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The interaction triangle as a tool for understanding stakeholder interactions in marine ecosystem based management

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ABSTRACT

Expectations about ecosystem based management (EBM) differ due to diverging perspectives about what EBM should be and how it should work. While EBM by its nature requires trade-offs to be made between ecological, economic and social sustainability criteria, the diversity of cross-sectoral perspectives, values, stakes, and the specificity of each individual situation determine the outcome of these trade-offs. The authors strive to raise awareness of the importance of interaction between three stakeholder groups (decision makers, scientists, and other actors) and argue that choosing appropriate degrees of interaction between them in a transparent way can make EBM more effective in terms of the three effectiveness criteria salience, legitimacy, and credibility. This article therefore presents an interaction triangle in which three crucial dimensions of stakeholder interactions are discussed: (A) between decision makers and scientists, who engage in framing to foster salience of scientific input to decision making, (B) between decision makers and other actors, to shape participation processes to foster legitimacy of EBM processes, and (C) between scientists and other actors, who collaborate to foster credibility of knowledge production. Due to the complexity of EBM, there is not one optimal interaction approach; rather, finding the optimal degrees of interaction for each dimension depends on the context in which EBM is implemented, i.e. the EBM objectives, the EBM initiator's willingness for transparency and interaction, and other context-specific factors, such as resources, trust, and state of knowledge.

1. Introduction

Expectations about ecosystem based management (EBM) differ due to diverging (disciplinary) perspectives. Many definitions of EBM exist (e.g. [53,2,15]), and "they invariably share a number of common characteristics", such as "broadening stakeholder involvement" and dealing with "multiple simultaneous drivers or 'pressures' on ecosystems" ([65]:682). This article uses the scientific consensus statement on EBM, which defines EBM as "an integrated approach to management that considers entire ecosystems, including humans" ([60]:1). Hence, comprehensive, effective and balanced EBM requires detailed understandings of not only environmental processes, but also ethical, social and economic processes [11].

Three characteristics pertaining to a holistic, integrated EBM approach render it a particularly complex process. First, EBM is about sustainability, meaning that management objectives should include social, economic and ecological concerns, requiring trade-offs. The exact needs and challenges, e.g. whether objectives and measures focus more on ecosystem health, economic opportunities or human well-being, or a combination thereof, depend on the place and time of implementation [54]. Second, EBM deals with different ecosystems as well as institutional settings, requiring multi-level governance [58,76]. Ecosystems are complex and often do not match existing policy scales (e.g. [15]). A mismatch of scale in ecosystem analyses can result in policy recommendation that are not meaningful to policy makers and impacted communities [11]. Furthermore, such inconsistencies can lead to institutional ambiguity and pose limitations to building effective multi-level decision making structures for EBM [95]. Third, EBM requires cross-sectoral coordination and the integration of sectoral concerns and management. Fisheries, shipping, oil and gas activities, MPAs, and tourism are all activities managed by different sectoral approaches. EBM initiatives have to build institutional linkages with sectoral governance arrangements to avoid conflicts or overlap [76].

Due to the holistic nature and complexities, EBM questions give rise to high scientific and political uncertainties as well as high and

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diverging stakes. EBM has many faces in how it can be implemented [86], i.e. there is not one single answer nor only one EBM implementation path to such complex problems, and more science cannot necessarily close the existing knowledge gaps (e.g. [22,16]). Rather, each individual situation requires context-specific trade-offs between ecological, economic and social sustainability criteria, based on an understanding of its institutional and political setting, local dynamics and context-dependent cultural constructs of the environment [9,11]. The complexities due to the high uncertainties [84] and stakes reinforce the need for decision makers, scientists and other actors to interact with each other [94,98,16,82], calling for approaches such as "post-normal science" [28,36,92], or risk communication [47,68,49,80,56]. The authors argue that implementation of EBM requires tailor-made, integrated interaction processes between the different stakeholder groups.

