Project N°: 036992

SPICOSA

ACRONYM : **S**cience **P**olicy **I**ntegration for **Co**astal **S**ystems **A**ssessment

REPORT

SAF PROTOCOL ON COASTAL ZONE SYSTEM APPRAISAL

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INTRODUCTORY REMARKS ON THE APPRAISAL STEP

This document provides an initial summary guide to the Work Tasks for the Appraisal Step (AS). In its edited form, this material will be expanded and inserted as a separate section in the operational portion (Users Guide) of the WP5 SAF Protocol Chapter following the SAF format. *Italics are used to indicate quotes from the DOW or special emphasis.*

Objectives. "*The purpose of this Step is simulation and interpretation of the CZ system's response to the selected Policy Issue(s).* The main goal then is to construct the Simulation Model for delivery of the specified outputs and to conduct the accompanying Interpretive Analyses to provide the scientific and descriptive supplements to these outputs. Because the tasks of the AS will vary somewhat depending on the methods chosen for a particular SSA, these guidelines will initially be more of a generic nature. Further revisions will offer more detail.

Implementation. The Spicosa strategy seeks to emphasize the self-evolving nature of the Project. The strategy encourages Study Sites to think of different ways of *'how to do a subtask'* and not get involved in endless debate about *'whether to do a subtask'*. Thus, it is important that the Work Tasks of the SAF and their subtasks are considered as milestones for the implementation since they need to be fixed for evaluation, comparison, and reporting. The supportive background and amplification of these subtasks here, and in the existing Node 2 WP5 document, should provide sufficient instructive detail for their implementation.

The Appraisal Step mostly conducts the simulation and analyses provided for by the previous Steps. Both the aspects of modelling and interpretation will share a similar effort. *The Appraisal Step runs the Simulation Model and conducts the Interpretive Analysis relative to the Policy Issue(s). It is thereby analogous to the write-up of a field or laboratory experiment in which new information is acquired and analyzed in reference to proposed hypotheses or objectives.*

The boundary between the Appraisal and the Formulation Steps is arbitrarily set at the point where the focus shifts from preparation to results. In the case of the Interpretive Analysis, the initiation of the assessments might start as soon as the formulation/preparation has been completed. Often the Interpretive results will have bearing on, or be dependent on, the final outputs of the Simulation Model. The SSA leaders should make this judgment and modify their activities accordingly.

The objective of Spicosa is to construct and demonstrate the SAF methodology, and therefore the priority is placed on completing a scientifically credible application rather than providing a comprehensive application that cannot be concluded due to time and resource constraints. *An important caveat: the Appraisal Step is the last opportunity to re-scale and re-target the scope of the application.* After this step, the SSAs will have to confront a larger audience that will be critical abour credibioity/feasibility in the "Real World". As stated in D4.1, it must be kept in mind that "models are not necessarily predictive tools, but also tools to build consensus, common understanding of some environmental and policy issues, group learning and communication between stakeholders and scientists".

Definitions. The glossary is a work in progress and will be available so that it can be referenced to in the AS document.

Preparation. The AS involves the implementation of the assessment methodologies prepared in the FS. In creating these guidelines for the first application, we assume the general case in which each SSA consists of an Expert Group of multidisciplinary researchers of varying experience (including not only ecologists and modellers, but also sociologists, ecologists, etc.) in quantitative assessments. Therefore, some tasks may seem obvious, some obscure, or dependent on special expertise. The supportive detail should be in the main text of the Appraisal Step Chapter.

In these guidelines, the descriptive comment on the text of the subtask is short or may be quoted from the DOW (in italics). The content of the WTs is maintained, but at the subtask level, additional content is added or combined to make a single product or action, which is indicated in the accompanying Table 1. In the explanatory text, examples are cited and some methods are suggested, both of which should be enriched in further versions. The systems approach includes Environmental, Social and Economical (ESE) components. When modelling a particular system, these components can be part of a single, holistic model, or can be separated into submodels that may be assembled or coordinated in a variety of ways (see WT 5.1a). To make the subtasks clearer for the three ESE components, specific references to each are treated separately and noted with the abbreviations (Environment Component (NC), Social Component (SC), and Ecological Component (EC).

Input from Formulation Step. The main products from the Formulation Step (FS) constitute the starting information for the Appraisal Step, shown schematically in Fig. 1 and list the major products available from the Formulation Step in Table 1.

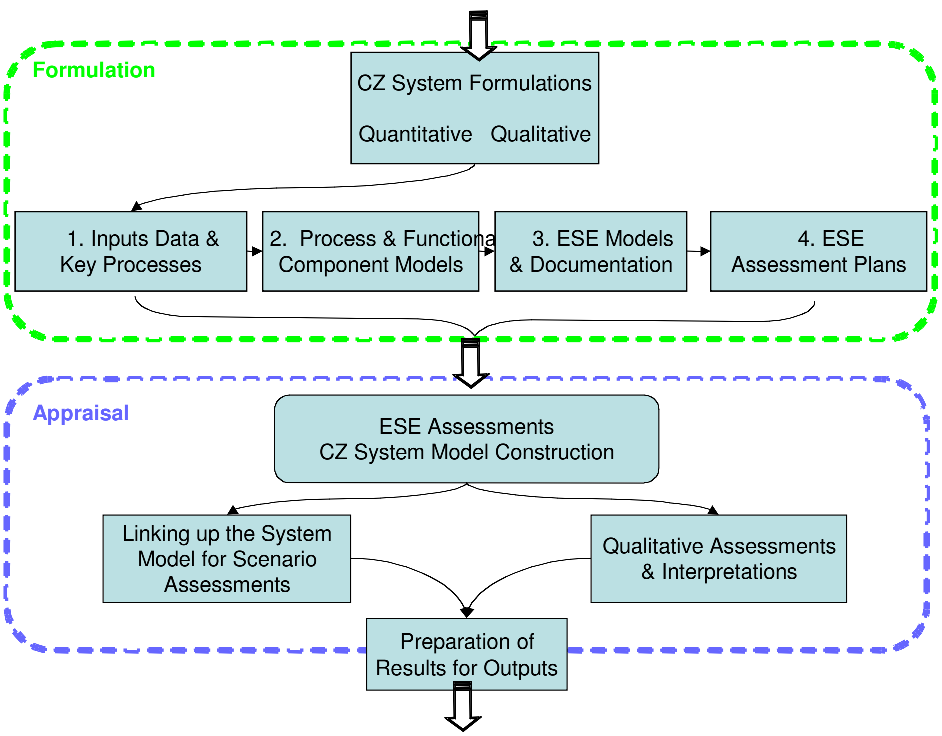

Figure 1. The four essential categories of information output passed from Formulation Step to Appraisal Step are information/data inputs needed for the Systems Analyses. A more specific list

of the FS outputs is in Table 1, and of the outputs of AS in relation to the WTs is given in Table 1.

FORMULATION OUTPUTS TO APPRAISAL
1. Table of Inputs + Data ready to use **2. Table of Key Processes + Refined Process Blocks** **3. Setup requirements for ESE Interpretive Analysis** **4. Specifications of inputs from auxiliary models/methods** **5. Refined Functional Component Models - Model Library** **6. Refined ESE Component Models + Hindcast calibrations** **7. ESE Assessment Plans + Compatibility check with scenarios** **8. Scientific Synthesis of Formulation**

Table. 1. The major Formulation products available to Appraisal Step. These may be combined but the content of each must be clearly distinguished (to facilitate review and comparison).

SSA Team Organization. The SSA Teams should focus on the first two Worktasks (see below page 8 for further detail)
1. Conducting the Interpretive Analyses and
2. Constructing the Simulation Model.

These should be the primary focus of the first Cluster meeting. The two can commence simultaneously by different team members – manner and choice decided internally. They both feed into the second two Worktasks (Systems Simulation and Output Preparation).

SSA Reporting.

Node 3 will specify the means of recording and reporting of the information generated in accordance with the three reporting trajectories: a *Critique Report* for Node 2 feedback, Technical Documentation of each Step for each SSA to be archived by WP8&9, and *Scientific Articles* to be recorded in outline form for each Step and for later editing to standard article format.

Products for Technical Documentation	
Refined versions of the ESE Component models	**5.1a**
Documentation of Simulation Model	**5.2a,b**
Documentation of Scenario Versions	**5.3a**
Input data for both Hindcast and Scenario Versions of the Simulation Model	**5.1a, 5.3a**
Activities for Scientific Results	
Interpretive Analysis of the ESE Component models	**5.1a**
Descriptions of final scenarios, linkages, and outputs	**5.3a**
Interpretive Analysis of Simulation Model	**5.2b**
Interpretive of Scenario Results	**5.3b**
Critique Report	**WT**
Summarize problems and suggestions as Feedback to Node2	**All**

Table 2. Major Appraisal Products in reference to the three reporting trajectories mentioned in the text above.

Procedures:

In the following WT guidelines, it is assumed that both a Simulation Model and an accompanying Interpretive Analysis are being formulated and planned, respectively. It is also assumed that the instructions are for all three of the ESE Components unless singled out, which will be abbreviated to NC, SC and EC respectively.

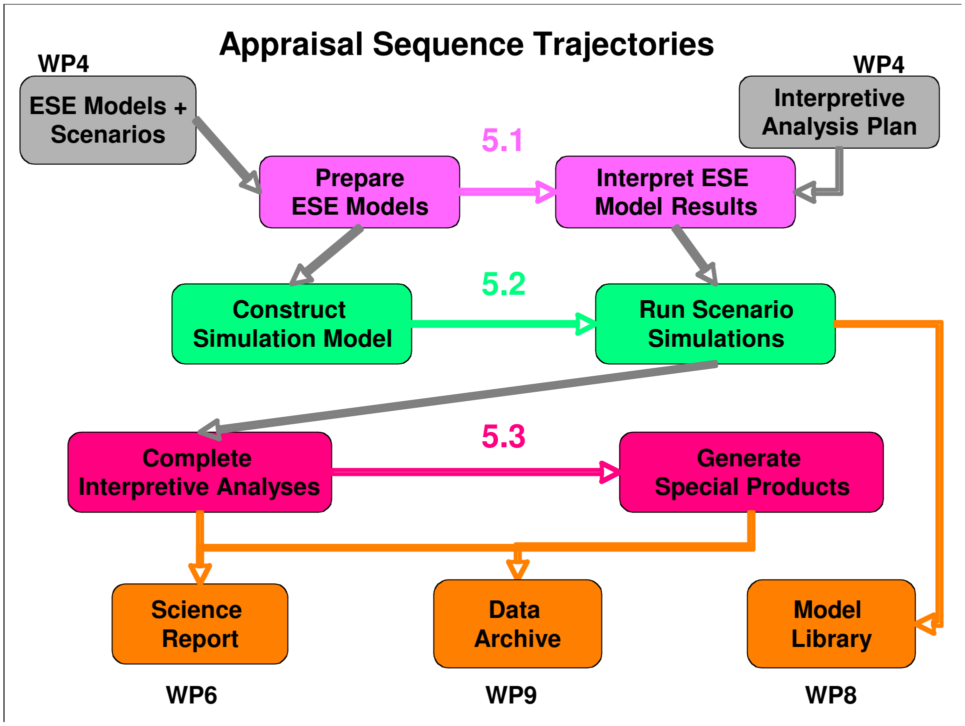

Figure 2. Schematic of sequence of Appraisal Work Tasks in terms of execution and reporting (excluding Critique Report).

APPRAISAL WORK TASKS

The Appraisal WTs must construct the Simulation model, conduct the Interpretive Analyses, and prepare the results for the Output Step. The Analyses for each of the ESE Components will differ somewhat and will be separately discussed, as appropriate, in the following WT descriptions. Note that the scenarios that will be presented and explained in the Output Step will be chosen and need to have been checked by experts and stakeholders so that they are credible when presented to a bigger audience.

WT5.1 ESE COMPONENTS

WT5.1a Prepare the ESE Models for Coupling

This WT evaluates the ESE components and utilizes them to answer certain functional questions particular to each Component before coupling them into the Simulation Model (SM). At this stage, the parallel activities, e.g. other types of models, modifications based on other analyses, can be merged into the ESE Component Models.

WT 5.1a Prepare the ESE Models for Coupling
1 Review ESE Models relative to Appraisal objectives **2 Integrate any links to other models or products of analyses** **3 Run ESE Models separately for purposes of Interpretive analyses**
This is primarily a Documentation Product

ACTIVITY EXPLANATIONS

WT 5.1a should be conducted concurrently with WT 5.1b. The first three subtasks are primarily reviewing what has been done in the FS. The most important subtask is that of conducting analysis on each of the ESE models in order to ensure that their structure and results can be run independently of each other. Linking the ESE components may be a problem, in particular if ecologists, sociologists and economists developed their models independently and did not intercommunicate well enough. Since the different ESE components often have different temporal and special resolution a special focus should be on converting this before linking the models. Several model blocks such as integrators and mean/variance blocks can be used to facilitate the conversion. The availability of a consistent library of EXTEND model blocks should facilitate the linking task (see D8.7). As noted above, SSAs may take the approach of implementing a single integrated model rather than separate models for ecology, economy and sociology. It is also possible that the sociological element may not be included as a model per se.

5.1a.1 REVIEW ESE MODELS RELATIVE TO APPRAISAL OBJECTIVES

This activity is a checking and reviewing task. The primary need is to focus on the integrated objectives of the Simulation Analysis, while in the FS, the focus was on the validity and appropriateness of the functional representations of the Virtual System. Thus, in the Appraisal Step, we need to ensure that the representations and analyses are focused on the simulation and their integrated information output for the selected scenarios (see Chapter 4 of the SAF protocol Chapter on CZ System Design concerning scenario selection).

It also likely that the ESE models disclose aspects that were not considered in the definition of the scenarios or, the contrary, that they cannot be strictly adapted to provide the planned output information. In both of these cases, one must decide either to re-express the scenarios or to re-formulate the model. Generally, the latter is more difficult and in the SSAs, we recommend redefining the scenario and explaining the modification to the Participant Group. However, if participant groups are to maintain ownership of the model, which is essential if they are ever to use it in any practical application, they must be involved in any adaptation of it. Perhaps it would be more appropriate to provide some form of education/ training so that they are able to decide for themselves the best means of adapting the model so that it integrates ESE components.

