4 Concepts, methods, and tools to support science-based decision-making in Integrated Coastal and Ocean Management: Examples from the Balearic Islands*

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1. Introduction

The sustainable management of coastal and marine ecosystems has become one of the greatest environmental challenges of the last decade and a major priority of the European Union (e.g. Integrated Coastal Zone Management Recommenda-

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tion, Integrated Maritime Policy, Water Framework Directive, Marine Strategy Framework Directive)[1] and of additional countries with established coastal and marine management programmes (e.g. USA, Canada, Australia). Global change, which may be defined as, "changes in the global environment (including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life" is increasing the susceptibility and vulnerability of coastal ecosystems to negative impacts of human and natural pressures, making the achievement of sustainability all the more challenging (Global Change Research Act of 1990). Population pressure and associated sustenance and economic needs are growing, tapping increasingly deeper into natural resource pools and "unspoiled" areas of the planet in order to satisfy the needs and desires of humans. Total protection of marine and coastal ecosystems, through banning all types of use across large areas is becoming a decreasingly realistic management option.

In this context, in order to address sustainability challenges in the last decade, the scientific community has dedicated increasing attention to the need to consider human social systems and ecological systems as one, often referred to as social-ecological systems (Alessa et al. 2008, Berkes et al. 2003, Cheong 2008, Ostrom 2009). This perspective is reflected in new Integrated Management (IM) approaches to addressing sustainability challenges that seek to combine scientific research and information with management processes and policy development. These include, among others, Integrated Coastal Zone Management (ICZM), Marine Spatial Planning (MSP), and Integrated Ocean and Coastal Management (ICOM). ICZM is an Integrated Management (IM) process that seeks to develop a model for sustainable development that is based on finding points of convergence among ecological, socio-cultural, and economic factors (Cicin-Sain and Knecht 1998, IOC 1997, Gentofte 2009). In theory, it is an effective tool for advancing towards sustainability in the coastal zone, ensuring equitable use of coastal resources (natural, socio-economic, and cultural) and integration among the different administrative and societal sectors. ICZM brings together coastal zone habitat conservation and socio-economic objectives and is often implemented through the establishment of geo-spatial and temporal plans. MSP extends procedures associated with terrestrial spatial planning and number of the principles of ICZM to the marine environment. Shared principles include integration, participation, and the goals of maximizing compatibility among human activities and minimizing negative impacts of these activities on ecosystems. ICZM was initially conceived under a definition of the "coastal zone" that incorporates the effects of land based activities on marine activities and vice versa (i.e. from the coastal plain to the edge of the continental shelf). However, ICZM in practice has not extended far enough inland or out to sea to account for all of the interactions on the land-sea interface. In this context, Ehler and Douvere (2009) describe MSP as, "the missing

1. See EC Environment and Maritime affairs websites for more information: http://ec.europa.eu/environment/water/index_en.htm; http://ec.europa.eu/maritimeaffairs/.

piece that can lead to truly integrated planning from coastal watersheds to marine ecosystems". In this chapter, we consider ICOM to be an approach based on the combined, related principles of ICZM and MSP.

Despite significant efforts from scientists and practitioners to mitigate the negative impacts of increasing anthropogenic and natural pressures, the state of the world's coasts is deteriorating (Burke et al. 2001, EEA 2006, 2001, GESAMP 2001, OECD 2001, UNEP 2006, United States Commission on Ocean Policy 2004). It is our view that this is not because there is a lack of "good" science, rather, it is due to the fact that this science is still not being used appropriately to make decisions related to sustainability. This challenge is commonly referred to as the "science-policy gap" (Lubchenco and Sutley 2010, Cheong 2008, Kates et al. 2001). As Ascher (2006) points out, we already have a good sense of what actions we need to take in the long-term in order to achieve sustainable development. The major challenge lies in inducing change at the socio-political level. This will require a shift from classic decision-making models, which are often top down, sector driven, and myopic, towards integrated, society driven processes that are based on long term visions and scientific knowledge. Dennison (2008) points out that traditional science is well established with respect to data collection yet has remained less effective at using this information to solve environmental problems. Recent developments such as the EC Statement on Marine Knowledge 2010[2] and the GISC project[3] are a testament to a growing awareness of the critical importance of using scientific knowledge effectively for decision-making.

