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Some guidance on how to use participatory modelling in fisheries governance: A synopsis of the literature reviews

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Abstract

Guidance on how to use partcipatory modelling in fisheries governance:

- Be upfront and precise about purpose, timing, type and level of involvement
- Define what is sought to be achieved
    - Collective learning for consensus-building and / or conflict reduction
    - Knowledge incorporation and quality control for better management decisions
    - Higher levels of legitimacy of and compliance with management decisions
    - Advancing scientific understanding of potential and implementation requirements of participatory modeling
- Define when to involve stakeholders and their particular contribution sought
    - Direct involvement: Providing input to model construction
    - Indirect involvement I: Providing input to framing the modeling endeavour
    - Indirect involvement II: Providing input to evaluating modeling steps
    - Indirect involvement I: Providing input to using the model
- Account for model complexity as a limiting factor for transparency and stakeholder motivation
- Provide for information and communication tools and stakeholder capacity-building (if required)
- Consider the need for independent verification
- Be aware of the challenge of integrating different forms of knowledge
- Provide sufficient room for deliberation in the participatory modeling process
- Select carefully the professionals that might be needed in the participatory modeling endeavor

Participatory modeling in natural resource governance: An emerging approach in Europe

The value of integrating science and public participation has been acknowledged for a range of management areas (Dietz & Stern 2008, p. 148). These include common-pool resource management (Dietz, Ostrom & Stern 2003), ecosystem and natural resource management (Dietz & Stern 1998), impact assessment (Dietz 1987, 1988; for an overview see van Asselt & Rijkens-Klomp 2002) and risk management (Stern & Fineberg 1996; Jaeger et al. 2001; Rosa, Renn, & McCright 2007). In this body of literature it is argued that both the scientific community and the public (stakeholders as well as the directly affected and the general public) have substantial expertise, however "of different kinds and on different matters" (Dietz & Stern 2008, p. 148).

The question of how non-scientists can be reasonably involved in the use as well as in the *production* of scientific knowledge and advice is receiving more and more attention. 'Participatory modelling' is one attempt to respond to this question. Increasingly, the marriage of modeling – as a way in which scientific analysis enters the process of decision-support – and participation is considered and discussed as an innovative mode of knowledge production and use in different areas of natural resource governance including fisheries.

Increasing attention to the potential that this liaison may hold for effective and legitimate governance needs to be seen against the background of a growing importance of models as tools in science informing policies on the management of natural resources. In fisheries and other areas of natural resource management the trend in the past one and a half decades has been to base management decisions to a greater extent on modelling. Further, there is the aim to develop more complex and sophisticated models for more integrated problem assessments and a broader knowledge basis for decision-making. In short, models do not simply serve theoretical or heuristic purposes but are intended as decision support tools and increasingly gain in importance in this function.

However, policymaking and decision-making solely or mainly based on modeling results are often fiercely debated and contested. Main reasons for this are the intrinsic, widely-acknowledged limitations of models – they do not represent reality but present abstractions and simplifications of reality and are built on assumptions of varying strength – and related to this their possible misuse or misinterpretation (cp. IRGC 2009, p. 30). Computer-based modelling has long been the central analytical method used for producing the scientific advice informing the European Common Fisheries Policy. On the side of many stakeholders, however, there has been considerable scepticism towards the validity of the models used, specifically of individual fish stock assessments based on Virtual Population Analysis models (Degnbol et al. 2007, p. 6). Between fisheries scientists and industry in particular strong tensions have grown around questions of credibility and legitimacy of scientific advice based on the use of such models (Hawkins 2007).

This critical governance climate has triggered efforts to research into ways to open up to stakeholders what has traditionally been the exclusive domain of 'expert' modellers (i.e. people with training and experience in the analysis and formal representation of systems) and considered a scientific-technical input into the policy and management process. Results of focus group research have confirmed the value of these efforts by showing that stakeholders in the fisheries field view increased accessibility of the modelling process as a way to improve credibility and legitimacy of model-based advice among stakeholders and the wider public (Degnbol et al. 2007, p. 6). The emerging research endeavour is also a response to growing calls by governance scholars and resource users to complement the enhanced inclusiveness of the management processes through the establishment of the stakeholder-led Regional Advisory Councils (RACs) with greater inclusiveness of the science processes advising management and policy (Rice 2005, p. 254; Hawkins 2007; Linke et al. 2011).

