Assessing the impact of stakeholder engagement in Management Strategy Evaluation

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Abstract

After completing a large, regional, multi-use Management Strategy Evaluation, we attempt to assess the impact of stakeholder engagement on the project. We do so by comparing the original project plan to the actual project development and highlight the changes which can be more directly related to stakeholder engagement. The impact can be summarised into four broad classes: a) a measurable change in the network of interactions both among researchers and stakeholders; b) changes in how the computer model was developed and run; c) changes in attitudes both among researchers and stakeholders and d) change in the actual project development. We discuss these changes, the way they have been detected and some lessons we learnt which may benefit future Management Strategy Evaluation projects.

1. Introduction

Adaptive management is a way of managing resources as a series of iterative experiments, through which managers and institutions learn (Holling, 1978; Walters, 1986) . However, there are two critical challenges associated with practicing adaptive management. Firstly, resource management problems are typically complex social-ecological system problems (Levin, 1999). Because of their complex feedback loops and their intertwined, dynamic, and uncertain nature, the workings of these systems often far exceeds the limits of human rationality, and as such, managers will inevitably make suboptimal decisions in these circumstances, due to lack of information and their inability to rationally process what information they do have (Simon, 1979; Hogarth, 1987; Ehrlich, 2000). Secondly, because of their complexity, resource management problems are also 'wicked' problems that are very difficult to define and resolve and typically span a myriad of disciplines and stakeholder interests (Rittel et al., 1973). Wicked problems have no optimal, right or wrong solutions (only better or worse from the viewpoint of different stakeholders), which, once implemented, have significant and far-reaching impacts, thereby rendering trial-and-error learning undesirable or impossible (Rittel et al., 1973).

Management Strategy Evaluation (MSE) is a framework for helping management agencies and stakeholders make informed decisions, one which is well-placed for addressing the above-noted challenges. Firstly, MSE helps humans deal with system complexity by using computers to model the dynamic interactions within and between the natural and human systems under examination. Secondly, MSE uses computer models to simulate the different steps in adaptive management framework (Butterworth et al., 1998; Cochrane et al., 1998; Butterworth et al., 1999; Sainsbury et al., 2000), and to assess performance and tradeoffs of different management strategies within these complex socio-ecological-economic systems. In this capacity, MSE projects allow the desirability of different management strategies to be assessed in the 'cyber' world before trialling them in the 'real' world. Thirdly, engaging different stakeholders in designing the models, formulating problems and assessing different strategies can ultimately lead to on-the-ground improvements in collective problem-solving and decision-making (D'Aquino et al., 2003)

Because the cooperation of many stakeholders[1] is needed to ensure the MSE model is actually used to assist with decision-making, and because, if used, the model will influence decisions affecting the lives and livelihoods of many different people, a stakeholder engagement process is needed if the project is to be both successful and ethically sound.

From a project management perspective, stakeholder engagement is likely to have considerable impact on how an MSE project unfolds, thereby presenting a number of challenges for budgeting and planning. When stakeholder engagement is carried out within a MSE framework, a modelling team usually applies a number of different strategies or actions, which include determining who the stakeholders are, explaining what models can offer, collecting information, understanding expectations, defining modelling questions and system indicators that are relevant to stakeholders, learning the most suitable way to communicate information and building trust, ownership and participation. However, our experience has shown that there is no clear one-to-one correspondence between such activities and achieving the goals of a MSE project. Nor is there a standard recipe for executing such strategies that can be successfully applied in all situations, as evinced by the limited application van den Belt's (2004) structured, three-stage 'mediated modelling' approach had for this study (Chapman et al. 2011). The composition, influence, knowledge, motivations and actions of stakeholders are 'turbulent', meaning they differ for any given place and for any given time, with groups forming complex and ever-changing webs of relationships which are inherently uncertain. Human relations, trust and mutual understanding, which are preconditions for cooperation (Putnam, 1995; Wondolleck et al., 2000), are not obtained in a one-off effort, but take time and repeated reciprocal interaction to develop (Pretty et al., 2001). Pinning down stakeholder systems can also be frustrated by the fact that the modellers themselves affect the stakeholder system – as soon as they begin engaging, stakeholders' perceptions, knowledge and actions begin to change in response (see Heisenberg (1930), and Capra (1997)). Modellers learn in the process too, which in turn affects their approach to model building. Expectations and modelling questions develop along with understanding of the modelling process itself as do information collection and communication needs. Given these circumstances it is unsurprising that planning and carrying out stakeholder engagement can be challenging. Very few actions in an engagement process can be performed and ticked off as planned: most need to be repeated, improved, and in some cases, discarded and replaced during the overall process.

In this work, we examine the effects of stakeholder engagement on the roll-out of a large, regional, multi-use MSE project in North of Western Australia. Stakeholder engagement for this project was part of a larger knowledge transfer initiative working to improve research and model uptake and bridge the science-management gap in the region. The engagement process we discuss was not planned at project inception, rather it emerged over time in response to stakeholder needs and suggestions as the engagement progressed and it reflects the adaptive nature of the project. A more detailed description of how modelling researchers adapted to socio-political turbulence in the region by adopting an emergent approach to knowledge transfer and model uptake is outlined in Chapman et al. (2011). In addition, in-progress research due for completion in 2012 (Chapman, personal communication) will provide an evaluation of how stakeholders' knowledge, practices and networks changed as a result of stakeholder engagement and the wider knowledge transfer process. As such, this paper specifically focuses on how stakeholder engagement affected the *roll-out* of the MSE project, in particular its effect on: a) actual project development, b) how the computer model was

[1] A widely accepted definition of 'stakeholder' is provided by Freeman (Freeman, R.E., 1984. Strategic Management: A Stakeholder Approach. Pitman, Boston.) as "any group or individual who can affect, or is affected by, the achievement of a corporation's purpose." In the instance of MSE, the 'corporation' can be defined as the MSE project team.

developed and run, c) the network of interactions both among researchers and stakeholders, and d) attitudes of both among researchers and stakeholders. We discuss the implications of these effects from a project management perspective, and provide some preliminary indications as to the apparent influence of these effects on the actual purpose of the MSE project – that being to help managers and stakeholders make informed decisions. These longer-ranging effects of stakeholder engagement on model uptake and decision-making in the region will be described in greater detail in Chapman's forthcoming thesis (in progress).