The science that is needed to support ICOM decision-making is more applied, interdisciplinary, and problem orientated than traditional science, which has resulted in the emergence of new disciplines such as sustainability science (Clark 2007). Sustainability is a complex and multifaceted goal that is influenced by a plethora of scientific disciplines (i.e. natural sciences, physical sciences, social science, economics, psychology, political science) and sectors of society. In order to solve sustainability problems, scientists and decision-makers must work together and draw on many, often all, of these dimensions. In practice, however, there is still a tendency towards disciplinary scientific studies and sectoral approaches to decision-making. Since it is unrealistic to assume that one scientist or decision-maker can address all relevant dimensions of sustainability, a participatory approach to science that is integrated in the governance system is necessary. Where the ultimate responsibility for making decisions is in the hands of managers and politicians, scientists can play an important role in guiding those decisions by ensuring they generate viable, relevant and practical information that equates with socio-political realities. In this chapter, we describe a series of concepts, methods and tools that scientists can use to achieve this. Although these examples are widely applicable, they are based on ICOM research that has been carried out in the Balearic Islands since 2005, described in more detail section 2. In section 3, we present a selection of methods and tools with

2. Website: http://ec.europa.eu/maritimeaffairs/
3. Website: http://gisc.ew.eea.europa.eu/gisc-project

specific examples of their application in the Islands. The final section outlines major conclusions of this chapter and suggests future directions for research.

2. The evolution of ICOM research in the Balearic Islands

The Balearic Islands are an autonomous region of Spain (i.e. with a regional government) located in the Western Mediterranean. The islands cover an area of 4970 km^2, with a coastline of 1428 km, and a population of just over one million in 2009 (IBESTAT). In 2009, 11.6 million tourists visited the islands (CITTIB 2009). The Balearics are a mature island destination, historically characterized by "sun, sea and sand" tourism and are also a major recreational boating hub. The Islands have maintained substantially high standards of environmental quality in many coastal areas. However, much like the majority of coastal zones around the world, negative impacts of human activities that challenge the achievement of sustainability have been observed. These include, among others, unplanned coastal development, pollution and residuals, overcrowding of anchoring zones and beaches, and periodic, increased pressure on natural resources during the high season for tourism (Murray 2005, Tintoré et al. 2009). The threat of such impacts is exacerbated by the insular environment of the Balearics characterized by, among others, limited space, natural resources, and waste assimilation capacity.

Sustainable development has been recognized as a priority by the government and civil society in the Balearic Islands. However, systematic, integrated management approaches to achieving sustainable development goals are challenged by limited scientific information, supporting legislation and the absence of a coordinated governance structure that responds to these goals (Barragán 2010, Diedrich et al. 2010). For the last five years, the scientific research community, with the support of the public administration and other civil society groups (e.g. Chamber of Commerce, Economic and Social Council) have been working to develop scientific tools to support the implementation of ICOM (e.g. Balaguer et al. 2008, Diedrich et al. 2010, Tintoré et al. 2009). This strong support from government, civil society and the scientific community, make the Islands an ideal and necessary location for advancing science based ICZM. Two major initiatives, from which the examples in this chapter are drawn, are outlined in the following subsections.

2.1. The Balearic ICZM Initiative

In 2005-2008 the Mediterranean Institute of Advanced Studies (IMEDEA), a joint institute of the Spanish National Research Council (CSIC) and the University of the Balearic Islands (UIB), implemented a project with the Government of the Balearic Islands (Directorate General of Research, Technological Development and Innovation) to support science-based Integrated Coastal Zone Management (ICZM). The project (I+D+i GIZC Project)[4] represents the

4. Project Website: http://www.costabalearsostenible.com/.

first major collaborative step towards establishing ICZM in the Islands. Project activities fell under three major categories: (1) Targeted, disciplinary research aimed at addressing specific data needs and priorities to progress towards ICZM, (2) multidisciplinary research aimed at addressing cross-cutting issues, and (3) the development of technological and conceptual tools and models to assist decision-makers to effectively manage the coastal zone and address specific issues related to ICZM. Figure 1 shows a conceptual diagram of the relationship among these research areas, including the crosscutting objective of transferring the results to society.