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5.1a.2 INTEGRATE ANY LINKS TO OTHER MODELS OR ANALYSES

This task is completely dependent on the extent to which other models have been used to complement or supplement the intended Simulation Analyses. To accommodate the SPICOSA resource and time constraints, we have suggested use of Extend for the Simulation Model. Other options are welcome, if they can be completed on schedule. There are three points of entry (discussed elsewhere): as auxiliary models provide input at the FS WT4.3a; as a separate component of one of the ESE Components that becomes integrated into the Simulation Model in this WT5.1a; or as a completely independent assessment that generates supplementary information for the Output Step.

Examples:

- The Formulation requires that *another model generates input to an Extend ESE component.* For example, a watershed hydrological model is used to calculate runoff and nutrients for inputs to a NC Component estuary model. This model is represented by file inputs containing time-series of its variables within the Extend Estuary model.
- The FS specifies that *another model is dynamically linked to an Extend ESE component.* For example, a watershed hydrological component model is linked in time with the Simulation Model so that those having to do with land-use scenarios can be simulated. This would be equivalent to the NC Component having two major components; however, if the watershed model is calculated outside of Extend software, it needs to have a compatible interface.
- The FS specifies that *another model contributes to the output independently of Extend.* For example, a spatial distribution of parameters is modelled that cannot be easily visualized through Extend software and must be done by another software (see 5.3a.1).

Systems involving ecological, economic and sociologic processes may be very complex, not only in terms of the state variables and the processes involved, but also regarding spatial-temporal scales of application. In many cases, it is necessary to link two or more different models. This linking may be "hard", in the sense of involving step by step of interchange of variables or parameters between the submodels, or "soft", when the output file of one submodel is used as the input for another submodel. In this case, it is necessary to assure that shared variables have consistent dimensions and scaling. Many modelling programs provide software for importing and exporting data with other applications. Due to frequent changes in the software versions of the different submodels, soft linking is in principle a better solution for long-term exploitation of the linked model.

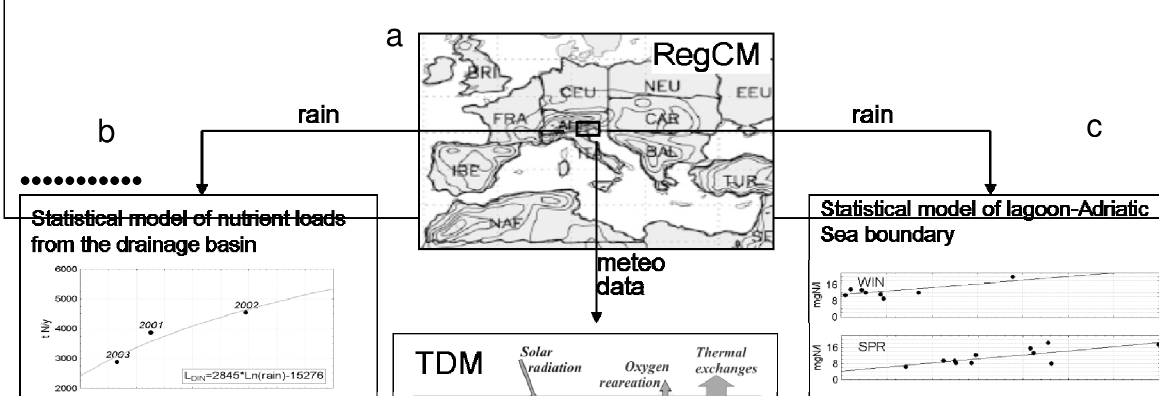
An important case of external connection may be the linking between system dynamics and spatial applications. Model packages such as Extend are especially well suited for allowing the development of system dynamics applications without requiring students and researchers to master basic programming languages (such as Visual Basic, Fortran, C++ or Java). In principle, EXTEND (or similar packages) could also be used to incorporate spatial applications, but coupling between system dynamics and spatial applications may be facilitated by software development initiatives aiming at linking systems dynamics with geographic information systems (see Chapter 6 of D8.3). One of the goals of WP8 is the implementation of a system in which all models, components and methods are stored in an EXTEND library, but which uses PCRaster for the spatial analysis of these models (D8.3, page 70).

An example of soft-linking between different models

One example of "soft-linking" approach is that used in the Millennium Ecosystem Assessment (MA, Carpenter et al., 2006). In this project, storylines were developed for different scenarios and a team of modellers was organized to quantify the scenarios. Five global models covering global change processes were selected, based on criteria such as global coverage, publications in peer-reviewed literature and relevance in describing the future of ecosystem services. Linkages among models were adjusted and test calculations were carried out using preliminary driving force assumptions. The results of these tests were used to clarify the procedures of linking the different models.

Consistency between the calculations of the different models was achieved by "soft-linking" them, in the sense that output files from one model were used as inputs to other models. For example, computations of food supply, demand and trade from the IMPACT model were aggregated for the various world regions and animal and crop types and used as input to the IMAGE land cover model. The changes in irrigated areas computed in IMPACT were entered in the WaterGAP model and used to compute regional irrigation water requirements.

The ESE model for the Venice lagoon receives input from a 3D biogeochemical model (TDM) forced by a combination of conditions derived from the regCM metorological model and from two statistical models that describe river inputs and exchanges with the sea.



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5.1a.3 RUN ESE MODELS FOR INTERPRETIVE ANALYSES

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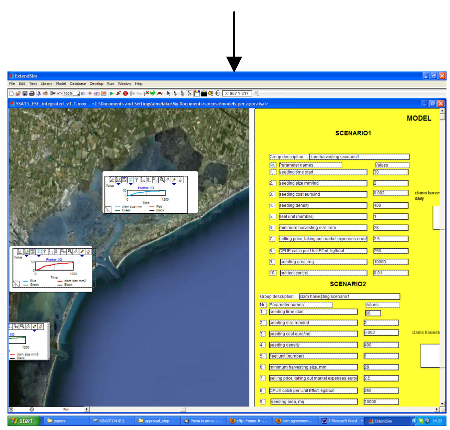

Figure 3. Venice lagoon downscaling scheme. Layout of the downscaling approach. The scheme depicts relationships among the atmospheric model RegCM (a, the upper panel shows the domain;), statistical models (b and c, left and right boxes), TDM (d the central panel illustrates main biogeochemical processes considered). The lower plot gives an example of the multi-decadal output (e, spatial average and dispersion of concentrations of chlorophyll), which are used to force the ESE extend based 0D model (f, bottom panel) The box in the upper map indicates the area of interest. (Solidoro et al. 2010, Melaku Canu et al. 2010)

The ESE Component models that are delivered to Appraisal should already have passed the validation tests (WT4.3b) and the hindcast calibration runs (WT4.4a.). However, the calibration runs used may not coincide with the intervals needed for the scenarios requiring some adaptation. For example,

- For the purposes of utilizing the best calibration data, a different data set may have been used in the FS, which might not coincide with the anticipated time period (or data inputs) as that needed for the scenario runs.
- For the purposes of demonstrating the qualities of an ESE model, a different data set may be required.

In these cases, SSAs could convert data to the lowest common denominator and lose accuracy, or extrapolate upwards from existing data and increase error margins. In general, the first option would probably be better.

Thus, the main emphasis of the WT is to individually run these ESE models to obtain results that can be presented scientifically and to complement some of the Interpretive Analysis specific to each particular ESE Component.

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WT5.1b Conduct ESE Interpretive Analyses

The Interpretive Analysis Task has two major focuses: that concerning the Component Models (WT5.1b) specific to their 'disciplinary' objectives and that concerning the Simulation Model (WT5.3a), which combines these ESE Components, specific to the response of the CZ system corresponding to the Policy Issues (scenarios). Analysis and assessment in each of the ESE Components must be completed at the beginning of the AS, because their results will bear on the final simulations and interpretations. The scope and methods for these analyses were decided in the DS and prepared during the FS (ESE Assessment Plans WT4.4b). Due to time restrictions, some aspects of them might need to be initiated in the FS.

WT 5.1b Conduct ESE Interpretive Analyses
1 Functionality of the Natural Component (NC) Model: **Results, Limits, Ecosystem Stability, Restorative Potential.** **2 Scope of Economic Component (EC) Model:** **Results, Limits, Opportunities for Sustainable Development.** **3 Scope of Social Component (SC) Model:** **Results; Limits, Relevance to Sustainable Development,** **Role of Stakeholders and Governance**
This is primarily a Scientific Product

ACTIVITY EXPLANATIONS

These subtasks pertain to the Interpretive Analyses, which are specific to the disciplinary objectives of each of the ESE components. It is particularly important that each component can pass review within its disciplinary area of expertise. Each of the ESE Component models has an intrinsic value with respect to the particular aspect that it is simulating. These need to be analyzed through separate runs of the respective ESE model and described. The reader is cautioned that some aspects of the below explanations may vary with the SSA.

5.1b.1 NATURAL COMPONENT ANALYSES

These analyses and descriptions interpret the simulation results of the Natural Component model and its objectives.

Process Approximations. In general, the simulation model represents the functionality most relevant to simulating the Impact with respect to the chosen scenarios. The way it is represented makes a large difference in its ability to capture the functionality in order that it can serve as a proxy for the behavior of the system to our scenarios. Each of these representations must be justified scientifically; it is important to record all the underlying assumptions to the choices being made. In the FS, much of this is done in a reductionist mode, process-by-process and component-by-component. This text will enter into the final Scientific Article in the methods section.

Examples:

- The input values of nitrogen were not available for an estuary. What methods were used to estimate these values and what is the nature of the errors introduced into the model?
- There were no local observations of sedimentation rates of particulates. How were these estimated and how do they compare with similar observations in other estuaries?
- A two-layer representation of the estuary was used. How were observed data treated to provide calibration data for the model?

Functional Limits. Similarly, our representation of the Virtual System must be described in a more holistic manner in terms of its validity of the entire component model to adequately represent the functionality for the proposed scenarios, e.g. how the major approximations affect the output. This description will ned to be communicated to stakeholders in the Output Step

Examples of justification:

• The model grows phytoplankton as food for a surface fixed mussel farm, and the model assumes that the mussels are only exposed, each time step, to the same proportion of the total surface layer as the farm occupies. Discuss and demonstrate this approximation and how it affects the model output.

• Discuss the importance of sediment re-suspension of organic matter from the bottom in retarding any proposed (scenarios) intending to consider only the effluent loading as an adjustable parameter. How might this be reflected in the model output, and how might it be better represented in future models?

• The model uses the two-layer structure for circulation, and it assumes lateral homogeneity. Describe how this might introduce an error. Describe how the carrying capacity of the relevant state-variables are affected, e.g. under what conditions is in enhanced or diminished for nitrogen, oxygen, etc.

Simulation Results. Here the purpose is to describe how the model responds to reasonable variations in its inputs, including any proposed changes in Inputs dictated by the chosen scenario. In addition, some analysis will be needed regarding how the NC model responds to pulses of energy that are beyond the range of the scenarios but within the range of risk factors specified in the Design Step.

Relative to the particular aspect that the NC simulation model addresses, the model may need or offer some scientific description. This will be particularly true if the model output is well correlated with observed data, e.g. in the hindcast runs, and thereby provide useful information on the dynamics of the system. The most likely situation will involve an agreement due to calibration adjustment, such as the use of different representations of processes, inclusion of new (or not well recognized) methods, or simply results that have not yet been reported. *Examples of these:*

• Because of the non-linear potential of Extend, certain parameters that are normally considered as constants can be made to be a function of another state variable (e.g. the value of particulate organic matter in the process of light absorption, available kinetic energy or stratification in the diffusion process, or dissolved oxigen values in denitrification).

- The use of time-dependent 'box' models (not defined in space but relative to a state variable) may offer alternatives to monitoring and assessment (e.g. instead of using concentrations at fixed locations in a system, providing estimates of total content, or total flushing, etc.).

The output of a model must not be a unique value but should be expressed by a triplet ($Y, \Delta\alpha Y, \alpha$), which represents the mean value Y of the result given by the mathematical modelling, the imprecision range $\Delta\alpha Y$ of the mean value and the degree α. of confidence of each value belonging to this imprecision range (example of the non-classical methodology based on the fuzzy set and fuzzy logic theory).

If the model results consist of a spatial information (a map like on the example hereafter), three maps should be proposed: one with the mean result (mode) as shown on Fig. 4, and two other maps which represent the upper (c) and lower (a) boundaries associated to the mean value (Freissinet et al., 2001).

As explained in section 10.4 of D4.1, following Morecroft (2007), evaluation of a model implies several categories of tests. Tests of behavior assessed, by visual or statistical means, the fit between the trajectories of simulated and actual data. Tests of structure include questions on boundary adequacy, dimensional consistency, parameter verifications, and robustness of behavior. Tests of learning refer to the comparison between the model results and the mental models and expectations of the public. Recommended approaches to evaluate the impact on model output of using imprecise input information include sensitivity analysis (see WT 5.21) and uncertainty analysis. The latter approach (see WT 5.3a2) estimates the uncertainty of the solution from the uncertainty of model input parameters (Fresissinet et al., 1999).