2. Ningaloo-Exmouth research

Ningaloo reef and Exmouth Gulf lies within the Gascoyne region of Western Australia (Figure 1). The area is sparsely populated (7744 according to the last census in 2006 in an area of 52 925 square kilometres), with its settlement sites largely a result of the pattern of development of the pastoralism industry, with the exception of Exmouth which was built to service the Harold E Holt Naval Base in the 1960s. The pastoral industry, which still makes up 80% of the land tenure, began in the late 1800s, when wool from the region was shipped to national and international markets. Today the economy is diversified – including tourism, pastoralism, oil and gas and many other sectors. The region is the focus of high tourism visitation due to its exceptional beauty; based around a 300km fringing coral reef along the coastline and Cape Range National Park and recreation on pastoral stations on land. Increasing industrial development in the broader northwest of Australia, largely based around oil and gas extraction and mining, is also providing new challenges and potential futures for the region. This close geographic association of the Ningaloo Reef (listed in 2011 by UNESCO as a World Heritage Area), other reserves (including Cape Range National Park), tourism and the diversity of local activities (including farming, fishing and oil and gas exploration) mean that any future development must be done carefully if the region's natural resources and attractions are to be maintained and unintended consequences avoided. The region was subject to a large research programme from 2007-2011 to provide the information required for science based management decisions about the future of the region.

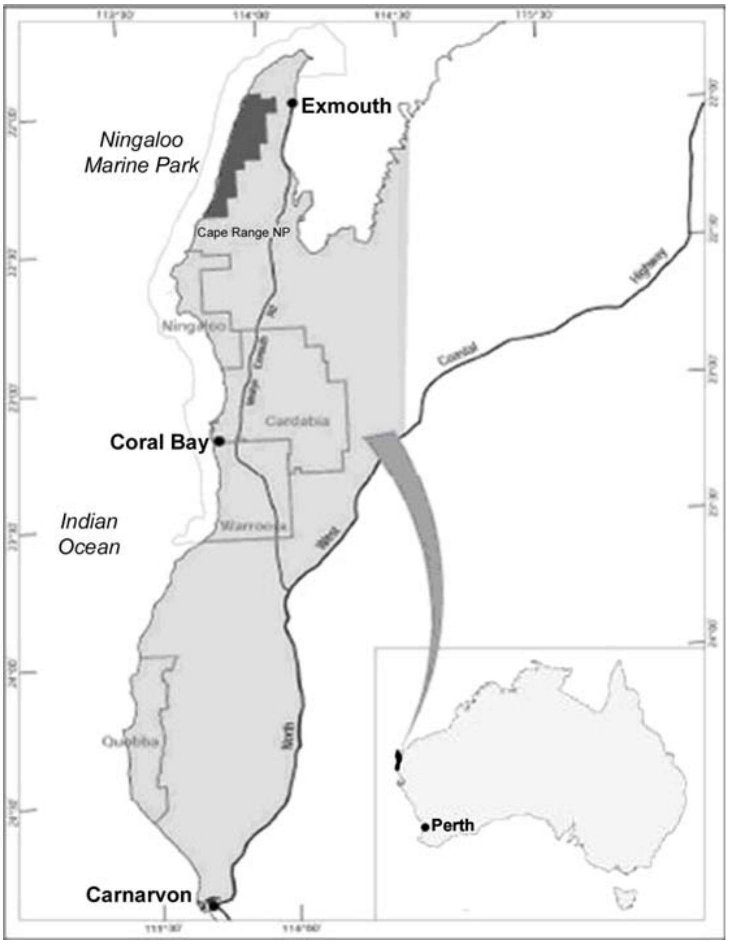


Figure 1: the Ningaloo coast region of Western Australia (Management, 2005). .

3. Assessing impact

Assessing the impact of decisions and actions is needed to determine their effectiveness as well as possible undesired implications. Businesses and local government routinely use several methods following a growing attendance to accountability in the public domain (Bovens, 2006).

The impact of an action can be judged by measuring its consequences. We call this Question 1. In our case, we could ask how many people attended a modelling workshop, how many people requested to use our model or how many scientists cited our report. There are two drawbacks with this approach: first, we are unable to evaluate the final actual consequence of these actions. For example, we are unable to judge whether attending our workshop had any real impact on the attendees. Second, we may include unwarranted impacts. If our model had not been developed, a stakeholder may have employed a different (but similar) model with no measurable difference in consequences.

The latter observation suggests a different approach. Inspired by an ideal definition of impact (Wolpert et al., 1999; Boschetti, 2007), we can ask what has occurred which would have *not* occurred had a specific action *not* taken place. We call this Question 2. In our case, this implies asking how different the outcome of this project would have been, had no stakeholder engagement occurred.

Since Question 2 involves a counter-factual (the impact of an action which did not happen), answering it precisely is obviously impossible. However, numerical experiments in a wide range of problems suggest that even a largely approximate answer to Question 2 can be much more effective that a precise answer to Question 1 (Wolpert et al., 2004; Boschetti et al., 2008a). Some possible implications of this approach for human behaviour are discussed elsewhere (Boschetti, 2007).

In this work we adopt Question 2 as a guide to assessing impact. We analyse the original MSE project plan and assume the project would have developed along those lines. After project completion, we highlight the differences between how the project actually developed and the original plan. Among these differences, we focus on the ones which can be most directly attributed to stakeholder engagement.

The above question can be framed within the Integrated Figure of Merit for public good research with multiple stakeholders (Geisler, 1996), according to which research (or modelling) outputs can be thought of in terms of four temporal and conceptual classes: a) *immediate* (in our case publications, other measurable research outcomes and changes which can be detected promptly in the system), b) *intermediate* (in our case whether the model is used, whether the MSE approach is adopted or whether model results are requested and accounted for in decision making), c) *pre-ultimate* (in our case, specific management activities that can be demonstrated to have occurred from the MSE implementation) and d) *ultimate* (the role of this project in achieving overall community benefit).

This paper is written in coincidence of the immediate stage and consequently concerns this type of results. It is also reasonable to assume this approach would become less and less reliable the farther in time from project completion we analyse events. Longer–term results can be monitored using an influence diagram, tracing model use through differing levels in the stake-holders network as described in (Geisler, 1996), or via an analytical hierarchy process, as suggested in (Syme et al., 2006). A discussion of how this approach could be extended to longer-tem impact is also given in Section **Error! Reference source not found.** below.