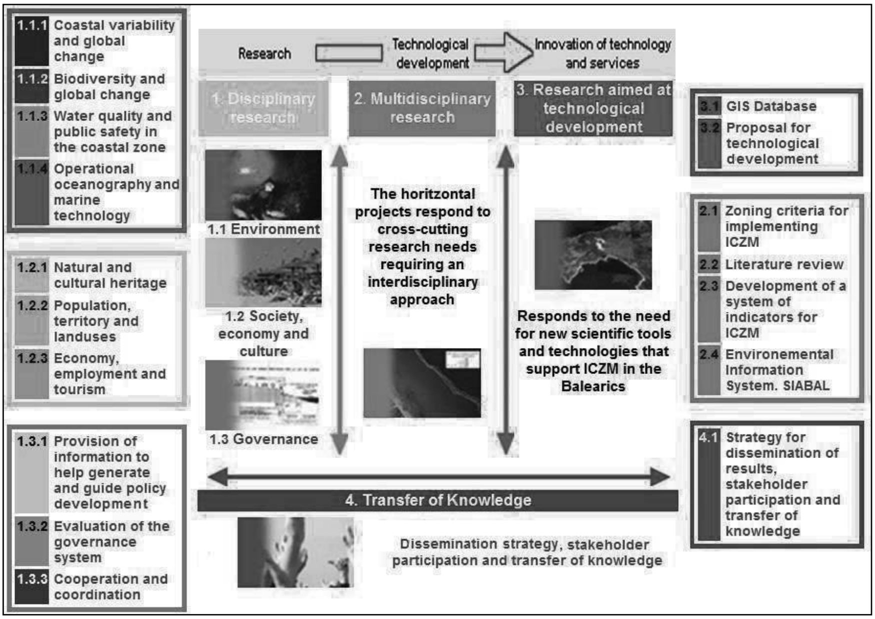

Figure 1. Structure of the I+D+i GIZC Project

The project involved over 70 scientists and resulted in the development of 35 ICZM related research projects. The involvement and collaboration of stakeholders and the continuous transfer of information in useable, comprehendible format to decision-makers were important components of this initiative.

The Balearic ICZM Initiative also pointed out the need for permanent and reliable routine modelling of coastal and marine zones for science-based decision-making related to sustainability. In order to respond to this need, a proposal was written in 2006 to set up a Coastal Ocean Observing System in the Balearic Islands. This research consortium, which was formally approved by the national and regional governments in 2009, is described in the following sub-section.

2.2. The establishment of a Coastal Ocean Observing System in the Balearic Islands (SOCIB) with an ICOM research programme

The Balearic Islands Coastal Observing System (SOCIB in Spanish)[5] is a multi-platform distributed and integrated system that will provide streams of oceanographic data and modelling services to support operational oceanography in a European and international framework, therefore also contributing to the needs of marine and coastal research in a global change context. The I+D+i GIZC project, is now being continued within the strategic research area of Sustainability Science and ICOM of SOCIB. The objective of this research group is to develop applications related to Coastal Operational Oceanography and ICOM, within the general framework of sustainability science. Specifically, the group is focusing on three dimensions related to ICOM which are considered to require attention in future research projects in the Mediterranean, and are also relevant in Europe and internationally. These aspects include: (1) applied, problem orientated science directed at developing and evaluating decision-making tools and frameworks for managing social-ecological systems, (2) monitoring and the use of interdisciplinary scientific data for decision making, and (3) research targeted towards effective governance systems for supporting science-based, integrated approaches to managing coastal and marine ecosystems, including the transfer of science to society.

3. Approaches, methods, and tools for bridging the science-policy gap: Major components of ICOM research in the Balearic Islands

In this section we present three crosscutting approaches and a series of methods and tools that are considered to be critical for generating science to support decision-making. The approaches include interdisciplinary research, stakeholder participation, and governance research. The methods and tools include the development and implementation of an interdisciplinary system of indicators, social science research aimed towards understanding priority objectives of stakeholders, and Geographic Information Systems (GIS). Specific examples of results are provided in each case. Although the approaches, methods and tools are provided in the context of the Balearic Islands initiatives described in the previous section, they are widely applied and relevant internationally.

3.1 Crosscutting approaches

Interdisciplinary research. As mentioned previously, sustainability is a concept that draws on multiple scientific disciplines. Although it would be unre-

5. Website: http://www.socib.es/

alistic and ineffective to attempt to combine too many methods and disciplines into individual scientific studies, at the very least, a consideration of how these studies fit into the larger “sustainability picture” is critical. Disciplinary divides are common in science, particularly between the social and natural sciences, and can hinder the progress of sustainability problem solving that must take into account data from both areas. As highlighted by Turner (2000), regular contact among scientists working on related projects is important for resolving disciplinary divides. The methods and tools presented in section 3.2, indicators and GIS in particular, are useful for combining information from different disciplines. In addition, social science research related to understanding the local context and priority objectives of stakeholders can help direct future research in all disciplines towards targeting important issues and provoking change at the decision-making level.

Stakeholder participation. The involvement of stakeholders in the ICOM process is important to align scientific research and resulting management plans with local priorities and capacities. Participation also ensures that stakeholders and resource managers remain fully informed and aware of new developments and provokes a higher level of consent and compliance with new regulations. As mentioned previously, a number of important stakeholders in the Balearic Islands have collaborated with the scientific community including the regional government, the Economic and Social Council, and the Chamber of Commerce.