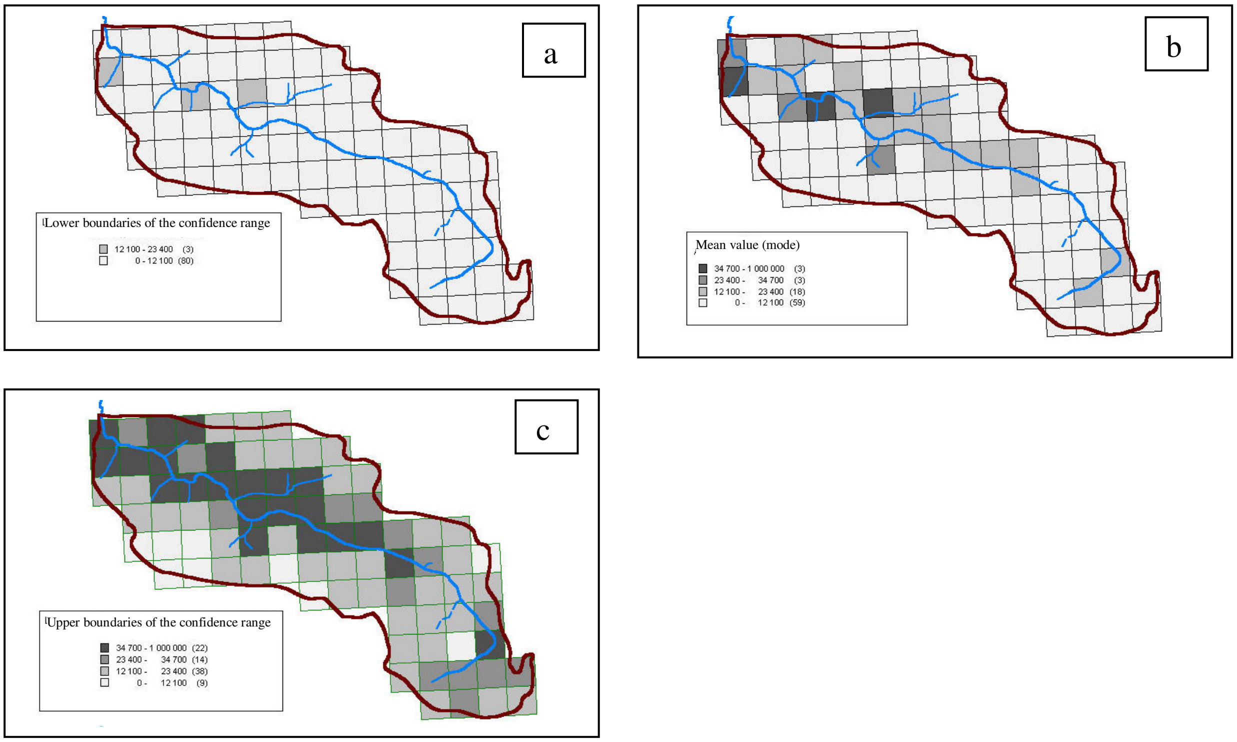

Figure 4. Example of vulnerability index of the surface water against Atrazine pesticide in the Vannetin Basin (France).

Scale of vulnerability	
0 to 12100	: low
12100 to 23400	: medium-low
23400 to 34700	: medium
34700 to ∞	: high

One part of the tests of structure is the study of model stability (not only of natural but also of the socio-economic components). This property has been defined in many ways. For example, a system may be considered unstable if an infinitesimal change in system parameters can cause qualitative changes in system behaviour. Food web models including several categories of organisms or functional groups are highly non-linear and can display dynamic behaviours ranging from asymptotically stable equilibrium points to limit cycles and to chaotic oscillations when parameters or forcing variables are changed. Understanding the intrinsic dynamics of these models is necessary for building realistic ecosystem models (Lima et al., 2002). A widely used method for studying stability in a differential equation model is based on the construction of a Lyapunov function (Rosen, 1970). Unstable models were often considered fragile and inadequate representations of real ecosystems (Goh, 1977). However, recent work has pointed out the potential significance of oscillations and chaos in natural situations (Huisman and Weissing, 1999; Benincà et al., 2008).

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5.1b.2 **ECONOMIC COMPONENT ANALYSES**

These analyses and descriptions interpret the simulation results of the Economic Component model and its objectives.

Scope and Limitations. For the first SAF applications, we are necessarily limiting the scope of the Economic Valuation (see discussion above on "scaling" in Introduction under Implementation). The example of economic assessment chosen for simulation analysis must be limited to the Virtual System and treat one or more of its scenarios. This is partially pre-determined in the expression of the scenarios.

Examples:

- *SSA 14 Scenario:*

  "Evaluating the environmental conditions controlling Mussels growth: To what extent would optimal environmental conditions reduce the costs of mussel culture and increase socio-economic benefits?" (See FS 4.1). This scenario requires a direct coupling with the mussel population produced, which is then converted to monetary values. Here for example, two areas for economic valuation are directly implied:

  1) The possibility of improved environmental conditions (e.g. different phytoplankton speciation) would allow the mussel farmer to reduce his costs for importing juveniles and to improve the quality of his mussels. This analysis is strictly linked to the simulation of the natural system through the simulation of how a modification in the food supplied by the ecosystem changes the quantity or quality of the mussel production. The costs of these

modifications would have to be evaluated. Economic analysis is required to assess the management strategies of the mussel culture.

2) Lowering production costs could affect the social benefits of employees and the local economy. This analysis uses the output of the natural system to determine the income, and it is only indirectly linked to the natural system. It is mostly concerned with evaluating the options management strategies of the distributing the income.

• *SSA 5 Scenario:*

How would the recreational demand change in response to increased transparency of the Himmerfjarden because of reduced nutrient inputs (paraphrased from Enveco report, 11Aug 08)? In this case, two area of analysis are implied:

1) The nutrient reduction involves the natural and economic components. The effectiveness and the short-term costs of measures needed to reduce the nutrient loading would be analyzed (simulated). These costs could then be compared with some of the benefits derived, e.g. recreational value to the local economy. Other consequences of the changed ecosystem may or may not be analyzed but should be discussed.

2) The recreational demand involves both social and economic components, in response to changes in the water quality, through the social benefit of an expanded recreational resource and the willingness of tourists to pay (contribute to the local economy) for this resource.

Discussion of Results. Here we would discuss the results of the Economic Component analysis independent of the Simulation Analysis, which will come later (WT 5.3a). This is to provide a credible basis for our approach to the specifics of the Economic Component, before assessing the interactions with the other Components and the System scenarios.

Simulation. This should describe the results of the Economic Simulation.

• Explain the objectives and what is being quantified in the model in the context of the policy option. Include the rational for the quantification of the Economic processes and the approximations used (already outlined by the FS)

• Explain the results of the quantification in the context of the objectives and what they demonstrate. For example, did they reveal any unexpected results, how do they compare with data, are they useful to the management of the economic enterprise involved?
• Document all underlying assumptions to facilitate the output step.

Supportive. Because this exercise is demonstrative, it is important to discuss its potential value with respect to a more complete exercise; i.e. Illustrate how the value of the exercise might be improved, or how it might be expanded to associated economic policy options.

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5.1b.3 **SOCIAL COMPONENT ANALYSES**

These analyses and descriptions interpret the simulation results of the Social Component model and its objectives.

Scope and Limitations. For the first SAF applications, we are necessarily limiting the scope of the Social Assessments (cf. scaling in the Introduction under Implementation). The example of economic assessment chosen for simulation analysis must be limited to the Virtual System and treat one or more of its scenarios. This is partially pre-determined in the expression of the scenarios. As mentioned in our contribution to WP 3, a report on *Social Aspects of ESE*

Assessment in Coastal Zones. We recommend that the SSAs choose a social component, which is relevant to the policy issue from the list below (see Chapter 9 of the SAF Protocol Chapter on CZ System Design for details):

- Economy: income, employment, tax, inflation, and seasonality of livelihood
- Institutions: Decision-making, Organisations, Politics and Governance
- Legal Systems

- Settlement, including Population (Urban Growth, Rural Depopulation), Displacement, Migration, and Relocation
- Society as a community of individuals:
  - defined according to range of characteristics such as geographical proximity, shared values, culture, social groups,
  - exhibiting a range of normative qualities that are considered beneficial, such as: Adaptive Capacity (Vulnerability), Community Cohesion, Lifestyle or Well-being, Health, Birth rate, Mortality, Culture, Educational indices, Access to Facilities, Affordable Housing, Social perceptions, attitudes and values (including attitudes to risk, change or development)

If this list seems to long, perhaps some kind of decision tree can be made to assist in the choice of component. In particular, we would emphasise the social component of communities relevant to the policy issue.

Limits. The selection of what social aspect to assess must (for present SSAs) have a direct connection with one or both of the other ESE Components and must have some relation with improved sustainability of the local CZ region. In other words, there must be some direct link between the Impact simulated in the NC or indirect connection to the Impact through economic responses to that Impact (in the EC). For example, "What are the consequences of declining shellfish stocks on employment levels?"

Methods and Inputs. These should be specified in the FS. However, we would emphasise the availability and usefulness of (1) National Census Data (2) Social Impact Assessments, especially those which focus on a 'bottom up' assessment of impacts or changes within relevant communities (3) Social Indicators or surveys of social trends. (Other approaches have been put forward by other SPICOSA social scientists, especially approaches relevant to institutional analysis). It may also be useful, where possible to use indicators and scales that are used at other SSA sites. This will facilitate comparison.

In terms of Interpretive Analysis stage of the Appraisal step, for the above Social Components this would most clearly be validated by a historical analysis of the situation. There might also be an opportunity to consider the different 'Futures' or broader 'Scenarios' under which these social assessments are conducted, and examine some of the assumptions underlying these. For every indicator, there should be a table summarizing these assumptions.

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WT5.2 SYSTEMS SIMULATIONS

These WTs must construct the Simulation Model from the latest versions of the ESE Component Models and with consideration of interactive feedbacks between these components.

WT 5.2a Construct Simulation Model (SM)

This WT creates a working Simulation Model and makes tests it for stability, validity, and agreement of its output variables with observations.

WT 5.2a Construct the Simulation Model
1 Review Inputs, linkages, outputs for the Simulation Model **2 Construct Simulation Model by linking up the ESE models** **3 Verify the Simulation Model, conduct Sensitivity tests, Error analysis, and Document** **4 Conduct a Hindcast simulation with Policy or other change**
This contributes to Documentation and Scientific Products

ACTIVITY EXPLANATIONS

These tasks combine all previous model preparation into the CZ Simulation Model. This model may have several versions because of the scenario specifications. The specializations of the Simualtion Model to accommodate the scenario requirements follow in WT5.2b. To understand this distinction, one can think of the product of this WT as the 'mother' model that represents the functionality surrounding the ecological impact and examples of the economic and social responses to that impact. The scenario versions are specific runs of the mother SM, which require certain changes in the input, internal function, or output of the Simulation Model – WT5.2b.

5.2a.1 **REVIEW INPUTS, LINKAGES, OUTPUTS FOR SIMULATION MODEL**

The systems approach developed in SPICOSA (see WP4 Guidelines) recognizes three main types of model subsystems or components: the Natural Component (NC), the Economical Component (EC), and the Sociological Component (SC). These three components are coupled in the Simulation Model (to be developed for each study site). The division into NC, EC, and SC is adopted for simplicity, but it should be taken into account that, as described in Wang et al (2001), the level of integration between these subsystems can be variable.

Based on the degree of integration between their economy-ecology subsystems, Wang et al. (2001) describe different types of models: Models with unilateral interactions and Integrated models (Wang et al., 2001) don't mention the sociologic subsystem, but their scheme could be extended to consider it also. System models with "unilateral interactions" may be ecologically or economically-oriented. In the first case, the model focuses on the changes in the ecological subsystem caused by the economic subsystem. In the second case, the ecological subsystem provides inputs for the economic subsystem. However, there is no real feedback between both subsystems. Integrated models link individual elements of both ecological and economic subsystems. In this case, Wang et al. distinguish integration through a "production function" (which transforms input of factors such as human labor and ecological resources into outputs such as investments and consumption) and integration via an "objective function", for example, by including ecological factors (such as resources or emissions) into economical functions such as a "consumer's utility function". Details concerning how to implement ecologic assessment within the SAF can be found in deliverables D2.1 to D2.3 of WP2. Chapters 4-6 of D8.3 review different integrated models that are available for coastal zone management.

According to Engelen et al. (2003), technical integration of submodels is very much a software problem involving a) the architecture chosen for representing the model base and b) the software technology used to implement the Decision Support System (DSS; see Glossary) and its model base. This last aspect will not be discussed here. These authors distinguish four possible solutions for the architecture (Fig. 1): "Access to loose and distribute models" uses existing models residing on the machines of their owners. In "Existing models linked to a single system", the existing models possess interfaces that allow to access and run them in a synchronous manner. In the solution "Systems model consisting in part of rebuilt models", which was the one used in WadBOS, most submodels are reformulated as part of an integrated model, which resides in the machine of the user. The last solution is a mixture of the previous ones. Integration of submodels is also a logistical problem, which should involve ecologists, economists and sociologists. Identification of cause and effect linkages is a very challenging activity, particularly across a range of scientific sectors. Clear concepts are required to facilitate this- for example, a particular ecological change may lead to economic and then social change, which then feed positively or negatively back into ecological status. Conclusions such as these need to be undertaken in an open and discursive way, and agreements have to be reached before the next stage can be attempted. Models developed will only represent the perceptions of the people involved in constructing them. These persons should therefore be chosen very carefully (for their expertise and open-mindedness to new approaches), a scientist-facilitator tandem is highly recommended. It is also necessary to assure good feedback with policy makers and stakeholders and define when and to which extend this feedback will be needed.

5.2a.2 CONSTRUCT SIMULATION MODEL FROM THE ESE COMPONENT MODELS

From the system formulation chapter you should already possess building blocks of your model in the modelling package you are using; that is sub components, which you have run, calibrated and validated. The environmental, social, and economic sections of the model need to be finalized and brought together into system based model before it can be used to inform stakeholders and decision-makers.

Linking ESE components is not an easy task. For example, it may be difficult to use EXTEND to integrate modeling routines using different time steps. As recommended in D8.7, it is best to use a time step that is sufficiently small to be applied to all the model components. This may no be very efficient; in the case of SSA 9 (Scheldt), the adopted solution was to build an estuarine compartment block that implements the time integration itself andhas a user dialog to fit the time step.. The Guadiana Estuary model (SSA11; Figs. 7- 8) uses blocks that accumulate the outputs of the environmental component and control when they are sent to the socio-economic model.

As you have been considering the system as a whole, and modelling the three aspects of the system mentioned above, it is logical to assume that these three aspects interact with each other. This is the basis of systems thinking, the bringing together of all aspects of a system and modelling them as a whole as opposed to their component parts. The problem comes in how we should go about integrating these three components.

