



# Monitoring and Evaluation of Spatially Managed Areas

## Deliverable D4.1

### An Inventory of management questions to be addressed with the tools

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**Coordinator: Katherine Cronin and Jan van Dalfsen**

Stichting Deltares, The Netherlands

(Partner 16, Deltares, The Netherlands)

**Contributors**

Myra van der Meulen

Stichting Deltares, The Netherlands  
(Partner 16, Deltares, The Netherlands)

Louise Lieberknect

University College London, Great Britian  
(Partner 2, UCL, Great Britian)

Sandra Voege,

Senckenbergische Naturforschende Gesellschaft, Germany  
(Partner 3, Senckenberg, Germany)

Carlo Pipitone

Consiglio Nazionale Delle Ricerche, Italy  
(Partner 9, CNR-IAMC, Italy)

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# 1 Introduction

At the broadest level, ‘marine spatial management’ encompasses stages, which are sometimes idealised as ‘steps’ although in reality they often do not happen in a clear sequence. These ‘steps’ or stages can be classified in different ways, e.g.:

- The development of new spatial plans or review of existing plans.
- the implementation of spatial plans, including the actual management of human activities within spatially management areas (SMAs)
- the monitoring of human activities and impacts in SMAs,
- the monitoring of ecosystems in SMAs,
- the evaluation of whether current (spatial) management is achieving stated ecological (and/or socio-economic) goals

There is a huge range of what one might classify as ‘tools’ that can be used during each of the above stages. The aim of the MESMA project is to monitor and evaluate spatially managed areas and for this tools are required.

This document starts by providing a brief overview of everything that could be classified as a ‘tool for MSP’, in the broadest sense. In itself, marine spatial planning (MSP) is advocated as a promising tool to support the implementation of ecosystem- based marine management (Stelzenmüller et al., 2012). The main focus of this piece of work is to categorise and inventorise a selection of some of the existing tools that are available for marine spatial planning and may be used to answer the management questions of the case studies in MESMA. This includes tools being used during the marine spatial planning process and for the evaluation of the effectiveness of spatially managed areas. There is conceptual guidance available for MSP, but practical tools to support the implementation of the various steps are still scarce (Stelzenmüller et al., 2012) and not all tools available for various stages of the marine management process relate directly to MSP. The type of tool needed by each of the nine case studies within MESMA depends very much on the management questions being addressed and on what way they apply the MESMA analysis framework. The use of the framework ranged from the observation of a process, either analytically or not, to the development and evaluation of spatially managed scenarios using spatial and temporal resolved data. Only relevant examples per category of tool will be presented in this report.

Different stages of the marine spatial planning process may be tackled with a range of tools. Not all steps of such a planning process require fundamental science and not all case studies will perform extensive data analysis. Thus the main scientific input is required for the initial assessment, the development of spatial management scenarios and for plan performance assessment (Stelzenmüller et al., 2012). In MESMA it is useful to relate the management questions of each case study to a category or combination of tools. This includes the questions one would ask when evaluating a spatially managed area (SMA) to determine if the management objectives are being met. It may also include the policy questions (from national to international) from which these management objectives were derived and what tools are needed to answer them.

Therefore, by examining these overarching management and evaluation questions in MESMA we can examine which tools are needed most or indeed which tools are missing.

## 1.1 *Tools in Marine Spatial Management*

Any successful MSP initiative will employ a range of tools, techniques and methods to achieve each of the above MSP stages. In the widest sense, ‘tools for marine spatial planning’ can encompass a wide variety of range and forms - conceptual, operational, analytical or technical. A tool may be a model, map,

database, legal/legislative requirements, permits, guidelines, a framework, criteria i.e. for indicators, a GIS, a statistical software package and include governance tools such as stakeholder interaction and participatory mapping and so on. The term 'tool' could refer to a piece of legislation used to underpin protected area designation or management of human activities, to a specific ecological modelling software package, to methods in stakeholder facilitation, or to specific mitigation measures (e.g. eco-moorings which reduce impacts from anchoring on sensitive seabed habitats). It could refer to tools and techniques used in communication, project management, or environmental and economic impact assessment. Clearly, different MSP initiatives will require or benefit from different combinations of tools, depending on their specific aims, context and resources.

One of the main obstacles to maritime spatial planning (MSP) is often the lack of relevant data or the inefficient use of such data. The use of the proper tools is essential to reap the benefits of improving data availability and quality. In the last decade there has been huge emphasis placed on the 'spatialisation' of marine management while in turn our understanding of marine systems and the ecosystem approach to fisheries is moving towards an integrative approach that crosses boundaries of individual species, human impacts or spatial zones (Kaplan et al., 2010).

Complete knowledge of the processes and interactions and supportive data are never fully available at the start of the planning process. The development of a marine spatial plan is influenced by the abundance and quality of its data, and the capacity for its analysis. The process is becoming easier with the increasing availability of new tools and techniques using remotely sensed images, geographic information systems (GIS) and global positioning systems (GPS) that increase the amount, precision and detail of spatial and temporal data (Douvere and Ehler, 2010). Geographic information science has provided the tools needed to manage and analyse data. Use should also be made of geodatabases to maintain spatial data in a consistent and accurate manner (Stamoulis, 2010; Essid and Sutton, 2012). Recent advances in habitat-mapping technologies and numerical modelling (Katsanevakis et al., 2010) have greatly enhanced our ability to describe marine ecosystems in detail. There has recently been a trend toward the use of more complex models which could include techniques such as data assimilation. The accurate assessment of species movement for example, is essential for predicting and understanding the impacts of spatial management therefore the development of new tools that enhance our knowledge of individuals' movements are essential (Kaplan et al., 2010).

A major challenge is processing the available information in a way that will aid management decision-making. As management decisions will increasingly be based on data from different sources, interoperability and open-access to data will become increasingly important. The use of various tools can enable and integrate these different aspects into MSP (Stamoulis, 2010). Tools allow for the management and analysis of data and give managers the ability to create alternative scenarios. MSP projects often cover a wide area and it can be difficult to obtain consistent datasets across the area of interest, particularly for ecological and human use data. Biological valuation can be a method to standardise different ecological datasets if consistent dataset is not available. Biological valuation maps compile all available biological and ecological information for a study area and allocates an overall biological value to subzones, which can be used as baseline maps for future spatial (Derous et al., 2007). These methods (biological valuation etc.) can serve as inputs into the growing range of analytical tools that aid reserve design (e.g. Marxan, C-plan) and other methods that allow forecasts of fishery responses to reserves (Ecopath and Ecospace) (Leathwick et al., 2008).

A spatial plan for an area can have multiple objectives and it is important to evaluate whether the management measures outlined in the plan actually achieve the desired results (Douvere and Ehler, 2010). Changes in processes and interactions, whether as result of climate change or economic developments, in the area of interest can affect the results of a marine spatial plan. The implementation of certain measures may cease to work because of a range of external factors or simply because it was not appropriate to start with. An adaptive approach to MSP can therefore help to identify more effective measures if this occurs. To do this evaluation and monitoring of performance of the management plan is essential (Douvere and Ehler, 2010). Therefore MSP is a dynamic process with many feedback loops. Tools should also be able to cope with this iterative process and aid in its success. Monitoring, evaluation, reporting and adaptive management are recognised as fundamental components for effective marine management (Day, 2008). Interactive decision support systems, such as Marxan with Zones, can create alternate spatial management scenarios, along with a clear evaluation of the tradeoffs associated with.

Proper use of these tools can greatly streamline the process and support its iterative nature (Stamoulis, 2010).

One of the objectives of MESMA is to gather, and develop where needed, a set of tools that can be used to evaluate the effectiveness of a spatially managed area and the marine planning process from the perspective of ecosystem-based management and in the context of climate change. Evaluation and valuation of these practical management tools is also important. According to Douvère and Ehler, (2009), there is currently a lack of the necessary tools to make an ecosystem approach operational in the marine environment. The Convention on Biological Diversity (CBD) review (CBD, 2007) and other research on ecosystem-based management (Arkema, 2006) concluded that an ecosystem approach to coastal and ocean management is a complex and demanding process and more practical tools need to be developed to make this process feasible. The Green Paper on Maritime Policy (EU, 2006) suggests that as the EU plays an important role in the planning process, it should help provide the tools to make the planning process work.

Many of the tools that will aid MSP initiatives are not specific to MSP, but are employed in a whole range of situations and processes. Ecological and economic impact assessments, for example, are legally required for a large range of plans and projects in many countries. Project management, process planning, communication, and stakeholder facilitation techniques are further examples of toolsets that play pivotal roles in many walks of life. It is vital for any MSP initiative to understand these tools and techniques, and make good use of them: bad process planning, bad project management or poorly thought-through stakeholder engagement can jeopardise the success of an MSP project.

This report focuses on the technical tools that are more specific to MSP-related projects and initiatives, including technical tools that can aid communication and stakeholder participation in MSP (such as participatory GIS tools). It also includes a brief description of MSP-specific conceptual tools and guidelines.

As stated above, legislation can be viewed as a 'tool' in itself. In Europe, most ecosystem-based MSP initiatives are driven by international and European legislation (Douvère and Ehler, 2008). Several policy documents have been created by the EC to implement MSP i.e. the Green Paper on Maritime Policy which identifies MSP as a key tool for the management of a growing and increasing competing maritime economy, while at the same time safeguarding maritime biodiversity.

This report does not cover MSP-related legislation in Europe, as this is already covered in a different MESMA work package (WP6).

## **1.2 What defines a good tool?**

Tools for marine spatial planning can take a wide variety of range and forms. A tool may be a model, map, database, legal/legislative requirements, permits, guidelines, a framework, criteria i.e. for indicators, a GIS, a statistical software package and include governance tools such as stakeholder interaction and participatory mapping and so on. Tools can be conceptual, operational, analytical or technical.

There are a number of criteria that tools should fulfil in order to be widely applicable. The criteria for a good tool generally depend on its specific purpose and the context. They should be:

- Cost-effective
- Generic
- Robust and statistically valid
- Field-tested
- Well documented
- Appropriate and responsive to needs
- Flexible
- Improved over time and open to feedback from experience and new knowledge
- Able to integrate new data that is becoming available and changing situations
- Fit to the purpose
- Easy to use

- Clear, easily usable result
- Open source
- Transparent (not a black box)
- Reliable
- The type of result should match with the effort required to set up and run the tool
- Objective
- Results should be traceable

These criteria can in turn be used to evaluate whether a tool is suitable and effective.