4. The engagement process

Figure 2 summarises how the stakeholder engagement was expected to occur at project inception. Stakeholder interactions were expected to happen mainly a) at the beginning of the project, when local information is collected and modelling objectives are discussed and simulation scenarios designed, and b) in the last stage of the project, when model results are delivered. This captures the initial perception different parties may have of the role of modelling within a MSE. For example, modellers may see the model as the final outcome of their effort and stakeholder engagement as a step in order to define, for example, what the model should do and how it should look. Non-modeller scientists may see the aim of modelling in model results, which can feed into other projects; decision makers may focus on result interpretation and consider stakeholder engagement as a natural consultative process. For each of these parties a model is a) defined early in the project, b) implemented (built and parameterised) during the project and c) fulfilled (via model runs, output generation and interpretation) at project completion.

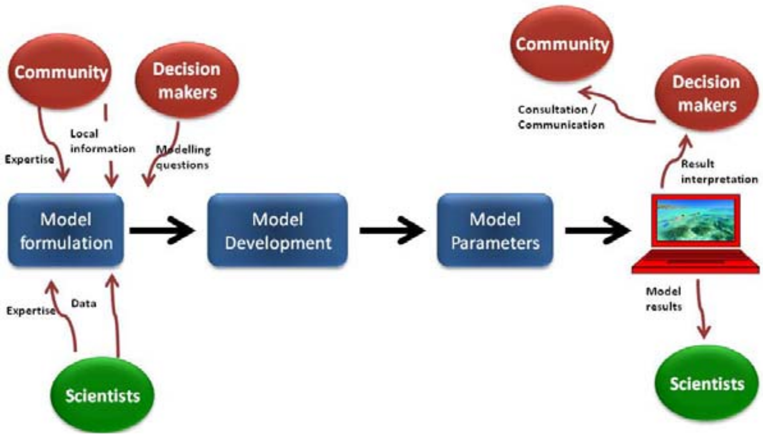


Figure 2. Traditional, sequential model development stages; stakeholder interaction occurs only in the first stage, when information and objectives are collected and in the last stage when model results are delivered.

Across other stakeholder groups there may be both different and diverse expectations. Some groups may even be hesitant, sceptical or suspicious of model use in a MSE framework. Others may have a more integrated view; they concern themselves with the inclusion of local knowledge and with the model's fate after project completion (will the model be updated and will new information be included?). For some of these parties, model definition and development happen during the overall project as well as after its completion. This view goes to the core of the MSE and the adaptive approach. Adaptation is not only fundamental to decision making, but also to the core of MSE.

This leads to viewing model development and stakeholder engagement as an iterative process in which a) the model shifts in complexity and in focus as the problem is better defined; b) stakeholder engagement increases in depth while the stakeholders improve their appreciation of what modelling can provide and trust in the process and c) modellers better understand how to relate to stakeholders and their concerns. This results in a number of feedback loops between modellers and stakeholders as in Figure 3.

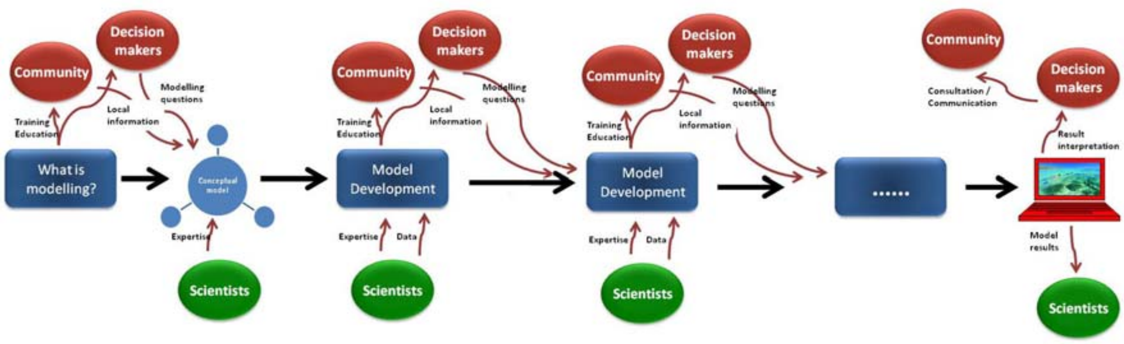


Figure 3. Alternative model development stages; stakeholder interaction occurs throughout the project and information flows into and out of the model at each step.

This also implies that engagement does not need to be a uniform step by step process, in which different stages follow each other in a predetermined way, rather it can be a parallel process in which different stakeholders are engaged separately at the same time as new engagement needs or opportunities arise. Accordingly, it is not necessarily a pre-determined schedule of engagement which is important, as much as allowing for the process to shape itself and evolve according to the project needs. This is particularly important when working in turbulent social-ecological systems, such as that found in Ningaloo (Chapman et al. 2011). Because these systems are always changing in unpredictable ways, detailed plans developed at the beginning of a project will quickly lose relevance and become outdated.

Figure 4 summarises the actual engagement actions taken by the modelling team during the project. Early stakeholder engagement was initiated before project commencement by properly designated staff. Unfortunately, staff turnover and illness interrupted this process; two years later the modelling team restarted and carried out the process directly. This has included several one-to-one meetings, workshops with other scientists, local and state government organisations and local communities. In particular, a total of 7 trips were taken to the Ningaloo region by different team members. These interactions between team members and stakeholders allowed for model improvement and acceptance, and also helped highlight the questions the model needed to address. Pivotal to community engagement was the extended presence in the region of a PhD student with professional experience in stakeholder engagement, and science communication whose effort not only filled the gap between local community and the research team, perceived as outsiders, but also informed the modelling team of the need to establish relationships and build trust with local stakeholders as a means of encouraging some level of local acceptance and ownership of modelling research, and possible ways of achieving this.

