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Using ecosystem services modelling to explore conflict mitigation in the coastal zone

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Abstract: Integrated coastal zone management is an emerging governance practice which aims at combining environmental preservation, economic development and social concerns in the context of complex ecosystem dynamics and increasing anthropogenic pressures. Coastal managers need socio-environmental integrated models in order to investigate the consequences of policy options which apply to different sectors simultaneously and pursue multiple objectives. The ecosystem services concept is equivalent for natural and social sciences; it offers a framework for a better understanding of users' conflicts regarding natural resources and the environment. This paper presents a model-based assessment of the ecosystem services supplied by freshwater in the coastal zone, under various local management options. The model is built through a participatory experiment which has been carried out in a coastal area of the Atlantic side of France, called "Pertuis Charentais", according to the methodology developed by the European project SPICOSA (*Science and Policy Integration for Coastal System Assessment*). The modelled socio-ecosystem is centred on the Charente river catchment. The stakeholders chose the allocation of freshwater as the core issue for integrated coastal zone management. They considered that freshwater provides mainly "support services" for natural habitats and shellfish farming and "provisioning services" for households and agriculture. The model is intended to produce a wide range of indicators for the integrated assessment of these ecosystem services. The model is used to support the deliberative process engaged with local managers in order to explore new rules for water allocation, their consequences on ecosystem services and their meanings in terms of conflict mitigation. For that purpose, the model will also allow for an economic assessment based on two methods (productivity losses and remediation costs).

***Keywords**:* ecosystem services modelling; integrated assessment platform; user conflict; integrated coastal zone management; freshwater management.

1. INTRODUCTION

Integrated Coastal Zone Management (ICZM) is a new paradigm which emerged from the Brundtland Report (WCED, 1987) and was then further promoted by the Chapter 17 of the Agenda 21 document (UNCED, 1992). According to (Cicin-Sain and Knecht, 1998, p.39), ICZM is "*a continuous and dynamic process by which decisions are made for the sustainable use, development and protection of coastal and marine areas and resources. (…) the process is designed to overcome the fragmentation inherent in both the sectoral* *management approach and the splits in jurisdiction among levels of government at the land-water interface*". ICZM is also a social process by which concerns at local, regional and national levels are discussed and future directions are negotiated, what requires the involvement of the interested public and many stakeholders with interests in how coastal resources are allocated and conflicts are mediated (GESAMP, 1996). Thus the commonly shared definitions of ICZM tend to emphasize its goal, which is to balance development and conservation within multi-sectoral 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).

As social-ecological interaction models provide a common language among scientists from different disciplines and managers from various domains, they are likely to improve the understanding of the dynamics of complex socio-ecosystems (Low et al. 1999; Arias and Fischer 2000; Etienne et al. 2003; Boulanger and Bréchet 2005). Among the various classification of models, system modelling approaches are well-adapted for the sustainability issues as emphasized by Boulanger and Bréchet (2005). In addition, system approach is often recommended in the context of expert advising for ICZM implementation (van der Weide, 1993; Fabbri, 1998; Varghese et al 2008). The "System Approach Framework" which is developed by the SPICOSA project aims at promoting new methodologies for the building of integrated assessment platforms, which will make possible to consider altogether the ecological, social and economical dimensions of coastal systems management, through interdisciplinary collaboration and science and policy integration (SPICOSA, 2006). The ecosystem services approach offers a reference system which makes easier 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 it offers a framework for a better understanding of users' conflicts. For these reasons, the assessment platform that has been developed during the SPICOSA project for freshwater management in the Charente river catchment is built on the basis of an integrated exploratory model whose logical frame follows the ecosystem services approach.

This paper describes the application of the SPICOSA methodology on the "Pertuis Charentais" site. This particular experiment illustrates the interest of the ecosystem services approach both for building an integrated model of a coastal socio-ecosystem and for exploring conflict mitigation toward more sustainable mechanisms of freshwater allocation.