## 2 Case study management objectives and their tool use

### 2.1 Management objectives

The type of tool needed by each of the nine case studies within MESMA depends very much on the management questions being addressed. An overarching tool that will be used by all case studies is the MESMA generic framework (Stelzenmüller *et al.*, 2010). It provides a best practice guide for monitoring and evaluation of spatially managed areas (SMAs) in seven distinctive and clearly outlined steps. These steps comprise of 1) setting the management context; 2) collation of existing information and mapping; 3) setting of management targets; 4) risk analysis and state assessment; 5) assessment of findings against operational objectives; 6) evaluation of effectiveness of management measures; and 7) adaptation of the current management regime based on the outcome of the assessments. The MESMA tool box for monitoring and evaluating of spatially managed areas is structured around these seven steps.

The nature of the management issues will vary throughout the case studies and depend on the operational objective of the analysis in question. Both WP2 and WP6 research analyse an existing initiative. Below Table 1 outlines the management questions and objectives associated with each case or sub-case study.

Those case studies that will mainly observe the processes in place (Östergötland [Baltic Sea], Pentland Firth, Puck Bay [Baltic Sea], Southern North Sea) require different types of tools as the majority of the work is to be based on desk study analysis. Most of the case studies that are more involved in the actual evaluation and development of spatial managed scenarios will apply a larger variety of tools (Ionian archipelago, Strait of Sicily, Basque).

**Table 1. Case study management questions**

Case Study	Management objectives
Belgium EEZ	<ul style="list-style-type: none"> <li>• The designation and evolution of MPAs in the wider Belgian part of the North Sea</li> <li>• To identify and quantify conflicts between current and future activities/ sectors and stakeholders</li> </ul>
Dogger Bank	<ul style="list-style-type: none"> <li>• To restore and maintain the natural features on the Dogger Bank to a favourable condition</li> </ul>
Wadden Sea	<ul style="list-style-type: none"> <li>• To restore and maintain the natural features represented in the SACs and SPAs in the Wadden Sea</li> </ul>
Skaggeiak	<ul style="list-style-type: none"> <li>• To restore and maintain the harbour porpoise conservation features</li> </ul>

	represented in the SAC
Barents Sea	<ul style="list-style-type: none"> <li>• Protection of the VVAs and species management</li> <li>• Provide a framework for sustainable use of ecosystem goods and services while at the same time maintaining the structure, function and productivity of the ecosystem</li> <li>• To provide an umbrella for the management of all (Norwegian and International) human activities in the Norwegian part of the Barents Sea and the marine areas off the Northern part of North Norway to achieve the twin objectives of use and conservation</li> </ul>
Bay of Biscay	<ul style="list-style-type: none"> <li>• To develop an ocean infrastructure for research, demonstration and operation of offshore wave energy harnessing devices and minimise impacts on fisheries</li> </ul>
Celtic Sea	<ul style="list-style-type: none"> <li>• To design a network of marine conservation zones in SW England, taking into account socio-economic impacts</li> </ul>
Pentland Firth	<ul style="list-style-type: none"> <li>• To facilitate the generation of 1.6GW of wave and tidal energy from the PFOW area by 2020.</li> <li>• To deploy and monitor wave and tidal energy devices ensuring that permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.</li> <li>• Ensure that the use of the marine environment is benefiting society as a whole, contributing to resilient and cohesive communities.</li> <li>• Identify areas with differing priorities for sustainable use (such as fishing, aquaculture, recreation and tourism, oil, nature conservation etc.).</li> </ul>
Strait of Sicily (Sicily)	<ul style="list-style-type: none"> <li>• Maintaining or restoration to favourable conservation status of conservation features</li> <li>• To ensure and organise stakeholder participation in this process</li> </ul>
Strait of Sicily (Malta)	<ul style="list-style-type: none"> <li>• Maintaining or restoration to favourable conservation status of conservation features</li> </ul>
Inner Ionian Strait	<ul style="list-style-type: none"> <li>• To designate a representative network that fulfils sufficiency requirements and effectively protect sites so they are maintained or restored.</li> <li>• Include at least 60% of priority habitats and species of the Habitats Directive in Natura 2000 network of sites</li> <li>• Achieve Good Environmental Status (GES) of species and habitats of European importance, according to the MSFD</li> </ul>
Baltic Sea/Puck Bay	<ul style="list-style-type: none"> <li>• Maintenance or restoration of favourable conservation status of conservation features in the Natura2000 sites.</li> <li>• Minimise maritime pollution</li> <li>• To enforce the restrictions and limitations of uses of the area, especially in terms of nature conservation</li> <li>• To settle the objectives for environment and cultural heritage protection.</li> </ul>
Black Sea	<ul style="list-style-type: none"> <li>• Maintenance or restoration of favourable conservation status of conservation features in the Natura2000 sites</li> <li>• To implement the Water Framework Directive at the national level</li> </ul>

## **2.2 Management questions to be addressed with the tools**

Based on this review of the case studies the following more generic management questions which we will seek to address with the tools can be constructed:

A very clear area of management objectives relating to Spatially Managed Areas is the designation and evolution of MPAs. Closely related to this are management questions related to objectives of (EU) policies such as designating spaces and measures to achieve Good Environmental Status (GES) of species and habitats of European importance, according to the MSFD and maintenance or restoration of favourable conservation status of conservation features in the Natura2000 sites; to implement the Water Framework Directive at the national level; to restore and maintain the natural features represented in the SACs and SPAs. Ultimately from the spatial component these management objectives seek to design a network of marine conservation and designate a representative network of areas that will fulfil policy implementation requirements and ultimately seeks to effectively protect sites and hence maintained or restore environmental status.

On the other side management questions relate to the goal of seeking a balance between the different uses of the seas and oceans. Hence a need to develop a framework that can assist in the management of human activities seeking sustainable use of ecosystem goods and services while at the same time maintaining the structure, function and productivity of the ecosystem. This framework than primarily seeks to designate areas with differing priorities for sustainable use while ensuring that the use of the marine environment is benefiting society as a whole, contributing to resilient and cohesive communities. In the wake of this management questions lies the identification of competing uses of the marine environment and the emerging conflicts between current and future activities/ sectors and stakeholders. Related to this is the goal of ensuring and organising stakeholder participation in this process

As a result of establishing spatially managed areas at sea a framework for the enforcement of restrictions and limitations of uses of the area, especially in terms of nature conservation and to settle the objectives for environment and cultural heritage protection emerges. In addition, such a framework can be used as a context in which newly developing activities at sea can be monitored and evaluated.

## **2.3 Case study questionnaire**

The following questionnaire was sent to the MESMA case studies participants to find out what the important management objectives are for their case study and where the tool gaps might be. From this it will be determined what tools are needed. The outcomes of the questionnaire showed that many of the case studies planned to use newly or recently developed tools. It is therefore important that these tools are properly evaluated in Deliverables 4.4 and 4.5. Only two case studies will modify existing tools for the purposes of their case study i.e. Marxan. Many of the case studies will also be developing new tools which will be described in later deliverables. Some case studies noted that their tool use is hindered by a lack of available or good quality data and so some data analysis tools will be needed. Results of the questionnaire such as what categories of tools the case studies are using, what framework steps they have tools for and for what framework steps they are lacking tools are given in Tables 2-4 respectively.

<b>TOOL CATEGORIES AND APPLICATION TO THE FRAMEWORK</b>	
<b>At which step in the framework are you starting?</b>	<input type="checkbox"/> 1a. Temporal and Spatial Boundaries for SMA Assessment <input type="checkbox"/> 1b. Goals and Operational Objectives for SMA <input type="checkbox"/> 2a. Ecosystem Components <input type="checkbox"/> 2b. Pressures and Impacts <input type="checkbox"/> 2c. Management Measures <input type="checkbox"/> 3. Indicators <input type="checkbox"/> 4. Risk Analysis and State Assessment <input type="checkbox"/> 5. Assessment of Findings against Operational Objectives <input type="checkbox"/> 6. Evaluation of Management Effectiveness <input type="checkbox"/> 7. Adaptation to Current Management
<b>What category(ies) of tools are you using in the MESMA case study?</b>	<input type="checkbox"/> Decision support <input type="checkbox"/> Governance <input type="checkbox"/> Data Management or Collection <input type="checkbox"/> Communication <input type="checkbox"/> Conceptual or Guidelines <input type="checkbox"/> Spatial Analysis <input type="checkbox"/> Visualization <input type="checkbox"/> Mapping <input type="checkbox"/> Data Processing <input type="checkbox"/> Fisheries Analysis <input type="checkbox"/> Numerical Model <input type="checkbox"/> Impact Assessment <input type="checkbox"/> Economics <input type="checkbox"/> Statistics <input type="checkbox"/> Spatial Planning <input type="checkbox"/> Project Management <input type="checkbox"/> All <input type="checkbox"/> Other (if so name below)

	<hr/> <hr/>
<p><b>What step(s) in framework do you currently have tools for?</b></p>	<ul style="list-style-type: none"> <li><input type="checkbox"/> 1a. Temporal and Spatial Boundaries for SMA Assessment</li> <li><input type="checkbox"/> 1b. Goals and Operational Objectives for SMA</li> <li><input type="checkbox"/> 2a. Ecosystem Components</li> <li><input type="checkbox"/> 2b. Pressures and Impacts</li> <li><input type="checkbox"/> 2c. Management Measures</li> <li><input type="checkbox"/> 3. Indicators</li> <li><input type="checkbox"/> 4. Risk Analysis and State Assessment</li> <li><input type="checkbox"/> 5. Assessment of Findings against Operational Objectives</li> <li><input type="checkbox"/> 6. Evaluation of Management Effectiveness</li> <li><input type="checkbox"/> 7. Adaptation to Current Management</li> <li><input type="checkbox"/> All</li> </ul>
<p><b>What step(s) in framework are you currently lacking tools for?</b></p>	<ul style="list-style-type: none"> <li><input type="checkbox"/> 1a. Temporal and Spatial Boundaries for SMA Assessment</li> <li><input type="checkbox"/> 1b. Goals and Operational Objectives for SMA</li> <li><input type="checkbox"/> 2a. Ecosystem Components</li> <li><input type="checkbox"/> 2b. Pressures and Impacts</li> <li><input type="checkbox"/> 2c. Management Measures</li> <li><input type="checkbox"/> 3. Indicators</li> <li><input type="checkbox"/> 4. Risk Analysis and State Assessment</li> <li><input type="checkbox"/> 5. Assessment of Findings against Operational Objectives</li> <li><input type="checkbox"/> 6. Evaluation of Management Effectiveness</li> <li><input type="checkbox"/> 7. Adaptation to Current Management</li> <li><input type="checkbox"/> All</li> </ul>
<p><b>TOOL USE QUESTIONS</b></p>	
<p><b>Are you or will you be using any new tools?</b></p>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Yes (describe below)</li> <li><input type="checkbox"/> No</li> </ul> <hr/>