This article analyses the importance of interactions between stakeholder groups in marine EBM processes, and identifies three dimensions and spectra of these interactions. The "interaction triangle" supports the analysis of the context-specific nature of EBM, and can help with the evaluation of past and the planning of future EBM processes. The presented approach can give direction to policy makers, scientists, and other actors working on applied EBM research questions, in setting up context-specific interaction structures for these EBM processes. The authors strive to raise awareness of the importance of interaction between three stakeholder groups and argue that choosing appropriate degrees of interaction between them in a transparent way can make EBM more effective in terms of the three effectiveness criteria salience, legitimacy, and credibility [62].

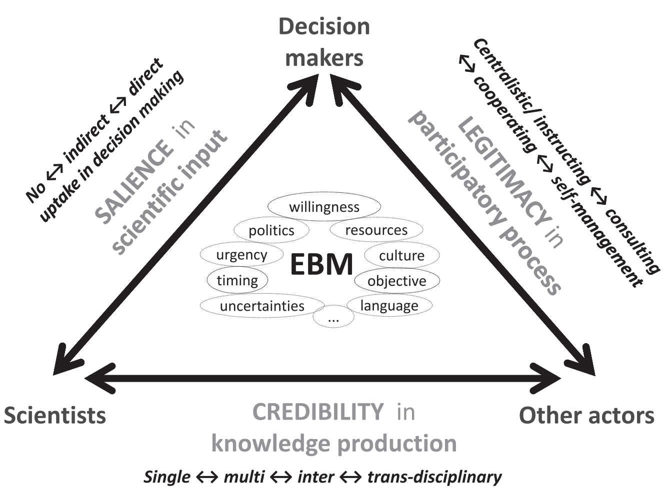

Fig. 1. The EBM triangle of interaction, specifying an interaction spectrum (outside, black) for each of the three dimensions (grey). Encircled inside the triangle, examples of context specific factors.

Our study is grounded on an interdisciplinary literature review covering and combining the fields of participatory knowledge production, inter- and transdisciplinarity, boundary work, role of science in decision making, and uncertainty and risk.

The article is structured as follows: The next section presents the interaction triangle, illustrating the three dimensions to be considered in the interaction between stakeholder groups in EBM processes, explaining their importance and spectra, i.e. their potential range/ degrees of interaction to choose from, depending on the specific EBM context. Context specific factors that determine how much interaction might be appropriate are then illustrated. The final section concludes with recommendations for effective EBM.

2. The interaction triangle in EBM processes

The "interaction triangle" consists of three dimensions, representing interaction pathways between (A) decision makers and scientists, (B) decision makers and other actors, and (C) scientists and other actors (Fig. 1). Each interaction dimension contributes to the process quality of dealing with an EBM challenge. To highlight the key focus and importance of each interaction dimension, each dimension is designated to one particular management effectiveness criterion: (A) salience in scientific input, (B) legitimacy in participatory processes, and (C) credibility in knowledge production (Table 1 adapted, based on Mitchell et al. [12,62]).

The relative importance of the three interaction dimensions can vary per situation, depending on different context specific factors, e.g. including formulation of the objective, time horizon, spatial scale, and available budget (examples are shown inside the interaction triangle, Fig. 1). Furthermore, it should be noted that the three dimensions and how they affect the EBM effectiveness criteria (Table 1) are interrelated. For example, increased credibility of the knowledge production process improves the chances for salient scientific input, thus relating directly to the interaction dimension between scientists and decision makers. Ultimately, higher credibility due to a better quality of the knowledge base and mutual trust is also expected to result in higher legitimacy, more compliance and thus more effective EBM.

The interaction triangle illustrates the interaction dimensions between three stakeholder groups, their potential contribution to management effectiveness, and the potential ranges of the interactions. Key to reaching consensus about the degree of interaction is transparency about the chosen strategies (and limitations) to engage in the interaction processes. The authors emphasize, though, that "transparency is no panacea, [...] it cannot alone initiate transformative change, but will work in conjunction with other practices and outcomes of governance" ([31]:7), namely the three stakeholder interaction dimensions, developed here, to foster salience, legitimacy, and credibility of EBM.

Table 1
Three requirements for EBM, modified, based on [62,12], with key question and issues to consider.