So far, participatory modelling is a relatively new approach in European natural resource governance with only few exercises that have been carried out. It is foremost an object of research, not an approved method. The objective of the deliverable at hand is to provide some general guidance on putting stakeholder-supported modeling into practice in fisheries governance and other areas of natural resource governance. It seeks to do so by pointing out a set of procedural and practical issues which require particular consideration when designing and performing modeling with stakeholder involvement. The account presents a synopsis of the main insights gained from the literature reviews[1] and the international expert workshop[2] which were carried out as part of work package 2 ("Review") of the JAKFISH project.

[1] Deliverable 2.3: Dreyer, M., Renn, O., Drakeford, B. & Borodzicz, E. (2009). Review of literature about participatory modeling in fisheries management with a focus on the Invest in Fish South West project and the PRONE project. Stuttgart: DIALOGIK.

Deliverable 2.4: Drakeford, B., Borodzicz, E., Dreyer, M. & Renn, O. (2009). Review of literature about participatory modeling in natural resource governance: Findings from forestry management (Part 1) and water resources / river basin management (Part 2). Stuttgart: DIALOGIK.

Be upfront and precise about purpose, timing, type and level of involvement

One basic principle of design of participatory processes is *clarity of purpose* of the participation procedure for all those involved in the participation process (Dietz & Stern 2008, p. 228). This basic principle applies to participatory modeling exercises as well. It is essential to design such an exercise with a clear purpose in mind (of both modeling and participation) and to make serious efforts to share this understanding with all participants. Some specific processes and tools of participation will be better suited than others to achieve particular purposes. Shared understanding of objective(s) and rationale(s) reduces the risk of tensions and conflicts grounded in different (or even divergent) expectations that a variety of affected and interested parties may otherwise link with the participatory modeling process.

Careful consideration and proper specification of purpose and aligned process design is vital given the variety of forms that participatory modeling may take. There is a wide range of approaches labeled as participatory modeling in recent research contributions. These differ notably in relation to timing and level of involvement of stakeholders in the modeling process. They might use a variety of both qualitative and quantitative modeling methods including mental modeling, simulation models and spatial mapping (Voinov & Bousquet 2010).

A commonly agreed definition of 'participatory modeling' does not exist. In a more 'narrow' understanding the term is used specifically to refer to the active involvement of model users or a broader diversity of stakeholders in the modelling process *itself*, i.e. in model *construction* (cp. van den Belt et al. 1998, van den Belt 2004). In a broader perspective which views the overall modelling process as composed of model construction and model *use* (Bots & van Daalen 2008; Hare 2009) participatory modelling may also refer to the *indirect* involvement of stakeholders in the modelling process through, for instance, providing input for model use in form of scenarios or policy/management options (co-)developed by the stakeholders. Overall, participatory modeling appears as a flexible method with several modeling and participation options available to design the exercise.

The following sections shall provide assistance to practical implementation of the concept by setting out different *purposes* that a participatory modelling exercise might envisage;

[2] Deliverable 2.5: Dreyer, M. & Renn, O. (2009). Summary report of the international expert workshop on "Participatory modeling in natural resource governance: promises, pitfalls, improvement opportunities". Stuttgart: DIALOGIK.

specifying different *phases* of a modelling endeavour at which stakeholders could be involved; and pointing out how the timing of participation is linked to the *degree* to which stakeholders can influence model-based knowledge output.

Define what is sought to be achieved

In the context of natural resource governance participatory modelling may serve one or more of the following purposes.

Collective learning for consensus-building and / or conflict reduction

Participatory modeling may serve the purpose of collective learning and reflection among a group of different stakeholders. First, there are models developed by professional model builders to satisfy this purpose. Agent-based models belong to this model approach. They shall provide individuals - in particular in their role as (stakeholder) group representatives - with the opportunity to learn about and experiment with the way in which a system may work and the way in which their actions may interact with actions of other individuals or groups to produce system outcomes (cp. Letcher & Bromley 2006, p. 290).

