proportion of study area covered by class, number of patches (NumP), mean patch size (MPS), median patch size (MedPS), standard deviation of patch size (PSSD), mean shape index (MSI), mean patch fractal dimension (MPFD or MFRACT), mean perimeter:area ratio (MPAR), mean nearest neighbour (MNN), mean patch edge (MPE), total edge (TE), edge density (ED), and mean proximity.

4.3. Case study 1: Spatial metrics for sea ecosystem accounts

4.3.1. Overview

Based on the study by Nowell et al., this case study aims to demonstrate the application of spatial pattern metrics for baseline characterization of a typical Mediterranean seascape (2013a). This information can be used to monitor changes in the quality and quantity of the habitats, an essential component of sea ecosystem accounting and for effective management.

As discussed in the previous section, a physical account provides a snapshot of the seascape that gains significance as it is monitored over time. As time series data was not available at the time of the study, a baseline account is created. In the second part of the study, we assessed whether spatial pattern metrics reflect the quality of benthic habitats through a comparative study. In the final part, we take the seascape structure analysis one step further and use a multivariate analysis to show how various habitats respond to different structural components.

4.3.2. Study area

The Balearic Islands are located 175 km west of the Iberian Peninsula in the western Mediterranean Sea. The Cabrera Archipelago (CA) is situated off the southern tip of Mallorca (see Figure 4.4) and consists of 19 small islands and islets covering around 10,000 hectares, of which nearly 9,000 hectares are marine environment.

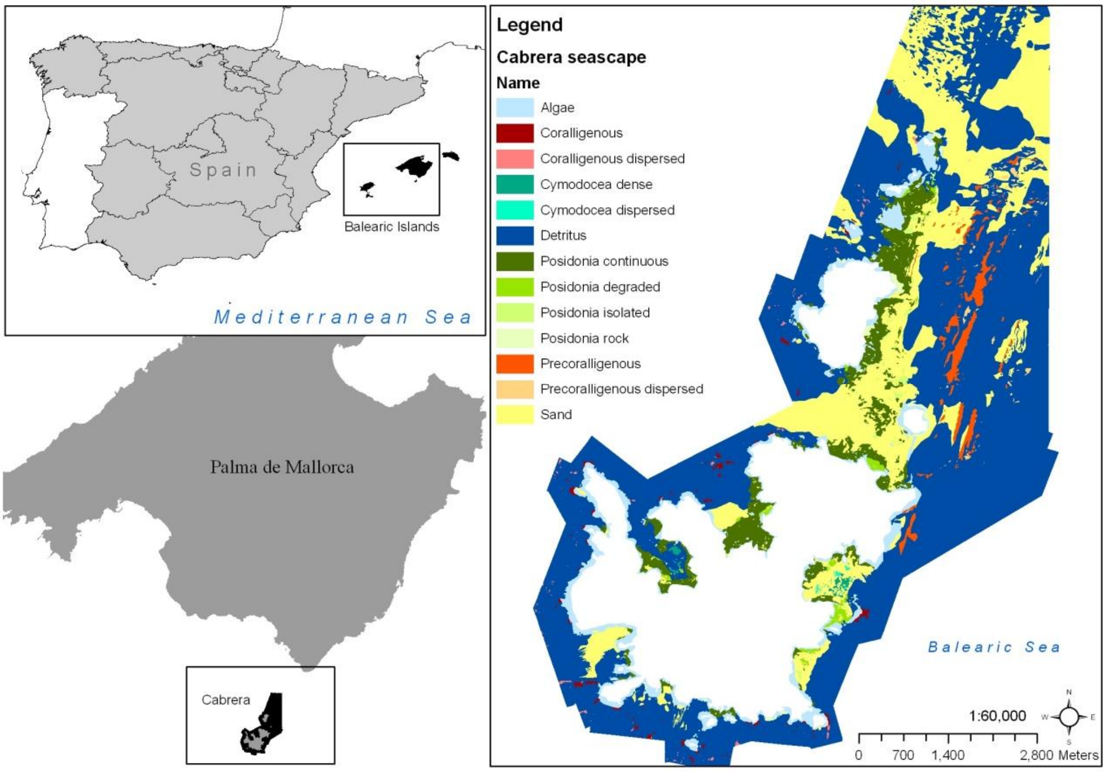


Figure 4.4: The Cabrera Archipelago is a national park in the Balearic Islands in the western Mediterranean Sea.

Human activities have been limited around the archipelago since 1916 when it became a military zone. The CA was declared a National Park (IUCN Category II) in 1991 and a Specially Protected Area of Marine Importance in 2003 under the Barcelona Convention. The archipelago has been protected in order to preserve the large-scale ecological processes and diverse array of coastal and marine habitats. This is a high biodiversity area with significant *Posidonia oceanica* and *Cymodocea nodosa* meadows as well as a number of important benthic habitats, including coralligenous and precoralligenous communities. Damage as a result of bottom trawling has been reported to the north and east of the CA resulting in a proposal to extend the national park (Oceana 2007; Oceana 2012).

4.3.3. Method

4.3.3.1. Data collection and processing

A detailed seascape map of the Cabrera Archipelago was obtained from the Posidonia LIFE project. The benthic habitats were mapped by the project using a side-scan sonar technique for areas between 5 and 35 m deep and orthophotos for areas at depths between 0 and 5 m. The maps were at produced at a scale of 1:1,000. The map was downloaded from the Posidonia LIFE website (http://lifeposidonia.caib.es).

4.3.3.2. Spatial pattern metrics

Spatial pattern metrics (Table 4.2) were calculated using the Patch Analyst extension (Rempel et al. 2012) in ArcMap v.9.3.0 (ESRI). Thirteen metrics were extracted that described shape complexity (shape index and fractal dimension), edge and spatial configuration (patch size and number).

	Spatial metric	Description
Shape complexity	AWMSI	Area weighted mean shape index
	MSI	Mean shape index
	MPAR	Mean perimeter:area ratio
	AWMPFD	Area weighted mean patch fractal dimension
	MPFD	Mean patch fractal dimension
Edge	TE	Total edge
	ED	Edge density (Total length of edge per unit area)
	MPE	Mean patch edge
Spatial config-uration	CA	Class area
	NumP	Number of patches
	MPS	Mean patch size
	MedPS	Median patch size
	PSSD	Patch size standard deviation

Table 4.2: Patch Analyst software was used to extract the spatial pattern metrics of the seascape.

4.3.3.3. Quality comparison

Four benthic habitats that had been classified into healthy and degraded classes were used to assess whether the spatial pattern metrics were able to represent habitat quality. The quality of the habitat was classified by the Posidonia LIFE project. *Posidonia oceanica*, *Cymodocea nodosa*, coralligenous communities and precoralligenous communities were used in this descriptive comparative assessment. For the purpose of this study, ‘healthy’ classes were defined as continuous habitats that that did not display signs of degradation, isolation or presence of erosion channels. Degraded classes were habitats that were classified as isolated (fragmented) or degraded.

4.3.3.4. Multivariate analysis

A Principal Components Analysis (PCA) and Spearman's rank correlation coefficient were performed on all benthic habitats and spatial metrics (except class area) to extract any latent, uncorrelated factors describing seascape patterning. Factors with an eigenvalue greater than one were included and the variables and cases plotted on the factor plane to explore the correlation with the PCA axes. The influence of the spatial attributes of the seascape on the benthic habitats was explored using a two-way joining cluster analysis.

4.3.4. Results

4.3.4.1. Baseline account

A baseline account of the Cabrera Archipelago was created using spatial pattern metrics to quantify the seascape structure (Table 4.3). These metrics represent the quality and quantity of the components of the seascape. When time series data becomes available, changes in these mtrics will reflect the changes in the stocks and flows.

4.3.4.2. Quality comparison

The spatial pattern metrics (Table 4.4) clearly reflect the quality of the benthic habitats. In all four benthic habitat quality comparisons, the fractal dimension of the degraded class was less complex than the healthy counterpart.

The shape index (AWMSI and MSI) was also less complex for the degraded classes with the exception of the coralligenous patches. The edge metrics showed mixed results with the two healthy seagrass habitats (Posidonia and Cymodocea) having a higher length of edge per unit area (ED) than the degraded habitats, while the coralligenous and precoralligenous habitats displayed the opposite. The mean patch edge (MPE), on the other hand, was higher for healthy patches in all cases. The spatial configuration metrics indicate that degraded habitats are more fragmented (many, small patches).

Habitats	AWMSI	MSI	MPAR	MPFD	AWMPFD	TE	ED	MPE	MPS	NumP	MedPS	PSSD	CA
Algae	4,75	1,89	2302,24	1,52	1,49	184572,78	268,79	696,50	0,92	265,00	0,12	2,32	243,23
Coralligenous	1,72	1,49	2978,46	1,56	1,44	19975,94	29,09	176,78	0,16	113,00	0,04	0,26	18,05
Coralligenous dispersed	2,98	1,54	5008,04	1,65	1,39	23552,03	34,30	148,13	0,34	159,00	0,02	3,64	54,55
Cymodocea dense	2,26	1,50	3329,57	1,56	1,47	5140,68	7,49	214,20	0,20	24,00	0,03	0,41	4,92
Cymodocea dispersed	1,59	1,47	4662,27	1,64	1,48	3618,29	5,27	97,79	0,06	37,00	0,02	0,11	2,12
Posidonia isolated	1,55	1,44	3709,35	1,60	1,46	25058,64	36,49	116,01	0,08	216,00	0,03	0,16	17,03
Posidonia with erosion holes	2,83	2,19	948,59	1,45	1,44	10806,59	15,74	900,55	1,37	12,00	0,77	1,60	16,45
Posidonia continuous	4,18	1,76	1911,86	1,49	1,44	92162,28	134,22	815,60	2,05	113,00	0,15	7,41	232,15
Posidonia degraded	1,53	1,51	2039,06	1,50	1,42	3434,58	5,00	214,66	0,21	16,00	0,14	0,20	3,33
Posidonia rock	2,09	1,61	1372,65	1,45	1,40	8387,90	12,22	441,47	0,71	19,00	0,33	1,00	13,52
Mixed meadow Cymodocea and Caulerpa	1,35	1,35	384,20	1,32	1,32	596,42	0,87	596,42	1,55	1,00	1,55	0,00	1,55
Precoralligenous	2,31	1,91	1376,57	1,47	1,40	10016,83	14,59	626,05	1,19	16,00	0,26	2,02	19,10
Precoralligenous dispersed	1,62	1,63	3017,28	1,56	1,45	16626,17	24,21	169,65	0,12	98,00	0,06	0,18	12,09
Precoralligenous on hard bottom	2,24	1,64	2136,89	1,50	1,41	31092,77	45,28	334,33	0,52	93,00	0,13	1,46	48,58

Table 4.3: The baseline account of the Cabrera Archipelago for 2003.