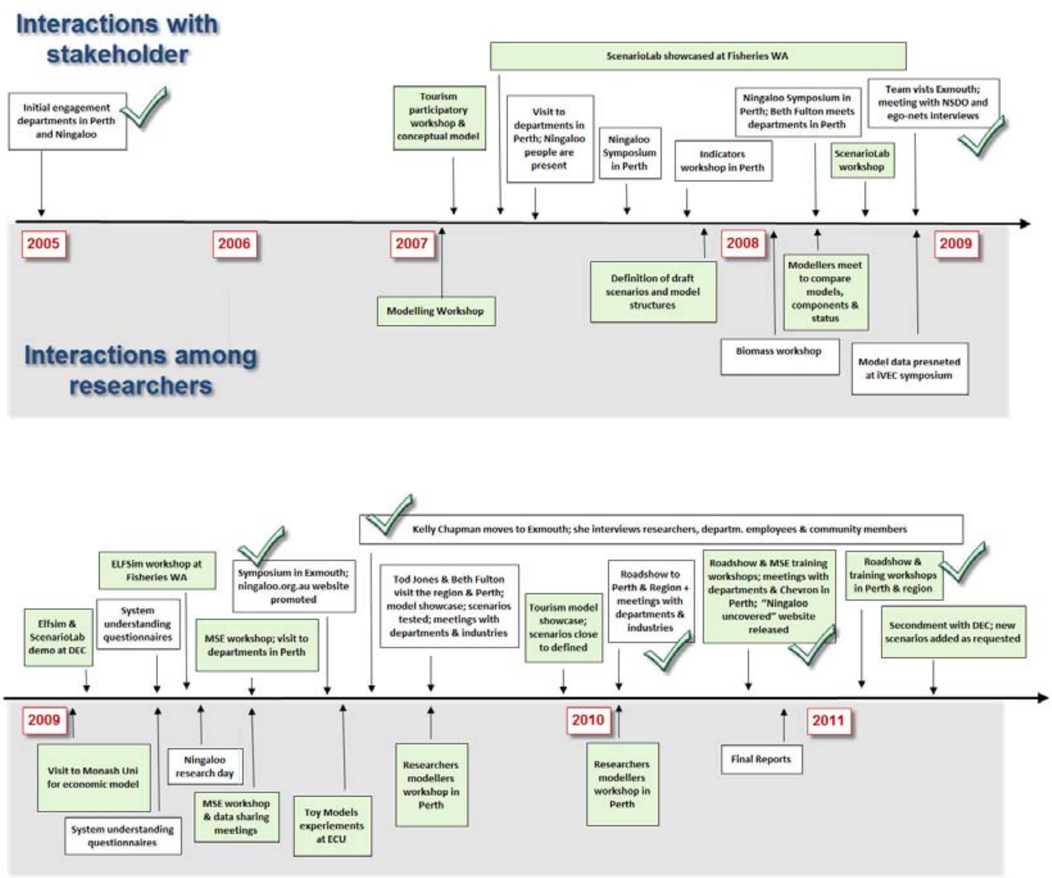


Figure 4. Actual stakeholder engagement process, as carried out during the project. Items above the time line indicate interaction between modellers and stakeholders; items below the time line indicate interaction among modellers and other researchers. Filled boxes indicate actions which directly involved model use or development. Accents indicate interaction which occurred in the Ningaloo region.

Moving from an engagement process as in Figure 2 to one as in Figure 3 involves not just considerable adjustments to the project plan but also change in priorities and effort allocation. While no staff had been specifically allocated to stakeholder engagement over the entire project, at the time of project completion a considerable amount of effort was dedicated to organising meetings, workshops and related travelling, and initiating and following a considerable flow of e-mail and phone communication. According to a rough estimate, stakeholder engagement accounted for approximately 43% of the effort of the overall modelling team, the remaining going to data collection, model development, and parameterisation and result visualisation. Clearly, assessing who and what will influence the impact of the model as a decision-making tool (recognising that this will continuously change from project start to finish and therefore must be continuously tracked), and cultivating and maintaining essential relationships accordingly, requires a significant investment of time and resources over the entire length of the modelling project. It also requires considerable skill and experience on the part of those conducting the engagement. This obviously highlights the importance during project inception of properly planning for the capacity, time and resources needed for stakeholder engagement, and understanding the characteristics of the locations and organisations that will be targeted for engagement.

5. Understanding the stakeholders groups

The stakeholders related to this project were particularly diverse and could be roughly grouped into three classes: a) decision makers from local and state government agencies, b) local community and tourists and c) researchers. The latter should be considered stakeholders of the MSE because several research projects were related to the modelling effort either as data providers or as beneficiaries of the model results.

The original stakeholder engagement was designed based on three premises; first, that stakeholders had an approximate idea of what questions the model had to address and that few specifically-designed meetings would suffice to define them in detail. Second, that while some stakeholders may question the scientific validity and real-world relevance of computer modelling, their understanding of the modelling activity was sufficiently well defined. More specifically, while the modelling team expected that it needed to explain the meaning of MSE and the role of modelling within it, it also expected that why and how we model could be taken as well understood. Third, it expected that basic understanding of system functioning was also well understood and that communication to the non-scientific audience needed to focus mainly on complex information, like the impacts of feedbacks loops among different sectors, the effect of interactions in large ecological networks and other counter intuitive processes which may affect the Ningaloo region.

The latter assumption, according to which most stakeholders had a reasonable understanding of basic system dynamics, is important since the understanding of the model result rests necessarily on such basis. Midway during the project, we become aware of recent work highlighting how decision makers' and public misconceptions of accumulation and feedback processes may affect the types of policy they implement and support (Moxnes, 1998; Moxnes, 2000; Sterman et al., 2002; Sterman et al., 2007; Sterman, 2008; Cronin et al., 2009; Moxnes et al., 2009). We thus decided it was important to verify such understanding within our stakeholder group and we designed a questionnaire for this purpose. Our results are discussed in (Boschetti et al., 2010; Boschetti et al., 2011b). Two results are of particular interest. First, our data confirm the estimates reported in the literature (ref): between 65% and 70% of interviewed people show difficulties in understanding basic stocks and flows processes (Sweeney et al., 2000; Sweeney et al., 2007; Sterman, 2008), which, in the context of our application, could result in overfishing (Moxnes, 1998), overexploiting other limited resources, or overdeveloping. Checking for the occurrence of these cognitive difficulties is important because overexploitation is usually associated with either greed or lack of environmental and community concern (Moxnes, 1998; Moxnes, 2000); policies designed to target cognitive misunderstandings of natural process or purposeful overexploitation can be considerably different. Similarly, misconception of causal effects due to feedback loops also holds potential implication for suggesting and supporting ineffective policies (Dorner, 1996; Sterman, 2008). The second interesting result is that performance of scientists, decision makers and the general public on these tasks was barely distinguishable (Boschetti et al., 2010; Boschetti et al., 2011b). While apparently surprising, this result also matches data found in the literature of expert knowledge (Camerer et al., 1991; Ericsson, 1993; Dorner, 1996; Tetlock, 2005). The main conclusions from these two observations are that a) even simple models designed to aid decision making tasks can provide a means to prevent common cognitive fallacies, b) modelling can provide training to develop our intuition on system functions and c) these tools are useful to both experts and non experts.