The easiest way to go about creating this integration is to consider a 'common currency' between these models. This can take the form of a variable, which is present in both models such that the output of one component is the input of another, remembering that there may well be a feedback loop of the output of that second component also acting as an input to the second. Often, it may be more realistic to have two or more linking variables.

Several examples of models involving ESE components are given below.

Construction of a fisheries model.

As a simple example of this, consider a fisheries model. This has three components, representing the ecology (fish population, spawning, habitat), economy (number of jobs, price that fish sells at market, possibility of cheap imports) and social (jobs and welfare associated with the fishing fleet). This system is shown in figure 5.

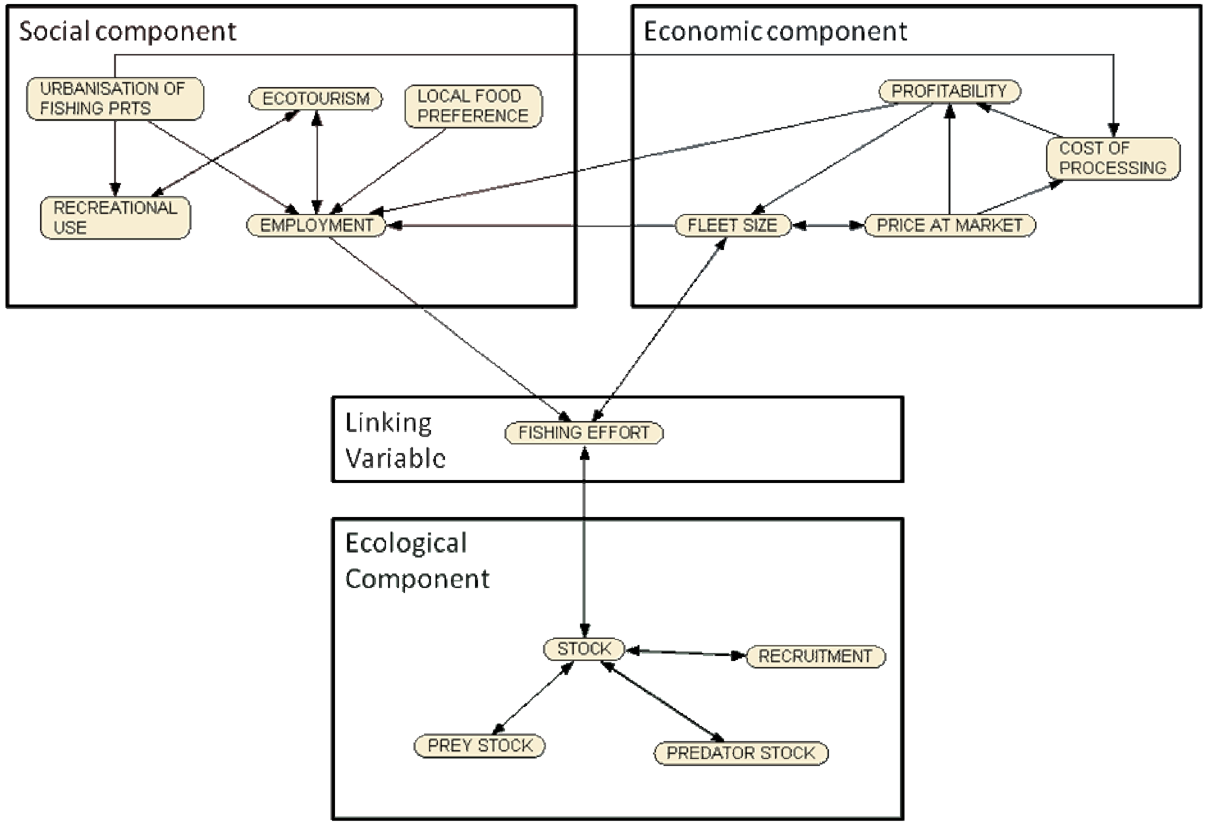

Figure 5. A simple fisheries model demonstrating direct links between social and economic components of the model, and linking the economic and social components to the ecological model through a linking variable.

Now let us consider how these three models might interact. Fish population may, in part be controlled by the number of fishing vessels, and number of days that those fishing vessels stay at sea. In terms of the number of vessels, or the frequency that those vessels leave port may be a product of the population of fish present. However it is also true that the number of vessels and economic viability of the vessels leaving harbor will be a product of the price that the fishers are able to achieve for their fish at market. Economic and ecological models can therefore be linked though variables, which describe fishing effort in the region.

Where no direct link can be developed between models, a binary approach may be adopted. This allows a switch to be turned on and off within a model dependent upon the output of another model being above or below a pre defined threshold. This may be in the form of a level adopted in a policy instrument, or for example a concentration of a substance known to have a physiological affect on the modelled species. This method results in a loss of definition in the model, and it should only be adopted if a more direct link cannot be established.

The Venice lagoon.

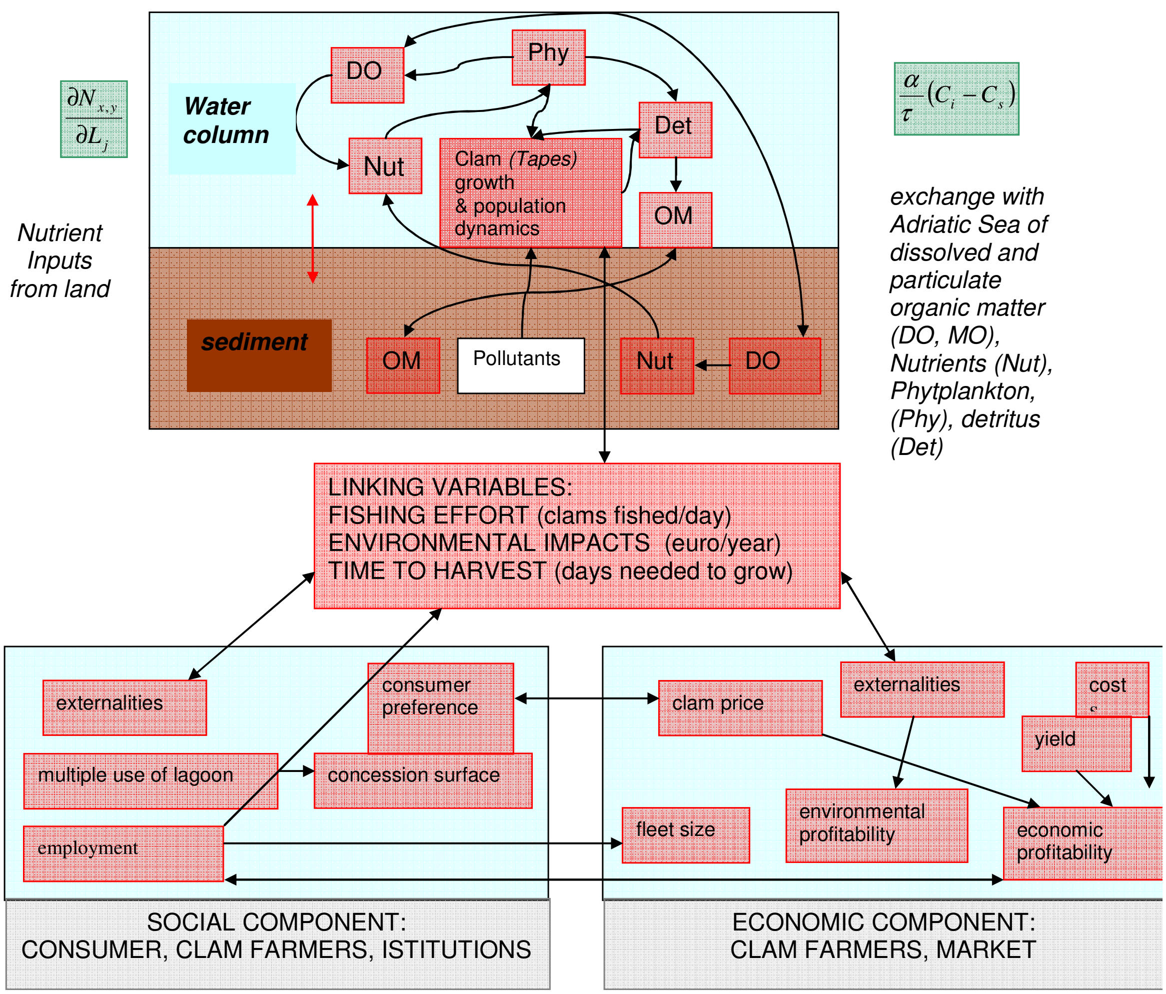

Figure 6. The Venice Lagoon (SSA15) ESE model simulates the dynamics of lagoon biogeochemistry, clam growth , harvesting and impacts.

Clam production depends on environmental conditions (nutrient loadings, nutrient exchange with the sea, local dynamics) as well as ecological conditions affectting the organisms; it also depends on social constrains, such as the surface of lagoon devoted to clam growth (defined by by institutions and consumer preference and demand) and on market constrains such as costs, prices and profitability. Clam production induces an environmental impact on the lagoon that enters as a feedback on the Economic Component, where it is used to compute externalities that affect the profit, and as a feedback on the Social Component, where it is assumed to be used by Institutions for area planning.

The model can de used to simulate alternative management scenarios which will allow policy-makers, control authorities, as well clam farmers themselves, to evaluate aspects such as the sustainability and health impacts (in terms of organic pollutants of different aquaculture concession proposals.

The Guadiana Estuary

The link between the Environmental and Socio-Economic Components (Fig. 7) was made under the assumptions that:

- An improvement in water quality (represented by the variable fecal coliforms concentration and N:P:Si ratios) leads to an increase in the economic benefits provided by that resource. These benefits have been calculated using Contingent Valuation Methods (willingness-to-pay) for residents and visitors of Guadiana estuary.
- The estuary’s trophic state (N:P:Si ratio) affects fish population, which will have an economic impact on fisheries and consequently on employment.
- Water quality has an impact on beach attractiveness that can be translated to to the number of visitors to the surrounding beaches and to employment.

A scheme of the technical linking done in ExtendSim is represented in Fig. 8. The main technical problem in order to perform the linkage was to harmonize the time step of the ecological submodel (one day) and of the socio-economical submodel (one year). Tissue was solved using equation blocks containing ModL language that integrate the outputs of the environmental component and feed them to the socio-economic submodel.

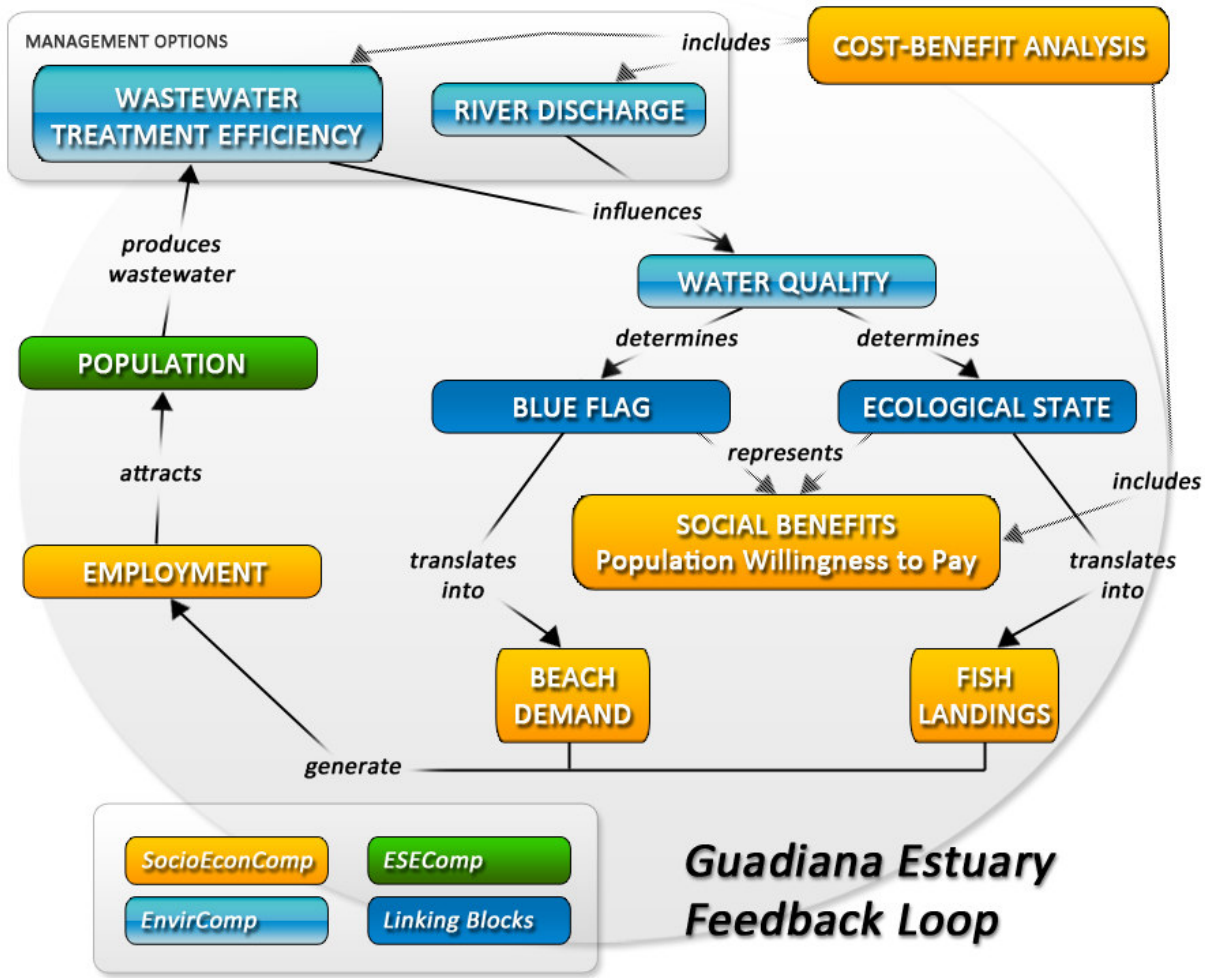

Figure 7. Relationships between the variables involved in the **ESE model of the Guadiana Estuary.**