It is not uncommon for stakeholder participation and engagement activities, to receive less attention, from a scientific perspective, than they deserve. Where they are clearly not purely scientific, they can be substantiated considerably through the implementation of social science research. For example, in the absence of a scientific approach to inquiry, identified stakeholder objectives run the risk of being biased or misrepresentative of the target population. In this context, Van Asselt and Rijkens-Klomp (2002) define participatory methods as, “methods to structure group processes in which non-experts play an active role in order to articulate their knowledge, values and preferences.”

Governance research. In an ICOM context, governance may be defined as the process by which governments, institutions and society generate, influence, and implement policies to support sustainability goals in the coastal zone (Ehler 2003). A functioning governance system should include all of the elements necessary to support the ICOM process which include, among others, institutions, legislation, and mechanisms for coordination, public participation, conflict management, and enforcement (Cicin-Sain and Knecht 1998). There is a clear need to improve coastal and marine governance, particularly in the Mediterranean, in order to support IM (Barragán 2010, Diedrich et al. 2010). This may be facilitated in part through research that aims to evaluate existing governance systems and mechanisms and establish the factors that determine their effectiveness or failure, in addition to research that responds to and works within the existing governance system.

3.2 Methods and Tools

3.2.1 The development and implementation of an interdisciplinary system of indicators

Indicators have been receiving considerable attention in recent years as one potential solution to bridging the science-policy gap (Belfiore 2003, Bell and Morse 2004, Bowen and Riley 2003, Conway 2007, Diedrich et al. 2010, Henocque 2003, IOC 2006). In general terms, indicators are measurements that should quantify and simplify information related to trends that cannot be easily observed. Indicators may be used to obtain punctual information about a specific phenomenon or may be measured over time in monitoring systems. Essentially, they can help decision-makers identify, evaluate and track progress towards solving sustainability problems.

In order to align indicator selection with local realities, an important first step is the identification of major goals or objectives associated with sustainability, which should reflect the opinions of stakeholders (Fontalvo-Herazo et al. 2007, IOC 2006, Rosenström and Kyllönen 2007, Roussel et al. 2007, Valentin and Spangenberg 2000). Indicators associated with evaluating and/or monitoring these objectives need to be viable from a scientific perspective (e.g. directly observable and measurable, interpretable, grounded in scientific theory, sensitive, response specific) and also practical from a management perspective (e.g. cost effective, relevant to management objectives, clear linkages to the outcomes being monitored). They should be part of the management and governance processes and not an end in themselves (IOC 2006).

One of the major outcomes of ICOM research in the Balearic Islands has been the development of a System of Indicators for ICZM, endorsed by civil society in the Islands (CES 2008, Diedrich et al. 2010). The objective of this project was to design an indicator system that is scientifically viable, comparative internationally yet locally relevant, and to facilitate its implementation. The system was not intended to replace other, similar initiatives on the Islands or in Spain, rather is was intended to draw upon existing works at international (e.g. DEDUCE project, IOC 2006), national (e.g. Sardá et al. 2005) and local levels (e.g. Blázquez et al. 2003, Murray 2010) wherever possible. 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 the needs of civil society, which it communicates to the government through official opinion papers (Dictamen). An outline of the methodological process used to develop the indicator proposal and implementation plan is provided the case study example below.

In December 2007, the system and implementation plan was formally adopted as a Dictamen by the CES, and was presented to the Government of the Balearic Islands at the end of 2008. In March 2009, a pilot study was initiated to implement the system on the island of Menorca, which has established experience working with indicators (e.g. through the implementation of the Insular Territorial Plan of Menorca). The first phase of this work resulted in the development of technical worksheets for each of the indicators, which are designed to facilitate a coordinated, consistent approach to data collection and measurement. This study was carried out with the leadership of the Balearic Statistics Institute (local Government) in collaboration with SOCIB, and Menorca's Socio-environmental Observatory (Insular Council). A second phase of the pilot study is being initiated in collaboration with the team responsible for implementing Local Agenda 21 on the Islands, with the objective of developing a legal instrument for establishing a governance structure to support ICZM in Menorca (based on Doménech et al. 2010). These activities are intended to advance the overall goal of implementing ICOM in all of the Islands, and the indicator system will be an integral component of this. ICOM is a long term, step-by-step process that often falls short due to unrealistic, short term goals. In this context, the current approach to starting activities in a pilot site and building upon them, including the incremental focus on the different factors that will be necessary for implementation (e.g. technical coordination, supporting governance system) is considered to be necessary for achieving long term ICOM goals. Subsequent steps, among others, will be to adapt the results of the pilot study to other islands and extend the indicators to include activities in marine areas (i.e. in order to ensure that marine activities that affect the coast are accounted for in the indicators system and vice versa).