<p><b>Have you seen new tools you would like to use but were hindered by a licence fee?</b></p>	<p><input type="checkbox"/> Yes (describe below)</p> <p><input type="checkbox"/> No</p> <hr/> <hr/> <hr/>
<p><b>Will you modify any of the existing tools you use for the MESMA case study?</b></p>	<p><input type="checkbox"/> Yes (describe below)</p> <p><input type="checkbox"/> No</p> <hr/> <hr/> <hr/>
<p><b>Are you developing any new tools under WP4</b></p>	<p><input type="checkbox"/> Yes (describe below)</p> <p><input type="checkbox"/> No</p> <hr/> <hr/> <hr/>
<p><b>Will you use any of your own (developed in your institute/by you) tools in the case study?</b></p>	<p><input type="checkbox"/> Yes (describe below)</p> <p><input type="checkbox"/> No</p> <hr/> <hr/> <hr/>
<p><b>In your search for tools, has the use of suitable tools been hindered by the lack of suitable data in your case study area?</b></p>	<p><input type="checkbox"/> Yes (describe below)</p> <p><input type="checkbox"/> No</p> <hr/> <hr/> <hr/>
<p><b>Please give a brief overview of the requirements for tools and the management questions you are addressing within your</b></p>	<hr/> <hr/> <hr/> <p><i>For example in the Strait of Sicily case study, the CS participants would like to test a set of tools for diverse management issues. This area is subject to professional and recreational fishing, as well as hot spots of</i></p>

<b>case study</b>	<i>biodiversity. Besides fishing there are transboundary issues and potential sites for a wind farm. They require a set of tools for conservation and restoration, data collection tools, stakeholder communication and engagement tools, conceptual modelling tools. They aim to test these tools on the most problematic areas within the Strait of Sicily from a management point of view.</i>																										
<b>Finally...please list the tools you will apply</b>	<table border="1"> <thead> <tr> <th data-bbox="606 504 861 571">Tool Name</th> <th data-bbox="869 504 1125 571">Framework step(s)</th> <th data-bbox="1133 504 1388 571">Tool Category</th> </tr> </thead> <tbody> <tr><td> </td><td> </td><td> </td></tr> </tbody> </table>	Tool Name	Framework step(s)	Tool Category																							
Tool Name	Framework step(s)	Tool Category																									

## 2.4 Questionnaire results – Use and necessity of tools

- Many of the case studies have conservation concerns and want to identify conflicts between the conservation requirements and human activities. For such management questions tools such as [Marxan](#) and [Nature Serve Vista](#) are useful as they help in the evaluation of marine reserve areas and check conflicts between different activities.
- Others want to involve stakeholders in the process of designation of MPAs. Therefore tools such as [Expert Choice](#), [IAN](#) and [E-Participation](#) are useful.
- Those case studies that have a more active role in the evaluation and development of spatially managed areas will need to apply more data analysis tools such as [MORPHO](#) and [MGET](#).
- All of the management questions will benefit from some degree of mapping and spatial analysis so tools such as [EAR](#) and [Nature Serve Vista](#) can be used by all case studies.
- Many of the case studies frame their requirements and structure what needs to be achieved from the different legislative tools such as the Marine Strategy Framework Directive and Natura 2000.
- Based on the questionnaire results (Tables 2-4), many of the tools already being used within the different case studies are for the earlier steps in the MESMA analysis framework that include assessing pressures and impacts, indicators and setting the boundaries. Others are lacking tools for the latter steps (4-7) where the risk analysis and evaluation of the management effectiveness are assessed. For these steps tools such as [Marine Map](#), a web-based decision support tool for open and participatory spatial planning in the marine environment, [Hierarchical Preference Analysis](#) (HIPRE) a tool for decision makers for decision analytical problem structuring, multi-criteria evaluation and prioritization and [SimCoast](#), a fuzzy logic rule-based expert system designed to enable researchers, managers and decision-makers to create and evaluate different policy scenarios for coastal zone management will prove to be very useful.

The case studies are provided with an inventory of these tools to answer different management questions available online at (<http://publicwiki.deltares.nl/display/MESMA/TOOLS>) and

described in the next chapter. Each tool in the inventory will be structured and described according to the following attribute:

1. Name and Category
2. What framework step
3. Description
4. Inputs
5. Data quality required
6. Modification required
7. Expertise required
8. Outputs
9. Spatial and Temporal scales
10. Licence/cost issues
11. Download location
12. References/manual
13. Evaluation

Table 2. Tools being used in the MESMA case studies

What Category of Tools are you using?	BPNS	Pentland Firth	Skagerrak	Black Sea	Strait of Sicily	Doggerbank	Barents Sea	Southern North Sea	Ionian Strait
Decision support		x			X		X		
Governance	x	X	X		X	X	X	X	
Date management or collection	x	X	X	X	X		X		
Communication	x	X			X	X	X	X	
Conceptual or guidelines		X			X	X	X		
Spatial Analysis	x	X	X		X	X	X		X
Visualisation	x	X	X		X	X	X	X	X
Mapping	x	X	X	X	X	X	X	X	X
Data Processing	x	X	X	X	X	X	X		X
Fisheries Analysis	x	X	X		X	X	X		X
Numerical model		X				X	X		
Impact Assessment		X	X			X	X	X	
Economics		X				X	X		
Statistics	x	X	X				X		X
Spatial Planning		X	X		X	X	X		X
Project Management		X			X	X	X	x	
Other	Biological valuation					SPAM			

**Table 3. Tools used associated with the MESMA framework**

<b>What steps in the framework do you have tools?</b>	<b>BPNS</b>	<b>Pentland Firth</b>	<b>Skagerrak</b>	<b>Black Sea</b>	<b>Strait of Sicily</b>	<b>Doggerbank</b>	<b>Barents Sea</b>	<b>Southern North Sea</b>	<b>Ionian Strait</b>
1a Temporal and Spatial boundaries	x	X			X		X	X	X
1b Goals and operational objectives		X		X	X		X		
2a Ecosystem Components		X	X		X		X	X	X
2b Pressures and Impacts		X	X	X	X			X	X
2c Management Measures		X			X		X		
3 Indicators			X	X	X		X		X
4 Risk Analysis and State Assessment									
5 Assessment of findings against operational objectives							X		
6 Evaluation of Management Effectiveness			X				X		
7 Adaptation to Current Management		x					x		X

Table 4. Tools necessary for use of the MESMA framework

What steps in the framework are you lacking tools for?	BPNS	Pentland Firth	Skagerrak	Black Sea	Strait of Sicily	Doggerbank	Barents Sea	SNS	Ionian Strait
1a Temporal and Spatial boundaries				X					
1b Goals and operational objectives									
2a Ecosystem Components				X					
2b Pressures and Impacts		X	X				X		X
2c Management Measures		X	X	X					
3 Indicators					X		X		X
4 Risk Analysis and State Assessment			X	X	X				X
5 Assessment of findings against operational objectives			X	X	X				
6 Evaluation of Management Effectiveness				X	X				
7 Adaptation to Current Management		X		x	x				

### 3 Inventory of Tools

Understanding and proper use of tools is essential for a smooth work flow in marine spatial planning. There are a large variety of tools available to aid from the start to the end of the process. Tools can very broadly be divided into two classes- those that aid with the implementation of ecosystem based management i.e. legal/institutional tools and permits and those that aid in the creation and/or evaluation of a marine spatial plan. The type of tools described here are those of the second class. These tools can in turn be categorised and applied at different stages of the MSP process. Legal and policy tools are described in The Emerging Policy Landscape for Marine Spatial Planning in Europe: overview of key policies, directives and regulations, and their interactions (Qiu, W and Jones PJS, 2011).

At a higher level, tools can be broadly divided into technical and non-technical tools. Technical tools comprise mostly software and programmes for modelling, mapping and other calculations. Non-technical tools may consist of governance methods and incentives, guidelines and more conceptual tools

Below is an inventory of the different tool categories that can be used in MSP and are available on the MESMA tool website (<http://public.deltares.nl/display/MESMA/Home>), further described in Deliverable 4.2. Some tools fit into several categories (Table 5 and Table 6 below). These categories are described in the next section. Only technical tools and software are given in Table 6. Other categories of tools are described separately in Section 3.2. A description of each category and each tool follows in Sections 3.1.1 and 3.1.2 respectively.

Table 5 Types of tools useful for different steps in the MESMA framework

FRAMEWORK STEPS	Context Setting (Step 1)	Existing information collation and mapping (Step 2)	Indicators (Step 3)	Risk analysis and state assessment (Step 4)	Assessment of findings against operation objectives (Step 5)	Evaluation of Management Effectiveness (Step 6)	Adaptation to current management (Step 7)
<b>TOOL TYPE</b>							
Visualisation and Mapping	X	X		X			
Data Collection, Processing & Management	X	X		X			
Decision Support				X	X		X
Spatial Analysis	X	X					
Statistical		X					
Conceptual tools/guidelines		X	X				X
Participatory Mapping and GIS						X	
Uncertainty analysis	X	X	X	X	X	X	X
Monitoring and Assessment		X		X			
Fisheries Analysis				X			
Numerical Modelling				X			
Project Management	X	X	X	X	X	X	X
Communication						X	
Socio-Economics							X

**Table 6** Categorisation of some of the technical tools available

<b>Tool Category</b>	<a href="#">Visualisation &amp; Mapping</a>	<a href="#">Data Collection, Processing &amp; Management</a>	<a href="#">Decision Support</a>	<a href="#">Spatial Analysis</a>	<a href="#">Statistical</a>	<a href="#">Participatory mapping &amp; GIS</a>	<a href="#">Monitoring and Impact Assessment</a>	<a href="#">Fisheries Analysis</a>	<a href="#">Numerical Modelling</a>	<a href="#">Communication</a>	<a href="#">Socio-Economics</a>
<b>Tool</b>											
Morpho		x									
Eonfusion	x			x							
Habitat Digitizer Extension	x										
Kepler		x									
Benthic Terrain Modeller		x		x							
Ecosystem Assessment and Reporting Tool		x		x							x
MGET - Marine Geospatial Ecology Tools	x	x		x	x		x	x	x		
Marine Map	x	x	x	x		x				x	x
CTAM - Coastal Transects Analysis Model	x		x	x		x		x	x		
C-PLAN	x		x							x	
Netica					x						
SimCoast	x		x								
Habitat Priority Planner	x		x	x						x	
Marxan with Zones, and Zonae Cogito	x	x	x	x							

