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Integrated coastal-zone risk management

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1.1 Introduction

Ecosystem-based management (EBM) is generally seen as the means to achieve sustainable development. There has been a decade or so of discussions on the need to incorporate the ecosystem into the management of human activities to ensure sustainability of goods and services for future generations (Christensen *et al.*, 1996). Initially, EBM recognized the interconnectedness between human societies and ecosystems. Over time, however, the approach also considered the importance of a sound understanding of ecosystem components and processes. To deal with uncertainty, the precautionary approach and adaptive management principles were added to the concepts and approaches to guide management decisions (McLeod *et al.*, 2005). Given the complexity and the variety of human activities within the ecosystem, integrated management processes were deemed necessary as a means to engage jurisdictions and stakeholders (UNESCO, 2006).

In support of these new concepts and management processes, various ecosystem research initiatives focused attention on enhancing understanding of ecosystem components and processes and their interactions. Biodiversity and ecological criteria were developed (UNESCO, 2009; DFO, 2004a, 2005a, 2006, 2009a; Wilkinson *et al.*, 2009), and extensive work on the modelling of ecological processes and human interactions was undertaken (ICES, 2007, 2008, 2009). In parallel, integrated planning and management processes spawned the need for indicators (DEDUCE, 2002; ICES, 2008, 2009). In refining management goals, and as a means to guide reporting on the state of ecosystem health, objectives were set from both ecological and socio-economic perspectives (OSPAR, 2007; DFO, 2007; US CEQ, 2009; ICES, 2010a). Among the various objective-setting initiatives, the EU Marine Strategy Framework Directive (EU, 2008) descriptors of good environmental status (GES; EU, 2010) can be interpreted as a comprehensive list of marine ecosystem-based management objectives that combine ecosystem conservation with the need to sustain ecosystem goods and services, and that are primarily applicable on regional geographic scales. Similarly, the recognition of the inherent weaknesses of project-scale environmental effect assessments resulted in the development of strategic environmental assessment approaches that broaden the geographic scale and scope of the impact assessment process to include the ecosystem context and all relevant human activities in the assessed area (EU, 2001; Canada, 2010). EBM concepts and approaches have been incorporated in both top–down integrated management and bottom–up environmental assessment initiatives.

Over the years, however, integrated management and, lately, marine spatial planning processes brought EBM into a location-based approach in which the ecosystem forms the framework for managing human activities on a scale that encompasses the range of their impacts. UNESCO (Ehler and Douvere, 2009) and UNEP (2011) identified core elements or principles of EBM from the perspective of marine spatial planning (MSP) and coastal and oceans management. They also follow classic EBM thinking concerning the interconnections and dependences among marine, coastal, and terrestrial ecosystems and human societies. In overview, these guidance documents establish the need to define the ecosystem basis for management by identifying the geographic area, the issues to be solved, the authorities and stakeholders that need to be involved, the existing management practices, and the need to set goals and objectives. Once complete, these documents would describe various phases of planning that include ecosystem assessments, governance and management options, and threat assessments against management objectives. At the operational end, the need to monitor, evaluate, and adapt the resulting plan is discussed, together with requirements for communication and financial support.

Regardless of the guidance used, very different policy, scientific, and technical information and advice is required throughout each step. In the initial stage, there is greater need for a descriptive inventory of ecological components, goods and services as well as assessment of the state of environmental health coupled to socio-economic profiling. There is also need to identify ecosystem vulnerabilities in light of existing drivers and pressures within the geographic space used for planning. In subsequent steps, expertise is needed to forecast future situations and to determine the risk of likely ecosystem and socio-economic impacts of various courses of action. In later steps, expertise is required to devise management strategies and measures that can effectively achieve ecosystem management objectives and thresholds. This also includes the need to monitor the state of environmental health in line with the implemented strategies as well as to evaluate the effectiveness and efficiencies of management strategies and measures. As Elliot (2002) mentions, marine environmental management needs to be "environmentally sustainable, technologically feasible, economically viable, socially desirable, legally permissible and administratively achievable".

At the ICES Annual Science Conference in 2010 (ICES, 2010b), a special session focused on the risks in integrated coastal-zone management. The session took stock of current work in relation to risk characterization and integrated decision-making frameworks, general frameworks for indicator selection processes, ecosystem goods and services assessments, and EBM integrated assessment processes. Of the 31 papers and posters presented, topics ranged from integrated management discussing the need for parallel approaches between strategic policy-setting and management measure implementation, to scenario-analysis decision-making tools and risk analysis. The session report is in Chapter 2 and the papers submitted in support of this report in Chapter 3.

A qualitative analysis of the papers and reports from the session were analysed against the UNESCO MSP step-by-step framework (Ehler and Douvere, 2009). The results of this analysis (Table 1.1.1) suggest that a large portion of the ecological scientific work is concerned with identifying ecological components, describing ecological processes, and monitoring trends in ecosystem change.

Table 1.1.1. Qualitative analysis of ICES ASC 2010 papers and reports in relation to the UNESCO Marine Spatial Planning framework.

UNESCO Marine Spatial Planning Steps	Number of Papers
Identifying need and establishing authority	6
Obtaining financial support	2
Organizing the process through pre-planning	7
Organizing stakeholder participation	11
Defining and analysing existing conditions	15
Defining and analysing future conditions	12
Preparing and approving the spatial management plan	5
Implementing and enforcing the spatial plan	5
Monitoring and evaluating performance	4
Adapting the marine spatial management process	3

The papers also highlight models that have been developed either to describe ecological processes or to identify potential impacts of future changes in human activities. However, the analysis does suggest that less research effort is being directed towards modelling scenarios of thresholds for either pressures or impacts, or towards management practices for determining management options. Also, few papers discussed tools for vulnerability and risk-profiling of environmental effects at the ecosystem level instead of impact-focused assessments.

Based on that analysis and because ecosystem-based management is moving from concept to implementation, the following are some areas of research that would complement such management initiatives:

- *EBM objectives based on environmental effect risks at the ecosystem scale.* From an operational perspective, such objectives would frame the level of acceptable risk for environmental effects that are directly linked to the management of human activities in support of strategic ecosystem or conservation outcomes that are set against ecological impacts. "Good Environmental Status" descriptors (EU, 2010) are very much in line with that approach.
- *Environmental effect criteria and thresholds at the ecosystem scale.* Using a diagnostic paradigm, the criteria and thresholds would be used to ascertain that an environmental effect is occurring rather than describing the state of the ecosystem and its ecological processes.
- *DPSIR causality or pathways of effects models.* The models would establish the functional relationship between pressures and effects that would be used to identify pressure load thresholds to establish management targets from the perspective of cumulative effects. Models are also needed to establish the functional relationship between the responses and effects, to determine whether management strategies are reducing the likelihood or the magnitude of the effect.
- *Regional vulnerability and risk assessment tools.* To implement these types of tools effectively, geospatial analytical models would combine ecosystem susceptibilities, environmental effects tipping points, and driver/pressure loads, to identify areas of high risks.
- *Social, cultural, economic, and policy repercussion assessment tools.* Such models would be used to identify the repercussions of not taking management action in terms of losses of goods and services.

- *Technical application of scientific knowledge.* Technical analysis of the vast amount of scientific knowledge should be conducted for developing management practices, standard operating procedures, and management targets designed to eliminate, control, or mitigate an environmental effect.
- *Performance measurement frameworks for the implemented management plans.* Such frameworks would guide the evaluations or audits of the management plans implemented, to determine conformity to the plan's implementation, administration, and operational requirements.

1.2 Conclusion

In addition to being a significant contributor to socio-economic prosperity, the coastal zone is the point of greatest interaction between land-based activities and the aquatic ecosystem. It is therefore the most vulnerable to cumulative human-induced pressures given that the management of human activities lies against a complex jurisdictional backdrop. Although the concepts of EBM approaches and processes are well recognized in environmental management generally, the complexity of integrating ecosystem, social, cultural, and economic demands within a defined geographic area requires substantial scientific and technical information to support decision-making. In such a complex environmental management construct, risk-analysis approaches provides a systematic way of gathering, evaluating, recording, and disseminating information, leading to recommendations for management actions in response to an environmental effect (WTO, 1999). From a quality-assurance perspective, risk analysis provides decision-makers with an objective, repeatable, documented assessment of the risks posed by a particular course of action (MacDiarmid and Pharo, 2003). To all intents and purposes, it provides operational procedures to EBM and integrated management concepts and approaches. The aim of risk management is to focus management strategies and resources towards priority ecosystem, socio-economic, and corporate risks.

2 Theme Session Report. The risk of failing in integrated coastal-zone management

Conveners: Roland Cormier, Beatriz Morales-Nin, and Josianne Støttrup

The ICES Annual Science Conference 2010 focused on coastal zones, one of three major thematic axes of the ICES Strategic Plan. The ecosystem-based approach to managing human activities as the leading principle for integrated coastal-zone management implies that knowledge of key ecosystem processes and properties in the coastal zone should be the core of the information that ICES could add to the process of integrated coastal-zone management (ICZM).

The conference contributed to the following priority areas in ICES Science Plan 2009–2013:

- marine spatial planning, including the effectiveness of management practices (e.g. marine protected areas, MPAs), and its role in the conservation of biodiversity;
- contributions to socio-economic understanding of ecosystem goods and services, and forecasting of the effect of human activities;
- the influence of the development of renewable energy resources (e.g. wind, hydropower, tidal, and waves) on marine habitat and biota.

Economic, environmental, and demographic pressures converge sharply in coastal regions, creating a complex situation that presents a multidimensional challenge to their effective and sustainable management and governance from social, economic, cultural, and environment perspectives. Tools, including spatial planning, are needed to assist in the decision-making processes, given that traditional users and interests are joined in the coastal area by new industries, recreational opportunities, and development interests.

With the implementation of an ecosystem-based approach to integrated management of the aquatic environment, risk-analysis decision-making tools and processes are being developed with the aim of assessing human activity against ecosystem component vulnerabilities. Therefore, it is important that indicator systems be developed within the context and in conjunction with management frameworks that will ensure their implementation. In order for this to happen, decision-makers at all levels need to be involved at all stages of the process. Using classical risk-analysis processes, these tools may provide a systematic way of gathering, evaluating, recording, and disseminating information leading to recommendations for management consideration in response to identified ecosystem vulnerabilities.

The presentations were organized along the following themes:

- Bringing together risk- and indicator-characterization approaches within an integrated decision-making framework.
- Developing a general framework for the indicator selection process for ICES countries, within which framework should be a clear definition of objectives and integration of the indicator system into the overall management process.

- Investigating the utility of assessing ecosystem goods and services as a tool to link the ecosystem approach to management, the assessment of human impacts, and subsequent decision-making.
- Investigating how the types of integrated assessment process can be included in EBM and hence also be included in a decision-making framework for ocean and coastal management.

In all, 31 contributions (17 papers and 14 posters) from ten countries were presented: Canada (5), Denmark (1), Finland (3), France (10), Germany (2), Latvia (1), Norway (2), Spain (2), UK (4), and the USA (1). Presentations covered different levels of research, development, and implementation of ICZM tools and practices. Some of the presentations discussed current work being done by the ICES ICZM working group. In addition, the results of relevant EU-funded projects were presented along with management strategies being developed and implemented in Canada.

Topics ranged from integrated management discussing the need for parallel approaches between strategic policy-setting and management-measure implementation. Several presentations addressed decision-making tools, demonstrating the use of spatial and scenario analysis models and techniques. Approaches to risk analysis were also discussed, underscoring the need to integrate natural and social sciences in decision-making. Within an integrated management context, it is important that social scientists use their knowledge of communication and social interaction in decision-making to bridge gaps between environmental scientists, management, and stakeholders.

The end-of-session discussion focused on the lack of uptake of scientific knowledge and modelling in management decision-making processes. This led to a discussion as to who should drive or lead the process with respect to the need for scientific knowledge. General views were that management and stakeholders have the most important role in framing the environmental problem and formulating the question to science. Formal advisory processes, similar to fisheries advisory processes, may enhance the formulation of the questions to ensure that relevant science addresses relevant environmental issues and scale.

The role of the ICES ICZM working group was also discussed in terms of leading the development of a structured framework and implementation for ICZM, including the perspectives of spatial planning in the coastal zone. Given that spatial planning and coastal-zone management are emerging as significant integrators of science and management, session participants suggested that the results of the session could inform the working group on upcoming topics for discussion among members.

3 Theme Session B Papers and Posters

3.1 Socio-economic and cultural objective setting for supporting the effective use of indicators for integrated management of ecosystems

Amy Diedrich and Joaquín Tintoré

The success of integrated management (IM) approaches such as marine spatial planning (MSP) and integrated coastal-zone management (ICZM) in improving, conserving, and protecting marine and coastal ecosystems has been limited by the challenge associated with translating scientific information into management action. One of the reasons science can fail to provoke management responses is that research is often conducted without appropriate consideration of the socio-economic, cultural, and political contexts of the ecosystem being managed. Although science cannot make management decisions, which often result from a combination of objective information and value judgments, it can provide valuable data to inform and monitor the consequences of management actions. However, it is critical that this information be orientated towards addressing priority objectives from socio-economic, cultural, and political perspectives, in addition to ecological objectives, if it is to be effective in generating appropriate actions at the governance level. Indicators have been receiving considerable attention in recent years as a potential solution to bridging the science–policy gap through the provision of viable, interpretable scientific information that responds to specific management objectives. The aim here is to emphasize the critical role of social science research in identifying priority objectives of stakeholders as a primary step towards the effective use of indicators and for guiding subsequent scientific research that will invoke management actions to support IM. The discussion is contextualized using the case study of an ICZM project in the Balearic Islands that has included the participation of the scientific community, civil society, and the private sector.

Keywords: cultural objectives, ICZM, indicators, socio-economic objectives.

Introduction

Achieving sustainability of coastal and marine ecosystems is one of the greatest environmental challenges facing the planet today. Global change is increasing the susceptibility of ecosystems to the negative impacts of human and natural pressures. Population and associated sustenance, natural resource, and economic needs are growing, and industry is reaching increasingly deeper into unexploited areas of the planet. Total protection through banning all types of use across large areas is becoming a decreasingly realistic management option.

In order to address the challenge of sustainability, the scientific community in the past decade has dedicated increasing attention to the need to consider human social systems and ecological systems as one, often referred to as social–ecological systems (Cheong, 2008). This perspective is reflected in new integrated management (IM) approaches that seek to combine scientific research and information with management processes and policy development, focusing on the link between human and ecological dimensions. These include, among others, integrated coastal-zone management (ICZM), marine spatial planning (MSP), sustainability science, the ecosystem-based approach, and social–ecological resilience. The science needed to support these approaches is more applied, interdisciplinary, and problem-orientated than traditional science, and is based on finding points of equilibrium among governance, economic needs, quality of life, and the preservation of natural resources.

The success of IM in attaining sustainable use of ecosystems has been limited by the challenge associated with translating scientific information into management action, an issue commonly referred to as the "science–policy gap" (Kates *et al.*, 2001; Cheong, 2008; Lubchenco and Sutley, 2010). Where the ultimate responsibility for making decisions is in the hands of managers and policy-makers, scientists can play an important role in influencing decisions by ensuring that they generate viable, relevant, and practical interdisciplinary information critical to defining, achieving, and monitoring sustainability goals. However, if that information is not actually used by decision-makers, it will not be effective in provoking a positive change in the sustainability of social–ecological systems.

A central element of IM is the need to consider and balance diverse human objectives in sustainability scenarios. Identifying and responding to these objectives is complicated by the fact that they are not based just on objective scientific information about the state of ecosystems and projected trends of human impacts. They are also influenced strongly by norms and values, shaped by the socio-cultural, economic, natural, and governance contexts of the associated social-ecological system. In this context, understanding the societal perspective is an important element for generating science that influences the way humans interact with the natural environment (Boxer, 1991).

Scoping research to identify sustainability objectives of different stakeholders and define the contextual elements (socio-cultural, economic, governance, natural) that influence those objectives is a valuable precursor to IM initiatives (Fabbri, 1998; Turner, 2000). Several social science research methods are well suited to obtaining this information and, in doing so, can help guide subsequent scientific research in both the natural and the social sciences, generating information relevant and meaningful to the management scenario. In this context, the aim here is to provide examples of how social science research aimed at defining the priority objectives of different stakeholders during the early stages of ICZM can be used for guiding indicator selection, future research, and other IM activities. The examples are provided from an ICZM project in the Balearic Islands of Spain (western Mediterranean).

Case study: defining priority objectives for sustainable development on the island of Mallorca

The Balearic Islands are an autonomous community of Spain and one of Europe's leading sun, sea, and sand tourist destinations. They are made up of the four main islands of Mallorca, Menorca, Ibiza, and Formentera, plus the smaller island of Cabrera, a land and sea national park. The islands cover an area of 497 000 ha, with a coastline of 1428 km, and had a population of just over one million in 2006. In 2007, 13.3 million tourists (9.8 million foreigners, 3.4 million Spanish) visited the islands. The islands face similar sustainability challenges as other coastal areas (habitat degradation, pollution, erosion, urbanization, natural resource use, etc.). The fact that they are islands and a major tourist destination exacerbates problems such as seasonal pressure on natural resources, residuals and unplanned coastal development, making the achievement of sustainability in the coastal zone all the more important and challenging. The need to address these challenges through sustainable development of the coast is recognized at a civil society level in the islands, yet there is a significant lack of baseline science and a governance structure to support related actions.

ICZM in the islands is still in its relatively early stages. In 2005, the Government of the Balearic Islands (DG Research, Technological Development and Innovation) and the Mediterranean Institute of Advanced Studies, IMEDEA (CSIC-UIB), initiated an ICZM project that was the first real coordinated effort towards implementing ICZM in the islands. The overall objective of the initiative is to generate scientific knowledge to help achieve sustainable development within an ICZM framework. The specific objectives are (i) to generate scientific knowledge related to coastal social–ecological systems, (ii) to develop techniques, frameworks, and tools to help implement ICZM, and (iii) to allow the transfer of scientific knowledge and innovation to society and decision-makers.

Balearic ICZM indicators project

One of the major outcomes of the Balearic ICZM project was the development of a system of indicators for ICZM in the Balearic Islands (CES, 2007; Diedrich *et al.*, 2010). This activity, which was initiated in 2006, was carried out by IMEDEA (CSIC–UIB) in partnership with the Economic and Social Council of the Balearic Islands (CES), the only organization on the islands with legal competence to represent the opinion and needs of civil society, which it communicates to the government through official opinion papers (Dictamen). Methods included a participative process of defining core objectives, selecting and adapting internationally accepted and tested indicators to be relevant at a local level, ranking of the usefulness and importance of each indicator using a series of quantified categories, and a Delphi Study. The result of this process was the development of a system of indicators and an associated implementation plan. In December 2007, the system and implementation plan was formally adopted as a Dictamen by the CES, and it was presented to the Government of the Balearic Islands at the end of 2008.

The sustainable development objectives defined during the development of the indicator system incorporated the views of two important stakeholders on the islands – the scientific community and the civil society (represented by the CES). These objectives are intended not only to guide the implementation of the indicators system, but also to inform the broader implementation of ICZM through deeper understanding of the priorities of the social system that is driving this process. As a next step, it was considered necessary to build on this work and to incorporate the opinions and objectives of another highly important stakeholder – the local business community on the largest island of Mallorca. That study was carried out using a mail-out survey instrument, described below.

The mail-out survey was sent to 918 businesses in Mallorca in September 2008. These businesses included all those listed on the local Chamber of Commerce´s list of contacts at the time. Follow-up calls were conducted one week after the surveys were issued to try to boost the response rate.

The two-page survey took approximately five minutes to complete and consisted of a series of closed and open-ended questions designed to obtain perceptions about (i) the concept of sustainability in Mallorca, (ii) the most unsustainable activities in the coastal zone of Mallorca, (iii) the general characteristics of the responding businesses, and (iv) the perceived importance of a series of objectives for sustainable development on the islands, previously defined in the System of Indicators for ICZM in the Balearic Islands described above (see Table 3.1.1 for a list of the objectives). The analysis presented here pertains to this section of the questionnaire, i.e. (iv).

Results

Of the 918 surveys mailed, 141 were returned fully completed and 42 never reached their destination. This represents a response rate of 17%, which is relatively low, although not uncommon for mail-out surveys. Despite the seemingly low level of representativeness of the overall population, however, the sample was considered to be an adequate size to conduct statistical analyses.

Table 3.1.1 shows the mean responses of the sample with respect to the level of importance of the 16 sustainability objectives. The responses were scored on a scale of 1 to 7 (1 = not important, 7 = very important), and single sample *t*-tests (test value = 4) were conducted to determine the statistical significance of the results. The test was significant (very important or important) for all variables except "facilitate access of the local population to housing (first home)", where the average response was neutral.

Table 3.1.1. Perceptions of the importance of 16 objectives of sustainability in the coastal zone of Mallorca ($n = 141$).

Sustainability Objectives	Not important			Neutral			Very important
Maintain healthy and productive ecosystems						X	
Minimize pollution						X	
Maintain enviromnental quality of beaches						X	
Minimize the negative effects of population, construction, and development on the coast						X	
Achieve sustainable tourism						X	
Decrease anthropogenic pressure on natural resources and maintain sustainable levels of use						X	
Guarantee an institutional and legislative framework to plan, implement, and achieve ICZM						X	
Maintain a competitive, sustainable, and productive economy						X	
Maximize innovation that contributes to sustainable development						X	
Minimize costs (economic and social) of coastal erosion						X	
Minimize the impacts of climate change on the coastal population						X	
Maximize corporate social responsibility					X		
Maintain a good network of social services					X		
Maximize employment and the qualifications of human capital					X		
Minimize the negative impacts of seasonality (tourism) on the local population					X		
Facilitate access of the local population to housing (first home)				X			

Clearly, the perceived level of importance of all objectives except the final one does not differ enough to be relevant on a practical level. With one exception, all are considered to be very important or important.

An exploratory factor analysis was then carried out in order to ascertain patterns among the responses. Three principal components, shown in Table 3.1.2, were retained using the scree test method.

Table 3.1.2. Principal component analysis (Varimax–Kaiser rotation, *n* = 141).

Objectives	Component 1	Component 2	Component 3
Guarantee an institutional and legislative framework to plan, implement, and achieve ICZM	0.679		
Maintain a competitive, sustainable, and productive economy	0.709		
Achieve sustainable tourism in coastal areas	0.623		
Maximize innovation that contributes to sustainable development	0.664		
Maximize and encourage corporate social responsibility	0.568		
Maintain environmental quality of beaches	0.910		
Maintain healthy and productive ecosystems	0.897		
Decrease anthropogenic pressure on natural resources and maintain sustainable levels of use		0.709	
Minimize pollution		0.614	
Minimize the negative effects of population, construction, and development on the coast		0.724	
Minimize costs (economic and social) of coastal erosion		0.811	
Minimize the impacts of climate change on the coastal population		0.732	
Maximize employment and qualification of human capital			0.716
Maintain a good network of social services			0.781
Facilitate access of residents to housing (first homes)			0.763
Minimize negative impacts of seasonality on the resident population			0.687
Percentage variance	30	21	17

The principal components in Table 1.2 may be defined as below.

Component 1. Sustainable development profile – This component represents the basic elements that are considered important for achieving sustainability in Mallorca. It includes general governance, environmental, and economic objectives, including more specific objectives of sustainable tourism and quality of beaches. The component also recognizes the central role of businesses in sustainability through innovation and corporate social responsibility.

Component 2. Natural and human impacts on coastal and marine environments – The objectives included in this component are related to human and natural pressures and impacts on coastal and marine environments. All these elements represent challenges to the achievement of sustainability on the island.

Component 3. Social aspects of sustainability – This component represents the sustainability goals at a societal level for ensuring the well-being of the resident population.

Conclusions

This is an example of how a participatory approach, combined with social science research aimed at defining priority objectives of different stakeholders during the early stages of ICZM, is being used to guide indicator selection and future research activity, with the intention of addressing the challenge of the science–policy gap in Mallorca, Balearic Islands. Three major stakeholders are involved: the scientific community, civil society (represented by the CES), and the private sector in Mallorca.

The objectives defined may be considered to be scientifically robust from a sustainability perspective because they were first developed by the scientific community through extensive consultation and literature review. In addition, they are each associated with one or more indicators that have also been evaluated scientifically. They respond to the needs of civil society as perceived by the CES, and have also been validated by the local business community in Mallorca. Additional information not included in the results has helped to understand the priorities of the different groups, including sectors in the business sample. The results of the principal components analysis demonstrate a comprehensive understanding of the basic elements of sustainable development on Mallorca, the associated pressures, and the link with the social dimension and quality of life of residents. It is important to note, however, that the results of the private sector survey may be biased by the fact that just a small proportion of the surveys was returned and the businesses that did respond most likely have a higher level of concern and understanding of sustainability issues than those that did not. However, understanding the perceptions of this group is important because they could be potential leaders in ICZM activities in the private sector.

To gain a more comprehensive understanding of the social dimension related to ICZM on the islands, it will be necessary to incorporate the perceptions of additional stakeholders, such as the general public, local and high-level decision-makers, and the business community from other islands. Given that the Balearic Islands are a tourist destination, the perceptions and needs of tourists will also be important elements in understanding this dimension. In addition, secondary information related to the socio-cultural, political, and economic environment (historical and current) needs to be determined to complement and contextualize stakeholder perceptions. The islands themselves have varied societal and environmental contexts, and understanding these variations will be important in adapting ICZM activities to the differing local realities.

The basic message conveyed here is that understanding the social dimension, e.g. priority objectives that motivate people's actions, local context, is essential in generating science (natural, physical, social, etc.) that is practical and conducive to change at the management level. Identifying priority objectives of stakeholders can help guide IM activities, indicators, and interdisciplinary research towards addressing critical issues. It can also help ensure the efficient use of resources because in many cases, as found with the indicators project, priority issues are already being addressed in some way and may simply require reorientation to be integrated into an IM framework. Social science research combined with a participatory approach with stakeholders, such as the example provided here, can contribute to understanding this dimension and should be a key component of IM scoping activities. Such research requires the engagement of local groups so, in addition to obtaining necessary qualitative and quantitative information to help understand the social dimension, it can serve the secondary purpose of raising awareness, encouraging involvement and capacity building of local groups.

3.2 Marine Scotland Science: the contribution of bathymetric surveys to marine planning for renewable energy developments

Peter J. Hayes and Ian M. Davies

Marine Scotland Science (MSS) has been tasked with assisting the emerging wave and tidal energy industries by providing regional datasets from selected areas around Scotland. One aspect of the work undertaken was to survey the bathymetry of the Pentland Firth, where tidal streams can attain 12 knots. Bathymetric data were

collected using the FRV "Scotia" with a Reson Seabat 7125-B multibeam echosounder system. Transect lines were spaced ensuring 50–100% coverage for the majority of the survey area. In total, 235 km^2 were surveyed in the Pentland Firth from 18 July to 5 August 2009. The data were post-processed using industry standard software, by Netsurvey Ltd. A quantitative approach was developed to make the best use of the bathymetric dataset. Within Arc GIS, the bathymetric data were used to create shape files with 10 m depth intervals and 5° gradient intervals. A separate shapefile was created with buffer zones running parallel with the coast, extending offshore at intervals of 1 km. Each of the layers created was classified, clipped to the same size, and brought together into a single shapefile in a geodatabase. This allows the data to be queried according to seabed depth, seabed gradient, and distance offshore. Areas of the seabed suitable for demonstration through to full-scale commercial deployment can be calculated, based on developers' operating tolerances for depth, gradient, and distance offshore.

Keywords: bathymetry, geodatabase, marine spatial planning, renewable energy.

Introduction

A key Scottish Government aim is to secure a marine vision of clean, healthy, safe, productive, and biologically diverse marine and coastal environments, managed to meet the long-term needs of nature and people. Marine Scotland, a directorate of the Scottish Government, has been tasked with managing Scotland's seas for prosperity and environmental sustainability in order to promote sustainable economic growth and the achievement of the Scottish Government marine vision. This will in part be delivered by Marine Scotland's implementation of the Marine (Scotland) Act 2010 in coordination with the UK Marine and Coastal Access Act 2009.

At the heart of the Marine (Scotland) Act 2010 are measures to address marine planning, licensing, conservation, and enforcement. Marine planning will be integral to establishing a statutory process to manage, through a strategic framework, the sustainable development of Scotland's marine resources and environments. The development of marine plans will provide a more transparent decision-making process, reducing uncertainty for marine developers, and encouraging greater stakeholder engagement.

The national marine plan will be in place approximately two years after the Marine (Scotland) Act 2010 is created. A similar time-scale is envisaged for regional marine plans, which will be coherent with the national plan and apply to sections of Scottish coastal waters. The creation of marine plans will greatly assist the collation, standardization, and archiving of existing spatial datasets, and will quickly establish the datasets required in order to underpin the marine planning process at different scales. In doing so, this will help direct future offshore survey work undertaken by Marine Scotland Science (MSS). The datalayers required to plan certain offshore developments will on occasion be specific to the type of development. However, some layers will have broad application to a wider range of development than others. Therefore, the acquisition of new datalayers needs to be prioritized to ensure efficient planning in strategically important marine areas that underpin the advance of Scottish Government policies and, in particular, provide support for marine wave and tidal energy development. It is also essential to realize that the production of new layers is not the end use of the data. Derived data from individual layers will be as important as the original layer.

Here, we focus on the bathymetric survey work undertaken by MSS in 2009 at the request of the Scottish Government to provide regional datasets to assist the emerging wet renewables industry. The collection of high-resolution bathymetric data provides information on the water depth and insight into the regional nature of the seabed, and it is an essential layer for deriving further spatial information. This greatly assists industry in selecting the site for the deployment of their devices, cable installation, the potential for site development, and array design.

The timing of the survey work coincided with The Crown Estate Pentland Firth and Orkney waters Round 1 seabed leasing for wave and tidal energy developments, and provided a focus for the initial survey work undertaken by MSS.

Methodology

Equipment

The Pentland Firth survey was completed during the period 18 July–5 August 2009. All survey work was undertaken using FRV "Scotia". This is a purpose-built Scottish Government research vessel, 68 m long with a complement of 17 crew and 11 scientists. The vessel provides a stable platform for surveying under challenging conditions.

The equipment used in the survey included a dual frequency Reson 7125 multibeam echosounder system attached to the bottom of the ship's drop-keel and georeferenced using an Applanix POS MV and Fugro STARFIX DGPS. Daily water-column profiles were recorded using a sound-velocity probe, and two RBR DR-1050 tide gauges were also deployed for the duration of the cruise.

Survey planning

The Pentland Firth is a narrow stretch of water located between the north coast of the Scottish mainland and the Orkney Islands, some 20 km long and 12 km wide (Figure 3.2.1). The phase difference between tides in the northwest and northeast of Scotland results in large sea-surface gradients along the Pentland Firth. The narrowness of the water body, coupled with the positioning of islands and peninsulars, results in a complex pattern of strong tidal currents that can reach 12 knots at mean spring tides in some locations. Traditionally, vessels spend as little time as possible in the Pentland Firth.

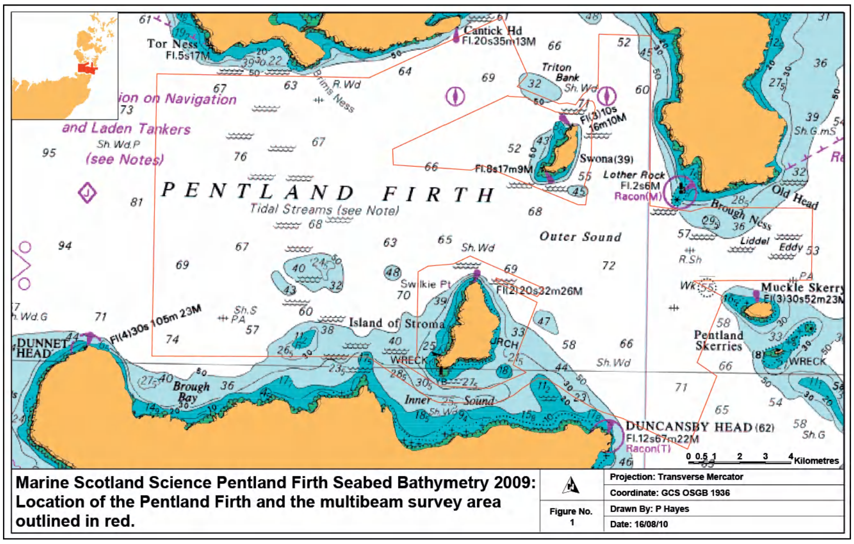


Figure 3.2.1. Marine Scotland Science Pentland Firth seabed bathymetry 2009, with the location of Pentland Firth and the multibeam survey area outlined in red.

Survey planning relied heavily on the Admiralty Tidal Stream Atlas for Orkney and Shetland Islands and Admiralty Total Tide software. This provided coarse spatial current information and predicted tidal information at 30 min intervals throughout any 24 h period. The Pentland Firth was broken down into more manageable areas with survey lines short enough to be completed within a tidal cycle. Using this information, periods of time for surveying within the Pentland Firth were identified. At the top of the spring tide, FRV "Scotia" left the Pentland Firth and surveyed areas southwest of Hoy and west of Mainland Orkney, where conditions were less demanding. The period covering the neap tide allowed 24 h of surveying, alternately boring and stemming the tide. Either side of the spring tide, alternate lines were surveyed during each tidal phase within the survey area. Data were recorded while FRV "Scotia" bored the tide along alternate lines in each survey area. When the tide changed, the "Scotia" would continue to bore the tide from the opposite direction, filling in the alternate lines missed from the previous tidal cycle. This ensured that the bathymetric data were always collected from opposing directions for adjacent lines.

Survey transect lines were spaced to ensure >50% overlap between adjacent lines for most of the areas, but 10% or less overlap was applied in the Inner Sound south of Stroma because of the limited time available for surveying that site.

Results and discussion

Raw Reson PDS files were tide-corrected using Caris Hips and Sips and post-processed using Fledermaus by Net Survey Ltd. In all, 230 km^2 of the Pentland Firth seabed was surveyed. Subsequent interrogation of the bathymetric layer and additional spatial layers was undertaken using a geodatabase in ESRI ArcInfo.

Although the basic information available in bathymetric data is essential to planning developments in the survey area, the data can be analysed to add considerable additional value. In this analysis, spatial layers of data have been classified according to how they were created and their application. Primary layers are generated from raw datasets that may already exist or have been collected for a specific purpose that may or may not have been for marine planning, e.g. the bathymetry or coastline layers. Secondary layers are new layers derived from a primary layer, e.g. a gradient layer derived from the bathymetry layer, or a buffer layer derived the coastline layer set at incrementing intervals offshore. Tertiary layers provide the spatial extent of certain parameters, e.g. the area of seabed between 10 and 20 m deep. Quaternary layers are new layers created from combining any combination of the previous layers that can be interrogated using a multiparameter query, e.g. what area of seabed is between 20 and 40 m deep with a gradient of 0–5° and up to 1 km offshore. Lastly, clipping layers are used to highlight other activities or resources or conservation interests that may overlap with the proposed strategic renewables sites. These layers may interact with the spatial extent available for the development of wet renewables devices. Also primary layers such as Tidal Resource may be used as a clipping layer. Once the tidal resource is mapped, areas of the seabed may be discounted based on Tidal Resource, e.g. insufficient tidal current or excessive water turbulence.

Theme: Pentland Firth Tidal Energy

Clipping layer – The spatial extents of all layers have been clipped to the outline of the bathymetry survey area (Figure 3.2.1).

Primary layer – The primary layers available for the Pentland Firth are the bathymetry and the coastline (Figure 3.2.2). The bathymetry provides qualitative insight into the variable nature of the seabed for the area surveyed. Readily identifiable, from the tide-swept nature of large areas of the seabed, are planes of weakness cross-cutting the exposed bedrock, along with other structural geological features such as folding of the local strata. Often, the planes of weakness have been exploited to form steep-sided canyon or gully structures. These are most noticeable in the eastern area of Figure 3.2.2 as linear features depicted in shades of blue. Sediment accumulation is apparent through the formation of ripple and dune structures. Most notable are the dune structures 50 m high to the west of Stroma.

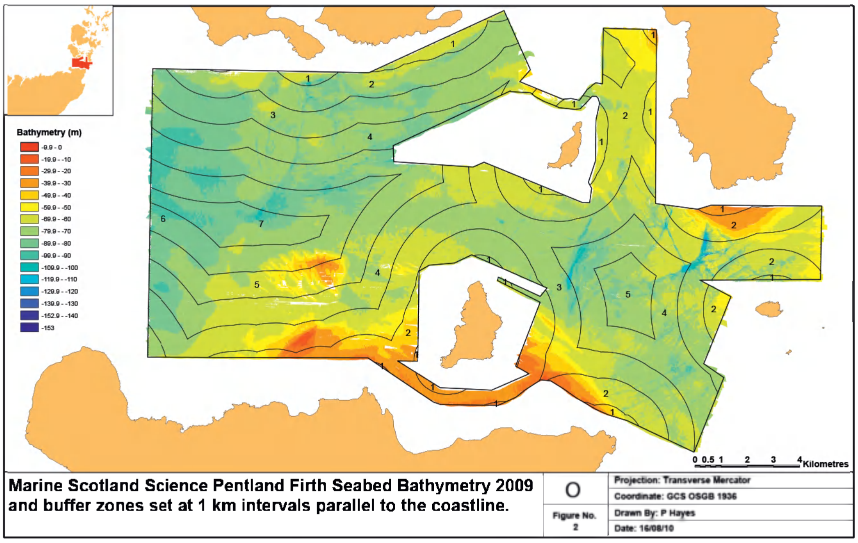


Figure 3.2.2. Marine Scotland Science Pentland Firth seabed bathymetry 2009, with buffer zones set at 1 km intervals parallel with the coastline.

Additional value can be derived from the bathymetric data. Reclassification of the bathymetry layer to demonstrate the spatial extent of 10 m depth intervals allows initial quantitative interrogation through simple queries of the dataset, e.g. the dominant depth range in the survey area is 60–80 m and accounts for 55% of the survey work undertaken in the Pentland Firth during 2009.

Secondary layer – A gradient layer was derived from the bathymetry layer and has been reclassified into 5° intervals; it indicates that the seabed gradient over almost 60% of the survey area is between 0 and 5° and >80% between 0 and 10°. Figure 3.2.3 shows increased variability of the seabed gradient in the eastern portion of the survey area. The steepest gradients are associated with the gully margins created from the eroded planes of weakness cross-cutting the local geology. Higher seabed gradients are also associated with the sand dunes located west of the Stroma.

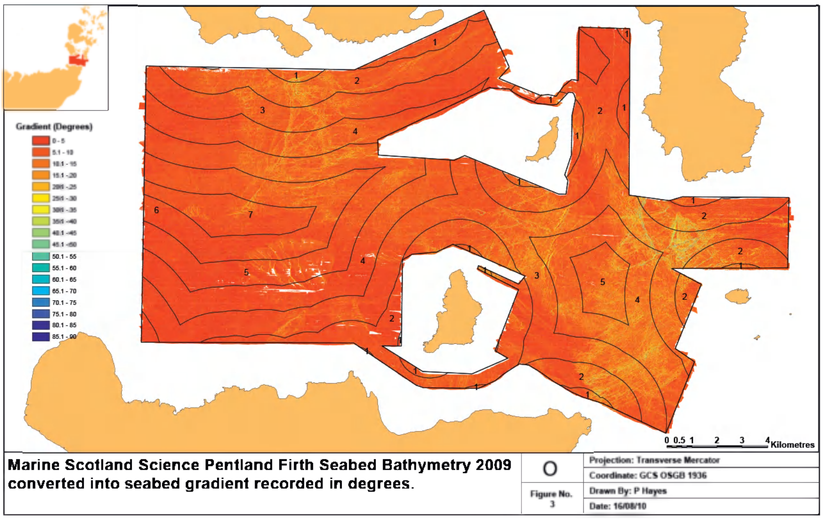


Figure 3.2.3. Marine Scotland Science Pentland Firth seabed bathymetry 2009, converted into seabed gradient recorded in degrees.

Quaternary layer – A series of maps is being generated, combining the buffer layer, reclassified bathymetry, and gradient layers in order to identify the spatial extent of a depth horizon for a set gradient at increasing distances offshore (Figure 3.2.4).

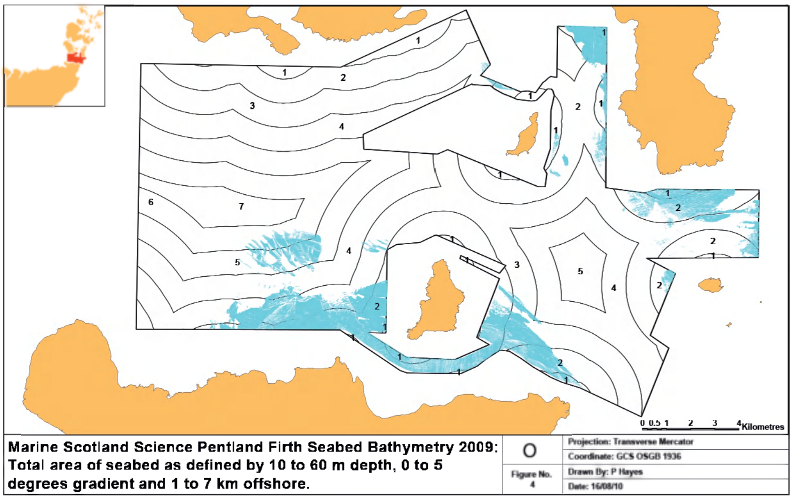


Figure 3.2.4. Marine Scotland Science Pentland Firth seabed bathymetry 2009, with the total area of seabed defined by 10–60 m depth, 0–5° gradient, and 1–7 km offshore.

Tertiary layer – A second query can then be applied to the quaternary layer that determines areas of the seabed of 0–0.01 km², 0.01–0.1 km², 0.1–1 km², 1–3 km², 3–5 km², and 5–10 km² (Figure 3.2.5). This provides spatial information on the sites that are suitable for demonstration deployments, small arrays, and larger full commercial development.

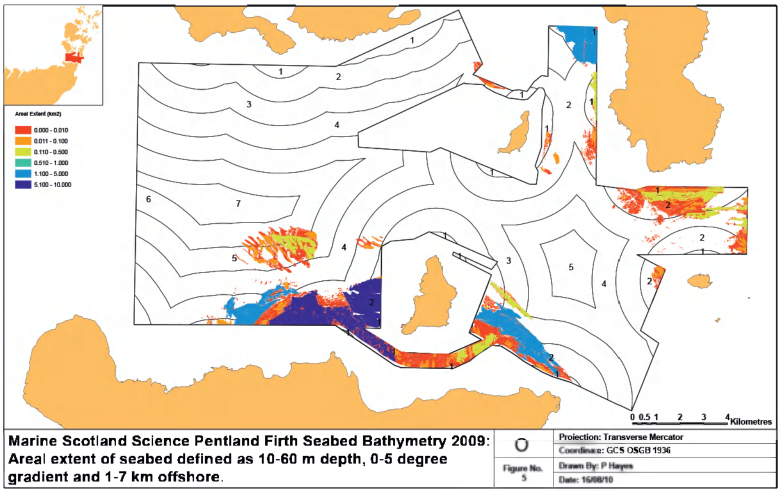


Figure 3.2.5. Marine Scotland Science Pentland Firth seabed bathymetry 2009, with the areal extent of seabed defined as 10–60 m depth, 0–5° gradient, and 1–7 km offshore.