2. MATERIALS AND METHODS

2.1 The "System Approach Framework" of the European project SPICOSA

SPICOSA (Science and Policy Integration for Coastal System Assessment) is an integrated European research project in support of ICZM. The project started in February 2007 and will end in January 2011. It encompasses 18 study site applications, one of them being the "Pertuis Charentais" site, a coastal area of the Atlantic side of France. The SPICOSA project develops a "System Approach Framework" (SAF), which aims 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 this framework, dynamic models are used to explore alternative policy options following a problem oriented and scenario based approach. Platforms for integrated assessment are developed using the software ExtendSim®, with special attention to user-friendly interfaces. The SPICOSA system approach may be described as the iterative implementation of the following steps:

- Step 1: issue resolution. It consists in working with a group of stakeholders in order to address the core sustainability problem of the area, so that it will be possible to prioritise one management issue according to the local policy agenda and the main social concerns.
- Step 2: defining the system. It consists in defining the natural, social and economic dimensions of the coastal system by making explicit the main relationships between the ecological processes, the human activities and the governance bodies.

- Step 3: building the model. It consists in the mathematical formulation of the ecological and social processes which are likely to explain the dynamics of the system, up to the achievement of the numerical modelling (including model calibration and validation).
- Step 4: deliberative analysis of results (and back to step 1). It consists in running the simulations and interpreting the model outputs, using the scenarios, the indicators and the systems of reference that have been built and selected with the stakeholder group.

2.2 Users conflicts in the Pertuis Charentais coastal zone

The "Pertuis Charentais" coastal region faces many problems which are typical of the user conflicts in the coastal zone: urban development, increasing demand for tourism infrastructures, ecosystem preservation (saltmarshes), etc. Due to the influence of the Charente river on the local ecosystems and the regional economy, freshwater management is also a core issue which combines ecological and social concerns on both the terrestrial and maritime side of the area. This thematic was thus selected for the SPICOSA experiment. The "Pertuis Charentais" site is characterized by the fragility and the 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 are dependent on freshwater: household water consumption, agriculture, oyster cultivation, tourism and leisure. The local governance system implements various regulations and management measures in order to preserve freshwater quality and to reach a sustainable level of its extractive uses, in accordance with the protection of natural habitats and other issues related to the welfare of the population. Nevertheless, the Charente river basin shows a risk of failing the objectives of the European Water Framework Directive towards the good ecological status (52% of the water bodies), due to agriculture diffuse pollution (nitrates, suspended matter and pesticides) and water shortage recurrent events. In addition, these failures of the freshwater management system have impacts on the marine waters and the coastal ecosystems. The SPICOSA stakeholder forum was thus intended to include the representatives of the local management bodies who are involved in or concerned by freshwater management: Regional Water Agency of the Adour-Garonne basin, South-West of 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), State local administration for maritime affairs (DDAM).

2.3 Defining the policy issue to be addressed by the SPICOSA experiment

As the Charente river suffers from low freshwater flows during the summer, two basic needs of the whole population may not be satisfied: the availability of drinking water for households and also tourists, and the 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 are dependent from the freshwater of the Charente river: agriculture, which needs to uptake 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 the 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. Our 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 lead to an agreement upon the general objectives and the methods. First, the hierarchy of the uses of freshwater has been fixed as follows: 1) good ecological status of the coastal ecosystems; 2) availability of drinking water for households (and tourists); 3) 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 2 first uses. Third, the operational objective of this management plan will be to make sure that the system is able to reach the RDTs during the summer at least 8 years out of 10. Henceforth, the political debate is now focusing on the modification of the "authorised volumes of water" for each consumptive uses (drinking water for households, irrigation for agriculture) and on the improvement of the limitation rules which apply to the consumptive uses during the periods of water shortage. Thus, in practice, 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. In order to address this question, an integrated exploratory model will be used to compare different management options, under various other assumptions regarding the forcings of the system and the behaviours of users.

3. THE MODEL

The integrated model 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): the regulation functions, which rely on the capacity of ecosystems to regulate essential ecological processes, the production functions, which permit the provisioning of food and other products, the information functions, which provide aesthetical, cultural or recreational benefits, and the support functions, which ensure the conditions necessary for all the other functions. However, all these functions are interdependent: human activities which 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 conflicts.