	Spatial metrics	Posidonia healthy	Posidonia degraded	Cymodocea healthy	Cymodocea degraded	Precoralligenous healthy	Precoralligenous degraded	Coralligenous healthy	Coralligenous degraded
Shape complexity	AWMSI	4,18	1,54	2,26	1,59	2,31	1,62	1,72	2,98
	MSI	1,76	1,47	1,50	1,47	1,91	1,63	1,49	1,54
	MPAR	1911,86	2874,20	3329,57	4662,27	1376,57	3017,28	2978,46	5008,04
	AWMPFD	1,44	1,44	1,47	1,48	1,40	1,45	1,44	1,39
	MPFD	1,49	1,55	1,56	1,64	1,47	1,56	1,56	1,65
Edge	TE	92162,28	14246,61	5140,68	3618,29	10016,83	16626,17	19975,94	23552,03
	ED	134,22	20,75	7,49	5,27	14,59	24,21	29,09	34,30
	MPE	815,60	165,34	214,20	97,79	626,05	169,65	176,78	148,13
Spatial configuration									
	MPS	2,05	0,14	0,20	0,06	1,19	0,12	0,16	0,34
	MedPS	0,15	0,09	0,03	0,02	0,26	0,06	0,04	0,02
	NumP	113,00	116,00	24,00	37,00	16,00	98,00	113,00	159,00
	PSSD	7,41	0,18	0,41	0,11	2,02	0,18	0,26	3,64
	CA	232,15	10,18	4,92	2,12	19,10	12,09	18,05	54,55

Table 4.4: The spatial pattern metrics for four healthy and degraded benthic habitats were compared.

4.3.4.3. Multivariate analysis

The Principal Components Analysis showed two important factors explaining 80% of the total variance. The projection of the spatial metrics in Figure 4.5a shows that factor 1 is closely associated with mean patch edge (MPE) and mean patch size (MPS), while factor 2 is a combination of descriptors of shape complexity.

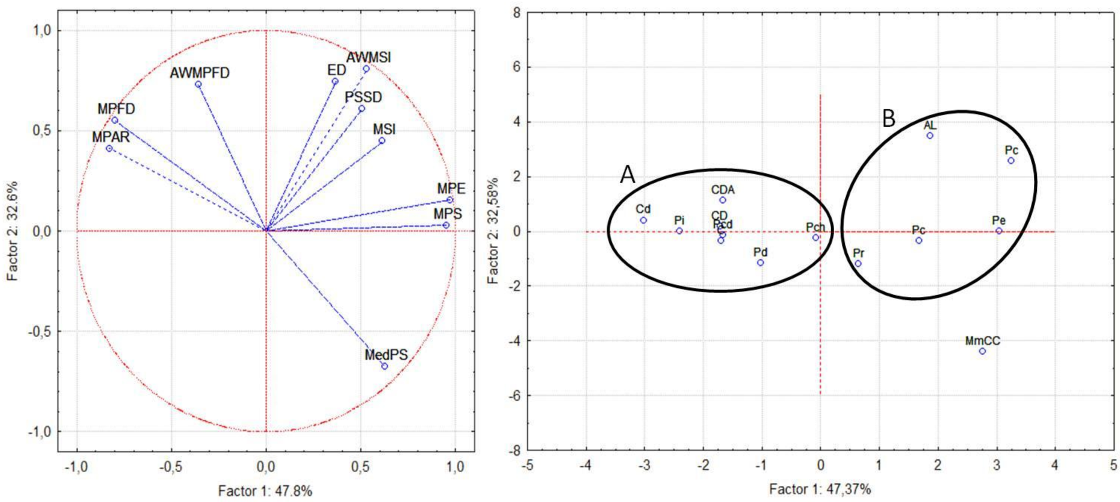


Figure 4.5: The projection of the seascape metrics (panel a) and the benthic habitat classes (panel b).

The loadings (Table 4.5) confirm these associations (0.97 and 0.95 for MPE and MPS, respectively) and also show that MPAR (-0.83) and MPFD (-0.80) are negatively related to factor 1. Loadings for factor 2 show that AWMSI (0.81) has the strongest influence, followed by ED (0.75) and AWMPFD (0.73).

Factor loadings	Factor 1	Factor 2
AWMSI	0.53	**0.81**
MSI	**0.61**	0.45
MPAR	**-0.83**	0.41
MPFD	**-0.80**	0.55
AWMPFD	-0.36	**0.73**
ED	0.37	**0.75**
MPE	**0.97**	0.15
MPS	**0.95**	0.03
MedPS	**0.63**	**-0.67**
PSSD	0.51	**0.61**

Table 4.5: The loadings of spatial metrics are given for factor 1 and 2 (bold indicates loadings > |0.60|).

When the cases (benthic habitat classes) were plotted on the factor 1 x 2 plane (Figure 4.5b) two distinct groups emerged. Group A consists of dispersed Cymodocea (Cd), isolated Posidonia (Pi), dispersed coralligenous communities (CDA), dense Cymodocea meadows (CD), dispersed precoralligenous communities (Pcd), coralligenous communities (C), degraded Posidonia meadows (Pd) and precoralligenous communities on hard bottoms (Pch). These benthic habitats are most influenced by fractal dimension (MPFD, AWMPFD, MPAR). This group is negatively correlated to factor 1 reflecting the fragmentation occurring within these classes. Group B consists of Algae (AL), continuous Posidonia meadows (P), Posidonia with erosion channels (Pe), precoralligenous communities (Pc) and Posidonia growing in rocky areas (Pr). These are mostly continuous habitats with a larger mean patch size and edge, therefore a larger core area. Group B habitats are most influenced by shape complexity. The mixed meadows of Cymodocea and Caulerpa (MmCC) class is an outlier resulting from a lack of representation by a single patch present on the seascape.

A two-way joining of the cluster analysis (Figure 4.6) was used to identify the influence of specific metrics on the benthic habitat classes. Algae (A) and continuous Posidonia (Poc) meadows respond to seascape patterns in a similar way, with the biggest influence from AWMSI, MPS, ED, MSI and MPE. These metrics describe patch shape and size.

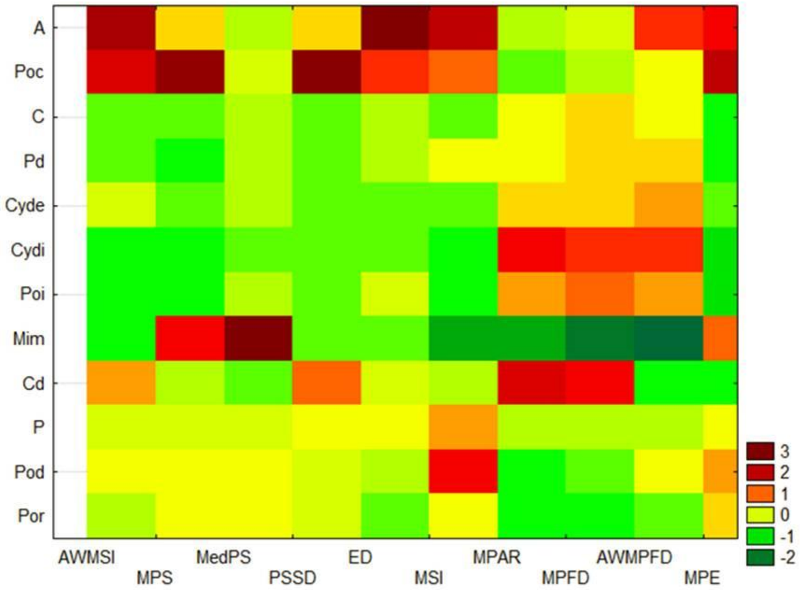


Figure 4.6: The two-way joining table shows that algae and continuous *Posidonia oceanica* meadows have a similar spatial structure.

The Spearman's rank correlation coefficient (Table 4.6) shows several significant relationships between the nine spatial metrics used in this study.

Variable	MSI	MPAR	MPFD	AWMPFD	ED	MPE	MPS	MedPS	PSSD
AWMSI	**0.76**	0.00	0.00	0.15	0.64	0.50	0.47	-0.03	**0.94**
MSI		-0.37	-0.32	0.05	0.45	**0.69**	0.54	0.38	**0.78**
MPAR			**0.99**	0.45	0.24	**-0.83**	**-0.80**	**-0.99**	-0.11
MPFD				0.47	0.27	**-0.82**	**-0.79**	**-0.97**	-0.11
AWMPFD					0.26	-0.17	-0.44	-0.45	-0.10
ED						0.15	0.11	-0.22	0.62
MPE							**0.92**	**0.81**	0.54
MPS								**0.78**	0.56

MedPS	0.08

Table 4.6: The Spearman's rank correlation coefficient is given for the spatial metrics (significant correlations ($p < 0.001$) are given in bold).