ARIES - Artificial Intelligence for Ecosystem Services	x	x	x								
Expert Choice			x							x	
AHP-OWA	x		x	x							
HIPRE			x								
LINK			x	x							
MIDAS			x			x		x			x
MIMES	x		x			x				x	
PAT			x	x							
IAN (Integration and Application Network)	x									x	
Open OceanMap		x									
E-Participation						x				x	
Habitat Modelling Toolbox					x				x		
SPAM (Sandeel Population Analysis Model)				x				x			
Biomapper	x			x	x						
IBMLib	x			x				x	x		
Fishery Analyst	x	x		x				x			
Connectivity Analysis Toolkit	x			x							
AHP in ArcGIS	x			x							
EASy Mapping Solutions for Marine Resources	x	x									
NatureServe Vista			x	x							

SDM (Spatial Data Modeler)	x				x						
NAMEM (Network Analyst for Marine Ecosystem-based management)		x									
PANDA (Protected Areas Network Design Application for ArcGIS)	x			x							
DIVA (Dynamic Interactive Vulnerability Assessment)	x						x		x		x
PATHMATRIX				x	x						
WeMO							x		x		
GADGET					x				x		
ISIS-FISH								x	x		
Marine Reserve and Local Fisheries Interactive Simulation								x			
EcoGIS	x	x		x				x			
Multi-species Virtual Population Analysis								x	x		
Atlantis				x				x	x		
GARP								x			
EcoWin 2000									x		
ERSEM (the European Regional Ecosystems Model)									x		
Fisheries Libraries in R					x			x	x		
Hyper Niche					x				x		
EcoPath									x		
Hydata Sonobuoy							x				

SAM v4.0 - Spatial analysis in macroecology	x			x	x						
CLUZ Conservation Land-Use Zoning Software											
EcoSeed			x								
ArcMarine	x	x		x							
MIRADI	x			x							
Zonation	x			x							
GRID (from Co-Exist)	x		x	x							
Biological Valuation Method	x			x				x			
BEQI		x					x	x			
Sustainability Indicator Tool	x	x	x							x	

### **3.1 Technical Tools**

The following section describes the tools outlined in Table 2. First, the meaning of each category as defined above is described, followed by a short description of each tool with further links for the reader. Further meta-information on each tool is available on the inventory of tools on the MESMA tool wiki (<http://publicwiki.deltares.nl/display/MESMA/Home>)

#### **3.1.1 Category Description**

##### **Data collection, processing and management tools**

The collection of relevant spatial data is very important in the MSP process. Ehler and Douvère, (2009) identified five primary sources of data for MSP including scientific literature, expert opinion or advice, government sources, local knowledge and direct field measurements. New technologies have made accurate and high resolution data more attainable in recent years. Geographic information systems, databases, metadata infrastructures (Sutton et al., 2011) and portals can be used to store and analyse large amounts spatial and temporal data at different scales. These tools are especially useful for large unorganised data sets and can be based on different methods such as algorithms, logistic regression and neural network methods to create different categories. This data may include administrative data (boundaries and governmental regulations); ecological data; environmental data (sea surface height, winds, currents, chemistry); and data on human use of the marine environment (shipping, fisheries, oil and gas developments, mining, military operations, renewable energies, recreation).

Organising and management spatially-explicit databases is usually one of the most time-consuming aspects of planning (Stamoulis, 2010). There are now many portals and databases available on the internet that provide access to hydrographic, oceanographic, biological data and more. A list of the data portals relevant for European waters can be found in Annex 1.

##### **Decision support tools**

Decision support tools (DSTs) constitute a class of interactive computer-based information systems that support decision making activities (Stamoulis, 2010) and are used in many aspects of planning and implementation. Decision Support Tools can focus on data, models, knowledge, or communication. Most DSTs allow users to enter options and then generate some form of result. They can be categorised by functionality including:

- Data management
- Mapping and visualisation
- Alternative scenario development and analysis
- Management measure option proposal
- Stakeholder participation and collaboration, and community outreach and engagement
- Adaptive management and assessment of achieving objectives.

In model-driven DSTs the results are generated by a mathematical, simulation, or statistical model. Data-driven DSTs use only data to generate results and knowledge-driven DSTs use stored information, rules and procedures to generate results. Another type, communication-driven DSTs facilitate the communication between different stakeholders (Stelzenmuller et al., 2012). DSTs that use interactive

software including maps, models, communication modules, and additional components can help solve problems that are too complex and multi-faceted to solve using human intuition or conventional approaches (Coleman et al., 2011).

## **Communication**

Communication tools can encompass a wide variety of tools/activities such as participatory mapping, e-participation, direct stakeholder engagement, presentation material, visual aids etc. and are strongly linked with governance approaches. Quite often communication tools are presented as guidelines or techniques although some software tools do exist.

Participatory mapping is a general term to define a growing toolbox of techniques that can help communities make decisions using maps. GIS specialists and others involved in mapping work with the public to collect, depict and interpret information that helps when making decisions about marine resources. The maps can be simple sketches or more complicated online GIS systems.

There are many methods and techniques for stakeholder engagement. As with any other category of tool, choosing the appropriate method depends on the issue and the stakeholders. Common techniques include, advisory group/task force, field trip, focus group, hotline, internet, surveys, public meetings, workshops etc. (NOAA, 2007). E-participation is a web-based interface for participation that provides the opportunity for everybody to participate at a convenient time. E-participation facilities are usually web-based mapping applications. They can be equipped with interactive interfaces for visualising and editing spatial scenarios. In this way, stakeholders can easily access comprehensive information in the form of maps, pictures, videos and visualisations, query, measure and edit maps and express opinions (Feucht and Pitkanen, 2007).

## **Participatory Mapping and GIS tools**

Participatory mapping refers to the gathering of spatial information from a range of people, and mapping the result in some way. That can include the gathering and mapping of knowledge (e.g. ecological knowledge, or information about the distribution of human activities, or about the economic and social value of different areas), as well as the mapping of management scenarios, e.g. the sketching of ideas for a reserve network or for a new wind farm development area. A range of tools exist for participatory mapping in relation to MSP.

## **Spatial analysis tools**

Spatial analysis tools are commonly GIS based tools and are used to analyse and map marine geospatial data and determine where conflicts can or are occurring. In that way scientists can understand individual ecosystem components and how they interact. One type of spatial planning tools for the marine environment consists of zoning tools. Zoning can be used to separate conflicting uses or to ban or restrict activities in sensitive, ecologically valuable areas (Day et al., 2002). By using zoning type tools, the potential (un-)suitability of an area for a certain activity can be determined. There are other different types of spatial analysis tools such as spatial autocorrelation, spatial interpolation, spatial regression, spatial interaction, simulation and modelling. As a minimum, data should be able to be referenced on a 2D frame. A wide variety of web-based tools are now available, allowing datasets to be analysed and mapped without the need for local GIS software installation. An important aspect of spatial analysis is visualisation.

## **Visualisation and Mapping tools**

Visualisation and mapping tools are commonly GIS based tools that facilitate interpretation and communication of environmental data. Many tools used in marine spatial planning are visualisation and/or mapping tools. With mapping tools this visualisation is conducted on a spatial scale, enabling the creation of for example suitability maps. Mapping tools are based on rasters and, depending on the size of these rasters, can vary in spatial coverage and thus in accuracy. Visualisation and mapping tools can be used to analyse connectivity, but also for example to demonstrate the effects of different management scenarios.

## **Fisheries analysis tools**

The fisheries sector is an important sector in the marine spatial planning process. Therefore, tools aiding in the analysis of fish populations and the evaluation of different fisheries management strategies such as the creation of marine reserves are very useful. Fisheries analysis tools are commonly models, which allow simulations of fish populations over time and under different scenarios. These models can allow for a spatial representation and comparison of the data but can also represent economic effects of different management scenarios. In some tools, like EcoGIS and MSVPA-X, ecological aspects such as by-catch and higher trophic levels, are taken into account allowing for outcomes to be placed within an appropriate ecological framework.

## **Numerical modelling tools**

Models are now a standard tool in many fields and can be used to evaluate many marine processes, both physical and ecological, important for marine spatial planning. They represent specific hypotheses, provide a structural framework for articulating and testing theories and evaluating future scenarios. Models contain a description of a process expressed as an equation or set of equations that describe the relationships between parameters. Models can be useful in linking observations to behaviour and processes. At one end of the model scale is reductionism, in which there is great process detail, and at the other end are abstracted models in which the system is described by a set of rules. Process-based models simulate the development and behaviour of large scale features based upon their underlying fundamental processes.

## **Project management**

This type of tool is also more generic and is used to optimize the process of managing a project. It is often software with a range of functions, such as planning, budget management, communication and quality management. Since MSP is a process in which many stakeholders and project partners are usually involved, this type of tool can aid in streamlining the management of such projects and track accomplishments within projects.

## **Monitoring and Impact assessment tools**

While monitoring and impact assessment isn't specific to MSP, there are many impact assessment tools available related to the marine environment which could be useful during the MSP process. Section 2 of

D1.1 (Katsanevakis et al., 2010) reviews the tools and methods to monitor and evaluate seabed habitats and marine populations. These tools can be used to study the current state of the ecosystem, and predict possible changes as a result of (human induced) stress. A resulting environmental impact assessment (EIA) describes the environmental and socio-economic aspects of an action or project, and is often used in decision making, for example prior to the construction of off-shore wind farms, to assess possible damage or benefits to the environment. Within this framework an ecosystem-based advice is created based on indicators (Livingstone et al., 2005). Indicators are measures that allow the assessment and evaluation of a systems status, for example the population size of a target species. Quantitative values are usually attributed to indicators, which specify when a certain indicator reaches an 'undesirable' level, representing an unwanted change.

## **Economics**

Economic tools can help assess the impact of sectorial changes on goods and services. This can be a challenge, since some of the services provided by the marine environment are public goods which are not 'owned' by a specific institution or private person. The marine environment provides use values (things that have a direct, often monetary value, for example fish as a source of food) and non-use values (things that human kind values even though it cannot be used in a direct manner). The latter are most difficult to assess. Economic tools also are very helpful to evaluate the effect of policy measure implementation as for example the implementation of an MSP and specifically a SMA. In a wider sense every policy measure can be evaluated on its (perceived) costs and benefits.

## **Statistics**

Statistical tools are useful at many stages of the marine spatial planning process and also in the evaluation of a marine spatial plan. Tools that calculate statistics of biological features and species distribution, shipping and other human uses help calculate when and where conflicts may occur. Statistical tools also summarise information metrically which aids in decision making.