With the correct layers, the Scottish Government will be able to predict with greater accuracy the potential energy available for exploitation in the Pentland Firth, based on the current wet renewables technology and how the industry will develop as the deployment and foundation technology within the industry advances.

Conclusions

The advantages of this approach are summarized below.

- The clear guidance it provides for the wet renewables industry in supporting site identification and where to focus research and development effort in order to accommodate the dominant seabed conditions found in the Pentland Firth if the resource potential of the area is to be developed.
- A workflow for interrogating spatial datasets to support and underpin key aspects of marine spatial planning.
- A workflow that can quantify the consequences of technical advances made by the wet renewables industry and how this will influence the future availability of power resource in the area.
- The Scottish Government can identify information gaps and effectively prioritize new work.

3.3 Institutional and regulatory reform to contribute to the achievement of development objectives in the marine environment

James C. McKie and Ian M. Davies

Wave and tidal stream power generation is a high priority for the Scottish Government in meeting its target of 30% of the total energy demand in Scotland to be met from renewable resources by 2020. Activities necessary to achieve this ambitious goal include a spatial-plan-led approach to development, and effective and efficient regulatory processes. A regulatory system review demonstrated that the consenting/licensing process had been complicated and multistranded, involving separate applications to several governmental regulators. Each regulator operated its own consultation process, resulting in some consultees (statutory and other) receiving multiple approaches from regulators for comment on the same project. The Marine (Scotland) Act 2010 introduced a single marine licence to be issued by a single new body, Marine Scotland. The marine licence incorporates the requirements under the various items of legislation which previously progressed independently. The regulatory processes therefore have been centralized within a single regulator who has established a single point of contact (a "one-stop-shop") for project developers. It also allows an approach to regulation in which a case officer takes responsibility for the processing and progression of all elements of work leading to the granting or refusal of a marine licence. Further supporting activities include the preparation of a licensing and environmental impact assessment (EIA) guidance manual for developers and regulators, and environmental monitoring guidelines.

Keywords: guidance manual, institutional reform, marine licence, monitoring, regulatory reform, renewable energy, simplification.

Introduction

The Earth's fossil fuel supplies (oil, gas, coal) are limited and will be depleted over time. As this process continues, remaining reserves will become increasingly difficult to access. It is also widely held that the gases released when fossil fuels are burned to produce energy contribute towards changes in the Earth's climate and rises in global temperatures. Renewables are energy forms that do not rely on the consumption of exhaustible resources such as fossil fuels. Renewable energy sources include wind (onshore and offshore), hydro, wave, tidal, biomass, solar, and geothermal. The key driver for renewable energy policy in Scotland is the legally binding EU 2020 targets (20% of EU's energy consumption from renewable sources by 2020). The Scottish Government is committed to achieving these targets through the following objectives (Scotland, 2010b):

- 100% of electricity demand from renewables (31% by 2011).
- 11% of heat demand from renewables.
- 10% of transport fuel from renewables.

In addition, the Climate Change (Scotland) Act 2009 sets statutory targets of at least 42% emissions cuts by 2020, and at least 80% cuts by 2050.

Scotland possesses significant wave and tidal stream energy resources; it is estimated to hold 25% of Europe's tidal power and 10% of Europe's wave power. The potential therefore exists to generate far more electricity from wave and tidal energy sources in coastal waters than Scotland currently requires. Tidal current energy is intermittent but largely predictable, whereas wave energy is also intermittent but less predictable. Some of the best resources are located in relatively remote areas off the northwest and north coasts of Scotland. The Scottish Government believes that wave and tidal energy will make a very important contribution towards meeting future demand for electricity, and to the future economic development of the country. It is therefore deemed essential to encourage the design, deployment, and exploitation of wave and tidal stream energy-generation systems.

Licensing of marine renewables developments

A critical element of any renewable energy project is obtaining the necessary licences and consents from regulatory authorities (Davies, 2008); an ineffective or inefficient regulatory system can introduce uncertainties and delays and act as a disincentive to development. Prior to 2010, the licensing/consenting requirements for marine renewables devices in Scottish waters were complicated and potentially confusing for developers (Figure 3.3.1).

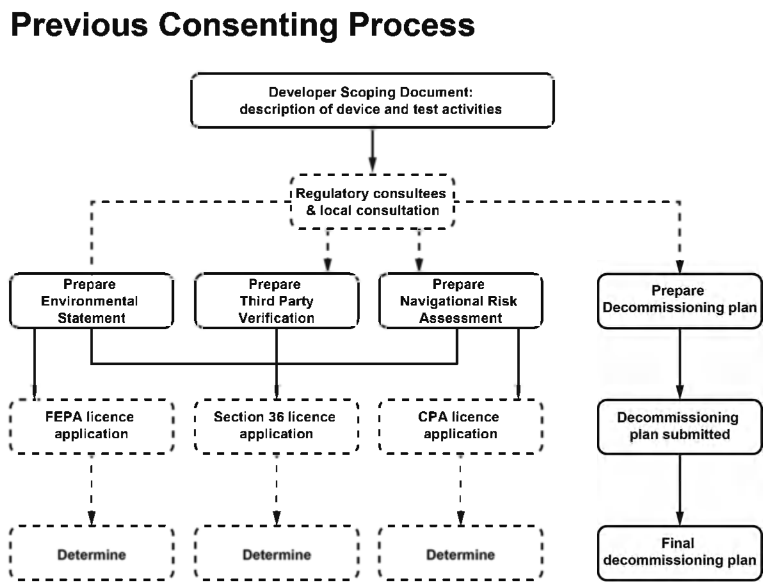


Figure 3.3.1. Consenting process for marine renewables energy projects in Scotland before 2010.

In overview, a project generally required licences/consents under the acts outlined below.

1) The Food and Environment Protection Act 1985, Part II (as amended) – This licence is required when a deposit (temporary or permanent) is placed on the seabed below Mean High Water Springs (MHWS). Most deployments would require some form of attachment to the seabed, so would require this licence. Issued by Marine Scotland Licensing Operations Team (MS-LOT).

2) The Coast Protection Act 1949, Section 34 – This licence is required for all deployments, and in particular addresses the navigational risk that arises from the placing of devices in the sea. Issued by the Scottish Government Ports and Harbours Branch.

3) The Electricity Act 1989, Section 36 – This licence is required for all deployments with a potential generating capacity equal to or greater than 1MW. Issued by Scottish Ministers through the Scottish Government Dept of Energy, Energy Consents and Deployment Unit (ECDU).

4) European Protected Species licence (EPS, 1994 Habitats Directive, Section 44) – This licence is required if there is a risk that the development might affect EPS-designated species, as listed in the EU Habitats Directive.

Issued by Scottish Ministers on advice from the Scottish Government Species Licensing Team.

5) The Northern Lighthouse Board Statutory Sanction (Merchant Shipping Act 1995) – This permit is required for some deployments, where device marking is required to mitigate navigational risk. Issued by the Northern Lighthouse Board.

6) The Decommissioning Programme (Energy Act 2004, Sections 105–114) – All projects need to provide, and have approved, a plan for the decommissioning of the equipment when it is no longer required. Issued by the UK Government Department for Energy and Climate Change.

The basic documents required for approval of a renewable energy project included

- an Environmental Statement (ES)
- a Navigational Risk Assessment (NRA)
- a Third Party Verification (TPV) Report
- a Decommissioning Plan.

In cases where significant impacts on species or habitats protected under EU legislation (a Natura 2000 site) may arise, a formal Habitats Regulation Assessment, including an Appropriate Assessment document, is also required to establish the scale of any impact.

All of the above consents/licences had to be pursued through different regulatory bodies or offices, by independent processes, working to different time-scales and with different requirements for supporting documentation. Most of the processes included external consultations with statutory and non-statutory consultees. The more prominent of these, for example the national nature conservation organization, Scottish Natural Heritage, would receive requests for comment from several regulators on the same development proposal. The regulators were generally able to include conditions in the consents/licences that they issued, though it was not uncommon for developers to receive conflicting conditions in different consents/licences.

Institutional reform

It is clear that such a complex and duplicative licensing/consenting system could have a negative impact on the achievement of the Scottish Government objectives for the development of wave and tidal stream power generation. A number of other pressures also related to the marine environment came together and resulted in new legislation, the Marine (Scotland) Act 2010 (Anon., 2009a). The Act (Figure 3.3.2) creates a new legislative and management framework for the marine environment. It also creates a new system of marine planning to manage the competing demands of the use of the sea while protecting the marine environment, creates a system of licensing with the aim of reducing the regulatory burden for key sectors, and includes powers to establish marine protected areas (MPAs) to protect natural and cultural marine features. The Act also introduces a new regime for the conservation of seals and gives powers for Scottish marine enforcement officers to ensure compliance with the new licensing and conservation measures.

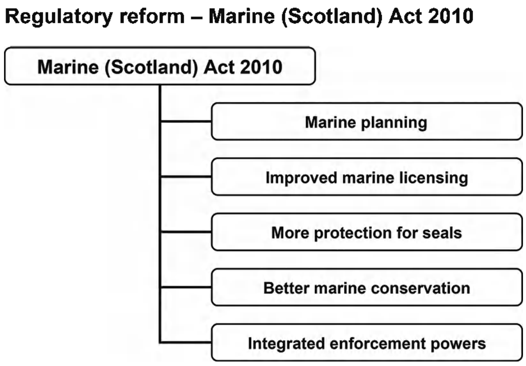


Figure 3.3.2. Main features of the Marine (Scotland) Act 2010.

In order to facilitate the implementation of the Act, a new Directorate called Marine Scotland (Figure 3.3.3) was created within the Scottish Government (Anon., 2009b). It brought together two former government agencies, Fisheries Research Services (which undertook research and advisory work on marine matters, including the issue of licences under the Food and Environment Protection Act 1985 (FEPA)), and the Scottish Fisheries Protection Agency (which enforced fishery regulations at sea and in ports), with the policy units within Scottish Government which dealt with the sea (e.g. marine fisheries, environment, aquaculture, etc.).

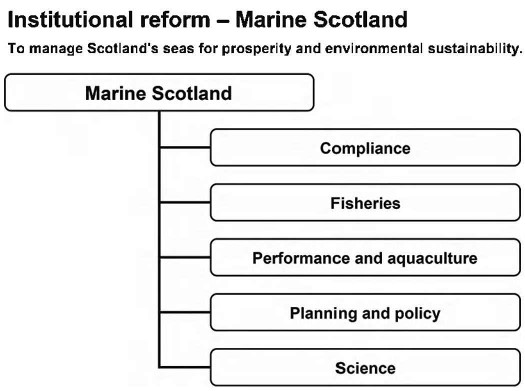


Figure 3.3.3. The purpose and structure of Marine Scotland, a division of the Scottish Government.

The compelling reasons behind the change in the management of Scotland's marine environment that led to the creation of Marine Scotland were

- to manage growing, often competing, demands for the use of marine resources;
- to meet existing and new marine obligations and aspirations;
- to improve integration and reduce the complexity of marine management and regulation in line with wider Scottish Government and EU policy aims;
- to strengthen coastal communities and give them a stronger voice in marine matters;

- to ensure a strong, coherent Scottish voice in the UK, EU, and internationally;
- to lead the way in Scotland in how the seas in northwestern Europe can be managed to deliver prosperity and sustainable economic growth.

Marine Scotland is charged with leading the delivery of the Scottish Government vision for the Scottish seas, which is sustainable economic growth through "clean, healthy, safe, productive, biologically diverse marine and coastal environments, managed to meet the long-term needs of nature and people."

Regulatory reform

In order to encourage sustainable marine development through simplification of the licensing/consenting processes, the Act introduced the concept of a single Marine Licence to be issued by Marine Scotland. With regard to marine renewables developments, the Marine Licence encompasses the requirements for the four licences/consents previously issued by different elements of the Scottish Government (see above). This has led to a more streamlined approach to licensing because applications for all four licences/consents can be considered through a single process (Figure 3.3.4). This simplified system is now fully established and is proving particularly beneficial in handling proposals for renewable energy developments. Efficiencies have been introduced to the licensing process, at the same time ensuring that environmental sensitivities and other uses are considered fully.

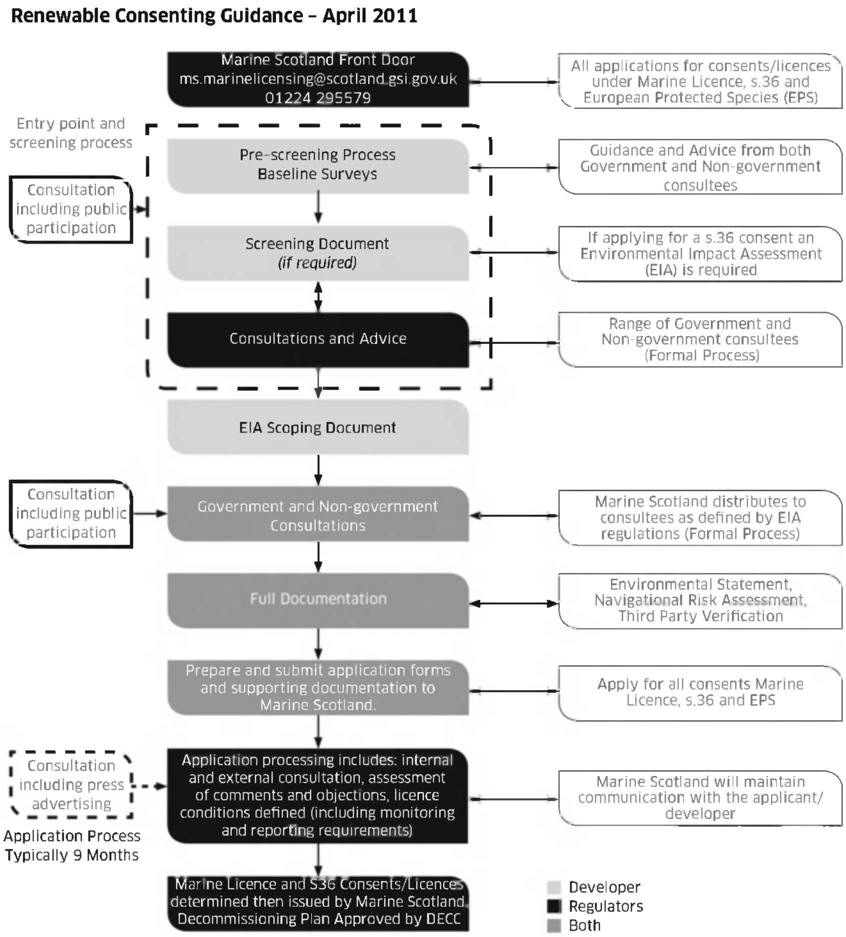


Figure 3.3.4. The single process by which applications for licences/consents for marine renewables projects have been assessed since April 2010.

A single point of access was established at the Marine Scotland – Licensing Operations Team (MS–LOT) on 1 April 2010 as the precursor to the "one-stop shop" for licence applications which was fully rolled out in spring 2011. From then on, developers have been able to make applications in combination for FEPA, the Coast Protection Act 1949 (CPA), and Section 36 licences/consents where appropriate, offering benefits by reducing the administrative burden and providing a single point of contact with a defined case worker for enquiries and to progress applications. This approach also allows single consultations with nature conservation bodies and other consultees, reducing the burden on them. EPS licensing was rolled into the process late in 2010.

A Licensing and EIA Guidance Manual for regulators and developers was produced to assist the progression of applications for licences in an efficient and effective way. The manual initially related to wave and tidal projects and was trialled by Marine Scotland in respect of FEPA licences and CPA consents as well as Section 36 Electricity Act 1989 consents. The Manual has now been updated to match the Marine Licence process. Subsequent guidance related to wind projects and general marine licence applications are now based on this model. The manual consists of four parts:

- Part 1 describes the streamlined single point of access or "one-stop shop" consenting/licensing process under which all necessary consents/licences for renewable energy projects in Scottish waters are sought and issued.
- Part 2 is specific to the marine renewables energy industries (wave and tidal), detailing the legislation that governs the licensing and deployment of commercial-scale wave and tidal energy developments, and explaining the documentation that needs to be produced by developers to support their applications. The documentation is an integral part of each consent/licence application and needs to be submitted together with the relevant forms at the application stage.
- Part 3 provides an explanation of the Environmental Impact Assessment (EIA) and Habitats Regulations Appraisal (HRA) processes in general, and includes summary discussion of the different stages involved in these processes.
- Part 4 is an industry-specific annex, containing information relating to the EIA and HRA processes that pertains specifically to the wave and tidal energy industries. It contains a number of industry-relevant appendices, together with references and bibliography for specific topic areas.

An important element of the guidance is the establishment of a Marine Renewables Facilitators' Group (MRFG), an expert group that liaises closely with MS–LOT, providing expert advice in respect of proposed marine renewables developments. MS–LOT issues all normal consultations and collates and prioritizes all feedback to developers at each stage of the consultation process, from the scoping request to consent/licence applications, ensuring that the developer has just one response that prioritizes the issues to be addressed. During the course of the collation of feedback there is occasionally a need to resolve conflicting stakeholder opinions, and this is one of the important roles of the MRFG. MS–LOT makes the final recommendation on each application and seeks the agreement of Scottish Ministers before officially informing the applicants and stakeholders of the decision.

The core membership of MRFG is specified to include named representatives of key stakeholder groups who are suitably experienced and empowered by their organizations to provide initial advice, to give formal feedback at the screening and scoping stages, and to administer feedback from the various consultations, ensuring consistency of all comments and reconciling any differences in advice. The administrative load on the stakeholder groups can be reduced, however, with general queries being dealt with by MS–LOT in the first instance and, as required, by the MRFG. Core membership of the group is

- Marine Scotland Licensing Operations Team (MS–LOT)
- Scottish Natural Heritage (SNH)
- UK Maritime and Coastguard Agency (MCA)
- Northern Lighthouse Board (NLB)
- UK Department of Energy and Climate Change (DECC)
- Scottish Environment Protection Agency (SEPA)
- The relevant Local (terrestrial) Planning Authority (LPA)
- Marine Scotland Science

The idea is that the process is supported by an Environmental Monitoring Protocol to clarify for developers the scope and detail of work required of them prior to application for licences/consents and developed through a linked workstream managed by Scottish Natural Heritage. This emphasizes interactions with key environmental receptors, such as seabirds, marine mammals and seabed habitats, which may be protected as designated features of Special Areas of Conservation, or Special Protection Areas under EU legislation.

Marine planning

The change to a low-carbon economy is a long-term project, and it requires plans to be made on a similar time-scale. Marine planning is becoming a more regular feature of national policy in European countries, and in addition to streamlined licensing/consenting, the Marine (Scotland) Act also introduced a new statutory marine planning framework to manage competing demands for the use of the sea while protecting the marine environment. By considering all activities together, from wildlife tourism and recreational sea-angling to energy and fishing, marine planning ensures that marine energy, fishing, aquaculture, shipping, recreational, and other users make use of marine resources wisely while maximizing the benefit to Scotland (Scotland, 2010c).

The Scottish National Marine Plan sets out the strategic objectives for the Scottish marine area and ensures that international and EU commitments are met. A UK Marine Policy Statement (MPS) created and adopted by the UK and devolved administrations allows an integrated approach to marine planning right across the UK, and guides the Scottish National Marine Plan, which in turn guides the Scottish regional marine plans.

The National Marine Plan identifies national priorities within certain areas (for example, expansion of marine energy projects) and provides clarity for decision-making. Scottish Marine Regions are being established, covering coastal waters and forming the basis for regional planning, through which local interests and accountability are met. Regional Marine Plans provide the context in which conflicts between different sectors can be resolved and by which key areas can be defined for key uses.

An initial application of a planning-based approach to marine wave and tidal stream energy development was described by Davies *et al*., 2010), and aspects of the underlying science and marine survey work were addressed by Hayes and Davies (2010).

Conclusions

The emergence of the development of marine energy (wave, tidal, wind) as a high priority in both international and national contexts led to the realization that aspects of the institutional and regulatory framework in Scotland were not ideally suited to the creation of these new industries. The Scottish Government response, through the Marine (Scotland) Act 2010, was to create a new organization, Marine Scotland, to lead on all marine issues in Scottish waters, to overhaul the regulatory system to create a "one-stop-shop", to develop guidance on EIA and monitoring requirements, and to start comprehensive marine planning processes at national and regional levels, with appropriate links at international level. By these actions, marine energy (and other uses of the sea) can be progressed in an efficient and sustainable manner.

3.4 Risk-based frameworks in ICZM and MSP decision-making processes

Roland Cormier, Andreas Kannen, Beatriz Morales-Nin, Ian M. Davies, Clare Greathead, Rafael Sardá, Amy Diedrich, Vanessa Stelzenmüller, and Erlend Moksness

The coastal zone is considered the point of highest interaction between land-based activities and local marine ecosystems. In addition, the coastal zone is a significant contributor to the socio-economic prosperity of local communities supporting a broad base of economic and cultural sectors. As a result, it is also the zone where aquatic ecosystems can be particularly vulnerable to pressures caused by human activities where management operates within a complex jurisdictional backdrop. An integrated management approach to both terrestrial and marine spatial planning aims at reducing conflicts while maintaining the productivity (in a broad sense) of aquatic ecosystems. Although fairly straightforward in the planning process, implementation and follow-up of such plans have proven to be challenging. Given the complexity of integrating ecosystem, social, cultural, and economic demands within a defined geographical area, decision-making approaches using classical risk analysis can provide structure that facilitates and informs the planning and implementation processes. Such an approach also assists fact-based priority setting while adhering to principles of inclusiveness and transparency. This paper presents lessons learned and best practices from integrated coastal-zone management projects and how these are converging towards a risk analysis approach and marine spatial planning.

Keywords: coastal zone, risk analysis, spatial planning.

Introduction

The coastal zone is considered generally to be the area of most important and strongest interaction between land-based activities and the local marine ecosystems. Given that a large proportion of the global population lives in proximity to the coast, the coastal marine ecosystem is most vulnerable to drivers of change arising from human activities. Considering the intensity and wide range of types of pressure such as wastewater and run-off arising from the coastal zone and the catchment area, estuarine and coastal marine ecosystems are likely to be the most vulnerable to cumulative adverse environmental effects. Climate change and sea-level rise are likely to exert increasing pressures over time.

The coastal zone is a significant contributor to the socio-economic prosperity of local communities, supporting a broad base of economic and cultural sectors. In terms of direct users, it is the primary interface between land and marine transportation as well as being used by the fishery and aquaculture industries. However, it is also the primary interface for land-based tourism and urban development in areas to which the local population attaches profound social and cultural significance. In some countries, demographic trends are increasing the pressures for coastal development as the population seeks retirement or recreational homes near the sea. In response to ever-increasing energy demands, emerging renewable energy initiatives such as wind and tidal power generation are adding to the complexity of marine spatial planning needs from a conflict-resolution perspective. Although sector-specific policies and best management practices are adhered to, the jurisdictional complexity of the coastal zone can be poorly adapted to mitigate against cumulative adverse environmental effects resulting from segregated planning and management initiatives.

An ecosystem-based approach to governance and management has to account for the inherent jurisdictional complexity of multiple levels of governments, programmes, and development objectives. Jurisdictions have established overall strategic ecosystem sustainability objectives, as is the case with the EU Marine Strategy Framework Directive and the Canadian Oceans Act. Although a coastal-zone planning process is fairly straightforward to envisage, implementation and follow-up of the resulting plans have proven to be challenging. Integrated management is more likely to succeed through the integration of ecosystem mitigation requirements within sector-specific policies and best management practice than through an all-encompassing high-level management plan. This approach has been implemented successfully in sectoral activity environmental assessments (e.g. the strategic environmental assessment process) and marine spatial management plans. However, integrated management approaches to the coastal zone require both planning and management of relevant terrestrial and marine activities, aiming to reduce conflicts between user groups while maintaining the integrity of aquatic ecosystems.

Given the complexity of integrating ecosystem, social, cultural, and economic demands within a defined geographic area, classical risk analysis can provide a structure that facilitates and informs the planning and implementation processes and aids decision-making. Risk analysis is a well-established approach in science-based decision-making. It is even enshrined in international agreements such as the Sanitary and Phytosanitary Agreement of the World Trade Organization. Not to be confused with risk assessment, a risk analysis is initiated with the explicit intent of informing a management decision. Classical risk analysis includes activities identified as hazard analysis, risk assessment, risk management, and risk communication. From the perspective of an ecosystem-based risk analysis, the hazard analysis phase establishes the scope of the problem by identifying significant ecosystem components and their susceptibility to adverse environmental effects resulting from pressures arising from drivers of human activities. It also identifies the ecosystem goods and services that are at risk. Risk assessment aims at identifying the likelihood of occurrence and severity of identified adverse environmental effects. However, a risk assessment must also be conducted to identify the social, cultural, and economic repercussions of not mitigating the effects, as well as to assess the feasibility of the management options based on existing jurisdictions and sector-specific management practices. Risk management is the implementation phase and can include a suite of plans, policies, and best management practices delivered under clear accountabilities and monitoring. Risk communication addresses issues of inclusiveness and transparency regarding the entire process. It also involves, however, feedback in terms of the effectiveness of mitigation and efficiency of the implemented plan in effectively adhering to the principles of an adaptive management approach. In a nutshell, a risk-analysis process strives to separate the perception of risk from the facts while focusing management efforts where and when they are required.

Integrated coastal-zone management and marine spatial planning

Integrated coastal-zone management (ICZM) has evolved to include catchments–coast interactions for the sustainable use of marine resources via integrated governance frameworks. In addition, it brings together coastal-zone habitat conservation and socio-economics (e.g. development objectives) drivers which are most often resolved through geospatial and temporal plans similar to marine spatial planning (MSP) initiatives. The ICZM Working Group of ICES recognized that ICZM and MSP are tightly linked, one providing the process and governance to the other.

Without clear objectives that allow the estimation of tangible risks to valued goods and services and which are managed under clear accountabilities, the resulting integrated management plan may have very good strategic goals but lack technical mitigation requirements that can be translated into sector-specific management practices. On the other hand, marine spatial plans commonly focus on one specific activity with the intent of resolving potential ecosystem and socio-economic conflicts mostly from a geospatial perspective. In practice, MSP initiatives based on strategic environmental assessments generally result in specialized technical management approaches that lack the environmental context in its contribution to cumulative effects. If a given ecosystem is under cumulative pressures of multiple drivers, sector-specific mitigation may result in futile investment. A regional strategic assessment conducted via a risk-analysis process that takes into account ecosystem goods and services susceptibilities and the pressures of the implicated drivers of human activities would result in feasible and equitable mitigation requirements. Such a regional strategic assessment would still provide a high level and general approach to planning, while providing tangible purpose. Any new development could then be assessed against such a regional environmental backdrop to determine the consequence of the proposed project for its immediate footprint and its contribution to cumulative pressures. The requirements under the EU Habitats and Species Directives for cumulative and in-combination effects to be taken into account in the assessment impacts on designated (protected) habitats and species is a clear response to this issue.

Case studies

Integrated management, environmental assessments, and spatial planning initiatives all contain elements of risk analysis. In most cases, the approaches are similar and differ mostly in the jargon. Some are more effective at proactive problem formulation and objective setting, others are focused on reactive mitigation of the immediate development project footprint. Few stipulate formal follow-up monitoring and auditing to ascertain the performance of the plan about mitigation effectiveness and implementation efficiencies. Monitoring requirements can arise as a consequence of conditions set during consenting/licensing procedures for individual projects, but links back to broader plans can be difficult to achieve. The following are some examples of integrated management, environmental assessment, and marine spatial planning initiatives that contain some elements of risk analysis.

Canadian oysters aquaculture class environmental assessment

Operating within federal and provincial regulatory requirements, a class environmental assessment (CEA) was conducted for suspended oyster aquaculture activities on the east coast of New Brunswick, Canada (TC, 2007). The CEA was initiated as a means of reducing the bureaucratic processes and costs for aquaculture lease applications. Up to that point, individual lease application required an environmental assessment that had to address several federal and provincial regulatory requirements. In addition, concerns were being raised as to the carrying capacity of the bays considered for aquaculture development. The CEA used an integrated management approach to identifying valued ecosystem components (VECs) that included key fish habitat, intertidal zones, fisheries, recreational activities, navigation, and migratory birds, and their susceptibility to this activity. Subsequently, regulatory and policy requirements were combined using a spatial planning approach. The resulting document identified zones for aquaculture leases and appropriate mitigation measures in the form of best management practices and buffer zones addressing the susceptibilities of the VECs (Figure 3.4.1). Given that the CEA normalizes the environmental requirements, all lease applications do not require an individual environmental assessment. The resulting integrated management plan provides effective and auditable mitigation measures and also enhances the efficiency of the lease-approval process in terms of approval time and costs.

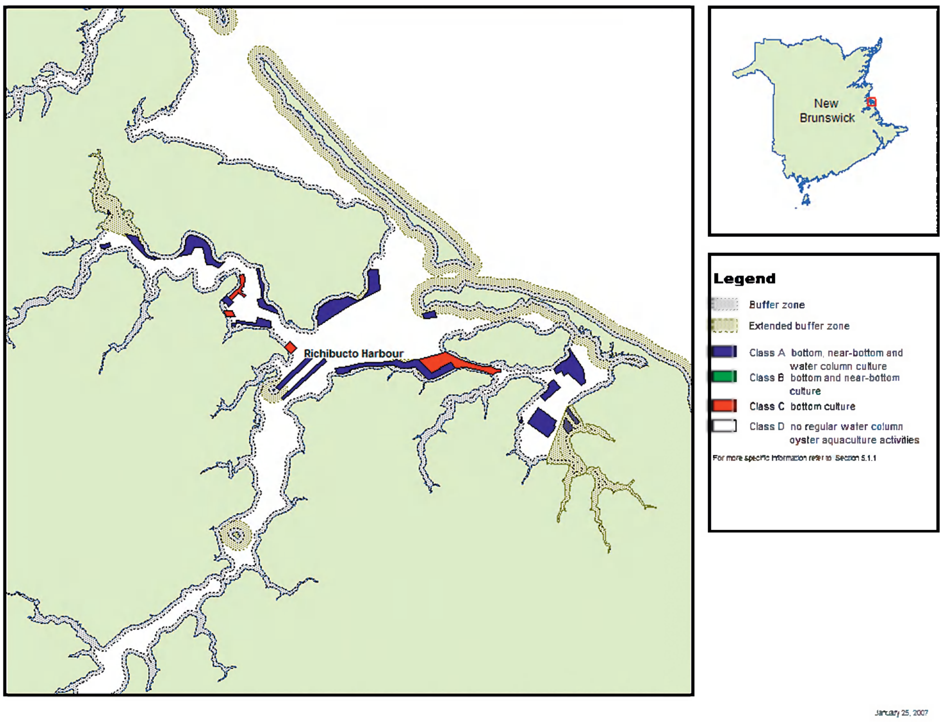


Figure 3.4.1. Example of a Canadian class screening Oyster Bay management plan showing buffer zones designed to integrate multiple levels of regulatory requirements.

Scottish sustainable marine environment initiative

Running across several government agencies within Scotland and linking directly to other relevant UK initiatives, the Scottish Sustainable Marine Environment Initiative (SSMEI) was initiated by the Scottish Government in 2002 (Scotland, 2002). Its principal aim was to develop and then test the benefits of possible new management framework options for the sustainable development of Scotland's marine resources through the establishment of four pilot projects for the Shetland Isles, Berwickshire, the Firth of Clyde, and the Sound of Mull. The pilot projects embraced the concepts of an ecosystem-based approach to protection measures, and were designed to investigate different aspects of sustainable marine management, including spatial planning, habitat mapping, and conflict resolution. They were tested through the implementation of a number of management schemes. The Shetland pilot used a spatial planning approach (Figure 3.4.2) that identified key habitats and their susceptibilities and documented susceptible ecosystem components and socio-economic values through extensive integrated management consultations. Key results include a spatial policy within which developers could identify locations prior to the submission of plans that would be considered unsuitable for a particular development or where a development would be looked on favourably by the regulators leading to long-term protection and use of the marine environment, with reduced delays and costs in the regulatory process.

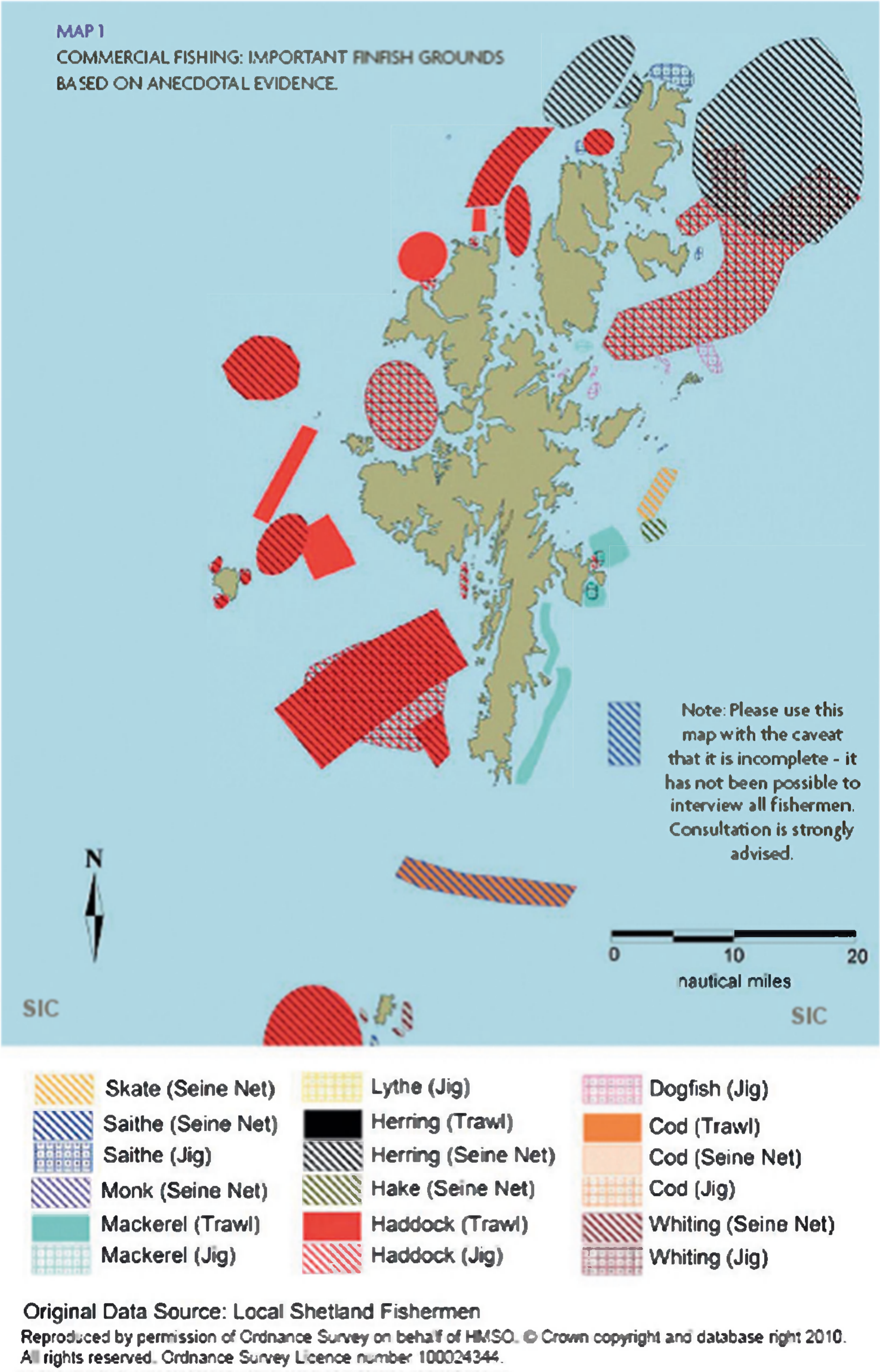


Figure 3.4.2. Example of a Scottish Sustainable Marine Environment Initiative spatial analysis, around the Shetland Islands.

Marine renewable energy industries in Scotland

Wave and tidal stream power generation is a high priority for the Scottish Government in meeting its target of 50% of the electricity demand in Scotland to be met from renewable resources by 2020. Renewable energy projects can interact with the environment (e.g. conservation objectives) and with other uses of the sea (e.g. shipping routes, fishing areas). A significant risk in the regulatory process is that these interactions need to be assessed formally (e.g. through EIA and appropriate assessment under the EU Birds and Habitats directives) and reduced to acceptable levels. Marine Scotland collaborated with The Crown Estate (landlords of the UK seabed) to identify areas of wave and tidal stream resource that avoided sensitive areas and limited any impacts on existing marine uses. The identification of potentially suitable development areas was addressed through the application of GIS-based marine spatial planning tools, to develop an information framework covering the availability of exploitable resource and a wide range of information on constraints including incompatible current uses, environmental designations, shipping, commercial fishing, recreation, biodiversity, and fish spawning and nursery grounds (Davies *et al*., 2010). The datalayers for constraints were used in restriction models, i.e. treated as giving graduated degrees of constraint on development according to the nature and intensity of the activity. The layers were categorized into a series of five sectors: environment, recreation, shipping, commercial fishing, and fish spawning and nursery areas. Within each sectoral restriction model, data layers were weighted according to subjective judgements of the relative importance of each layer in relation to others within the sector. A range of scenarios was then examined, which varied the weighting between sectors (Figures 4.3 and 4.4). The output was a series of maps identifying the relative extent of constraint on wave and tidal development areas around the Scottish coast, to support decisions on areas to consider for early leasing for wave and tidal power development. The approach used included elements of risk analysis, but was not framed within risk-analysis terminology. For example, the weighting and scoring systems applied to datalayers and sectors combine elements of hazard identification and risk assessment, but the selection of potential development areas is the outcome of risk management within broad policy guidance. Risk communication with the generality of stakeholders took place late in the process through public invitation to comment on the proposals.

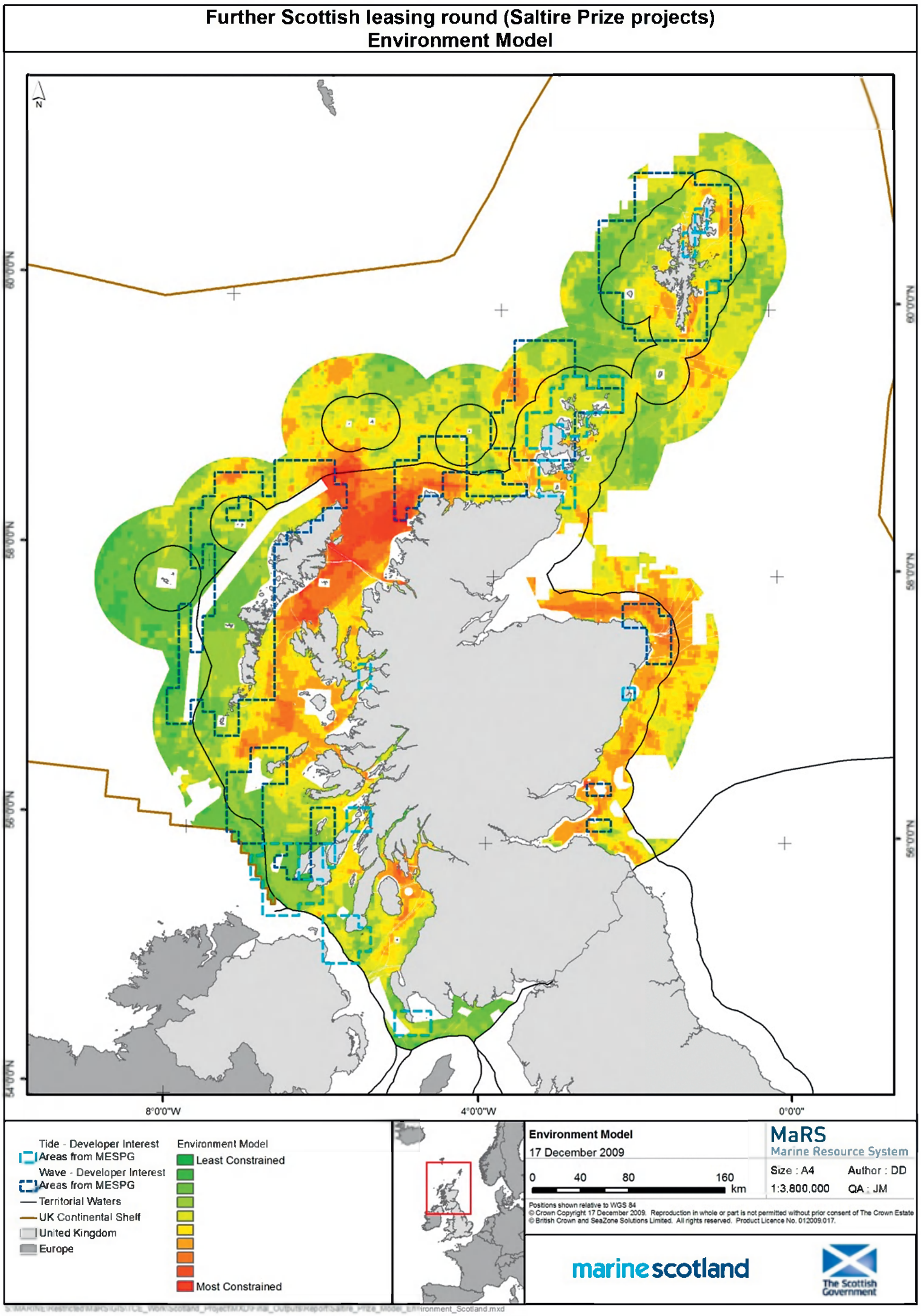


Figure 3.4.3. Output from a model that emphasized environmental protection compared with industrial uses around Scotland. Red areas show the highest levels of constraint on wave and tidal power development, and green areas show the lowest levels. White areas are exclusions.