There is, second, the approach to use the process of model *construction* to built capacity among those with a stake in the resource management issue. A widely noticed concept representing this approach is ‘mediated modelling’. Mediated modelling denotes a process whereby stakeholders jointly develop a simulation model about a specific problem drawing on the principles of system dynamics. Usually, this collaboration takes place in a series of modelling workshops with support by a facilitator who makes use of system dynamics software to conduct the model building process during the workshops (van den Belt et al. 1998; van den Belt 2004; Videira et al. 2004; Antunes et al. 2006).

The body of literature about mediated modelling characterises this tool as a particularly useful method for scoping out a complex problem (by identification of system ontology, problems, causes, consequences and solutions) and consensus building among diverse interests. Models at the scoping level shall help to understand dynamic behaviour patterns, rather than attempt to make precise predictions (van den Belt 2004; Sandker et al. 2008; Kallis et al. 2006, p. 220). They are models of high generality usually with many values and relationships that are “’estimates’, ’guesstimates’ or assumptions to further the discussion in terms of ‘what if’ -

scenarios" (Antunes et al. 2006, p. 49). These scoping models may be further developed into more detailed and complex research or management models.

A central argumentation is that models built in a system dynamics perspective help to develop a holistic view of the respective problem. This holistic view may facilitate creation of a shared vision of the problem which may in turn foster mutual understanding between science, management professionals and stakeholders (van den Belt 2004; van Asselt & Rijkens-Klomp 2002). The idea underlying this approach corresponds with Sterman's assertion (1994, p. 320) that "To learn […] participants must become modelers, not merely players in a simulation" (quoted in Rouwette et al. 2002, p. 32).

Collective learning does, however, not need to be aimed at consensus-building. It may also be targeted at understanding of dissent. Participatory modelling may consist in a conceptual modelling exercise in which the different perspectives of stakeholders are elicited and presented graphically in individual cognitive maps (so-called 'mental models'). The multiplicity of models showing the plurality of views might help to unfold the basis of controversy and conflict and foster among the stakeholders mutual understanding and possibly also acknowledgement of the hypotheses underlying the individual perspectives (cp. Hare et al. 2006). In this sense, qualitative modelling has particular potential in dealing with conflicting stakeholder perspectives. It can make visible areas of consent and dissent and demonstrate the legitimacy of dissenting views.

Knowledge incorporation and quality control for better management decisions

Another purpose that participatory modeling may serve is improving the quality of policy and management decisions through inclusion of stakeholder knowledge into model construction and/or use. Models aimed at assistance in management and decision-making are increasingly computer- and simulation-based and allow exploring alternative scenarios or policy options. There are various ways in which stakeholders can contribute their knowledge to the overall modelling process. These include (cp. Wilson & Pascoe 2006, p. 350):

- provision of data;
- assistance in designing the structure of the model(s) (e.g. by pointing to environmental or human-dominated processes that have been neglected in the model structure; Voinov & Bousquet 2010, p. 1276);

- review of choices, assumptions and priorities underlying the model construction;
- developing scenarios (e.g. in terms of a plausible description of a management plan or control option);
- selecting indicators as tools to compare the impacts of the alternative scenarios;
- evaluating the management options in the light of their performance in the different simulated scenarios.

One main assumption underlying this approach to participatory modelling is that “those who live and work in a system may be better informed about its processes and may have observed phenomena that would not be captured by scientists” (Voinov & Bousquet 2010, 1274).

Higher levels of legitimacy of and compliance with management decisions

Incorporation of stakeholder knowledge into the models used in natural resource governance is widely understood as a basic prerequisite for strengthening the credibility of the advice informing policy and management and enhancing the legitimacy of policy and management decisions. This, in turn, the assumption in the fisheries field goes, can improve the quality of the information base for knowledge production, e.g. by reduction of the high level of misreporting in the mixed fisheries throughout Europe (cp. Moto & Wilson 2006, p. 425; see also Wilson & Pascoe 2006).