Case Study Example. Methodological process for developing the system of indicators for ICZM in the Balearic Islands (extracted from Diedrich et al. 2010)

Phase 1. Definition of ICZM objectives, literature review and production of draft list of indicators

The first phase involved the definition of a series of objectives for achieving sustainability through the implementation of ICZM in the Balearic Islands. The objectives were classified into three general categories: governance, socio-economics (including culture), and environment, including a series of sub-categories. The first draft of the objectives was prepared by a Technical Committee consisting of 3 scientists from IMEDEA and one technician from the CES. The Committee consulted with a diverse selection of local and regional scientists and practitioners from within and outside the partnership.

Once a general consensus on the objectives had been reached, a review was carried out of the literature and projects related to indicators at international and local levels and, from this, indicators associated with each objective were selected. The resulting draft document contained a proposal for 56 indicators, with associated measurements, and spatial and temporal scales.

Phase 2. Evaluation of indicator feasibility and importance, and development of the implementation plan

In Phase 1, there were some important aspects that were not addressed, such as the availability of data, measurement methodology, cost, and prioritization of objectives. These matters are of vital importance to the successful implementation of a system of indicators. In this context, Phase 2 of the project was intended to develop recommendations to help facilitate the implementation of the system. Tasks included:

a. Viability Analysis. Seven parameters were used, ranked on a scale of one to three (1 = low viability, 3 = high viability). The parameters were: 1) availability of data, 2) availability of data at necessary spatial scales, 3) availability of data at necessary temporal scales, 4) state of development of the methodology for calculating indicator, 5) complexity of managing the indicator, 6) time sensitive, and 7) provides a response to a specific objective related to sustainability or ICZM. Indicators with a score of less than 15 were categorized as having low viability, 16-18 medium, and over 19 high (based on methodology in Borja et al. 2004). The indicators were ranked according to their level of viability.

b. Estimate of cost. This estimate was based on the dedication of personnel and technology that would be required for the development, implementation and measurement of each indicator. It was not possible to calculate the exact cost in Euros due to the fact that voluntary involvement of entities already obtaining these measurements cannot be anticipated until the system is actually implemented. In this context, indicators were simply defined as requiring high/medium/low dedication of personnel and with respect to whether or not additional research or technology would be required.

c. Designation of the level of importance. Independently of the viability analysis and estimation of costs, the indicators were ranked on the basis of their perceived importance (high, medium, low) for monitoring sustainability and ICZM-related objectives for coastal areas in the Balearic Islands. This was considered important because viability scores were based largely on objective measurements, which resulted in the fact that many indicators which are highly important (in particular environmental indicators) had low viability scores as a result of being complicated to measure and lack of data. A first ranking of importance was carried out by an interdisciplinary team of IMEDEA scientists. This was considered to be the "expert" scientific opinion of the most important elements necessary to achieve sustainability in the Balearic Islands. Following this, in November 2007, IMEDEA researchers carried out a Delphi Study (Garrod and Fyall 2005, Okoli and Powlski 2004) with a group of 13 members of the CES. Conflicting opinions were rare but, in the few cases where they did occur, CES was given the final decision in the case of socio-economic and governance indicators and IMEDEA in the case of the environmental indicators. Indicators were ranked according to their level of importance.

The importance and viability rankings represent two complementary perspectives that can help with decisions regarding which indicators should be implemented in the absence of resources to implement the entire system: where resources are limiting factors, the viability ranking would be a more relevant reference since indicators with high viability require minimal or no resources to implement. If resources are available, the importance ranking would be a better reference since it represents a more complete system of indicators with respect to measuring sustainability objectives. The final proposal for the system of indicators consisted of 54 indicators (see Table 1) categorized as governance (G), socio-economic (SE), or environment (E), including an implementation plan for the system.

Table 1. List of indicators included in the System of Indicators for ICZM in the Balearic Islands

Indicator	Category
Area of land and sea protected by statutory designations	G
Existence and level of activity of organisations supporting ICZM	G
Existence and adequacy of legislation facilitating ICZM	G
Existence and functioning of a representative coordination mechanism to resolve conflicts in ICZM	G
Efforts to minimise environmental impact in coastal areas	G
Existence of mechanisms for the routine control, assessment and adjustment of ICZM initiatives	G
Sufficient availability and adequate distribution of human, financial and technical resources for ICZM	G
Existence, dissemination and application of research and information related to ICZM	G
Unemployment	SE
Occupation of tourism accommodation supply	SE
Evolution of tourism demand	SE
Consumption of water	SE
Consumption of electricity	SE
Fishing	SE
Density of resident population	SE
Seasonality of population	SE
Immigration	SE
Construction of homes	SE
Water treatment	SE
Number of moorings	SE
Existence and use of roads and social infrastructures	SE
Quality of tourism accommodation supply	SE
Cost of tourism accommodation supply	SE
Patterns of sectoral employment	SE
Evolution of tourism accommodation supply	SE
Production of urban solid waste	SE
Rate of development of previously undeveloped land	SE
Area of artificial coast	SE
Quantity of social services	SE