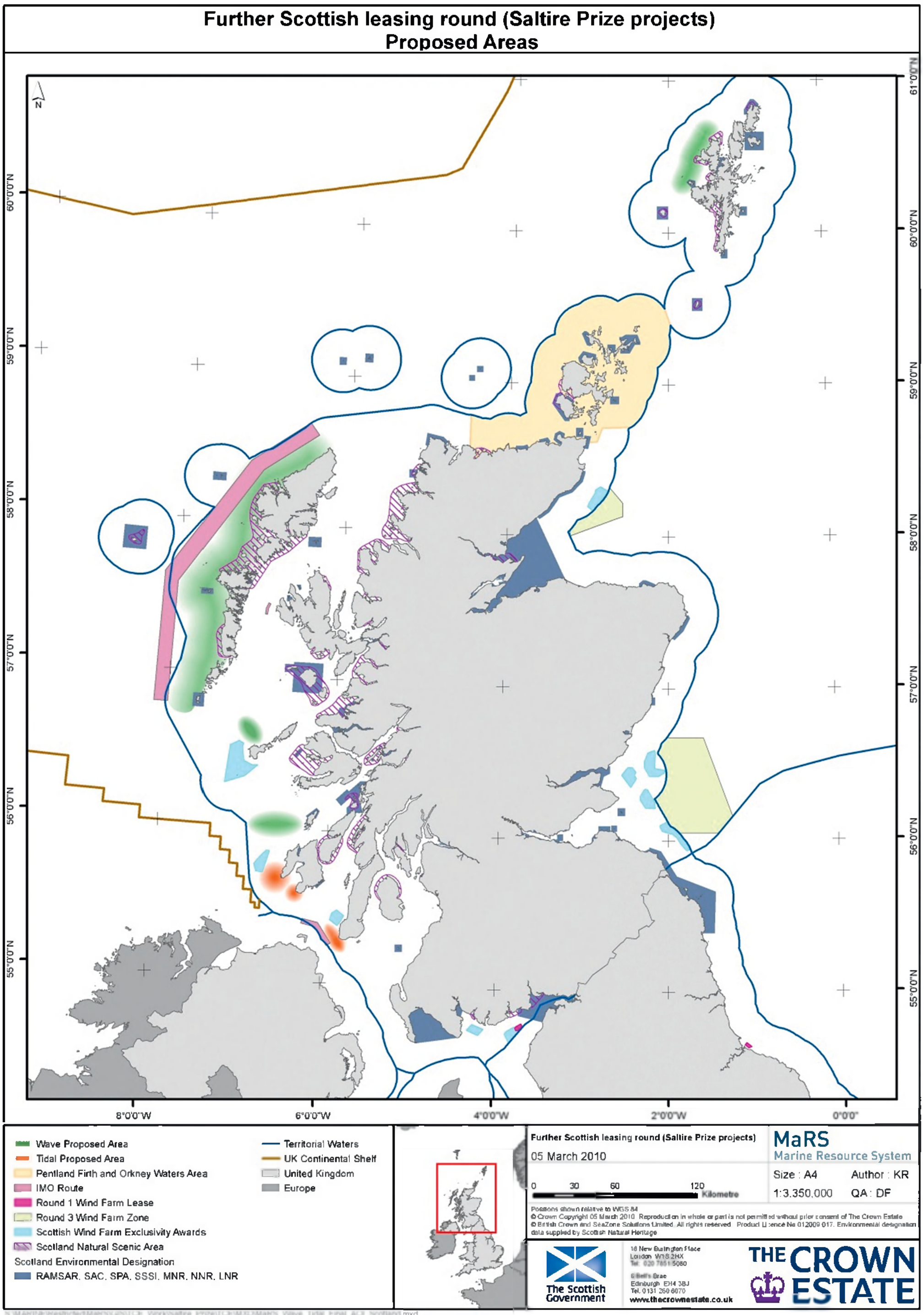


Figure 3.4.4. Areas selected for further consideration for marine renewables development, including the west coast of Shetland, west coast of Lewis, north of Tiree, and areas around Islay and the Mull of Kintyre.

UK continental shelf

A Bayesian Belief Network and framework for geospatial analysis was developed to visualize relationships between cumulative human pressures, sensitive marine landscapes, and landscape vulnerability (Stelzenmüller *et al.*, 2010), to assess the consequences of potential marine planning objectives, and to map uncertainty-related changes in management measures. The results of the analysis revealed that the spatial assessment of footprints and intensities of human activities have more influence on landscape vulnerabilities than the type of landscape sensitivity measure. The framework addresses the consequences of potential planning targets and the necessary management measures, providing spatially explicit assessment of their consequences. The framework is a practical tool allowing the combination of ecosystem sensitivities and management objectives, informing spatial management scenarios via the engagement of different stakeholder views within an integrated decision-making process, adhering to adaptive marine management approaches.

Offshore wind-farm development and marine spatial planning in the German part of the North Sea

On the German North Sea coast, >100 offshore wind-farm projects are currently at the planning stage. So far (March 2012), 27 have received a licence from the Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH; www.bsh.de). At a federal level, government expects offshore wind energy to play a major role in reaching the German renewable energy target. If plans go ahead, offshore wind farms could provide between 20 and 25 gW by 2030, meeting ca. 15% of the German electricity demand (BMU, 2002). All planned projects are located in the Exclusive Economic Zone (EEZ), >30 km from the coast, in order to avoid conflicts with local communities and to protect Wadden Sea National Parks, which cover large parts of German territorial waters in the North Sea. The considerable spatial requirements of offshore wind-farming apply in an EEZ where space is already at a premium. Unsurprisingly therefore, offshore wind-farming has become the main trigger for the development of spatial plans based on a zoning concept for the German EEZ (Figure 3.4.5). However, the debates in and around the public hearings for these spatial plans demonstrate that concurrent growth in different policy fields may lead to an "overbooking" of marine space (Kannen *et al*., 2010). Shipping, nature conservation, and offshore wind-farming all lay claims to large parts of marine space, but they are not necessarily spatially compatible. The research project "Coastal Futures" (Lange *et al*., 2010) identified some limits to the spatial planning approach, e.g. local people attribute values to the sea that demonstrate that the sea is more than just its "hard" uses (Gee, 2010). Comprehensive forms of sea management, as well as marine spatial planning and zoning, need to take account of multiple sea values (tangibles and intangibles), including optional values, rather than limiting themselves to matching existing demands in a sort of "best fit" approach. Other outcomes from the "Coastal Futures" initiative point to the importance of cumulative impacts of sea-use patterns on ecosystem functioning. This implies that future assessments (and planning and management) need to consider the cumulative impact of many wind farms rather than individual plans, and also need to take greater account of the overall pattern of sea use, because, for example, some bird species avoid shipping areas as well as wind farms. Similarly, Berkenhagen *et al*. (2010) identified cumulative effects from wind farms on fisheries. Tools applied in "Coastal Futures", such as the ecosystem service approach or the Drivers–Pressures–State–Impacts–Response (DPSIR) framework, might support risk assessments for large-scale development activities in marine areas.

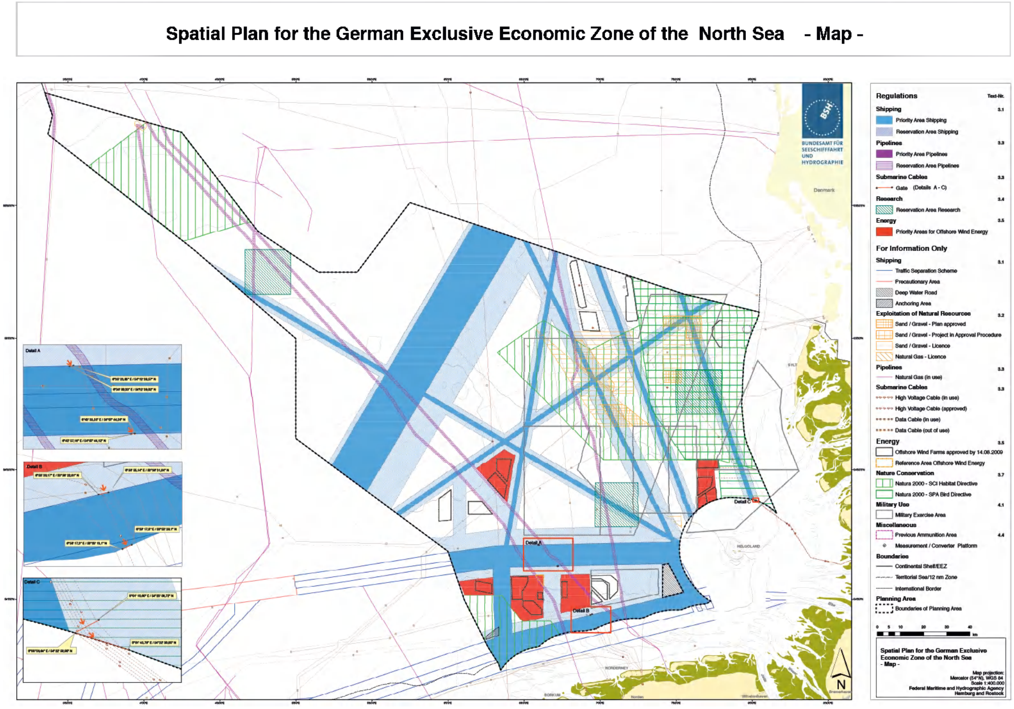


Figure 3.4.5. Spatial plan for the German EEZ of the North Sea (www.bsh.de/en/Marine_uses/Spatial_Planning_in_the_German_EEZ/documents2/MSP_DE_NorthSea.pdf, accessed 19 August 2010).

Risk analysis as a tool for modern beach management in Spain

From a socio-ecological perspective, beaches are considered one of the most important shoreline ecosystem goods and services in Spain. Beach social–ecological systems are usually viewed as natural places supporting hedonic socio-cultural activities (e.g. sun and sand). However, beaches are complex systems that have many other ecological, social, cultural, and economic functions and services. Given that these resources and activities are managed traditionally on a sectoral basis, beaches suffer from large losses. Rather than a one-dimensional approach to management from a physical or recreational perspective, the complexity of these systems requires a multidimensional approach to management. A demonstration study was carried out at S´Abanell beach (Blanes, NW Mediterranean Catalan coast), a beach with two differing zones for occupation, beach use, hinterland, morphodynamics, and management. The study consisted of two phases: a risk profile linking hazards and ecosystem services was formalized in an analysis of pathways of effects on the beaches, and a risk assessment process developed to associate risks with each hazard. The assessment established the main ecosystem services affected, facilitating the identification of the riskiest hazards and setting decision-making priorities for the risk-management phase. Risk reduction or mitigation measures were then proposed for risk management, to be based on clear integrated management principles, strong communication, and coordination and cooperation between at least three administrative levels involved in beach management. This type of management approach significantly contributes to enhancing the present situation where beach management is still carried out by different private and public organizations operating without a structured flow of information or clear common medium-term policy objectives, and with dispersed responsibilities.

Conclusion

A risk-analysis process applied to integrated management, regional environmental assessment, or marine spatial planning initiatives can combine ecosystem susceptibilities effectively with drivers of human activities to identify risks to valued ecosystem goods and services. Establishing pathways of effects, it also facilitates regulatory and policy gap analysis to identify where enhanced management measures are required in light of integrated policy objectives. Given that the process is explicitly initiated to inform management decision-making, it addresses the principles of ecosystem-based management, follow-up monitoring, and adaptive management.

Various integrated planning and management initiatives, such as those presented above, already include elements of risk analysis. A formalized process of risk analysis would enhance the effectiveness of management measures by ensuring that the correct measure is applied to the right risk via the most effective accountability and governance structure. It would also expedite such initiatives by normalizing the planning and management elements, providing an interchangeable suite of management measures.

3.5 Policy fragmentation implications in ecosystem-based management in practice

Roland Cormier, Andreas Kannen, Ian M. Davies, Rafael Sardá, and Amy Diedrich

Integrated assessment processes are a practical outworking of ecosystem-based management principles. In their simplest form, most assessments involve the overlaying of geospatial components highlighting susceptible ecosystems in relation to a given project or sectoral activity. The end-product aims at minimizing environmental impacts through implementing mitigation measures. Generally, this approach is ill-equipped to deal with cumulative effects resulting from multiple-sector-based activities. Although integrated assessments may ascertain the impacts adequately, the implementation of resulting management plans is hampered by the complexity and potentially conflicting jurisdictional policy objectives of various levels and arms of government in a given geographic area. In the coastal zone, this complexity is amplified when land-based interactions located in the catchment area are considered. These are typically managed by policy objectives that may not align with marine ecosystem integrity. Such management plans can also have limited effectiveness without clear established formal accountabilities. Here, policy fragmentation is identified as a key impediment to effective ecosystem-based integrated management approaches, and examples are provided of successful projects, notably highlighting institutional and policy-integration initiatives.

Keywords: ecosystem-based management, policy fragmentation.

Introduction

Integrated assessment processes are a practical outworking of ecosystem-based management principles. In practice, environmental assessments are considered to adhere to ecosystem-based principles. Being either an impact assessment of a localized project (EIA, environmental impact assessment) on the environment or a regional assessment of a large-scale development proposal of plan (SEA, strategic environmental assessment), these types of assessment require considerable effort in identifying the ecosystem components that potentially will be affected. Social and cultural considerations are also taken into account when projects can generate some wider public issues, for example, if the project can lead to large-scale modification of the landscape or seascape. In their simplest form, most assessments involve the overlaying of geospatial components highlighting susceptible ecosystems in relation to a given project or sectoral activity. The end-product aims at minimizing environmental impacts through identifying key interactions, and implementing mitigation measures.

This approach is, however, ill-equipped to deal with cumulative effects resulting from multiple activities within several industrial/developmental sectors, because each environmental assessment is generally conducted in isolation from other drivers of human activities. The requirement for consideration of cumulative and in-combination effects of projects/plans on the conservation interests of Natura 2000 protected sites under the EU Habitats Directive (EU, 1992) is one exception to this generality. In the coastal zone, each driver of human activity operates under its own regulatory, policy, and best management practices, all designed to deal with the specificity of their potential environmental impacts. For example, road development has specific design criteria for bridges to avoid hydrological changes to a river meander, agricultural activities have buffer zones along water edges to avoid sediment reaching the water ways, and municipalities have guidelines for the release of sewage water. However, each specific set of mitigation requirements was developed to allow these activities to take place. Being "driver-centric", each of these activities is managed by a public policy that operates under a set of jurisdictional mandates that have as an underlying objective to develop and promote the specific driver of the activity. Road networks do need to be built to support the movement of people and goods, agriculture is required to provide employment and to feed communities, and municipalities need to be planned and organized to service the needs of local populations. Notwithstanding, each public department was not created to address ecosystem issues. Driver-specific environmental requirements were developed to manage their respective impacts through a customized suite of mitigation measures and best management practices that often still result in residual effects. Without a comprehensive plan that takes into account all implicated drivers and their respective residual effects, individual environmental assessments and, albeit, regional environmental assessments, are often not equipped to account for the cumulative contribution of the residual effects on the ecosystem. In the coastal zone, this complexity is amplified when interactions of land-based activities located in the catchment area with the marine environment are considered.

It is within this backdrop of driver-specific policies and best management practices that conflicts arise. For instance, a wastewater treatment plant may be built in an area that affects shellfish aquaculture, or a marine wind farm might be built in front of a major seaside residential and recreational area that values scenery aesthetics or traditional angling and recreational fisheries. The issues and strength of feeling that can be raised in such examples underscore the need to undertake marine spatial planning and integrated management to alleviate potential conflict. Although these planning and management initiatives strive to adhere to ecosystem-based management principles, they are seldom conducted with an adequate inventory of ecosystem components and their carrying capacities, in part the result of incomplete scientific knowledge and understanding of these complex ecosystem processes. Although integrated assessments of all drivers and their residual impacts in a given geographic area can ascertain the impacts, significant challenge still lies in the implementation of the resulting management plans. Without integrated policy objectives and accountabilities aligned with marine ecosystem integrity, any plan that attempts to separate one driver from another is likely to be hampered by the complexity of the potentially conflicting jurisdictional policy objectives of various levels and arms of government in a given geographic area.

Integrated assessments are only likely to succeed in implemented management measures if they are conducted within an integrated policy-objective framework and governance mechanism based on existing jurisdictional accountabilities. In most integrated management initiatives, considerable effort is dedicated to the formulation of strategic ecosystem objectives that are to be adhered to by relevant jurisdictions and stakeholders, regrouped under an integrated management governance structure. Measurable results of such ecosystem-based initiatives cannot be achieved, however, without the development of management measures and practices designed to achieve the objectives and integrated within driver-specific operational policies.

Some country examples

Canada

The intent of the Canadian federal government Oceans Act 1997 was to define Canada's authority in line with internationally agreed jurisdiction of the oceans, to establish the Department of Fisheries and Oceans as lead agency for ocean management, and to implement an integrated management approach in Canadian oceans, which includes estuarine, coastal, and marine ecosystems. As early as the 1970s, policy fragmentation was recognized as an impediment to the sustainable development of ocean resources. The Oceans Act was implemented with the goals of reducing policy fragmentation in ocean management, based on a strategy of sustainable development, ecosystem-based integrated management, and a precautionary approach. In addition to the development and implementation of integrated management plans, technical provisions also included authority to establish marine protected areas, and marine environmental quality guidelines, criteria, and standards. To support the development of integrated management plans, it also allows for the creation and recognition of advisory bodies and governance structures. This means incorporating ecosystem-based, social, economic, and cultural considerations into decision-making processes through collaborations with affected and relevant stakeholders.

Activities relating to integrated management in Canada were afforded higher priority in March 2005 when the government committed "to move forward on its Oceans Action Plan by maximizing the use and development of oceans technology, establishing a network of marine protected areas, implementing integrated management plans, and enhancing the enforcement of rules governing oceans and fisheries, including rules governing straddling stocks." Five Large Oceans Management Areas (LOMA) were established: the Pacific north coast, Beaufort Sea, Gulf of St Lawrence, eastern Scotian Shelf, and Placentia Bay/Grand Banks. LOMA governance is assured through a regional oceans committee of federal, provincial, and territorial authorities, and includes stakeholder and scientific advisory bodies. However, the application of the precautionary approach and integrated ecosystem-based planning are currently at the forefront of discussion of a number of management and advisory issues relating to the coast. The LOMA initiative included producing the following elements:

- Ecosystem Overview and Assessment Reports (DFO, 2005a) are comprehensive descriptions of the knowledge base and present current scientific understanding of the structure and function of the ecosystem.
- Ecologically and Biologically Significant Areas (DFO, 2004a) and Ecologically Significant Species and Ecologically Significant Community Properties (DFO, 2006) represent a high ecological or biological significance and require a greater-than-usual degree of risk aversion in management of activities that can affect them.
- Conservation Objectives (DFO, 2007) are science-based objectives related to the status of the non-human components of the ecosystem.

These guidelines form the basis for ecosystem-based integrated policy-objective setting from a strategic perspective within the LOMA, normalizing the approach across the country for defining and describing these significant ecosystem components. Socio-economic and cultural overview and assessment reports are being developed with the intent of formulating objectives for the integrated management process and effectively identifying key ecosystem goods and services. The challenge, however, lies in the translation of such strategic objectives into management measures that can be implemented in operational guidelines and best management practice. By linking the susceptibilities of significant ecosystem components to adverse environmental effects, legislative and policy overview and assessment initiatives are currently being developed to identify management measures that comply with integrated management objectives along with the gaps that require enhancement.

In the mid-1980s, federal fish habitat protection requirements were integrated in the Maritime Provinces watercourse alteration-permitting systems. At the time, that approach was considered to provide a one-window approach for developers. Previously, each development project submitted to provincial authorities had been referred to DFO for review and assessment. Over time, effective sector-specific guidelines and standard operating procedures have been implemented in activities such as agriculture, forestry, and transportation. Considered low risk, these are then monitored and audited to ascertain management effectiveness.

Germany

The foremost challenge for coastal and marine management in the German North Sea and Baltic Sea is to govern a complex maritime system linked to several policy arenas. The increasing policy interest in the sea is driven by various factors, including the growing perception of marine areas as economic space, the political interest in utilizing marine resources, and the role of the maritime industry in regional development and regional economic growth (Kannen *et al.*, 2008). The development of spatial plans for the German North Sea and Baltic Sea EEZ has been the administrative response to deal with the increasing pressure from a large number of human activities in the sea.

However, both the North Sea and the Baltic Sea are characterized by strong transnational linkages between coastal states, with European policies and transnational regulations as additional policy levels. Currently, two major policy lines interact: first, the EU's Integrated Maritime Policy (IMP), which focuses mainly on the economic utilization of marine resources and the development of strong maritime industries, and second, the EU Marine Strategy Framework Directive (MSFD), which is the environmental pillar of the IMP and seeks to achieve good environmental status (GES) for Europe's seas. Their primary focus on economic and environmental objectives, respectively, puts the IMP and MSFD on a potential collision course. Although the conflicting targets may not come to the fore at a political and strategic level, problems will certainly arise when it comes to local implementation and the definition of priorities in spatial planning or regional development plans (Kannen *et al*., 2010).

In both policies, integrated coastal-zone management (ICZM) and marine spatial planning (MSP) are specified as essential tools for implementation, including a request for stronger integration and more interactive ways of stakeholder involvement in the respective implementation processes. A highly relevant aspect for the implementation of EU policies is the way in which tools such as MSP are applied. This is the responsibility of individual Member States, and usage can thus be rather diverse between Member States. In Germany, policies and mechanisms are initiated at the national level, but influence activities at a regional level or even at a level of districts and municipalities. From a jurisdictional perspective, MSP in Germany is framed by national and regional jurisdictions on the one hand (specifically within territorial waters, where MSP is the responsibility of the Länder), and EU directives and international legislation on the other (e.g. UN Law of the Sea, IMO regulations for shipping). Transboundary (environmental) issues are largely mediated by conventions at regional sea level, such as OSPAR for the Northeast Atlantic (including the North Sea) and HELCOM for the Baltic Sea.

As a result, the organizational and institutional setting for integrated planning and management is characterized by a highly complex web of policies, institutions, and mechanisms that cut across a range of different spatial and jurisdictional scales. For processes such as ICZM, or for processes of decision-making more generally, the lesson is therefore that local-level activities are increasingly constrained by national and international legislation. At the same time, regional and local knowledge and conditions do need to be taken into account if decisions are to be understood, accepted, and enforced at a local level. If the different interests and targets for a particular marine area are to be truly integrated, policies such as IMP, legal requirements such as the MSFD, statutory planning tools such as MSP, and non-statutory or even informal mechanisms have to be brought together in a transparent multilevel, multisectoral governance architecture (Kannen *et al*., 2010).

Besides additional structures, processes leading to decisions (who decides what, and based on what rules?) and involvement (who is involved when and how?) are at least as important. Perceptions of relative priority of policy aims, or mismatches in policy objectives, e.g. between different ministries or government authorities, might form a major constraint in the implementation of coherent planning. Traditional approaches to planning are not well-suited to deal with contradictory value sets and the potential value conflicts surrounding, for example, offshore wind farms and other human uses of the sea. However, integrated assessments could assist in this context if they use, for example, the ecosystem service approach to identify (cumulative) causal interactions between natural and social processes, and link this with a thorough policy and actor analysis from all issue relevant levels (Kannen *et al*., 2010).

Scotland

The need for some regulatory authority to plan and manage developments in terrestrial environments is widely recognized in Scotland, and town and country planning is an established profession. Land-based planners mainly work in Local Planning Authorities, operating in response to local needs and pressures within principles and guidance provided by the Scottish national government. Work leading to the granting of planning consent is the first phase in a project, and subsequent phases are subject to a variety of regulations.

Until relatively recently, no such planning system operated in the nearshore marine environment (with the exception of aquaculture development). Projects could proceed straight to the later phases of regulatory control. Regulation of marine development was complex and multifaceted, involving licences/consents from several different regulatory bodies or offices, by independent processes, working to different time-scales and with different requirements for supporting documentation. Most of the processes included external consultations with statutory and non-statutory consultees. The more prominent of these, for example the national conservation organization Scottish Natural Heritage, would receive requests for comment from several regulators on the same development proposal. The regulators were generally able, howver, to include conditions in the consents/licences they issued, and it was not uncommon for developers to receive conflicting conditions in different consents/licences.

Developments that crossed the land/sea boundary (e.g. construction of a concrete jetty or boat-slip) had to be pursued through both the marine and terrestrial systems, which had no clear mechanism for interaction. There were no mechanisms to ensure coherence between marine and terrestrial development objectives, and the coasts of a single coherent water body (such as the estuary and Firth of Forth) were controlled by numerous local planning authorities. It is clear that such complex and fragmented licencing/consenting and planning systems could have a negative impact on the achievement of Scottish Government objectives for the sea. A number of other pressures also related to the marine environment came together and resulted in new legislation, the Marine (Scotland) Act 2010 (Anon., 2010).

That Act creates a new legislative and management framework for the marine environment (McKie and Davies, 2010). It also introduced a new statutory marine planning framework to manage competing demands for the use of the sea while still protecting the marine environment. By considering all activities together, from wildlife tourism and recreational sea-angling to energy and fishing, marine planning ensures that marine energy, fishing, aquaculture, shipping, recreational, and other users of the sea handle marine resources wisely while maximizing the benefits to Scotland.

The draft Scottish National Marine Plan (Scotland, 2010a) sets out the strategic objectives for the Scottish marine area, in the context of the UK Marine Policy Statement, and includes ensuring that international and EU commitments are met. It identifies national priorities within certain sectors (e.g. expansion of marine renewable energy projects) and provides clarity for decision-making. Scottish Marine Regions have been proposed covering coastal waters and would be the basis for regional planning, through which local interests and accountability would be met. Boundaries between regions would be drawn on logical geographic/ecological grounds and, for example, would bring together local planning authorities around the coasts of recognizable bodies of water, such as the Firth of Forth, to ensure that development takes full account of environmental opportunities and constraints. Regional marine plans will be consistent with the National Marine Plan and will provide the context in which conflicts between different sectors can be resolved and by which key areas can be defined for key uses.

The Marine (Scotland) Act 2010 also creates a system of licensing with the aim of reducing the regulatory burden for key sectors, and includes powers to establish marine protected areas (MPAs) to protect natural and cultural marine features. A new division, Marine Scotland, was created within the Scottish Government, and it brings together all pre-existing government agencies and policy units within the marine field. Marine Scotland administers the licensing system for marine developments which integrates all previously disparate requirements into a single Marine Licence. In that way, the fragmentation of policy and regulation is minimized.

Spain

Recently, several integrated coastal-zone management (ICZM) researchers and practitioners in Spain have been working together in association with AENOR (the Spanish Association for Standardization and Certification) to develop guidelines for the implementation of a system of ICZM for the Spanish coast (Doménech *et al*., 2010). The guidelines respond to the need to "build instruments and methods for ensuring consistency between land and marine systems in order to avoid duplication of regulations, or the transfer of unsolved land planning problems to the sea", as stated in the European Commission Green Paper. Management of coastal and marine space in Spain is particularly susceptible to the challenge of policy fragmentation given a significant number of overlapping jurisdictions and lack of supporting legislation for ICZM. The guidelines are intended to serve as a tool to develop and harmonize ICZM-related activities, particularly in relation to governance, at local, regional, national, and European scales. Essentially, they describe a step-by-step approach for decision-makers, administrators, and managers who wish to implement ICZM in any coastal and marine space, and it facilitates the integration and adaptation where necessary of existing norms and legislation, including coordination among implicated entities. The guidelines were published in June 2010 and a working group for their implementation was formed that will continue to initiate and stimulate related activities in the different autonomous communities.

Conclusion

Coastal policy fragmentation issues require the establishment of coordinating mechanisms such as high-level policy planning bodies whose basic role is to deal with the issue of policy fragmentation and coordination among different stakeholders and levels of governance. Governance mechanisms need to operate both at the strategic objective setting level, working across jurisdictions, and at the operational management level, linking management measures to strategic objectives. Management measures are likely to achieve strategic objectives through tangible performance indicators established for those objectives.

Management measures effectively have to eliminate, control, or mitigate against adverse environmental effects arising. Such measures must take the form of sector-specific standard operating procedures and best management practices. For example, the concept of GES of the EU's MSFD establishes a high-level backdrop for which integrated management objectives should aim. Once translated into management measures, performance indicators would then be able to ascertain the performance of the measures in achieving GES. Key integrated management elements of success lie within integrated policy-objective frameworks and enshrined governance mechanisms that are based on existing jurisdictional accountabilities. A particular challenge in Europe is the transnational character of

EU policies, requiring integration between Member States which currently have to deal with integration of their own sectoral policies, including the involvement of public and private actors.

Another challenge in achieving effective integrated management lies in the long time-frames that may be needed to establish governance mechanisms and trust between the relevant actors as a prerequisite to developing integrated management plans in the coastal zone and marine spatial planning initiatives. These development and implementation activities often have lifespans that surpass those of political cycles. Changes in public policy priorities can impede the continuity of such initiatives.

Integrated planning and management initiatives would benefit from normalized processes and technical knowledge bases, from open and transparent institutional structures, and from flexible organizations. This could reduce the number of lengthy customized scientific studies and simplify policy-objective exercises. Although government priorities change over time, integrated ecosystem-based standardized operating procedures, guidelines, and best management practices are likely to continue at the operational level. In addition to integrated policy objectives and governance mechanisms, sustainability is likely to require the implementation of sector-specific management measures and regular integrated assessments that address cumulative effects.

3.6 Integrated coastal-zone management: bridging the land–water divide

Marc Ouellette and Matthew Hardy

The coastal zone is an area of great ecological complexity and productivity, given its intrinsic connectivity between habitats and processes of freshwater and marine aquatic ecosystems. It is also an area of complex anthropogenic interactions, with variable social, economic, and cultural components. Further, it is the zone where aquatic ecosystems are the most vulnerable to cumulative pressures caused by human activities of various types and intensity, as well as where management lies within a complex jurisdictional backdrop. Hence, it is a complex mosaic of variable zones of influence and ecosystem component vulnerabilities along the land–water interface. Canada is a maritime nation bordered by the Pacific, Atlantic, and Arctic oceans. It has the world's longest coastline, ca. 244 000 km, and also borders interior freshwater "seas", the Great Lakes. Given this setting, integrated coastal management seems a formidable challenge, yet it is particularly important that it is done strategically and efficiently using the best available information and tools. Under the Health of the Oceans Initiative, four Centres of Expertise (CoE) were established within the Oceans sector of the Department of Fisheries and Oceans in order to understand and address national integrated coastal and oceans management issues better. An overview of the objectives of the CoE on coastal management allows a focused update on efforts at integrating risk-analysis decision-making tools, the development of ecosystem-based approaches in relation to cumulative effects, and regional environmental vulnerability profiles.

Keywords: adverse environmental effects, integrated coastal-zone management, risk analysis, risk characterization.

Introduction

The continental shelf, continental margin, coastal ocean, and coastal zone are concepts for which various definitions have been proposed. In essence, the coastal zone is generally taken to include the coastal ocean and the portion of the land adjacent to the coast that influences coastal waters (Gattuso *et al*., 2010). Others have described the coastal zone as "The area where the ocean meets the land, which constitutes 10 per cent of the ocean's area but contains 90 per cent of all marine species" (Draper, 2001). It is an area of great ecological complexity and productivity in its intrinsic connectivity between habitats and processes of freshwater and marine aquatic ecosystems in relatively shallow landscapes. It is also an area of complex anthropogenic interactions with variable social, economic, and cultural components.

Human activities of various type and intensity can induce severe pressures on aquatic ecosystems that will affect their structure (species and habitat) and functioning. Additionally, land-based activities can have a profound effect on coastal aquatic ecosystems as water, being a powerful solvent and fluid, also acts as a conduit (stream network) and accumulator (drainage basin) of those pressures. Moreover, the zones of influences can be significant. Hence, coastal aquatic ecosystems are particularly vulnerable to cumulative adverse environmental effects from human activities because they are under pressure from both land- and water-based activities. Human pressures, which lead to cumulative adverse environmental effects, can translate into direct impacts on an ecosystem (e.g. aquatic habitat fragmentation from roads crossing watercourses), as well as indirect impacts (e.g. increased coastal erosion from storm-surges related to climate change). The coastal zone is therefore a complex mosaic of variable zones of influences and ecosystem component vulnerabilities along the land–water interface. Furthermore, it is the zone where management often lies within a complex jurisdictional backdrop.

Integrated coastal and oceans management (ICOM) in Canada

Canada is a maritime nation bordered by the Pacific, Atlantic, and Arctic oceans. It has the world's longest coastline, ca. 244 000 km, and also borders interior freshwater "seas", the Great Lakes. The role that oceans have played in Canada's history cannot be overemphasized: they are an integral part of the country's environmental, social, cultural, and economic fabric, and aboriginal peoples and Canada's coastal communities have long-standing ties to their oceans and other marine resources (DFO, 2005b). A recent analysis revealed that in 2001, some 38% of the Canadian population lived within 20 km of a coast (Ricketts and Harrison, 2007).

With the passage of the Oceans Act in 1997 and the subsequent release of its Oceans Strategy in 2002, Canada established a new legislative and policy framework to modernize oceans management (DFO, 2005b). This brought a major shift in the way Canadians looked at the oceans and how they are managed (Stewart *et al*., 2003). The Oceans Act is founded on three principles: sustainable development, integrated management, and the precautionary approach. In addition to changes such as defining territorial limits and separating federal and provincial responsibilities, the Oceans Act gave the Minister of Fisheries and Oceans Canada (DFO) the mandate for leading an integrated approach to oceans management and marine protection on behalf of the federal government. This proved to be a challenging task considering that 30 federal departments, agencies, and other organizations have ocean-related activities and responsibilities attached to 62 key federal statutes. The jurisdictional complexity is even greater in the coastal zone, with the multiple governmental authorities and responsibilities (federal, provincial/territorial, and municipal; DFO, 2009b, 2009c). An added governance complexity is the consideration that two of Canada's ten provinces are part of the zones of influence of the coastal zone (through watersheds) but do not receive direct benefit from it (i.e. have no provincial boundaries on the coast).

It is recognized that oceans governance arrangements are not designed to deal with the challenges of modern ocean management. The approach has been described as fragmented, exceedingly complex, and lacking transparency, and is focused on solving problems after they appear (DFO, 2005b). Despite these challenges, the Oceans Action Plan (DFO, 2005b) committed the country to moving forward by maximizing the use and development of oceans technology, establishing a network of marine protected areas (MPAs), implementing integrated management plans, and enhancing the enforcement of rules governing oceans and fisheries, including rules governing straddling stocks (Ricketts and Harrison, 2007).

DFO's Oceans Centre of Expertise on coastal management

Under the Health of the Oceans Initiative (2007–2012) that succeeded the Oceans Action Plan, four Centres of Expertise (CoE) were established within the Oceans sector of DFO in order to understand and address issues related to conducting integrated coastal and oceans management better. The objectives of the CoE on Coastal Management are: (i) to clarify DFO's role in coastal-zone management in relation to its federal, provincial, and territorial partners; (ii) to focus its efforts in the development of ecosystem-based frameworks and tools in relation to cumulative effects and risk assessments in order to inform relevant jurisdictions in their decision-making processes better; (iii) to leverage products and practices currently developed for Large Ocean Management Areas (LOMAs); (iv) to validate the approaches via a network of regional, national, and international experts; and (v) to contribute to the overall knowledge base of coastal management practices.

We here focus on three priorities for the CoE in consolidating and leveraging information into the context of coastal management:risk analysis, ecosystem-based conceptual models, and regional environmental vulnerability profiles.

Risk analysis

In Canada, there is an expectation for federal departments to implement integrated risk-management approaches within their existing structures (DFO, 2004b; TBS, 2003, 2004). This represents the general principle of "good governance" and the responsible deployment of resources in order to achieve results. In the context of DFO, one objective is to apply risk management in decision-making consistently and explicitly in order to deliver on priorities while recognizing limited resources and potential trade-offs (DFO, 2004b). At its core, risk analysis is an approach to assist in decision-making by providing a systematic means of gathering, evaluating, recording, and disseminating information, and leading to recommendations for management consideration in response. It is an approach intended to provide decision-makers with an objective, repeatable, and documented assessment of the risks posed by a particular course of action or inaction (CSA, 1997; FAO. 2000).

The need for a risk analysis and integrated risk-management approaches in dealing with ecosystem-based decision-making can be particularly appreciated on considering Elliott's (2002) statement: "The human response to the changes resulting from our activities has to be defined in such a way as to meet what we may call 'six tenets for environmental management'. Our actions have to be:

environmentally sustainable; technologically feasible; economically viable; socially desirable; legally permissible; and administratively achievable."

One of the critical requirements is that risk-based approaches be used to integrate better the ecological, socio-cultural, and economic with the corporate or governance risks. For example, the Species at Risk programme is working on the refinement of a risk-analysis-based approach to assist in the decision-making process when providing recommendations on whether or not to list a species (e.g. endangered or threatened). It is crucial that decision-makers understand the potential consequences of a particular course of action or inaction.

It is our view that risk-based approaches and principles can be applied in the context of integrated coastal and ocean management. Risk analysis and management approaches are at the core of ecosystem-based frameworks and tools that can enhance the effectiveness of identification of priority-setting and lead to more pragmatic and feasible management. The initial phase of the CoE, using classical risk-analysis processes, focuses on the risk-characterization phase of the process designed to connect ecosystem health vulnerabilities with coastal community viability (ICES, 2008).

Ecosystem-based conceptual models

The implementation of the ecosystem-based approach to integrated management requires the development of tools, approaches, and frameworks to bringing together the various policy and science products to support effective decision-making in increasingly complex circumstances. It is widely recognized that economic, environmental, and demographic pressures converge sharply at the world's coasts, creating a complex situation that presents a challenge to effective and sustainable management and governance. The development of tools for integrated coastal management refers to the process of creating or adapting existing methodologies and approaches to be applied in the nearshore environment (Hardy and Cormier, 2008).

The challenges are inherently complex in the coastal zone, so there is benefit in robust conceptual models that help categorize information and identify relationships between ecological, social, economic, and cultural aspects. The DPSIR (Drivers–Pressures–State–Impacts–Response) conceptual model adopted by the European Environment Agency is an analytical framework that can be used as a tool to determine and illustrate the causality between human activities and the ecosystem, based on the best available information (Elliott, 2002; Borja *et al.*, 2006; Hardy and Cormier, 2008). It can assist in problem formulation and the scoping of risk-based analyses. The various components of the DPSIR framework in an ecosystem-based approach can be described as: Drivers of environmental change (e.g. industrial production); Pressures on the environment (e.g. discharges of wastewater); State of the environment (e.g. water quality in rivers and lakes); Impacts of those changes on the ecosystems and society (e.g. water unsuitable for drinking); and Response of the society (e.g. prevent, control, mitigate, and/or allow).

The DPSIR framework was used as the basis for the development of a Community Viability Ecosystem Dependencies (CVED) conceptual model in order to illustrate the risk to the viability of coastal communities in relation to the ecosystem health risks posed by their own social, cultural, and economic activities (Figure 3.6.1; Hardy and Cormier, 2008). The model also shows that ecosystem-based integrated management of coastal zones is a truly multidisciplinary endeavour and that both bottom–up and top–down approaches are required. The natural sciences are required for understanding the structure and functioning of ecosystems, and the pathways of effects that describe the relationships between human activities (Drivers), the Pressures they generate, and their Impacts on ecosystem components. They are also essential in understanding the dynamics of adverse environmental effects, induced by the actions of those human activities, that result in negative Impacts (alteration, disruption, or destruction of species, habitats, functions, or attributes). Moreover, natural sciences can identify adequate indicators and reference points that allow one to evaluate the State of the ecosystems and the thresholds at which there will be change .

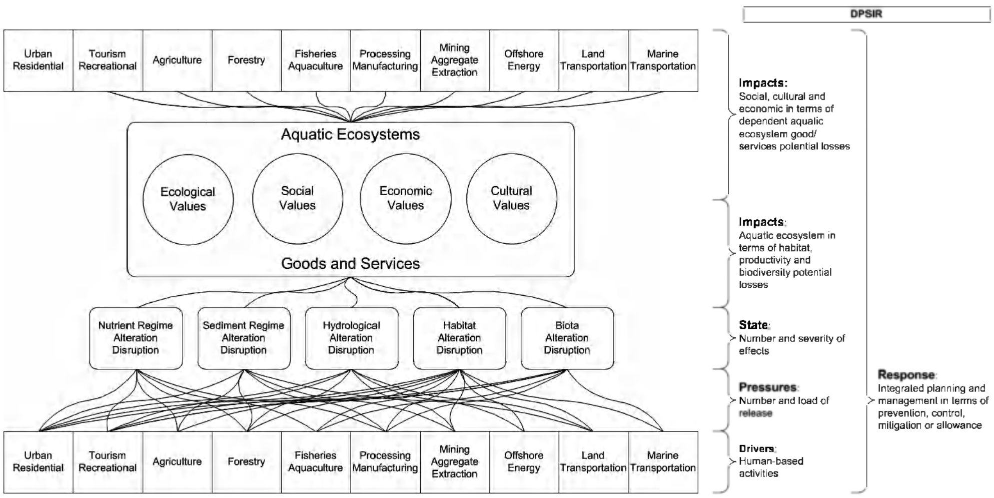


Figure 3.6.1. Community Viability Ecosystem Dependencies (CVED) model. The adverse environmental effects (red boxes) are induced by pressures from human activities (high-level version; adapted from Hardy and Cormier, 2008).

Meanwhile, the social sciences are required for understanding human values and needs in order to define the ecosystem services one relies upon and to understand the socio-economic and cultural consequences of actions or inactions. Ecosystem services are the benefits people obtain from ecosystems. They include provisioning services such as food, water, timber, and fibre; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling. The human species, although buffered against environmental change by culture and technology, remains fundamentally dependent on the flow of ecosystem services (MEA, 2005). A clear understanding of this dependence is essential in allowing the appropriate formulation of conservation objectives and in identifying action points to the Responses (policy, regulations, best management practices, etc.), defining the tolerance of "adversity" of changes to the State of ecosystems.

In this adapted version of the CVED (Figure 3.6.1), ecosystem services are presented in simple components (ecological, social, economic, and cultural values). The intent is to illustrate simplistically that all ecosystem services valued by coastal communities rely on the integrity of the ecosystem. The CVED also illustrates on its horizontal axis that human activities (Drivers) can induce various Pressures that can lead to various adverse environmental effects, and that an adverse environmental effect can be induced by cumulative Pressures from various activities. Therefore, the State of ecosystems along the coast will result from a permutation of cumulative adverse environmental effects originating in multiple Drivers.

Conceptual models allow for the consolidation of a pathway of effect relationships that can be as detailed or high level as required. Although this would be informative on its own, it can support integrated coastal and ocean management better when applied within operational tools for decision-making.

Regional environmental vulnerability profiles

Regional environmental vulnerability profiles are being developed as an operational tool to identify and scope the environmental pressures associated with a number of human activities from a geospatial perspective, and to illustrate their respective and relative intensity. The profiles take the form of an atlas of environmental pressures and vulnerabilities, and build on the work undertaken by the United States Environmental Protection Agency's Regional Vulnerability Atlas (http://www.epa.gov/reva/).

The profiles are not an assessment in the traditional sense, although they may serve to identify research or assessment needs. Rather than assessing the impacts through costly field monitoring, it is desirable first to profile where such monitoring might be directed most effectively, based on proxy indicators of human pressures and known vulnerabilities. The intent of the profiles and maps (Figure 3.6.2) is to highlight outliers or "hotspots" that assist practitioners in drawing attention to areas of greatest human activities (Drivers) that induce Pressures. Therefore, the maps are presented in regards to the relative Pressures within the scale under consideration. The potential consequences of the Pressures, which are highlighted in the maps, are based on the significance of the areas (i.e. valued ecosystem components or services) and its susceptibility to adverse environmental effects. For example, a given estuary may be significant because of the nursery created by beds of aquatic vegetation, yet particularly vulnerable to nutrient-regime alterations given lower-than-average tidal exchanges and flushing. There is a need, however, to understand better the effects of natural processes (i.e. flushing rates, areas of greater rainfall, climate change, etc.) that could mitigate or exacerbate the potential for adverse environmental effects.