	Key question	Issues to consider
Salience	Is knowledge relevant for the decision or policy in question?	Does the knowledge provided fit into the policy challenge behind the question? Was the knowledge presented at the appropriate scale for decision/policy-making? Does the scale and timing of information meets the needs of decision makers?
Legitimacy	Has the process been fair and open to perspectives from representative stakeholders?	Did all stakeholders have an equal/balanced amount of resources (in terms of time, budget, access to information or other) during the participatory process? Does the decision making process show a preference for certain types of data or information?
Credibility	Is knowledge true or technically adequate in its handling of evidence?	Has the knowledge been produced according to the scientific standards? Is the methodology appropriate? Was the appropriate expertise (different disciplines) applied when producing the knowledge? What is the quality of data/information? Are procedures transparent?

The interaction triangle can be applied in both, an analytical and a normative way, e.g. as a tool to assess ongoing, or to plan and set up new EBM processes. The triangle is built upon the analytical and practical "interactive governance" concept ([50]:2), which "emphasizes solving societal problems… through interactions among civil, public and private actors"; the role of scientists is included in the interaction triangle, as EBM is supposed to be grounded on an 'adequate knowledge base' [23,24,86]. The "interactive governance" concept also has "a normative side to the equation, and understanding that broad societal participation in governance is an expression of democracy and therefore a desirable state of affairs" ([50]:3). The authors argue that the appropriateness and optimal degrees of interaction between stakeholder groups may vary from low to high, depending on each individual EBM situation. More interaction is not necessarily always better. The challenge is to find the appropriate degree of interaction depending on the specific EBM context. The responsibility for that lies with the actor who initiates EBM; the exact degree of interaction, though, depends on all actors together.

The following paragraphs introduce each interaction dimension and their three respective interaction spectra, i.e., the potential range/degrees of interaction.

2.1. Interaction between scientists and decision makers to foster salience in scientific input

Applied science responds to and informs a policy making process [11], and results are expected to be implemented in real life. This is not straightforward, though, due to different perspectives, expectations, drivers, and obligations of the involved people in the specific situation [8,85,89]. Linking science and decision making is considered "boundary work" [29,30,42,32]. Boundaries help to protect science from potential biases caused by what is at stake in decision making; however, at the same time they can lead to problems in communication and collaboration.

The spectrum of interaction between scientists and decision makers ranges from no, via indirect, to direct interaction in terms of scientific input in decision making. A "no interaction" expectation can be appropriate in a context of strong top down political management. For example, decision makers might be under extreme time pressure to take an urgent decision and not be able to wait for up to date scientific input. From the scientists' perspective, the scientific state of the art might be too new/preliminary/uncertain to be applied directly at that time in an early scientific stage.

Indirect interaction refers to contexts with time lags between scientific discovery and application, for example, environmental assessments "conducted at early stages are unlikely to lead to immediate and direct policy change" ([62]:309–310); or decision makers realize that already existing scientific information points towards areas that call for management action/decision making today. A time lag can also apply the other way around, i.e., scientists becoming interested in and more capable of studying a particular issue that management had called for earlier [62].

Direct interaction increases the potential for scientific output to be directly applied in decision making. Joint problem framing at the beginning of a process is crucial to define an applied research question [82]. Mitchell et al. [62] propose lessons that can aid in bridging the gap between scientists and decision makers and making scientific input more salient, e.g.: focus on process and not only (scientific) output, acknowledge decision makers' concerns, perspectives and values, involve other actors, and make use of existing networks.