The mean perimeter:area ratio (MPAR) is strongly correlated to the mean patch fractal dimension (MPFD). Both of these metrics are negatively correlated to median patch size (MedPS) suggesting that as the median patch size increases, the perimeter of the patch become less complex. Mean patch edge (MPE), mean patch size (MPS) and median patch size (MedPS) are also strongly correlated to each other reflecting the relationship between the size of the patch and the amount of edge it contains.

4.3.5. Conclusions

In this case study, spatial metrics were used to create a baseline physical account of the Cabrera Archipelago seascape. The ability of spatial metrics to reflect the quality of the benthic habitat was demonstrated. This information can be used to monitor changes in the stocks and flows of benthic habitats. Additionally, this case study shows how habitats are correlated to different components of the structure of the seascape. Not only does this provide valuable information for management, but also about the stocks and flows of specific habitats in the seascape.

The multivariate analysis was able to identify two important factors that determine seascape structure in the Cabrera Archipelago. The first is landscape diversity. The results show a negative correlation between patch size and fractal dimension. This means that smaller patches have a more complex edge and contribute to a greater landscape diversity. A diverse landscape has the potential to provide a range of habitat niches and therefore support a wider variety of species, however if the patches are too small this may reduce source habitats, reduce connectivity and ultimately lead to an extinction debt. The second factor is shape complexity. This factor is an indicator of habitat health and in turn can be linked to effective ecosystem service delivery. Shape complexity was most strongly linked to algae and continuous Posidonia meadows, both of which consist of extensive areas whose ecological processes are most threatened by fragmentation. Understanding the ecological consequences of these spatial patterns can provide invaluable information for effective management, planning and monitoring of the coastal environment.

This study on the applicability of spatial pattern metrics to a Mediterranean seascape is starting point for sea ecosystem accounting. The results presented in this paper confirm that landscape ecology spatial pattern metrics provide valuable information on the stocks and flows of typical Mediterranean benthic habitats.

4.4. Case study 2: Including pressures in sea ecosystem accounts

4.4.1. Overview

Anthropogenic disturbance from both the land and sea drives changes in the stocks and flows of seascapes. The following case study demonstrates how changes in the seascape structure can be linked to pressures on the environment. Spatial pattern metrics were used to identify: i) how seascape structure responds to anthropogenic disturbance; ii) whether the protection status influences seascape structure and iii) which aspects of Mediterranean seascape structure are most sensitive to disturbance (Nowell et al., 2013b).

4.4.2. Study area

Spain's Balearic Islands were chosen as a case study due to the presence of a mosaic of habitats representative of typical Mediterranean seascapes, the high conservation interest in the area and the availability of accurate and fine scale benthic habitat maps. The location of the study sites also made for an interesting comparative study between difference disturbance and protection levels.

The Balearic Islands are located 175 km west of the Iberian Peninsula in the western Mediterranean Sea. Eight study sites were chosen (Figure 4.7) to represent different levels of disturbance (red bars), protection (yellow bars) and seascape richness (green bars).

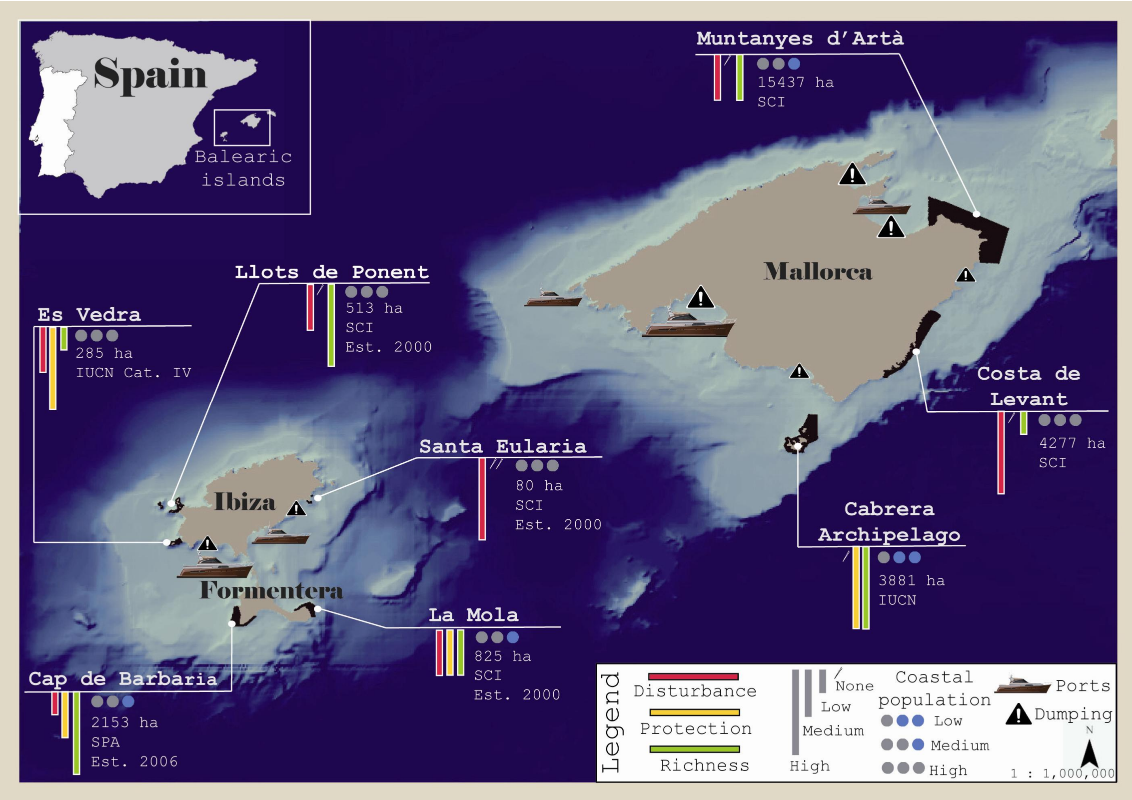


Figure 4.7: Eight study sites were chosen in the Balearic Islands representing different protection and disturbance levels. The red bar indicates the level of disturbance, the yellow bar shows the protection status and the green bar represents seascape richness.

Agricultural runoff, shipping (container ships, ferries, and recreational vessels), commercial fishing, and tourism related pressures (coastal development, additional pressure on natural resources) constitute the main sources of disturbance (Box et al., 2007; Diedrich et al., 2010). While all of the 8 study sites are classified as Sites of Community Importance (SCI) under the European Union Habitats Directive, only two are IUCN category protected areas, namely the Cabrera Archipelago (IUCN category II) and Es Vedrà (IUCN category IV).

4.4.3. Method

4.4.3.1. Data collection

Detailed seascape maps of the eight study sites were obtained from the Posidonia LIFE project (CAIB, 2003). The benthic habitats were mapped by the project using a side-scan sonar technique for areas between 5-35 m deep, and using orthophotos for areas at depths between 0-5 m. The maps were produced at a scale of 1:1,000. The GIS cartography was obtained from the Posidonia Life project (http://lifeposidonia.caib.es).

Spatial pattern metrics were calculated using the Patch Analyst extension (Rempel et al., 2012) in ArcGIS 9.3.0 (ESRI). Twelve metrics were extracted describing shape complexity, spatial configuration and seascape composition. Shape complexity metrics included the mean shape index (MSI), area weighted mean shape index (AWMSI), mean patch:area ratio (MPAR), mean patch fractal dimension (MPFD) and area weighted mean patch fractal dimension (AWMPFD). The metrics representing spatial configuration included the mean patch size (MPS), median patch size (MedPS), patch size standard deviation (PSSD), edge density (ED) and mean patch edge (MPE). Class area (CA) and the number of patches (NumP) described seascape composition.

4.4.3.2. Disturbance indicator selection

Five indicators of disturbance were selected based on the availability of fine-scale data covering the Balearic Islands, namely (i) Sensitive areas due to dumping (MarinePlan), (ii) Commercial shipping pressure at a 1×1 km spatial resolution (Halpern et al., 2008), (iii) Coastal population (number of inhabitants per municipality) (MarinePlan, 2009), (iv) Risk of hypoxia at a 1×1 km spatial resolution (Halpern et al., 2008), and (v) the Global Human Influence Index score (HII) at a 719×719 m spatial resolution) (WCS, 2005). The HII is based on nine global data layers that cover human land use and infrastructure, human population pressure and human access. Study sites were given a score for each disturbance indicator based on the whether the pressure was low (0), medium-low (0.25), medium (0.5), medium-high (0.75), or high (1). To facilitate comparisons between study sites, a general disturbance score was calculated as the sum of the pressure scores.

4.4.3.3. Multivariate analysis

A Principal Components Analysis (PCA) was performed using STATISTICA 8.0 (StatSoft, 2007) to extract any underlying, uncorrelated factors and to determine if, and which disturbance indicators were influencing the spatial patterning of the seascape. Factors with an eigenvalue >1 were extracted and the variables and cases plotted on the factor plane to explore the correlations with the PCA axes. The seascape metrics were projected as active variables with the disturbance and protection indicators as supplementary variables. Spearman's rank correlation coefficient was calculated to test the statistical relationship between each spatial metric and disturbance/protection indicator.

4.4.4. Results

Baseline accounts were created for the 8 study sites using spatial pattern metrics to describe the quality and quantity of the stocks and flows (see annexes 4.1-8).