3.1 Ecosystem services in the Charente river catchment

The ecosystem services associated with the availability of freshwater in the Charente river catchment are depicted in the Figure 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 which is considered significant within the local policy debates.

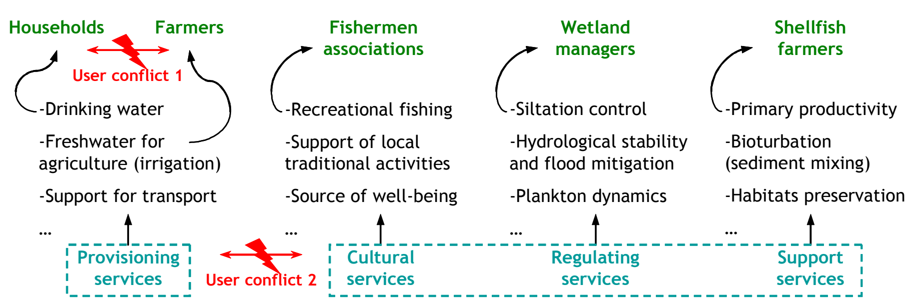


Figure 1. User conflict in the "Pertuis Charentais" coastal area: ecosystems services depending on freshwater availability and main associated human activities.

Basically, freshwater scarcity generates user conflicts, which reflect the need to mitigate the different ecosystem services that freshwater may provide. These conflicts are the following:
1) conflicts between the extractive uses of the water from the Charente river catchment,
2) conflicts between the extractive uses (provisioning services) and other services (support services, regulating services, cultural services) provided by freshwater.
The current state of the system gives priority to the provisioning of drinking water, which is thus considered as satisfied in any cases. 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), benefits from two management tools: the UNIMA canal and the Saint-Savinien dam. Thus, three main ecosystems services are subject to the risks associated with unpredictable variations of river flows and water shortage events: the

primary productivity of coastal waters, the supplying of freshwater for irrigation and the recreational fishing activities which are affected by the drying out of rivers.

3.2 The integrated assessment platform

The integrated assessment platform includes a dynamic model which is based on a system view of the freshwater allocation issue in the "Pertuis charentais" region (Figure 2). The model is developed on the basis of hierarchical blocks which are organised according to a three-floors approach reflecting the social, economic and ecological dimensions of the system (see Balle-Beganton et al, this issue): (1) on top, governance and regulation, including irrigation limitations based on river water flow monitoring, (2) in the middle, freshwater direct or indirect uses e.g. agriculture, drinking water for households, recreational fishing and shellfish farming, (3) on bottom, the ecological system including the Charente river hydrology, wetlands and coastal water productivity.

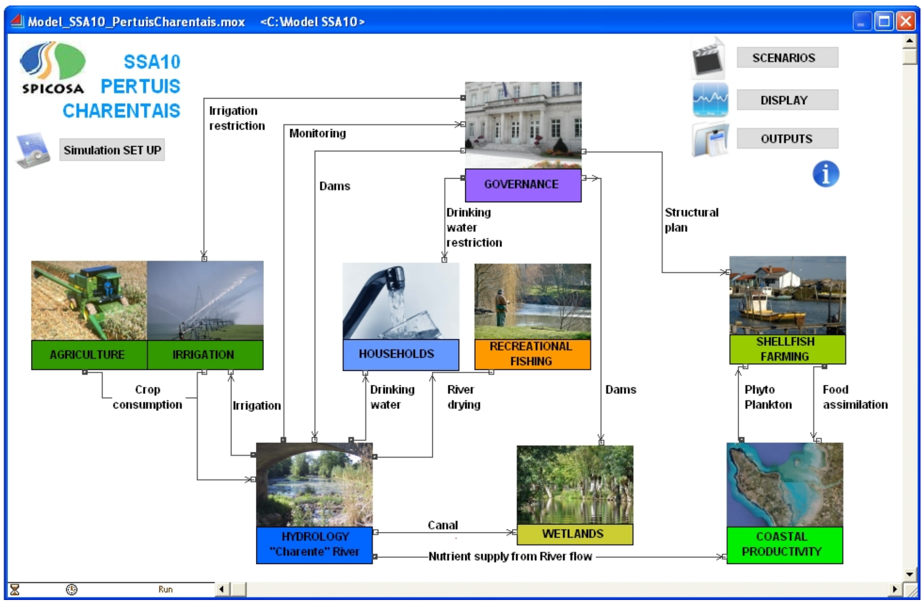


Figure 2. User interface of the model: a system view of the freshwater allocation issue.