Note that interactions between scientists and decision makers in applied research can be various and variable. A project can start with direct interaction, but along the way, the quality of interactions may ebb, depending on context specific factors, such as differences in personal 'chemistry' between individuals [11]. Moreover, the role played by scientists is an important factor in the salience of scientific input. Pielke [71] presented four extreme roles: the pure scientist (who strives for scientific truth and has no direct connection with decision makers) or the science arbiter (who interacts, providing scientific expert judgement) as the two extremes of the linear model of science, versus the issue advocate (interacting with decision makers, narrowing down available options) or the honest broker (engaging in the decision-making process, proposing new policy alternatives) as the extremes of the stakeholder model. Skolnikoff [83] identified an additional fifth role that can be added to Pielke's model: the scientist's non-role, describing situations where scientific evidence is irrelevant for the decision-making process because the issue at stake is of a high political nature. In such cases, scientific knowledge is overshadowed by large political stakes. Another extreme is scientific advice or knowledge adopted in decision making without much scrutiny. Brown [7] pointed out that many scientists appear not to be aware of the fact that they can choose their role depending on the context. Some just want to work in their ivory tower, according to the linear model. Yet, in practice the linear model is only applicable to narrow technical questions where there is consensus on values and uncertainty is low. Currey and Clark [14] evaluated the consequences of making active choices in the context of Pielke's framework, concluding that scientists who actively evaluate their position can be more effective creating salience in policy/ decision making processes.

The uptake of scientific input in decision making depends on various factors such as the need and urgency for scientific knowledge to reduce uncertainty regarding a political problem and the state of available knowledge. Personal characteristics can also pose barriers to salience in scientific input for decision making, for instance when decision makers have limited or no interest in the available scientific knowledge, or when scientists are unable to deliver applicable scientific input.

2.2. Interaction between decision makers and other actors to foster legitimacy of participatory processes

Participation means the involvement of user groups in the decision making and implementation process and has been called "the cornerstone of democracy" ([3]:216). The importance of participatory processes has increased in natural resources governance [19] and in EBM in particular since stakeholder participation is viewed as a key element of EBM [21,27,43,55,73]. However, participatory processes need to be well designed, because if handled badly, they can result in counterproductive negative consequences (e.g. erosion of trust between partners and end of cooperation [45,78].

The main motivations for (increased) stakeholder involvement and participatory processes are well known [99]: Participation can strengthen democratic cultures and processes [97], bring additional knowledge and values into decision-making in order to make better decisions [4,80], provide greater legitimacy [75,74], increase trust [81,64,57,17,99], enhance compliance [44,11,10], and reduce the intensity of conflict [99]. An improved overall process quality can result in increased management efficiency, equity, sustainability, reduction of administration and enforcement costs [75], making the management not only more legitimate, salient, credible, but also enforceable and realistic [26,91,13,54,80,98,86,18,92].

A spectrum of interaction between decision makers and stakeholders was described by Arnstein in 1969 as "gradations of citizen participation" identifying a "typology of eight *levels* of participation" ([3]:217). The bottom rungs describe levels of "non-participation", meaning "not to enable people to participate in planning or conducting programs, but to enable power holders to 'educate' or 'cure' the participants". A bit higher up in the ladder, the levels of informing and consultation allow participants "to hear and to have a voice"; however, participants "lack the power to ensure that their views will be heeded”. The top levels of the ladder “are levels of citizen power with increasing degrees of decision-making clout”. Citizens can enter into partnership, can be delegated power, or at the very top, can have citizen control, obtaining “the majority of decision-making seats, or full managerial power”.

Similar spectra of participation have been described in other fields, for example the “Effective Community Participation” model for coastal development projects [59], a typology of community participation in tourism [87], or the typology of co-management arrangements in fisheries management [75]. The latter continuum ranges from a centralistic top-down government-based management via instructing, consulting, cooperating, advising, being informed, to self-management of the user-groups.

This continuum thus assigns different roles and responsibilities to the managers and those being managed. Neither top down government centralistic management, nor bottom-up self-management is necessarily the best way for natural resources management. The important aspect is to be transparent about the roles and responsibilities expected from the involved parties. Many have highlighted the importance of early involvement of stakeholders, i.e. in the problem framing/ scoping phase of a participatory process [20,35,82]. Stakeholders' roles in the process should be clarified [25,63,99], and “a common vision including the objectives for marine EBM” be defined ([54]:542, [23]). Clarity and transparency can help to prevent misunderstandings, as it enhances the joint understanding of the management question to be solved.