### **3.1.2 Tool Descriptions**

#### **Morpho**

Morpho helps scientists to create and manage data and metadata that can be shared with others. A catalog of data & metadata can be created that can be used to query, edit and view data collections. It was created to provide an easy-to-use, cross-platform application for accessing and manipulating metadata. Morpho also provides the means to access networked data servers such as Metacat, which provides searchable access to large collections of data. It can also be used to create and edit metadata, search and query metadata collections, view data and data collections, verify and edit data and provide access control.

#### **Eonfusion**

Eonfusion is a new application that provides 4D analysis and visualisation of time-varying spatial data. It can handle large data sets and fuse them together, enabling users to easily assemble sets of attributes. It can combine vector and raster data and also synchronise video with time-referenced vector data. These capabilities are important for applications in which ground-truthing (field validation) is undertaken such as environment and habitat mapping and remote species identification which in the past have proven to be very time consuming or impractical. Eonfusion makes data exploration and analysis easier through an

intuitive graphical 'data flow' environment. In this environment, users can design and build a flow chart of graphical elements defining data inputs, transformations, fusion algorithms, 4D output scenes and exported data sets. Customised data processing methods can be written within a user coding environment. Completed data flows can be exported as data processing methodologies in XML and shared with other Eonfusion users.

### **Habitat Digitizer Extension**

The Habitat Digitizer Extension is designed to use a hierarchical classification scheme to delineate habitats by visually interpreting geo-referenced images such as aerial photographs, satellite images, and side scan sonar. The extension allows users to create custom classification schemes and rapidly delineate and attribute polygons, lines, and points using simple menus. The extension allows new hierarchical classification schemes to be easily created, modified, and saved for use on future mapping projects. There are several advantages to using classification schemes with a hierarchical structure including: the detail of habitat categories can be expanded or collapsed to suit user needs, the thematic accuracy of each category/hierarchical level can be determined, and additional categories can be easily added or deleted at any level of the scheme to suit user needs.

### **Kepler**

Kepler is a software application for the analysis and modelling of scientific data. Using Kepler's graphical interface and components, scientists with little background in computer science can create executable models called "scientific workflow," which are a flexible tool for accessing scientific data (streaming sensor data, medical and satellite images, simulation output, observational data, etc.) and executing complex analysis on the retrieved data. Kepler promotes effective documentation of analytical procedures and data processing, and simplifies access to distributed data repositories containing environmental data.

### **Benthic Terrain Modeller**

The benthic terrain modeller functions as an interactive toolbar within ArcMap, and relies on a methodology to analyse benthic terrain from input multibeam bathymetry in ESRI's GRID (raster) format. The benthic terrain modeller toolbar contains a set of tools that allow users to create grids of slope, bathymetric position index and rugosity from an input dataset. A unique feature of the tool is its wizard-like functionality that steps users through the processes involved in benthic terrain characterisation, and provides access to information on key concepts. More experienced users can access the various tools contained in the benthic terrain modeller for ArcGIS directly from the toolbar.

### **Ecosystem Assessment and Reporting Tool**

The Ecosystem Assessment and Reporting Tool (EAR) provides a simple, but powerful interface designed to answer questions such as "Which ecosystems are least protected?" "Of these ecosystems, where and how do we need to improve management?" and "Where are the opportunities to most efficiently reduce threats to these ecosystems?". This is done by combining biodiversity, socioeconomic and protected area datasets. The EAR tool has been designed around The Nature Conservancy's (TNC) approach for calculating "Effective Conservation" (Higgins et al, 2007). This approach is a way of measuring progress towards achieving established conservation goals for ecosystems. The framework for calculating the level of effective conservation uses three markers together: 1) Viability Status - the biological potential for a given ecosystem to persist (e.g. ecosystem size, condition, and landscape context); 2) Threats Status - the degree of anticipated negative impact (i.e. socio-economic activity) to a given ecosystem (e.g. severity, scope of threat); 3) Conservation Management Status - the likelihood that management activities will secure biodiversity and allow it to persist within a protected area (e.g. intent, tenure, and effective management potential).

### **MGET – Marine Geospatial Ecology Tools**

Marine Geospatial Ecology Tools (MGET), also known as the GeoEco Python package, is an open source geo-processing toolbox designed for coastal and marine researchers and GIS analysts who work with spatially-explicit ecological and oceanographic data in scientific or management workflows. MGET includes over 180 tools useful for a variety of tasks, such as converting oceanographic data to ArcGIS formats, identifying fronts in sea surface temperature images, fitting and evaluating statistical models such as GAMs and GLMs by integrating ArcGIS with the R statistics program, analyzing coral reef connectivity by simulating hydrodynamic larval dispersal, and building grids that summarise fishing effort, CPUE and other statistics. Currently under development are tools for identifying rings and eddy cores in sea surface height images, for analysing connectivity networks, for estimating fishing effort when no effort data are available, for predicting hard bottom habitat from coarse grain bathymetry, and much more. MGET may be accessed from ArcGIS as a toolbox in the ArcToolbox window and from programming languages as a set of Python modules and COM components.

### **MarineMap**

MarineMap is a web-based decision support tool for open and participatory spatial planning in the marine environment. MarineMap offers a simple, flexible and powerful means of gathering expertise from resource managers, scientists, stakeholders and public in a process of collaborative decision making. It offers users web-based access to all of the data, methods and analyses that scientists use to evaluate Marine Protected Areas (MPAs). As a result, users can discuss and evaluate prospective MPAs without any special training.

There is another version of MarineMap under development, called SeaSketch. SeaSketch has added features like discussion forums that stakeholders, planners and decision-makers can make use of, therefore it is not only a technical decision support tool, but a tool for participatory GIS and communication as well. It has been designed specifically so that non-technical users can use it with ease. It can help to evaluate socio-economic impacts of different spatial management scenarios and can be adapted to provide feedback on ecological and economic design criteria for spatial configurations of protected areas. See <http://mcclintock.msi.ucsb.edu/projects/seasketch> for further information.

### **Ecosystem Management System Support**

Ecosystem Management System Support is an application framework for decision support of ecological assessments at any geographic scale. The system integrates GIS, logic, and decision modelling to provide decision support for a substantial portion of the adaptive management process of ecosystem management. The NetWeaver logic engine evaluates data against a knowledge base that provides a formal specification for the interpretation of data.

### **CTAM – Coastal Transects Analysis Model**

Coastal Transects Analysis Model (CTAM) is a simple visualisation and decision-support tool that can assist coastal managers, practitioners, policy makers, coastal communities and other coastal stakeholders in addressing multiple present and future demands in coastal areas. CTAM analyses interactions and flows between natural and human systems, with emphasis on fisheries and aquatic resources, using information provided by users, coupled with literature and experts' judgment.

### **C-PLAN**

C-Plan is an interactive decision support system for conservation planning. It links with GIS to map options for achieving explicit conservation targets. It can be used as an interactive tool during negotiations over land use planning; a tool to aid individual planners in identifying alternative systems of reserved lands that meet their conservation requirements; an educational tool to demonstrate conservation planning principles to students; a research tool for gap analysis, conservation planning, and simulating alternative futures for an area of land under study. It interfaces with ESRI ArcView GIS 3.X, Marxan, and spatial

configuration software to create an interactive decision support tool that can be useful for assessing spatial managed areas.

### **Netica**

Netica is a program for working with belief networks and influence diagrams. It has an intuitive user interface for drawing the networks, and the relationships between variables may be entered as individual probabilities, in the form of equations, or learned from data files (which may be in ordinary tab-delimited form). Belief networks (also known as Bayesian networks and causal probabilistic networks), provide a method to represent relationships between propositions or variables, even if the relationships involve uncertainty, unpredictability or imprecision. They may be learned automatically from data files, created by an expert, or developed by a combination of the two.

### **SimCoast**

SimCoast is a fuzzy logic rule-based expert system designed to enable researchers, managers and decision-makers to create and evaluate different policy scenarios for coastal zone management. It aims to combine traditional and advanced specialist knowledge about coastal zones with a set of reasoning and analytical tools. Experts that can be involved include engineers, natural and social scientists, lawmakers, administrators, community and national leaders. Sensitive issues such as trans-boundary pollution and cross-sectoral socioeconomic effects can be translated into rules for policy formulation and decision-making. The conceptual basis of SimCoast is a two-dimensional multi-zoned map on to which key features such as ports, legal regimes and different habitats and activities such as shipping, tourism, aquaculture are mapped. It aims to combine traditional and advanced specialist knowledge about coastal zones with a set of reasoning and analytical tools. Activities are often associated with different zones and processes to which they are linked.

### **Habitat Priority Planner**

This tool helps in decision making about habitat conservation, restoration, and land use planning. It reduces subjectivity in the process by providing a means of obtaining critical habitat analyses that are consistent, repeatable, and transparent. The program allows users to easily test various ideas and "what if" scenarios.

### **Marxan with Zones, and Zonae Cogito**

Marxan can assist with the evaluation of existing reserve systems to identify gaps in biodiversity protection, identify areas to include in new reserve systems, and provide decision support by producing a number of different options that meet both socio-economic and conservation objectives. Marxan has also been used to support multiple-use zoning plans that balance the varied interests of stakeholders. Marxan is a software package developed at the University of Queensland, designed for use in systematic conservation planning (Ball et al., 2009). It uses optimisation algorithms to identify spatial configurations of areas that efficiently meet targets for biodiversity features for minimal cost (e.g. represent a specified amount of each of a set of habitats within a reserve network, minimising the cost of buying the necessary land, or minimising the overall size of the network). It is designed to apply systematic reserve design principles (Margules & Pressey, 2000). Marxan requires technical (GIS) expertise and good coverage of spatial data on the distribution of conservation features within the planning region. The strength of the tool lies in its capacity to solve complex problems where lots of data layers stack on top of each other, and there are a number of design criteria to consider, as well as in its capacity to provide multiple near-optimal solutions for any given scenario. Users should refer to the information and references listed on the Marxan website (<http://www.uq.edu.au/marxan/>), and to the Marxan good practices handbook (Ardron et al., 2010). Marxan with Zones is a newer version of the software which can be used to explore spatial zonation scenarios, e.g. reserves with different protection levels, or reserves combined with zones for economic use (Watts et al., 2009). Zonae Cogito (Segan et al. 2011) is a GIS interface that has been developed for Marxan and Marxan with Zones (which can also be used as in interface for C-Plan, see above).

**ARIES - Artificial Intelligence for Ecosystem Services**

ARIES is a web-based technology to assist rapid ecosystem service assessment and valuation (ESAV) in order to make environmental decisions easier and more effective. ARIES helps discover, understand, and quantify environmental assets and what factors influence their values, in a geographical area and according to needs and priorities set by its users. ARIES can accommodate a range of different use scenarios, including spatial assessments and economic valuations of ecosystem services, optimization of payment schemes for ecosystem services, and spatial policy planning.