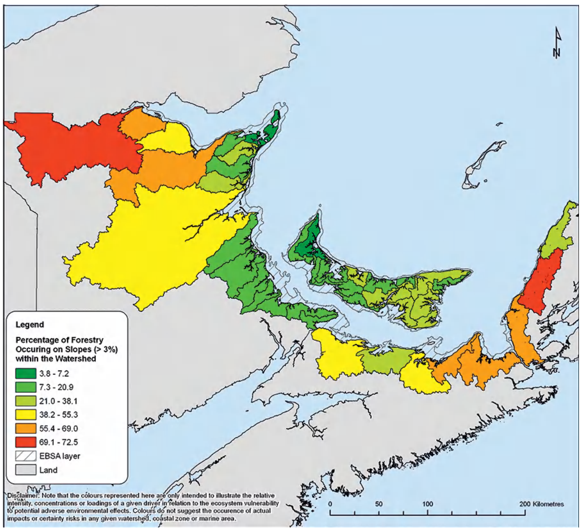


Figure 3.6.2. Example of a regional environmental vulnerability profile for the southern Gulf of St Lawrence, Canada. This draft map (regional scale) represents the "Percentage of forestry lands occurring on slopes greater than 3%" (US–EPA ReVA methodology) and the legend is a relative percentile distribution between the 38 watersheds. The map identifies watersheds that are likely to be at risk from soil erosion during severe rainfall. These watersheds (i.e. catchment areas) could be priority areas for conformity and compliance monitoring of the effectiveness of mitigation measures in reducing the potential for sediments to enter watercourses.

The principle layers of information that we use to define significant areas were identified through scientific advisory processes, such as Ecologically and Biologically Significant Areas (DFO, 2004a) and Ecologically Significant Species and Community Properties (DFO, 2006). These pre-established, peer-reviewed criteria provide an objective basis against which to weigh the potential consequences of the adverse environmental effect pressures in significant areas in relation to management objectives. Moreover, the application of a similar approach through socio-economic and cultural overview assessments is also being examined.

For practical management purposes, these tools help in the identification of priority monitoring areas, to evaluate the effectiveness of mitigation measures in reducing the potential for adverse environmental effects. There is also an opportunity to align departmental resources more efficiently in planning for effectiveness monitoring and compliance audits (Hardy and Cormier, 2008). Integrated policies and sectoral best management practices can be developed as required to address significant regulatory gaps in mitigating cumulative environmental effects.

Conclusion

Integrated management involves stepping back to see the whole picture and looking at it from different perspectives, rather than looking at individual pieces of a puzzle in isolation (Stewart *et al*., 2003). However, sustainable development brings the added complexity of the temporal dimension of ecosystem dynamics and the variability of human values. Hauff (1987, in Müller and Burkhard, 2007) refers to sustainable development as a holistic principle that requires an interdisciplinary, systems-based framework to consider social, economic, cultural, and ecological features on various interacting spatio-temporal scales.

In this context, integrated coastal management in a sustainable manner seems to be a formidable challenge, yet it is particularly important that it is done strategically and efficiently, with the best available information and tools.

3.7 Architecture for integrated coastal-zone development

Knut Torsethaugen

Coastal areas are a limited resource with dynamic physical and biological properties and varying social and economic restraints and management. Cost-efficient, sustainable use of coastal areas is therefore a complex and interwoven issue. One challenge is how actors involved in coastal development can digest, accumulate, and use state-of-the-art political, social, economic, and natural science knowledge in their daily work? How can the gap between advanced science and local coastal-zone management be bridged, for example? Here, an architecture concept is introduced, a top–down holistic description of all elements and relations between elements that is part of the system, in this case coastal-zone development. Similar concepts are used in sectors such as enterprise management, intermodal transport systems, and software development. The overall aim of the suggested approach is to establish a common framework for integrated coastal management based on overall goals, experience, existing models, and cross-disciplinary knowledge. It is an attempt to create an arena where all stakeholders can find their place and can see connections with other stakeholders and overall goals. The model can be used to identify conditions for how new scientific knowledge should be implemented in decision-making, be a guide for cost-efficient collection of information to fill knowledge gaps, and be the basis for functional and information specification for decision-support tools for users on different management levels. The architecture will foster a holistic approach and hence reduce the risk for failure in coastal-zone development. This version of the architecture is preliminary, however, representing a concept rather than a real model. The approach presented is simply a concept for knowledge integration and cannot replace established knowledge and methods. The intention is that the concept can be a platform for cross-disciplinary and cross-sectoral discussion, leading to best-practice solutions for coastal-zone management and development.

Keywords: architecture, best practice, coastal-zone development, framework, reality model.

Introduction

This paper presents some ideas for what is generally referred to as an architecture for coastal-zone development. The work is partly based on the project iCoast, supported by the Norwegian Research Council, Fishery and Aquaculture Industry Research Fund and partners. The partners represent cross-disciplinary research institutes and main users in the study areas. They are: the University of Tromsø – Norwegian College of Fishery Science (Project leader) and the Norwegian University of Science and Technology, NTNU; the Institute of Marine Research, NOFIMA Marine AS, the Geological Survey of Norway, the Norwegian Institute for Urban and Regional Research, the Norwegian Institute for Nature Research, Centre for Rural Research, the Northern Research Institute, the NTNU Social Research AS (Studio Apertura), and SINTEF Fisheries and Aquaculture; the Coast is Ready (Network of Municipalities in Trøndelag), the County Governor of Sør-Trøndelag, the Directorate of Fisheries (Region Trøndelag), the Norwegian Coastal Administration (Mid-Norway), the Fishermen's Association (Mid-Norway), and the Norwegian Seafood Federation (Trøndelag).

The work in iCoast is divided into several work packages: the social system, the knowledge system, the institutional system, the value-adding system, and the ecological system. The goal is to combine information from these sectors in an architecture that describes best practice for integrated coastal-zone management.

Some of the main elements in the architecture are described, together with a few examples of the structure.

Main elements

Human factors

Coastal-zone management has many dimensions, and one of the challenges is that humankind is part of the problem (Figure 7.1). To avoid conflicts and non-sustainable use of resources, all actors need to have the same agenda and a common understanding of reality. Often, however, it seems that stakeholders are not willing to contribute to an agreement and that simple solutions are easy to sell to policy-makers and media. Another challenge is what can be called the "Gold rush effect" (Ludwig *et al.*, 1993): "It is more appropriate to think of resources as managing humans than the converse; the larger and more immediate are prospects for gain, the greater the political power that is used to facilitate unlimited exploration."

Conflict resolution is not only a scientific exercise. Tools are needed to bridge the gap between science and policy-making, in a language that can be understood by scientists, politicians, and users (Fedra, 2004). Information on nature and ecological relationships may be of little value if not understood and accepted by the end-users.

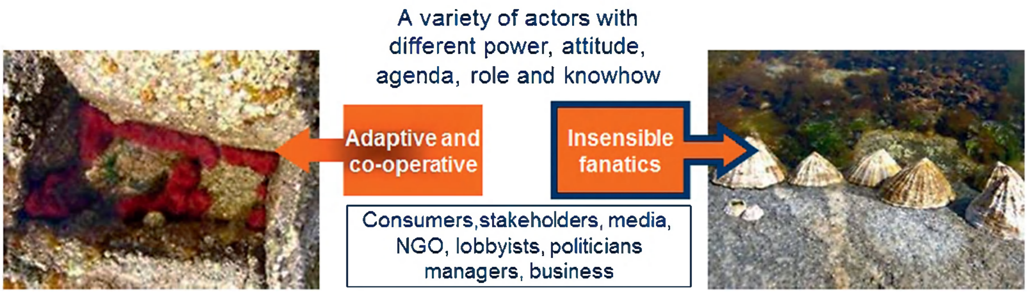


Figure 3.7.1. Humankind is part of the problem.

Management system

The sustainable management of coastal areas and resources depends on cross-disciplinary research and practical management. A goal for coastal science is to contribute to a shift from a precautionary approach to a more knowledge-based management of the coastal zone. The challenge is to integrate and make accessible the scientific results and knowledge that already exist, and to analyse socio-cultural hindrances to utilizing this knowledge. How, for instance, can actors that are involved in coastal development digest, accumulate, and use state-of-the-art knowledge from political, social, economic, and natural science in their daily work? How also does one bridge the gap between advanced science and local coastal-zone management? Making decisions within such complex systems can be more difficult the more information that is available. Simple solutions not based on a holistic, knowledge-based view are risky and can in the worst case lead to disaster. It should be obvious, therefore, that a systematic approach is necessary to manage such complexity. Many methods and indicators have been developed and used (Steins and Edwards, 1999; EU, 1999; Polski and Ostrom, 1999; Banica *et al.*, 2003; Ostrom, 2007; Billé, 2008).

Coastal-zone science

The coastal zone includes probably the most complicated ecosystems on the planet, yet a large part of the world's population lives there and the region has great potential for conflict. In addition, coastal areas are particularly vulnerable to climate change. Because of this, challenges in the coastal zone have been studied by scientists of different disciplines, and there is a large amount of knowledge. On the other hand, there is still a long way to go before one can say that one understands the dynamic connections between all elements. To illustrate the complexity, some of the elements that need to be included in the knowledge base are:

- Climate change – global warming – extreme weather
- Environment – ecology – biodiversity – food chain
- Culture landscape – culture – traditions
- Local communities – infrastructure – transport – economy
- Stakeholders – experience
- Use – protection – conflict – management
- Recreation – tourist attractions
- Fishery – resource management
- Aquaculture – production – environmental impact
- Renewable energy – visual pollution
- Oil and gas – pollution – oil spills

The total picture

To contribute to a holistic view, an architecture concept is introduced here as an attempt to create an arena where all stakeholders can find their place and can see connections with other stakeholders as well as the overall goals. Similar concepts are used in other sectors such as enterprise management, intermodal transport systems, and software development. The architecture is based on a top–down description of all elements along with the relationships between elements that are part of the system. The aim is to establish a common framework that defines, describes, and systemizes the overall goals and the operational goals, the human interactions and experiences, and the cross-disciplinary knowledge. The model can identify how new scientific knowledge may be implemented in decision-making, act as guideline for cost-efficient collection of information to fill knowledge gaps, and be the basis for functional and information specification of decision-support tools for users at different management levels. Such tools need to have access to standardized information and indicators for all elements that influence the overall goals. The architecture will foster a holistic approach and hence reduce the risk of failure in coastal-zone management. The model will also make it easier to disseminate research results and gain acceptance of the decisions.

The architecture

The suggested architecture consists of two main parts. The framework is a systematic description and definition of overall goals, major tasks, roles, and information on natural and human resources. The second part, the reality model, describes the dynamic connections between elements in the political system, the managing system, the implementation system, and the production system, and how it is linked to the framework.

Framework

The framework is based on an object-orientated concept and has five main classes: goal, role, task, resource, and indicator. The role is responsible for a task, and the task needs resource to produce the intended result. The result has to be evaluated by indicators and compared with the original goals. The connections are shown in Figure 3.7.2.

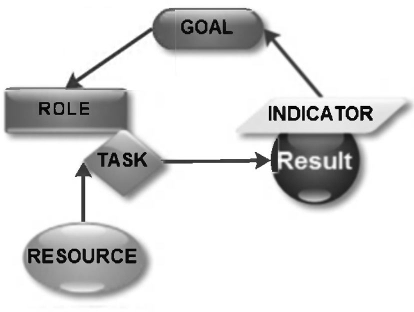


Figure 3.7.2. Main classes in the framework.

The goal is defined as the overall goal or political goal as defined in international agreements or user needs (Figure 3.7.3).

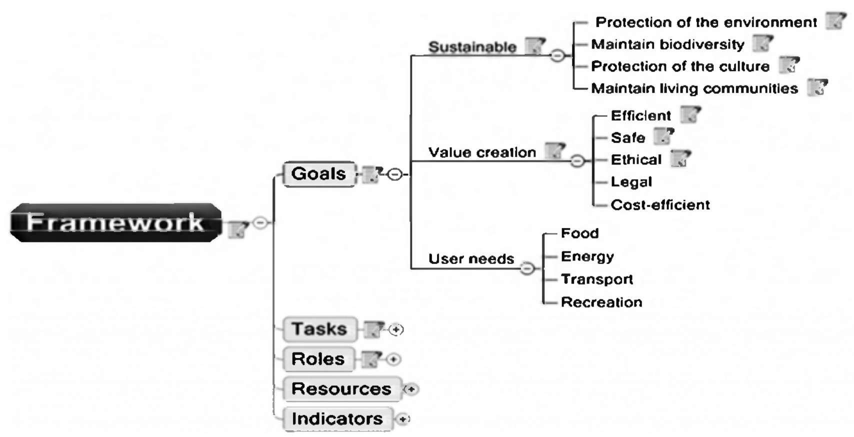


Figure 3.7.3. Example of goals.

These goals are not easy to measure, and they often conflict with each other and with short-term interests and traditions. They reflect the struggle between use and protection, and often also between efficiency and safety. How different actors relate to these goals is essential. A task is an activity with a defined responsible actor. At the top level, examples of tasks are infrastructure management, sea safety, surveillance, enforcement, and education. Roles are connected to tasks, but include users, stakeholders, and other roles. A single actor can have different roles and a role can have many actors, which can be conflict-generating. All tasks and activities depend on some sort of resource, which can be a natural resource, human resource, or economic resource. Information on the resources is, however, crucial to achieving the goals. Figure 3.7.3 also illustrates some practical aspects of the architecture concept. It shows the top–down structure and splitting of elements and how information connected to elements at all levels is linked directly to the structure. The interdependence of elements and information flow is illustrated in Figure 3.7.4.

The reality model

The second part of the model is the operational part, describing the dynamic connections including the political, management, implementation, and production systems (Figure 3.7.4). Some details about these systems are provided below.

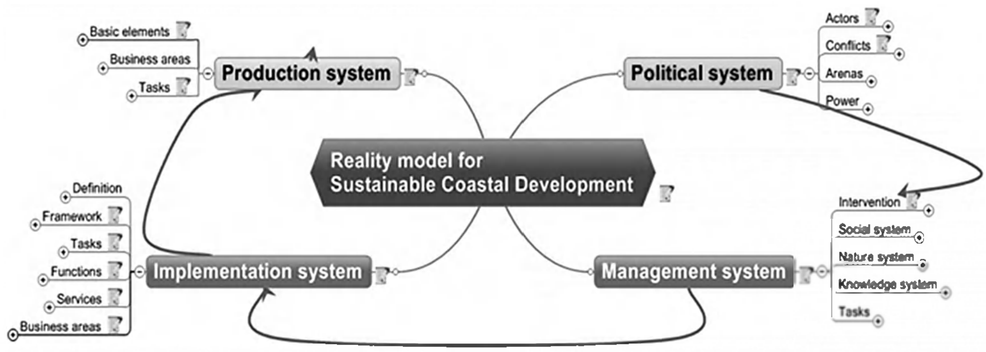


Figure 3.7.4. The reality model.

Political system – The political or social system describes the actors, conflict areas and causes for conflicts, the arenas for political activity and discussions, and the power and tools available to actors when addressing their interests. The political system is the study arena for social science, as detailed in Figure 3.7.5.

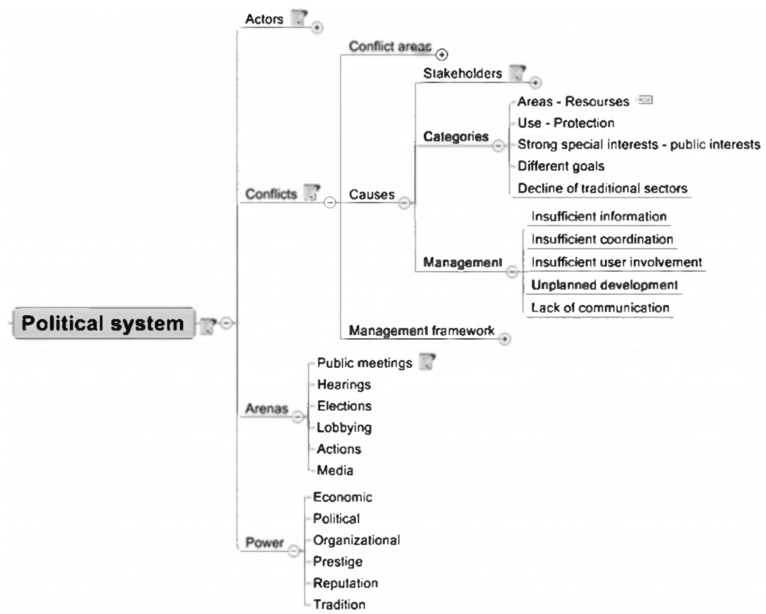


Figure 3.7.5. Details of the political system.

Management system – This includes activities that are mainly the responsibility of the authorities (Figure 3.7.6), and have a link to the political system represented by the arenas for intervention between stakeholders, institutions, legislation, and management. To achieve knowledge-based management, a manager needs effective information systems that provide access to relevant information for planning and control. As the complexity and pressure on resources increases, there will be a need for more dynamic management, which can be achieved by a close and responsible partnership between private and public users. The private sector has experience and knowledge that will support management, and the reality model can act as a common platform for a dynamic private–public management system based on best practice.

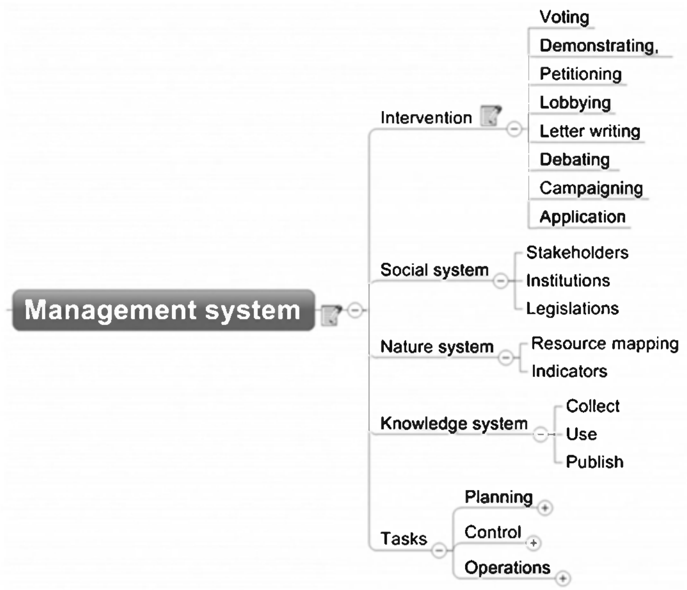


Figure 3.7.6. Some details of the management system.

Implementation system – The implementation system includes activities or measures needed to attain overall goals, and it can be the production of food or energy, a management activity, or even an environmental protection measure. Implementation needs, however, to be based on operational goals that are the result of a political, administrative, or business process. Operational goals often represent political and practical compromises, but should also include plans for how to communicate to the public what is going on, so the role of the media and the importance of public reputation have to be included. The implementation phase includes all functions and services needed for performing safe and efficient activities, and the architecture is the basis for technically specifying these functions and services. Prerequisites for using decision-support tools are access to standardized information and control of the uncertainty in the information used, elements which are in themselves important inputs to the risk assessment. Another important aspect is the level of risk acceptance, which will be different for different actors, regions, and cultures. More detail is shown in Figure 3.7.7.

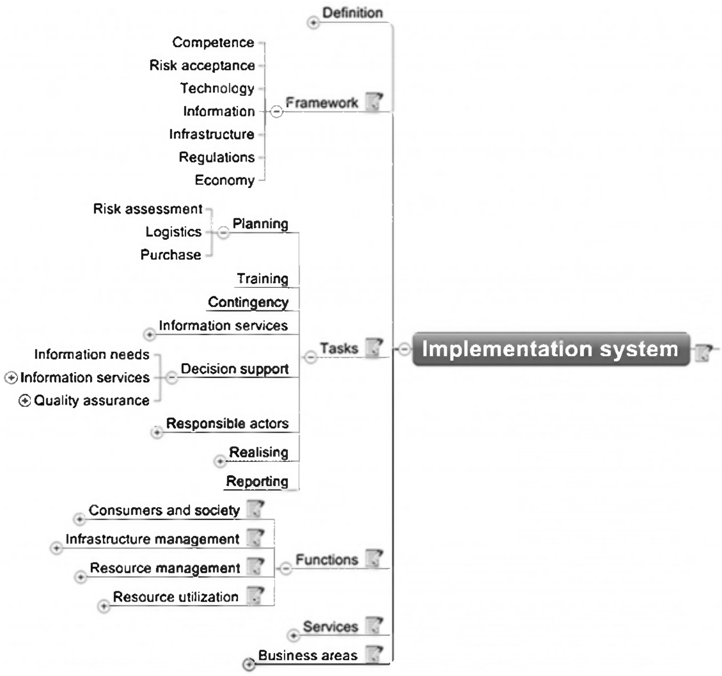


Figure 3.7.7. Some details of the implementation system.

Production system – The production system includes all the activities undertaken with the purpose of making money by indirectly or directly exploiting natural resources. Detail is not provided here, but what needs to be stressed is the close connection between the political and the production systems; many of the users and stakeholders active in the political system represent economic interests (see Figure 7.4).

Integrated model

When looking carefully at the overall (total) model, it is not surprising that it is complicated, especially when one realizes that the current version represents just a small part of the total architecture (Figure 3.7.8). The benefit, however, is that the model is connected at the top level and that details can be added later without changing the overall structure. One actor can follow the architecture from the top down to a certain level, then farther down relate only to his single discipline of interest. The architecture is important, however, in reducing the risk of failure in management by providing all actors, especially the manager, with an overview and insight of the total picture. The architecture has two main functions: it is a systematic means of collecting information and a method of illustrating relationships and dependence between elements. Of course, it can be expanded by including new information or experience and hence be a valuable tool for developing and describing best practice.

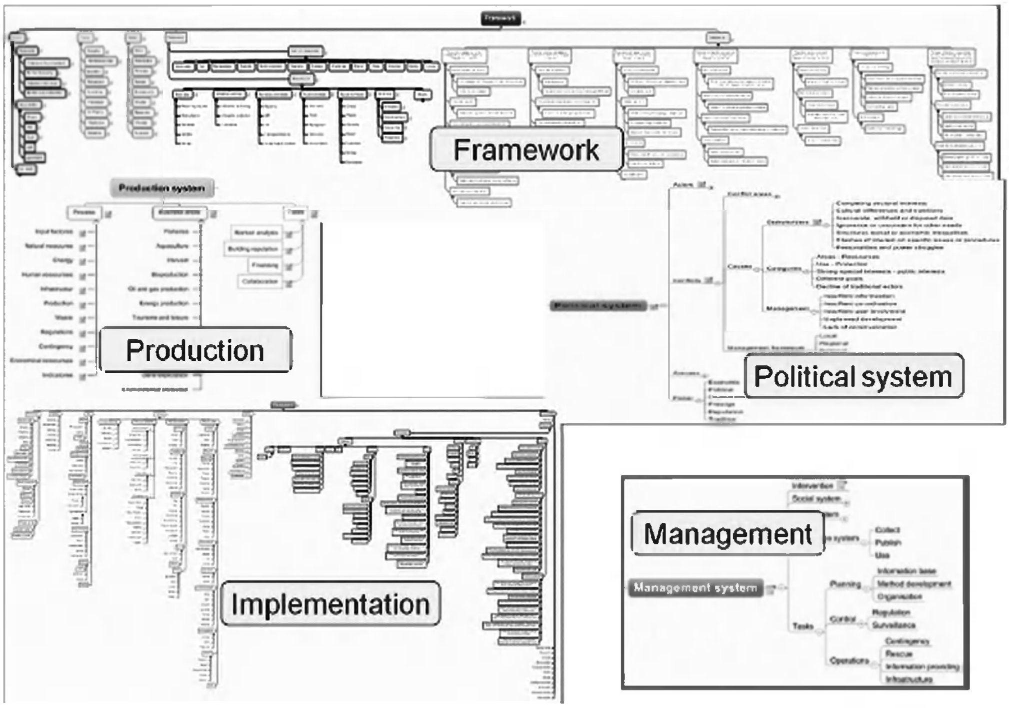


Figure 3.7.8. Details of the architecture.

Conclusion

Integrated coastal-zone management includes many challenges, and there is a need for knowledge-based decision support. Some of the challenges can be summarized as listed below:

- simple solutions not based on knowledge of the total system can lead to catastrophe;
- one cannot carry out experiments on full-scale socio-economic systems;
- humankind is an important part of the problem;
- simple economics may overrule environmental protection and sustainable development.

Hopefully, the content of this subchapter has presented an adequate, though short, description of an architecture for coastal-zone development. The architecture itself is subdivided into a framework and a reality model, the framework being a systematic information system based on an object-orientated concept, and the reality model a description of roles and activities, how they are interconnected and how each relates to the framework.

There are many reasons for using such an architecture. Some of these are to

- gain a total view of reality;
- be a common platform for discussion among stakeholders;
- reveal and hopefully solve conflicts;
- be a system to integrate knowledge and experience;
- develop "simple" integrated and knowledge-based best-practice solutions.

Once again, it needs to be stressed that this version of the architecture is preliminary, representing more of a concept than a real model. It is important to point out that the approach is just a concept for knowledge integration and cannot replace established knowledge and methods. The intention, however, is that the concept can be a platform for cross-disciplinary, cross-sectoral discussions, and ultimately lead to best-practice solutions for coastal-zone management and development.

3.8 The Gerrico project: when modelling helps integrated management of a coastal area

Laurent Barillé, Morgan Dussauze, Stéphan Gaillard, Julian Gille, Benoist Hitier, Laurent Le Grel, Hélène Oger-Jeanneret, Marc Robin, Martin Sanchez, and Cyril Tissot

The Gerrico project is managed jointly by Ifremer and the University of Nantes, and focuses on the Bay of Bourgneuf. Located in the southern part of the Loire estuary on the French Atlantic coast, the bay is utilized extensively for oyster farming (13 000 t annually) and is characterized by many habitats, such as seagrass beds and honeycomb worm reefs. The Bay of Bourgneuf has been faced with a number of problems in recent years related to oyster growth and edible quality, survival rates, the maintenance of water quality and biodiversity, and the sustainability of oyster farming and related activities. The originality of Gerrico lies in its objective to develop methods capable of taking the entire area into account, from watersheds down to marshes and the coastal zone, using a chain of coupled models to integrate different activities by combining physical modelling (sedimentology, hydrodynamics), biological modelling (growth of algal biomass, oyster growth), and economic modelling (managing oyster-rearing parks at the scale of the production basin or the shellfish-farming business as a whole). The common issue driving this approach is water quality; optimization of coastal activities depends heavily on it. Several scenarios at different spatial and temporal scales (increasing nutrients, oyster growth variability between sites, impact of trophic competitors such as slipper limpets and wild oysters, and water-carrying capacity), for example, have been implemented in order to simulate the biological and socio-economic consequences of different types of management. The objective is to establish a dynamic tool that will provide a reliable platform for integrated management of the coastal area.

Keywords: coastal area, ecological modelling, economic modelling, marshes, oyster farming, physical modelling, watersheds.

Introduction

Coastal marine resources are one of the natural riches of the Pays de la Loire region in France. They are fragile, nevertheless, and subject to high levels of demand by many different users. The inherent risks of exploiting natural resources are heavily influenced by the sum of human activities that create increasing pressure on the coastal strip and can lead to problems, conflicts, and wastage. Ifremer (the French Instutute for Exploitation of the Sea) and the universities of Nantes and Brest joined forces in 2007 in response to a call for action on the part of the Pays de la Loire regional authorities to address these challenges. The purpose of Gerrico is to create a centre of expertise on the sustainable management of marine resources and risk in coastal areas, and ultimately to advance fresh solutions for their management. For this reason, a major component of the project is the development of appropriate tools to help decision-makers.

The project focuses on oyster culture, which is particularly sensitive to environmental changes, and the development of human activities such as tourism, agriculture, and industry. It has become apparent as the project runs its course that the rearing of bivalve molluscs poses a number of problems that can only be solved by a multidisciplinary approach, and many research teams are now collaborating and combining their different skills in marine biology, physiology, economy, geography, and marine technology to address the specific problems this industry faces.

The Bay of Bourgneuf (Figure 3.8.1) was selected as a pilot site for a variety of reasons. Some of the human activities have existed there for many years (oyster farming, salt production) and some are more recent (tourism, spat production), and the bay also has interesting physical and biological features (saline underground waters used for oyster-rearing and spat-production). It is located in the southern part of the Loire estuary on the French Atlantic coast, sheltered from the ocean by the island of Noirmoutier, which is today linked to the mainland by a bridge.

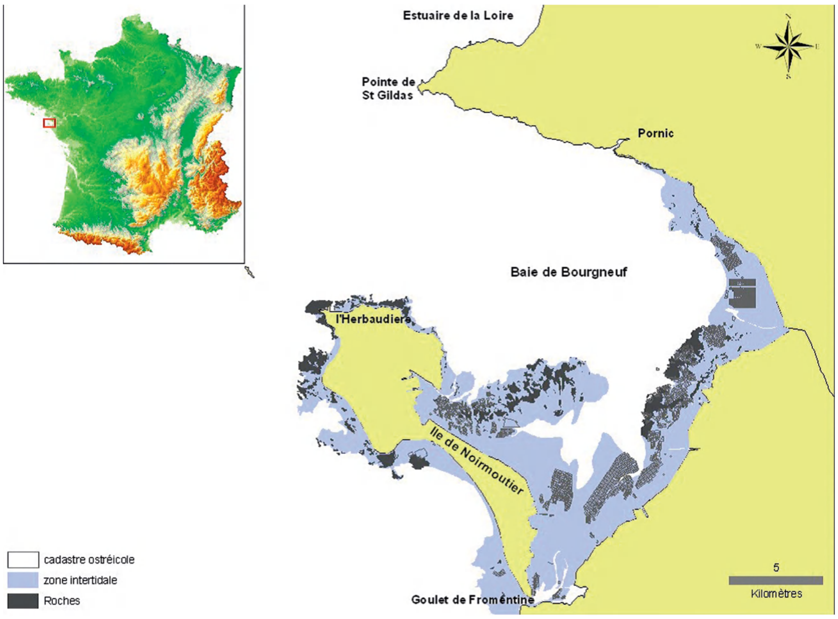


Figure 3.8.1. Location of the Bay of Bourgneuf.

The mean depth of the bay is ca. 10 m and its tidal range is ca. 6 m. Turbidity levels can reach 200 g l^{-1}, as a consequence of the combined effects of flooding in the Loire estuary and the fine sediments lying in the bay (Gouleau, 1968). The intertidal zone covers an area of ca. 100 km^2, having both environmental and economic importance, and there are many fascinating habitats, such as seagrass beds and honeycomb worm reefs. Moreover, the area is used intensively by oyster farmers: 13 000 t of oysters (10% of the total French oyster production) are produced annually by some 300 farms in the Bay of Bourgneuf.

For a number of years, the Bay of Bourgneuf has been facing problems such as varying oyster growth rate (closely depending on turbidity levels and the concentration of oysters growing on the banks), survival rate, product quality, spat availability, food safety, and the maintenance of water quality and biodiversity. Knowledge gaps include information on hydrosedimentary exchange between local watersheds, the Loire estuary, and the Bay of Bourgneuf, and the impacts of turbidity, pollution, and climate change on oyster growth. In the past such problems have generally been studied separately, but Gerrico aims to take all the problems of the bay into account to increase understanding of how the bay functions globally and to be able to propose the best possible solutions.

Administrative structure of the Gerrico project

Gerrico is run jointly by Ifremer and the University of Nantes, and is monitored by an Evaluation and Diffusion Committee (EDC) that assesses the results produced by Gerrico's teams and sets out guidelines to improve research initiatives (Figure 3.8.2). The EDC consists of local partners (oyster-farming and salt-culture syndicates, the Water Agency, and associations for water management or environmental protection) and three independent scientists.

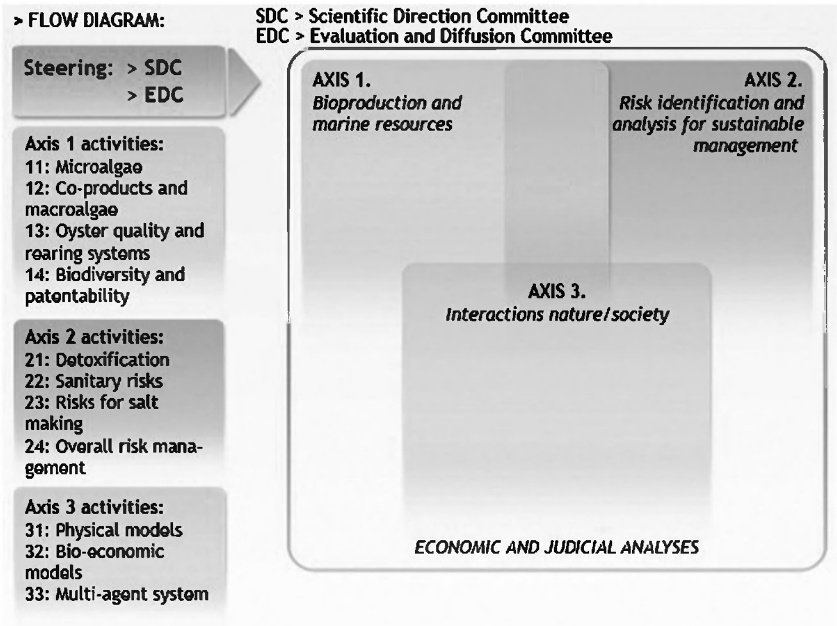


Figure 3.8.2. Administering the Gerrico project.

The project covers three main areas, outlined below.

- *Bioproduction and marine resources* – This part of the project proposes to develop knowledge and production techniques along with their commercial applications in the areas of microalgae, shellfish farming, macroalgae, and fishery by-products, including new techniques and procedures of potential interest for sustainable production. As these questions are likely to stimulate wide public debate, scientists specializing in maritime law work in the area of marine biodiversity and the patentability of living matter and related legal aspects.
- *Risk identification and analysis for sustainable development* – The second part of the project enhances understanding of the different risks oyster farmers have to face, including the risk to public health (microbiological), toxic risk (microalgae), the overloading of shellfish-farming basins, multiple uses of the waters in and around the coastal zone, and interactions with other local users (agriculture and tourism). The outcome will be the identification of means of prevention, corrective action, and management that account for the frequency with which these risks arise, their intensity, and correlations between them.
- *Interactions between nature and society* – The third part of the project is to study how inputs from local shellfish farming, and those from the sea and

the estuary, affect water quality in the Bay of Bourgneuf, and to analyse the resulting constraints (natural, human) on oyster rearing. This is achieved by combining physical, biological, and economic modelling to build different development scenarios and simulate their impact. The results obtained in this part of the project are detailed below.

Material and methods

The originality of the third part of the Gerrico project lies in its objective to develop methods capable of taking the entire area into account, from watersheds down to marshes and the coastal zone. The common issue driving this approach is water quality, because it is that on which the optimization of coastal activities depends. This part of the research aims to establish a method that will provide a firm basis for integrated management of the whole coastal area.

The proposed methodology consists of building and combining models from the watersheds down to the coastal zone. This means that one or many models will be developed in any one project part or "compartment" (Figure 3.8.3):

- an agro-hydrological model in the watersheds compartment;
- a hydraulic model in the freshwater and saltmarsh compartment;
- in the bay itself, physical models (hydrodynamics and sedimentology), biological models (growth of algal biomass, oyster growth), and economic models (at the scale of a group of individual farms or at the scale of the whole production basin).

The outputs each model provides become inputs for the subsequent model: for example, nitrogen as an outcome of the hydraulic model will be used directly as input for the hydrodynamic and sedimentary model. Furthermore, at each step of the process field data are collected for the purpose of validating the different models.

An artificial intelligence model is envisaged for the purpose of suggesting different scenarios and simulating their impact. The model is based on fine-scale spatio-temporal descriptions of practices in the basin. The main idea consists of building a decision tool (a management tool) for coastal managers that will help them identify priority areas where intervention is most needed to restore coastal water quality.

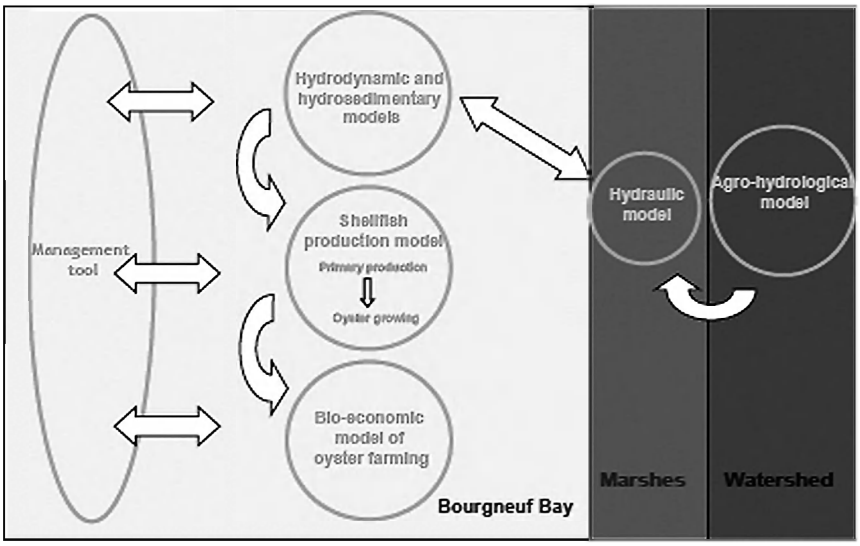


Figure 3.8.3. The principle of coupling between models in the different project compartments.

Several models were employed for the purpose of studying the Bay of Bourgneuf and its watershed system, adapted to suit the study zone in question; in some instances, the models were interconnected. They are listed below.

- The *agro-hydrological SWAT model* interfaced with ArcGIS (Di Luzio *et al.*, 2002) models what happens to diverse substances utilized or produced in watersheds (nitrates, phosphates, bacteria, phytosanitary products, etc.) as a function of land use (Conan *et al.*, 2003; Lomakine, 2005).
- *Mascaret* is a mono-dimensional hydraulic model (CETMEF, 2008) that tracks what happens to diverse substances traversing the marshland.
- The *hydrodynamic Mars 2D model* (Salomon *et al.*, 1991) has been used for many years to predict the behaviour of contaminants and the movements of larvae in the coastal zone (Riou *et al.*, 2007).
- The *hydrosedimentary model, MIKE 21* (DHI, 2007), reproduces the behaviour of materials in suspension (Sanchez, 2008), this being a vital component in the overall functioning of the Bay of Bourgneuf (for silting and phytoplankton growth).
- The *biogeochemical ECO-MARS 3D model* (Ménesguen *et al.*, 2006; Lazure and Dumas, 2008) spatially displays variations in primary production in the bay (simulation of temperature, chlorophyll *a*, and utilization of the solids in suspension as output from *MIKE 21*).
- A purpose-built *biological oyster growth model* based on a Scope for Growth type model (Barillé *et al.*, 1997) was developed for the Bay of Bourgneuf (Haure *et al.*, 2008), and uses the data provided by *ECO-MARS 3D* as input.
- Coupling of the *economic and oyster growth models* was initiated using the STELLA application to simulate the changing numbers of oysters being cultivated by the different types of oyster-farming enterprise.
- Finally, a *multi-agent model* utilizes output data from hydrosedimentary, biological, and economic models to simulate how these activities operate at the scale of the individual marine concession (Tillier *et al.*, 2010).

Results and discussion

- The *agro-hydrological SWAT model* is based on an exhaustive database structured around ArcGIS. The model has been calibrated and can simulate watershed flows using land use and land occupation as a starting point, complementing this with meteorological and pedological data. The contribution each drainage basin makes to the flows entering the bay can be quantified and visualized (Figure 3.8.4). These drainage basins are mostly agricultural, and the main substances tracked are suspended matter and nutrients. Phytosanitary products were not simulated by the model, because of the problems associated with obtaining reliable information on some of the agricultural practices in the area. Simulated data ouput from the *SWAT model* is used as input data for the *Mascaret* model.

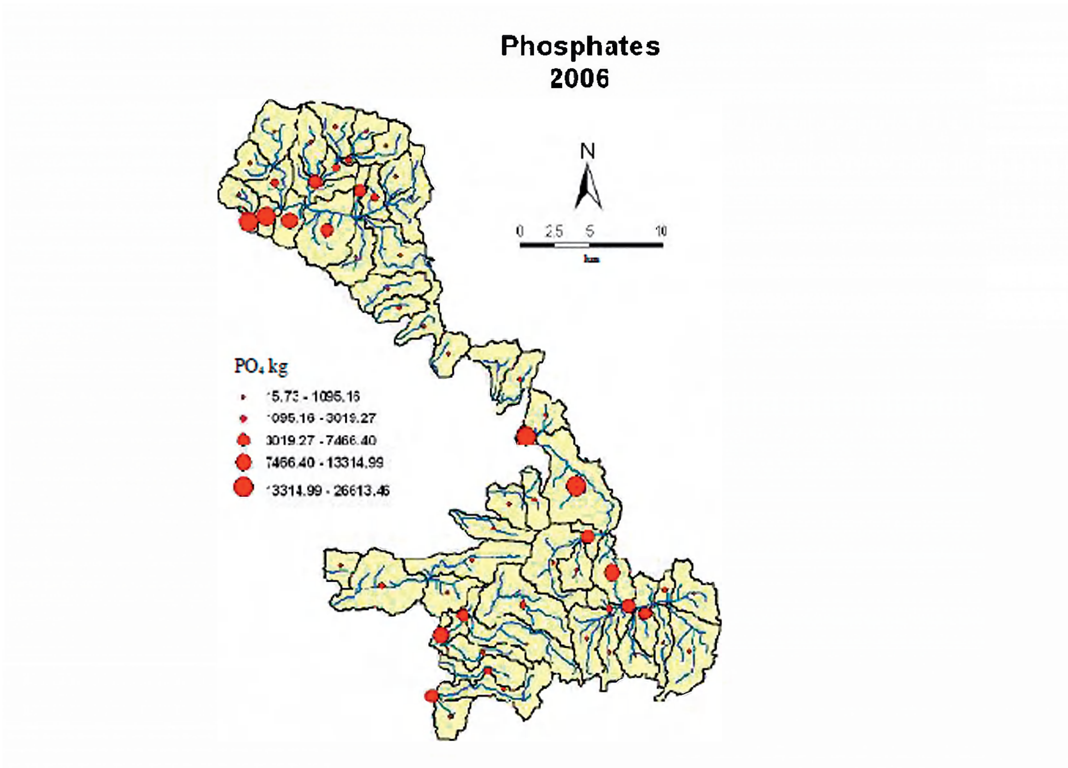


Figure 3.8.4. Identification of drainage basins yielding the highest levels of phosphate.

- Modelling the marshland area using Mascaret represents an original advance because the hydraulic complexity of this type of zone situated between watershed and coastal water is rarely taken into account. Because of the relative complexity of the task, it was decided to model just the Falleron, the river responsible for the main inputs into the bay. The modelling made it possible to assess for the first time how long it takes water to traverse the marshland, under different hydrometeorological conditions and when subjected to different types of hydraulic management. Difficulties encountered were mainly related to the lack of detailed information on managing the hydraulic installations. Today, all *SWAT* routines and modules are implemented to simulate pesticides and bacteria, although some input data are still lacking, e.g. the amount of pesticides used and how much *Escherichia coli* comes from sewage plant discharges. Moreover, output data are as yet insufficient to calibrate and validate the model, so the work remains in progress while new datasets are sought. Nevertheless, recent results show that the 1-D model is a reliable tool for simulating pollutant transfer through coastal wetland drainage channels, and it is possible to link landward and seaward models to *Mascaret*, which allows water and pollutant propagation from watershed to coastal sea through wetland drainage channels to be simulated with a high level of confidence (Gille *et al.*, 2012).