Indicator	Category
Negative social effects of seasonality	SE
Values (not market) of sea and coastal economy	SE
Indicator of residential tourism	SE
Evolution of complementary tourism supply	SE
Existence of cleaning routines for beaches and coastal waters	SE
Regeneration of the coastline	SE
Indicator of public expenditure related to tourism	SE
Economic production by sector	SE
Direct investment in coastal areas	SE
Housing prices	SE
Resident perceptions of tourism	SE
Density of beach users	SE
Qualification of human capital	SE
Patterns of tourism demand	SE
Natural, human and economic assets at risk	SE
Investment in technology and technological training	SE
Indicator of second residences of local population	SE
Density of occupation of housing	SE
Public employment service	SE
Evolution of GDP	SE
Corporate Social Responsibility	SE
Index of physical integrity	E
Indicators associated with the European Union Water Framework Directive	E
Biological diversity	E
Quality of beaches	E

3.2.2 Research aimed towards understanding priority objectives of stakeholders

Sustainable development is a general concept that only becomes operational in a locally specific context (Gale and Cordray 1994, Kelly 1998). ICOM and other initiatives aimed towards changing the way humans interact with the natural environment should therefore reflect local realities in order to be effective in achieving sustainability (Boxer 1991, McKenna et al. 2008, Olsen 2003). The identification of sustainability objectives of different stakeholders, including the contextual elements (socio-cultural, economic, governance, natural) that influence those objectives, is a critical component of ICOM initiatives (Fabbri 1998, Turner 2000) and a key first (and continuing) step of many policy cycles or management processes (GESAMP 1996, IOC 1997, McKenna et al. 2008, Olsen et al. 1999; 2003). As demonstrated in the previous example of the Balearic Islands Indicator project, indicators combined with specific sustainability objectives can help guide ICOM activities and future research towards addressing and monitoring critical issues (Diedrich et al. 2010, IOC 2006, Roussel et al. 2007, Fontalvo-Herazo et al. 2007, Rosenström and Kyllönen 2007, Valentin and Spangenberg 2000, Henocque 2003).

Social science research, such as the case study example outlined below, can contribute to identifying objectives and understanding the local dimension and should be a key component of ICOM (Cheong 2008). Such research requires the engagement of local groups so, in addition to obtaining necessary qualitative and quantitative information, it can serve the secondary purpose of raising awareness, encouraging involvement and capacity building.

Case study example. Survey of the perceptions of sustainability of business owners/managers in Mallorca

A quantitative social science research study was carried out by IMEDEA/SOCIB, in collaboration with the Chamber of Commerce of Mallorca, to understand the perceptions of local business owners/managers of sustainable development and associated objectives. The private sector is a critical, often underrepresented player in ICOM and, given that Mallorca is a mature tourism destination, an essential participant in ICOM on the island, particularly through the implementation of Corporate Social Responsibility Strategies (Argandoña 2010, Ayuso y Fullana 2002, Bengoechea et al. 2006). Understanding what their priorities are with respect to sustainable development is important for guiding ICOM activities towards addressing these priorities and for developing strategies for private sector participation in the process.

In September 2008, a survey was sent to 918 businesses in Mallorca. The survey was comprised of a series of closed and open ended questions designed to obtain perceptions about (a) the concept of sustainability in Mallorca, (b) the most unsustainable activities in the coastal zone of Mallorca, (c) general characteristics of the responding businesses, and (d) 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. The results of the survey, which will be published in a joint publication of IMEDEA/SOCIB and the Chamber of Commerce in 2011, showed that the respondents agreed that the objectives defined in the System of Indicators for ICZM are important and suggested that they have a comprehensive understanding of the basic elements of sustainable development, associated pressures, and the link with the social dimension and quality of life of residents.

In order to gain a more comprehensive understanding of the social dimension related to ICOM 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 Islands are a tourism destination, the perceptions and needs of tourists will also be important elements to understanding this dimension. In addition, secondary information related to the socio-cultural, political and economic environments (historical and current) should be ascertained to complement and contextualize stakeholder perceptions. The islands themselves have varied societal and environmental characteristics and understanding these variations will be important for adapting ICOM activities to these differing local realities.