The PCA showed two important factors explaining 60% of the total variance. The projection of the variables (Figure 4.8a) shows that the first axis represents the disturbance-protection continuum. Mean and median patch size (MPS and MedPS) are closely linked to two major disturbance indicators, namely commercial shipping and coastal population. The factor loadings (Table 4.7) also show that the fractal dimension metrics (MPFD, AWMPFD, MPAR) and the number of patches (NumP) have an inverse relationship with disturbance. This indicates that highly disturbed areas are associated with fewer, larger patches with a lower fractal dimension. Mean patch edge (MPE) was closely related with disturbance.

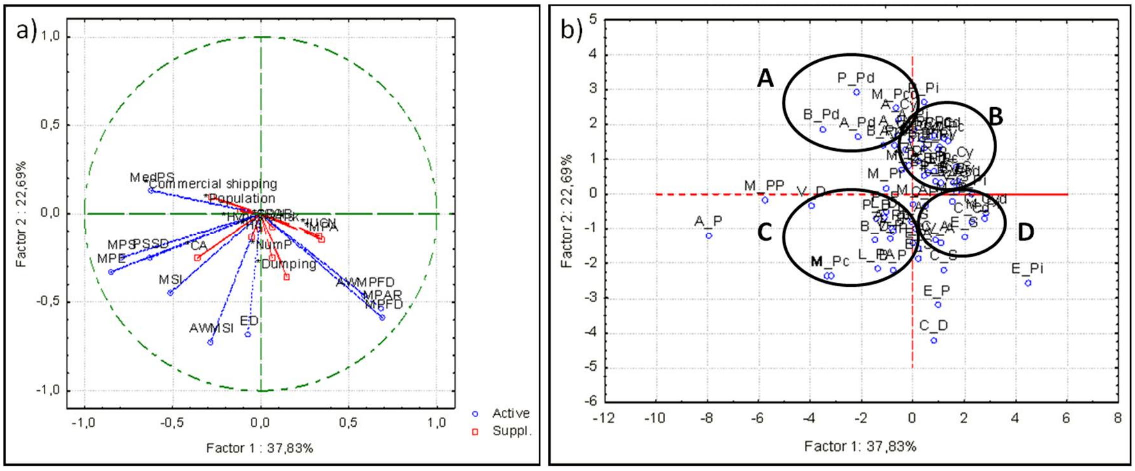


Figure 4.8: The factor loadings of the spatial metrics, disturbance indicators and protection status are projected in panel a. Panel b shows the four groups that emerge when the benthic habitats were plotted. Group A: degraded and fragmented Posidonia meadows; Group B: Cymodocea, coralligenous communities and precoralligenous communities; Group C: continuous Posidonia meadows and detritus; and Group D: sand and algae.

Variables	Factor 1	Factor 2
AWMSI	-0,28	**-0,72**
MSI	-0,52	-0,45
MPAR	**0,68**	-0,53
MPFD	**0,69**	-0,58
AWMPFD	0,58	-0,46
ED	-0,07	**-0,68**
MPE	**-0,85**	-0,33
MPS	**-0,79**	-0,25
MedPS	**-0,62**	0,13

PSSD	**-0,63**	-0,25
*NumP	0,06	-0,25
*CA	-0,36	-0,25
*Dumping	0,15	-0,36
*Commercial shipping	-0,28	0,10
*Hypoxia risk	-0,01	-0,09
*HII	-0,05	-0,13
*Population	-0,12	0,02
*MPA	0,35	-0,15
*SCI	0,07	-0,08
*SPAB	0,07	-0,08
*IUCN	0,33	-0,13

Table 4.7: The factor loading are given for the variables. The asterisk (*) denotes supplementary variables. Bold indicates loadings > |0.60|.

Factor 2 (the y-axis in Figure 8a) is associated with metrics representing the spatial complexity of patches. The loadings show a relatively strong relationship between factor 2 and the area weighted mean shape index (AWMSI) and edge density (ED). Both of these metrics are weighted for patch area meaning larger patches have a higher mean shape index and more edge.

The projection of the benthic habitat classes and study sites on the factor-plane (Figure 4.8b) shows grouping based primarily on habitat type, suggesting that habitats are responding to disturbance in a similar way. The projection of the cases can be grouped into four main classes: Group A consists of predominantly degraded and fragmented *Posidonia* meadows; Group B consists of small patches of *Cymodocea*, coralligenous communities and precoralligenous communities; continuous *Posidonia* meadows and detritus are the dominant classes found in Group C and are most responsive to shape complexity; finally Group D consists of extensive patches of sand and algae that are strongly linked to the fractal dimension metrics.

The Spearman's rank coefficient (Table 4.8) shows that most disturbance indicators are negatively correlated to the fractal dimension metrics. Coastal population is also negatively correlated to the number of patches (NumP). This suggests that the higher the density of the coastal population, the fewer the number of patches in the seascape. While the mean patch fractal dimension (MPFD) and mean perimeter:area ratio (MPAR) have an inverse relationship with disturbance, the area weighted mean patch fractal dimension (AWMPFD) is positively correlated to sensitive areas due to dumping. This is a result of larger patches being weighted more in the AWMPFD formula. Interestingly, the IUCN protection indicator is positively correlated to fractal dimension and negatively correlated to patch size. This means that the seascape of IUCN protected areas tends to consist of smaller patches which have a higher fractal dimension.

Spatial metric	Dumping	Shipping	Hypoxia risk	HII	Population	SCI/SPAB	IUCN
AWMSI	0.25	0.01	0.23	0.12	0.01	-0.05	-0.04
MSI	0.03	0.06	-0.04	0.00	-0.01	0.16	-0.03
MPAR	0.09	**-0.33**	-0.03	**-0.34**	-0.29	**0.32**	**0.36**
MPFD	0.19	**-0.31**	-0.02	-0.28	-0.26	**0.31**	**0.35**
AWMPFD	**0.38**	-0.19	-0.07	-0.06	0.12	0.07	**0.33**
ED	0.28	-0.12	0.09	0.16	0.22	-0.04	-0.01
MPE	0.00	0.15	0.11	0.17	0.09	-0.03	**-0.31**
MPS	-0.05	0.17	0.15	0.17	0.04	-0.06	**-0.32**
NumP	0.08	-0.02	0.25	-0.10	**-0.39**	-0.06	0.28
MedPS	-0.15	0.26	-0.03	0.19	0.18	-0.11	-0.25
PSSD	0.02	0.10	0.28	0.13	-0.08	-0.07	-0.21
CA	0.00	0.14	0.24	0.07	-0.21	-0.09	-0.08

Table 4.8: The Spearman's rank correlation coefficient shows the correlations between the spatial metrics and the disturbance and protection indicators. The significant correlations ($p<0.001$) are given in bold.

4.4.5. Conclusions

Due to the rapid loss and degradation of marine biodiversity and coastal ecosystem services globally, it has become imperative to understand how disturbance affects seascape structure. Here, we have shown how spatial pattern metrics can be linked to anthropogenic disturbance indicators as inputs for sea ecosystem accounts. While five indicators are used in this case study, any number of pressures can be included in the multivariate analysis as can other environmental variables. This technique provides a comprehensive approach to understanding how variables affect different components of the seascape structure.

The case study showed that the fractal dimension of patches is most sensitive to disturbance. Disturbed seascapes consisted of larger, fewer, less complex patches, while protected areas were found to be more heterogeneous. Fractals were used by Kostylev et al. (2005) to explore the species-area relationship in intertidal zones and found that complex habitats support more species. In the case of the Balearic Islands, reducing disturbance in the coastal zone, for example by relocating commercial shipping routes away from the islands would certainly influence seascape structure and therefore also biodiversity.

This study on the applicability of spatial pattern metrics in a Mediterranean seascape is a starting point for understanding the ecological consequences of seascape structure. The technique can be used to identify how disturbance indicators are driving changes in the quality and quantity of seascape stocks and flows. We conclude that landscape ecology spatial pattern metrics provide valuable information on the effects of disturbance on seascape structure for typical Mediterranean benthic habitats.

4.5. Conclusions and recommendations

4.5.1. Main conclusions

As the human population continues to increase, so does the pressure on coastal and marine natural resources. It has become imperative to understand how these ecosystems respond to anthropogenic pressure and how the ecosystem services are linked to human uses and economics. Ecosystem accounting addresses this need by tracking the changes in the quality and quantity of ecosystem goods and services in relation to human activities.

It has proved challenging to create ecosystem accounts for the marine environment due to limited understanding of ecosystem processes and scarce spatial data. In this report, we propose a solution to this problem using seascape structure as a proxy for both the stocks and flows required for ecosystem accounting. In this way, the inputs required for accounts can be provided quickly and automatically using user-friendly software that is available free of charge. Furthermore, this data can also be used as a decision-support tool, a consistent method of monitoring seascapes at multiple spatial and temporal scales, and for identifying priority areas for protection.

A basic framework for sea ecosystem accounting using spatial pattern metrics is outlined along with a case study to demonstrate the creation of baseline accounts for seascapes. A second case study shows how pressure indicators or environmental variables can be included in sea ecosystem accounts to track which components of the seascape are affected. While time series data is required to further develop this ecosystem accounting method, the seascape ecology approach is certainly a positive step in the direction of creating physical ecosystem accounts of coastal ecosystems.

4.5.2. Limitations

The main limiting factor of this study was the availability of spatial data. While spatial metrics can provide valuable information at all scales, even coarse resolution data is lacking in the Mediterranean Sea. Benthic habitat maps are confined to scattered local scale studies or modelled distribution maps at the regional sea-scale (currently only available for the Western Mediterranean). Time-series data is practically non-existent. Disturbance data is in most cases only available at coarse spatial resolution (minimum of 1 km^2) resulting in a limited number of disturbance indicators that could be included at the scale of this study. It is therefore recommended that future studies carefully weigh their objectives against the availability of data.