2.3. Interaction between scientists and other actors to foster credibility in knowledge production

Science has an important role to play in providing credible knowledge for EBM. However, science alone cannot provide all the answers, since EBM is complex, surrounded by many uncertainties, value-laden and intrinsically linked to stakeholders' interests and values. The holistic nature of EBM requires more complex approaches to deal with the three pillars of sustainability. The ecological pillar becomes more complex, as more ecosystem components (e.g. multi-species instead of single-species management) and possible environmental influences (e.g. climate) are considered. Complexity of the social and economic pillars increases because integrated management needs to take into account multiple sectors and potential cumulative effects. Thus, depending on the specific context and question to be dealt with, different approaches of knowledge production can be appropriate. Science may involve quantitative as well as qualitative approaches. Quantitative methods are generically required, e.g. for statistical analyses. Qualitative approaches are indispensable for scoping and framing, such as determining model boundary settings, assumptions, interpreting results, but also for generating in-depth knowledge about the effects of multiple social, political and economic factors. In addition to research based knowledge, traditional ecological knowledge [5,39,1] is increasingly considered useful in marine management to deal with issues of uncertainty, offering “a means to improve research and also to improve resource management…” ([39]:1270). Yet, such experience based knowledge cannot easily be analysed, compared, or linked to information on a broader scale [98].

The interaction dimension between scientists and other actors reflects the degree to which knowledge production is entirely in the hands of scientists, based on research based knowledge, or moves towards collaborative knowledge production, with research projects conducted jointly with other actors. The spectrum of approaches to knowledge production ranges from single, via multi- and inter- to transdisciplinary.

Single disciplinary approaches comprise very specific disciplinary approaches, such as chemical measurements of elements in an environmental substance, as well as generic approaches such as statistical analyses, document writing, etc.

Multidisciplinary approaches, “a conglomeration of disciplinary components” ([40]:80), allow collectively working with different disciplines in parallel on a similar problem, approaching it from different angles, but having different foci and still applying one's own individual disciplinary approaches.

Interdisciplinarity is “a more synthetic attempt of mutual interaction”, best understood “as a variety of different ways of bridging and confronting the prevailing disciplinary approaches” ([40]:80). An interdisciplinary approach links “phenomena, research approaches, and conceptual tools that had previously been pursued independently” ([70]:302); it implies that the different disciplinary experts jointly analyse the problem, “formulating a global question at the outset of a process” ([34]:1), thus having one and the same focus. The interdisciplinary team decides which of the different disciplinary approaches are best suited or how to combine and integrate, potentially synthesizing an innovative approach to jointly tackle the advanced interdisciplinary questions [69]. Transdisciplinarity goes even further, implying a joint and collaborative research process involving scientists and other actors [66,48,38]. Scientists need to cross the science-stakeholder boundary to include stakeholders in the process of collaboratively working together to produce new knowledge. The methodological spectrum requires the integration of qualitative and quantitative science [93]; it requires an integration of traditional ecological knowledge from practitioners in the field and any other actors, with scientific information. By integrating these different types of knowledge, the complexity of the knowledge base can increase, and its quality can potentially improve.

In fisheries and watershed management, transdisciplinary approaches were tested (e.g. mutual sharing of knowledge, jointly and openly discussing about input data, model parameters, assumptions); positive effects were demonstrated, such as joint problem understanding; comprehension and acceptance of the common knowledge basis; collective learning; advancing scientific understanding [19,35,46,52,82,90]. Such collaborative processes can build trust and result in a higher credibility of science and scientific advice [33,19,82]. To further improve methods for stakeholder involvement in research for EBM, lessons learnt need to be shared from experience so far [52].

Regarding the management of complex environmental problems, [34] conclude that the “scientific knowledge base has to be expanded in a more holistic direction by incorporating social and economic issues” in addition to the natural science basis. A review on marine and coastal research “argues that theories and methods should conform to a perspective that ocean management is a societal activity with diverse goals ideally informed by interdisciplinary information” ([11]:172). Not always but increasingly EBM requires a move from single- towards inter- and trans-disciplinary approaches [34,69].