Cognitive abilities do not live in a vacuum; rather they are influenced by cognitive styles (the way we approach a problem and the amount of effort we are willing to dedicate to it) and interact with worldviews and attitudes in shaping our choices and decisions (Boschetti et al., 2011a). A second type of questionnaire was used to assess the stakeholders' world views, that is, perceptions of how the world functions and the values they hold. This was motivated by literature showing that people tend to polarise according to specific beliefs which affect not only their decision, but also the way they process and filter novel information (Duckitt et al., 2002; Unger, 2002; Lewandowsky et al., 2005; Heath et al., 2006; Kahan et al., 2007; Mirisola et al., 2007; Duckitt et al., 2009). Effective communication of research results may need to be tailored according to such beliefs. According to (O'Riordan et al., 1999; Leviston et al., 2010a), these beliefs can be broadly summarised into 4 statements:

a) The environment is fragile and will only be protected if there are large changes in human behaviour and society.
b) The environment can be managed by the government and experts if there are clear rules about what is allowed.
c) The environment can adapt to changes and technology will solve environmental problems eventually.
d) The environment is unpredictable and we can't control what happens.

We asked this question to two types of stakeholders: a) 'Workshop Attendees', participants who attended our modelling workshop, which include fishers, tourism operators, educators and local government representatives based both within and outside the Ningaloo region; b) 'Ningaloo Public', participants who attended our public presentations. This group includes both people based in the Ningaloo region and tourists. The vast majority of the stakeholders we interviewed subscribe to Belief *a* (environmental management is a social problem), with a minority subscribing to Belief *b* (environmental management is a governance issue). Very few stakeholder subscribed to Belief *c* (environmental management is a technological/economical problem) or to Belief *d* (environmental problems are hard or impossible to manage).

It is reasonable to suspect that such skewed results are a consequence of the voluntary nature of the participation to our workshops and that a less environmental-oriented result would be obtained if a larger section of the population was interviewed. In order to check this we ran the same questionaries via an on-line survey targeting two different groups not related to the Ningaloo region: a) 'General Public' (116 people), which includes participants not residing in the Ningaloo Region and not involved in scientific research and b) 'Researchers', participants not residing in the Ningaloo region but who were involved in scientific research. As shown in Table 1, the responses to this question become more homogenous moving from the Ningaloo Public, to Workshop Attendees, to Researchers, to the General Public. In particular the choice "The environment is fragile and will only be protected if there are large changes in human behaviour and society" becomes less and less prevalent. The difference in responses between participant groups is statistically significant (pValue=0.1), except between 'Workshop attendees' and 'Ningaloo Public'.

Finally, we compared our results to large national survey on attitude towards climate change (Leviston et al., 2010b) (bottom row in Table 1). This differs significantly (pValues ≈ 0.01) from all other responses. Particularly noticeable is the much higher prevalence of Belief *d* (The environment is unpredictable and we can't control what happens) in the large national survey compared to the groups we interviewed. This is encouraging, since it suggests a much stronger belief on some level of human agency on the fate of the environment in our stakeholders.

We summarise this section by highlighting the main impact which occurred from gaining a better understanding of the stakeholder group. First, the awareness that when dealing with system dynamics, intuition can be misleading and it can affect even experts , lead us to implement a number of simple models to address this challenge (Dorner, 1996; Moxnes, 1998; Moxnes, 2000; Sterman, 2008), as described in Section 7 below. Simple models can be very useful not only in checking basic assumptions on how systems works and how our decisions may affect them, but also in providing basic training to develop an intuition for general system dynamics, which can then be employed in thinking about specific problems. Second, these simple models can be used in interactive mode in public sessions, during which basic scenario developments or interventions can be discussed, projected in the future and then modelled in real time to provide a dynamical check on the projection. Our experience is that the learning and discussion arising from these public sessions can be pivotal in generating change in certain stakeholder groups. Third, the communication style used during both technical workshop and public presentations has changed during the project, focussing on the type of audience and accounting both for cognitive styles (that is presenting information in a format which can be easily understood) and attitudes (in order to prevent alienating the audience). Fourth, some forms of interactions have been repeated a number of times to increase effectiveness. It is unlikely a single act of communicating a piece of information is going to reach all stakeholders. Finally, we tried to test whether learning occurs by using simple models. During our workshops, we used post-workshop questionnaire to get a subjective evaluation of this learning, which appears to be positive. However, we also ran a more objective test with university students. The purpose of the test was to see whether improvement in a complex task was obtained by first training he students with simple dynamical models. The results are discussed in (Boschetti et al., 2011b) and, despite the small sample of student employed, are encouraging, suggesting that this is a field of research which is worth pursuing. Importantly, a much more deep learning has occurred within the research team. This has resulted in a batch of models (Fulton et al., 2001) and a specific questionnaire (Boschetti et al., 2011a) has been designed as a result of this research which we plan to formally incorporate in future MSE projects.

Table 1. Responses from the worldviews and attitudes question for different audiences related to the Ningaloo Research Project and from the general public as surveyed in **(Leviston et al., 2010b)**. For each of the statements in the questionnaire (a-d) we give the percentage of people who agreed with them.

	Belief *a*	Belief *b*	Belief *c*	Belief *d*
Workshop attendees	91%	5%	0%	4%
Ningaloo public	68%	26%	3%	3%
Researchers	51%	35%	3%	11%
General Public	38%	26%	25%	11%
Large national survey	50%	15%	13%	22%

6. Network of interactions

Social network theory (e.g. (Bodin et al., 2005; Ernstson et al., 2008)) was used early in the project to assess the network of interactions among different groups. The aim of the exercise was to ensure that the network of interactions could provide for successful collaboration and information dissemination among the overall research team. This was motivated by the fact that, while the team, as a whole, may have all the information needed for the overall project, ensuring that this information reaches the specific researcher or manager who needs it is much less straightforward. Interviews were carried out with 44 individuals from government and non government organisations having distinct ongoing roles in the project. Participants were asked to draw an egonet (or egocentric map (Marsden, 1990; Wasserman et al., 1995)) of the parties they interacted with and the perceived relationship between them. This provided a provisional map of a) where critical positive interactions occurred, b) where disruptive feedback loops or structural holes may be and c) which are the key nodes for the transmission and interpretation of particular forms information (Reagans et al., 2001).