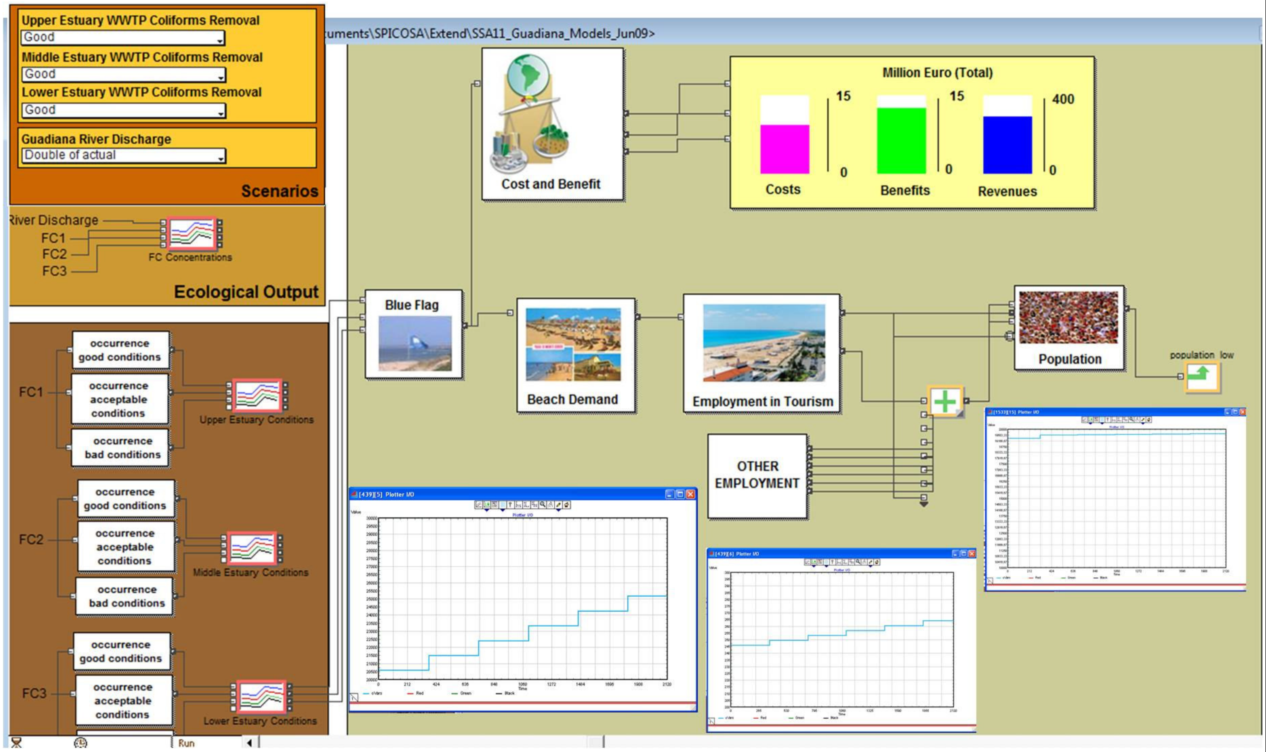

Figure 8. ExtendSim screenshot of ESE model linking for the Guadiana Estuary.

5.2a.3 VERIFY THE SIMULATION MODEL, CONDUCT SENSITIVITY TESTS AND ERROR ANALYSIS, AND DOCUMENT RESULTS

Verification. The initial stage of validating the models is that of verification. This is simply running the model and making sure that it functions would be expected on a qualitative level. This initial validation step checks the general functioning of the model, partly to make sure that it has been implemented properly in the modelling package, and partly to verify that the relationships that have been entered into that model are correct.

The simplest way to undertake a verification check is to run the model through a simulation run and confirm with the experts within the SSA that the variables in the model are acting as they would expect. It is not necessarily the modeler's responsibility to check this, as the modeller is not expected to be an expert in the minutiae of the system being modelled. The other members of the SSA are there for this purpose.

A good way to undertake this sort of verification is to have the members of the SSAs present in a meeting while the model is being run. This then allows discussion within the group as to the models functioning and may result in feedback that would not be encountered if participants were approached individually. More often than not, this then allows changes to be made to the model while all members are present and results in a model that consensus considered correct. It may be necessary to repeat this exercise two or three times until consensus is reached. Also be aware at this stage that some experts will dispute the accuracy of the model and might try to influence its construction. It is therefore advisable that a trained facilitator is present at the session to ensure all experts provide input to model reconstruction and to ensure that parties are aware of the benefits of joint working in this area. See the SAF Protocol on CZ System Output concerning requirements for the facilitator.

A second and more mathematical method of checking the functioning of the model is the process of validation (see WT5.2.b). This is the process of checking the numerical output of the model against expected data in one form or another. These data may include the outputs of other models, real data in hind casting validation or models run in other systems. Possible actions if the model does not produce the results expected include: Check accuracy of data going in, check linkages between components, check weightings/ calculations at each component part, check for positive and negative feedback loops. It might also be useful to provide contact details of someone who can assist if all other avenues have been exhausted.

The scale at which these checks are made depends on the scale of the data available. Ideally, a dataset of variables entering and exiting the model will be used as this allows a simple validation check of the system. If this is not the case, and only partial datasets are available, or the validation using this method shows unacceptable error, then a more complex validation procedure on a function-by-function basis must take place. In the case of a lack of data, this allows verification of each link in the system, in the case of a failed validation on a macro scale; this allows the tracking down of the faulty functions within the system.

It is worth reiterating here that the point of the SAF is that it is a Systems Approach. One important premise in systems thinking is that emergent properties will be evident when the system is modelled as a whole, which are not present when the sub components of that whole are modelled individually. This presents a problem when it comes to validation based on real data. If we are validating the ESE components individually, then the interplay between these components is present in the real data, which the model is being validated against, but not in the model itself. This would results in increased error in the model..

Example of verification

Mathematical validation is a time consuming procedure. To determine if carrying out validation is worthwhile, verification is first used. As an example, a simple eutrophication model as shown in figure 9. The model has been setup to show the responses of chlorophyll concentration (an indicator of eutrophication) to changes in nutrient pressures and drivers.

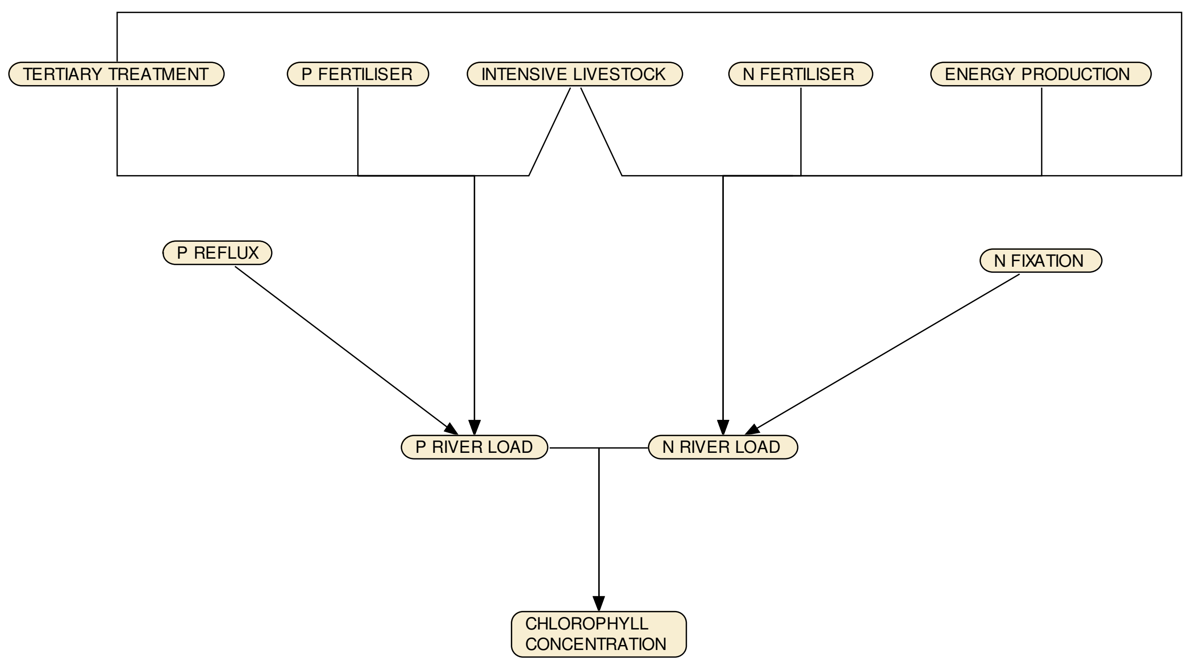

Figure 9. A eutrophication model, showing the human drivers along the top, pressures in the middle and chlorophyll concentration, a eutrophication indicator at the bottom. Arrows represent function links between variables.

The modeller has set this model up based upon the directions of the group of experts and stakeholders, and now produces a series of test runs, changing the driving variables, to see what happens to the model.

The modeller is not an expert in eutrophication, or the local area that the model represents so s/he takes these results to the expert group.

Some questions to be considered:

- Are the variables acting as expected? If a driving variable is increased, does the corresponding pressure change in the right direction? For example, does an increase in application of N fertiliser result in an increase in the load of N in the river?
- Does a combination of changes of driving variables have the right effect? For example, if the level of N fertiliser is decreased and the level of tertiary treatment of sewage increased, would the N-loading in the river decrease even though both of these changes individually had the right effect?
- Is the weighting of the drivers correct? For example if N fertiliser increases and tertiary sewage treatment decreases, would you expect the N river load to go up or down?

These questions, and more complex ones that are specific to the system should all be asked at this stage. These errors may be a result of mistakes in the implementation of the model in the software, or they may be a problem associated with the understanding of the system. Either way it is important to identify them at this stage so that they can be either corrected, or investigated further. If these deviations from expectations are in fact because of incomplete understanding of the system, this can often be an important finding. Such deviations will be verified through mathematical validation and then be studied further.

Sensitivity Analysis. Sensitivity analysis examines how much the model output is affected by changes in a parameter value or a forcing function. If a minor change in a parameter value results in a huge change of model output then the model is said to be sensitive towards this parameter.

In relation to model validation, sensitivity tests are mainly used to evaluate how uncertainties in the estimated forcing functions or parameter values affect the model output. A lot of uncertainty in model output is introduced due to inaccurate approximations of the forcing functions. This inaccuracy is mainly caused by lack of data, poorly temporally or spatially resolved data, poor data quality etc. The potential variability in forcing functions should be estimated and used to make a sensitivity analysis.

Several parameters in complex system dynamics models represent quantities that are difficult, expensive or impossible to measure and which have to be estimated from a model calibration procedure. It is import to evaluate the sensitivity of these parameters in order to increase the credibility of the model.

The model parameters that have a high sensitivity should be identified and documented in preparation for the output, since the reliability of model scenarios is highly depended on how well/precise these parameters can be estimated and often pinpoints the need for high quality data for a better determination of these critical parameters.

Quantification of Error. Quantification of model error (i.e. measures of the difference between output from a hindcast simulation and empirical data) is part of the validation procedure. A series of techniques are described and applied in Allen et al (2007). As an example the Nash Sutcliffe Model Efficient Measure (ME) that is a simple way of assessing model performance is calculated as:

$$ME = 1 - \frac{\sum (D - M)^2}{\sum (D - D')^2}$$

Where D are the observational data, D' is the mean of observational data and M the model output. Allen et al categorise model performance levels as ME > 0.65 excellent; 0.65-0.5 very good; 0.5-0.2 good; < 0.2 poor. Another technique is to calculate the percentage model bias (i.e. model error normalized by the data) as:

$$PB = \frac{\sum (D - M)}{\sum D} * 100$$

Values can be categorised as: < 10 excellent; 10-20 very good; 20-40 good; > 40 poor. It should be noticed that the choice of categories are highly subjective.

Documentation. See D8.10 (MBB Model update) and D9.13 (Information Management Report Draft).

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5.2a.4 CONDUCT A HINDCAST SIMULATION WITH POLICY OR OTHER CHANGE

Hindcast Model. Comparisons between model output and observational data are one of the most effective ways to tests whether the model sufficiently resembles reality. The purpose with a hindcast simulation is to validate the model, by making model simulated data that are suitable for comparison with empirical data. A hindcast simulation requires forcing data, which will be used to approximate the forcing functions that drive the model during the simulation. In addition, empirical data suitable for model comparison are required. These data should correspond to the model state variables or process rates and they should have been measured during the same forcing conditions as the forcing data.

It is highly recommended that the forcing data and data used for model comparison have been measured during a major policy change in order to test that the model responds correctly to this change.

To conduct a hindcast simulation it is necessary to construct proper initial values for each state variable and to construct the forcing functions. An initial value defines the state variable at the beginning of the simulation period (i.e. at time t = 0). Mathematically speaking the initial value for the state variable Cs is described by the function $Cs(x,y,z,t = 0) = ps(x,y,z)$. Unfortunately, this function is often unknown and has to be approximated based on data and data inter-/extrapolation, good guess or model simulations (spin up period). A simple way of constructing initial values for a validation simulation is to find data observed close to the beginning of the

simulation period and then makes a simple linear interpolation (or extrapolation) in time and space.In general, it is an advantage if the simulation period is initiated during a period when the system dynamics is slow (for example, in winter for an ecological submodel) or after a given temporal boundary (for example, the beginning of new fiscal or laboral regulations for economical and sociological submodels).
Forcing functions (or external variables) describe how the external world influences the state variables described by the model. In a hindcast simulation, all forcing functions have to be based on observations from the simulation period in order to simulate what has happened previously (hindcast). This is not a requirement in e.g. forecast scenarios.