4.5.3. Recommendations

This is a first step towards creating sea ecosystem accounts and as spatial data becomes available, so the ability of these accounts to represent reality will improve. We recommend that the techniques presented in this report be tested with time-series data at a various scales to ensure their robustness. The next step is to link spatial metrics to ecosystem services for the purpose of creating monetary ecosystem accounts. Valuation of ecosystem services is required for externalities to be included in the market price of marine resources. Linking spatial metrics to biological variables is recommended to further enhance the possibilities for effective marine spatial planning and management.

4.6. Acknowledgements

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4.7. References

Airoldi, L., Balata, D., Beck, M.W., 2008. The Gray Zone: Relationships between habitat loss and marine diversity and their applications in conservation. Journal of Experimental Marine Biology and Ecology 366, 8-15.

Böstrom, C., Pittman, S.J., Simenstad, C., Kneib, R.T., 2011. Seascape ecology of coastal biogenic habitats: advances, gaps, and challenges. Marine Ecology Progress Series 427, 191-217.

Box, A., Sureda, A., Galgani, F., Pons, A., Deudero, S., 2007. Assessment of environmental pollution at Balearic Islands applying oxidative stress biomarkers in the mussel Mytilus galloprovincialis. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology 146, 531-539.

CAIB, 2003. Posidonia LIFE Project, In: Ambient, C.d.M. (Ed.), lifeposidonia.caib.es. Govern de les Illes Balears.

Costanza, R., 1999. The ecological, economic, and social importance of the oceans. Ecological Economics 31, 199-213.

Cushman, S.A., McGariyal, K., Neel, M.C., 2008. Parsimony in landscape metrics: Strength, universality, and consistency. Ecological Indicators 8, 691-703.

Diedrich, A., Tintoré, J., Navinés, F., 2010. Balancing science and society through establishing indicators for integrated coastal zone management in the Balearic Islands. Marine Policy 34, 772-781.

Gray, J., 1997. Marine biodiversity: patterns, threats and conservation needs. Biodiversity & Conservation 6, 153-175.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R., Watson, R., 2008. A Global Map of Human Impact on Marine Ecosystems. Science 319, 948-952.

Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, R.G., Kay, M.C., Kidwell, S.M., Kirby, M.X., Peterson, C.H., Jackson, J.B.C., 2006. Depletion, Degradation, and Recovery Potential of Estuaries and Coastal Seas. Science 312, 1806-1809.

MarinePlan, Sea disposal sites and protected areas, In: MarinePlan (Ed.). www.marineplan.es, Seville.

MarinePlan, 2009. Coastal population. www.marineplan.es, Seville.

Meynecke, J.O., Lee, S.Y., Duke, N.C., 2008. Linking spatial metrics and fish catch reveals the importance of coastal wetland connectivity to inshore fisheries in Queensland, Australia. Biological Conservation 141, 981-996.

Nowell, M., Ivanov, E., Morisseau, F., Haines-Young, R., Breton, F., 2011. Extending Ecosystem Accounting Methods for the Mediterranean and Black Sea Basins, In: Ozhan, E. (Ed.), Medcoast 11, Vols 1 and 2, pp. 135-144.

Nowell, M.S., Kalwij, J.M., Breton, F., Salvati, L., 2013b. Composition, configuration or complexity:spatial metrics to manage disturbed seascapes, DGM Mitteligungen.

Nowell, M.S., Salvati, L., Breton, F., 2013a. Seascape metrics for the Mediterranean Sea: A case study, In: Ozhan, E. (Ed.), Global Congrass on ICM, Marmaris, Turkey.

Pittman, S.J., Christensen, J.D., Caldow, C., Menza, C., Monaco, M.E., 2007. Predictive mapping of fish species richness across shallow-water seascapes in the Caribbean. Ecological Modelling 204, 9-21.

Pittman, S.J., Kneib, R.T., Simenstad, C.A., 2011. Practicing coastal seascape ecology. Marine Ecology Progress Series 427, 187-190.

Rempel, R.S., Kaukinen, D., Carr, A.P., 2012. Patch Analyst and Patch Grid, In: Resources, O.M.o.N. (Ed.). Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario.

StatSoft, 2007. STATISTICA, Data analysis software system, 8.0 ed.

WCS, 2005. Global Human Influence Index, In: Wildlife Conservation Society (WCS), C., Columbia University (Ed.), Last of the Wild project Version 2. NASA Socioeconomic Data and Apllications Center, Palisades, NY.

Wedding, L.M., Lepczyk, C.A., Pittman, S.J., Friedlander, A.M., Jorgensen, S., 2011. Quantifying seascape structure: extending terrestrial spatial pattern metrics to the marine realm. Marine Ecology Progress Series 427, 219-232.

4.8. Annexes of chapter 4

Annex 4.1: Baseline account of the Muntanyes d'Arta seascape

Habitats	NP	CA	MPS	PSSD	Prop	TE	MPE	MSI	MPAR	MFRACT	DIV	SPLIT	MESH	MNN
Cymodocea	4	89700,06	22425,02	34282,99	0,03	2883,51	720,88	1,524	0,08	1,387	16,57	1,2	74836,28	16,907
Cymodocea dispersed	12	148814	12401,17	26490,21	0,05	5284,07	440,34	1,436	0,791	1,448	53,64	2,16	68987,09	343,086
Detritus	894	25270289	28266,54	169071,4	9,21	594617,4	665,12	3,03	5,869	1884,653	95,89	24,31	1039538	25,296
Posidonia	825	43079717	52217,84	751395,1	15,69	709250,5	859,7	2,786	5,338	1,937	74,78	3,97	10864511	0,982
Posidonia CRI	142	2508146	17663	39137,28	0,91	113954,8	802,5	4,92	19,637	2,593	95,84	24,03	104382,5	45,917
Posidonia degraded	316	14910908	47186,42	319982,8	5,43	255776,4	809,42	2,832	2,271	1,943	85,13	6,73	2217069	17,083
Posidonia isolated	212	1833740	8649,72	14246,61	0,67	88629,94	418,07	3,175	5,374	2,097	98,25	57,1	32114,77	110,072
Ripples	1656	55289481	33387,37	994916,6	20,14	979955	591,76	2,575	4,527	2,357	46,32	1,86	29681100	22,621
Rocky	78	1152512	14775,8	39237,76	0,42	60453,18	775,04	3,461	5,611	1,873	89,68	9,69	118973,4	63,949
Sand	312	10086390	32328,17	347362,1	3,67	174665,3	559,82	4,134	12,538	4,014	62,68	2,68	3764689	50,952

Annex 4.2: Baseline account of the Cap de Barbaria seascape														
Habitats	NP	CA	MPS	PSSD	Prop	TE	MPE	MSI	MPAR	MFRACT	DIV	SPLIT	MESH	MNN
Algae	24	199432,1	8309,67	9562,37	0,07	14442,76	601,78	3,296	12,041	5,568	90,32	10,33	19313,6	23,889
Cymodocea	3	14548,14	4849,38	6384,07	0,01	769,15	256,38	1,43	0,253	1,518	8,9	1,1	13253,83	1852,398
Cymodocea dispersed	9	97962,98	10884,78	14592,21	0,04	3552,91	394,77	1,4	0,23	1,485	68,92	3,22	30447,2	554,211
Detritus	21	2320714	110510,2	393159	0,85	37617,7	1791,32	4,687	9,528	4,027	34,97	1,54	1509241	5,913
Posidonia continuous	55	6049825	109996,8	563168,1	2,2	98493,03	1790,78	5,498	36,293	2,8	50,52	2,02	2993337	10,107
Posidonia degraded	19	2771399	145863,1	446110,5	1,01	28829,87	1517,36	3,161	3,229	3,525	45,51	1,84	1510256	97,793
Posidonia isolated	31	109440,2	3530,33	7679,98	0,04	7252,23	233,94	1,456	1,734	1,494	81,51	5,41	20237,6	124,574
Posidonia rock	10	140695,7	14069,57	16870,01	0,05	7590,4	759,04	4,585	7,77	9,385	75,62	4,1	34297,43	62,666
Precoralligenous	29	395364,7	13633,26	51219,89	0,14	11472,56	395,61	1,729	2,02	1,534	47,88	1,92	206065,3	37,025
Sand	204	9425872	46205,25	392563,4	3,43	161684,1	792,57	2,592	9,912	1,544	64,13	2,79	3381454	20,183

Annex 4.3: Baseline account of the Cabrera Archipelago seascape														
Habitats	NP	CA	MPS	PSSD	Prop	TE	MPE	MSI	MPAR	MFRACT	DIV	SPLIT	MESH	MNN
Algae	415	2432331	5861,04	14172,15	0,89	245686,4	592,02	2,967	11,382	1,959	98,35	60,61	40129,71	8,772
Coralligenous	123	180457	1467,13	2511,38	0,07	20577,32	167,3	1,864	2,655	1,989	96,8	31,3	5766,02	60,361
Coralligenous dispersed	169	545543,1	3228,07	35257,93	0,2	24294,35	143,75	1,714	1,068	1,97	28,82	1,4	388326,2	32,454
Cymodocea dense	29	64707,52	2231,29	4570,09	0,02	6057,61	208,88	1,569	0,542	1,715	82,09	5,58	11591,64	12,991
Cymodocea dispersed	38	21160,88	556,87	1089,71	0,01	3662,9	96,39	1,559	0,621	1,721	87,29	7,87	2689,27	19,072
Detritus	550	23377231	42504,06	333982,9	8,52	506287,2	920,52	2,618	2,723	2,019	88,59	8,77	2666832	4,496
Posidonia continuous	205	2321507	11324,43	53823,59	0,85	113305,8	552,71	2,593	10,925	2,168	88,49	8,69	267141,3	10,950
Posidonia degraded	43	197806,9	4600,16	9230,19	0,07	17268,68	401,6	2,495	5,099	1,953	88,31	8,56	23120,46	54,223
Posidonia isolated	233	170290	730,86	1550,18	0,06	25946,06	111,36	1,531	0,867	1,697	97,64	42,37	4018,86	43,239
Posidonia rock	28	135222,1	4829,36	8175,38	0,05	10299,09	367,82	2,081	1,796	1,717	86,19	7,24	18669,06	151,249
Precoralligenous	117	676758,2	5784,26	15254,71	0,25	41851,7	357,71	2,079	1,968	1,773	93,2	14,71	46015,21	35,827
Precoralligenous dispersed	103	120906,9	1173,85	1740,54	0,04	16637,86	161,53	1,642	0,959	1,638	96,89	32,2	3754,66	44,048
Sand	521	8569244	16447,69	176116,3	3,12	243963,2	468,26	2,225	7,06	1,937	77,8	4,5	1902242	15,258