A full description of the reconstructed social network can be found in (Dzidic et al., 2010). It highlighted weak inter-group connections, that is weak links between research, management, industry and local stakeholders as well as between different research teams. While connections within individual groups appeared to be quite strong, the disruption of a few inter-group links may have resulted in isolating an entire group with consequent large impact on the overall project connectivity and organic management.

In order to check how the interactions actually developed during the project, the exercise was repeated after project conclusion. 36 researchers replied to an online survey, specifying which interaction was included in their project plan and which was initiated and eventuated outside the project plan. The egonet resulting from this online survey is found in Figure 5. Here, the interactions included in the researchers' project plan are described via dashed links, while the unplanned ones by thick links. A number of features can be noticed. First, according to the project plan, the interaction at the researcher level (dashed black lines in Figure 5) is much denser that the one at project management level, as described above. It is likely that this would have ensured a certain level of information exchange among researchers, even in the case that some management link had been disrupted, effectively making the researchers' network more resilient than hypothesised in (Dzidic et al., 2010). Second, the actual interactions at the researcher level (dashed plus thick links in Figure 5) is even denser than planned, which suggests that much initiative was undertaken by researchers to initiate new interactions and new research projects when opportunities and gaps emerged. Naturally, this also implies that a certain level of flexibility was allowed in order for this to occur. This adds to the interaction between stakeholders and researchers, which also occurred to a larger extent than originally planned, as discussed in Section 4 and summarised in Figure 4, which also relied on considerable flexibility and improvisation.

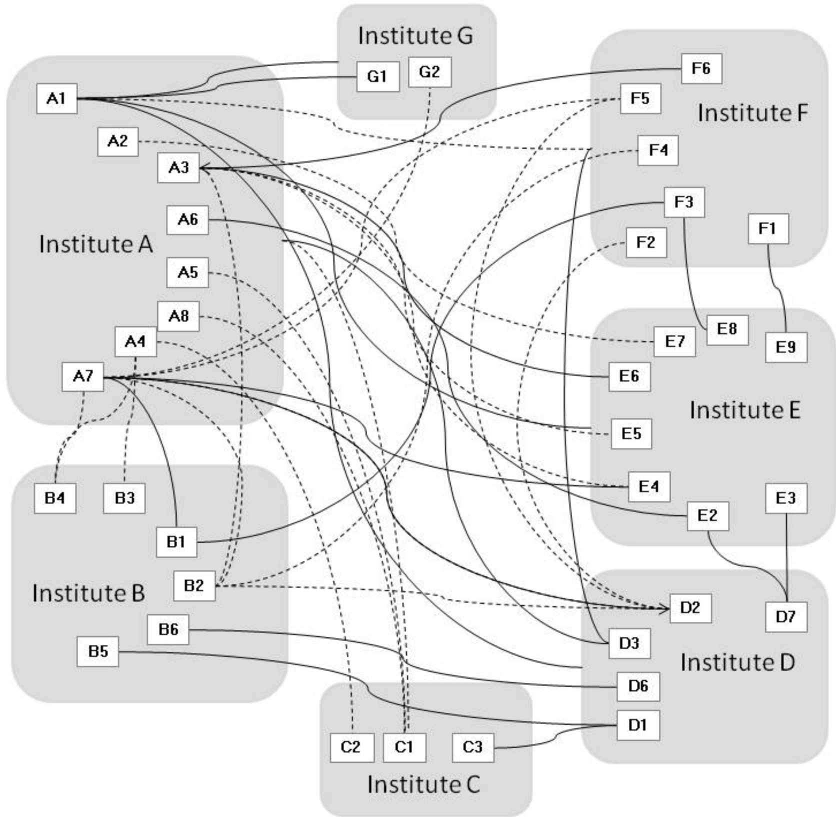


Figure 5. Econet at project completion. Grey boxes refers to different research institutes. Small white boxes refer to individual researchers. Dashed links refer to interactions at researcher level which were included in the project plan. Think links refer to interactions which were not included in the project plan and were developed adaptively during the project.

7. Model development

The original project plan envisaged that the MSE would be based on the model InVitro (ref), a large mixed agent-based and continuous equation model previously used for a MSE project in a nearby region (Gray et al., 2006). The plan also required a considerable level of model re-engineering, plus re-parameterisation in order to port it to the Ningaloo region.

While the engagement actions in Figure 4 resemble a continuous, two-way process as in Figure 3 more closely than a sequential process as in Figure 2, the re-development of a large full-system model like InVitro, requires a software engineering team, whose workflow resembles Figure 2 much more closely than Figure 3. Clearly a certain level of flexibility is required by model developers, modellers and engagement team alike, in order to ensure that the model development progresses smoothly according to software engineering requirement, while the engagement both adapts to the stakeholders needs and informs the final model design.

As discussed in Section **Error! Reference source not found.**, it also soon became clear that a model was needed in order to facilitate stakeholder interactions. InVitro was not expected to be ready in time for the engagement process to initiate. Furthermore, InVitro's size and complexity did not make it suitable to a stakeholder group which included some members with little to no model experience. To circumvent this problem, the modelling team also designed or used a number of models of smaller size and scope specifically suited to the engagement stages discussed in Section 4. These include conceptual models, toy-models, single-system models, and shuttle-models. In conceptual models the main drivers of a system are highlighted for subsequent representation as components of the full-system model; this usually results in a diagram summarising our understanding of how the system works. In toy-models a problem is simplified in such a way that only a handful of components are included. The purpose of these models is mostly educational. We want to understand how each component affects the problem and in order to achieve this, we temporarily renounce a satisfactory understanding of the overall problem. In single-system models we include a fairly detailed representation of a single component of the system (in our case recreational fishing and tourism). These models can be used to introduce stakeholders to modelling, provide temporary results from the study of a single activity, which will feed into the development of the final full-system model, or address sector-specific issues. In shuttle-models, we include the minimum number of processes we believe are crucial for a basic understanding of the overall problem. We know these models are still too simple for a full system description, but they provide a sufficient understanding to enable us to contemplate, build and use the more complex models needed for full problem description. The term ‘shuttle’ refers to taking us from a minimum to a full description of the problem, a journey which is necessary both to developers in model definition and parameterisation and to stakeholders in the interpretation of the final full-system model results. The details of each model used in this project are discussed in (Fulton et al., 2011).