**Expert Choice**

Expert Choice software is designed to help decision-makers overcome the limits of the human mind to synthesize qualitative and quantitative inputs from multiple stakeholders.

**AHP-OWA**

The AHP-OWA module brings the capabilities of two major procedures of Analytical Hierarchy Process and Linguistic Quantifier Ordered Weighted Averaging into ArcGIS environment for spatial decision making problem solving. This tool integrates ArcGIS with an analytical hierarchy process (AHP) module using quantifier-guided ordered weighted averaging (OWA) procedure. AHP-OWA is a multi-criteria combination operator. The nature of the AHP-OWA depends on some parameters, which are expressed by means of fuzzy linguistic quantifiers. By changing the linguistic terms, AHP-OWA can generate a wide range of decision strategies.

**HIPRE**

HIPRE 3+ is a web-based decision support software integrating the two decision analysis and problem solving methods: AHP - Analytic Hierarchy Process and SMART - Simple Multi-Attribute Rating Technique. Both methods can be run independently or combined in one model. HIPRE 3+ is designed to be a powerful but simple tool that gives a visual and customisable graphical interface.

**LINK**

LINK is a set of ESRI ArcGIS tools designed to analyse habitat patterns across a landscape. LINK uses species habitat matrices to model potential species habitat and habitat diversity using raster data sources. Raster data sources allow LINK to model habitat over a much larger area than its vector based ancestors. LINK's main purpose is to make comparisons of conservation potential between management units and the surrounding landscape. LINK does this by summarising potential species richness, habitat diversity, and habitat composition.

**MIDAS**

MIDAS (Marine Integrated Decision Analysis System) offers managers and other users of marine managed areas (MMAs) the ability to analyse outcomes that result from the interaction of governance, socioeconomic and ecological factors.

MIDAS is a software tool that was developed with three main objectives in mind: (1) to assist MMAs users and managers in understanding the critical factors that influence the MMA's effects so that they can plan accordingly; (2) to estimate likely MMA effects based on the ecological, socioeconomic and governance conditions; (3) and finally, to advise management plan revisions that will result in optimisation of outcomes and outputs.

## **MIMES**

The Multi-scale Integrated Models of Ecosystem Services (MIMES) is a suite of models for land use change and marine spatial planning decision making. The models quantify the effects of land and sea use change on ecosystem services and can be run at global, regional, and local levels. The MIMES use input data from GIS sources, time series, etc. to simulate ecosystem components under different scenarios defined by stakeholder input. These simulations can help stakeholders evaluate how development, management and land/sea use decisions will affect natural, human and built capital.

## **PAT**

The Protected Area Tools need to be used with the highest quality data (i.e., spatial delineation and critical evaluation of habitats/species, protected areas, and risks to focal habitats) available and conducted an ecological inventory and assessment of these data layers through as well as carefully considered all model scenario settings. PAT consists of three conservation modules which operate within the ArcGIS 9.2 software: Environmental Risk Surface (ERS); Relative Biodiversity Index (RBI) and Marxan Tools.

## **HPP- Habitat Priority Planner**

The Habitat Priority Planner (HPP) is a spatial decision-support tool (for ArcGIS 9.2 or 9.3) designed to assist users in identifying high-priority areas in the landscape or seascape for land use, conservation, climate change adaptation, or restoration action. HPP contains several landscape-based spatial analyses and the scenarios can be displayed and changed easily. In addition to the scenarios, the tool also generates reports, maps, and data tables.

## **IAN (Integration and Application Network)**

The IAN symbol libraries contain over 1500 custom-made vector symbols (in 32 categories) designed specifically for enhancing science communication skills. The libraries are designed primarily for use with Adobe Illustrator, however there are also eps and svg versions for non-Illustrator users. The symbols allow diagrammatic representations of complex processes to be developed easily with minimal graphical skills.

## **Maps**

Maps are vital communication tools in MSP. They can take the form of hard copy (paper) maps, stand-alone digital map products (e.g. PDF documents with multiple layers that can be clicked on and off), or more complex online GIS systems where multiple layers of information can be explored, and the user can zoom and pan around. Through applications such as Google maps and Google Earth, online GIS has become a feature of everyday life for many people, so digital map products will increasingly be expected to form part of MSP processes even when they include non-technical audiences.

Unlike most of the other technical tools listed here, 'maps' obviously does not refer to a specific software application or methodology. Nevertheless, they are listed because they play such a pivotal role in any spatial planning or management process. It is important for GIS technicians and cartographers to spend sufficient time and effort designing good maps. In order to be effective, maps may need to be tailored to a specific process, audience or task. Decisions need to be made on what information to display (avoiding information overload, focussing on key layers of information), what medium to use (hard copy or digital, interactive or static), and on appropriate scale and size. It is also important to consider what symbology to use – e.g. a GIS analyst might use bright red on the screen to highlight areas of particular interest in their day-to-day data processing, but to a non-technical audience, bright red areas on a paper map might intuitively signal 'danger'.

### **Open OceanMap**

Open OceanMap is a data collection tool used to effectively collect local expert knowledge in support of marine spatial planning, developed by Ecotrust (<http://www.ecotrust.org/marineplanning/OpenOceanMap.html>). Using open source technologies, Ecotrust has developed Open OceanMap as a cross platform and transferable tool, published under the GNU General Public License. It can be accessed as a stand-alone desktop tool or via a web-based interface, and has been used to collect information on the economic value of fishing areas off the US West Coast, to support marine protected area planning in California.

### **E-participation**

Electronic participation is a tool in the governmental planning process and are usually web-based mapping applications. It is developed to enable and facilitate public participation in complex situations. E-participation is not a public participation method as such, but a collection of tools that can be used in conjunction with many other methods. Web-based applications enable stakeholders to easily access comprehensive and targeted information in the form of maps, pictures, videos or 3D visualisations and also provide the possibility to query, measure and edit maps, express opinions on the planning issue and collaborate with planning authorities.

### **Habitat Modelling Toolbox**

This toolbox produces multivariate habitat prediction rasters using ArcGIS and the open source R statistical package for implementing classification and regressing (CART), generalised linear models (GLM) and generalised additive models (GAM) and includes a connectivity modelling toolbox. This toolbox is distributed by Pat Halpin and the Marine Geospatial Ecology Laboratory at Duke University.

### **SPAM (Sandeel Population Analysis Model)**

The Sandeel Population Analysis model is a spatial explicit process-orientated scenario simulation tool to study the influence of various environmental, climate and anthropogenic factors on sandeel stocks. Sandeel stocks, being mid-trophic in the ecosystem are sensitive ecosystem indicators. This model has previously been used for analysing the ecological impact of marine protected areas, as well as socio-economical effects, by coupling SPAM to the socio-economical model BENCOM. It is currently set up to describe sandeel stocks in the North Sea but can also be reparameterised to describe other sedentary species in an arbitrary habitat network.

### **Ocean**

The OCEAN framework is comprised of a set of tools that includes GIS databases, analyses, and decision support systems for spatial analysis and interpretation of ecological and socioeconomic data. It allows scientists, managers and communities to take an integrated and systematic look at ecosystems, fishery policy and marine conservation.

### **Biomapper**

Biomapper is a GIS and statistical tool kit designed to build habitat suitability models and maps for any kind of flora or fauna. It is based on the Ecological Niche Factor Analysis (ENFA) that allows habitat suitability models to be computed without the need for absence data.

**IBMlib**

IBMlib is a generic self-contained individual-based modelling framework able to assess marine habitat connectivity. It can be used to analyse the recruitment impact of marine protected areas, to model the effect of different factors on habitat connectivity and the effect of environmental changes. The model has been used for many species in different regions to predict and analyse recruitment variability.

**Fishery Analyst**

Fishery Analyst is an ArcGIS 9.x extension developed to effectively analyse and visualise temporal and spatial patterns of fishery dynamics. The main functions are quantitative estimation and visualisation of catch and effort and their variation in space and time, analysis of fishing vessel use, data quality control and deriving information on the location of important economic and threatened species.

**Connectivity Analysis Toolkit**

The Connectivity Analysis Toolkit provides conservation planners with tools for both linkage mapping and centrality analysis. The toolkit allows users to develop and compare three contrasting centrality metrics based on input data representing habitat suitability or permeability, in order to determine which areas would be priorities for conservation measures.

**AHP in ArcGIS**

AHP 1.1 is an ArcGIS extension which performs a criteria weight determination according to the well known Analytic Hierarchy Process (AHP). It is a powerful tool for the creation of suitability maps (spatial planning, risk mapping and more).

**EASy Mapping Solutions for Marine Resources**

EASy (Environmental Analysis System) is an advanced GIS with the capability to view, analyze and store diverse types of environmental data. EASy has been used in a wide range of applications from resource management and oceanography, to pollution studies and coastal monitoring. Unlike other GIS software, EASy has been specifically designed to display data with time, depth and geo-spatial information.

**NatureServe Vista**

NatureServe Vista is an ArcView 9.x extension that provides a conservation planning framework that helps users integrate conservation with land use and resource planning of all types. Vista was specifically designed to support non-GIS and non-conservation experts to assist integration of conservation with other assessment and planning activities.

**SDM**

SDM (Spatial Data Modeller) is a collection of geoprocessing tools for adding categorical maps with interval, ordinal, or ratio scale maps to produce a predictive map of where something of interest is likely to occur. The tools include the data-driven methods of Weights of Evidence, Logistic Regression, and two supervised and one unsupervised neural network methods, and a knowledge-driven method Fuzzy Logic. All of the tools have help files that include references to publications discussing the applications of the methods implemented in the tool. Several of the tools create output rasters, tables, or files that require the user to enter a name.

**NAMEM (Network Analyst for Marine Ecosystem-based Management)**

NAMEM performs large-scale connectivity analysis of marine habitats using recent advances in the application of network theory to source-sink population structures. A simple wizard interface guides analysts through assembling GIS data layers, building a network model and analysing its properties. Results are provided as GIS outputs so that they can easily be incorporated into mapping and visualisation products.

**PANDA (Protected Areas Network Design Application for ArcGIS)**

PANDA is a stand-alone application that was developed to provide a user friendly framework for systematic protected areas network design to ArcGIS users. Through the use of P.A.N.D.A. the designer can explore different hypothetical configurations of a system of protected areas in the planning area. The designer can edit a scenario by interactively modifying the status of the planning units among four categories (Included, Protected, Available, Excluded). The target table can then be explored to see the resulting changes in conservation achievements of the new scenario and the associated costs.