3.3 Incorporating legal frameworks and institutional arrangements in the model

In the present situation, the amount of ecosystem services 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 in use as regards the access-right to freshwater and its services, which reflect the institutional arrangements regarding the use of these common-pool resources. In our case, the compromise which defines the level of anthropogenic pressure and the rules in use is unstable because it leads to unsustainable uses of freshwater. Our model explores the way toward a more sustainable compromise, by incorporating the main institutional arrangements regarding water uses in the area and the possible changes. These institutional arrangements can be depicted according to the frame developed by Ostrom (1990), which distinguishes national (or supra-national) laws, local rules and collective agreements.

Table 1. Institutional framework for the management of freshwater and the associated uses.

	Water policy	*Agricultural policy*	*Shellfish farming policy*
Laws	Water framework directive	Common agricultural policy	National Decree on marine cultures
Local rules	Hierarchy of water uses	Authorised volumes for irrigation	Structural plan (leasing grounds allocation)
Collective agreements	Schedule of water releases from dams	Irrigation schedules	Oyster banks management

As laws are promulgated by the European or the national Parliaments, they are considered as external variables vis-à-vis the system. Local rules are defined by the representatives of the State and other local management bodies, while collective arrangements are defined jointly by managers and users or inside one particular user group. The model allows for the exploration of institutional changes regarding these local rules and collective agreements, like the reduction of authorised volumes for irrigation, the introduction of more constraint irrigation schedules or the modification of the structural plan for shellfish farming activities.

3.4 Modules providing ecosystem services assessment

Three modules provide a dynamic assessment of ecosystem services: the irrigation module, the recreational fishing module and the coastal productivity module. The coastal productivity module simulates primary productivity of the Marennes-Oléron basin, which depends on nutrient fluxes from the watershed, ambient water temperature and light, and provides the available phytoplankton concentration to the Shellfish farming module (see Bacher et al, this issue). The recreational fishing module estimates the linear of the dried rivers according to the observed statistical relationships between water discharge thresholds and the occurrence of drying out. The irrigation module is connected to the regulation sub-module (included in the governance module), which commands the enforcement of the rules applying to the farmers' use-rights for irrigation. It encompasses the estimation of crops demand for irrigation depending on crop cultivation systems (see Vernier et al., this issue), the dynamic adjustment of authorised volumes for irrigation, the crisis limitations and the eventual irrigation schedules. The satisfaction of crops demand for irrigation depends on the available authorised volumes for irrigation, which are subject to temporal limitation (water shortage crisis management). The irrigation module utilises the following variables:

- *IDC* is the Irrigation Demand for Crops, estimated by the agriculture module as the difference between potential evapotranspiration and real evapotranspiration (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 authorisations (in $m^3.d^{-1}$),
- *PAT* is the Provisional volume of Authorised Takings per period, without crisis limitations (in m^3),
- *RAT* is the Real volume of Authorised 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 time period *d* (year, 10-days period, week or day, depending on the irrigation schedules), the irrigation consumption of crops is given by:

$$ICC(t) = \min\left[IDF(t), RAT(t)\right] \quad (1)$$

where

$$RAT(t) = PAT^{d}(1-\alpha) - \sum_{t=1}^{t-1} ICC(t) \quad (2)$$

Thus, the real volume of authorised takings depends on a parameter α whose value ranges from 0 to 1 and which defines the level of temporary irrigation limitations at each time step. The limitation parameters are fixed for each sub-basin by a yearly by-law, and depend on successive "alert" thresholds, the last one being the "cutting threshold" (when the value of the limitation parameter is 1). The number of management thresholds varies from 2 to 4, according to the sub-basins and the season. The model applies the limitation parameters automatically, after having read the monitoring data provided by the hydrological module.