Forcing functions are represented either by a prescribed value (e.g. sunlight, temperature) or by a flux condition (e.g. nutrient loading from a river). In both cases forcing functions have to produce a value or flux in each time step of the simulation and often also over large spatial domains. Normally data are not available on such short time scales and with a high spatial resolution and it is therefore often necessary to interpolate or extrapolate observed data. Various inter and extrapolations techniques are available but simple linear interpolation is often recommended.

Boundary conditions are a special type of forcing that is traditionally used in the context of partial differential equation based models (i.e. models with a spatial component). For each state variable of the model, either it is necessary to prescribe the boundary value of the state variables or to describe the trans-boundary transport of the substances represented by the state variables. In coastal ecosystem models, it is very common that the boundary condition at the open border separating the coastal area from the sea is prescribed with a boundary value. This boundary value (that changes over time) can be approximated based on inter/extrapolations of available concentration measurements close to the model domain. The open boundary at river discharge areas is normally prescribed with a flux condition approximated by measurements of the water inflow and the concentration in the river. If the EXTEND model of the coastal zone does not explicitly deal with space then the transport in and out of the “model domain” has to be parameterized.

Once the initial values and forcing functions have been constructed and implemented in the simulation model, the model output from the hindcast simulation can be used for comparison with empirical data for validation purposes. Observational data that are often used for comparisons with model output are "pool" measurements that correspond to the model state variables (e.g. algae concentration and mussel biomass) but it is also important to have rate measurements for model comparison (e.g. measurements of primary production or grazing rates). In practice it is often, necessary to "translate" model output to the semi-equivalent measured parameter because exact match between model output and measurements are rare. A typical example is modelled and observed concentrations of algae biomass. Most models calculate algae biomass in carbon or nitrogen units whereas algae biomass is measured as chlorophyll a. In this case, algae carbon (or nitrogen) has to be "translated" to chl_*a* before comparison with empirical data.

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WT 5.2b Run Scenario Simulations.

The purpose of this WT is to test and run versions of the Simulation Model for the selected scenarios and to document its results.

WT 5.2b Run Scenario Simulations
1 Review and evaluate priority and feasibility of scenarios **2 Generate necessary input data for selected scenarios** **3 Prepare, conduct, and test scenario versions of the Simulation Model** **4 Document Results of Scenarios**
This contributes to Documentation and Scientific Products

ACTIVITY EXPLANATIONS

These activities and products are focused on the application of the mother Simulation Model to the specific Policy Issues, expressed as several scenarios that reflect different forcing and policy options. The long process of scenario selection and definition, initiated in the Design Step (for details, see the SAF Protocol Chapter on CZ System Design) should end at this WT, with the exception that during the deliberation process (Output Step) certain re-runs might be requested (see WT5.3b). Consequently, again this WT should review the capacity of the Simulation Model to simulate the scenarios and make the required changes. The Participant Group should be involved in this process and should be assured that scenario revision and reformulation are expected and part of an iterative procedure. The feasibility of a scenario run will not be obvious until the input data and the testing are completed.
Table summarizing assumptions for each indicator (see Methods and inputs in 5.1b.3).

5.2b.1 REVIEW AND EVALUATE PRIORITY AND FEASIBILITY OF SCENARIOS

The role of scenario building in environmental studies is to develop exploratory views of the future. Scenarios are not to be confused with predictions or forecasts but are an attempt to describe a "range of possible futures" (WP2 D.2.1 manual).

Within the SAF frame, a scenario can be defined (WP3 manual, WP4 guidelines) as a set of forcings, boundary conditions, initial values, model parameters and constraints that can be used with a numerical model of a CZ system to assess what will happen in response to a change in these forcings, etc. It is thus a combination of policy options (i.e. modifications in components of the virtual system itself) and changes in forcing functions used to explore the potential future of the system through the representation of system trajectories.

Within SPICOSA, the chosen scenarios can explore those changes in policy options and forcing functions by defining several sets of input data and the model can be run with each of these sets, to show the changes incurred in the system.

So far, in the project, the issue resolution task of the Design Step focused on the environmental impacts and their socio economic consequences that were of concern to the stakeholders and coastal managers. Through a collaborative process with the stakeholders, the key issue to be modelled has been agreed on (read WP1 deliverables that provide the framework of the policy issue and stakeholder mapping).

Since the local system managers control some of the forcings, model parameters or boundary conditions of the model representing the dynamics of the key issue, the issue resolution task also included discussions with the stakeholders about the different options of scenarios for change in these environmental impacts. Scenario building is a powerful support tool to involve stakeholders or policy makers and stimulate the discussion, facilitate the assessment of the relevant action, policy, decision or governance issue at stake (European Environment Agency, 2001).

The main scenarios were clarified and agreed upon with stakeholders in a second phase of the collaborative process during the Formulation Step. The storyline (qualitative component of the scenario) that describes the options concerning the policy issue and how its relevant changes unfold in the future was made clearer. The numerical estimates (quantitative component of the scenario) that present future environmental, social or economic indicators were defined. The data questions related to the needs of scenario building were also tackled. A table summarizing assumptions for each indicator was prepared (see Methods and inputs in 5.1b.3).

Within the SSA teams, three different areas of scenarios can be identified:
The first one relates to public policy and describes a change in the management options and regulations. Local policy makers could for instance introduce new constraints on water treatment (see box on effects of sewerage management options in Barcelona beaches), encourage the development of organic agriculture or develop a new protected area.

Scenarios concerning effects of sewerage management options on the Barcelona beaches (SSA14):

There are various possible combinations of management options for examining how the sewerage characteristics impact on bacteria. The baseline and six additional scenarios combining five options for both “the percent of combined sewer overflow released directly” and “the capacity of storm water collectors” are investigated here to demonstrate the output limits of the model.

Scenario 1 (baseline):
- 50% combined sewer outflow (CSO) directly released with a storm water.
- Collector capacity of 0.52 GL. Note that 100% of CSO released directly is the same as zero storm water collector capacity.

Scenario 2 (no collectors):
- 100% of CSO released directly = 0 GL stormwater collector capacity.

Scenario 3 (actual collectors; 25% direct):
- 25% CSO directly released with a storm water.
- Collector capacity of 0.52 GL.

Scenario 4 (actual collectors; 0% direct):
- 0% CSO directly released with a storm water.
- Collector capacity of 0.52 GL.

Scenario 5 (planned collectors; 50% direct):
- 50% CSO directly released with a storm water.
- Collector capacity of 1.5 GL (planned).

Scenario 6 (planned collectors; 25% direct):
- 25% CSO directly released with a storm water.
- Collector capacity of 1.5 GL (planned).

Scenario 7 (planned collectors; 0% direct):
- 0% CSO directly released with a storm water.
- Collector capacity of 1.5 GL (planned).

The model indicates that at the current percent of direct release, tripling the capacity of storm water collectors will have no effect on suspended matter (figure 10). The key variable is the percent of CSO directly released, and this only has a significant effect on the lower concentrations of suspended matter.

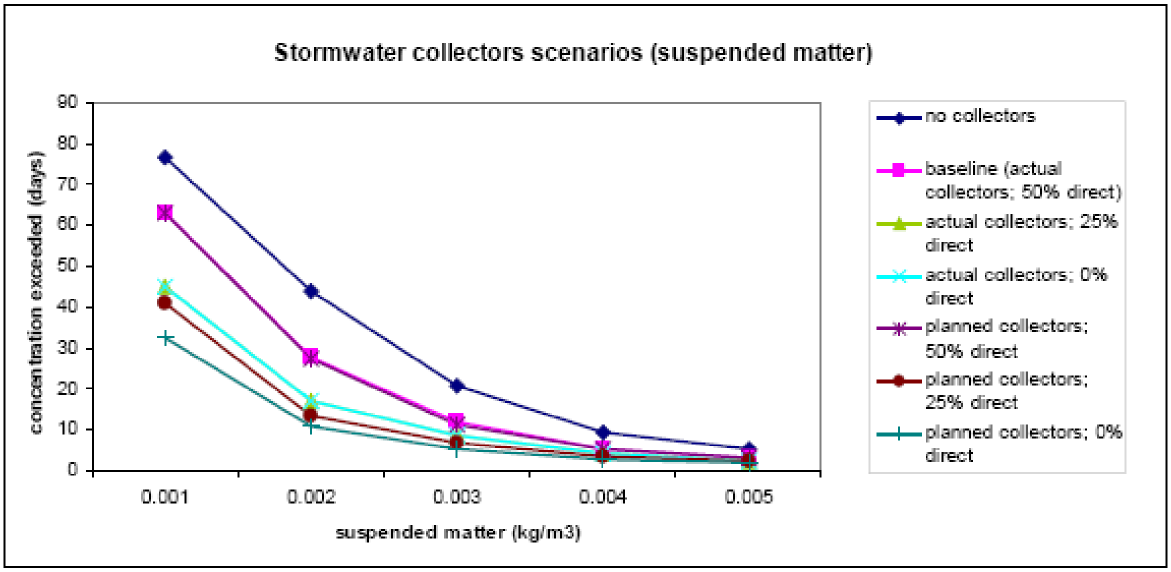

Figure 10. Storm water collector scenarios – impact on suspended matter.

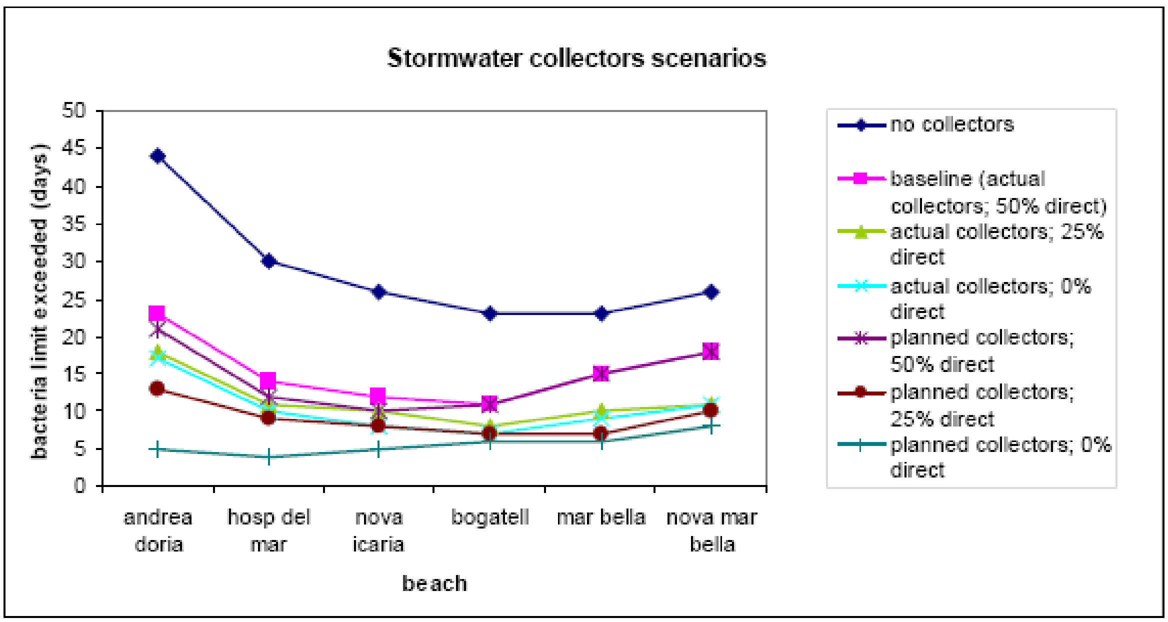

Figure 11. Storm water collector scenarios – impact on bacteria.

Conversely, both the percent of CSO directly released and the capacity of storm water collectors have a shared effect in reducing days in which bacteria limits are exceeded (figure 11). The difference between the baseline scenario and no collectors is also greater for bacteria than for suspended matter.

The second one relates to the occurrence of natural events: meteorological events or global change. For instance, the stakeholders might be concerned by a meteorological event such as a storm or tsunami occurring in the short term. The long-term change can also be a concern, climate change or sea-level rise for instance should be taken into account when there is a likelihood of change. Where the extent of the change is uncertain the scenarios should cover the range of realistic possibilities. To assess such long term or more global changes, specific types of scenarios can be used such as emissions scenarios. IPPC Special reports on emission scenarios for instance describe four socio economic scenarios families (based on assumptions about determinants such as population, economic growth, technological change, or environmental policies). The Millennium Ecosystem Assessment also developed a range of different scenarios to assess outcomes of global ecosystem services and their impact on human well-being.

The third one relates to interactions between nature and society. Stakeholders may for instance want to know the impact the increase of a specific type of HA may have on the system. For example, if the policy issue deals with eutrophication, the reduction of point and/or diffusive nutrient loadings or the increase/decrease of the leisure boating industry in the coastal zone might be studied. The impacts of these options for instance on the aquaculture sector or the tourism industry will be reflected in the chosen indicators (ecological, economic or social).

Most of the scenarios will be evaluated by comparison to baseline scenarios representing the future states of society and the environment in which policies either do not exist or do not have an influence on society or the environment. Multiple baselines can be developed to reflect different trends, some of which have a lower probability, and some a higher (e. g. different trends on nutrient inputs or greenhouse gas emissions). If the time horizon is long, multiple baselines will be more needed since uncertainty over environmental, social and economic systems increases with time.

The three types of scenario described above can further be classified in levels of increasing difficulty with respect to the modelling exercise (Formulation Step guidelines):

• The scenarios involving merely changing input values (any forcing functions, parameters, initial or boundary conditions of state variables) or testing the output sensitivity to change.

• The scenarios that require modifying an internal component – like inserting an alternative technology, making another type of economic or social analysis, or exploring another scale of policy options.

• The scenarios that require adding an internal component – like a different land use problem.

• The scenarios relating to changing to an unrelated Impact such that a different cause-effect chain or assessment would be required; or changing the economic method or social assessment.

Further changes of scenarios (whether at the storyline level or at the numerical estimates level) are possible during the Appraisal Step but should be lower than the first level of difficulty described above.

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5.2b.2 GENERATE NECESSARY INPUT DATA FOR SELECTED SCENARIOS

Once calibrated and validated, the model will be used to make simulations[1]. The results should meet the requirements of the stakeholders and provide an insight into the policy issue they wanted to focus on.