Participatory modelling with the primary purpose of generating higher levels of legitimacy and compliance will need moreover to create high levels of transparency of all steps in the building and use of the models applied, not only of those in which stakeholders are actively involved. In fisheries, this approach to participatory modelling has been prominently discussed given the often cited ‘black box’ problem. This denotes the opaqueness of the knowledge base and the ways in which it has been presented to industry and other stakeholders. The main idea underlying this approach is that greater access to the modelling process – allowing stakeholders, for instance, to judge the validity of the model themselves and engage in the debate about their usefulness and continued development - could reduce perceptions of a biased advice generation process and result and hence lead to higher legitimacy of both assessment and management outcome and eventually, increasing compliance with management rules.

Advancing scientific understanding of potential and implementation requirements of participatory modeling

As mentioned above, only few exercises of participatory modelling have been carried out in natural resources management up to now, and these have been used and are being used predominantly as a method in applied research into participatory management. In these cases the primary purpose is to learn about the potential and implementation possibilities and requirements of the innovative participatory method. If the research exercise is about involving stakeholders in a modelling process aimed at decision-support, there needs to be clarity among researchers and participants about whether the research project has links with actual decision-making and what this implies for practical usage of the modelling results. Anyway, there needs to be clarity that "investigative decision-making" (Hare 2009) is different from 'real' decision-making (Hare et al. 2006, p. 219). Lack of clarity about the fact that a research project lacks links with actual decision-making (or has only weak links) may lead to processes by the end of which "participants have lost trust, feel exploited or become disappointed" (Hare et al. 2006, p. 218; see also Hare et al. 2003).

Define when to involve stakeholders and their particular contribution sought

When the purpose of the participatory modeling exercise has been specified, the appropriate stage(s) in the modeling process at which the stakeholders can provide the desired input need to be identified (cp. Bots & van Daalen 2008; Gottschick 2005). The table below summarizes the basic modeling stages and their subcomponents to which stakeholders can make a contribution. The table may facilitate the task of planning a particular participatory modeling exercise by creating awareness of the various options available and providing a tool to communicate about these options and selections to be made with the participating stakeholders. In what follows these different options are briefly described.

Indirect Involvement	Direct Involvement	Indirect Involvement	
Framing the modelling endeavour	**Model construction**	**Model evaluation**	**Model use**

<table>
<tr><td rowspan="3">Contribute to problem identification and specification of goals and terms of reference for further analysis</td><td>Provide input (data, conceptual considerations) for model construction</td><td rowspan="3">Review choices, assumptions and priorities underlying model construction ('extended peer review)'
either only after the model has been built, or
at each sub-step of the model-building process</td><td>Provide input for model use (scenarios and/or policies) and selection of evaluation indicators</td></tr>
<tr><td rowspan="2">Make decisions on model design</td><td>Interpret outputs from simulation runs</td></tr>
<tr><td>Co-decide on policy/ management measures</td></tr>
</table>

Table 1: Options for stakeholder involvement in modelling
(drawing on and extending the distinctions proposed by Bots & van Daalen 2008)

Direct involvement: Providing input to model ***construction***

As mentioned above, the term participatory modeling refers in 'narrower' perspective to the involvement of model-users or a broader diversity of stakeholders in the *building* of the model. Within model construction it is possible that participants provide information (relevant data or knowledge, e.g. through interviews) for the modeller to build the model. They may also actually model themselves, i.e. make decisions (or co-decide together with expert modellers) on the design of the model (cp. van Asselt & Rijkens-Klomp 2002, p. 172; Bots & van Daalen 2008, p. 397).

Stakeholders may act as (co-)designers and/or information providers for the formulation of *conceptual (qualitative) models* (by identifying respectively informing the identification of the main variables characterizing a dynamic problem and the causal links established between them applying, e.g., causal-loop diagramming) or *formal models* (by estimating respectively informing the estimation of parameters, initial conditions and behaviour relationships that need to be specified precisely in computer models based on quantitative system dynamics and simulation (Vennix et al. 1994; Ford & Sterman 1998).

They may also be involved in the formulation of both types of models, if the qualitative models are developed to serve as an early stage in the construction of the quantitative models. In these cases, system component structures (e.g. stock and flow diagrams) are developed from conceptual models and then functional forms are specified and parameters and behavioural relationships numerically estimated.