3. Context specific factors that affect stakeholder interaction

The interaction triangle shows how three important groups with stakes in EBM engage with each other across three interaction dimensions and to different degrees on the respective interaction spectra (Fig. 1). In this section, some context-specific factors are discussed, in order to illustrate the importance of recognizing and acknowledging the context in which EBM is implemented (cf. [11]). That is, EBM, positioned in the middle of the interaction triangle, is decomposed into different context-specific factors, examples of which are also shown inside the interaction triangle (Fig. 1). The context of EBM processes depends on: “the actors involved, contents of dominant discourses, presence of rules and the availability of resources” ([37]:52) as well as the quality of interaction processes [54,99]. Within this context, the authors elaborate on important context-specific factors that influence the degree of interaction: availability of resources, trust, the quality or state of available (scientific) knowledge, and the willingness to interact (cf. Table 2). Table 2 is not supposed to provide a comprehensive checklist, because EBM contexts are too divers to be listed comprehensively on one page. The table is rather meant as an inspiration to help create context awareness, providing a few concrete questions. Cultural and socio-economic factors are often neglected when nature conservation is the fundamental management objective [4]. Here, those factors are considered inherent to the sustainability debate and the required trade-offs between ecological, economic and social objectives that need to be made in any EBM challenge.

Awareness, recognition, and acknowledgement of context-specific factors are a first step in defining the degree of interaction across the interaction triangle. The actor taking the lead in EBM processes has an important responsibility in choosing how much transparency is warranted, and how much interaction is appropriate, necessary and feasible in the specific context. However, as there is no one-size fits all method, there are no clear-cut solutions as to how much interaction is required. Context-specific factors will shape the degree of interaction. In doing so, the context-specific factors can comprehensively affect all three dimensions of stakeholder interactions at the same time, but they can also affect specifically one or two stakeholder interaction dimensions.

3.1. Resources

Availability of resources, such as manpower, time, money, space, interaction fora/channels, language capacities, are prerequisite to all three stakeholder groups for interacting with each other. Resources are often distributed unequally—between different stakeholder groups and/or within one group [67]. When resources are limited, whether for all or just one group, the first step towards a more transparent process is to identify and acknowledge this problem openly. For example, if smaller parties are not well represented due to insufficient manpower or financial means, this can result in powerful interests dominating a participatory process [27]. Furthermore, inflexible work agendas and “differences in work demands” can be an involuntary but decisive reason for stakeholder groups not to participate ([41]:8). The availability and distribution of resources among stakeholders can set “limitations in how many, and which actors can participate” ([37]:56). Limited resources can also limit the possibilities of scientific research. There might be a trade-off between the cost of research and the resulting benefits [23].

Moreover, the existence or absence of interaction fora can affect interactions between stakeholder groups. For example, [67] observed that fisheries stakeholders actively participate in fisheries policy, but hardly in the implementation of the Marine Strategy Framework Directive (MSFD). This lack of interaction, and resulting lack of integration, is due to the disconnect between intuitional levels and the lack of an appropriate stakeholder forum at the relevant levels, i.e., fora related to the MSFD and DG Environment (Regional Seas Convention, Common Implementation Strategy of the EU) are different from fora related to fisheries and DG MARE (e.g. Regional Advisory Councils).

Linguistic capacity represents another context specific factor. Communication across professional cultures can fail simply due to linguistic misunderstandings [41], caused by the use jargon or

Table 2
Examples of context-specific factors and related issues to consider for choosing an appropriate degree of interaction.