**DIVA (Dynamic Interactive Vulnerability Assessment)**

DIVA is a tool that allows its users to produce consistent quantitative information on a range of social, ecological, and economic coastal impact indicators based on user-selected climatic and socio-economic scenarios, as well as coastal adaptation strategies. DIVA was developed within the European-funded project DINAS-COAST (Dynamic and Interactive Assessment of National, Regional and Global Vulnerability of Coastal Zones to Climate Change and Sea-Level Rise). DIVA comprises four major components: 1. A detailed global database with biophysical and socio-economic coastal data; 2. Global and regionalised climate and socio-economic scenarios until the year 2500; 3. An integrated model of interacting biophysical and socio-economic coastal processes including adaptation 4. A graphical user interface for selecting data and scenarios, running model simulations and analysing the results. DIVA does not support analysis for operational coastal management and planning, as this requires a differently scaled approach.

**SDM (Spatial Data Modeler)**

Spatial Data Modeller, SDM, is a collection of geo-processing tools for adding categorical maps with interval, ordinal, or ratio scale maps to produce a predictive map of where something of interest is likely to occur. The tools include a range of data-driven methods such as Weights of Evidence, Logistic Regression and Fuzzy Logic. Several of the tools create output rasters, tables, or files that require the user to enter a name.

**PATHMATRIX**

PATHMATRIX is a GIS extension to compute matrices of effective geographic distances among samples, based on a least-cost path algorithm. Punctual locations (points) or zones encompassing sample data points (polygons) are used in conjunction with a species-specific friction map representing the cost of movement through the landscape.

Three different types of distances can be computed. 1) least-cost distance, 2) length of the least-cost path, 3) Euclidean distance. Matrices of effective distances can then be exported to other software to test, for example, for isolation by distance. The use of effective distances allows investigation of the role of the environment on the spatial genetic structuring of populations.

**WeMO**

WEMo (Wave Exposure Model) is a simple hydrodynamic model that calculates the wind wave exposure of a site (Malhotra et al., 2007). WEMo helps coastal managers and ecologists to estimate wave parameters in coastal and estuarine environments. This involves estimating the wave energy reaching the shoreline taking into account the effects of wind, local topography and bathymetry.

WEMO was designed to bridge the gap between ecologists and managers on one hand, and physical hydrologists on the other by providing access to quantitative forecasts of wave energy in estuarine environments. WEMO has two distinct modes: Representative Wave Energy or RWE mode and Relative wave Exposure Index or REI mode, the selection of which depends on the project requirement, geographical area for the study and time scale used in the study.

### **GADGET - Globally applicable Area Disaggregated General Ecosystem Toolbox**

Gadget is a tool for creating ecosystem models. Gadget models can be both very data- and computationally- intensive. The program was developed for modelling marine ecosystems in a fisheries management and biology context, however models have also been developed to examine marine mammal populations. Gadget allows you to include a number of features into your model: One or more species, each of which may be split into multiple stocks; multiple areas with migration between areas; predation between and within species; maturation; reproduction and recruitment; multiple commercial and survey fleets taking catches from the populations. It is written in C++ and can be run under UNIX/Linux and PC (using cygwin).

### **ISIS - FISH**

ISIS-Fish is a spatial and seasonal simulation model describing the dynamics of resources, exploitation and management. It has been developed to explore the impact of a range of management measures upon fisheries dynamics. It enables one to compare the respective impacts of conventional management measures like catch and effort controls, and measures like Marine Protected Areas (MPA) in the wider sense, i.e. any spatialised measure. ISIS-Fish aims at being as generic as possible in order to be applied to different types of fishery. Existing knowledge about each fishery may be stored in a database included in the software, and may be easily modified. This includes the parameters describing each population and each fishing activity. ISIS-Fish allows for flexibility in several model assumptions (for instance stock-recruitment relationships, selectivity models) which make it possible to use it for most demersal and/or benthic fisheries. Management measures and fisher's response to management measures and to economic conditions may be interactively designed through a Script language. ISIS-Fish is currently being applied to several European fisheries, through national and European research projects.

### **Marine Reserve And Local Fisheries Interactive Simulation**

This simulation-based exercise is an educational tool that allows users to explore various factors that influence fish population viability and fishery sustainability, and experiment with the use of marine reserves as tools in fisheries management. This exercise allows users to explore issues related to marine reserves and local fisheries via interactive simulations. Users are able to control (1) some attributes of a local fishery - including population dynamics and mobility of the target species as well as aspects of fisher behaviour and economic factors, and (2) the extent and placement of marine reserves. By exploring the contributions of these issues to fisheries productivity over time, users should gain some understanding of the factors contributing to how reserves can interact with local fisheries.

Many of the factors and dynamics in this exercise are based on actual interdisciplinary research conducted in The Bahamas (see <http://bbp.amnh.org>). Nevertheless the exercise represents a simplification of the real complexities of population dynamics, fisheries economics, and marine resource management.

### **EcoGIS**

The EcoGIS project is developing a set of GIS tools to better enable both fisheries scientists and managers to adopt ecosystem approaches to fisheries management. Prototype GIS tools are being developed to address fishing effort and catch analysis, area characterisation, by-catch analysis, and habitat interactions. These tools generate spatial and temporal analysis using specified criteria from a variety of

data sources, including base map layers and fishery dependent and independent data. The end products will enable simplified and more efficient data query, the ability to visualise data over time and to synthesize multi-dimensional data from diverse sources, and to provide new information for analysing specific issues from an ecosystem perspective.

### **Atlantis**

Atlantis is an ecosystem box-model intended for use in management strategy evaluation. It was originally developed in Australia, but is increasingly used in the USA as well. The overall structure of Atlantis is based around having multiple alternative sub-models to represent each step in the management strategy and adaptive management cycles. The Atlantis framework, developed from the "Bay Model 2" ecosystem model, is a deterministic model that tracks the nutrient (nitrogen and silica) flow through the main biological groups found in temperate marine ecosystems, and three detritus groups (labile detritus, refractory detritus, and carrion). The primary processes considered are consumption, production, waste production, migration, predation, recruitment, habitat dependence, and natural and fishing mortality.

### **GARP**

Desktop GARP is a software package for biodiversity and ecologic research that allows the user to predict and analyse wild species distributions. GARP is a genetic algorithm that creates ecological niche models for species. The models describe environmental conditions under which the species should be able to maintain populations. GARP searches iteratively for non-random correlations between species presence and absence and environmental parameter values using several different types of rules. Each rule type implements a different method for building species prediction models.

### **EcoWin 2000 (E2K)**

E2K makes use of an object-oriented programming (OOP) approach to implement ecological models for aquatic systems. The basic underlying structure is that of a spatial (1D, 2D and 3D) framework of boxes, within each of which the relevant biogeochemistry and population dynamics are resolved. Each object in E2K groups together multiple state variables (Ferreira 1995). E2K contains about one hundred objects, corresponding to hierarchies for simulating e.g. hydrodynamics, air temperature, oyster growth, seeding and harvesting processes, etc. This ecological model is applicable to the ecosystem scale, corresponding e.g. for the EU WFD to: Water body and regional scale. The usage of object-oriented methods to simulate processes in ecological systems simplifies model development due to the flexibility associated with the modularity and inheritance properties of the objects themselves and provides a much greater conceptual approximation between natural ecosystems and interacting objects relative to structured programming.

### **ERSEM (the European Regional Seas Ecosystem Model)**

ERSEM is a generic model that describes the pelagic and benthic ecosystems and the coupling between them. ERSEM (the European Regional Seas Ecosystem Model) is a mature plankton functional type model that was initially developed within a Framework 3 European project. It includes several refinements necessary to correctly represent the key processes of temperate shelf ecosystems; the main ones being some plankton community complexity, the microbial loop, variable nutrient stoichiometry, variable carbon, chlorophyll ratios and a comprehensive description of benthic biochemical and ecological processes.

### **Fisheries Libraries in R**

The FLR library is a collection of tools in the R statistical language that facilitates the construction of bio-economic simulation models of fisheries and ecological systems. It is a generic toolbox, but is specifically suited for the construction of simulation models for evaluations of fisheries management strategies. The FLR library is under development by researchers across a number of laboratories and universities.

### **HyperNiche**

HyperNiche is user-friendly software for nonparametric regression. The primary purpose is to provide a flexible tool for multiplicative habitat modelling - habitat models where the predictors are combined multiplicatively rather than additively.

### **IBMLib**

IBMLib is a generic self-contained individual-based modelling framework able to assess marine habitat connectivity. Eggs, larvae, juveniles and adults can be modelled. The model has been used for many species in different regions to predict and analyse recruitment variability. To predict the dynamics of a representative set of eggs/larvae/juvenile/adults the framework solves ordinary/stochastic differential equations, ranging from simple to highly complex, for model state variables. Model state variables are position and condition variables for each member of an ensemble of biological particles.

### **EcoPath**

Ecopath with Ecosim (EwE) is a free ecological/ecosystem modelling software suite. EwE has three main components: Ecopath - a static, mass-balanced snapshot of the system; Ecosim - a time dynamic simulation module for policy exploration; and Ecospace - a spatial and temporal dynamic module primarily designed for exploring impact and placement of protected areas. The tool aims to:

- Address ecological questions;
- Evaluate ecosystem effects of fishing;
- Explore management policy options;
- Analyse impact and placement of marine protected areas;
- Predict movement and accumulation of contaminants and tracers (Ecotracer);
- Model effect of environmental changes.

### **Hydata Sonobuoy**

The Hydata Sonobuoy is a device to determine the absolute underwater acoustic sound pressure levels from natural or anthropogenic sources in the marine environment. The determination of possible disturbance impacts to marine mammals and other ecology from sound sources, such as marine tidal energy devices. It can also be used in the regular monitoring of study sites.

### **DIVA**

DIVA (Dynamic and Interactive Vulnerability Assessment) is a user-friendly tool that allows its users to produce consistent quantitative information on a range of social, ecological, and economic coastal impact indicators based on user-selected climatic and socio-economic scenarios, as well as coastal adaptation strategies. DIVA was developed within the European-funded project DINAS-COAST (Dynamic and Interactive Assessment of National, Regional and Global Vulnerability of Coastal Zones to Climate Change and Sea-Level Rise). DIVA comprises four major components: 1. A detailed global database with biophysical and socio-economic coastal data; 2. Global and regionalised climate and socio-economic scenarios until the year 2500; 3. An integrated model of interacting biophysical and socio-economic coastal processes including adaptation 4. A graphical user interface for selecting data and scenarios, running model simulations and analysing the results.