To involve stakeholders as model designers does not mean necessarily to give every model decision over to them or include them at the earliest stage of model construction. In the case of modelling of biocomplexity in the Tisza River Basin (TRB), for instance, causal loop diagramming was applied by expert modellers and other researchers in advance of collaboration with stakeholders (Sendzimir et al. 2007a; Sendzimir et al. 2007b). The purpose of this "preliminary modeling" (Sendzimir et al. 2007a, p. 608; cp. Vennix 1996) was to prepare for facilitating discussion during group modelling exercises for actors and stakeholders in the TRB. The plan is to improve the causal loop diagram in such a participatory process and to use the refined conceptual model to build formal models for exploring the relative strengths with which different interactions affect system dynamics (Sendzimir et al. 2007a).

Indirect involvement I: Providing input to ***framing*** *the modeling endeavour*

In a broader perspective, the linkage of modelling with participation refers also to the indirect involvement of stakeholders in the modelling process. One way of indirect involvement is inclusion in the first phase of a modeling process which can be referred to as the "framing" stage. At this stage, stakeholders can contribute to identifying the resource problem and the goals and scope of the modeling endeavor. They may also contribute to specifying the terms of reference for the detailed modeling including for instance the definition of the boundaries of the system to be modeled, the choice of the level of detail that will be used in its description or the way in which uncertainties shall be addressed and accounted for (Voinov & Bousquet 2010, p. 1274-5; Castelletti et al. 2007, p. 1080).

Indirect involvement II: Providing input to ***evaluating*** *modeling steps*

Another way of indirect involvement is sharing in ***model evaluation***. Here, stakeholders can be asked to review the model's design in a process which would correspond to what has been called an extended peer review (for instance, by using pedigree matrices, cp. JAKFISH Deliverable 3.2), denoting a process whereby the quality of the knowledge inputs to policy issues are assessed (Functowicz & Ravetz 1990; van der Sluijs 2002). The demand that stakeholders should be able to understand and review the various model assumptions and their implications for the modelling results has been described as an important trend in natural resource management (Refsgaard et al. 2005, pp. 1201-1202). One main reason stated for the reasonableness of involving stakeholders in model evaluation – also stated for involving them in model construction already – is that models are not (fully) based on factual objective scientific knowledge but are laden with (more or less implicit) judgments and choices and thus depend on assumptions and priorities of those doing the modelling. Therefore, models should not be treated as merely technical inputs to the management and policy process. Instead, modelling should be understood as a social as well as a technical process (cp. for instance, Smith Korfmacher 2001; van der Sluijs et al. 2005).

Stakeholders might also be continuously involved in review dialogue processes throughout the modelling process. The concept by Refsgaard et al. (2007) designed for water resources management envisages at each step of the main modelling process assessment of the quality of results through internal and external reviews "that also provide platforms for dialogues between water manager, modeller, reviewer and, often, stakeholders/public" (Ibid., p. 1545). Whether stakeholders would directly contribute to the review or only act as observers, for instance, is considered as dependent on the level of public participation in a specific case (Ibid.).

Indirect involvement I: Providing input to ***using*** *the model*

Another way of indirect involvement is inviting stakeholders to provide inputs for ***model use*** in form of scenarios or policy/management options (co-)developed by the stakeholders themselves, or in form of knowledge to test the causal logic of these inputs. In the IRMA-SPONGE project dealing with the development of flood management strategies for the Rhine and Meuse basins, experiential and contextual knowledge of stakeholders was used to test the causal logic of scenarios which were developed top-down by the researchers. This was done "both ex-ante through storylines developed by stakeholders as well as ex-post through stakeholder evaluation of the scenarios" (van Asselt et al. 2001, p. 176).

Within model use, stakeholders may also be asked to actually *run* model simulations and jointly explore, discuss and interpret the outputs that result from the alternative scenarios or policy options which can be tested in isolation of as packages generated by stakeholders (Brown Gaddis et al. 2007, p. 621; Bots & van Daalen 2008, p. 397). They could also share in the selection of indicators as tools to compare the impacts of the alternative scenarios or policy options. In the case of applying a participatory modelling approach to two villages in a watershed in northern Thailand, for instance, stakeholders were not involved in model construction but directly confronted with the model by assessing its assumptions (i.e. they got involved at the stage of model evaluation) and by suggesting scenarios and interpreting simulation results (Becu et al. 2008).