4. PRELIMINARY RESULTS

4.1 Exploratory scenario

The new rules that may improve the efficiency of the water management system may also affect ecosystem services distribution. In the upstream area of the *Charente* river catchment, the management system requires a planned irrigation schedule based on 10-days periods:

$$PAT = \sum_{d=1}^{n} PAT^{d}$$, where n is the number of 10-days periods during the irrigation season.

In the downstream area, irrigation behaviours are “myopic” because the farmers are not required to allocate their annual volume of authorised takings over time periods. The baseline scenario depicts the present situation (Table 2). The exploratory scenario will consider a shift in the governance system, which will be unified by the extension of the upstream area management scheme to the downstream sub-basins.

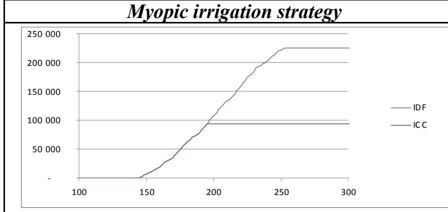
Table 2. Water management schemes under the baseline and the exploratory scenario.

	Baseline scenario: current water management scheme	***Exploratory scenario: unified Water management scheme***
Upstream sub-basin	Scheduled irrigation strategy	Scheduled irrigation strategy
Downstream sub-basin	Myopic irrigation strategy	Scheduled irrigation strategy

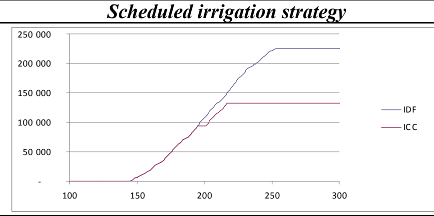
4.2 Assessing ecosystem services under two contrasted management schemes

The preliminary results estimate two indicators of the variation of ecosystem services: the volume of water which is available for irrigation (provisioning services for agriculture) and the occurrence of water shortage events (number of days under the reachable discharge thresholds) which indicates how often the river flow is too low to ensure the preservation of the river ecosystem good status and the associated regulating and supporting services. Figure 3 depicts the impacts of the different irrigation strategies that may be implemented by the local water governance systems in one sub-basin. The scheduled irrigation strategy is more efficient for both indicators. As regards provisioning services, the total amount of water available for irrigation is higher and the irrigation is forbidden during shorter periods, what reduces crop stress. As regards regulating and supporting services, the days under reachable discharge thresholds are less numerous, what should be at the end beneficial for the ecosystem services provided by freshwater flows in the wetlands and coastal areas.

Myopic irrigation strategy



Scheduled irrigation strategy



Myopic irrigation strategy	***Scheduled irrigation strategy***
Provisioning services: -satisfaction of irrigation demand = 41,5%	*Provisioning services:* -satisfaction of irrigation demand = 63,8%
Regulating and supporting services: -number of days under warning threshold = 9 days -number of days under cutting threshold = 172 days	*Regulating and supporting services:* -number of days under warning threshold = 47 days -number of days under cutting threshold = 107 days

Figure 3. Impacts of myopic and scheduled irrigation strategy on crop irrigation consumption and river discharge thresholds in the “Tardoire” sub-basin.

5. DISCUSSION

The model will be used to produce a wide range of indicators for the integrated assessment of the ecosystem services provided by the Charente river freshwater. Physical estimates will include the volume of water available for irrigation, the water stress indicators for cultivated crops, the occurrence of problems with drinking water supply, the occurrence of problems with Reachable Discharge Thresholds, the length of dried river bed and the production of phytoplankton in the coastal waters. In addition, the model will allow for the estimation of economic indicators concerning the variations of provisioning services (drinking water supply, irrigation of crops) cultural services (recreational fishing) and supporting services (coastal productivity). These economic indicators will be based on the damage cost assessment method, which will be implemented by considering productivity losses for agriculture and shellfish farming (due to the variations of irrigation and coastal productivity) and remediation costs for recreational fishing (assumed to be revealed by the expenses due to the fish saving operations of the fishermen associations).