- The *Mars 2D model* has allowed the construction of a number of simulations of dissolved substances (phytosanitary products, bacteria, nutrients). An attempt was made to couple the *SWAT*, *Mascaret*, and *Mars 2D* models to track the movement of nitrates from the Falleron drainage basin through to the oyster parks (Figure 3.8.5). The results demonstrate that it is possible to set up a modelling chain allowing simulation of transfers of water and solids in a continuum formed from different types of environment (drainage basins, coastal wet zones, coastal waters). Once perfected, such a modelling chain could be deployed in a coastal management setting (Gille *et al.*, 2009).
- The *hydrosedimentary model MIKE 21* was used to map the turbid plume observed in the Bay of Bourgneuf in fine detail, notably through refinements made possible by the utilization of Lidar altimetric data acquired in 2008 on the intertidal zone (Dussauze *et al.*, 2009). The *MIKE 21* model was validated (Figure 3.8.6) using ground-truth data (Acoustic Doppler Current Profiler (ADCP), altimeter, etc.) and satellite imagery (Lerouxel *et al.*, 2007). The model succeeds in reproducing variations in the intensity of turbidity in the bay. These variations are partly caused by some bottom sediment returning to suspension (owing to water turbulence, for example), and this is now taken into account by our model. The output data from this model are used as input for the primary production model.
- The *biogeochemical model ECO-MARS 3D* simulates the evolution over time of the three forcing variables from the *oyster-growth model* (Dussauze, 2008): temperature, the concentration of suspended matter, and the concentration of chlorophyll *a* (an estimator of food utilization).
- The *oyster-growth biological model* uses data provided by *ECO-MARS 3D* as input data. A comparison of growth simulations and observations reveals a close match between model and data for the three main compartments of the *oyster-growth model*: gonad reserves, soma, and oyster-flesh dry weight. The results of the growth simulation reveal strong spatial variability, depending on the oyster-producing area, as a function of immersion time and above all turbidity intensity (Figure 3.8.7, right). Finally, a coupling of this model with *ECO-MARS 3D* allowed the construction of different scenarios with varying stock concentrations of trophic competitors (slipper limpets and wild oysters; Figure 3.8.7, left). The ecosystem model now functions with a realistic turbidity signal, and equally well for short-term (semi-diurnal tidal cycle) and seasonal variations, representing a significant improvement in the ability to simulate the way a macrotidal ecosystem operates, and this for ecosystems with some of the highest turbidity levels in western Europe (Barillé *et al.*, 2004).

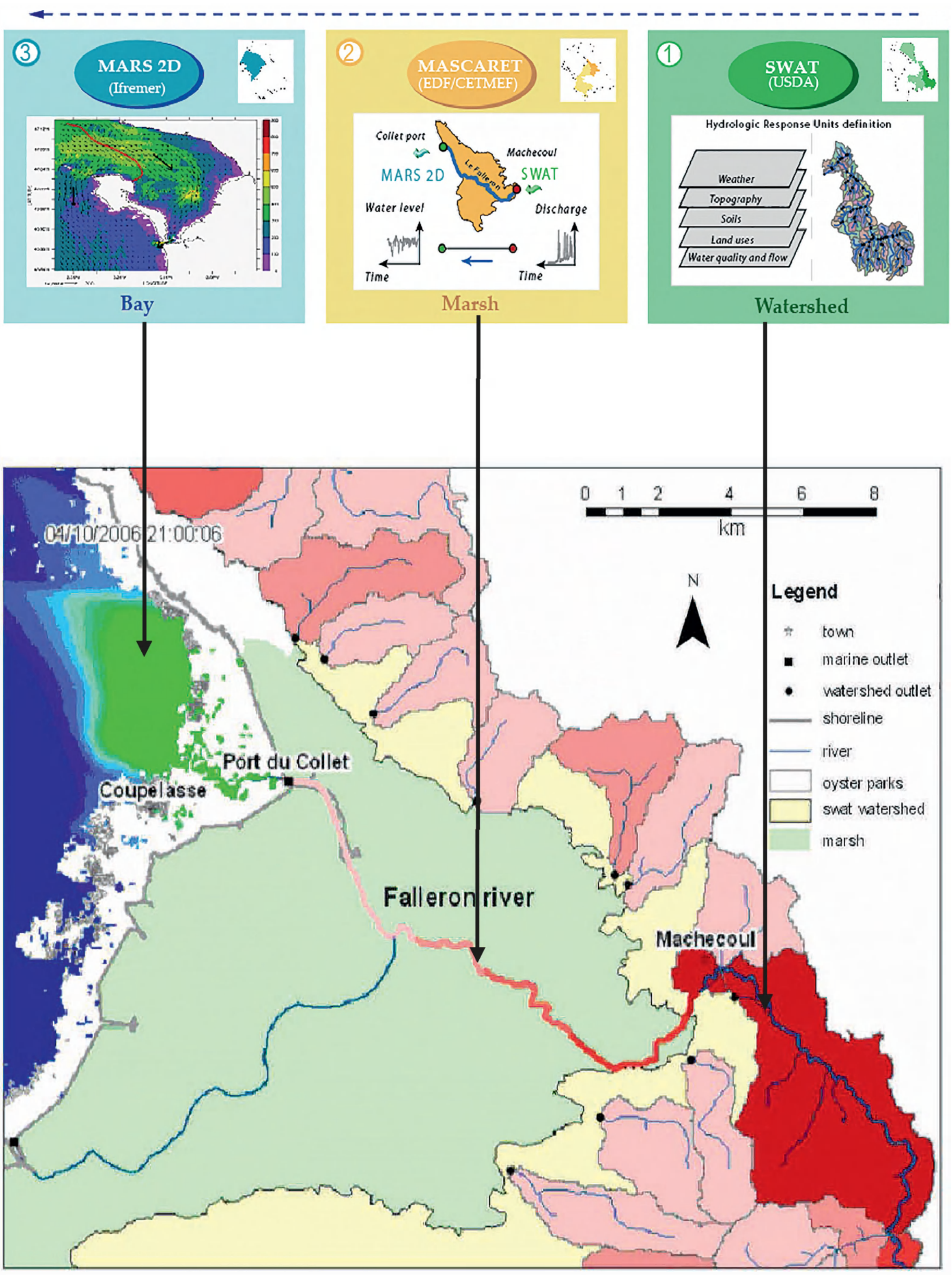


Figure 3.8.5. Coupling circulation models for water and solid flows.

- To perform *Economic modelling* of oyster-farming activities in the Bay of Bourgneuf a survey was conducted directly with individual enterprises, and countable data was gathered. Three types of enterprise were defined together with their financial profiles, considerably improving knowledge of oyster farming in the Bay of Bourgneuf (Le Grel and Le Bihan, 2009). However, some areas still remain obscure owing to difficulty in accessing information on oyster-farming practices.

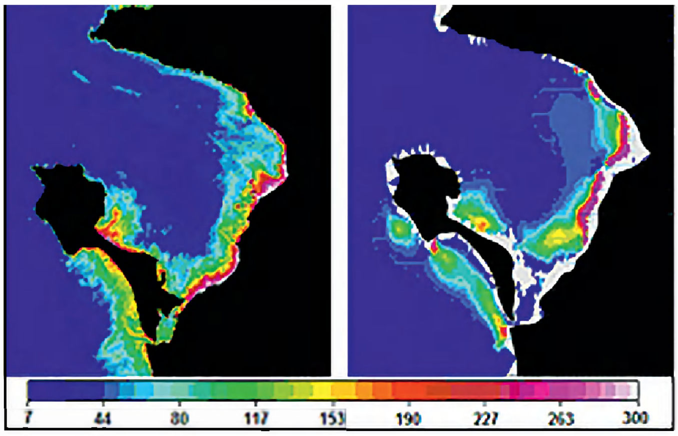


Figure 3.8.6. Turbidity (mg l⁻¹) in the Bay of Bourgneuf. The left panel shows a SPOT image taken at 11:00 on 13 December 2005; the right panel image is produced by the *MIKE 21* model, taken on the same day and at exactly the same time.

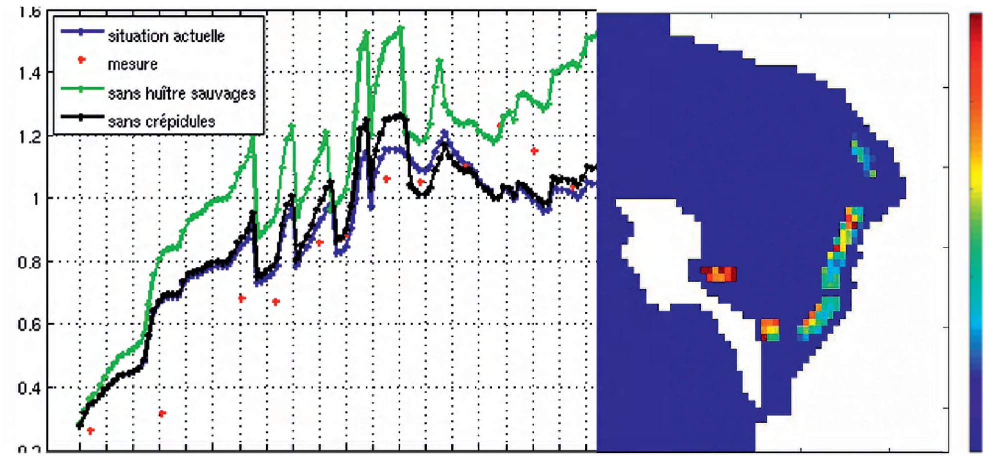


Figure 3.8.7. Impact of populations of trophic competitors. Left: slipper limpets and wild oysters *Crassostrea gigas*, March–September 2005, with field measurements in red, the modelled current situation in blue, without wild oysters in green, and without slipper limpets in black. Right: spatial variations in the annual growth of oysters.

- The results obtained with the *DAHU-MAL multi-agents platform* are essentially methodological. Nevertheless, case studies allow us to illustrate how activities evolve while taking into account production strategies, the associated spatial organization, and the different species involved. For instance, a simplified version (Haure *et al.*, 2008) of the model produced by Barillé *et al.* (1997) was implemented within the platform, allowing simulation of the impact of turbidity on oyster growth and how production infrastructures might be usefully adapted. The results from this model match the ones from the biological model well (Figure 3.8.8). The copious quantities of various data needed to validate the different steps of the production cycle present further difficulties. Finally, the development of scenario-based and foresight approaches is being explored with a view to contributing to better management of shellfish farming (Tissot *et al.*, 2012). The approach combines two objectives: (i) to test the resilience of current production facilities when faced with declining production conditions (associated with unexpected mortality or decline in environmental performance); (ii) to assess the relevance of partial transfer of current production systems to offshore facilities and their potential within the Bay of Bourgneuf. Collaboration with the local oyster farmers' association is allowing us to test scenarios for introducing an offshore longline system for some of the oyster production.

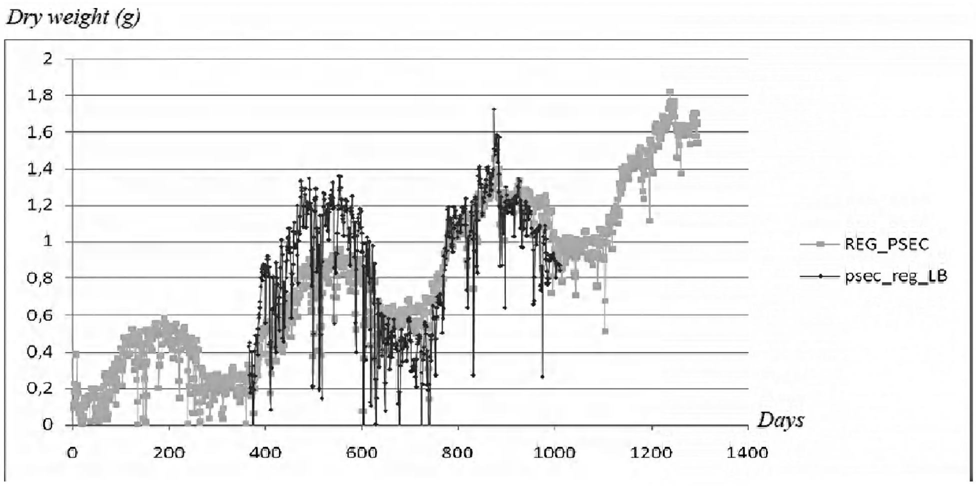


Figure 3.8.8. Variability in dry weight of *Crassostrea gigas* under environmental constraints (temperature, chlorophyll *a*, suspended matter) over the period 2004–2007. The simulation using a multi-agent model is shown in red, and using a biological model in blue.

Conclusion and new perspectives

The results obtained already demonstrate the possibility of setting up a modelling chain to simulate the transfer of water and solids in a continuum that includes different types of environment (drainage basins, coastal wetlands, and coastal waters). The coupling of models represents a significant advance in the integration of tools for scenario construction and decision support. A scenario integrating all project compartments has been tested, opening possibilities for other scenarios such as shellfish culture offshore, the deteriorating quality of coastal waters, or changing agricultural practice.

This new tool allows practitioners to work with greater precision on problems linked to bacterial concentration and concentrations of phytosanitary products and their elimination, a critical problem in numerous coastal zones. Nonetheless, new avenues for perfecting the system may be useful to explore, whether at a) a thematic level, with the refining and enhancing of some data relating notably to agricultural and oyster farming practice, or b) a technical level, with, for example, automated coupling between models.

3.9 Participatory approach to identifying governance indicators for integrated coastal-zone management: the case of marine protected areas

Gilbert David, Bertrand Cazalet, Anne-Sophie Barnay, Eric Charbonnel, Emmanuel Coutures, Jocelyne Ferraris, Pierre-Gildas Fleury, Pauline Malterre, Nicolas Pascal, Dominique Pelletier, Pascale Salaun, Emmanuel Tessier, and Aurélie Thomassin

Marine protected areas (MPAs) are a laboratory of integrated coastal management. Driving an MPA system requires the implementation of a battery of indicators of governance, governance that must consider both the internal dynamics of the system and the threats arising from the system environment. As part of a research project funded by the French Ministry of Ecology (the Liteau Programme), four coral reef MPAs were selected as pilot studies (St Martin in the Caribbean, Réunion and Mayotte in the Indian Ocean, and the South Lagoon of New Caledonia in Oceania) to develop MPA governance indicators jointly between scientists and managers. The approach is bottom-up and based on the co-construction of indicators. In that way, the views of scientists bringing their knowledge of governance and ICZM were matched with the views of MPA managers bringing their field knowledge and specific requests relating to the management of MPAs. The process was conducted in five steps, and the main indicators are presented and discussed.

Keywords: French overseas territories, governance indicators, ICZM, marine protected areas, participatory approach.

Introduction. Marine protected areas as a laboratory of integrated coastal management

In general terms, management is "the application of a set of decisions in the service of a strategy to achieve the objectives defined in relation to issues" (Corlay, 1998). Coastal area management aims either to avoid or reduce conflicts of use, to limit human pressures on natural resources or areas considered at risk of overexploitation. It proceeds by establishing zoning and a management plan that regulate the uses of each type of zone. The application of these principles is subject to various drivers. Hence, coastal management usually varies from a prescriptive approach to a negotiated one. The prescriptive approach is the oldest. It inspired the bulk of public policy development and management of the French coastline from 1970 to 2000 and remains active in the French administrative culture. Under that perspective, integrated coastal-zone management (ICZM) should be "the disposition of each coastal segment to the most appropriate business, according to decisions taken by the public authorities in light of scientific knowledge, thanks to which we can ensure consistency in the use (avoiding the adverse effects that would result in sterilization of the rich shores), and harnessing the energy of nature to serve our needs rather than abruptly counter the natural system" (Pinot, 1998). This prescriptive approach put space at the centre of the management process: it proceeds by rules, and takes little account of the views of local people, from whom we expect strict compliance.

On the opposite side, a negotiated approach aims to involve stakeholders in the management process, particularly in defining management objectives and the regulations associated with them. Ideally, such participation of the population in coastal management is endorsed and institutionalized in the form of co-management agreements. Between the prescriptive approach and the negotiated approach, however, most ICZM strategies currently in force are hybrid approaches because they involve practices from both sides.

Marine protected areas (MPAs) have experienced a similar developmental trend. Introduced to preserve marine biodiversity or ensure its recovery, they initially operated under a unique model in which the local population was excluded. In such a conservation/exclusion model, local people were considered a set of poachers or potential spoilers of habitats to preserve. This conservation/exclusion model tends to be replaced today at the international level by a conservation/participation model. According to its logic, biodiversity cannot be preserved without the support of the local population. Given the strong interactions between an MPA and its adjacent land, where humans live and work, MPAs are clearly a laboratory of integrated coastal management.

The contribution of scientists to the study of MPAs

This trend from exclusion to participation in the operating model of MPAs leads to a step-change in the input of scientists in MPA management. Under the preservation/exclusion model, their role was essential. Zoning and its associated management rules were driven directly by scientific knowledge, including the monitoring of MPA habitats and biodiversity. Hence, management of the MPA was limited to the regulation of the relationship between a predator and its prey. Predators are MPAs users and local populations and prey constitute the ecosystem that needs preservation.

With transition to the conservation/participation model, the task of MPAs becomes more complex. They need to continue to address the predator/prey relationship directly, but they also have to work with the predators (humans) in order to self-limit their predation. Yet because of their initial training focused on the ecology and biology of marine populations, MPA managers are powerless to address these new facets of their business. Scientific knowledge of habitats and their biodiversity is of no help in this work. In this framework, the contribution of scientific knowledge in MPAs is doomed to decrease unless it provides managers with a new field of knowledge dealing with the MPA users (the predators), their uses of the ecosystem, their perceptions about the ecosystem, their impact on it, and the rules established by MPA managers to protect it. This type of knowledge deals with governance and belongs also to the field of social science. Usually, the involvement of such science in the acquisition of knowledge of MPAs and their management is low, but demand is increasing dramatically in the form of more general knowledge of the coast and its management. Therefore, we deal here with the governance of MPAs. The work is part of an applied research project known as PAMPA and funded by the French Ministry of Ecology (the LITEAU Programme).

The PAMPA project

The project aims to develop and validate indicators of the performance of MPAs in managing coastal ecosystems, resources, and their uses. The indicators need to be presented in the form of a dashboard, permitting managers to drive their MPA in a sustainable manner. Three types of indicators are included in this dashboard, the first dealing with the status and dynamics of the ecosystem and related resources in and around MPAs, the second with the impact of uses on the ecosystem and resources and the role of MPAs in the nature and extent of the impact, and the third with the state of governance and the role of MPAs in coastal space use dynamics, including user conflicts. Eight study sites were selected, four on the French coast of the Mediterranean, four in French overseas territories. The process of developing governance indicators is most advanced in the latter group, so this case subsection deals only with these four tropical MPAs: St Martin in the Caribbean, Réunion and Mayotte in the Indian Ocean, and the South Lagoon of New Caledonia in Oceania. All contain broad areas of coral reef. The approach used to building the governance indicators is presented first, followed by a presentation of indicators and a discussion on the prospects of applying this type of approach in the context of ICZM.

Methodology: the process of building MPAs as governance indicators

The approach is definitely bottom–up, based on the co-building of indicators. In that way, the views of scientists bringing knowledge of governance and ICZM are cross-matched with the views of MPA managers bringing their field knowledge and specific requests relating to the management of MPAs. The process was conducted in five steps, outlined below.

The first step was a critical review of the governance indicators proposed by Pomeroy *et al*. (2004) in their guide published by the International Union for Conservation of Nature (IUCN) to assess the effectiveness of MPAs. Presented at the first overseas PAMPA project workshop in Noumea in June 2008, this critical review was supplemented by discussions with participants: all the MPA managers in New Caledonia, representatives of the public authorities involved in coastal management in New Caledonia, and the MPA managers of Réunion and Mayotte. The discussions led to the development of an initial set of 40 indicators focusing on three themes: (i) establishing and maintaining structures and management strategies, (ii) participation and representation of actors, and (iii) acceptance of the MPA and conflict reduction (Pelletier *et al*., 2008; David, 2009).

As a second step, these indicators were presented to the first national PAMPA seminar held in Brest in November 2008. A critical review of the indicators was started then, being conducted fully for the second overseas PAMPA project workshop, held in Réunion. Finally, 43 indicators were proposed (David *et al*., 2009a).

The third step involved these 43 metrics being discussed by managers and scientists involved in the project during the second national PAMPA seminar, held in Marseille in December 2009. This dialogue resulted in a list of 66 indicators of governance (David *et al*., 2009a). Of course, this total is too large to be operational within a dashboard of indicators to drive an MPA. At the conclusion of that seminar, therefore, all PAMPA stakeholders (managers and scientists) were asked to select among the following metrics of governance:

- a set of ten (key) indicators prioritized for inclusion in the final dashboard;
- a set of ten indicators considered secondary but still important for MPAs;
- specific indicators rarely shared with other MPAs but which seem compulsory to local governance (David *et al*., 2010).

Then, as the fourth step carried out during the first five months of 2010, 13 indicators were selected as key or important secondary indicators.

As the fifth and final step of the process, the selection was validated during a workshop held in Banyuls, France, in June 2010.

Results

The 13 indicators selected deal with four major topics: (i) the control of the regulation, (ii) the sustainability of management, (iii) the participation of local stakeholders in MPA management and its activities, and (iv) the acceptance of the MPA, and reducing conflict (Table 3.9.1).

Table 3.9.1. The major topics of the 13 indicators of MPA management.

Topic	Number of indicators
Sustainability of MPA management	2
Implementation and enforcement of MPA rules	2
Participation of local stakeholders in MPA management and its activities	4
Acceptance of the MPA, and reducing conflict	5

To adequately fulfil its role of protecting and restoring biodiversity, any MPA needs to be sustainable, so securing financial resources is a central element of its strategy. In the French context, the financing of MPAs is covered by the government: state, regions, departments, and municipalities. These funds are therefore considered to be secure, although the total of such budgetary allocations may vary according to the economic or political situations at the different institutional levels. Ideally, the amount increases with inflation, but in an environment characterized by greater volatility of budget, as is the case in many countries in the tropics, secure budgets for MPAs require the loyalty of big donors, who each provide at least 25% of the budget of the MPA. The role these loyal donors play in the budget of the MPA is vital: the risk of crisis in the finances of an MPA is reduced when such loyal donors play a key role in the management.

In addition to financial security, any MPA, to be sustainable, needs to fulfil for a notable time its main objective of preserving remarkable marine ecosystems and restoring them when they are damaged. Such a goal requires monitoring of the protected marine area, arresting offenders and deterring poaching and other offences by the mere presence of MPA staff, and regular monitoring of the state of ecosystem health in order to measure the impact of MPA management in conservation or restoration. To be sustainable, an MPA requires a large portion of its worktime to be mobilized on both tasks (Table 3.9.2). All other actions are secondary, including environmental awareness and education, although the latter task tends to take on growing importance in MPAs because it is hoped that it will change stakeholder behaviour in the direction of better marine ecosystem conservation. However, it is difficult to assess the effectiveness of such outreach, and there is a risk that some MPAs require more than half their time spent on this issue at the expense of implementation and enforcement of MPA rules, including maritime surveillance, and monitoring the state of health of the ecosystem. If these two latter tasks mobilize < 25% of the MPAs worktime, the MPA can be considered to lose its effectiveness and well on its way to becoming a paper MPA.

Table 3.9.2. Indicators dealing with the sustainability of an MPA.

Indicator	Comment
Percentage of time spent working by MPA staff dedicated to (i) implementation and enforcement of the rules and (ii) monitoring of ecosystem health	Provided directly by MPA staff
Percentage of aid donors providing 25% of the budget for five years	Provided directly by MPA staff

The implementation and enforcement of MPA rules is the key to the success of a large number of them. If habitats and biodiversity are damaged by illegal use, the core of the conservation project is threatened. The presence of MPA staff in the field is the main deterrent to potential offenders, and where carried out together with the police, monitoring effort is increased and the apprehension of offenders is facilitated. It is therefore logical that this indicator be considered a priority. Poaching is generally at night, so one can consider that the proportion of trips made at night with police along is a good estimator of the effectiveness of monitoring effort (Table 3.9.3).

Table 3.9.3. Indicators dealing with implementation and enforcement of MPA rules.

Indicator	Comment
Percentage of trips watching for poachers, carried out jointly by the MPA law enforcement officers and the police at night	Provided directly by MPA staff
Percentage of trips watching for poachers, carried out at night	Provided directly by MPA staff

The participation of local stakeholders is key to negotiations about MPAs as part of an IZCM. Such participation has two dimensions; first, the willingness of MPA managers to involve local stakeholders in the management process, and ensuring the representation of each category of local stakeholder in the management committee, and second, the willingness of local stakeholders to participate in the management committee or activities driven by MPA managers. Three of the four indicators in Table 3.9.4 fall into this category. Fishing is the use that generally suffers most from the creation of an MPA, so the participation of professional and recreational fishers in managing fish stocks in or around MPAs is a good indicator of the support of fishers with the objectives behind the creation of the MPA. Without their involvement, the process will lack credibility. Therefore, the final two indicators in Table 3.9.4 also reflect social acceptance of the MPA by fishers.

The reduction of conflict and the generation of public support for an MPA is a very high priority of managers, because it determines the success of the MPA in meeting its targets (Table 9.5). Without at least minimal acceptance by the local population and users of what is being achieved by the MPA, it runs the risk of not being effective unless massive resources are targeted at the detection and apprehension of offenders. The local press plays an important role in educating the public about the goals of biodiversity conservation as aimed for by the MPA. The corresponding indicator implies that managers regularly evaluate the literature for content related to the MPA. The willingness of MPA users and the local population to punish offenders is an interesting indicator, but it requires many questionnaires to be constructed, as demonstrated by the example of Réunion (Thomassin *et al.*, 2010).

Table 3.9.4. Indicators related to the participation of local stakeholders in MPA management and its activities.

Indicator	Meaning of the indicator
Number of user representatives on the committee compared with the total number of committee members	Representativeness of local stakeholders in the management committee
Percentage of management committee meetings where (i) 75% and more, (ii) between 50 and 75%, (iii) < 50% of user representatives are involved	Involvement of local stakeholders in the management committee
Percentage of recreational fishers who inform managers of MPAs on their catch and effort	Willingness of recreational fishers to collaborate with MPA staff
Ratio of reported catches to the catches recorded by the MPA managers or the fisheries authority	Willingness of professional fishers to submit accurate logbooks on catch and effort and to provide them to MPA managers

Table 3.9.5. Indicators relating to the social acceptance of an MPA and conflict reduction.

Indicator	Meaning of the indicator
Percentage of people asked who are able to explain three management objectives of the MPA	Knowledge of MPA management objectives
Percentage of people asked who are able to cite three management rules of the MPA	Knowledge of MPA rules
Percentage of each type of local stakeholder having (i) good relationships with other types of stakeholder, (ii) no relationships, but who do have conflicts	Identification of potential conflicts between users
Percentage of press articles showing (i) a positive perception of the MPA, (ii) a negative perception, (iii) showing user conflicts	Perception of the local press towards the MPA
Willingness of local stakeholders to punish offenders	Balance between use value and heritage value of the MPA

Discussion and conclusion

The PAMPA project has shown clearly that if the word "governance" is mentioned to MPA managers, most managers have only a vague idea of what it means. In that context, the project constructed a set of indicators according to expert knowledge. However, such an approach is ineffective if the so-called experts do not consider the realities in the field. The indicators proposed for MPA managers respond only imperfectly to their needs, but where those needs are specified, a participatory approach seems more effective. The use of a questionnaire is likely the easiest way to document such needs, but if the questionnaire is poorly constructed, its results are meaningless. MPA management is therefore in a circular debate where lack of clarity by MPA managers as to what they want is being addressed by a suggestion of what they probably need made by so-called experts. Such a situation has already been experienced at Réunion as part of a proposed use of satellite imagery for integrated management of reef areas in association with upper watersheds (David *et al.*, 2009b). What happened there was that the needs and objectives of the managers were being specified by potential users of remote sensing who managed the coastal watersheds (Antona *et al.*, 2007). A similar approach was used in the PAMPA project. Its main failing was the length of the process, which required multiple round trips between the MPA managers involved in the project and the experts who were suggesting a range of indicators. However, such iteration is ultimately the key to the success of the indicator development process. Another failing is the heterogeneity of the MPAs studied and particularly the specificity of local context. To develop a dashboard that is generic enough to apply to all cases while being adequately appropriate and sufficiently precise for individual MPAs is a challenge. However, the challenge is worth facing. Only time can show whether the governance indicators developed collaboratively as part of the PAMPA project will prove satisfactory to MPA managers, or whether only a small number of them will stand the test of time, at least unless each dashboard evolves with time in the direction of new indicators better suited to local problems of governance. Such development would mean that the search for a generic dashboard that is locally relevant is meaningless. Given the difficulty of developing such a dashboard, it is important that it be made flexible and that new indicators can be included or old ones withdrawn at the request of local managers. All in all, the PAMPA project does appear to be serving a good purpose and to be applicable to a large number of ICZM cases.

3.10 The risk of ICZM failure

Gilbert David and Aurélie Thomassin

The question is posed whether the risk of integrated coastal-zone management (ICZM) failure is elevated solely by increasing anthropogenic pressures in the coastal environment? Based on the example of Réunion Island and other French overseas regions, the main risk is the result of the lack of structure in ICZM as it relates first to the coastal public authorities themselves, and second to the interaction between public authorities and private players. Integration between public authorities is driven by coastal planning schemes, but does not apply as hoped. Hence, daily management of coastal activities remains sectoral. Local politicians tend to be wary of the concept of ICZM, which they see as a top–down concept. The relationships between authorities and local stakeholders dealing with coastal management are usually driven by rules, but enforcement is often weak and acceptance of the rules by local stakeholders is limited. To improve the situation, there is a need for bodies to be established that allow dialogue and consultation between public authorities and local stakeholders. In a more realistic manner, developing indicators of social acceptance would be an improvement. The establishment of a body dealing with information sharing, including indicators, among public authorities would then be a second step. Therefore, integrated information management is a prerequisite to ICZM, and omitting it might jeopardize the whole process.

Keywords: ICZM, indicators of social acceptability, information sharing, Réunion Island, risk of failure.

Introduction

Integrated coastal-zone management (ICZM) is a new concept. It appeared for the first time as an administrative document in 1972 when the Coastal-zone Management Act was published in the United States, but its use will continue to increase for several decades (Godschalk, 1992). In 1992, Agenda 21 urged countries to implement ICZM (Strong, 1992), and since then, literature on the subject (Cicin-Sain and Knecht, 1998; Dauvin, 2002) and methodological guides have proliferated. Most major international agencies working in the fields of development or environment have produced their own guide: OECD (1993), the World Bank (Post and Lundin, 1996), UNEP (2011), UNESCO (Hénocque *et al.*, 1997; IOC, 2005). During the same period, the feedback on ICZM programmes conducted in various countries around the world has also increased (Sorensen, 1997; Hénocque, 2006; McKenna *et al.*, 2008). Today, as outlined by Billé (2006), ICZM is the central paradigm for sustainable development of coasts around the planet. As a result of the amount of knowledge, both theoretical and applied, which has been gained since the early 1990s, ICZM is now probably the most knowledgeable concept in environmental management.

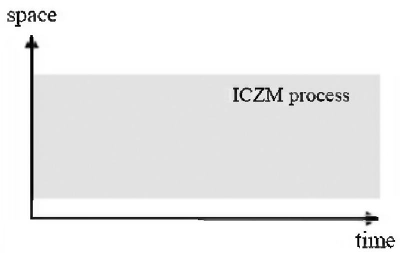
In this context, it is paradoxical that the conference on which this report is based is addressing the risk of failing in ICZM, and that the introduction of the particular session on ICZM at which this case study was presented stresses that "tools are needed to effectively assist in the decision-making processes". Is the knowledge available insufficient, or are the processes currently in place not generic enough? Perhaps coastlines have changed dramatically in recent years, as some scientists are saying, in which case anthropogenic pressure could be intensifying and becoming more complex, with new actors (e.g. industries) and new uses, including recreational forms. However, can this complexity and intensification of pressure along the coast explain the increasing risk of ICZM failing ?

Answering in the positive to the last question would mean that guides and books dealing with ICZM are obsolete or do not fit with current ground-truthing initiatives (PNUE/PAM/PAP, 2001; Rey-Valette and Roussel, 2006). Such a position is hardly tenable, though. New pressures on, and complexity at, the coast are not sufficiently large to reject previous tenets as obsolete or to radically alter the dynamics of ICZM. Answering in the negative to the same question would require current advisors to seek the causes for risk of past ICZM failure in the dynamics of what has already transpired, knowing that increased pressure and complexity at the coast could increase such risk. The issue of the relevance and generic knowledge mobilized by scientists working on ICZM would then again come to the fore, because clearly the knowledge was insufficient to drive successful public or private action in the discipline of ICZM.

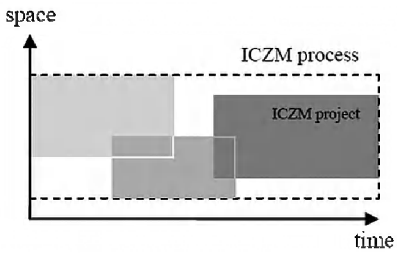
In reality the issue is less about information content than about how the information is communicated to and shared between ICZM stakeholders, what form it takes for those stakeholders to use in the ICZM process, and how information is transformed to action. Based on the example of Réunion Island and other French overseas regions, the main risk of ICZM failure results from the lack of structures for integrated management of the information being collected and for coordinating the actions of the multitude of stakeholders; firstly, in the domain of public authorities with the mandate to administer the coast, and secondly, among private actors and between public authorities and the private actors. Before developing these points, however, we return to the relationship between information management and the drivers of ICZM.

The coastal zone and integrated information management

A system approach has proven particularly fruitful in conceptualizing ICZM (Hénocque *et al.*, 1997, 2001), but it does lead to simplification, which in itself leads to misunderstanding of what ICZM really is. For instance, the image that comes to mind when considering "drivers" of a coastal system is that of a car being driven. This image is misleading, however, because it leads to the conception of ICZM as an ongoing process centralized in the hands of a single management structure that acts in a homogeneous space over time (Figure 3.10.1a). In the real world in a given coastal area, however, management is not integrated over the long term; instead there are many coastal projects, integrated or not in terms of their management, which succeed each other in time. Each is important to different players and only affects a portion of the coastal area (Figure 3.10.1b). In the long term, managing this space is more akin to a process without a pilot, i.e. autonomous management without a manager, as outlined by Billé (2006).



a) The perception: one driver, spatial and temporal homogeneity of the ICZM process



b) The reality: spatial and temporal heterogeneity of the ICZM projects

Figure 3.10.1. Perception of coastal system drivers and the reality of ICZM.

Misunderstandings also arise at the ICZM project scale. The image of driving a coastal system leads to a simplified design which erases the diversity of people responsible for managing a part of the coastal system, the diversity of users, and the heterogeneity of the area to be managed. That area consists of physical units (seascape and landscape units), each carrying several uses and being managed by several public authorities or private bodies (Figure 3.10.2).

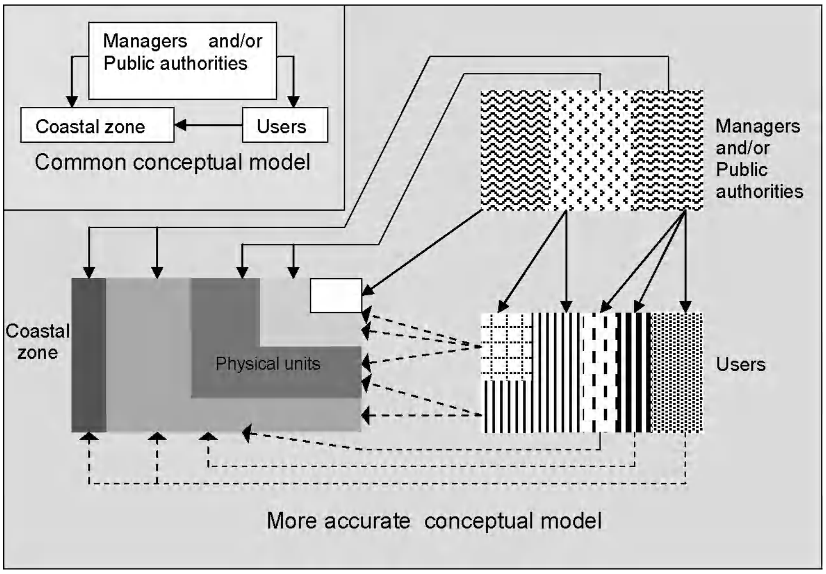


Figure 3.10.2. The conceptual models dealing with coastal-zone drivers.

In reality, to ensure that projects lead to better management of the coastal zone, coordination is necessary over a span of time exceeding the duration of each ICZM project (usually 4–5 years). It is also essential to ensure the coordination of all the actors involved in each project. Hence, managing the coastal system through ICZM projects involves coordinating the projects and stakeholders actions. This coordination can be in a direct way and in a centralized framework. A management steering structure needs to be established to coordinate all coastal management actions and regulate all coastal uses. Information management is subordinate to that goal, but must also be organized within a centralized framework. The management steering structure then becomes responsible for enforcing the gathering and synthesis of information in order to assist its own coordination actions. In this context, the success or failure of any management action will depend on the effectiveness of the management steering structure in mobilizing the information for coordination, and the effectiveness of the coordination between coastal management projects and between the actors who implement them. Coordination can also be carried out in an indirect way and in a decentralized framework. In that context, the success or failure of management actions will depend more on the effectiveness of information management.

The risk of failing ICZM vs. public authorities and coastal managers

Having both a marine and a terrestrial component, the coastal areas of French overseas territories are not a true administrative space with specific limits and specific regulation. The Coastal Act (le loi littorale) is the single administrative document of national jurisdiction that recognizes coastal zones as areas with specific problems that need to be solved by specific regulation. Outside of that Act, coastal areas are regarded administratively as interface areas with land lying partly in the space (i) of one or more municipalities, (ii) of one or more associations of municipalities (referred to as "communities of municipalities"), (iii) of a department, (iv) of a region, (v) of the French state, and (vi) of Europe. At each spatial level there is a specific institutional level. The coastal area of a coastal zone is included in the territorial sea and sometimes in inland waters, so as such, it is in the public maritime domain and managed by the State. As a part of these different jurisdictions, without being recognized as a specific space in itself (with the exception of being covered by the Coastal Act), the coastal zone falls under many sectoral policies and is simply a space for application.

Within this context, coastal-zone management begins with the coordination of sectoral policies so that they can act synergistically to improve the efficiency of public spending in the service of coastal management. Because of the number of institutions acting at each spatial level and the number of these levels (six – see above), it is unrealistic to expect coordination to be informal. On the one hand, each administration and technical service has its own culture and administrative practice, so collaboration is rare among these bodies. On the other hand, coastal management is not among the priority objectives of any technical service or administration, and for these to collaborate and have a common goal, i.e. coastal management, expert guidance is required. The coordination of sectoral policies therefore requires the setting up of a steering structure for management that serves as overall manager of the coastal zone.

The question then is to which spatial and institutional levels is it necessary to create such a structure, and what form should that structure take? Clearly, the space for administrative intervention in the management steering structure cannot be inferior in size to the coastal zone to be managed. Conversely, it cannot be massively larger. That is why the coordination structure cannot work at the municipality level (which is too small) or at the State level (which is too large), let alone the size of Europe. For a medium-sized island such as Martinique, Guadeloupe, Réunion, or Mayotte, the island is clearly a good choice of size to set up an ICZM coordination and management structure, because it is the largest biophysical unit for ICZM project implementation.

Implementation of an ICZM-facilitating structure: the example of Réunion

From the perspective of administration and institution, the island of Réunion is both a department and a region. A management steering structure for ICZM was first created there in 1992. Called LOCE (LOcal Cell for Environment), the structure was common to DIREN (the local body representing the Ministry of Environment), to the regional council, and to the departmental council. Aiming to coordinate environmental policies, LOCE introduced the concept of ICZM to the island and organized a symposium in 1999 to enhance environmental awareness among elected people, especially at a municipality level. Regrettably, however, the initiative of raising awareness failed. Local councillors failed to embrace the concept of ICZM and the two pilot ICZM projects planned in the short term were not carried out. Following that failure and internal problems, LOCE ceased to exist in late 1999.

This failure could have meant the end of ICZM at Réunion, but the creation of IFRECOR (French Initiative for Coral Reefs) allowed DIREN in 2000 to become the local leader in setting up and coordinating ICZM projects. Problems threatening the coastal zone were swiftly diagnosed, but the actions designed to solve these problems were not implemented, again because of the lack of support from local councillors. In 2004, the regional council embraced the concept of ICZM and created the position of special adviser. Then, in 2006, in response to a request from the French government, an ICZM demonstration project was launched by the regional council in the context of the regional Agenda 21. The team of consultants appointed emphasized a diagnosis of the coastal zone to be managed, but nothing for ICZM implementation in the field. Disappointingly, relationships have since deteriorated within the regional council, disenchanted with delivery of the concept, and nothing concrete came from the project. In 2007, the ICZM special adviser left the regional council and since then neither DIREN, the department, nor the region has focused on ICZM.

The immediate question that arises, therefore, is why did these initiatives fail. All the ICZM projects of LOCE or DIREN were designed at a municipality level, and unfortunately, both LOCE and DIREN faced total indifference to the concept by local councillors. Local priorities are always urban planning, health, and law enforcement (police), so any ICZM project has little chance of success without the support of local councillors, who perceive ICZM as a top–down process initiated by institutions outside the island, e.g. the French state or Europe, or international NGOs, represented by scientists. The councillors have a poor perception of ICZM researchers who claim to develop applied procedures devoted to decision support; instead they see this form of research as the dream of intellectuals. They know that the temporal framework of research is very different from their own, making decisions every day generally without the support of scientific knowledge. If the concept of ICZM could be mobilized quickly and simply, they would probably embrace the concept of scientific knowledge as a form of decision support. However, collecting and analysing information to assist decision-making usually takes several months or even years, so it is unsurprising that ICZM remains for most local councillors a matter that is foreign to them and in reality useless!

Without the active support of local councillors for ICZM, it was in retrospect unrealistic to start a demonstration project and to set up a structure devoted to coordinating public action. Without any demand for it at a local level, any ICZM project would be doomed to failure. This is the first observation that can be drawn from the example of Réunion. In this context, a steering structure for ICZM has two immediate objectives: to initiate the process of ICZM and to coordinate the actions of the public. The pitfalls experienced at Réunion need to be avoided, and are discussed in some detail below.

ICZM should not be initiated by mobilizing funding that is then allocated to a project leader who can spend it in any way he wishes. The probability is great that such a project leader would go no further than making a simple diagnosis of the coastal zone to be managed. ICZM needs to be developed in collaboration with local councillors and key technical services and administrations operating around the coast (Antona *et al.*, 2007; David *et al.*, 2009b). The steering structure will be heavily involved in the process, which means that it needs to include qualified people. As a minimum this structure should establish precise specifications and terms of reference, but it should also look beyond pilot projects and seek means of bringing everyone on-board, provided its legitimacy is recognized by all stakeholders.

Another pitfall to be avoided is local politics. The municipalities at Réunion where coastal reefs are found (of greatest interest in an ICZM perspective) were all dominated by conservative party members, whereas the regional council was led by the communist party until 2010. Any initiative by the regional council to establish an ICZM project along the coast would be seen as a manoeuvre to interfere in the lives of coastal communities. It is therefore not surprising that the ICZM demonstration projects to be implemented around the coast in 1999 and 2006 failed. In 2006, realizing the existence of political intrigue, the project consultant commissioned to launch the project preferred to settle for mobilization of knowledge through simple diagnosis of territory rather than to engage in any action that might fail and result in him not being paid by the project sponsor, the regional council. Such a pitfall can be avoided by establishing ICZM at an institutional level, i.e. below the department and the region, in this case the community of municipalities. At such a level, councillors of either political persuasion might work together for the good of their municipalities, leaving their political disagreements to higher institutional levels, i.e. departmental or regional councils. Without a steering structure that is competent and politically independent, ICZM will always be doomed to failure.