The information produced by DIVA will enable its users: - To explore the effects of climate change on coastal environments and societies; - To explore the costs and benefits of coastal adaptation options; - To set priorities for international co-operation with respect to climate change and development; - To use data, scenarios and results for further scientific and policy analysis.

### **Cost-benefit analysis**

In a cost-benefit analysis, a comparison is made between the costs of a certain decision and the benefits it creates, sometimes using a weighing factor. A CBA has two purposes 1) to assess whether a certain investment should be made, 2) to provide a tool for comparing different projects or management options. Outcomes are expressed in monetary terms. CBA is a valuable tool for a range of sectors, including governments and industries, to evaluate the desirability of a certain decision or policy.

### **SAM v4.0 - Spatial Analysis in Macroecology**

SAM (Spatial Analysis in Macroecology) is a program designed as a package of tools for spatial statistical analysis, mainly for applications in Surface Pattern Spatial Analysis and range from simple tools for exploratory graphical analysis (e.g. mapping and graphing) and descriptive statistics of spatial patterns (e.g. autocorrelation metrics), to advanced spatial regression models (e.g. auto-regression and eigenvector filtering). SAM is mostly used in the fields of Macroecology and Biogeography, but also in Conservation Biology, Community and Population Ecology, Geography, Geology, Demography, Econometrics, Psychology and Epidemiology.

### **Conservation Land-Use Zoning software (CLUZ)**

CLUZ is an ArcView GIS interface that allows users to design protected area networks and conservation landscapes. It can be used for on-screen planning and also acts as a link for the Marxan conservation planning software.

### **EcoSeed**

EcoSeed is a zoning tool for the EwE software package designed to evaluate placement of protected areas. EcoSeed builds on the spatial-dynamic module of EwE, Ecospace, and is designed to consider economic, social biodiversity, and ecological criteria. It works by the user defining potential sites ('seed cells') for placement of protected areas (can be all spatial cells); the program will then evaluate each of the seed cells, and iteratively pick the one that optimizes a given objectivity function. It will turn the best cell into a protected area, its neighboring cells will be designated as seed cells (if they have not already been deemed protected), and the process will continue till all cells have been protected. In the process the benefit and associated cost is recorded and visualized. EcoSeed evaluates alternative forms for optimization by enhancing the functionality of Ecospace to accommodate Marxan solutions.

### **ArcMarine - The ArcGIS Marine Data Model**

Arc Marine (or the ArcGIS Marine Data Model - MDM), is a geodatabase model tailored specifically for the marine GIS community. The ArcGIS Marine Data Model represents a new approach to spatial modeling via improved integration of many important features of the ocean. The goal is to provide more accurate representations of location and spatial extent, along with a means for conducting more complex spatial analyses of marine and coastal data by capturing the behaviour of real-world objects in a geodatabase. The model also considers how marine and coastal data might be more effectively integrated in 3-D space and time. Although currently limited to 2.5-D, the model includes "placeholders" meant to represent the fluidity of ocean data and processes.

### **MIRADI**

The Miradi software tool helps conservation practitioners implement the Open Standards for the Practice of Conservation. Miradi provides an interview-style interface that walks a project team through each step of the process of designing, managing and monitoring their project according to the best practice standards established and tested by the world's major conservation organisations.

The software supports several key features including conceptual modelling of the project situation, strategic planning (including developing goals, objectives, and monitoring indicators), and spatial mapping of the project site, work planning (including Gantt charts), grant reporting and budgeting.

### **NAMEM**

NAMEM performs large-scale connectivity analysis of marine habitats using recent advances in the application of network theory to source-sink population structures. An interface guides analysts through assembling GIS data layers, building a network model and analysing its properties. Results are provided as GIS outputs so that they can be incorporated into mapping and visualisation products.

### **Zonation**

Zonation is a framework for large-scale conservation planning. Zonation can be used for various purposes such as the identification of near-optimal reserve networks, identification of expansions for reserve networks, assessment of proposed reserve networks and priority ranking for conservation decision support. Typical input data of Zonation consists of observed or predicted distributions of biodiversity features. Output of Zonation can be visualised by two intuitively appealing graphs - the rank priority map and species-specific performance curves.

Features of Zonation that distinguish it from other conservation planning software include (i) direct workflow between GIS, statistical species distribution modelling and Zonation, (ii) an ability to work with data sets having millions of selection units (grid cells), (iii) ability to set connectivity constraints in a species-specific manner, (iv) potential modelling of species interactions, and (v) uncertainty analysis to identify robust reserve solutions. While the main operational principle and output of Zonation are different from those of target-based planning, Zonation can also be used to carry out traditional target-based analyses.

## **3.2 Non-Technical Tools**

### **3.2.1 Conceptual tools and guidelines in MSP**

This type of tool is more abstract and are presented as in document form. They need to be interpreted by the user and can be directed either at scientists or managers. An example of this type of tool are the DPSIR guidelines. DPSIR stands for Drivers, Pressure, State, Impact, Response and was developed to evaluate impacts on coastal environments and helps to understand the inter-relations between ecological and economic dynamics of coastal zones. The aim of this approach is to provide scientifically-based information required by managers and decision-makers to evaluate previously adopted policies as well as future scenarios. Information of DPSIR in a study area can be interpreted by users and policy makers but collection of the data and categorisation of the Drivers, Pressures, State Changes, Impacts and Responses requires expert judgement.

Many of this type of conceptual tools, guidelines and methodologies are available on the MESMA Tool wiki and are often linked with different categories of tools i.e. the Marxan good practices handbook'.

Other examples of this kind of tool include documented methodologies to guide managers and scientists, such as:

- The UNESCO document on marine spatial planning – 'Marine Spatial Planning: A step-by-step approach towards Ecosystem-Based Management'.

- The NOAA documents on stakeholder engagement and analysis – ‘Introduction to Stakeholder Participation’; ‘Stakeholder engagement strategies for participatory planning’ and ‘Marine Spatial Planning Stakeholder Analysis’
- A BALANCE project report – ‘E-participation as a tool in the planning process’
- The Vlaams Instituut voor de Zee (VLIZ) studies on biological valuation – ‘A concept for biological valuation in the marine environment’.

### 3.2.2 Governance

Governance tools include incentives and institutions that are combined in order to achieve long-term and strategic conservation goals. There are five categories of incentives/institutions:

- Economic incentives – using economic and property rights approaches to promote the fulfilment of MSP objectives (market control)
- Interpretative incentives – promoting awareness of the ecological and cultural values of the SMA, the related objectives for conserving them, the policies for achieving these objectives and support for related measures
- Knowledge incentives – respecting and promoting the use of different sources of knowledge to better inform MSP decisions
- Legal incentives – use of relevant laws, regulations etc. as a source of ‘state steer’ to promote compliance with decisions and thereby the achievement of MSP obligations (state control)

Participative incentives – providing for users, communities and other interest groups to participate in and influence MSP decision-making that may potentially affect them in order to promote their ‘ownership’ of the SMA and thereby their potential to cooperate in the implementation of decisions Qiu, W and Jones PJS, (2011).

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## 5 ANNEX 1

Table A.1. Overview of European data portals

<a href="#">Nationaal Georegister</a>	This is a catalogue of online geo-information in the Netherlands
<a href="#">EMODnet Biology</a> (European Marine Observation and data network)	This is a data port and access service for biological data
<a href="#">OneGeology Europe</a>	Portal for geological data
<a href="#">EMODnet Hydrography</a>	This is a data port and access service for hydrographic data (water depths and coastlines etc.)
<a href="#">Coastal and Marine Spatial planning</a> (NOAA)	Website about coastal and marine spatial planning (USA)
<a href="#">MEDIN</a>	Marine environmental data and information for the UK
<a href="#">MATROOS</a>	MATROOS gives you easily access using your internet browser to all recent and historical model and monitoring data relevant to the storm surge forecasts. MATROOS offers also the facility of an international near-real time multi-model forecast analysis: water level forecasting data and weather forecasting data from the NOOS partners around the North Sea can be intercompared.
<a href="#">EU-SEASED</a>	A guide to seabed samples from ocean basins and European continental waters
<a href="#">GeoSeas</a>	Geo-Seas is expanding the existing SeaDataNet marine and ocean data management infrastructure to handle marine geological and geophysical data, data products and services, creating a joint infrastructure covering both oceanographic and marine geoscientific data.
<a href="#">EMECO</a>	European marine ecosystem observatory data portal

<a href="#">UN Atlas of the Oceans</a>	<p>The Atlas is an information system designed for use by policy makers who need to become familiar with ocean issues and by scientists, students and resource managers who need access to underlying data bases and approaches to sustainability.</p>
<a href="#">European Atlas of the Sea</a>	<p>In the Atlas you can find reliable data on topics such as the European fishing fleet, motorways of the seas, the relief of the ocean floor, coastal erosion, maritime transport. It is regularly being updated as new data becomes available</p>
<a href="#">INSPIRE GeoPortal</a>	<p>The INSPIRE geoportal provide the means to search for spatial data sets and spatial data services, and subject to access restrictions, view and download spatial data sets from the EU Member States within the framework of the <a href="#">Infrastructure for Spatial Information in the European Community (INSPIRE) Directive</a>. INSPIRE aims at making available relevant, harmonised and quality geographic information to support formulation, implementation, monitoring and evaluation of policies and activities which have a direct or indirect impact on the environment.</p>
<a href="#">EEA Data and Maps and Water Data Centre</a> (WISE - Water Information System)	<p>European Environment Agency with European environmental datasets, maps, charts and applications.</p>
<a href="#">OBIS</a> - Ocean Biogeographic Information System	<p>OBIS allows users to search marine species datasets from all of the world's oceans. Users can identify biodiversity hotspots and large-scale ecological patterns, analyse dispersion of species over time and space and plot species locations with temperature, salinity and depth. There are 30.3 million datasets available!!</p>
<a href="#">EurOBIS</a> European Ocean Biogeographic Information System (as part of MarBEF Data System)	<p>EurOBIS has been developed within the MarBEF network and acts as the European node of OBIS.</p>
<a href="#">DATRAS</a>	<p>Database of trawl surveys. From this page you can get access to trawl survey data covering: The Baltic Sea, Skagerrak, Kattegat,</p>

	North Sea, English Channel, Celtic Sea, Irish Sea, Bay of Biscay and the eastern Atlantic from the Shetlands to Gibraltar. There is up to 45 years of continuous time series data.
<a href="#">British Oceanographic Data Centre</a>	UK national marine data centre
<a href="#">Netherlands Oceanographic Data Committee</a>	The National Oceanographic Data Committee (NODC) of the Netherlands is the national platform for exchange of oceanographic and marine data and information.