Annex 4.4: Baseline account of Santa Eularia seascape													
Habitats	NP	CA	MPS	PSSD	Prop	TE	MPE	MSI	MPAR	MFRACT	DIV	SPLIT	MESH	MNN
Algae	9	103678,7	11519,86	13395,15	0,04	7789,46	865,5	3,516	14,246	1,525	73,87	3,83	27095,58	79,321
Posidonia continuous	32	624278,9	19508,71	83776,68	0,23	18246,68	570,21	6,003	122,52	4,625	39,25	1,65	379272,6	1,894
Posidonia isolated	11	1954,73	177,7	160,84	0	782,68	71,15	1,54	0,582	1,756	83,46	6,05	323,28	12,856
Posidonia rock	10	10345,58	1034,56	1300,41	0	1455,03	145,5	2,778	15,889	1,533	74,2	3,88	2669,15	20,656
Sand	41	62724,46	1529,86	3894,29	0,02	6377,68	155,55	4,779	94,928	3,417	81,76	5,48	11442,85	6,517

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Annex 4.5: Baseline account of the Costa de Levant seascape													
Habitats	NP	CA	MPS	PSSD	Prop	TE	MPE	MSI	MPAR	MFRACT	DIV	SPLIT	MESH	MNN
Algae	40	370752,5	9268,81	15972,04	0,14	36357,61	908,94	2,761	0,202	1,563	90,08	10,08	36791,85	15,964
Cymodocea	93	459119,5	4936,77	22320,06	0,17	27652,18	297,34	1,427	1,716	1,474	76,95	4,34	105850	24,394
Detritus	60	4670701	77845,02	287837,9	1,7	115870,9	1931,18	2,115	0,091	1,43	75,55	4,09	1142148	33,399
Posidonia	260	20055928	77138,18	1066115	7,31	231830,1	891,65	1,841	17,735	1,479	26,15	1,35	14811745	18,271
Posidonia Algae	40	903486,2	22587,15	28994,23	0,33	78359,58	1958,99	3,693	2,544	1,553	93,38	15,11	59805,89	2,409
Sand	723	15721193	21744,39	229668,6	5,73	392168,2	542,42	1,743	10,538	1,482	84,43	6,42	2447549	18,933

Annex 4.6: Baseline account of La Mola seascape														
Habitats	NP	CA	MPS	PSSD	Prop	TE	MPE	MSI	MPAR	MFRACT	DIV	SPLIT	MESH	MNN
Algae	18	260120,6	14451,14	18815,4	0,09	16969,31	942,74	2,986	1,925	2,805	85,03	6,68	38948,82	33,039
Detritus	19	1295003	68158,06	137818,2	0,47	25345,87	1333,99	1,759	0,179	1,456	73,22	3,73	346831,7	75,916
Posidonia continuous	20	3864397	193219,9	668015,8	1,41	56771,79	2838,59	6,592	16,055	6,072	35,24	1,54	2502740	2,475
Posidonia isolated	8	7866,51	983,31	1088,64	0	1128,37	141,05	1,609	0,476	1,674	72,18	3,59	2188,55	575,395
Posidonia Precoralligenous	5	815949,4	163189,9	222376,7	0,3	16912,34	3382,47	4,633	4,051	12,413	42,86	1,75	466219,6	129,276
Posidonia rock	9	175540,1	19504,45	16370,58	0,06	12243,11	1360,35	4,553	8,713	1,463	81,06	5,28	33244,69	55,125
Precoralligenous	7	1476774	210967,7	516307	0,54	19047,58	2721,08	8,092	8,249	2,957	0,15	1	1474540	10,796
Precoralligenous dispersed	2	31739,9	15869,95	1270,55	0,01	1400,11	700,06	1,582	0,045	1,352	49,68	1,99	15971,67	336,840
Sand	163	322492,8	1978,48	5441,9	0,12	34127,11	209,37	1,975	1,664	1,641	94,75	19,03	16946,63	29,738

Annex 4.7: Baseline account of the Llots de Ponent seascape														
Habitats	NP	CA	MPS	PSSD	Prop	TE	MPE	MSI	MPAR	MFRACT	DIV	SPLIT	MESH	MNN
Algae	105	911515,1	8681,1	31731,5	0,33	70590,55	672,29	4,71	9,306	7,9	86,32	7,31	124667,4	11,629
Coralligenous dispersed	1	765,71	765,71	0	0	121,52	121,52	1,239	0,159	1,446	0	1	765,71	0,000
Cymodocea	3	1861,2	620,4	159,18	0	373,56	124,52	1,398	0,201	1,497	64,47	2,81	661,24	12,675
Detritus	51	1868291	36633,16	94588,04	0,68	57486,4	1127,18	4,802	15,129	3,198	84,97	6,65	280862,7	4,912
Posidonia continuous	56	1768116	31573,51	162285,5	0,64	52234,14	932,75	3,987	11,817	2,027	51,04	2,04	865708,8	2,751
Posidonia degraded	1	71829,98	71829,98	0	0,03	1501,52	1501,52	1,58	0,021	1,308	0	1	71829,98	17,454
Posidonia isolated	1	1389	1389	0	0	144,31	144,31	1,092	0,104	1,374	0	1	1389	0,000
Precoralligenous	6	8699,54	1449,92	1813,57	0	971,45	161,91	4,492	24,205	1,485	57,26	2,34	3718,34	90,986
Sand	72	330853,2	4595,18	19047,51	0,12	18769,8	260,69	2,028	2,741	1,624	74,75	3,96	83549,1	31,094

Annex 4.8: Baseline account of the Es Vedra seascape														
Habitats	NP	CA	MPS	PSSD	Prop	TE	MPE	MSI	MPAR	MFRACT	DIV	SPLIT	MESH	MNN
Algae	42	261183,3	6218,65	12805,28	0,1	23316,51	555,15	2,458	3,35	1,657	87,52	8,01	32586,96	28,763
Detritus	11	953378,3	86670,76	126774,2	0,35	24019,68	2183,61	3,517	3,418	2,318	71,46	3,5	272104,7	0,000
Posidonia continuous	16	1441659	90103,67	315944,8	0,53	28744,7	1796,54	3,861	10,068	2,131	16,9	1,2	1197951	25,326
Posidonia isolated	3	28254,42	9418,14	7347,18	0,01	1795,78	598,59	1,707	0,072	1,398	46,38	1,87	15149,75	471,881
Posidonia rock	11	123420,3	11220,02	10775,42	0,04	8125,99	738,73	2,023	0,099	1,442	82,52	5,72	21568,46	29,549
Precoralligenous	3	2559,96	853,32	765,44	0	325,64	108,55	1,184	0,228	1,484	39,85	1,66	1539,93	247,247
Sand	34	41859,08	1231,15	1541,43	0,02	5986,82	176,08	1,537	0,304	1,568	92,45	13,24	3161,06	34,443

5. Integration of results, discussion, lessons learned, and Recommendations

5.1 Integration of results

There is a wide recognition that spatially explicit accounts on the distribution and changes of habitats and communities at land and sea are strongly needed for a sound implementation of ecosystem based strategies such as ICZM (Claudet and Frashetti, 2010, Frashetti et al, 2011).

At the same time, the land-sea linkages must be strengthened in terms of data that should be available and uniform for both part and their interface. Accounting is not possible without data. For the land, remote sensing data has been most used. But in the complex marine environment, remote sensing is helful for some issues but not sufficient for full accounts. So data collation is also based on available monitoring data and models. There are many data monitored for the sea water, species and habitat, the main problem we faced is their availability.

There is also a need to streghten land-sea linkages through planning (e.g. ICZM and MSP) and governance, including both land and marine stakeholders (e.g Marine Protected areas managers, aquaculture producers, etc.), (Cicin-Sain and Belfiore, 2005), that would greatly help to gather more and more relevant data.

As a matter of fact, when stakeholders are implicated in the methodology and its validation, when they understand the usefulness of the results for their own decisions, they use to help in providing data compilation at national, regional or local scales. Some FP7 projects that monitor marine water and ecosystems are more reticent to provide data, even to another FP7 projects. Data are needed to construct accounts and to validate the draft results.It is the way to release a high quality final product.

The last developments of ecosystem accounts in the sea are generally focused on resource like fisheries because the link with economy is easier to define and because we have historical data for some species and areas. The goal of PEGASO project was not to provide separated accounts of what happen in land and of what happened in the sea but, at the contrary, to strengthen the link between the two environments.

In the accounting framework that has been developed, three innovative complementary axes have been produced:

-An accounting methodology based on a land cover map, PEGASO LAND COVER (PLC), done with different remote sensing data, to determine and measure stocks. Produced at two dates (2000-2011), the PLC allows measuring changes in land cover flows and identifying their drivers over the Mediterranean and the Black Sea coast. These basic accounts have been associated to the change in the quality of ecosystems, approximated by a biodiversity indicator.