New **data** is often needed to run the model with the different scenarios such as ‘simulated inputs’ to take into account the projection into the future, boundary conditions or additional time series (Note that these data issues regarding the scenarios should have been tackled during the Formulation Step).

5.2b.3 PREPARE, CONDUCT, AND TEST SCENARIO VERSIONS OF SM

[1] This section mainly builds on HarmoniQuA’s Modelling Support Tool (MoST).

The main model structure often represents the baseline or business as usual scenario. This **structure** might have to be adjusted to match the other chosen scenarios (or the last changes made during the Appraisal Step, consecutive to the conclusions of the Interpretive Analyses). The model structure might need to be changed even when the scenario involves no apparent "structural" change to the system. For instance, extreme high flows may not have been included in the available calibration and validation data even if they are needed to run the chosen scenarios. Since high flows may bring different flow paths or processes, the model needs to be adjusted to consider this.

The adjustment of the structure implies additional testing of the revised model and re-assessment of its soundness. However, it is impossible to recalibrate or revalidate the adjusted model, because no data exist for the possible future situation characterised by the scenario.

5.2b.3 DOCUMENT RESULTS OF SCENARIOS

The Scenarios are the objective of the Simulation Model and represent the primary interface point between the research team and the policy decision-makers that requested information from the SAF exercise. Therefore, each SSA should document and explain the Use and Effectiveness of the Scenarios in the SAF, in particular, from the point of view of the Systems Simulation and of their use in focussing information for policy and end-users. Two main aspects should be addressed:

1. Science. If the scenarios were posed correctly, if they had to be modified and why, if were effective in capturing much information to be passed on to Policy, and if they could be considered scientifically as objectives for simulating change in complex systems (i.e. could they be improved or expanded, with examples, etc.).
2. Policy Interface. Was it possible to provide sufficient prognostic answers for the scenarios to meet the needs of the policy issue? How were the preliminary results of the scenarios received by the SSA's Participant Group (are they interested and do they understand what you are assessing)? Was there a lot other ancillary information that was needed to explain the scenarios?.

Note. Some of the part 2 will shared with the Output Step - mainly the parts concerning the reaction to the SSA products. In the AS, the focus should be SSA Team's the opinion and examples resulting from the AS. For example, "we weren't able to address several of the scenarios promised, because . . . , or "we found that we should have designed our model differently to capture some questions/scenarios that are now obvious but were not previously in the DS or FS".

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WT 5.3 OUTPUT PREPARATIONS

These WTs involve completing the scientific description of the Simulation Analysis (Model plus Interpretive) and addressing requirements of the Output Step.

WT 5.3a Complete the Interpretive Analyses

This WT completes and describes the scientific assessments of the results of the Simulation Model (both the mother Simulation Model and its scenario versions)..

WT 5.3a Complete Interpretive Analyses
1 Describe and Interpret the Hindcast and Scenario modeling results **2 Complete Collateral Analyses** **3 Draft the conclusions of the Simulation Analysis**
This is primarily a Scientific Product

ACTIVITY EXPLANATIONS

The major objective of the SAF is to provide a methodology for both diagnostic and prognostic assessments of complex systems. Because systems science is still a relatively young field, it is important that the presentation of SAF results is well described and documented in a credible manner. This emphasis is broadened with the SPICOSA objective of creating a more viable science-policy interface where 'scientific credibility must be translated in to non-scientific terms. Thus while the main effort of the SSAs is on learning and testing the SAF, they must transform this effort into solid, scientific interpretations.

The second portion of the Interpretive Analysis is completed in this work task. It includes the assessments of the ESE Models (WT5.1b), the evaluation of the Simulation Model and its scenario runs, and in addition, it includes the results of the Collateral Analyses, which have been conducted in support of the Simulation Model objectives.

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5.3a.1 DESCRIBE AND INTERPRET THE HINDCAST AND SCENARIO MODELING RESULTS

This task includes a series of explanatory activities, with versions addressed to scientists and to the general public. The production of manuscripts for scientific peer-reviewed and publication will be important, both to disseminate the results and to gather insight from the scientific community. However, it will be essential to produce also a descriptions and interpretations that will be understandable to non-scientists. These may include decision-makers and the wider stakeholder community.

A first step will be to explain how the scenarios were chosen. Why was a certain scenario chosen to be eventually presented to the stakeholders? Which were the reasons for it? What were the criteria for the selection? What where the alternatives? A description of a procedure for the selection process will need in front of the stakeholder audience in the output step. It must be noted that the chosen scenarios are only (each of them) one suggestion and that they may not be the best possible solution. The SSAs should document their choices – for example why they decided not to include a particular variable in the model, what would have been needed (more data, additional surveys,) to include it.. It will be important to clearly describe the assumptions, decision and added value that have led to a certain model representation and to the selected scenarios. The process needs to be explained in a transparent way in the Output Step when the scenarios are shown to the stakeholders. In this context, it will be necessary to think carefully about how many softwares should be recommended for overall SAF application: we are now dealing with CMaps, Extend, KerCoast, PCRaster and possible some interface for visualization in WP6. At some points we might include a statement that SAF Application is also possible with other softwares (a list could be provided).

A second step would be to explain what is being quantified in the model and what is shown by the results. As described in the Formulation Step, this implies a confrontation between the simulations of the model and the expectations derived from the mental models produced by people, in particular when the virtual model detects unexpected behaviours. Increased understanding and confidence in the model by policy makers and stakeholders can be obtained by exploring the system dynamics. For example, simplified versions of the model can be used to show highlight some aspects of the dynamics and to explain some counter-intuitive results obtained when the whole system is simulated.

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5.3a.2 COMPLETE COLLATERAL ANALYSES

The Collateral Analyses are the supplementary assessments and analysis that enrich the Simulation Model and its Scenario results. The suite of analyses accompanying to support the Simulation Model will vary from SSAs as did that for the individual ESE Component Models. In this subtask, we describe some categories and provide examples.

Error Analysis. Prognostic descriptions have a particularly strong requirement for credibility, particularly in regard with obtaining the confidence of the end-users, as Policy-Makers, Stakeholders, and public. Some of this effort falls in the Output Step, but the basic information on the actual or expected reliability must be done in the Appraisal Step. This requires an evaluation of error over the complete range of validity for the simulation model.

The evaluation of the range of validity is taken here as the evaluation of "application niche uncertainty", which refers, as explained in Pascual et al. (2003) to the set of conditions under which the use of a model is scientifically sound. This evaluation can be considered as a part of the sensitivity analysis. It can be carried out (STOWA/RIZA, 1999) by feeding the model with extreme values of inputs in order to find which conditions cause it to crash or to show undesirable behaviour. The Stella manual (Stella, 2001, p. 150) recommends:

(a) Challenging the extensive (breath of application) and intensive (level of aggregation) model boundaries.
(b) Examine boundary conditions in the model. Consider the outcome of adding stocks and associated flows to make explicit certain inputs or outputs.
(c) Look at interesting stocks (or variables) in the model. Consider whether they could be candidates for desegregation.
(d) Select parameters or functions in the model that were shown to be "sensitive" (changing them made the model's conclusions to change). Disaggregate them and see if they lose their "sensitiveness".

The evaluation of error centres on the total effects of uncertain factors on the model results, rather than on the relative sensitivity of factors (STOWA/RIZA, 1999). Different sources of uncertainty are described above.

The evaluation of uncertainty depends on the calibration method used. The uncertainty of a calibrated parameter vector can be represented by a variance-covariance matrix (STOWA/RIZA, 1999). This can be used to give an uncertainty or confidence interval in the model results. Another method is the min-max approach, in which a Monte-Carlo simulation is used to construct an uncertainty interval. The uncertainty can also reflect the existence of parameter ranges, rather that uncertainty in their determination. Often, statistical assumptions such as that of a lognormal distribution of error in a parameter value are needed. First order uncertainty analysis, based on a truncated Taylor series expansion, is useful when the coefficient of variation of each parameter is known. The fuzzy set approach allows the notion of graduation to express whether an element belongs to a set (see example in Freissinet et al., 1999). In some cases, as in the Millennium Ecosystem Assessment, determination of uncertainty may be carried out in a subjective way (see below). Practical advice for carrying out uncertainty analyses can be found, for example, in STOWA/RIZA (1999) and Odum and Odum (2000).

Example of uncertainty evaluation: Exploration of uncertainty in the Millennium Ecosystem Assessment

In the MA, the scenario analysis was adopted because the complexity of the systems studied and the associated uncertainties were too large to use alternative approach such as prediction (Carpenter el al., 2005). The scenarios used in the MA were selected to sample broadly the space of plausible futures and to provide answers to the focal questions that needed to be addressed, but the MA researchers recognized that it was not possible to distinguish between the probabilities of the different scenarios. However, the scenarios contained statements that could be intuitively judged as more or less likely. In order to communicate this level of certainty/uncertainty, they adopted the scheme used by the Intergovernmental Panel on Climate Change (Moss and Schneider, 2000), which associated to each statement a confidence level ranking form 1 (absolutely certain that the statement is true) to 0 (absolutely certain that the statement is false). The range 0 to 1 was divided according to the scale “Very certain” (0.975 to 1), “High certainty” (0.975-0.83), “Medium certainty” (0.93-0.67), “Low certainty” (0.67-0.525) and “Very uncertain” (0.525-0.5). In the MA, these levels of confidence were not estimated numerically; rather, they were based on subjective judgements of the scientists.

After validation and sensitivity analyses, the results of the simulation model need to be subjected to a number of additional checks. Some of them have been already pointed out in the Systems Formulation Chapter (D4.1):

- Simulations need to be compared with expectations, bearing in mind the different groups of stakeholders.
- Does the model point to the existence of previously unrecognized behavior?
- Can the model reproduce the behavior of other examples of systems in the same class as the model?
- Are the policy recommendations sensitive to plausible variations in parameters and changes in the structure to represent alternative formulations?

Pasqual et al. (2003) advise external peer-review as a mechanism for independent assessment of models, particularly when these models need to be used as a basis for regulatory or policy/guidance decision-making. Recommended mechanisms for accomplishing peer review include using ad hoc panels or holding a technical workshop.

According to Refsgaard and Henriksen (2004), the decision of when a model is good enough must be taken in a socio-economic context. Accuracy requirements may be different from case to case depending on the intended use of the model and on how much is at stake. The appropriate degree of evaluation cannot be defined only by modellers or scientists, but needs to consider the view of decision-makers.

Risk Analysis. In the Design Step, possible risks to the system represented (Virtual System) were defined. Some of these risks define the validity limits (above) of the Model in the sense of the model structure, e.g. the change in the resilience of the trophic web by the introduction of an alien species not included in the model. Other of these risks may have been included in the Scenarios, e.g. what would be the risk of habitat loss by urbanizing the shoreline, etc.

Example of a “disaster scenario” off Barcelona (SSA14) involving the wastewater treatment plant and the pumping station (figure 12, “100% release of untreated current output”). The baseline situation is compared to the possibility of the waste water treatment plant releasing effluent directly into the water near the beaches. Currently the treated effluent is pumped 3 km offshore and so has no impact on the beach water quality (“baseline”). Other scenarios investigate if the effluent is treated or not and at various increased outputs. It is clear that releasing the treated effluent away from the beaches has a significant effect. Increases in output of effluent also significantly negatively affect the water quality. Although, this disaster scenario is unlikely to occur, it helps to verify that the model behaves as expected.

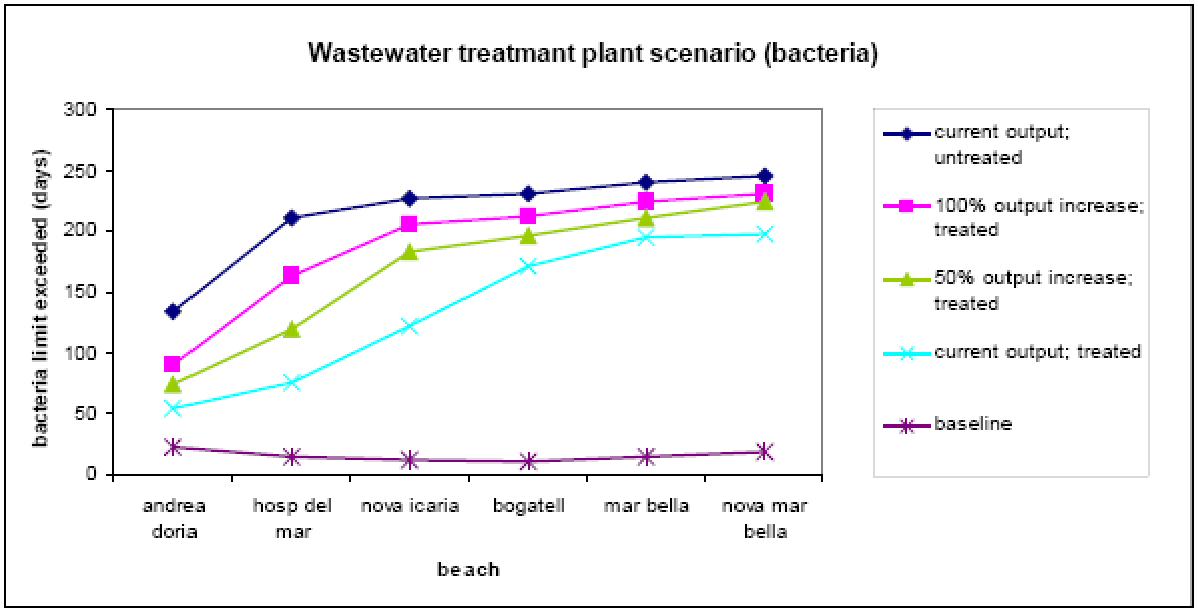

Figure 12. Wastewater treatment plant disaster scenario – impact on bacteria.

System Dependence. A sub-objective of SPICOSA is to provide a clearer definition about the degree to which the Simulation Model, the Impact, and Policy Issues, the Social and Economic responses can be considered system-independent (resulting from forcings external to the system and not affected by it) and which should be considered as system- dependent (included within the system). These assessments must be demonstrated in a sound scientific manner.