3.2.3 Geographic Information Systems (GIS)

Geographical, spatial data are essential for informing ICOM from the scientific perspective and also because maps are effective focal points for decision-making and for communication among stakeholders (Domenech et al. 2010, Moreno-Jiménez 2005, Pitt et al. 2010). Although this statement may seem trivial, the value of GIS for supporting science-based decision-making has only recently received the significant attention it deserves. This is exemplified by the widespread use of geospatial mapping tools for ICOM (includes MSP and ICZM) decision-making among government organizations worldwide (e.g. National Oceanographic and Atmospheric Administration (NOAA), USA; Great Barrier Reef Marine Park Authority, Australia; Department of Fisheries and Oceans, Canada) and an increase in open-source spatial tools such as MarineMap[6], designed to integrate human and ecological dimensions of coastal and marine science and policy.

The high diversity of coastal environments and the need to manage these areas from an integrated perspective, requires the use of large amounts of interdisciplinary, geo-referenced information that have to be accessible and manageable for all actors and stakeholders involved in the IM process. The use of GIS applied to the coastal zone has led to the advancement and improvement of techniques of multi-criteria analysis that support decision-making (Gómez and Bosque 2004, Kitsiou et al. 2002, Vallega 2005), the development of models of physical and environmental processes at multiple scales of analysis (Rodríguez et al. 2009) and, in addition, the connection between spatial databases can facilitate synergy among environmental, economic and social dimensions (Alessa 2008, Fowler et al. 2010).

GIS is being used by researchers in SOCIB to support a number of ICOM needs including the definition of ICZM management zones (Balaguer et al. 2008), the application of MSP in the Bay of Palma, and environmental sensitivity mapping based on NOAA's Environmental Sensitivity Index criteria[7] (see figure 2 in the case study example below). Spatial data have also been combined with data from a statistical survey of user perceptions and used to calculate optimal use levels for informing management of a heavily used recreational boating bay in Mallorca. This methodological process was developed with the objective of being applicable to a number of scenarios where spatial environmental and social criteria are needed to establish management measures or limits. The study was carried out in collaboration with the Chamber of Commerce of Mallorca as part of

6. Website: http://marinemap.org/
7. Website: http://response.restoration.noaa.gov/index.php

a larger initiative to research and generate awareness in the business community about the need to take into consideration limits to growth when planning activities in the coastal zone. SOCIB and the Chamber of Commerce are in the final stages of producing a publication, directed at decision-makers (particularly in the private sector) that proposes a step-by-step process for ensuring that future activities in the coastal zone support as opposed to hinder the achievement of sustainable development. The process draws together the approaches (interdisciplinary research, participation, governance), methods, and tools (indicators, social science research, GIS, etc.) presented in this chapter into a structured, coordinated decision-making system. Through publishing this process and organizing associated capacity building activities within the business community and with other stakeholders, it is anticipated that they will become aware of the long-term benefits of engaging in the process when planning future activities, growth, or reforms in coastal areas. Ideally, this would result in a change in the current growth model on the island whereby decisions would be made from an integrated perspective, based on the achievement of sustainable development goals, and supported by science.

Case study example: Environmental sensitivity mapping of the coast of the Balearic Islands

The establishment of the environmental sensitivity of the coast of the Balearic Islands is based on the recognition of the different types of coasts of the Balearic Islands, based on geomorphological, bio-ecological and socio-economic characteristics) defined in Balaguer et al. (2006), and on the coastal sensitivity typologies proposed by NOAA (2002). The NOAA typologies have also been applied to other Mediterranean environments (Adler & Inbar, 2007). The maps that have been developed include 1,525 km of coastline and a total of 4,522 segments. The adaptation of the standard proposed by NOAA (2002) have differentiated 9 types of shoreline (according to geomorphological sensitivity) divided into 17 subtypes.[8] Figure 2 shows an example of the application of these categories to the waterfront of the city of Palma (Mallorca). The establishment of the sensitivity of the coast of the Balearic Islands is an important decision support tool for responding to contamination events which emanate both on land and in the sea. In 2007, the Di-

8. The types of coastline, which are ordered on a scale of increasing sensitivity include: 1-A) exposed rocky cliffs; 1-B) exposed solid man-made structures; 1-C) exposed rocky cliffs with boulder talus base; 2) exposed low rocky coasts; 3-A) fine- to medium-grained sand beaches; 3-B) Scarps and steep slopes in sand, calcarenites and/or eolianites; 4) coarse-grained sand beaches; 5) mixed sand and gravel beaches; 6-A) gravel beaches; 6-B) exposed low rocky coasts with boulders, cobbles and gravels, and exposed ripraps; 7-A) sheltered rocky coasts (cliffs and low rocky coasts); 7-B) sheltered solid man-made structures; 7-C) sheltered low rocky coasts with boulders, cobbles and gravels, and sheltered ripraps; 7-D) sheltered rocky cliffs with boulders talus base; 8-A) sheltered mud and/or fine- to medium-grained sand beaches ; 8-B) sheltered gravel beaches ; 9) salt- and brackish-water marshes, wetlands and lagoons.

rectorate General of Emergencies of the Government of the Balearic Islands used the results of this study to respond to an oil spill that occurred off the coast of Ibiza (Don Pedro, http://www.costabalearsostenible.es/donpedro/).