-A methodology allowing spatial explicit quantification of human activities pressures, measuring also potential impacts of each activity over coastal and marine ecosystems. In this methodology, land based pressures are calculated on the basis of land cover/land use changes at the coast and in the catchments. Therefore any improvement of land cover mapping done in the LEAC part will allow improving the index. Moreover, the ability to calculate land use changes for the all Mediterranean, should allow to model where land based pressures are mostly increasing.

-Spatial pattern metrics provide an interesting and innovative approach to sea ecosystem accounting byquantifying changes in the quality and quantity of benthic ecosystems. This tool requires spatial data of coastal and marine habitats which serves as a proxy for the stocks and flows of these ecosystems. Using this approach, baselines of coastal and marine habitats can be characterized and monitored to determine where benthic ecosystem state is improving or degrading

The work on LEAC/SEAC has represented a real challenge for the team, as most of these methodologies have had to be re-invented, in relation with available data, (1) to extend PEGASO Land Cover to all coastal areas of the two basins, Mediterranean and Black Sea. It is the first time that such a product is achieved. (2) to link land ecosystems and sea ecosystem accountings.

The impossibility for applying the same methodology used at land to the sea has been explained in the introduction. The most similar to LEAC is the work done on measuring changes in benthic ecosystems. As it focuses on the seascape as a whole, it can be easily compared with landscapes, and interconnexions should be applied to assess the quality of coastal landscape through land cover and ecosystem changes with the quality of marine ecosystems, even though the methods for monitoring and measuring are different.

The emerging field of seascape ecology provides the multi-scale tools necessary to quantify seascape structure and can be used as a proxy for biodiversity. Furthermore, seascape structure can be linked to ecosystem services. A framework for sea ecosystem accounting is given in chapter 4.

A cumulative Impact and Pressure Index was developped reviewing Halpern methodologies that have been already applied at global scale, and at regional scales in the Baltic Sea and the North Sea. The conceptual frame is more focused on appraisal of stressors and on the cumulative pressures and impacts they exerced on the coastal marine ecosystems. A mapping of coastal and marine ecosystems was done based on sea bed EUNIS communitiy map (EUSEAMAP). At present it has been produced only for the Western Mediterranean, but it is planned to be extended in the future to the whole Mediterranean. This has represented a gap in coverage, but the methodology is robust and reproducible when data will be available.

After many team discussions and exchanges, to drive the work in a real integrated direction, it was decided that first a better appraisal of each method was needed, as they had *per se* a hight level of technicality. Therefore development of those methodologies run in parallel during the PEGASO project, to get the best results from each, validate them and identify the uncertainty threasholds together with the stakeholders, and therefore analyse at how they can relate together in an accounting exercise.

We quickly understood that the integration of those three methodologies should provide important improvement to identify trends in where human activities (land and sea) are intensifying, the risks of impact on the surrounding ecosystems, helping to assess their current state (quality) of habitats and identifying the main stressors (e.g. which activities impact mainly and where they need to be regulated, planned and managed) to improve the quality of coastal and marine ecosystem.

5.2 Discussion

If the three methods have been developed separately, they can be integrated in coastal and sea accounts in different ways. (1) Through the hierarchical classification framework used in LEAC that has facilitated a multi-scale approach to the production of statistical data for different analytical units of the coastal zones. (2) The results on pressures and impacts on the ecosystems (WMIIE) have been also processed in a statistical way, by spatial units, using the same 1km grid than LEAC for the coast and the sea. (3) The SEAC results on seascapes provide a uselful approach to quantifying changes in the quality and quantity of the stocks and flows of benthic ecosystems. The approach also allows for the inclusion of land and sea-based variables (such as human population, land cover change, water quality or other marine pressures) for a more targeted and inclusive analysis that reflects the dynamics and interactions between the terrestrial and marine realms. . All three data bases are currently incorporated into the Spatial Data Infrastructure (SDI, WP3) of PEGASO that is accessible throught the web.

LEAC results at the coast helped to map land pressures in coastal and marine ecosystems in the WMIIE. This methodology used to to identify and measure pressures, developing quantitative indexes on pressures and impacts on coastal and marine ecosystems allows at the same time to create direct links between land and sea by calculating land based pressures as a function of coastal and watershed land cover maps. As such, it does not provide marine ecosystem accounts but rather an estimation of where changes in quality and quantity of marine habitats and species may occur and which are the causes of those changes both from land and sea.

Spatial pattern metrics provide a simple and consistent method for baseline characterisation and monitorization over time. This information can be easily combined with other types of spatial data, for example land use changes and protection status (developed in LEAC), pressures and impacts (from the WMIIE), and their main stressors are key information to understand current seascape structure and in which direction they can evolve. This tool allows for the identification areas of ecological importance, sensitive areas and management priorities. Combining these results with LEAC and WMIIE should help tp give a multi-scale appraisal of the land-catchment- sea links through a combined ecosystem health index, a map of ecosystems that have reached Good Ecological Status (GES) or are in risk of not achieving the MSFD goal. Therefore driving forces not allowing GES can be identified on land and sea and properly managed to reconduct the situation towards GES.

Both explorative studies for the sea, even if they are limited in coverage and by data availability, can be considered as important methodological milestones towards an innovative Land/Sea Ecosystem Accounts (LEAC/SEAC).

Another key issue is to better understand how the three methodologies can be used together to support the work of local or subregional decision-maker at a determined scale and be useful to their work. This demand is of high importance for the Mediterranean stakeholders. Cartographic representations are very attractive for people and can be easily confused with the reality. Those methodologies currently still have a very high associated uncertainty (in some places more than others), that should be well explained when sharing the results with stakeholders. Discussions with them have clearly identify two priorities: (1) the need for a systematic validation of the products with the involvement od stakholders, and (2) based on validation results, products should be properly corrected with high resolution data and expert judgements. Therefore they would constitute a consistent data base for both basins (coast and sea) as well as comparative cartographic and statistical tools to measure stocks, flows, pressures and impacts, as well as driving forces and the state of coastal and marine ecosystem. A database that should be repeated every 5 years to make the follow up of management actions on the status of ecosystems, ensuring the basis for a Blue Growth, a main concern for the European Commission.

In PEGASO we have developed this innovative tool which is an enormous added value, we have begun to test it in PEGASO CASES, with PEGASO stakeholders, but still work remains to be done. It would be more costly not to do it than to update the PEGASO products already useful. It is a key message to include in the PEGASO Business Plan.

5.3 Lessons learned

The presentation and discussions with the PEGASO ICZM Platform ha brough a number of lessons learned:
-Spatial explicit data on marine (benthic and pelagic) habitat and species distribution and changes at basin large scale are currently not available for the Mediterranean and Black Sea Basins. Lots of monitoring data exist, but they are difficult to access and, when accessible, they usually need time to be processed and made usable for a concrete assessment.

-The decision on a chosen methodology has taken time and the team has enlarged exchanges with other experts working on accounting (e.g. EEA, ETC-SIA, DG MARE and the use of EMODnet products, JRC, etc).

-Once decisions were taken, the production of each part of the work has been also time consuming. The methods had to be updated, even re-invented, to be able to have the wider coverage for our product, having into account the best use of available data.

-These products are the first prototypes of the application of a reproducible methodology. Lots of innovations, creativity and rigor are embedded in this work. The process of production has not been easy, with lots of doubts, re-doing again and again to see what was given better results. Methodological discussions among the team and with PEGASO stakeholders have been intensive.

- Validation with stakeholders has already be very fruitful, but not sufficient to ensure a much smaller margin of error, so less uncertainty and better quaity products.

- PEGASO LC will need more detailed validation work in the post-PEGASO phase, using in the areas with potencial errors high resolution remote sensing data and local expert knowledge to have a final updated and high quality data set for the two basins. Once the methodology is consolidated, therefore, it will be easy to repeat the exercise every 2 or 5 years.

- For the three products, validation will have to continue in the Post PEGAO phase, as a part of the task of building a common shared and validated knowledge for the coastal zone and the sea.

-All these results are currently included in the Spatial Data Infrastructure of PEGASO and will be fully available before the end of the Project.

- The Tools update and the SDI are part of the post PEGASO ICZM Governance platform for the Mediterranean

6. Links with envisioning and prospective exercices, with participatory tools and socio economic evaluation (WP4 toolbox)

Accounting methodologies are extremely useful for scenario building as they allow to explicit how the changes in one or more parameters would influence the other ones.
The PEGASO 4.2 tools, by linking land use changes and human activities to the risk for the ecosystems allow producing visual representation of the effect of changes in human activities on the surrounding ecosystem.
As exploratory scenarios are generally build upon the changes of certain human activities, those tools could help to create visual representations of certain hypothesis.
At the same time, by integrating and linking data both from the environmental, industrial and commercial sectors that are generally exposed separately, those tools could help the participatory process between stakeholders from different backgrounds has it has been underlined by PEGASO End Users.

Together with other PEGASO tools, the LEAC/SEAC will have **Integration needs.**

The implementation of public policies faces many difficulties. Interactions between natural processes (physical, chemical and biological) and social processes (institutional, sociological, economical) involved are complex and often poorly understood. In addition, strategies for environmental management cannot be reduced to the search for technical solutions. It is much more likely to negotiate rules in arbitrating between competing interests and build the legitimacy of public choice. Both in the field of knowledge and governance, current systems are too compartmentalized and do not respond effectively to the challenges raised by these environmental issues. This partitioning applies to economic sectors together as well as civil society, administrative areas, scientific disciplines or consultancy. Causes and social and economic consequences of environmental quality and biodiversity degradation are numerous and increasingly become a major issue for the territorial development and its attractiveness. The need for an integrated approach mobilizing knowledge from expertise and experience is increasingly felt. The diversity of powers between States and the various levels of local governments, the lack of participatory process, and transdisciplinary research poorly valued, are among factors that do not facilitate the implementation of integrated approaches, especially when addressing the land-sea continuum and watersheds.