Finally, stakeholders could be involved in decision-making on management or policy measures being informed by the results and interpretations of the model run.

If the primary or one of the main purposes of participatory modelling is collective learning about the nature of a complex resource problem, it is essential that stakeholders are involved in some way in the model construction process. If the primary or one of the main purposes of participatory modelling is assistance to policy or management decision-making it is vital that stakeholders are involved *at least* at the model use stage. If the primary or one of the main purposes is knowledge incorporation for improved decision-making or higher levels of legitimacy and compliance stakeholders would ideally be involved in as many stages of the modelling process as possible, at least however, at the model evaluation and model use stages. In case of research projects the choice of types and level of involvement depends on which of the possible purposes of participatory modelling the particular project seeks to research into.

Account for model complexity as a limiting factor for transparency and stakeholder motivation

In fisheries in particular, participatory modelling techniques have increasingly been discussed as one possible way forward in developing *transparent* procedures for generating and using knowledge. The opaqueness of the knowledge base within the EU fisheries management system to industry and other stakeholders, and the black box that the generation of this base means to these actors have been identified as one of the main reasons for the failure of the European Communities Common Fisheries Policy to provide either biological or economic sustainability (cp. Moto & Wilson 2006).

However, the intended creation of transparency is developing into an ever challenging task due to the trend within fisheries science to develop and use increasingly large and *complex* computer-based models (this trend is observable also in other areas of natural resource management; cp. Refsgaard et al. 2005, 1201). These highly complex models are not the product of overambitious computer freaks. They are mainly a response to demands from policy and stakeholders to carry out more integrated assessments and to better account for uncertainty. Stakeholders without a scientific-technical background may find assessment outcomes and the underlying models cryptic. Even if they contribute to the model-building process, they might develop only little understanding of the way in which the various types of data drive the assessment outcomes. Co-modelling requires an exceeding amount of skill and background knowledge.

Hence, the modelling procedure might remain a black-box problem *despite* stakeholders sharing in the tasks of model development and use (Aranda & Motos 2006, p. 414; de Oliveira & Butterworth 2004; Hilborn 2003; Degnbol et al. 2007). Applied research on the management strategy evaluation (MSE) approach, for instance, has faced the problem that the great complexity of the modelling tools reduces their comprehensibility and accessibility (e.g. Kell et al. 2006; Aranda & Motos 2006; Smith et al. 1999) [3]. Within the IiFSW project, the complexity of the bio-economic modelling tool is said to have placed an "onerous burden on partners and other stakeholders who may have a steep learning curve to be able to use such tools effectively but also manage their development (IiFSW 2007, p. 74). The very potential of these tools to model at a very detailed level can drive the building of ever more complex models when those involved in model building have different views on what constitutes an appropriate level of detail in modelling (cp. EFIMAS 2008).

The quest for more integrated assessments which better account for uncertainties *and* greater transparency creates a *conflict of objectives*. When planning a participatory modelling exercise it requires careful reflection about whether the level of complexity of the model to be built and/or used might run counter to creating transparency and, as a consequence, might impede keeping a high level of commitment and motivation of the stakeholders in the modelling activities or generate and nurture stakeholders' reluctance to engage at all in such endeavours (Wilson & Pascoe 2006, p. 344; Sandker et al. 2008, p. 2; Voinov & Bousquet 2010, p. 1276; Smith Korfmacher 2001, p. 172).