The rationale for the use of such a diverse batch of models lies in our belief that in the MSE framework, a large section of the stakeholder group should interact with modelling: technical staff in public or private organisations may become model users by inheriting the model from scientists; some decision makers will interpret model results to formulate and implement policies; and the community will hopefully support and follow polices if they understand how and why they were developed. It is reasonable to believe that familiarisation with the models will benefit all these parties and make it more likely that MSE makes an impact. For this to be possible modellers need to provide a certain level of education in modelling philosophy and process. A computer program simulating an individual stakeholder’s everyday environment and daily actions can be received with a certain level of healthy scepticism, which needs to be overcome (‘how can a model account for the complexity of daily life?’, ‘how can a model prediction be believed, when the future is so uncertain?’). It is the modeller’s responsibility to explain why we model, how we do it, how uncertainty is addressed and to what extent the model results are informative.

We carried out this task via four types of activities: a) seminars and public presentations, b) conceptual model building, c) modelling showcases and d) modelling workshops. Our experience is that some activities need repeating for successful reception. We have collected anecdotal evidence of ‘flashes of understanding’ occurring suddenly at the 3rd or 4th presentation as a result of a slightly different communication styles.

8. Scenario development

The final aim of the MSE is to assess what futures are desired and possible, and to evaluate their likely trade-offs. These futures represent the ‘questions’ we ask the model and the ‘answers’ the model provides give us some indication of the likely trade-offs. Formulating these questions is not easy. A stakeholders group as diverse as the one related to the Ningaloo region can naturally produce a very diverse range of desired futures and opinions on what is acceptable. Also, only a limited number of questions can be asked to complex models for the computation, analysis and communication of the results to be manageable.

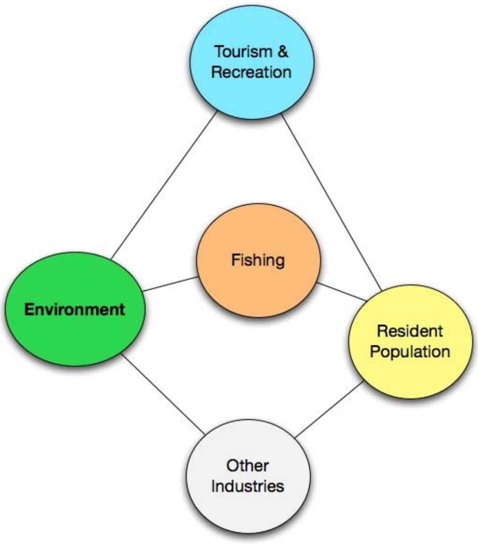
Here we focus on an unexpected further difficulty we encountered: the lack of familiarity with modelling (both in term of philosophy and practise) made it difficult for some stakeholder groups to formulate the questions. In other words, certain stakeholders struggled to define the scenarios for the model to run. This resulted in paralysis or in asking questions either too general or too specific. Modellers found this issue perplexing and at times frustrating, because of its impact on the project workflow. This is a very practical example of how different backgrounds, assumptions and knowledge can affect communication and it highlights the importance of stakeholder engagement.

To some modellers it appeared that the model was supposed not only to provide answers, but also to formulate questions, which is logically impossible from a modelling perspective (Boschetti et al., 2008b). However, it is indeed what is supposed to happen from an engagement perspective, if we accept that modelling is not what expert outsiders do, but rather a process that includes experts, stakeholders and the local community. Indeed, a combination of repeated modelling seminars, workshops, showcases and one-to-one meetings eventually did deliver the scenarios for the full-system model. It is important to notice that, while some workshops were organised specifically to design scenarios, the final scenarios were ultimately developed via a more complex and ad-hoc process, involving phone calls and e-mails, as well as workshops designed for different purposes. This is a further example that engagement goals and actions do not necessary coincide precisely.

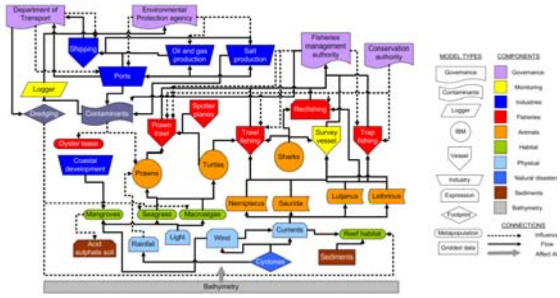
In summary, stakeholder engagement impacted the model development in three ways. First, it inspired the implementation and use of a set of ‘small’ models (conceptual, toy, single-component and shuttle-models). Second, it defined the questions the models needed to answer, sharpening the focus from broad regional queries to questions about specific development issues of local concerns. Third, it influenced the structure and parameterisation of the full-system InVitro model, taking it from a simplified form of a version inherited from a previous project to its final implementation. The technical details of this transformation are beyond the scope of this work, but a rough appreciation can be obtained visually by comparing the model structures at different stages through the project, as summarised in #

1. Conceptual Model	**2.** Pilbara InVitro model structure used as an implementation starting point
3. Ecological components (after biological advice)	**4.** Tourism relevant components (after expert and local advice)
5. Initial full system model (focusing on direct connections)	**6.** Final full system model form

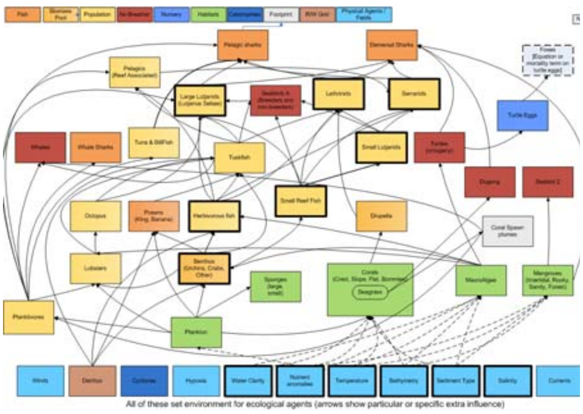
Figure 6.