Yet another pitfall revolves around who or which party is providing and managing the data on which the success of ICZM depends. The ICZM steering structure must not appear simply as an applicant for data, but also as an information provider or as a facilitator of management information to help municipalities develop effective ICZM tools. While such tools are essential to the success of the project, they can also be used by municipalities or communities of municipalities for other purposes, so everyone stands to gain. This issue is as important to private stakeholders in the process as it is to managers and public authorities.

The risk of failing vs. private stakeholders

If public authorities with their sectoral organization of various administrative structures are heterogeneous and reluctant to coordinate their actions, private stakeholders can be even more so. The latter tend to be very heterogeneous, some being members with vested business interests, i.e. businesses and their employees who work in the coastal zone or who have an effect on the coast, even if located elsewhere. Other such stakeholders are the residents, both the local residents who actually use the coast, and the non-resident users who are present only intermittently but can be vociferous when they are. At Réunion, as in all French overseas territories, such people are normally not well organized, with just a few involved in trade unions or similar associations of users. Others are not represented by any user association through which they can express views regarding the coastal zone.

This diversity and the weak organization of the actors usually means that everyone sees themselves as exclusive users of the coastal zone and pay scant attention to the impact of their use in the broader coastal environment context, to the potential deterioration of the quality of service to other users of that environment. A knowledge test on the health status of the reef, including presentation of photographs of coral habitats in varying degrees of degradation, has revealed that real and potential users of the coastal reef of Réunion have only a very rough assessment of the state of the environment (Thomassin and David, 2008; Thomassin *et al.*, 2010). Some show little willingness to accept the established rules regulating the use of the reef coast, and the enforcement record of these rules is also poor. To improve the situation, bodies need to be established for dialogue and consultation between public authorities and local stakeholders. Gathering indicators of social acceptability would be a good way to monitor this improvement.

A first step toward coastal user support for ICZM is to provide clear information on the state of the environment. The aim would be to make users aware of the fact that the coastal environment is deteriorating because of too many uses and users that are either poorly regulated or not regulated at all. Following dissemination of this information, users will need to embrace the notion of deterioration as ultimately affecting their own use of the coast. Change will therefore be required for the coastal environment to recover. Furthermore, users will need to be made aware that they benefit from their use of the coastal zone, as do other users, and that their present activities can affect their own future use as well as that of others. Finally, the outcome of this process would be that of finding solutions to improve the quality of the coastal environment and generating acceptance of user involvement in the process by changing their own practices where necessary.

Even if the principle is clear, implementation will always pose a logistic problem. Succinctly, how are users of the coastal zone encouraged to participate in the necessary communication process? On the one hand, it is unrealistic to expect bodies set up for dialogue to follow an endogenous and informal process involving several localities and all user groups in order to facilitate integrated management of the coastal zone. On the other hand, it is also unrealistic to expect the ICZM steering structure to conduct this dialogue with users through public meetings. Only few users would be likely to participate.

The most elegant solution would seem to be a median one, requiring the involvement of public authorities, specifically the ICZM steering structure, in initiating these bodies for dialogue with users and then supporting them in their efforts. Once they reach a certain size and are representative of the majority of the users they are supposed to represent, such user committees can generate reflection within each user group that may encourage users with bad impacts on the coastal environment to change their practices. The user committees represent users within the ICZM steering structure as well as acting as spokesperson for the ICZM steering structure with the users. Ideally, this dialogue between the ICZM steering structure and user committees would be strong enough to engage coastal users in co-developing new user regulations, the best way to generate social acceptability of coastal management.

To summarize, the most essential role within the process of integrated management of coastal areas is the management of information. This information management needs to be central in the structure of the ICZM steering group, which means that the staff of that body needs to include at least one specialist in the field. The exchange of information and the support for the development of tools is indeed a key point in co-developing ICZM demand with local councillors and stakeholders. Information management is also central to the coordination of the public authorities involved in coastal management. However, it is even more critical in supporting user committees so that they promote awareness among the coastal users that benefit from use of the coastal zone, because it is they who must manage it as a heritage to be left in good condition for future generations.

3.11 Using Bayesian network modelling to address MPA governance

Jean-Baptiste Marre, Jocelyne Ferraris, Moana Badie, Pierre Leenhardt, Pierre-Henri Wuillemin, and Christian Chaboud

Bayesian networks are useful tools for modelling interactions and predictions in social–ecological systems; they offer a robust theoretical framework for addressing risk and uncertainty management problems through the use of probabilities and they provide the possibility to combine expert knowledge and data. This explains why they have been used successfully in the resource-management decision-making process in many case studies. The technique is applied here to the marine protected area (MPA) governance issue. Based on six case studies, three Mediterranean and three in French overseas territories, a comprehensive model is developed that encompasses the ecological, economic, and institutional components that underlie MPA governance. The model allows (i) development of a synthetic, comparative framework that represents expert knowledge relative to MPA implementation and its consequences on different components of the social–ecological system, and (ii) simulation of a governance scenario for a specific case study, either for the impacts of different regulations on ecosystem resources and biodiversity conservation or for the satisfaction of users such as fishers and tourists, once the parameters have been set up using both the database and expert judgement. A brief example is presented where simple Bayesian networks were used in a French Polynesia case study relating fisheries responses to regulations at Moorea Island.

Keywords: Bayesian networks, expert knowledge, fishery management, governance, integrated approach, marine protected areas.

Introduction

Marine protected areas (MPAs), for which implementation results mainly from conservation goals, are complex social–ecological systems that embrace a wide range of uses, original institutional forms, and socio-economic and environmental contexts. Dealing with MPA governance issues comprehensively is therefore challenging and requires a rigorous multidisciplinary approach.

Tools need to be developed to help MPA managers and public decision-makers, both of whom are interested in two types of information. First, they need descriptions of current system state in order to assess MPA effectiveness in terms of goals. Second, they need to be able to predict the impact of different measures that could be established, dealing with risk and uncertainty.

We present an original model based on a Bayesian network framework that aims at helping decision-makers as discussed above. The model was developed during the "GAIUS" research programme in order to summarize knowledge of MPA governance gleaned from six case studies. Bayesian networks are powerful probabilistic, graphic modelling tools that use causal graphs and conditional probability diffusion, and they handle quantitative, accurate knowledge as well as qualitative knowledge provided by experts. They are adapted to represent and model complex systems and to take into account explicitly the uncertainty and incompleteness of the available knowledge. The context of the research programme through which the model is developed is introduced first together with the main objectives that underlie its construction, followed by a presentation of the Bayesian network modelling framework and a discussion on its utility in addressing our research problems. The structure of the model is explained next before discussing the parameter learning process as a means of dealing with governance scenario simulations. Finally, a simple example of a simulation derived from the Moorea case study is provided.

Context: MPA governance and the GAIUS research programme

Many definitions of MPA exist in the literature, of which the classical one is presented by the IUCN (Kelleher, 1999): "An MPA is defined as an area … which has been reserved by law or other effective means to protect part or all of the enclosed environment". MPAs can be very different in terms of rules, management, and geography, and have various goals, but globally they aim to protect marine ecosystems because of their value (cultural, economic, historical, ecological, social, etc.).

The concept of governance is used in numerous scientific contexts, from biological to social, so many meanings are applied to the term. Here, however, the term is used to refer to the changes in MPA user behaviour and activity ascribed to the creation of the MPA and the implementation of specific measures linked to its management plan. Seeking good governance is to provide a way for people to interact to achieve the MPA's objectives.

How then does one configure MPAs and their regulations as a means of attaining the goals set, generally biodiversity conservation, sustainable fisheries management, local heritage and capital conservation, and the sustainable development of recreational activities and tourism? The question raises the problems faced by the GAIUS research programme, which aims to provide answers through a multidisciplinary analysis of six case study sites (three Mediterranean and three in French overseas territories) with different ecological, economic, institutional, and political contexts. Together with data analysis, synthesis, and indicator development, several modelling approaches have been explored within the programme.

The study outlined here aims to introduce, through the structure of a Bayesian network, a synthetic and comparative framework that represents GAIUS expert knowledge relative to MPA implementation and its consequences for the different components of the social–ecological system. A second objective is to simulate a governance scenario for a particular case study – in the form of the impacts of different regulatory measures on the resources and biodiversity conservation of the ecosystem or on how users such as fishers or tourists view it – once the parameters of the model have been set up, using both database and expert judgement.

Bayesian network modelling

A Bayesian network consists of a probability distribution and directed acyclic graph (Jensen, 2001), whose nodes are variables (states, events) linked by causal relationships represented by directional arcs (i.e. arrows). It enables the use of information relative to the state of one variable in determining the state of another, using conditional probabilities, whatever the link between the two variables. Both the graph and the probabilities of a Bayesian network can be obtained automatically, from databases, or manually, from expert knowledge and the literature of the domain to be modelled. For a detailed presentation on Bayesian networks, refer to Naïm *et al*. (2007).

This study, which follows on from the work of Badie *et al*. (2009), appears to be the first attempt to use a Bayesian network framework to address the marine protected area governance issue from a global perspective. Such a network does, of course have advantages and disadvantages for the primary objective, some of which are discussed below.

The structure of the network is based on numerous variables, whose states can be determined through the use of expert judgement, indicators, and other data, or all. The main objective is to describe and analyse the behaviour and impact of MPA users such as fishers, individual recreational users (divers, yachtsmen), or service providers based on the set of regulations introduced by the MPA. Using a Bayesian network theoretical framework provides several benefits compared with other models (Marcot *et al*., 2001):

- Rigorous handling of uncertainty in probabilistic terms: networks are suitable for risk analysis and management context, making them particularly relevant in data-poor situations.
- The possibility to combine prior knowledge with new information as well as empirical data and expert judgement. In the context of an MPA,

expert knowledge could be crucial in overcoming the lack of data on the global ecological situation and ecosystem vulnerability, informal fishing, and the MPA user's impacts or adherence to regulatory measures.

- Capacity to evolve and change: Bayesian network modelling offers flexibility because updated or refined knowledge is easily incorporated, either through new nodes or through new probabilities.
- The use of a causal graphic representation as a communication tool: decision-makers can understand the global operating system of a network, i.e the chain of cause and effect and conditional independence between the different nodes. This makes it possible to bridge the gap in understanding between scientific and non-scientific decision-makers which arises where complex models are often perceived as "black boxes".

It is also worth recording some of the weaknesses of the approach. The main one is the result of the limited number of direct parents that can have a given variable in practice, because each parameter of a Bayesian network is a joint probability distribution whose size grows exponentially depending on the number of parents of a given variable. In complex systems such as MPAs, which cannot be described without the use of numerous variables and interactions, this becomes a major hurdle. However, several methods of simplifying a conditional probability distribution exist: here again, for further detail, refer to Naïm *et al.* (2007).

Further, the Bayesian network approach does not lend itself easily to dynamic system modelling, because no feedbacks are allowed (as a result of the acyclic property). However, it is possible to model the dynamics of a system using time slices inside the model or by developing several models, each referring to a specific period. For example, the dynamics of MPA governance can be modelled by developing different networks representing different MPA development stages. Similarly, inside a given network, it is possible to introduce initial and final states for the same variable, thus distinguishing two nodes for each state.

Development of the network structure

The development of a "Bayes net" begins with eliciting mental models on the cause-and-effect relationships among system variables from subject-matter experts. Represented as a graphic network, these models imply a set of assumptions about the conditional dependencies among variables, which simplifies the problem of working with imprecise knowledge (Borsuk *et al.*, 2004).

A multidisciplinary questionnaire survey was submitted to GAIUS researchers, in order to select and prioritize the different variables and their interactions that describe social and institutional context, extractive and non-extractive activities, and their impacts on the ecosystems. The selection was made to design the most parsimonious, yet realistic, model so that each possible node for the network was reviewed to determine if the variable it represented was (i) controllable, (ii) predictable, or (iii) observable at the scale of the management problem (Borsuk *et al.*, 2004). If none of these, the node was removed from the network. The strategy in building the structure was also linked to the fact that parameter learning is based mainly on expert knowledge, which means more expert surveys or interviews. The two main consequences were:

- restriction of the number of direct parents (up to a maximum of four);
- restriction of the number of variable states. Wherever possible only binary variables were selected (up to a maximum of three possible states for some variables).

In all, ten researchers from different domains answered the entire questionnaire. Several possible structures were developed from these answers; the chosen structure was arrived at after several peer reviews.

The final network is subdivided into four interacting parts:

- A "context" part in which is explained the probability of adherence to the regulations introduced by the MPA of fishers, non-extractive users, and service providers. This amounts to identifying the links between MPA functioning (regulations, control and communication measures, contribution of users in the decision-making process, available logistical, financial, and human capital) and the users' adherence to regulations.
- An "extractive and non-extractive uses" part in which an attempt is made to describe the evolution of uses depending on the institutional, socio-economic, and environmental context of the MPA. Once the probabilities of adherence to regulations have been assessed, the consequences of MPA measures on fisheries (fishing effort and catches) and non-extractive uses (visits) needs to be specified, and the probabilities of their evolutions identified.
- An "environmental" part, fully linked to the previous part, in which the conditional links between availability of natural resources and the evolution of extractive use are described along with the main impacts of the different activities on ecosystems, depending on their intensity.
- An "output" part, which gives the probability of user satisfaction evolving relative to the evolution of their activities (catches for fishers, ecosystem quality for recreational users) and to overall visitation (space competition).

Figure 3.11.1 shows a simplified structure of the network. Each node represents a network that contains numerous other nodes, making the overall structure much more complex and precise.

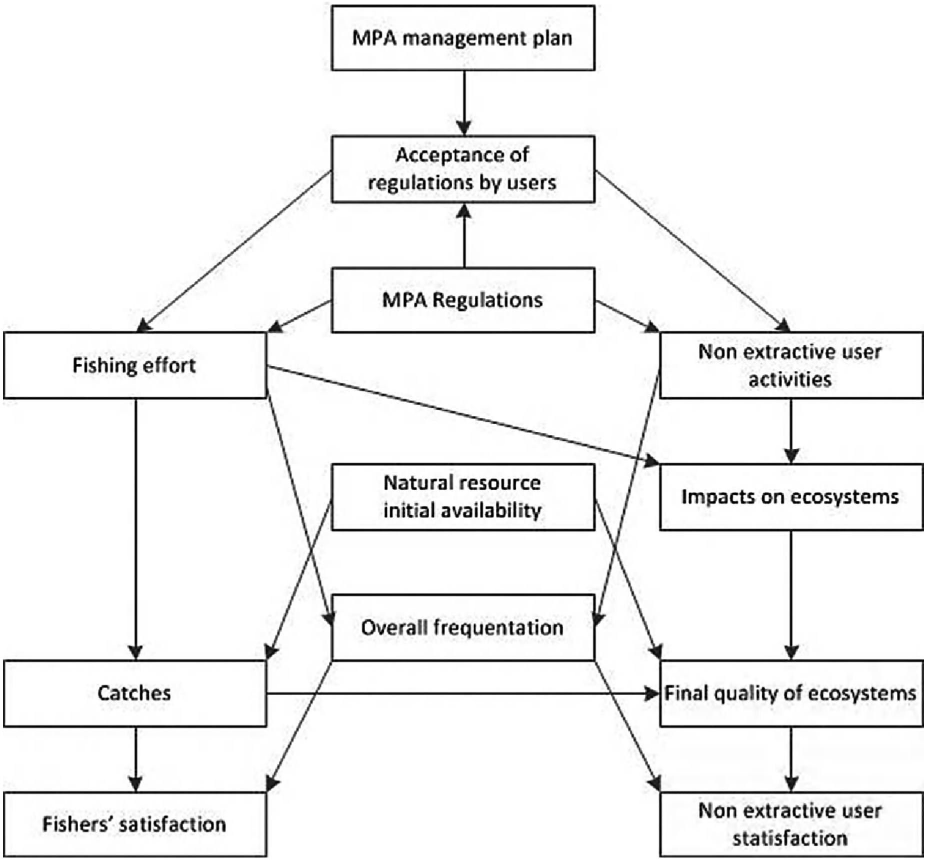


Figure 3.11.1. Basic structure of the network.

Modelling framework and hypothesis

The model was designed originally to be constructed and inferred through expert knowledge, the aim being to find the best compromise between convenience (through a simplistic structure) and precision. Thus, the consequences of MPA implementation are supposed to be expressed and described in qualitative terms associated with probabilities. Indeed, it was decided to work on trends for the different states of all the "extractive and non-extractive uses" nodes (fishing effort, catches, user visitation) and "output" nodes (satisfaction of users, final quality of ecosystem). Succinctly, the probabilities of evolution of these variable states attributable to MPA governance measures between a reference date and the final date are used. This approach seems to be more relevant in a data-poor context and well-adapted to the fact that the network was meant to be adapted to several case studies.

Furthermore, care is necessary when looking at model structure. All the nodes of the "extractive/non-extractive uses" and "output" parts represent the consequences of the MPA's measures and regulations on a specific variable, which means that only variations attributable to the presence of the MPA are explained and described.

We considered two geographic areas for the network: zone 1, where all the MPA regulations were considered in order to analyse their consequences on ecosystems and human activities; and zone 2, which is adjacent to zone 1, where possible human activity transfer towards non-regulated areas and ecological spillover is assessed. In the model, zone 2 is introduced only for nodes relative to fishing activity, i.e. fishing effort, fish catches, and natural resource initial availability.

Categories of user

Different types of users were distinguished in order to specify adherence to regulations, evolution of different activities, and different impacts on the ecosystems. They were selected such that they may fit into an MPA's official user category, thus guaranteeing compatibility between the model and existing data from the MPA, and providing a more understandable and readable model to the MPA manager.

Description of the network

The different nodes shown in Figure 11.1 are defined and explained below.

MPA management plan

The MPA management plan represents the main measures of the MPA considered for the network, i.e. control and communication. Both are linked to the MPA's financial status. Control and communication nodes can be specific to a user category.

MPA regulations

There are two different effects to consider here. On the one hand, the regulations are a parent node to fishing effort and non-extractive user activity, because the regulations introduced for the MPA will have consequences for the different uses, if they are respected. If users disregard the regulations (which means no acceptance), then there will be no change in fishing effort or visitation frequency. On the other hand, regulations are a parent node of the "acceptance of regulations by users", which represents the impact of the regulation on adherence of MPA objectives: indeed, the more restrictive the regulations, the less likely the users are to accept them.

Natural resource availability

Fish catches are linked to fishing effort and to the availability of the resource, which we consider to be indicated by abundance or biomass. Distinction is here made between zones 1 and 2. Only two possible states for initial abundance are considered: high or low total biomass.

Fishing network structure

Nodes of a fishing network are differentiated following fisher categorization and fishing gears used. Three main fisher categories were distinguished: commercial fishers (whose activity is mainly commercial), subsistence fishers (whose activity is mainly for home or family consumption), and recreational fishers. Adherence levels to the regulations are specific to each category.

There are also different fishing gears for each category: on the one hand, most fishing regulations apply to specific fishing gears, whereas on the other hand, each gear has its own impact on the ecosystem for catches and degradation.

The trends in fishing effort and catches are described as either increasing, stable, or decreasing within a given timeframe and between zones 1 and 2.

Non-extractive user categories and detailed network structure

Several non-extractive user categories were considered. The main categories were individual non-resident non-extractive users, individual resident non-extractive users, and service providers, and within this third category, hotels and other activity centres were distinguished in order to deal specifically with coastal management issues.

The level of adherence of different users to regulations explains the evolution of visitation frequency (increasing, stable, or decreasing relative to a given reference time) for different activities. These trends of visitation frequency explain the evolution of impacts on the ecosystems. Visitation frequency and impacts on ecosystem nodes concern only zone 1.

In terms of impact, visitation frequency, and regulations, we only considered two main types of activity for our global network: underwater activities (snorkeling, diving), and activities on the surface of the water (boating, board sports). Regulations and impact nodes for hotels can be added if necessary.

Acceptance of regulations by users: the adherence process

This concerns the general mechanics behind each representative user of a category that can define the process of supporting or not MPA existence and regulations. As already stated, if the acceptance of regulations is specific to each user category, the adherence process remains the same (excluding the one for non-resident users where adherence is only the result of communication and control).

Four main factors explain why an individual would accept or refuse to respect MPA regulations: restriction or benefits from regulations, presence and efficiency of control, the level of communication, and consultation/participation of/by users. Distinctions have also been made between the legitimacy of an MPA, which is defined as the raison d'être of the MPA for users, and their beliefs regarding MPA performance.

Degradation and final quality of the ecosystem

As stated above, impacts on ecosystems are differentiated according to the cause of the degradation: fishing activities (each gear type has its own impact), non-extractive activities, and hotels. Three possible states for the impacts on ecosystem variables are considered: increasing, stable, or decreasing level of degradation. All these impacts, as well as fishing pressure, have consequences on the final quality of the habitat and biodiversity of the MPA. Here again, the final quality of the overall ecosystem can be described through three possible states: better, same, or lower quality than before.

Satisfaction of users

Satisfaction nodes are also derived for each category of users. They represent the variation in satisfaction level attributable to the impact of MPA measures on user activities. Fisher satisfaction is mainly economic and the consequence of catches. Moreover, spatial competition with other users (both fishers and non-extractive users) has an impact on fisher satisfaction. For individual non-extractive users, what matters most is the pleasure they take from their activities, which is mainly the result of the overall quality of the ecosystem (habitat, biodiversity, and emblematic species) and to the availability of space (spatial competition). Finally, for service providers and hotels, the satisfaction level is mainly the result of economic considerations, more precisely the number of customers.

Validation of the global structure and construction of six networks

The structure was derived from a questionnaire and expert interviews, and the only way of validating it was through peer review. Once the global structure had been validated, it had to be adapted to the different case studies in order to commence parameter derivation and simulation. Therefore, for each MPA, a specific network was derived from the one presented above, with appropriate zoning, regulations, fisher categories and fishing gears, non-extractive users, and ecosystem impacts. If sufficient data were available, the models could be validated by carrying out statistical tests on the different conditional probability distributions involved in the causal relationships between nodes.

Parameter learning

Parameter learning based on expert knowledge

Probability elicitation issues have been discussed before (see Renooij, 2001). Usually, the most difficult task is to find experts who understand the basic theory of probability. Having found them, appropriate tools have to be provided so that each expert can associate qualitative and quantitative beliefs in order to assign a probability to each event or state of one variable. The most well-known means is the probability scale (Campos and Huete, 2000), which allows the expert to use numerical and textual information in order to set a realization degree of one or other assertion.

Subsequently, the coherence of expert estimations has to be assessed, especially if there are several estimations to be combined; possible biases have to be taken into account. In the current case, the main difficulty was how to obtain and to merge expert knowledge from different research areas.

A simple example: coral reef fisheries in the French Polynesia case study

Because we are only just beginning to initialize the global model for specific case studies, one example, derived from the PGEM (Marine Management Plan) of the Moorea case study, is presented. The PGEM, which covers a network of eight MPAs, was launched in 2004 with the main objectives being fishery viability and biodiversity conservation for tourism. The model (presented in Figure 3.11.2) is a simplified part of the global fishery Bayesian network presented above.

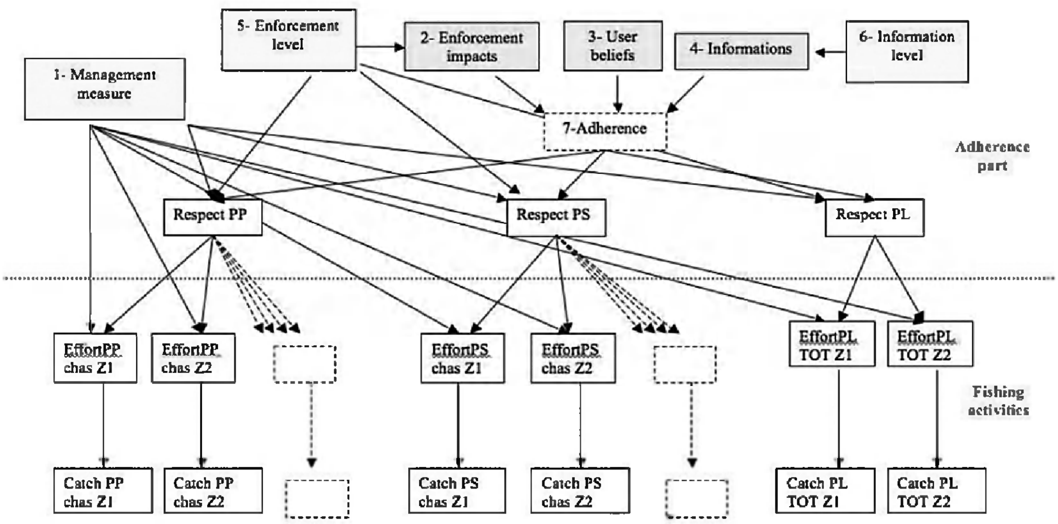


Figure 3.11.2. Bayesian network developed for the Moorea MPA fisheries.

Fishing activities in the Moorea coral reef lagoon are carried out by professional (PP), subsistence (PS), and recreational users (PL). Therefore, effort and catch nodes are described by the status of the fisher (PP, PS, PL), the fishing gear used (spearfishing = chas, gillnet = fil, line = lig), and the fishing area (Z1, Z2). Catches are expressed in cpue (catch per unit effort). In this network, there is no consideration of fishery impact on the ecosystem; in fact, there are no environmental considerations at all.

Fishing areas are divided into two zones. Zone 1 is the MPA, and Zone 2 is outside the MPA, i.e. it is a zone that might benefit from possible spillover (McClanahan and Mangi, 2000). However, the zones are delimited by ecological rather than field considerations. In tropical reef fisheries, fishers refer to a pass over the reef to describe their fishing zone. Zone 2 is delimited from the border of Zone 1 to the next pass over the reef. Effort and catch are described by three possible trends: decreasing, stable, and increasing.

It is now necessary to detail briefly how to interpret each of the upper nodes of the network (identified by a specific number):

Node 1 Three types of MPA regulation are possible: no-take sectors, catch size limitation sectors, and gear restriction sectors. The type of management measure applied affects a fishers' respect of regulations: the stricter the measure (cf. no-take sectors), the less the respect. It also affects fisher effort on marine resources inside and outside the MPA. Basically, the probability of high effort in a no-take sector should be smaller than in a gear-restriction sector.

Node 2 Does enforcement level have an impact on fisher adherence? Yes/No

Node 3 Do fishers have environmental consciousness? Yes/No

Node 4 Are fishers well informed about PGEM and management measures in their fishing areas? Yes/No

Node 5 Does enforcement level matter to fisher behaviour? Enforcement is currently limited, but what would happen if it was strengthened?

Node 6 Does the level of communication matter to a fisher? The information communication level is currently low, but what would happen if it was greater?

Nodes 5 and 6 allow us to make assumptions about enforcement and information levels so that we can model hypothetical scenarios.

Node 7 Decision rule: if (node 2 = yes, node 3 = yes, node 4 = yes), then Adherence = yes. If not, then Adherence = no. Fisher respect of MPA regulations will affect fisher behaviour in terms of choice of fishing area.

Quantitative surveys were used in conjunction with qualitative interviews. A multiple choice questionnaire was completed in face-to-face interviews with 96 fishers in three areas with management measures in place. Several experts were interviewed on how coral reef fishers are affected by MPAs, the extent of their knowledge regarding regulations, and their opinions on management. Expert knowledge from Fishery Service Administration permits was used to derive information about fishers not covered by field data.

Experts used the Verbal Elicitor software of Hope *et al*. (2002) to describe all conditional probabilities of fishing activities. Probability values are entered into the software as likelihood descriptors. The domain expert makes qualitative assessments using a scale with numerical and verbal anchors, selecting verbal values such as "unlikely" or "almost certain". The associated numerical probabilities are either set manually or optimized to minimize probabilistic incoherency.

The data collected, together with the questionnaire, were used in statistical tests to validate the network structure: several models based on binomial distributions were compared using the Akaike information criterion. In addition, Chi-squared tests were carried out and confirmed that fisher respect for regulations has to be differentiated by category.

The network was then constructed using ELVIRA software (for a detailed explanation of the use of ELVIRA software, refer to Lacave *et al*., 2002). The major interest in this type of graphic representation is the possibility of easily simulating numerous management scenarios through inference: the probability for one given the state of a specific variable is substituted by any chosen value, and the information is then echoed through the entire network, modifying other conditional probabilities. An example of possible outputs is presented in Figure 3.11.3, describing professional underwater fisher response to total prohibition. When looking at this model, any observer can see, for instance, the probabilities of fish catches evolving as a result of the regulation. That is why Bayesian network modelling is such a powerful communication tool.

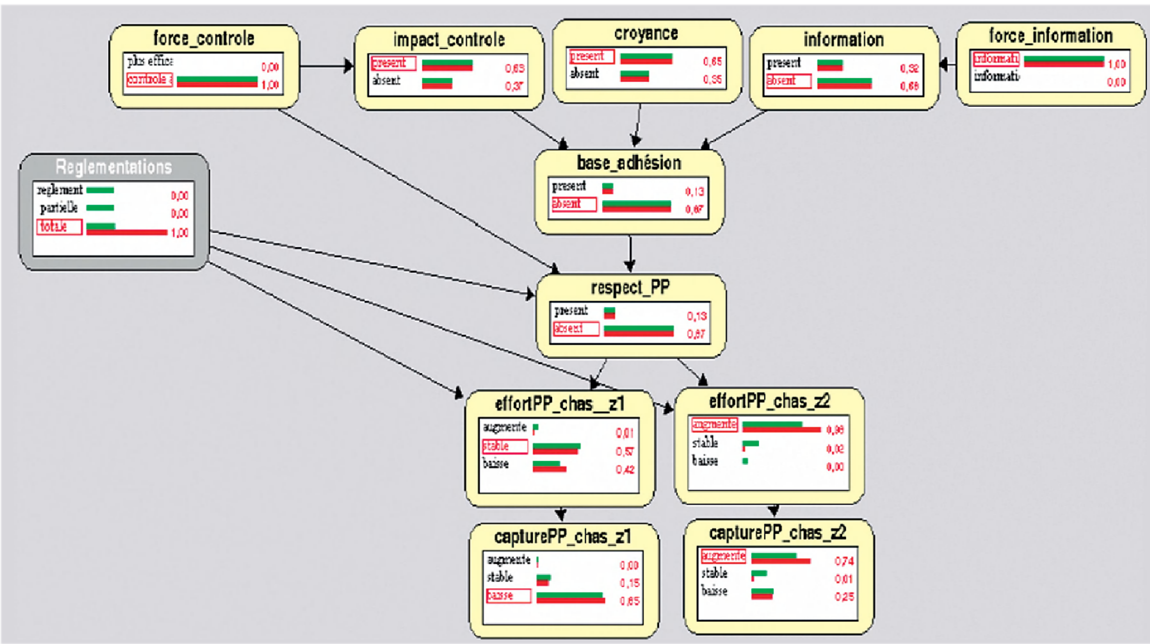


Figure 3.11.3. Model outputs of professional underwater-hunting fishers' response to total prohibition fishing regulations. "Capture" = catches, "croyance" = user beliefs, "controle" = enforcement, "base adhesion" = adherence, "reglementations" = regulations, "augmente" = increase, "baisse" = decrease.

Several scenarios were tested, for all fisher categories and fishing gears, and the impacts of the different nodes were analysed. In addition, several sensitivity analyses of the model to marginal probabilities were carried out. However, those results are not presented here because the main goal was to show a simplistic example of what can be achieved using Bayesian networks for MPA governance issues.

Conclusion

The simulation of MPA governance scenarios requires a multidisciplinary model including ecological, socio-economic, and institutional knowledge, and Bayesian networks fulfil this requirement. They are powerful tools that can manage different types of knowledge in a single model, from many different sources, based on bibliography, statistical estimation, or expertise. Uncertainty, imprecision, and variability are explicitly represented by probabilities. Updating or refinement of knowledge is easily incorporated.

Simulations can provide many outputs, based on different final states of some chosen variables used as indicators, which reflect the states of an MPA and its sustainability. However, the criteria associated with each of them are often in conflict for a single individual, and they are not the same for all players, implying that the perfect scenario does not exist. A multi-criteria, multi-actor analysis based on outranking methods must then be developed to compare different scenarios. The dynamics of MPA governance can also be modelled by linking different networks representing different MPA development stages.

Acknowledgements

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3.12 Economic assessment of the ecosystem services provided by freshwater in the coastal zone: an application to the Charente river catchment

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Integrated coastal-zone management is an emerging governance practice that aims to combine environmental preservation, economic development, and social concerns within the context of complex ecosystem dynamics and increasing anthropogenic pressures. Coastal managers need economic assessments in order to investigate the consequences of policy options which apply to different sectors simultaneously, and to pursue multiple objectives. The ecosystem services concept offers a framework for better understanding of user conflict and management trade-off regarding natural resources and the environment. This article presents, for various management options, an economic assessment of the variations in ecosystem services supplied by freshwater in the coastal zone. The assessment has been carried out according to the system approach framework methodology developed by the European project SPICOSA (Science and Policy Integration for Coastal System Assessment). An integrated assessment framework based on system modelling has been built following a participative approach in order to address the issue of freshwater allocation in the Pertuis Charentais region. The stakeholder forum agreed on the assumption that freshwater scarcity mainly affects provisioning services used by households (drinking water) and agriculture (irrigation), cultural services used by recreational fishers, support services used by shellfish farming, and regulation services needed by wetlands. The economic assessment of these ecosystem services is based on two methods: productivity loss and remediation cost. The results contribute to the deliberative process engaged with local managers to explore new rules and institutional arrangements for water allocation, their consequences on ecosystem services, and their meanings in conflict mitigation.

Keywords: economic assessment, ecosystem services, integrated coastal-zone management, productivity loss, remediation cost, user conflict.

Introduction

The commonly shared definitions of integrated coastal-zone management (ICZM) tend to emphasize its goal, which is to balance development and conservation within multisectoral planning, and its method, which is an adaptive governance process seeking to manage the allocation of coastal resources through participation and conflict mediation (McGlashan, 2002; McFadden, 2007). Coastal managers need economic assessments in order to investigate the consequences of policy options that apply to different sectors simultaneously, and to pursue multiple objectives. Integrated ecological–economic models may provide such decision support, especially when they account for different stakeholder perspectives (Antunes and Santos, 1999) and attempt to quantify the trade-offs between ecosystem services in complex, dynamic systems (Farber *et al*., 2006). Indeed, conflict mediation and community social organization are key factors for the sustainability of social–ecological systems (Ostrom, 1990; Berkes and Folke, 1998) and information about trade-offs across alternative ecosystem services could hence be used to assess the desirability of different management outcomes (Heal *et al*., 2001). The ecosystem services approach offers an analytical framework which facilitates the integrated representation of the interactions between ecological and social processes in relation to a specific management issue: it is equivalent for natural and social sciences, and favours a better understanding of user conflicts. In this paper, an economic assessment of ecosystem services provided by freshwater in the coastal zone is presented, based on an ecological–economic exploratory model that has been built following the methodology developed by the Science and Policy Integration for Coastal System Assessment (SPICOSA) project.

A system approach is often recommended in the context of experts advising on ICZM implementation (van der Weide, 1993; Fabbri, 1998; Varghese *et al*., 2008). The system approach framework developed by the SPICOSA project aims at promoting new methodologies for the building of integrated assessment platforms that can bring together the ecological, social, and economic dimensions of coastal systems management, through interdisciplinary collaboration and science and policy integration (SPICOSA, 2006). SPICOSA is an integrated European research project supporting ICZM. The project started in February 2007 and ended in January 2011. It encompassed 18 study site applications, one of them being the "Pertuis Charentais" site, a coastal area on the Atlantic side of France. The SPICOSA project developed a system approach framework (SAF), which aimed at incorporating the ecological, social, and economic dimensions of coastal systems in order to support decision-making. A way to overcome the difficulties raised by the complexity of coastal systems is to build a framework for knowledge integration (SPICOSA, 2006). Within that framework, dynamic models can be used to explore alternative policy options following a problem-orientated and scenario-based approach. Platforms for integrated assessment are developed using the software ExtendSim®, with special attention given to user-friendly interfaces. The SPICOSA system approach may be described as the iterative implementation of the following steps:

- Step 1, issue resolution, consists of working with a group of stakeholders in order to address the core sustainability problem of an area, so that it will be possible to prioritize one management issue according to the local policy agenda and the main social concerns.
- Step 2, defining the system, consists of defining the natural, social, and economic dimensions of the coastal system by making explicit the main relationships between ecological processes, human activities, and governance bodies.
- Step 3, building the model, consists of the mathematical formulation of the ecological and social processes likely to explain the dynamics of the system, up to the achievement of numerical modelling (including model calibration and validation).
- Step 4, deliberative analysis of the results (and back to step 1), consists of running the simulations and interpreting the model outputs, using the scenarios, indicators, and systems of reference built and selected with input from the stakeholder group.

Here, we describe the application of the SPICOSA methodology to the "Pertuis Charentais" study site, up to the building of economic indicators for integrated assessment. User conflicts and management issues raised by freshwater scarcity are described and analysed. The framework for the economic assessment of ecosystem services is based on damage-cost methods. The preliminary results and the discussion show that the ecosystem services provided by freshwater can be neither optimized nor restored (back to which state and for the benefit of whom?), and that they should rather be viewed as the result of more-or-less sustainable social compromises that encompass evolving user practices and adaptive management rules.

Freshwater allocation in the Pertuis Charentais region

The Pertuis Charentais site is characterized by the fragility and instability of the continuum between the freshwater from the Charente river catchment and the coastal zone, which is submitted to variable gradients of salinity. Many activities of this large territory depend on freshwater: household water consumption, agriculture, oyster cultivation, tourism, and leisure. The local governance system implements various regulations and management measures to preserve freshwater quality and to reach a sustainable level of extractive use, in accordance with the protection of natural habitats and other issues related to the welfare of the population. Nevertheless, the Charente river basin exhibits a risk of failing the objectives of the European Water Framework Directive towards good ecological status, as a result of agricultural diffuse pollution (nitrates, suspended matter, and pesticides) and recurring water shortage events. In addition, these failures of the freshwater management system have impacts on the marine waters and the coastal ecosystems. A function of the SPICOSA stakeholder forum was therefore to include representatives of local management bodies involved in or concerned with freshwater management (Mongruel *et al.*, 2010): Regional Water Agency of the Adour-Garonne basin, southwestern France (AEAG), Territorial Public Agency for the Management of the Charente River (EPTB), River Division of the Council of the Charente-Maritime Department (CG17), State local administration for spatial planning (DDE), State local administration for agriculture and forestry (DRAF), and State local administration for maritime affairs (DDAM).

As the Charente River suffers from low freshwater flows during summer, two basic needs of the whole population may not be satisfied: the availability of drinking water for households and tourists, and good ecological status of the coastal ecosystems (rivers, saltmarshes, nurseries, coastal water productivity), which may provide many support services and environmental amenities. In addition, two private industries of the primary sector depend on the freshwater of the Charente River: agriculture, which needs water for irrigation during summer for crop cultivation (mainly irrigated maize), and shellfish farming, which needs freshwater for spat production and river nutrients for oyster growth. These are the reasons why the stakeholder group decided to focus on the quantitative management of freshwater in the Charente River basin. This policy issue has been addressed by the regional plan for water management (SDAGE), which includes a "Water shortage Management Plan" (PGE) dedicated to the Charente River. The SPICOSA experiment is part of the ongoing debate regarding the improvement of the PGE. The water management scheme formed by the SDAGE and the PGE has led to an agreement on the general objectives and the methods. First, the hierarchy of the uses of freshwater has been fixed as follows: (i) good ecological status of coastal ecosystems; (ii) availability of drinking water for households (and tourists); (iii) other private uses (agriculture, shellfish farming, etc.). Second, Reachable Discharge Thresholds (RDT) have been defined at different control points in the Charente River catchment, which are supposed to be sufficient to ensure the first two uses. Third, the operational objective of this management plan will be to make sure that the system is able to reach the RDTs during summer of at least 8 years out of 10. Henceforth, the political debate focuses on the modification of the authorized volumes of water for each consumptive use (drinking water for households, irrigation for agriculture), and on the improvement of the limitation rules which apply to consumptive uses during the periods of water shortage. In practice, therefore, the main expectations of the SPICOSA stakeholder group are related to the search for a collective consent regarding the possible ways to achieve the objectives of the freshwater management system, which are fixed (Mongruel *et al*., 2010).

To address this issue, an integrated exploratory model was built, the logical framework of which follows the ecosystem services approach. Ecosystems functions may be defined as the capacity of natural processes and components to provide goods and services that satisfy human needs directly and/or indirectly (de Groot, 1992), and are now usually classified into four main categories (de Groot *et al*., 2002; MEA, 2003): regulation functions, which rely on the capacity of ecosystems to regulate essential ecological processes; production functions, which permit the provisioning of food and other products; information functions, which provide aesthetic, cultural, or recreational benefits; and support functions, which ensure the conditions necessary for all the other functions. However, all these functions are interdependent: human activities that use the provisioning services of the ecosystem may reduce its capacity to deliver support or regulating services. Therefore, the variety of ecosystem services generates user conflict. The ecosystem services associated with the availability of freshwater in the Charente River catchment are depicted in Figure 3.12.1, according to the above-mentioned four categories. Each category of services encompasses a series of functions, at least one of which satisfies a human need or concern that is considered significant within the local policy debate.

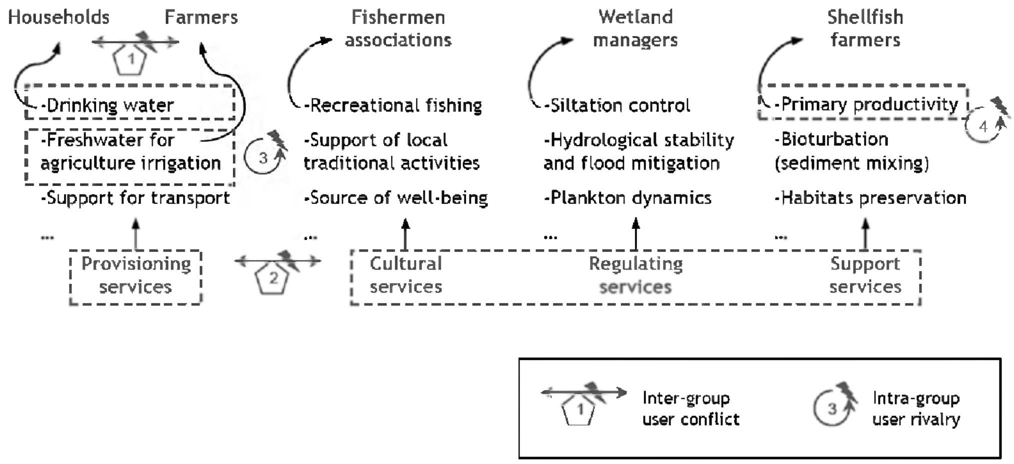

Figure 3.12.1. The Pertuis Charentais coastal area: ecosystem services depending on freshwater availability and main associated human activities.