To that purpose, PEGASO attempts to develop a methodology and tools for mobilizing and integrating knowledge about environment, uses and governance that meets decision makers and managers needs, supporting by expertise and existing information systems (indicators, LEAC, participation, scenarios).

The integration of tools will not perform the integrated assessment. Integration has emerging properties that go beyond of the sum of tools' properties. To cope with this issue, an integrated assessment scheme was developed.

Constraints brought by integration over LEAC/SEAC

Among the different tools developed by PEGASO within WP4, LEAC and SEAC are of particular interest regarding the integration issue. They are both innovative tools, when other are rather restructured existing tools. But what could make their success or failure regarding integration is closely link to their appropriation by stakeholders and end-users:
- Appropriation regarding their understanding and added value brought to ICZM;
- Appropriation in terms of implementation, dissemination and communication.

A first issue is how to communicate about accounting, a concept inherited from management and economics sciences. Accounting is at the core of LEAC, but it goes beyond of stocks and flows and it has to avoid mismanagement with traditional account from finance.

A second issue relies in the compliance with the integrated assessment approach that is based on a problem oriented approach. As a consequence it goes beyond of producing series of maps and LEAC/SEAC will have to leave an exhaustive review of environmental threats to focus on the policy issue identified and defined with and by stakeholders, with the possibility of facing lack of related relevant data to be able to issue some results.
At last a third issue relies in the technical appropriation of the tool by end-users, so that they can avoid technical bottlenecks when wishing to implement LEAC/SEAC. If the technical gap is too important, then a technical support should be planned and it raises the question of maintaining such support beyond of the project life.
The choice of an Integrated Information System to act as an integrated assessment scheme through the Environmental territorial Diagnosis (PEGASO Deliverable D4.6) allows for a compatibility with LEAC/SEAC tool. Outputs can be seen as spatialized indicators in terms of state of change between two periods. Being non dynamics, they will technically fit with the integrated assessment scheme and allow for easier articulation with other PEGASO tools.

Ecosystems services approach

Issues are multiple and arise in terms of sources of anthropogenic pressures, of impacts over the environment or human activities, and in terms of public policies. These are in part issues related to the maintenance of ecosystem services essential to support a number of activities, market and non-market, particularly in the areas of water quality and biological productivity. Other relates to the preservation of the support functions that affect biological diversity without necessarily and directly affect human activities. For all these aspects, public policies' objectives and regulatory requirements are becoming more stringent, while statements of continued deterioration seem more frequent than the reversal of trends. To difficulties related to increasing and combining effects of anthropogenic pressures, are added changes in ecosystems due to climate change.

Beyond of delivering indicators in terms of stock and flows of biomass and carbon, the LEAC / SEAC is seen to be closely used with two other PEGASO tools: scenarios and foresight analysis tool and the economic assessment tools. The articulation with the last one raises a number of issues that could impact the implementation way of tools. Following a similar approach than the one used for LEAC and dealing with non markets goods and services having a value but no price, the approach for economic assessment would rely on the successive i) Ecosystem biophysical assessment to derive Ecosystem function from biophysical structure or process, ii) then social assessment to derive ES and socio-economic benefits (private and collective well being) and iii) valuation to derive value (Figure 6.1). These steps are overlapping each other and at the scale of regional seas, valuation claims for the value transfer approach in order to capitalize and reuse the acquired knowledge.

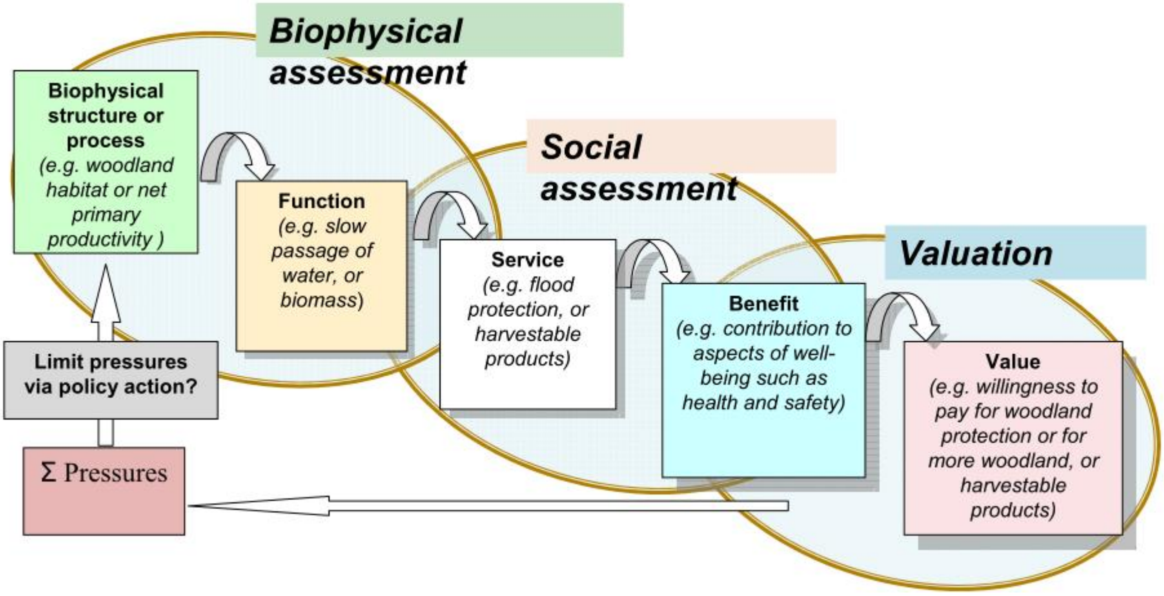

Figure 6.1: The cascade model. Defining ecosystem functions, services and benefits (Haines-Young and Potschin, 2010; modified de Groot et al. 2009).

But paucity of data (reference values database especially in the field of coastal areas) is expected to limit what can be achieved at an aggregate level. An additional issue deals with the value itself that couldn't be considered as an absolute value that will not bring useful information to the decision making process. Economists are focusing on changes and then value of changes. Adding monetary value to Carbon and Biomass fluxes will not improved the information level. For instance, if a biomass of some trees species – oaks – is destroyed and then recovered in other species – pine trees – for the same amount of biomass unit, proceed to monetary valuation will not solve the issue of biomass characterization in terms of quality due to a similar issue with monetary valuation. The redistribution issue is also unknown and despite amount expressed in monetary terms, this will not inform about who gains who loses, leading to additional biases in the assessment. This would also lead to further consider analyses of values as well as focusing on the interface of values and decision making. Conditions and context evolve and successful implementation of policies does not solely depend on costs and benefits alone (institutional and social context). Instead of using such costs and benefits approach as a decision-making tool it can be used in a much more heuristic manner, where sensitivity analysis is employed in order to explore elements of the analysis which may be uncertain or controversial.

Finally, rather than linking LEAC to economics through the monetary valuation of ecosystem services, it would benefit far more from the environmental and economic accounting, also known as green accounting or system of environmental accounting (SEA). This would rather suit to the LEAC/SEAC approach but implementing such approach would go far beyond of the solely PEGASO project capabilities and capacities in terms of resources.

7. Main Conclusions

- Little is known about the ecological processes and services of coastal and marine ecosystems, PEGASO has answered to a major challenge looping at ways for developing ecosystem accounts for the sea and integrated accounts linking land and sea.

-This is not a hazard if each methodology has been developed at a different scale and this fact is well representative of a current reality related to data availability.

The LEAC methodology has been developed at the basin scale because it is mostly based and satellite data that are now available for the all world.
The cumulative impact methodology has been developed only for the Western Mediterranean by using modelised datasets for most of the layers because our knowledge of the sea is still very inferior to our knowledge in land.

-To go further in the assessment of the state of ecosystem there is a enormous need for a well planned in situ monitoring data, taking into account what exists, and make all data (old and new) largely available.

-The three different scale of work are therefore representative of our difficulty to go seaward that is still represented as a blue area in all the maps. It represents the data gap that still exists in those environments, but also the exploratory effort that PEGASO has done.

-The response of landscapes and seascapes to disturbance is often complex and poorly understood, yet PEGASO effort for bringing the most relevant information is essential for effective management.

-The PEGASO 4.2 results are useful for the implementation of ecosistem based ICZM and also for the Integrated Marine Policies, including Marine Spatial planning (MSP). MSP is at at early stage of its application and decision support tools for doing current MSP are varied and inconsistent. Therefore this LEAC / SEAC work represents an important added value as they are useful to these policies.

-The stakeholder collaborative work has been key to identify how product should be updated and presented to them, in the frame of a useful post-modern and shared science and knowledge supporting decision.

- This deliverable shows some high value new and exploratory products developed by PEGASO. This is of high added value fort he project, having into account that the co-work done with the PEGASO Governance Platform has created great expectations and great demand on the PEGASO coordination. More than 700 stakeholders have been involved in the participative workshops and works in the governance platform during these four years. They strongly ask for a continuation of the work, to get a performant comparative method to link coastal and marine ecosystems through efficient and easy to use maps and accounts, useful in their work. Finally, with some more efforts, the PEGASO LSEAC would constitute a consistant data base for both bassins (at coast and sea), including comparative cartographic and statistical tools to measure stocks, flows, pressures and impacts, as well as driving forces and the state of coastal and marine ecosystem. A database that should be repeated every 5 years to make the follow up of management actions on the status of ecosystems, ensuring the basis for the Blue Growth, a main concern fort he European Commission. The cost of this action of updating an already existing material would be less than the cost of doing nothing.