Sustainable Coastal Zone Management.. Again, an emphasis on the discussion of results must include some assessment and criteria concerning the relevance to Sustainability in all the ESE Components.

***ESE Interrelationships*.** The ESE assessments of WT5.1 will not have completed the discussion of the potentially important feedback loops between the ESE Components; and likewise, some of these will not be represented by the restricted linkages used in the Simulation Model. A discussion of these is essential in terms of the holistic aspect of the SAF, i.e. they exist but were not represented as not being fundamental to the immediate functionality representing by Simulation Model. The final end-user audience may not want to restrict their field of interest to that represented by the SM, and the end-user discussion needs not either. In other words, the fuller holistic functionality of the CZ must be recognized at least in a qualitative manner if not represented qualitatively.

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5.3a.3 **DRAFT THE CONCLUSIONS OF THE SIMULATION ANALYSES**

In this WT, the major scientific conclusions are defined and explained at a preliminary level for their use in the Output Step. These conclusions will be integrated into the material for the Science-Policy Interface (WT5.3b) so that the combined results can be finalized for both the Scientific Article and the Science Policy Report.

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WT 5.3b Generate Scientific Products

This WT completes the synthesis of the Appraisal and produces special products for the Output Step. The WT works much more closely with its Participant Group.

WT 5.3b Generate Scientific Products
1 Construct interactive versions of the Simulation Model for End-users **2 Insure compatibility with Deliberation Support Tool requirements** **3 Discuss with Output Step the particular needs for End-user versions of the Interpretive Analyses** **4 Maintain contact with Participant Group**
This contributes to Documentation and Scientific Products

ACTIVITY EXPLANATIONS

This WT essentially completes the scientific appraisal of the SAF implementation. However, these scientific products are utilized in the Output Step to create the special less-scientific products of various formats. Consequently, this WT provides the products and scientific text needed both for the SSA scientific article and for the Output Step. All of these subtasks require continued contact with the Participant Group and the Output Step.

5.3b.1 CONSTRUCT INTERACTIVE VERSIONS OF THE SIMULATION MODEL FOR END-USERS

The ultimate SAF goal is to include in the information package for End-users interactive versions of the Scenario Runs. This might be read only models in which the operator can change inputs or switch internal options that would be informative for decision-making or management planning. Depending on the model level produced, there would need to be some simplifications and embellishments on the model and its output options. These modifications would depend on the level expertise (Extend) of the end-user. They may require reducing the number of blocks, so that End-users can avail themselves of the economic Extend licenses. The needs for constructing these interactive models should be anticipated in the Appraisal Step, i.e. a demonstration model that can be shown to the Participant Group. With the help of WP8 WP6 and WP11, tools and examples will be provided for improving the transparency of the ESE models and making them easier to use. WP8 developed and sent around a large number of blocks to do this, such as an animated Cost-benefit block and dialog blocks, together with Extend example models demonstrating the use of these blocks.

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5.3b.2 INSURE COMPATIBILITY WITH DELIBERATION SUPPORT TOOL REQUIREMENTS

The policy options and decision making for ICZM can be considered as a dynamic an iterative process since stakeholders' views and positioning relative to each other will evolve over time. WP1 is developing tools to insure that the dialogue and link between Science and Policy is maintained throughout the process of scientific assessment.

This dialogue began with the policy issue and stakeholder mapping. In a second phase, the evaluation of the final scenarios by the stakeholders and policy makers will be made based on the output of the scientific assessments.

The evaluation approach proposed by WP1 presents the 'social choice' problem as a multi-stakeholder deliberation about the merits and demerits of policy alternatives that exist in society. The structuring of the multi-stakeholder dialogue and deliberative process is discussed in detail in WTs 7-12 of the SAF Protocol Chapter on CZ System Output. The stakeholder involvement process may be facilitated by means of the SPICOSA KerDST (Deliberation Support Tool). An overview of the procedures in case ker-DST cannot be used is presented in WT10 of the SAF Protocol Chapter on CZ System Output.

The core of the Deliberation Support Tool is the "Deliberation Matrix" (henceforth DM for short), offering a multi-stakeholder multi-criteria deliberation framework.

The specification of three categories of information will be needed to present the social choice problem in the frame of the three dimensions of the DM (see Fig. 13) and proceed to the evaluation:

-The **scenarios**, representing the available choices that were selected during the consultation process and that are scientifically assessed in the model (along the Z-axis of the DM);

-The **stakeholders**, listing the clusters of the full spectrum of stakeholders engaged in the deliberation process and identified during the stakeholder-mapping exercise (along the Y-axis of the DM); and

-The **issues**, representing the different dimensions of the so-called policy issue (or key issue) that the stakeholders identified during the stakeholder-mapping exercise (along the X-axis). Note that the chosen issues should represent all the three components of the model (Environmental, Economic and Social) to avoid the over-representation of one of its specific components.

The crossing of these three dimensions leads to the three-dimensional matrix or cube represented below (see Fig. 13). The DM permits a presentation of the processes and results of valuation of each category of stakeholders, for each variety of scenarios, across the spectrum of issues determining the policy issue at stake.

The indicators that will be used to evaluate the different dimension of the policy issue have been agreed on with the participant group. In order to allow comparison of the different scenarios, these indicators (up to five) should be common to all the stakeholders evaluating the same issue throughout all the scenarios. Furthermore, these indicators will be part of the output of the modelling process and adding them to the stakeholder judgments will help to marry Science with Policy perspectives. In practice, the indicators will be grouped in a SPICOSA KerBabel Indicator Kiosk (KIK) and access to the KIK will be provided through the on-line interfaces of the DM.

When the DM structure is in place, the evaluation activity proceeds step-wise (individually or collectively within a group): the actors focus on each cell of the DM and offer a judgement (i.e. satisfactory, unsatisfactory, neutral, using a colour code) of each scenario in relation to each of the dimensions of the policy issue. The indicators (through the KIK) will provide the basis for cell-by-cell judgements during the deliberation process, each stakeholder being allowed to give a relative weighting (‘power’) to each of the indicators (registered on a scale of importance).

Please refer to WP1 deliverables, users’ guides and training sessions for more information regarding the Deliberation Support Tool.

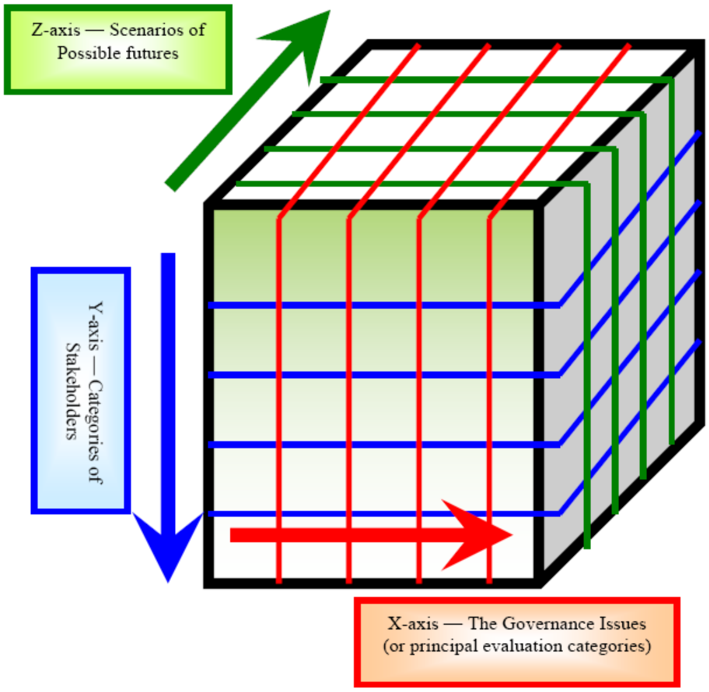

Figure 13. Representation of the Deliberation Matrix.

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5.3b.3 DISCUSS THE CONTENT AND FORMAT NEEDED FOR END-USER VERSIONS OF THE INTERPRETIVE ANALYSES

This activity is inserted to insure that appraisal-dependent material is made available to the Output Step. While this may seem obvious, it can easily be neglected. The consequence of not anticipating the extra material needed for the Simulation and Analyses can cause delays. Thus, the persons responsible for the Science-Policy Interface should be included in the discussions concerning information output and format.

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5.3b.4 MAINTAIN CONTACT WITH PARTICIPANT GROUP

Similarly, this activity is an essential part of the final stages of the SAF. In this case, however, a product will be produced concerning the Science-Policy Interface. Some formalization of the sharing of the final adjustments to Scenarios is considered essential (along with the interactive models) to avoiding the impression of science simply delivering a product instead of the product being a joint effort. During the final meeting with the participant group, it may be worth reflecting on the advantages and disadvantages of the exercise. A trained facilitator could help. Feedback from other SSAs may also be of use. It might also be worth suggesting that the participant group selects a “champion” to continue with this work, now that good relationships and understandings have been developed- perhaps to apply for future funding grants.

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APPRAISAL CHAPTER REFERENCES

Allen, J. I., Somerfield, P. J., Gilbert, F. J.- 2007. Quantifying uncertainty in high-resolution coupled hydrodynamic-ecosystem models. J. Mar. Syst., 64:3-14.

Benincà, E., Huisman, J., Heerkloss, Jöhnk, K. D., Branco, P., Van Nes, E. H., Scheffer, M., Ellner, S. P.- 2008. Chaos in a long-term experiment with a plankton community. Nature, 451: 822-825.

Carpenter, S. R., Pingali, P. L., Bennett, E. M., Zureck, M. B. (Eds.).- 2005. Ecosystems and Human Well-being: Scenarios, Millennium Ecosystem Assessment Series, Vol. 2. World Resources Institute, Island Press, Washington, DC.

Engelen, G., Uljee, I., van de Ven, K.- 2003. WADBOS: Integrating knowledge to support policy-making in the Dutch Wadden sea. In: Geertman, S., Stillwell, J. (Eds.), Planning Support Systems in practice, Advances in Spatial Science, Springer-Verlag, pp. 513-537.

European Environment Agency.- 2001. Scenarios as tools for international environmental assessments. Environmental issue report n.24, Copenhagen, Denmark.

Freissinet C., Vauclin, M., de Bruyn, B.- 2001. Utilisation couplée des techniques d'analyse spatiale et de l'arithmétique floue pour évaluer la vulnérabilité d'un bassin versant (Combined use of spatial analysis techniques and fuzzy arithmetic to evaluate catchment area vulnerability). In "Geographical information and regional planning", volume on "Spatial risk management", pp. 47-61, Edition Hermés, ISBN 2-7462-0319-7.

Freissinet, C., Vauclin, M., Erlich, M.- 1999. Comparison of first-order analysis and fuzzy set approach for the evaluation of imprecision in a pesticide groundwater poluution screening model. Journal of Contaminant Hydrology, 37: 21-43.

Goh, B. S.- 1977. Global stability in many-species systems. The American Naturalist, 111: 135-143.

HarmoniQuA Consortium, HarmoniQuA's Modelling Support Tool (MoST), version 3.1.5.

Huisman, J., Weissing, F. J.- 1999. Biodiversity of plankton by species oscillations and chaos. Nature, 402: 407-410.

Intergovernmental Panel on Climate Change, Nebojsa Nakicenovic and Rob Swart (Eds.).- 2000. IPCC Special Report on Emissions Scenarios, Cambridge University Press, UK.

Lima, I. D., Olson, D. B., Doney, S. C.- 2002. Intrinsic dynamics and stability properties of size-structured pelagic ecosystem models. J. Plankton Res., 24: 533-536.

Melaku Canu D., Solidoro C., Cossarini G., Giorgi F. (Submitted). Effects of Global changes on clam aquaculture in Venice Lagoon Climate research (under revision in Climate Research).

Millennium Ecosystem Assessment.- 2005. Ecosystems and Human Well-being: Scenarios, Millennium Ecosystem Assessment Series, vol. 2. World Resources Institute, Island Press, Washington, DC.

Morecroft, J.- 2007. Strategic Modelling and Business Dynamics. John Wiley and Sons, 430 pp.

Moss, R. H., Schneider, S. H.- 2000. Uncertainties in IPCC TAR. Recommendation to Lead Authors for more consistent Assessment and Reporting. In: Pachuari, R., Taniguchi, T., Tanaka, K. (Eds.). Guidance papers on the cross-cutting issues of the Third Assessment Report of IPCC. Geneva, Switzerland, World Meteorological Organization, 33-51.

Odum, H. T., Odum, E. C.-2000. Modelling for all Scales. An Introduction to System Simulation. Academic Press, San Diego, California, 458 pp.

Pascual P., Stiber N., Sunderland E. – 2003. The Council for Regulatory Environmental Modelling Draft Guidance on the Development, Evaluation and Application of Regulatory environmental models. Office of Science Policy, Washington, D. C. www.epa.gov/crem/library/CREMguidancedraft12_03.pdf.

Refsgaard, J. C., Henriksen, H. J.- 2004. Modelling guidelines- terminology and guiding principles. Advances in Water Resources, 27: 71-82.

Rosen, R.- 1970. Dynamical System Theory in Biology. Vol I. Stability Theory and its Applications. Wiley-Interscience, New York, London, etc., 302 pp.

Solidoro C., Cossarini, G., Libralato, S., Salon, S.- 2010. Remarks on the redefinition of system boundaries and model parameterization for downscaling experiments. Progress in Oceanography, 84: 134–137

Stella.- 2001. Introduction to Systems Thinking. High Performance Systems Inc.

Sterman, J. D.- 2002. All models are wrong : reflections on becoming a systems scientist. System Dynamics Review, 18: 501-531.

STOWA/RIZA.- 1999. Smooth modelling in Water management, Good Modelling Practice Handbook; STOWA report 99-05, Dutch Dept. Of Public Works, Institute for Inland Water Management and Waste Water treatment report 99.036, ISBN 90-5773-056-1.

Wang, S., Nijkamp, P., Verhoef, E.- 2001. Modelling externalities between ecological and economic systems. Tinbergen Institute Discussion Paper. TI 2001-098/3