Basically, freshwater scarcity (especially water-shortage events during summer) generates user conflicts, which reflect the need to mitigate the different ecosystem services that freshwater may provide. These conflicts are : (i) conflicts between the extractive uses of the water from the Charente River catchment, (ii) conflicts between extractive uses (provisioning services) and other services (support services, regulating services, cultural services) provided by freshwater, and (iii) and (iv) the intra-group rivalries for the use of the same service (the classic situation of a common-pool resource). The current state of the system gives priority to the provisioning of drinking water, which is therefore considered satisfied in any case. On the other hand, the estuarine part of the ecological system, which delivers most of the regulating services (hydrological stability, flood mitigation, and siltation control), is managed with two dedicated tools: the UNIMA canal and the Saint-Savinien dam. Hence, three main ecosystem services are subject to the risks associated with unpredictable variations in river flow and water shortage: the primary productivity of coastal waters, supply of freshwater for irrigation, and the recreational fishing activities that are affected by the drying out of rivers (Mongruel *et al.*, 2010). These are the three ecosystem services that fall into the scope of economic assessment.

Economic assessment of freshwater services

The implementation of an economic assessment methodology is based on a simple comparison of the damage costs associated with varying environmental conditions and management options. Even if the overall assessment procedure of the field experiment relies on an integrated model encompassing all three dimensions, ecological, social, and economic, the aim was not to provide an integrated economic assessment ending with the estimates of the total economic value of the ecosystems or the cost–benefit analysis of management options. Below is briefly demonstrated why, in the context of the integrated management of coastal social ecosystems, a partial economic assessment based on a simple comparison of damage costs may be sufficient to address effectively the policy issue at stake, followed by a description of the material and methods used to estimate these costs.

Economic assessment of ecosystem services: why damage estimates are sufficient

Any economic assessment is meaningful provided it has been carried out for a particular purpose. The present methodological discussion examines the economic assessment of ecosystem services, illustrating why the complete economic evaluation of ecosystem services, in all empirical cases raised by the sustainable management of social ecosystems, is both unfeasible and, fortunately, useless. The famous first synthesis proposed by Costanza *et al.* (1997) has been followed by numerous scholars who fairly attempt to improve the capability of estimating the economic value of ecosystem services, while many other scholars are still asking why ecosystem services should be priced; this is seemingly a never-ending story (Gatto and De Leo, 2000). The latter issue encompasses at least two dimensions: for what purpose, and is it useful? In practice, ecosystem valuation may pursue two main objectives (Pritchard *et al.*, 2000): (i) to provide a general description of the relative importance of various ecosystem types to ensure that nature is represented *per se* in decision-making processes and that its role in the economy is not merely aesthetic, and (ii) to sort different policy options in particular places where trade-offs between a set of alternatives have to be made, which in most cases is carried out within the framework of a cost–benefit analysis. In the first case, the intention is to show that the economic value of ecosystem services is not zero. In other words, the main reason for ecosystem valuation is political, aiming at changing the current situation in which "individuals and societies already assess the value of nature implicitly in their collective decision-making, too often treating ecosystem services as "free"" (Daily *et al.*, 2000) by demonstrating that ecosystem conservation would be a highly beneficial choice for society (Balmford *et al.*, 2002). The values themselves are often of poor significance, especially for those ecosystem services whose loss could mean the end of life: in practice, "there is little that can usefully be done with a serious underestimate of the infinite" (Toman, 1998). In the second case, the cost–benefit analysis appears to be a comfortable oversimplification of reality based on the ignorance of the ancient and always valid foundations of the economic theory of natural resources. Especially with regard the sustainability of social–ecological systems, this theory highlights the necessity of "viewing the various possible objectives of public policy as being substantially incommensurable on any simple scale and therefore necessitating the generation of various kinds of information, not summable into a single number, as a basis for political decision" (Herfindahl and Kneese, 1974).

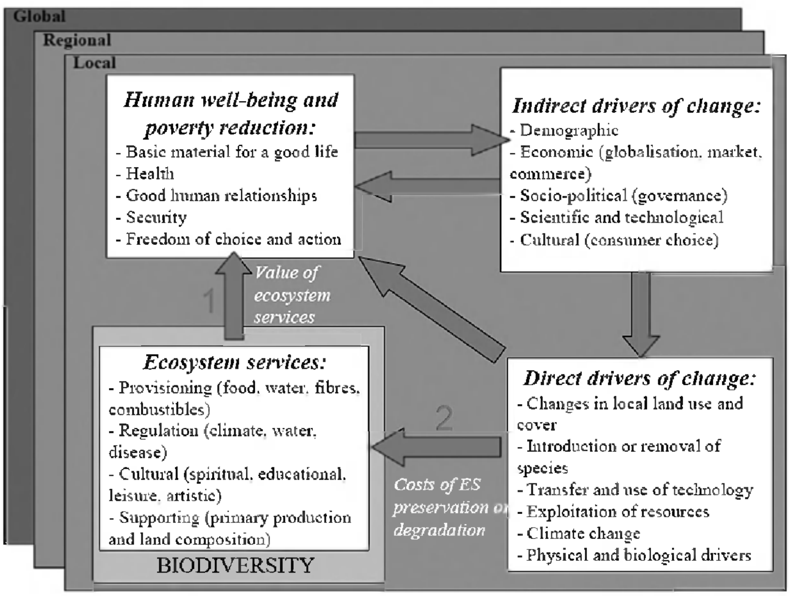

Figure 3.12.2. Drivers of change, ecosystem services, and human well-being (from MEA, 2005).

Because the economic valuation of ecosystem services will always remain incomplete and the result of a cost–benefit analysis is merely a single number combining all heterogeneous, and often intangible, effects of environmental change, such methods may be seen as uncertain, risky, and misleading. Basically, their main weakness is that economic valuation and cost–benefit analysis are not rich enough on information to determine policy choices (Toman, 1998). Multicriteria analysis techniques were therefore developed as an alternative approach to help decision-making (Gatto and De Leo, 2000). According to Heal (2000), the role of economics is simply to assist in designing institutions that can provide incentives for the preservation of important ecosystems and the mitigation of human impacts on the biosphere. Indeed, institutions are essential to nature conservation because they ensure the implementation of the trade-offs that social groups may agree upon when deciding to mitigate their impacts on the environment. From that perspective, economic valuation and cost–benefit analysis are useless because they pay no attention to the trade-offs implicit in the preferences expressed at one moment by people (through market price or customer willingness to pay), which means that they offer only a partial and static view of the dynamic process by which societies permanently re-organize themselves to adapt their relationship with nature according to its evolution (Pritchard *et al.*, 2000). On the other hand, simple economic techniques, such as cost–distribution estimates, may help to assess the sustainability of the social trade-offs that underlie the possible institutional innovations in response to environmental change.

Finally, what should be the purpose of an economic assessment of ecosystem services, and in practice, what kind of economic information do we need in the context of an empirical assessment of a social–ecological system which is carried out within the framework of a multicriteria analysis? The argument here is that cost–distribution estimates give sufficient information because they provide an idea of the acceptability of the institutional changes needed to maintain ecosystem services. As shown in Figure 3.12.2, human well-being is mainly made of intangible goods such as health, good human relationships, and freedom, to which ecosystem services contribute (arrow 1). Conceptually, this contribution of ecosystem services to human well-being explains why ecosystem services have a presumably high value, which is incommensurable too because most of the dimensions of well-being are intangible. On the other hand, direct drivers of change have impacts on ecosystem services (arrow 2), which explains that people suffer from these damages and that it is necessary to implement preservation or restoration measures: direct damages as well as preservation or restoration measures may often be easily estimated for costs, be they private or public. The obvious place for human intervention towards the sustainable management of social ecosystems, especially at the local scale, is typically in the relationships between direct drivers and the state of ecosystem services, where costs (not values) matter. What environmental managers are likely to implement is an institutional innovation or a technical measure which will affect, it is to be hoped positively, the ecosystems at the expense of some social groups (eventually the entire community), for the prospect of an incommensurable benefit which does not need to be assessed. Environmental managers, especially local ones, are less likely to intervene on mental representations by which people value ecosystem services, even if such a change is a long-term process that interacts with their willingness to support remediation rather than damage costs. Nevertheless, this relationship between people's system of values and their preference for environmental preservation calls here for more advanced social learning and, again, not necessarily for better economic valuation.

When a social–ecological system is subject to such anthropogenic pressures that its resilience is threatened, it makes sense to assess and compare the costs of the current situation (damage costs) with the costs associated with possible future situations (remediation costs and residual damage costs), provided that such estimates provide a clear view of the distribution of those costs, which gives indications whether the future trade-offs are likely to be acceptable or not. Succinctly, for operational purposes and practical reasons, we argue that environmental management decisions are more likely to be facilitated by estimates of damage than by estimates of value, and by comparisons of the distribution of costs among stakeholder groups rather than by comparisons of the ratios of aggregated costs and benefits.

Integrated modelling and the damage-based assessment methods

In integrated modelling of social–ecological systems, the economic dimensions need to be present during all steps of the building of the model: it is of particular importance that the model integrates economic dimensions such as the intensity of the uses of resources, the level of the demand for ecosystem services, and the objective functions of producers and other user strategies. The main function of the model is therefore not necessarily to contribute to the estimation of synthetic economic indicators such as total economic value or cost–benefit ratios, especially because such indicators tend to end with a final classification of management options based solely on the economic criterion, which is in contradiction with the initial objective of carrying out a multicriteria assessment from a multidisciplinary perspective. The model is meaningful for economic assessment because it encompasses the objectives and behaviours of stakeholders, be they private firms, non-profit associations, consumers, or citizens. When based on a holistic system-approach framework, a dynamic ecological–economic model should be expected to provide not an integrated economic assessment, but relevant economic information for an integrated assessment. We have assumed here that the assessment of damages and cost distribution are definitely among the most useful economic information for comparing alternative management options in the framework of an integrated assessment.

In principle, the functioning of damage cost assessment methods is not to discover the cost of restoring ecosystem services or to avoid their degradation; this would imply that solutions do exist for the recovery of ecosystem services, and such recovery would consist in practice in applying techniques based on real costs. Damage-based assessment methods are rather aimed at defining how much benefit has been lost because of ecosystem degradation (O'Connor *et al.*, 2001). This means that, in practice, damage assessment turns out to be the estimation of revenue (or wealth) losses with reference to an ideal situation. The reference situation may be chosen accordingly, whether the social–ecological system suffers from accidental pollution, progressive degradation, or recurrent adverse events. In the Pertuis Charentais study site, the problem of freshwater scarcity is the result of an increase in the number of dry summers in recent years: it falls therefore within the third category.

Three types of benefit loss derive from the degradation of ecosystem services and are attributable to freshwater scarcity in the Pertuis Charentais region: productivity losses of corn farmers, productivity losses of oyster farmers, and amenity losses of recreational fishers. Estimating income loss is a classic method of damage assessment in agriculture (Swinton *et al.*, 2007; Wang *et al.*, 2010) and aquaculture

(Garza-Gil *et al.*, 2006). The purpose is to establish a production function that combines the factors necessary to obtain a given output. To estimate net losses, production factors whose costs vary in relation to the availability of the considered ecosystem service need to be accounted for; the costs of other production factors are assumed to be identical, whatever the situation. Net income losses are then given by

$$-\Delta I = (Y^* - Y).p - (C^*_{es} - C_{es}) \quad , \qquad (1)$$

where Y^* and Y are the reference production and the estimated production, respectively, p is the ex-farm price of the commodity, and C^*_{es} and C_{es} are the variable costs associated with the availability of the considered ecosystem service in the reference and the estimated situations, respectively.

Obviously, C_{es} depends on producers' short-term strategies to adapt to the availability of the considered ecosystem service. For agriculture, as one considers the economic impacts of the availability of freshwater, the short-term adaptive strategy is based on irrigation, so we estimate the cost of irrigation in each situation. For oyster farming, the short-term adaptive strategies depend on the effects of freshwater availability on the different cultivated cohorts, because the production cycle lasts three years in the Marennes–Oléron area. The output target of the whole production basin and the ideal growth function of oysters provide a reference that may be used to forecast the initial population of spat needed, considering also the mortality dynamics; depending on environmental conditions, the observed levels of intermediate or final products may deviate from this ideal production function, and in the case of production deficit, oyster farmers import animals to fully utilize the harvest reference level (Pérez Agúndez *et al.*, 2010). In practice, the adjustment may be made at the three stages of the production cycle: at the beginning of a cycle for spat, at the middle of a cycle for half-grown animals, and at the end of a cycle for marketable adult animals (Figure 3.12.3). Within the framework of an ecological–economic model that simulates the availability of freshwater it is assumed that, *ceteris paribus*, other environmental factors have marginal or random effects and that the observed production deficit will be considered equal to the damage attributable to freshwater scarcity. The imports of spat and half-grown animals are then assumed to be the costs (C) of this ecosystem service availability, and the output deficit is the difference between the reference and the observed final output (Y).

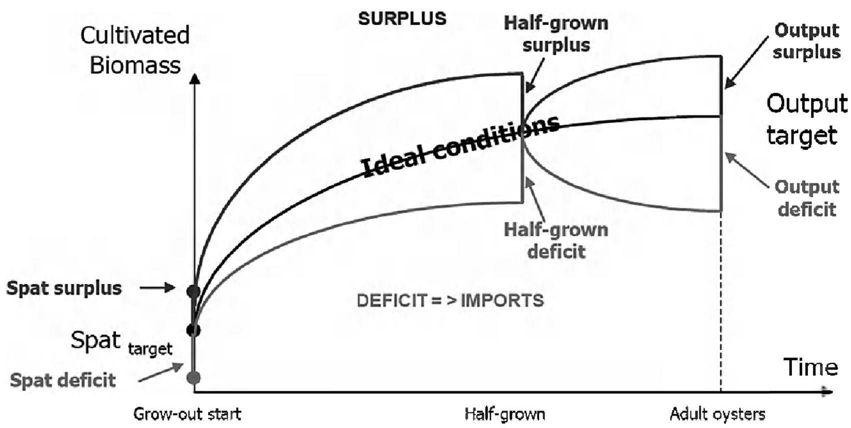

Figure 3.12.3. Production target and short-term adaptations in the oyster-farming sector.

The amenity losses incurred by recreational fishers are proxy for the availability of cultural services provided by freshwater. They may be estimated by the method of the avoided damage costs, i.e. the costs incurred by those who want to maintain the benefit of the considered ecosystem service (Swinton *et al.*, 2007). In the case of a river drying out, fisher associations carry out fish-saving operations. The amenity losses incurred by recreational fishers will therefore be assumed to be the expenses related to these fish-saving operations. And finally, because irrigated crop production is the human activity that depends most on freshwater availability, the chosen reference situation will be the year in which the yield of the maize culture is highest during the simulation period.

Preliminary results

Ecological–economic model

The ecological–economic model is based on a system view of the freshwater allocation issue in the Pertuis Charentais region (Figure 3.12.4). The hierarchical model is developed with three levels reflecting the social, economic, and ecological dimensions of the system (Ballé-Béganton *et al.*, 2010): (i) on top, governance and regulation, including irrigation limitations based on river water-flow monitoring; (ii) in the middle, direct or indirect uses of freshwater, e.g. agriculture, drinking water for households, recreational fishing, and shellfish farming; and (iii) on the bottom, the ecological system including the Charente River hydrology, wetlands, and coastal water productivity.

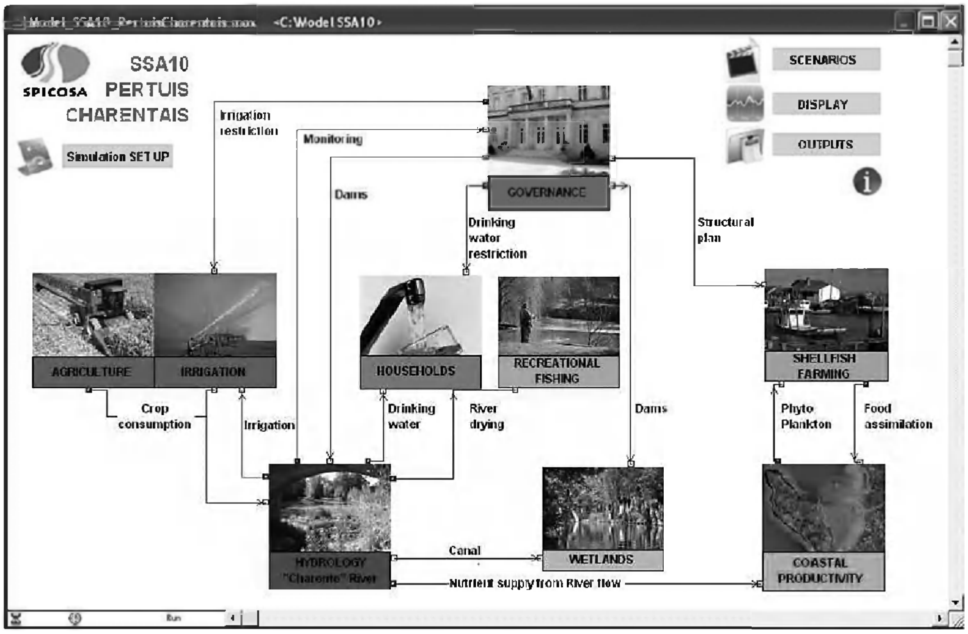

Figure 3.12.4. User interface of the model: a system view of the freshwater allocation issue.

In the present situation, the amount of ecosystem service available for each user group depends on both (i) the current level of human activities, which reflects the degree to which the Charente River catchment has already been modified by anthropogenic pressures, and (ii) the current rules regulating access to freshwater and its services, which reflects institutional arrangements for the use of these common-pool resources. In this case, the compromise that defines the level of anthropogenic pressure and the rules in use is unstable because it leads to unsustainable uses of freshwater. The model explores the way towards a more sustainable compromise, by incorporating the main institutional arrangements regarding water uses in the area, and the possible changes.

Basic assumptions for model formulation

The agriculture submodel estimates the total production of cultivated crops. First, the maximum potential yield Y_m is fixed according to the concepts of yield response to water by De Wit (1965) and data from Doorenbos *et al.* (1979):

$$Y_m = e.n.\left[F(a+b.y_m)y_0 + (1-F)(c+d.y_m)y_c\right], \tag{2}$$

where F is the part of the daytime when the sky is overcast, y_0 the gross dry matter production rate of a standard crop for a given location on a completely overcast day in kg ha^{-1} d^{-1}, y_c as y_0 for a cloudless day in kg ha^{-1} d^{-1}, n the duration period for same conditions (here, 1 d), and a, b, c, and e are correction terms according to the maize species and production site.

One approximation for the j-daily yield ratio to maximum yield Y_m is then (Stewart *et al.*, 1977):

$$\frac{Y_j}{Y_M} = 1 - Ky_j\left(1 - \frac{ETR_j}{ETM_j}\right) \tag{3}$$

with

$$ETR_j = P_j + ICC_j$$

where ETR_j is the daily maximum evapotranspiration for the crop, K_y is given according to maize species, P the precipitation, and ICC is the real irrigation consumption of crops, calculated by the irrigation module.

The irrigation module is intended to provide more realistic estimates of ETR, by considering the real consumption of crops attributable to irrigation restrictions. The irrigation module is based on the earlier formulation of irrigation strategies by Labbé *et al.* (2000), which has been combined with a formulation of current governance rules. This module uses the following variables: IDC is the irrigation demand for crops, estimated by the agriculture module as the difference between potential evapotranspiration and the available soil water (in m^3 d^{-1}), IDF is the irrigation demand of farmers, depending on local agricultural practices (IDF may be expressed as a fixed percentage of IDC) and limited by the capacity of equipments (in m^3 d^{-1}), ICC is the irrigation consumption of crops, depending on farmer practices and irrigation authorizations (in m^3 d^{-1}), PAT is the provisional volume of authorized takings per period, without crisis limitations (in m^3), and RAT is the real volume of authorized takings at each time-step, considering the past water consumption within the current period and the application of eventual crisis limitations (in m^3). At each time-step within a given period d (year, 10-d period, week or day, depending on the irrigation schedules), the irrigation consumption of crops is given by

$$ICC(t) = \min\left[IDF(t), RAT(t)\right], \tag{4}$$

where

$$RAT(t) = PAT^d(1-\alpha) - \sum_{t=1}^{t-1} ICC(t). \tag{5}$$

At this stage in the process, the marine coastal system is kept simple. Even if multi-box models (Raillard and Ménesguen, 1994; Bacher *et al.*, 1998) and 2D models (Struski, 2005) have already been developed for this ecosystem, a unique box of 358 Mm^3 represents the coastal zone. The water exchanges at the Atlantic Ocean boundary are assessed from the residence time of water in the Marennes–Oléron basin (approximately 10 d; Struski, 2005), which results from the tidal residual circulation and the Charente River flow. Even if the phosphate is now known to be probably the most limiting nutrient for micro-algae growth (Struski, 2005), the only nutrient taken into account is nitrate (NO_3). The phosphorus cycle was considered to be of too great complexity (adsorption on suspended and sediment particles) to be implemented in earlier Marennes–Oléron Bay primary production models, and consequently, in SPICOSA. The river NO_3 concentration is from an annual periodic function based on data from the Adour–Garonne Water Agency waterbase. Influenced by the Gironde River plume, the nitrate and phytoplankton concentrations at the marine boundaries are determined from data measured at the Auger Ifremer/RAZLEC station. The annual entrance of oceanic nitrate is adjusted to the assessments of Struski's 2D model (Struski, 2005).

The primary production model simulates phytoplankton (*PHY* in fg chl l^{-1}) growth according to light intensity and nutrient (*NUT* in f^{mol} N l^{-1}) availability. In a first approach, the attenuation of light by suspended matter is not considered in this physical dimensionless system. The phytoplankton is grazed by zooplankton (by a simple closure function) and filtered by oysters (*OYS*). A pool of benthic detrital material (*DET*) is supplied by the zooplankton-grazed phytoplankton and by oyster faeces. The mineralization supplies regenerated nutrients to the water column.

$$\frac{dPHY}{dt} = -graz \times PHY^2 + \mu \times PHY - OYSingest \times J\mathrm{to}B\,, \tag{6}$$

with *graz* the zooplankton grazing rate (d^{-1}), μ the phytoplankton growth (d^{-1}), *OYSingest* the ingestion rate of oysters (J d^{-1}), and *J*to*B* the energetic conversion factor of phytoplankton biomass (μg J^{-1}).

The growth in size and weight of each oyster cohort (*c*) is based on a DEB model (Pouvreau *et al.*, 2006). The ingestion is controlled by water temperature (*T*) and phytoplankton concentration (*PHY*). As the spawning and the recruitment of the Japanese oyster are still the object of experimental studies, the reproduction is not described in the model.

$$OYSingest = \sum_{c=1}^{NbC} (Pxm(T) \times f \times V(c)^{2/3}) / BV \quad \text{with} \quad f = \frac{PHY}{PHY + Xk}\,, \tag{7}$$

where *Pxm(T)* is the maximum ingestion rate, controlled by T (J cm^{-2} cl^{-1}), *Xk* the half-saturation coefficient (μg chl l^{-1}), *V(c)* the volume of the oyster cohort *c* (cm^3), and *BV* the volume of the bay (in litres).

The food demand is satisfied when *f* = 1. It is a theoretical value never reached in this system, because of a high *Xk* parameter. For the other processes of the DEB model, refer to Pouvreau *et al.* (2006). The oysters population dynamics are the result of natural mortality and human culture practices. Each year in spring the stock of oysters is increased with bags of new oysters, divided in three cohorts:

1) the spat produced locally that complete their life cycle in the basin,
2) half-farmed oysters that have grown during their first 18 months in more productive coastal areas,

3) adult oysters that are immersed many months in the basin before their refinement in "claires" (old flooded saltflats diked into water parcels connected with a canal network).

Oysters are harvested many times during the year (principally at the end), as soon as their size has reached marketable grade. The annual harvest target is ca. 43 000 t (Girard *et al.*, 2005). The stock dies at a constant rate even though random massive mortalities are observed in some years. The dynamics of the oyster population is the sum of the dynamics of the NbC cohorts:

$$\frac{dOYS}{dt} = \sum_{c=1}^{NbC} (s(c) - h(c) - m \times OYS(c)) \quad (8)$$

with *s(c)* the bags of new *c* cohorts (ind. d^{-1}), *h(c)* the harvest (ind. d^{-1}), and *m* is the mortality rate (d^{-1}).

After five years of stabilization of the model, the climate scenario is tested in the sixth year. Oyster stock analysis and economic assessment are performed in the spring (1 April) of the next normal year following this climate scenario test.

Exploratory simulations

The model provides physical estimates of the availability of ecosystem services and physical and economic estimates of the resulting impacts on human activities. Because a complete estimate of net income losses that takes variable costs into account has not been arrived at yet, presentation of the preliminary results is limited to physical estimates of the availability of ecosystem services and the yields obtained for intermediate and final products in both primary sectors (agriculture and shellfish farming). The exploratory scenarios are based on the following basic assumptions: first, the direct pressures of human activities on the ecological system are fixed, which means that each year, farmers cultivate the same areas of irrigated crops and oyster farmers introduce the same level of spat in the basin; second, the irrigation strategies are those currently implemented by farmers (a "provisional" irrigation strategy on the upstream side of the river catchment and a "myopic" irrigation strategy on the downstream side). The exploratory scenarios compare the production yields of the reference year (the year when the agriculture production is maximized), a year of average climate conditions, and a dry year.

For the agricultural sector, the relative availability of the provisioning service provided by freshwater from the Charente River catchment may be estimated through the difference between the irrigation demand of crops and the irrigation consumption of crops (Figure 3.12.5). As regards the shellfish farming sector, the relative availability of the support service provided by freshwater from the Charente River catchment may be estimated through the difference between the oyster food demand and actual food ingestion (Figure 3.12.6). The preliminary results indicate that, under contrasting climate conditions, variation in the availability of ecosystem services associated with freshwater from the Charente River is definitely more pronounced for the provisioning service used by maize farmers than for the support service used by oyster farmers.

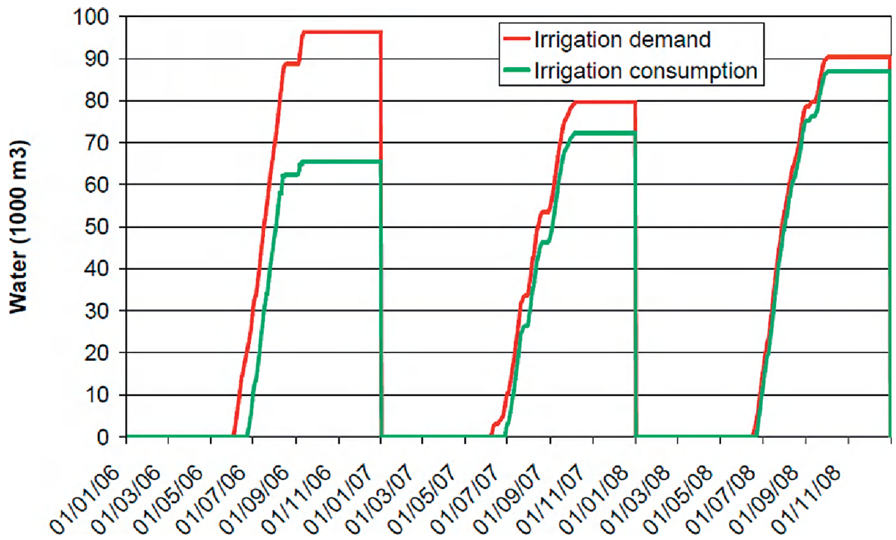

Figure 3.12.5. Irrigation demand and irrigation consumption in the Charente estuary sub-basin.

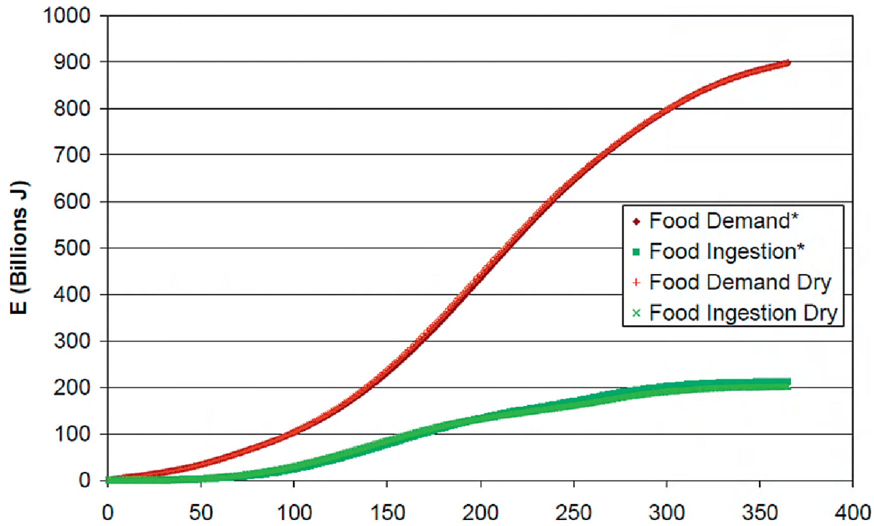

Figure 3.12.6. Food demand and food ingestion of oysters: reference situation and dry year.

For yield losses (Table 3.12.1), the results indicate that the production level obtained under average climate conditions is only slightly less than the maximum observed: maize production may fall a few percentage points whereas oyster production could generate a surplus. When extreme levels of freshwater scarcity are considered (dry year), the maize yield may fall by >20%, representing a big loss for farmers. However, for net loss, the difference between the average situation and the extreme one may be less, because farmers can irrigate much more under average conditions than during a dry year, and the cost of irrigation (which is basically the cost of the energy needed to pump water from the river), when accounted for, should also reduce the net income of farmers during an average year. The impacts of drought on the shellfish farming sector may be relatively marginal as regards final production, but it appears that the intermediate production (half-grown oysters) may fall by >10%. Even if such an intermediate production deficit can be compensated for by oyster farmers, that activity probably generates additional production costs which also need to be accounted for. Pending confirmation in further simulations, such contrasting results at different stages in the production cycle might demonstrate the utility of integrating the adaptive practices of oyster farmers into the ecological–economic model.

Table 3.12.1. Yield losses in the agriculture and oyster farming sectors with reference to the best possible (observed) conditions for maize production.

		ABSOLUTE YIELD LOSSES $Y - Y^*$	RELATIVE YIELD LOSSES $(Y - Y^*)/Y^*$
Agriculture final production	A: Average conditions	−8 928 t	−2.4%
	B: Dry conditions	−84 909 t	−23.2%
Oyster farming final production	A: Average conditions	285 t	0.8%
	B: Dry conditions	−620 t	−1.8%
Oyster farming intermediate production	A: Average conditions	−272 t	−2.1%
	B: Dry conditions	−1 526 t	−11.6%

Discussion

The ecological–economic model investigates the impacts of relative freshwater scarcity in the Charente River catchment on the availability of the ecosystem services used by irrigated maize culture and oyster farming. In terms of oyster farming, the model accounts for the influence of freshwater scarcity on coastal primary production and the resulting consequences on the yield of half-grown and adult oysters. However, the scarcity of freshwater is probably just as relevant to another stage of the oyster-farming production cycle: spat collection. Natural oyster recruitment depends on the success of spawning and spat collection during summer. Investigations into the role of the freshwater supply in the survival of oyster larvae are still ongoing and need to be added to the model as the next step.

The primary production model is currently not very sensitive to interannual variation in hydrological conditions, so the yield of oyster farming is similarly not sensitive to that parameter. Some environmental factors are not taken into account in the growth of microalgae, however: the suspended particular matter discharged by the Charente River and resuspended by the tide attenuates the penetration of light down the water column, and water temperature modulates physiological processes. At this stage of the work, some of the forcing variables that vary from one year to another are considered identical for the scenarios: solar irradiance (a simple periodic function) and oceanic boundary conditions. These are influenced by the plume of a large river, the Gironde, and probably co-vary with the discharge from the Charente River. Multiyear field data from Marennes–Oléron Bay are regrettably lacking, so it becomes difficult to refine this external forcing. Until the sensitivity of the primary production model is improved, therefore, our scenarios remain exploratory, but they do demonstrate the potential of this integrated modelling.

The purpose of this paper was to present the approach, the methodology, and some preliminary results. Further improvements to the model will include the simulation of scenarios considering changes in the governance system, because improved access rules and more coordinated strategies are already envisaged by local managers and maize farmers. For instance, it has been suggested that the scheduled irrigation strategy adopted by farmers in the upstream sub-basin be implemented also in the downstream sub-basin. Other improvements of the governance system may include the progressive enforcement of new institutional arrangements that would favour collaborative behaviour between farmers, such as the spreading over time of water consumption exercises between farmers to avoid a sudden massive requirement for freshwater that would make the river flow fall under the threshold at which an abstraction issue arises. In addition to the physical estimates of the resulting state of ecosystem services, variation in the damage costs associated with such new institutional arrangements should provide useful indicators for exploring the social willingness to implement them.

Acknowledgements

The work was funded by the 6th Framework Program of the European Commission Research Directorate under Priority 1.1.6.3 "Global Change and Ecosystems" (IP SPICOSA, project 2007–036992). The representatives of the management bodies of the Pertuis Charentais site who participated in this collaborative work between researchers and managers are gratefully acknowledged. The views expressed in the article are those of the authors only.

3.13 Contribution of seabed habitat surveys to marine planning for renewable energy developments

Marion Harrald, Peter J. Hayes, Ian M. Davies, and Mike R. Robertson

Sustainable development of marine renewable energy (wave and tidal stream power) in coastal waters requires that due account be taken of the biodiversity and conservation value of seabed habitats in development areas. Areas of high tidal streams may contain reef habitat, an Annex 1 habitat in the EU Habitats and Species Directive. As part of Marine Scotland Science (MSS) assistance to the emerging wave and tidal energy industries, regional seabed survey datasets are being collected from selected areas around Scotland. Inshore waters west of the Isle of Lewis contain one of the best wave resource areas in the UK and have not previously been surveyed using multibeam. Bathymetric data were collected by the FRV "Scotia" with a Reson Seabat 7125-B multibeam echosounder system together with ground-truthing data collected using a dropframe TV. In total, 260 km^2 of predominantly hard ground were surveyed, 36 seabed TV tows were completed, and >600 digital still images were collected west of Lewis between 21 July and 4 August 2010. The bathymetry and backscatter data were post-processed using industry standard software. An integrated approach was applied in which bathymetric, backscatter, and derived datasets were used to identify regional changes in the seabed facies. Subsequent ground-truthing of the seabed facies using the footage from a dropframe TV permitted the compilation of a regional seabed habitat map and led to an assessment of conservation interests in the area.

Keywords: backscatter, bathymetry, habitat map, wave and tidal energy.

Introduction

Scottish seas contain some of the best wave energy resources in Europe and can produce a significant proportion of Scotland's electricity demands from wave power. In light of the Scottish Government's commitment to produce 100% of Scotland's electricity demands from renewable sources by 2020, there is enthusiasm to support the emerging wave and tidal industries and provide them with regional-scale datasets to assist in planning for the successful location of wave and tidal devices. Alongside policy to support renewable energy generation, Scotland is also committed to the provision of a network of marine protected areas (MPAs) under the Marine (Scotland) Act 2010. The MPAs are being selected according to presence of species and habitats of particular significance to Scotland, known as priority marine features (PMFs; SNH, 2011b). The ecological impacts of wave devices are as yet poorly understood, but concerns have been raised over the effects of energy reduction on the seabed (Shields *et al.*, 2011), the introduction of artificial habitats such as foundations of energy-producing devices (Langhamer, 2010), and the risk of pollution through mechanical failure or leakage (SNH, 2011a). An in-depth knowledge of seabed bathymetry and its substratum types is vital for assessing site suitability for mooring the device in question, and information on habitats and species present permits an evaluation of conservation interests in the targeted area.

Site suitability and potential impact depend on the type of wave device and the number of machines deployed. Offshore floating devices such as the Pelamis (Pelamis Wave Power) operate in waters of 50 m or greater, are moored using a set of anchors, and require a subsea cable to transmit the power to shore. Nearshore devices such as the Oyster (Aquamarine Power) are usually fixed to the seabed and are typically designed to operate in 10–25 m of water (Cameron *et al.*, 2010).

The west coast of the Isle of Lewis in the Outer Hebrides has some of the best wave resource in British inshore waters (BERR, 2008), being open to the full reach of the Atlantic Ocean. Moreover, the area between Loch Roag and the Butt of Lewis has been recommended for consideration in the Further Scottish Leasing Round for wave and tidal energy (Harrald and Davies, 2010; Harrald *et al.*, 2010), having relatively low levels of conflict with other marine users and the environment. No multibeam echosounder bathymetric surveys of that area appear to have been undertaken previously and very few data are available on marine habitats and species. Parts of inner Loch Roag are designated as a marine Special Area of Conservation (SAC) for its saline lagoons, tidal rapids, and reefs, but they are inshore of the potential wave-power development. A diver survey in and around Loch Roag provided evidence of rocky substratum, dense kelp forests, and rich fauna (Howson and Duncan, 2002). However, the survey was limited to within 100 m of the shore. In September 2010, Marine Scotland Science surveyed an area off the west coast of Lewis between Loch Roag and the Butt of Lewis using multibeam, video, and photography. The multibeam and backscatter data were processed to obtain maps of the bathymetry and the backscatter, and other derived layers. The videos and photographs were biotoped and assessed for conservation interests (Moore and Roberts, 2011). Examination of all these layers allowed compilation of a substratum and habitat map.

Methods

Study area and multibeam sonar survey

The survey was carried out between 21 July and 4 August 2010 from Loch Roag (58°16′30″N 06°57′18″W) to the Butt of Lewis (58°32′16″N 06°12′31″W), west of the Isle of Lewis in the Outer Hebrides (Figure 3.13.1). The sheltered lagoon complex of Loch Roag in the south of the area surveyed supports a wide range of sublittoral sediment habitats, whereas the more exposed outer edges of the loch and its islands are characterized by boulders and steep rocky reefs. The coastline north of Loch Roag has steep cliffs of Lewisian gneiss interrupted by small bays and culminating in cliffs 18–25 m high at the Butt of Lewis.

Multibeam echosounding was undertaken on-board the FRV "Scotia" (69 m) using a dual frequency Reson 7125 system attached to the drop keel of the ship. The 400 kHz frequency is designed to provide high-resolution bathymetry and acoustic reflectivity (backscatter) data at depths of 0.5–150 m, and swathe widths are ~4 ×

water depth. The position was georeferenced using an Applanix POS MV™ and a Fugro STARFIX DGPS. A sound velocity probe was used daily to take water-column profiles and two RBR DR-1050 tide gauges were deployed for the duration of the cruise. Transect lines were drawn in ArcMap for the vessel to follow, to ensure a minimum 50% overlap between adjacent lines. These were orientated parallel with the shore to minimize the number of times the vessel needed to turn during the survey. The vessel maintained a steady speed of 4 knots over water depths < 60 m and 8 knots over water depths >60 m.

Video and camera deployment

Video and photographic footage was obtained to ground-truth the backscatter imagery and to identify species or habitats of potential conservation interest. It was carried out using a dropframe TV with video (Kongsberg Simrad) and digital stills (Canon) camera, both in waterproof housings, towed using the bow-thrusters of the vessel. Locations for video transects were selected by examining preprocessed swathe bathymetry to include a range of different substratum types. Transect duration ranged from 5 to 15 min. The dropframe TV was suspended above the seabed guided by a steel weight attached by a line to the dropframe. Maintaining the steel weight (66 mm diameter) just on or above the seabed ensured the correct height for accurate focusing of the video and digital cameras. Two laser spots set 100 mm apart provided a scale for identifying features. Video-footage was collected for the duration of the deployment, and digital stills approximately every 60 s. Most deployments were undertaken during slack water. Deployments were not carried out when flow conditions were >1.5 knots, and the camera was towed against the tide at ~1 knot. The location of the dropframe and the digital stills were recorded directly into ArcView. A log of the substratum and macrobenthos was recorded every minute of the tow.

Post-processing

The swathe bathymetry data were acquired as .pds files using the software PDS 2000 (3,5,0,11). The .pds files were corrected for tide, heave, and total propagated uncertainty (TPU) using the software Caris Hips and Sips Professional (7.0). The tide file used was generated using an extract from a modelled offshore tide and current computation system. The data were merged and exported as .gsf files. These were cleaned using the software Fledermaus (7.0). The data were projected to WGS 84, UTM Zone 29°North and gridded to 3.3 m before being exported to ArcInfo. Further derived layers were created including a hill-shade relief map, rugosity, aspect, and slope. Backscatter mosaics were processed using the mosaic editor component of Caris to a resolution of 1 m.

Substratum and biotope interpretation

The type of substratum present was interpreted using a combination of the bathymetry, backscatter, and other derived layers. Differentiation of hard from soft substrata was carried out by overlaying the hill-shade map as a translucent layer over the bathymetry, whereas variation in the softer sediments was interpreted using the backscatter layer. Polygons of the substratum types were traced over the data layers using the ArcEditor component of ArcMap.

The biotopes present were derived from the videos and photographs in a separate publication (Moore and Roberts, 2011). In brief, Moore and Roberts (2011) used the images to describe the physical structure and species assemblages. The MNCR SACFOR scale (Connor and Hiscock, 1996) was used to quantify the species present, and biotopes were allocated based on their physical and biological attributes (Hiscock, 1996; Connor *et al*., 2004). The biotope map was derived from the substratum map previously created in combination with the biotopes observed in each of the TV tows.

Results

An area of >260 km^2 between 1.5 and 4.5 km offshore was surveyed bathymetrically, during which 36 seabed TV tows were completed and >600 digital still photographs taken. The survey area, between the Butt of Lewis and east of Loch Roag, lies between 16 and 77 m deep (Figure 3.13.1). The seabed is mainly metamorphic rock, known as Lewisian gneiss, with areas of softer sediment in the south and boulders of mixed sizes farther offshore. These three broad substratum types, sand, cobbles, and boulders and rock, are illustrated in Figure 3.13.2. The backscatter layer is particularly useful for differentiating between sediment types and soft vs. hard substratum types. Patterns of sediment outflow from Loch Roag are clear in the backscatter and hill-shade relief map (Figure 3.13.1). Sand ripples >1 m high are also evident in the region. Due east of the area of soft sediment (from 06°48′W) the seabed becomes mainly rocky, with large expanses of cobbles and boulders. Farther east still, approaching the Butt of Lewis, the complexity of the seabed increases. Bedrock walls up to 8 m high are interspersed with gullies containing coarse sand. Rocky outcrops, as illustrated by the backscatter image (C in Figure 3.13.1), and boulders of mixed size, dominate farther offshore.

In all, 11 biotopes were identified in the survey area (Moore and Roberts, 2011) to EUNIS level 4 or 5. At that level of detail, the geographic extent of each biotope could not be extrapolated because variation in the backscatter layer did not reflect such a level of detail. It was possible to map the biotopes as four broader categories, however, representing EUNIS levels 3 and 4 (Figure 3.13.2). More detailed biotope descriptions derived from the videos and photographs were available at the locations of the video tows.