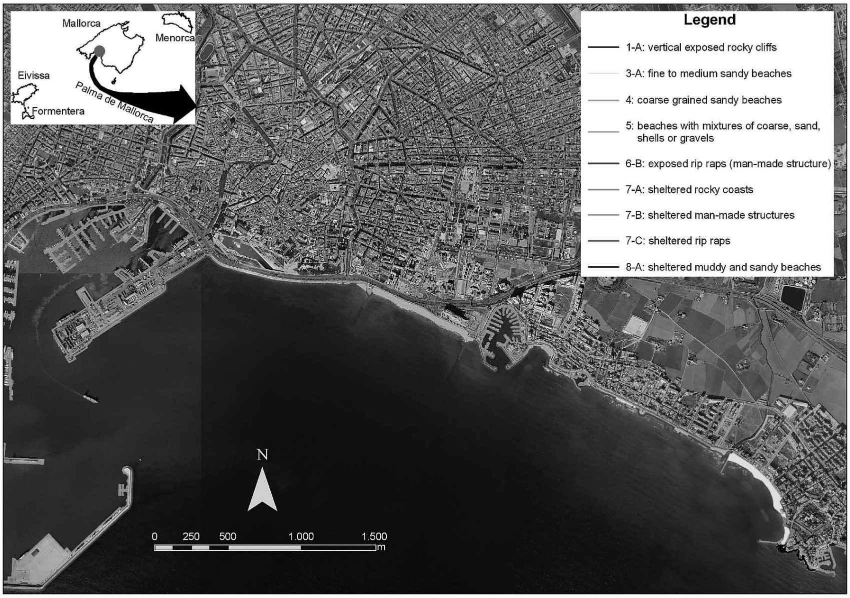

Figure 2. Coastal sensitivity typologies of Palma de Mallorca, Balearic Islands

4. Conclusions and future directions for research

Interdisciplinary and applied approaches to science that provide practical methods and tools for conforming conservation goals to local realities are necessary to support ICOM decision-making and emerging policy instruments. This chapter has highlighted a series of concepts, methods, and tools that are being used for ICOM related research in the Balearic Islands with a primary consideration of bridging the science-policy gap. Although significant progress is being made, the Balearic Islands, similar to numerous locations, still have a significant number of challenges to overcome in order to achieve ICOM. These include, among others, allocation of financial and technical resources, adjustments in the governance system, education and awareness raising, enforcement, the development of new legislation, the active involvement of more stakeholders, and more scientific research and tools development. Although this may seem daunting, recognizing the complexity and long term commitment that is involved in implementing ICOM is an important step towards achieving success.

Indicators, monitoring, observing and prediction systems that make use of multiple types of data (e.g. spatial, social, ecological, etc.) are critical to the success of ICOM, but need to be integrated into governance frameworks and adapted to local realities in order to be effective. The latter can be facilitated by research orientated towards governance and stakeholder participation. New Coastal Observing and Forecasting Systems such as SOCIB in the Mediterranean, or other initiatives in the USA (OOI[9], IOOS[10]) or Australia (IMOS[11]) can generate data for indicators and monitoring related to the state of ecosystems, their changes and evolution forecasts, thus providing valuable technological, scientific support to ICOM (Shepherd 2007). The integration of the data generated by these systems into terrestrial and marine spatial planning will be an important scientific priority over the coming years, in addition to the development of methodologies for establishing linkages between data from the natural and physical sciences with social science data.

In order to respond to decision-making needs, scientific research should be targeted towards priority issues and objectives of society. This represents a movement away from traditional hypothesis driven science towards more applied research. It is also important to note that changing the way in which we approach science for solving sustainability problems cannot be effective without parallel, complementary changes in associated socio-economic and governance systems. These systems must also evolve and adapt to address emerging issues, resulting in a change in the way we make decisions about our future. The need to change the current growth model, and how we make decisions about growth, is a topic of increasing debate in the Balearic Islands (Forcades 2006, Manera 2009, Navinés et al. 2010). Such changes should include, among others, comprehensive strategies that incorporate multiple dimensions and sectors (i.e. economic, social, environmental), the establishment of coordination mechanisms, the increased use of science for decision-making, long term planning for sustainability, and governance mechanisms that permit continuity of new policies across short term political cycles. Sustained, incremental and coordinated commitment will be required from scientists and decision-makers in order to achieve sustainability in the future.

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