The experiences made in the IiFSW project suggest that highly complex models are not well suited if the purpose (or one of the purposes) of participatory modelling is to initiate or foster

[3] The operating models underlying management strategy evaluation frameworks are often significantly more complex than the models underlying most stock assessments. MSE frameworks are relatively new tools to manage fisheries in Europe. They are likely to gain increasingly in importance because the current European Union's Common Fisheries Policy recommends that multi-annual recovery plans should be applied for depleted fish stocks. Use of such plans requires the explicit choice of definite harvest control rules designed to reach pre-agreed management objectives (Motos & Wilson 2006, p. 427; Hegland & Wilson 2009). Moreover, the comparison of the simulation outcomes shall allow for testing the robustness of the fisheries system to the various sources of uncertainty. In the view of fisheries management analysts this makes the use of these frameworks consistent with the precautionary approach to fisheries management (Ibid; cp. also Aranda & Motos 2006; Kell et al. 2006).

a process of collective learning about the nature of the resource problem and appropriate solutions. The IiFSW bio-economic modelling tool served a dual purpose: to increase chances that policy makers accept the project's conclusions as legitimate *and* support multi-stakeholder discussions and decision making through encouraging common understandings of the problems, opportunities and challenges that characterise the fishing situation in the south-west of the UK. However, the level of complexity of the modelling tool turned out to be not really suited to serve the second purpose. One conclusion drawn from this experience is that a 'simple' model was likely to be a more instrumental tool in creating a supportive learning environment for stakeholders (IiFSW 2007, p. 74).

In any case, if participatory modelling includes highly complex models it should be considered whether there is a need for procedural devices able to enhance comprehensibility and accessibility of the technical matters of the modelling endeavour and the trustworthiness of the data and computational procedures used.

Provide for information and communication tools and stakeholder capacity-building (if required)

Research on the use of computer-based models for integrated assessment within the EU project ULYSSES provides some general insights particularly relevant to involvement of stakeholders in model *use*. Results suggest that non-experts (these were citizens in the ULYSSES project, however, the experiences made seem to be relevant also for stakeholder involvement) evaluate the usefulness of such models relying on computer tools higher if (amongst others) the following *information and communication tools* are used: a comprehensible and detailed user manual; an understandable model presentation; an interactive and attractive user interface; a comprehensible account of the uncertainties; and an adequate model moderation (van der Sluijs 2002, p. 143; van der Sluijs 2001).

Depending on how familiar stakeholders are with the logic and techniques of modelling and thinking in terms of dynamic systems more or less efforts in *capacity building* will be required. Experiences of the IiFSW project have led to the proposal to consider the potential of *science communications* for 'translating' the technical matters throughout the modelling processes so that they become comprehensible to non-experts in modelling (Squires 2009).

In a project dealing with water allocation in the Gwydir and Namoi river basins in New South Wales, Australia, one tool applied for capacity building were *software workshops*. The aim of the project was to achieve a basic agreement on model assumptions and uses before the resulting models were applied for decision-making in these basins. The main purpose of one type of software workshop was to teach model-building skills in the software platform that was applied in the project to State Government agencies and research institutions in order to enable these groups to make future modifications to the model. The second workshop type was targeted at users who were trained in interacting with the models through a reasonably user-friendly interface (Hare et al. 2006, p. 211.).

Consider the need for independent verification

Quantitative skill is always going to be a hindrance to full transparency which means that a certain level of trust between scientists, expert modellers and stakeholders is required (Degnbol et al. 2007, p. 7). In case that there are strong tensions between the scientific-technical experts and some or all of the stakeholders it might be advisable to make the data and/or software available for independent verification, especially by critics (IRGC 2009, p. 30).

Be aware of the challenge of integrating different forms of knowledge

Those who consider improvement of the quality of advice and management outcome as the main objective of participatory modeling usually stress that such a process serves “to integrate all types of knowledge (empirical, technical and scientific) from a variety of disciplines and sources” (Voinov & Bousquet 2010, p. 1276). The underlying idea is that incorporation of experiential, local and folklore knowledge is required to take account of the idiosyncratic features around the specific resource problem and the accumulated expertise of practitioners.