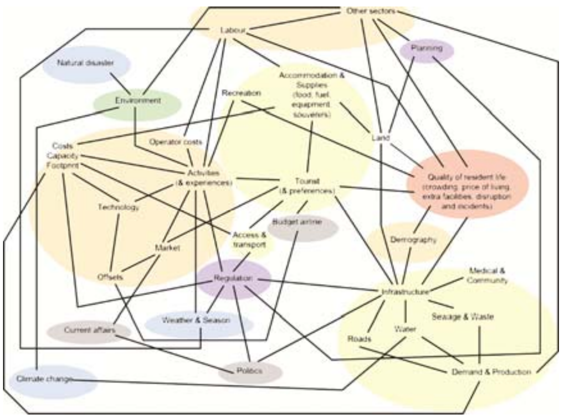
1. Conceptual Model



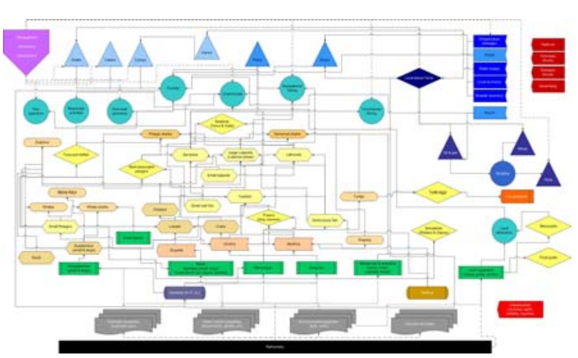
2. Pilbara InVitro model structure used as an implementation starting point



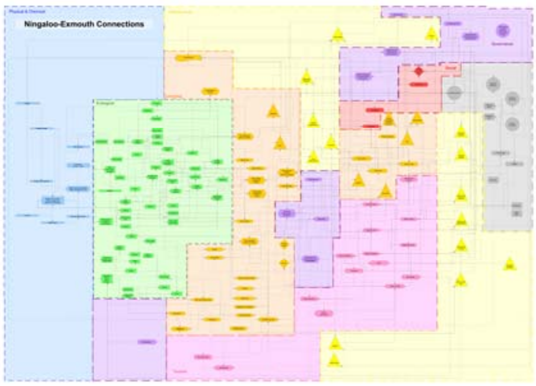
3. Ecological components (after biological advice)



4. Tourism relevant components (after expert and local advice)



5. Initial full system model (focusing on direct connections)



6. Final full system model form

Figure 6. InVitro model structure at different stage through the project.

9. Discussion

Other research into the engagement process (Chapman et al., 2011) characterises the Ningaloo coast as a turbulent socio-political environment due to the constant staff turnover, the dynamic nature of tourism and the growing resource sector industry. The adaptive response of researchers to engagement and their willingness to repeat engagement processes was necessary in this environment in order to elicit emergent behavioural responses, and then reinforce them through responding to requests for information or modelling results. In turn, the emergence of new behaviour amongst stakeholders elicited the adaptive modelling processes described here. While this is a positive and necessary development, further steps could be taken in future projects to initiate, foster and reinforce similar processes in stakeholder-modeller interactions. In particular, the presence of locals on research management committees, a focus on and readiness to take advantage of local issues as soon as they arise as a research management priority, and local engagement at the early stages of formulating communications plans and strategies would further enhance the impact of a modelling project (Chapman et al., 2011).

Of course, the numbers of people, level of interaction, and amount of information exchanged are likely to lead to chains of events going far beyond the impacts discussed in this paper. Here we purposely limited our analysis to impacts which could be assessed, in a semi-objective fashion, by comparing a project plan against an actual project development. The definition of impact we propose in Section 3 involves identifying specific events (stakeholder engagement initiatives in our case) and evaluating their consequences against the counterfactual guess of what would have happened in their absence.

In principle, the same approach could be employed to establish the longer-term impact of a project. What is needed is a) a prediction of how we expect a system (the Ningaloo Region in our case) would have developed in the absence of the MSE project, b) the actual future development and c) a reasonable assessment of what actual events are more strongly related to the project outcome.

As we mentioned above, the further ahead we look into the future, the less reliable such approach will inevitably be. Nevertheless, it may still be worth carrying out. At the core of involving stakeholders in designing a MSE process there is the intent to predict, prepare for and, as far as possible, steer the future. Mankind has tried to do this since the beginning of time, with efforts becoming more rigorous, formal, frequent and larger since the 1950s (Bezold; Bootz; Coates et al.; Durance; Ringland). Unfortunately, much less effort is put into evaluating these projects: which one predicted better? Which ones better steered the future according to the stakeholders' intent? Under what conditions did they work or fail? An effort pertaining to the future needs waiting for the future in order to evaluate; not carrying out this evaluation is like performing a lab experiment without bothering to check the results. Knowing what worked and what failed in a specific project will be of immense value to the next one.

In the short to medium-term all parties will likely monitor project outcomes somehow: decision makers and project initiators have an administrative pressure to justify the work; scientists need to demonstrate their relevance outside academia; local stakeholders' effort in trusting and collaborating with the process will be vindicated by seeing practical outcomes. But there is also a longer-term purpose in monitoring project impacts and the proposed approach may provide a framework for such effort.

10. Conclusions

Looking back at an MSE project after completion and comparing it against the original project plan, we detect a number of examples of how the project evolved in unexpected ways, adapting to circumstances as they occurred. Most of these changes can be attributed to different aspects of stakeholder engagement. First, the project plan itself and the researchers' effort changed considerably: 43% of the total research time was dedicated solely to stakeholder engagement. Second, the researchers' network is much tighter than the project plan envisaged. Many more collaborations and much more information exchange have occurred, which in turns may lead to serendipitous future developments. Third, the computer model at the core of the MSE looks very different from its original design as a result of both information collected and the requirement to address issues of specific local interest. Fourth, the stakeholder engagement process triggered a number of novel behaviours among some groups and organisations in the Ningaloo region, as local individuals and groups took more interest in using the modelling research for decision-making, and began to organise in ways that facilitated the transfer of modelling knowledge and capacity (Chapman et al. 2011). We have reason to believe that, at least among some stakeholder groups, model acceptance and the general understanding on how the region functions at a socio-ecological level has improved. In-progress research due for completion in 2011 will provide a qualitative evaluation of how stakeholders' knowledge, behaviours and networks have changed as a result of the engagement process. Fifth, researchers have a much deeper understanding of who the stakeholders are, of their concerns and how best to communicate with them. Finally, the overall view of what a MSE project involves has matured within the research team.

This interaction and learning depends on the good will, open minds, dedication and enthusiasm on all parties, which we optimistically like to believe are most often available. Crucially however, it also depends on allowance for flexibility: on being able to change project schedule, move effort allocation and act on opportunities as they occur. In other words, allowing the MSE project to be as adaptive as the adaptive management it aims to simulate. This allowance may not always be present, especially when the MSE project involves the development of a complex piece of software engineering. We suggest that project planning will need to carefully account for all these factors in order to be successful.

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