The scenarios that will be defined with stakeholders are intended to include management options and also adaptive behaviours of some users. Our assumption here is that the level of ecosystem services may not be "optimised" or "restored" (back to which state and what for?) because it is always the result of a stable or unstable social compromise which encompasses user practices and management rules. In our case, the current social compromise is not stable and new management options have to be explored, taking into account that user practices may evolve in the meantime. This is the kind of holistic exploration of the future that the integrated modelling of social-ecological systems allows. Local managers, among whom some were sceptical towards a numerical model dedicated to the sole question of freshwater allocation, are now convinced that such a model, when based on a system approach, may provide new insights for the understanding of the concrete management issues related to complex common-pool resources in the coastal zone.

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REFERENCES

Arias, E.G., and G. Fischer. 2000. Boundary Objects: Their Role in Articulating the Task at Hand and Making Information Relevant to It. International ICSC Symposium on Interactive and Collaborative Computing, University of Wollongong, Australia, December 11-15. Academic Press, Wetaskiwin, Canada, pp. 567-574.

Boulanger P-M and Bréchet T., (2005), "Models for policy-making in sustainable development: The state of the art and perspectives for research", Ecological Economics, Volume 55, Issue 3, pp. 337-350.

Cicin-Sain, Biliana and Knecht, Robert W., 1998. Integrated coastal and ocean management: concepts and practices. Island Press, 518 p.

De Groot, R.S., 1992. Functions of Nature: Evaluation of Nature in Environmental Planning, Management and Decision-Making. Wolters-Noordhoff, Groningen, The Netherlands, 345 p.

De Groot, R.S., M. Wilson, and R. Boumans, 2002. "A typology for the description, classification, and valuation of ecosystem functions, goods and services". Ecological Economics, 41(3), 393–408.

Etienne M., Le Page C. and Cohen M., (2003), "Role-Playing Games, Models and Negotiation Processes: part I. A Step-by-step Approach to Building Land Management Scenarios Based on Multiple Viewpoints on Multi-agent System Simulations", JASSS, vol.6, issue 2, http://jasss.soc.surrey.ac.uk/6/2/2.html.

Fabbri, K. P., 1998. A methodology for supporting decision making in integrated coastal zone management. Ocean & Coastal Management, 39(1-2): 51-62.

GESAMP, 1996. The Contributions of Science to Integrated Coastal Management. GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), Reports and Studies No. 61, 66 p.

Low B., R. Costanza, E. Ostrom, J. Wilson and C. P. Simon, 1999. Human–ecosystem interactions: a dynamic integrated model. Ecological Economics, 31(2), pp 227-242.

McFadden, Loraine, 2007. 'Governing Coastal Spaces: The Case of Disappearing Science in Integrated Coastal Zone Management', Coastal Management, 35(4):429–443

McGlashan, D.J., 2002. Coastal Management and Economic Development in Developed Nations: The Forth Estuary Forum. Coastal Management, 30:221–236

Millenium Ecosystem Assessment, 2003, "Ecosystem and Human Well-Being – A Framework for Assessment". Island Press, 212p.

Ostrom E., 1990. Governing the Commons. Cambridge, Cambridge University Press.

SPICOSA, 2006. Description of Work. Integrated Project SPICOSA, Contract for the 6th Framework Program of the European Commission, Annex 1, 218 pages.

UNCED, 1992 Agenda 21: Earth's action plan. In: Robinson NA, editor. The United Nations Conference on Environment and Development (UNCED). NY, Oceana: Dobbs Ferry, 1993.

van der Weide J., 1993. A systems view of integrated coastal management. Ocean & Coastal Management, Volume 21, Issues 1-3, 1993, Pages 129-148

Varghese Koshy, L.S. Ganesh, Monto Mani, P.P. Anilkumar, Ramana Murthy, and B.R. Subramaniam, 2008. Identifying critical variables for coastal profiling in ICZM planning—A systems approach. Ocean & Coastal Management, Volume 51, Issue 1, Pages 73-94.

World Commission on Environment and Development (WCED), 1987. Our Common Future. Oxford University Press, New York.