The sediment substrata off east Loch Roag were classified as either circalittoral fine, mixed, or coarse sediment (Figure 3.13.2, photo A). Little life was apparent on the sediment, with the exception of occasional *Luidia ciliaris* and *Ophiocomina nigra* (echinoderms), *Flustra foliacea* (an erect bryozoan), and *Hydrallmania falcata* (a hydroid). The rocky substratum was generally characterized by large urchins and crustose communities (CR.MCR.EcCr), such as corraline algae, tubeworms, and encrusting bryozoans. Brittlestars, primarily *Ophiothrix fragilis* or *Ophiocomina nigra,* were locally abundant or superabundant (Figure 3.13.2, photo B). Sponges in massive forms, such as *Cliona celata* and *Pachymatisma johnstonia,* were present in the more exposed sites. Outcrops of bedrock and boulders and cobbles on a sandy substratum supported a dense community of sponges, erect bryozoans such as *Porella compressa* and *Pentapora fascialis*, and the solitary coral *Caryophyllia smithii* (CR.MCR.EcCr.CarSp.PenPcom). The area north of the Butt of Lewis supported a diverse community with an abundance *of Alcyonium digitatum*, *Corynactis viridis*, and brittlestars (CR.MCR.EcCr.CarSp.Bri) on the steep rocky walls (Figure 3.13.2, photo C). Observations of mobile species were relatively sparse. However, ling (*Molva molva*) were observed in the rockier habitats and grey gurnard (*Eutrigla gurnardus*) over the sand.

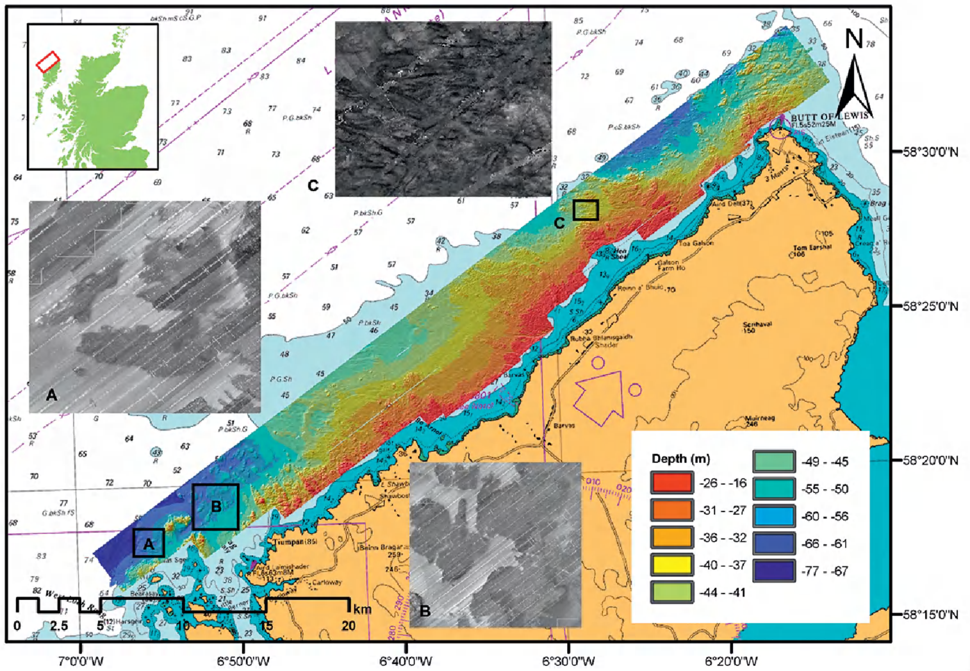

Figure 3.13.1. Bathymetric and hill-shade relief map of the survey area off the west coast of Lewis in the Outer Hebrides of Scotland. The insets (A, B and C) are backscatter images of sediment flows (A and B) and scouring in rock (C).

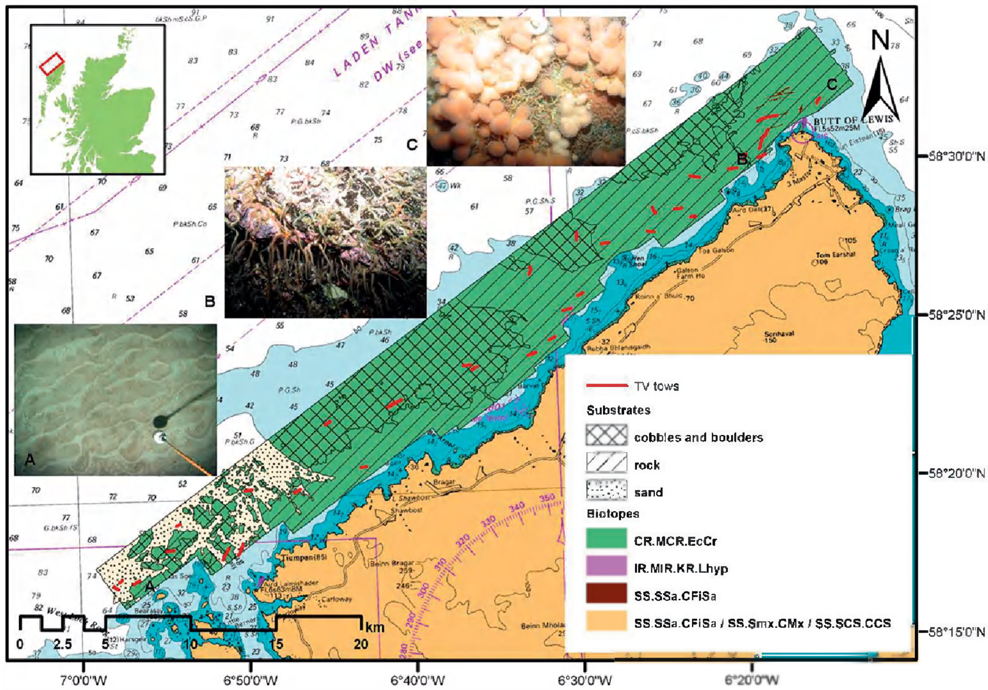

Figure 3.13.2. Substratum and biotope map of the survey area and locations of dropframe TV tows. The biotopes plotted include CR.MCR.EcCr (echinoderms and crustose communities), IR.MIR.KR.Lhyp (kelp and red seaweeds on moderate energy infralittoral rock), SS.SSa.CFiSa (circalittoral fine sand), and SS.Smx.CMx (sublittoral mixed sediment and SS.SCS.CCS (circalittoral coarse sediment). The insets (A, B, and C) are examples of biotopes and species photographed using the dropframe camera, depicting circalittoral fine sand (SS.SSa.CFiSa; A), brittlestar beds on circalittoral rock (CR.MCR.EcCr.FaAlCr.Bri; B) and *Alcyonium digitatum* and *Corynactis viridis* on circalittoral rock (CR.MCR.EcCr.CarSp.Bri; C).

Discussion

This first multibeam survey of the area between Loch Roag and the Butt of Lewis off the west coast of Lewis revealed detailed bathymetry and habitats not previously described in the area. The bathymetric information adds to continued work carried out by the UK Hydrographic Office to map the seabed for navigational purposes. It also provides essential information for marine planning and for potential wave developers looking to locate wave-energy generation devices in the region. The combination of multibeam backscatter data with video and still images provides firm evidence for the production of substratum and habitat maps. The potential conservation value of the habitats and species observed can also be assessed with a view to minimizing development in sensitive areas and locating regions that contain priority marine features that may be worthy of MPA status.

These survey data are in broad agreement with depths and substratum types illustrated on the UK admiralty chart, although some areas, particularly in deeper water, are up to 8 m deeper than on the chart. Other sources of substratum and habitat data are mostly contrary to the findings of this study. The British Geological Survey (BGS) seabed sediments data (DigSBS250) and the EUSeaMap Predicted EUNIS Habitats (MESH, 2011) categorize the area as sand to gravel and circalittoral sands/coarse sediment, respectively. Areas of sand were found in this study offshore of Loch Roag along with outcrops of rock or boulders. However, due north of this, the study revealed large areas of rock, with boulders and cobbles farther offshore. There are a number of possible reasons for these discrepancies. First, the BGS and EUNIS maps are mapped to a lower resolution (250 m and 300 m, respectively) and are based on fewer sample points. Second, it is possible that the backscatter data used to map some areas of this study penetrate deeper than the surface layer. The BGS data are based on seabed grab samples of the top 0.1 m, which in certain cases may overlie harder substratum. However, in this study photographs and video were used to ground-truth backscatter and bathymetric data. The photographs are sampling the same top layer of substratum as a grab sample 0.1 m deep. A limited area of coast has been mapped in much greater detail north of Loch Roag through the EUNIS Habitats (MESH, 2011). Most of it is inshore of the survey area in the present study, but the overlapping segment does correlate well with the survey data.

The survey area displays a rich variety of habitat types, including sublittoral sands and stony and bedrock reef. The bedrock reefs off the Butt of Lewis are particularly rich in soft corals, anemones, and sponges characteristic of exposure to strong currents and wave energy. Such reefs provide a habitat for numerous other species and are one of the search features used to identify future SACs defined in Annex I of the Habitats Directive. The rocky outcrops and stony reefs due south of the Butt of Lewis contained rare species such as ross coral *Pentapora fascialis*, an erect bryozoan. This is the most northerly inshore record of the species in Scotland (National Biodiversity Network Gateway, 2011). The biotope IR.MIR.KR.LhypTX.Pk (mixed kelp park on lower infralittoral mixed substrata) is a PMF and was identified in one location (58.42°N 06.50°W; SNH, 2011b). It is likely that there are more extensive kelp forests inshore in shallower water. Although the survey was primarily designed to study sessile benthic species, two mobile PMFs were also observed. Ling *Molva molva* were frequently seen at the more northerly sites in rocky areas on the video footage, and basking sharks *Cetorhinus maximus* were observed daily from the vessel.

The consequences of wave-energy device installations on habitats and species assemblages is very much dependent on the type of seabed developed and the size and number of the devices in question. Currently, the industry has only installed single devices for demonstration and testing purposes, but it is working towards installing larger test and commercial arrays of between 10 and >100 devices (Shields *et al*., 2011). Bedrock reef habitats that may be of conservation interest could be damaged during the construction or operation phase (Faber Maunsell and Metoc PLC, 2007), and physical damage to the seabed and associated species assemblages may result from cable-laying and mooring of the device. The areas in the north of the survey area that displayed the richest bedrock reef habitats were also the most complex in their bathymetry. The reefs exhibited steep bedrock walls up to 8 m high interrupted by narrow sandy gullies, and as such it is likely that the area would be relatively difficult to develop. More likely areas for development would be on the flatter hard ground to the south or on soft sediment. Scouring and sediment resuspension is likely in areas of softer sediment (Faber Maunsell and Metoc PLC, 2007). However, few recordings of macrobenthos were made on the sediment, so damage to benthic species would be limited, although there may be loss of habitat and feeding ground for fish.

Further ramifications may result inshore of the wave devices resulting from changes in the hydrodynamics (Shields *et al*., 2011), particularly if a large number of wave devices are installed. A reduction in wave energy on the shoreline may result in a more benign environment and consequently result in a shift towards species that tolerate lower energy conditions. Anecdotal reports from divers suggest that much of the nearshore environment (to 15 or 20 m deep) is dominated by kelp, and variation in wave action may affect its development (Gaylord *et al*., 2003; Shields *et al*., 2011). Indirect consequences of the installations may also result. For example, fishing may be restricted around the devices, which could result in the recovery of benthic habitats and produce refuge for fish populations (Langhamer, 2010). The devices and their moorings provide an artificial habitat and may result in an increase in habitat heterogeneity and attract species not otherwise present in the area (Shields *et al*., 2009). Ultimately, given the scale of developments, their design and methods for installation, the potential for devices to affect the marine environment will require assessment on a case-by-case basis.

Conclusion

The study has revealed a complex seabed containing a range of features from flat sand to complex bedrock reefs between 20 and 80 m deep, offering a broad range of environments for installation of offshore wave devices. The level of detail mapped from this study is far greater than that currently available on Admiralty Charts and in existing BGS and EUNIS substratum maps. Such information will be an asset for marine planning. Hayes and Davies (2010) and Hayes *et al*. (2011) created a marine spatial planning tool for the Pentland Firth and the west of Lewis in which a developer can select a site based on distance offshore, depth, and slope of seabed. A future version could now incorporate the ability to select by substratum type and habitat. There are conservation interests within the area, such as the rocky reefs and the presence of basking sharks, but without knowing how extensive these are beyond the boundaries of the site, it is difficult to judge the level of concern that should be applied. The environmental impact of wave-energy devices on such habitats and species is still poorly understood, although monitoring of test devices and early arrays should provide information on the impacts in due course. Damage to bedrock and stony reef communities in the area should be considered along with potential ramifications of loss of wave energy on the communities inshore. Further multibeam and video work is taking place to better understand this nearshore environment.

Acknowledgements

We are grateful to the crew of the FRV "Scotia" and scientific staff including Derek Moore, Philip Copland, Eric Armstrong, Michael Robertson, Malcolm Rose, Paul Stainer, Jane Heron, and Colin Megginson. We also thank the Scottish Government for continued financial support towards multibeam habitat mapping in support of marine renewables.

3.14 The development of a novel regulatory and planning tool to guide the sustainable development of oyster aquaculture in New Brunswick, Canada

Sophie Bastien-Daigle and Matthew Hardy

Conservation and protection of fish habitat in coastal zones is proving to be inherently challenging because of the myriad regulators and stakeholders interacting there in a complex web of legitimate uses and conflicts. Innovative management regimes are required in that zone in order to protect fish habitat and other ecological resources while allowing for its sustainable development. Emergence of the aquaculture industry in the coastal zone has sparked calls at the global level for integrated regulatory frameworks to guide its development. The federal and provincial governments agreed in 2002 to develop a comprehensive framework covering environmental review and management, site selection, design criteria, and operating conditions to guide oyster culture. The main objective of that framework was to streamline and bring a greater measure of predictability, consistency, and timeliness to the environmental review process of oyster aquaculture projects within the context of sustainable development. Key elements were: (i) this class screening relied on geospatial analysis to reduce spatio-temporal interactions between the activity and valued ecosystem components such as locations of bird colonies, species at risk, waterfowl and fish habitat, wetlands, dunes, and saltmarshes; (ii) in addition to these safeguards, possible use scenarios with various management options were evaluated. Zones were subsequently defined where shellfish leases could be best located to protect the environment, to reduce conflict with other users and to meet regulatory requirements; (iii) the replacement class screening report will continue to be updated via an adaptive management process that will provide continuous feedback as to its effectiveness; (iv) a code of practice was developed with the industry to complement the numerous regulatory mechanisms in place and to define practical steps to achieve environmental stewardship. The industry has adopted this code of practice and is responsible for its implementation.

Keywords: aquaculture, environmental assessment, oyster, regulatory framework.

Introduction

Conservation and protection of fish habitat in coastal zones is proving to be inherently challenging because of the myriad regulators and stakeholders interacting there in a complex web of legitimate uses and conflicts. Innovative management regimes are required in the coastal zone to protect fish habitat and other ecological resources while allowing for its sustainable development. Emergence of the aquaculture industry in the coastal zone has sparked calls at the global level for integrated regulatory frameworks to guide its development.

This was the case for oyster aquaculture in New Brunswick (NB), where the industry has been expanding over the past few years. The federal and provincial governments agreed in 2002 to develop a comprehensive framework covering environmental review and management, site selection, design criteria, and operating conditions to guide oyster culture. The main objective of this framework was to streamline and bring a greater measure of predictability, consistency, and timeliness to the environmental review process of oyster aquaculture projects within the context of sustainable development (TC, 2007).

Regulatory context

The development of the oyster aquaculture industry is subject to the Navigable Waters Protection Act, administered by Transport Canada, and to the conditions for protection of fish and fish habitat as defined in the Fisheries Act, administered by Fisheries and Oceans Canada. The industry is also subject to evaluations under the Canadian Environmental Assessment Act (CEAA; Canada, 2007), which is the legal basis for the federal environmental assessment process. It sets out the responsibilities and procedures for carrying out environmental assessments of projects. The federal environmental assessment process is applied whenever a federal authority has a specified decision-making responsibility in relation to a project, also known as a trigger for an environmental assessment. It ensures that projects are carefully reviewed before federal authorities take action, so that projects do not cause significant adverse environmental effects. It also promotes cooperation and coordinated action between federal, provincial, and territorial governments on environmental assessments (Canada, 2007).

By and large, oyster aquaculture environmental assessments (EAs) in NB were carried out on a project-by-project basis. Among agencies, there was a concern that this approach did result in shortcomings, such as delayed permissions, inconsistent outcomes, or regulatory overlaps. More significantly, it was felt that the approach failed to address cumulative effects over the long term, notably in the context of a rapidly developing industry (Bastien-Daigle *et al.*, 2007). For oyster aquaculture (defined as works under the CEAA), the majority of projects submitted for an environmental review are considered to be similar in nature. Oyster aquaculture works in NB have common design, construction, operation, and decommissioning characteristics (Doiron, 2006).

The culture of oysters in NB relies upon the native species (*Crassostrea virginica*). Husbandry techniques and siting are similar throughout the industry given the comparable environmental conditions and constraints in estuaries where suitable growing conditions are found.

Process

The CEAA allows for the assessment of projects similar in nature to be streamlined through the use of a class screening report rather than having individual environmental assessments. The replacement class screening process permits the preparation of a single report (a RCSR) that defines a well understood class of projects and describes the associated environmental effects, design standards, and mitigation measures for projects assessed within that class. The use of such integrated regulatory tools had been recommended to federal agencies as a means to bring a greater measure of predictability, consistency, and timeliness to the environmental review process (Canada, 1995). Class screenings are used with the intent of having clear, well-defined classes of recurring projects, and are considered applicable only when projects meet a number of specific criteria, such as a well-understood environmental setting, projects unlikely to cause significant adverse environmental effects, no project-specific follow-up measures required, or an effective and efficient planning and decision-making process.

Spatial assessment of valued ecosystem components (VECs) was done to identify important components of coastal and marine ecosystems as well as heritage and conservation sites (Figure 3.14.1). This included locations of bird colonies, species at risk, waterfowl and fish habitat, wetlands, dunes, and saltmarshes. Different digitized layers of coastal and sensitive areas were systematically identified and considered in the process. Agencies were consulted on other planning elements, such as the presence of coastal users, closed and contaminated zones, and proposed developments. Different scenarios were subsequently developed based on respective agencies' policies and concerns. The main objective was to reduce spatial and temporal interaction between aquaculture and VECs (see Figure 3.4.1.2 for an example of existing aquaculture leases and zones for future aquaculture development).

Where potential adverse effects could not be avoided through marine spatial planning (MSP), they were subsequently addressed under the analysis of environmental effects in the RCSR. Effective mitigation measures and best management practices (BMPs) were developed collaboratively and form part of the regulatory framework governing that industry. Thus, every new oyster aquaculture project approved under the RCSR is administered using a coordinated and streamlined regulatory regime.

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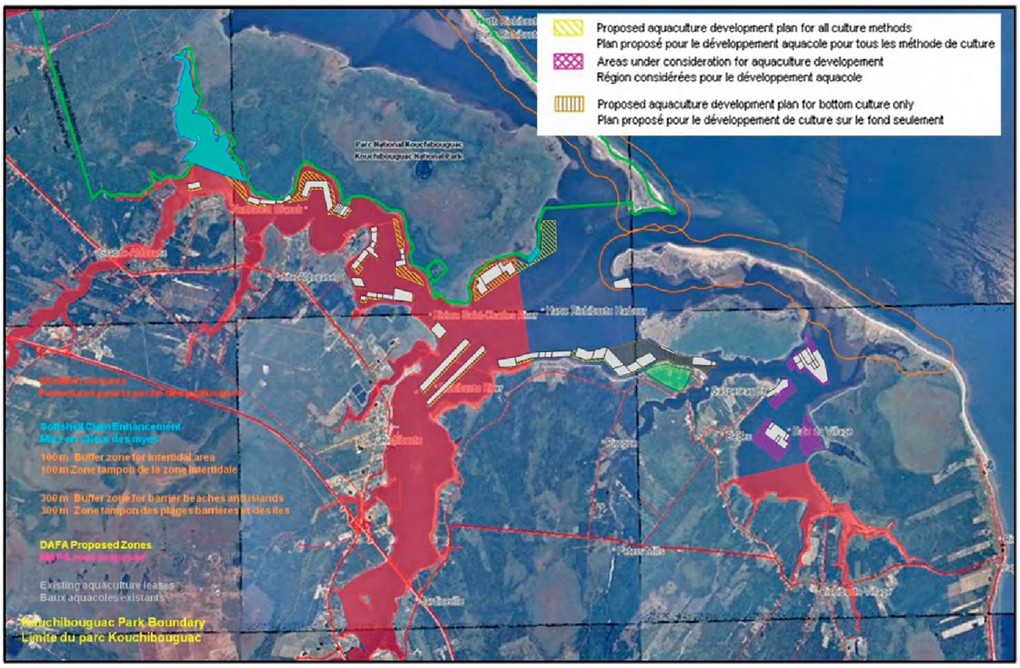

Figure 3.14.1. Example of the geospatial analysis of valued ecosystem components.

Key elements:

- This class screening relied on geospatial analysis to reduce spatio-temporal interactions between the activity and VECs such as locations of bird colonies, species at risk, waterfowl and fish habitat, wetlands, dunes, and saltmarshes.

- In addition to these safeguards, possible use scenarios with various management options were evaluated. Zones were subsequently defined where shellfish leases could be best located to protect the environment, to reduce conflict with other users, and to meet regulatory requirements.
- The RCSR will continue to be updated via an adaptive management process that will provide continuous feedback as to its effectiveness.
- A code of practice was developed with the industry to complement the numerous regulatory mechanisms in place and to define practical steps to achieve environmental stewardship. The industry has adopted this code of practice and is responsible for its implementation.

Benefits

Using this approach, federal and provincial agencies

1) streamlined the environmental review of water column oyster aquaculture projects;
2) integrated multi-agency regulatory requirements into a single governance process;
3) improved the consistency of mitigation measures and BMPs;
4) captured potential cumulative environmental effects and reduced them by anticipating and reducing spatio-temporal interactions between ecosystem components and the industry's activities;
5) provided a planning framework to guide future development of this industry in NB;
6) saved considerable amounts of financial and human resources; and
7) significantly reduced delays for oyster aquaculture site approval.

3.15 Environmental vulnerability profiles: characterization of pressures in the southern Gulf of St Lawrence, Canada

Matthew Hardy, Marc Ouellette, Pascal Levesque, and Roland Cormier

The worldwide realignment of research and management objectives in recent years to respond to the implementation of the ecosystem approach represents a departure from past practice where emphasis was mainly on a single-species fishery or single-activity basis. Although there is a broad consensus on the purpose of this realignment, its practical application continues to be a significant challenge given the complexities of attempting to develop multispecies/activity-integrated management plans, frameworks, and approaches for all factors affecting the aquatic environment. The management of aquatic and land-based human activities that can contribute to adverse environmental impacts on aquatic ecosystems is one of the major challenges associated with integrated coastal and ocean management. There is recognition that effective integrated management will require new pragmatic approaches, in addition to current practices. It is also particularly important to develop approaches that build greater credibility with the public in regard to integrated planning initiatives and that are based on clear, factual, and interpretable information. The Gulf of St Lawrence regional vulnerability profile is being developed by the Department of Fisheries and Oceans Canada with contributions from a number of federal and provincial departments. The development of that atlas represents an ongoing effort to assemble a new toolbox by the department and builds on the work being done by the US-EPA regional vulnerability atlas (http://www.epa.gov/reva/). The purpose of the atlas is to identify and scope the environmental pressures associated with a

number of human activities from a geospatial perspective, and to illustrate their respective and relative intensity. This work represents part of the problem formulation in a classic risk analysis framework. This is not an assessment, but it may serve in the identification of priority monitoring areas to evaluate the effectiveness of mitigation measures in reducing the potential for adverse environmental effects and identifying research or assessment needs. It can also serve as the basis for engaging relevant federal and provincial partners as well as in communicating with the public in a structured and factual manner.

Keywords: atlas, coastal management, geospatial, vulnerability.

Introduction

The worldwide realignment of research and management objectives in recent years to respond to the implementation of the ecosystem approach represents a departure from past practice where emphasis was mainly on a single-species fishery or single-activity basis. Although there is broad consensus on the purpose of this realignment, its practical application continues to be a significant challenge given the complexities of attempting to develop multispecies/activity-integrated management plans, frameworks, and approaches for all factors affecting the aquatic environment.

The management of aquatic and land-based human activities that can contribute to environmental effects on aquatic ecosystems is one of the major challenges associated with integrated coastal and ocean management. There is recognition that effective integrated management will require pragmatic new approaches in addition to current practices. It is also particularly important to develop approaches that build greater credibility with the public in regard to integrated planning initiatives and that are based on clear, factual, and interpretable information.

The Gulf of St Lawrence regional vulnerability atlas is being developed by the Department of Fisheries and Oceans Canada with contributions from a number of federal and provincial departments. The development of that atlas is part of an ongoing effort to assemble a new toolkit by the department and builds on the work being done by the US-EPA regional vulnerability assessment (ReVA) programme (http://www.epa.gov/reva/).

The purpose of this atlas is to identify and scope the environmental pressures associated with a number of human activities from a geospatial perspective, and to illustrate their respective and relative intensity. This work represents part of the problem formulation in a classic risk analysis framework. It is not an assessment, but may serve to identify research or assessment needs. It can also be the basis for engaging relevant federal and provincial partners and for communicating with the public in a structured and factual manner.

Risk analysis

Risk analysis (RA) is at the core of this work. It is internationally recognized as an approach to assist decision-making, representing a systematic way of gathering, evaluating, recording, and disseminating information leading to recommendations for a position or action in response to an identified risk. It is a tool intended to provide decision-makers with an objective, repeatable, and documented assessment of the risks posed by a particular course of action.

In Canada, the Treasury Board Secretariat (TBS) has also described risk management as "a systematic approach to setting the best course of action under uncertainty by identifying, understanding, acting on and communicating risk issues" (TBS, 1999, 2001, 2004, 2005). Although it does not make difficult problems simple or provide easy solutions, the approach is particularly useful for organizations needing to deal with uncertainty and complexity in a robust, thorough, and defensible manner using the best available information.

A risk-based approach also helps managers to prioritize issues and focus efforts when regulating the activities considered to have the greatest potential impact. For practical management purposes, this means the identification of feasible policies and best management practices to mitigate the potentially adverse environmental effects, once identified. There is also an opportunity to better align departmental resources more efficiently in planning, effectiveness, monitoring, and compliance audits.

DPSIR

One of the tools being used to provide structure to this process is the Driver–Pressure–State–Impact–Response (DPSIR) framework (DEDUCE, 2002). The categorization of information appropriately is critical in the accurate representation of risks and the connectivity between the causes, effects, and management actions that can be taken. For this application, the focus relates to the human activity drivers that can induce pressures in relation to the adverse environmental effects on the state with particular regard to significant areas or species. Typical categories of environmental effects include habitat alterations and fragmentation, biota alteration and disturbance, contaminants, sediment regime alteration, and nutrient regime alteration.

Pressures

The intent of the maps illustrated in this document is to highlight outliers or hotspots that assist the practitioners in drawing attention to areas of greater human activities that can induce pressures (type and intensity). Therefore, the maps are presented with regard to the relative pressures within the scale under consideration. As such, each map is independent of the others. The data represented have been analysed and categorized based on percentiles and are relative to the average statistics within the database being queried. The nature of the information implies that colour schemes are represented on a relative basis as opposed to absolute values (i.e. the absolute intensity of one fishery vs. another may be orders of magnitude different). Areas represented as orange or red (or darker colours for watersheds) should only be interpreted as being above average, whereas those in dark green (or lighter colours) should be interpreted as being below average.

Significant areas and species

The potential consequences of the pressures highlighted in maps is based on the significance of the areas and its susceptibility to adverse environmental effects (see Figures 16.1 and 16.2).

Several ecologically and biologically significant areas (EBSAs) have been determined for the region based on pre-established and peer-reviewed criteria. The intent of this work is to provide guidance on areas of particularly high significance in order to "facilitate provision of a greater-than-usual degree of risk aversion in management of activities in such areas" compared with other areas (DFO, 2004a). Criteria for EBSAs include:

- uniqueness – where characteristics are unique, rare, distinct, and for which alternatives do not exist in most important features;
- aggregation – where most individuals of a species are aggregated for some part of the year, or for some important function in their life history, or for a structural feature or ecological process with a high density;
- fitness consequences − where the life-history activity(ies) undertaken make a major contribution to the fitness of the population or species;
- resilience – where the habitat structures or species are highly sensitive, easily perturbed, and slow to recover;
- naturalness – where conditions are pristine and characterized by native species.

Additional criteria have been prepared for species and community properties (DFO, 2006). These criteria provide an objective basis against which to weigh the potential consequences of the adverse environmental effect pressures in significant areas in relation to management objectives.

In practice

These tools are being developed to help in a number of ways:

- to set priorities based on higher risk issues;
- to formulate what can be managed now and adapt later as new science/needs emerge;
- to be more effective with mitigation measures and efficient at the deployment of human and financial resources;
- to focus monitoring and compliance auditing in the most appropriate areas;
- to sort out perceptions of risk in relation to risk based on current knowledge;
- as a communication tool to promote dialogue and for building consensus on the issues.

The current steps being undertaken aim to optimize existing mitigation measures (i.e. policies and practices) that reduce the risk, likelihood of the event, or potential severity of consequences. There is also a need to understand better the effects of natural processes (i.e. flushing rates, areas of greater rainfall, climate change, etc.) that could mitigate or exacerbate the potential for environmental effects to produce adverse impacts.

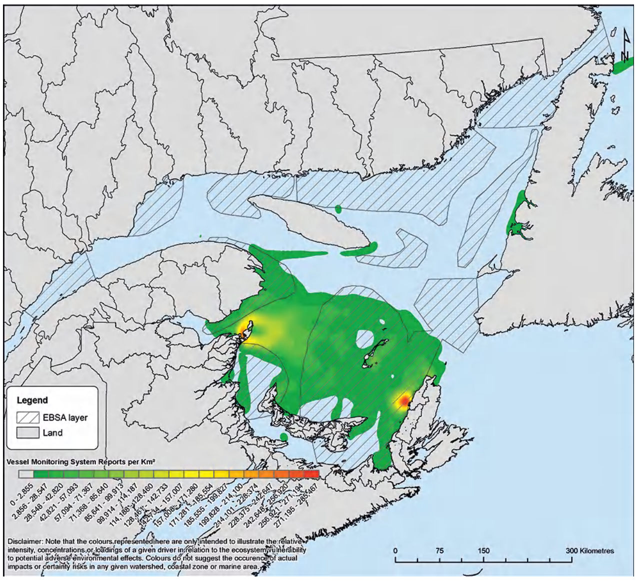

Figure 3.15.1. Navigation intensity of fishing vessels in relation to marine mammal significant areas, used for identifying priority monitoring areas to evaluate the effectiveness of mitigation measures in reducing the potential for the disruption of marine mammals.

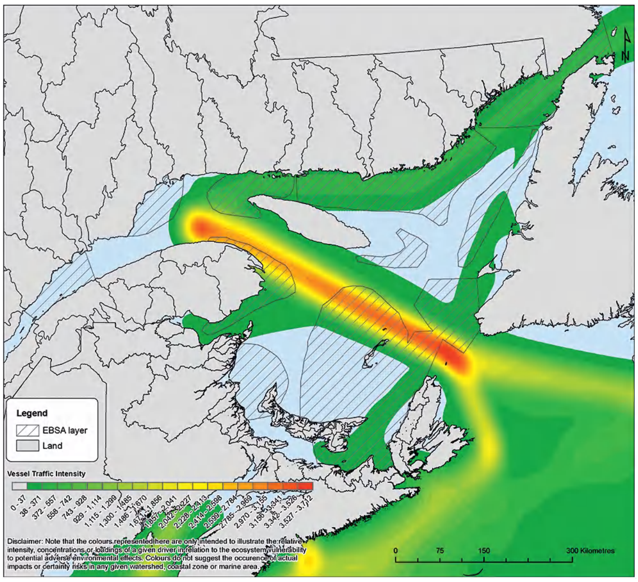

Figure 3.15.2. Navigation intensity of commercial transportation vessels in relation to marine mammal significant areas, used for identifying priority monitoring areas to evaluate the effectiveness of mitigation measures in reducing the potential for the disruption of marine mammals.

3.16 The adaptation of a risk-based approach for integrated coastal management

Matthew Hardy and Raymond MacIsaac

In Canada, the importance of risk management has been growing steadily during the past few years and is a key pillar in governmental policy and accountability frameworks. The Treasury Board of Canada Secretariat (TBS) defines the corporate context and practices for managing organizational and strategic risks proactively such that key risks are identified and managed through a (i) risk lens in decision-making, (ii) a risk smart culture, and (iii) a capacity to communicate and manage risk

in public context. The development of a risk-analysis based framework is being examined as a means of providing an objective, rigorous, and iterative approach that may serve to validate facts and perceptions around public concerns while enhancing communication and engagement. The elements being considered are founded on the recognition of jurisdictional authorities and their respective accountabilities for the management of cumulative adverse environmental effects that cannot be resolved unilaterally by any organization or entity alone. It is our view that the application of risk analysis concepts provides a viable means to assist regulatory authorities in the strategic deployment of resources to manage issues in the coastal zone more effectively. Although integrated coastal and oceans management remains a highly complex endeavour, the structure and concepts associated with risk analysis lend credibility to the process in a manner that can support collaboration between sector-based institutions. It is believed that a formalized framework that is defensible and logical will provide the mechanism that will allow for integration and achieve reductions in policy and regulatory fragmentation.

Keywords: coast, integrated management, risk analysis, vulnerability.

Introduction

In Canada, the importance of risk management has been growing steadily during the past few years and is a key pillar in the management accountability framework (TBS, 2003, 2004). The Treasury Board of Canada Secretariat (TBS) defines the corporate context and practices for managing organizational and strategic risks proactively such that key risks are identified and managed through (i) a risk lens in decision-making, (ii) a risk smart culture, and (iii) a capacity to communicate and manage risk in public context.

The development of risk-based approaches to support decision-making is considered a potential means to facilitate the implementation of integrated coastal and ocean management.

A conceptual framework for risk-based integrated management, although not prescriptive, can provide guidance for effective use of existing information. It can also aid in ensuring the efficient deployment of resources while renewing focus on priority setting to resolve the issues of greatest concern.

Adaptation of risk analysis

The adaptation of the existing information is being considered in the context of risk analysis to provide a more pragmatic structure. Specifically, strengthening the initial phases of this process is key to building a credible and pragmatic management process that has the potential to be successful at achieving realistic goals within a well-defined scope and scale of issues. The intent is to provide the context to frame preliminary decisions with regard to the appropriate approach and level of response required for leading to more focused assessments relating to ecology, socio-cultural and economic, and governance issues.

The elements being considered are founded on the recognition of jurisdictional authorities and their respective accountabilities for the management of issues that cannot be resolved unilaterally by any organization or entity alone. Moreover, a risk-based framework is being examined as a means to provide an objective, rigorous, and iterative approach that may serve to validate facts and perceptions around public concerns while enhancing communication and engagement.

Our view is that the adaptation of risk analysis concepts in the context of integrated management and coastal and marine spatial planning provides a viable means to deal with the intrinsic complexities and uncertainties. We believe that it can enhance the ability to find a course of action to pass from strategic goals and reach operational level outcomes.

The following sections provide a brief overview of our views on the application of the risk analysis approach in the context of integrated coastal and ocean management: (i) initiation, (ii) problem formulation, (iii) risk assessment, (iv) risk management, and (v) risk communication (Figure 3.16.1).

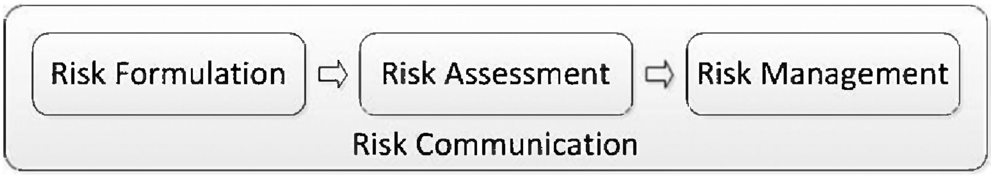

Figure 3.16.1. Generalized steps in risk analysis.

Initiation

The rationale for initiation is often a call for action by the public to relevant government agencies. The request is to respond to a publicly stated perception that there is something broken, but proactive approaches by government agencies are also possible to initiate action. The broken aspect may involve social, environmental, or economic adverse effects, and the perception that the existing governance models and decision-making authorities are not working.

Problem formulation

The problem formulation process entails undertaking an analysis of current conditions and establishing the scope and boundaries of the affected area. Included in such an analysis of conditions is the current operational and fiscal climate in which the initiative is undertaken. There is also a need to acknowledge realistic time constraints; it cannot be an open-ended process of scoping.

The development of environmental vulnerability profiles as part of the problem formulation (i.e. hazard analysis) can be used to incorporate existing information such as:

1) ecologically and biologically significant areas (EBSAs),
2) socio-cultural and economically significant areas (SCESAs),
3) human use activities and their zone of influence, in order to
4) characterize the potential conflicts and compatibilities.

These components are linked on the basis of pathways of effects, conceptual models that describe interactions between human activities, pressures, and adverse environmental effects (e.g. agriculture, fertilizer application, increased potential for nutrient regime alterations in the aquatic environment).

Most importantly, seeking agreement among regulatory authorities on the scope that quantifies and qualifies the nature, frequency, and intensity of risk relative to adverse environmental effects is defined in this phase.

Strategic risk assessment

Strategic assessments roll out of the environmental profiling carried out in the problem formulation phase of the process. Focused assessments on the issues of greatest concern with clear questions allows for more effective use of expert capacity. The purpose of this phase is the strategic and proportionate deployment of resources for mitigation of adverse environmental effects.

The consideration of ecological, social, and governance aspects on an equal platform for assessments is important in creating a credible process. Concurrent assessments (i.e. ecological, social, or regulatory) are conducted, as required, to validate the relationships between a human activity and an adverse environmental effect. Rather than simply describing the problem, this phase seeks to extract the technical information required to inform the development of management options for mitigation.

Risk management

Management in the coastal zone requires the bridging of land-based resource management to coastal and marine spatial planning. Policy integration is most likely to arise with the commitment to ensure effective management with the purpose of preventing cumulative adverse environmental effects and user conflicts. This means recognizing which authorities are best positioned to achieve effective mitigation. Rather than change existing governance mechanisms, this implementation implies the coordination of sector-based management working within existing mandates.

Monitoring for the effectiveness of actions in relation to established environmental objectives and auditing for efficiency and compliance of regulatory regimes are a specific output of the process. We believe that performance indicators can be more readily determined in the context of a focused approach to mitigation of adverse environmental effects. This then flows logically to reporting on the state of the ecological unit and the application of adaptive management approaches.

Risk communication

Risk communication should be considered throughout the process where there is a commitment to incorporate an engagement of interested parties in a manner that builds awareness, understanding, and trust using audience-appropriate tools. Transparency is enhanced when interested parties have a clear understanding of the process to be employed and recognize where and when they can contribute. Also understood is the commitment to provide reporting and records of decisions, describing on what basis regulatory authorities have made decisions and how balance was sought between ecological and social goals.

Key lessons to date

The experience in advancing the implementation of integrated management has been particularly useful in providing feedback from interested parties and regulatory partners. This feedback includes:

Formal governance

1) partners are looking for an integrated management approach in the context of a way of doing business that needs to be pragmatic from a whole-government perspective;
2) recognition of existing authorities and jurisdictional accountabilities to the decisions taken (or not taken).

Engagement

1) integrated management for its own sake is not a sufficient justification to mobilize and engage partners or resources;

2) public perceptions often raise the issues that need to be addressed, validated, and managed when confirmed;
3) commitment to a process is important before engagement and expectations are raised.

Agreement on approaches

1) there is typically little appetite for the development of so-called omnibus integrated management plans;
2) resources are too limited government-wide to expend on initiatives with little support or low priorities – the triage of key issues needs to be fact-based;
3) there is more support for issue-specific action plans (as required) through the use of complementary sector-based policies and feasible management practices.

Conclusions

It is our considered view that the application of risk analysis concepts can assist regulatory authorities in the strategic deployment of resources to manage issues in the coastal zone more effectively. Although integrated coastal and ocean management remains a highly complex endeavour, the structure and concepts described above lend credibility to the process in a manner that can support collaboration between sector-based institutions.

A formalized framework (Figure 3.16.2) that is defensible and logical will provide a mechanism that will allow for integration and achieve reductions in policy and regulatory fragmentation. Collaboration between multiple authorities, jurisdictional levels, and within jurisdictions through the alignment of actions to speak to both broad-based and operationally specific objectives is the goal.

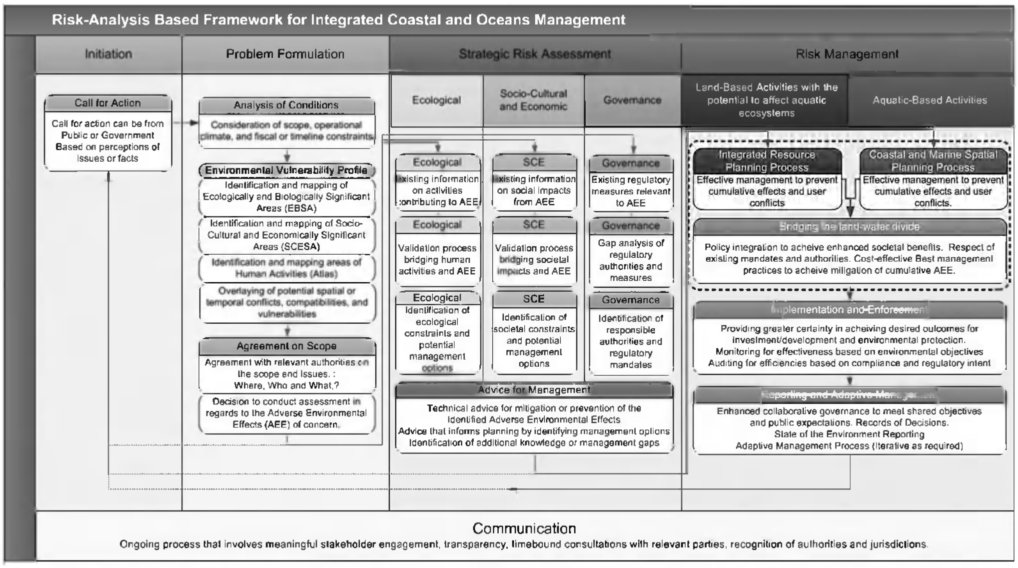

Figure 3.16.2. Risk-analysis based framework for integrated coastal and oceans management.

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6 Abbreviations and acronyms

BMP	best management practice
CEA	class environmental assessment
DPSIR	Drivers–Pressures–State–Impacts–Response
EBM	ecosystem-based management
EBSA	ecologically or biologically significant marine area
EIA	environmental impact assessment
EPS	European Protected Species (1994 EU Habitats Directive)
GES	good environmental status
HRA	habitats regulations appraisal
ICZM	integrated coastal-zone management
IM	integrated management
IMP	EU Integrated Marine Policy
IUCN	International Union for Conservation of Nature
LOMA	large ocean management area
MPA	marine protected area
MSFD	EU Marine Strategy Framework Directive
MSP	marine spatial planning
PDS	Planetary Data System (a NASA format for storing astronomical images)
PMF	priority marine feature
RCSR	replacement class screening report
SAC	special area of conservation
SEA	strategic environmental assessment
VEC	valued ecosystem component