At the planning stage, it needs, however, reflection on the level of difficulty of integrating different types of knowledge at the different modeling stages and possible ways to cope with the challenges implied. Typically, it will be easier to cope with the task at the framing, evaluation and use stages (at the latter stage, for example, by inviting stakeholders to contribute to scenario development) than at the stage of model construction. The IiFSW project faced great methodological difficulties when it tried to integrate stakeholders’ non-scientific knowledge into the bio-economic modelling tool at the model development stage (Squires 2009). The literature about knowledge production in fisheries management has identified this technical barrier as one of the main challenges in using models developed for simulation and evaluation of alternative management options in a participatory setting (Aranda & Motos 2006; Baelde 2003; Smith et al. 1999). There is still a need to find "more creative ways of embracing alternative hypotheses and data, including fishermen's perceptions and experience" (Smith et al. 1999, p. 976).

Provide sufficient room for deliberation in the participatory modeling process

When planning a participatory modelling process, one needs to address the question of how much room for *deliberation* – besides input of expert knowledge and structured thinking – is required for effective stakeholder involvement, and how to provide sufficient time, space and facilitation tools for argumentative exchanges. For a discussion to be called deliberative it is essential that it relies on mutual exchange of arguments and reflections rather than decision-making based on the status of the participants, sublime strategies of persuasion, or social-political pressure (cp. Stern & Fineberg 1996; Renn and Webler 1998, pp. 48-57; Habermas 1984, 1987). The need for deliberative processes should be considered in relation to the purpose of the participatory modelling exercise and the modelling stages at which stakeholders will be involved.

If, for instance, the main purpose is collective learning or improvement of the quality of advice and management results, deliberation at the framing stage around definition of the role and relevance of the different forms of knowledge for model development and use would be required.

Take another example: If the main purpose is to assist management decision making with the help of a management strategy evaluation (MSE) approach and by including stakeholders in model use, deliberation takes center stage and needs to be carefully organised, for instance by having it moderated by a professional facilitator. It is a key characteristic of the MSE approach in a participatory context that it confronts the stakeholders with *choices* to explore rather than 'optimal' solutions in the form of unitary policy advice highlighting a single or very small sub-set of possible courses of action (for instance a recommend catch level or technical measure; Motos & Wilson 2006, p. 426). What constitutes the 'best' way forward – usually in face of substantial uncertainties – is made a subject of deliberation. This deliberation is informed by the outcomes of the simulations of alternative management scenarios which allow for the evaluation of trade-offs between the performance of different strategies relative to the pre-agreed management objectives (Ibid.). Ideally, stakeholders would be invited to collaboratively specify the objectives against which the performance of the management alternatives is assessed (as was the case in a MSE-based process for line fishing in the Great Barrier Reef in Australia; Mapstone et al. 2008). Then, it requires a carefully planned deliberative process also at the framing stage.

Select carefully the professionals that might be needed in the participatory modeling endeavor

When designing a participatory modelling process, it is essential to reflect and decide on which *professionals* to include in the exercise.

There is general agreement that there is a need for both in participatory modelling: *modelling expertise* and *facilitation expertise*. Careful choice is required between the option to have these two types of expertise provided by a single person, and the alternative option to have the facilitator and modeller roles segregated and fulfilled by different individuals. If special expertise in modelling was deemed indispensable for successful facilitation, the first option might be regarded as the right choice (van den Belt 2004).

It needs to be considered, however, that the skill sets for modelling and facilitating are very different. Even if an expert modeller would develop to some extent skills such as conflict handling and communication by practice, s/he could not bring the same level of specialised expertise to the process than a trained facilitator. Moreover, as the modeller primarily cares about the product (the model itself and/or the working of the model) s/he will face a real challenge to remain neutral and avoid overly influencing the outcome and restricting her/himself to acting as a catalyst for co-operation in modelling. In that sense, the modeller is also a stakeholder. There are thus good reasons to prefer the second option and let the facilitator and modeller roles be performed by different persons (Cockerill 2005). What is vital then, however, is continuous exchange and consulting between the two, also and essentially before and after the modelling sessions.

Further possible candidates for bringing specialised expertise to a participatory modelling exercise are *science brokers* whose task it would be to try to translate expert discourse into comprehensive non-expert language. *Computer scientists* might be included in order to provide *technical support*, in regard to critical aspects of software applications. The requirements for including these professionals will vary depending on the specific setting of the participatory process. There will be more need for science brokerage, for instance, when stakeholders themselves participate than in those cases in which they delegate participation to self-selected experts.

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