Context	Issues to consider/questions
Resources (e.g. time, money, space, manpower, interaction fora/channels, language capacities)	– Are resources distributed (un)equally? – Do those with more resources dominate? – Are work agendas overloaded? – What are the costs versus benefits of interaction? – Do interaction fora exist already? – Who participates in what forum? Are fora linked? – Do different actors understand each other's language/ jargon? – How much time is available to build common understanding?
Trust	– Is there transparency about roles and responsibilities expected from the involved parties/actors? – Are there institutional arrangements in place (e.g. co-management) to enhance trust? – Are there interactive means to build trust, e.g. cooperation, regular meetings, face to face contacts, direct communication? – What is the state/ quality of the involved knowledge/ expertise/ competence? – Are results/ future developments predictable? – Is there a general (societal) climate of openness, honesty, absence of bias, objectivity, fairness? – Is there a general (societal) climate of concern, care, commitment to a goal, consistency, faith, empathy, dedication? – Can actors participating in the process be held accountable for their input?
Quality of knowledge	– Is the (scientific) knowledge considered adequate and appropriate? – Is there consensus on the quality of the available (scientific) knowledge? – Are scientists interested in studying a particular management issue? – Are the uncertainties in the knowledge known and documented systematically? – Can quantitative approaches be coupled to qualitative approaches, including problem framing from multiple perspectives and stakeholder involvement? – Is the scientific discovery ready to be applied right away or is there a time lag?
Willingness	– Are actors willing to engage in joint problem framing? – Are actors interested in learning from/understanding other actors? – Are actors willing to share information? – Are there hidden agendas? – How is the governance process organized? Top down, bottom-up/participatory, or a combination of both? – How urgent is it to deal with the EBM challenge? Is there time to add the 'best available knowledge'? – Are actors willing to acknowledge the decision makers' concerns, perspectives and values?

unclear, ambiguous terminology (i.e. different meaning of a phrase used in different disciplines). It takes time and commitment to generate a common language and common meaning [11,88,70].

3.2. Trust

Trust is a prerequisite for interaction, and – as a positive feedback – transparent interaction processes can build additional trust (e.g. [82]). Three main determinants of trust have been suggested—already by Aristotle over 2000 years ago, and more recently summarized and empirically confirmed by [68]: (1) knowledge, expertise, competence, predictability; (2) openness, honesty, absence of bias, objectivity, fairness; (3) concern, care, commitment to a goal, consistency, faith, empathy, dedication. The latter string of determinants comprises notions of responsibility, also termed accountability [6]. Are actors willing to accept responsibility or to account for their actions?

Ref. [17] observed trust growing among Dutch fisheries stakeholders through the "establishment of Study Groups […] to cooperate on sustainability innovations". Several obligations, such as regular meetings, "face to face contacts and direct communication (instead of via representatives)", and "joint study trips abroad led to mutual experiences, which enhanced trust relationships" ([17]:895). Other collaborative science-industry projects highlighted the importance of mutual contact for trust building to achieve a good collaborative process and credibility in data collected by practitioners (instead of by scientists) [45,51].

On the contrary, feelings of distrust between stakeholder groups, for example due to differences in problem perception, can lead to frustration, resulting in unfruitful discussions, hindering effective participation; "participation can even come to a halt due to controversies, for instance when fishermen do not feel 'heard' by scientists and policy makers" ([96]:522–523). Also, [57] state that "conflicting interpretations about an important […] issue add to the growing erosion of public trust in advice from experts." Furthermore, they state that "public trust in science is the greatest resource at stake in the dialogue about complicated risks", concluding that "trust is better served by a focus on why disagreements exist rather than who is right" ([57]:1814).

Trust building processes can be enhanced by "institutional arrangements such as co-management", but these are no panacea; institutional arrangements not adapted to the context can even "lead to distrust when new challenges are being faced and institutional arrangements fail to adapt to these changes" ([18]:218).

3.3. State of available knowledge

The current "state of the art" of science potentially affects the two interaction dimensions linked to scientists. One of the caveats to be aware of is the potential bias caused by the accessibility of information. Information is more present and available once it is published. For example, the selection of indicators to measure progress against EBM objectives was based on familiarity with a well-known indicator rather than a proper evaluation against appropriate criteria [72]. Scientists and decision makers would need to interact more to overcome this bias and to jointly choose appropriate criteria for the management question.

Regarding the use and combination of different sources of information, there appears to be a gradient of increasing confidence in the suitability of information to inform management. Simulation models are often considered the culmination of much of the underlying information in a formalized framework; the danger is, though, that such models can be misused if the underlying assumptions are not understood or in general their limitations ignored [79]. More complex models are not necessarily better than less complex models, nor are simulation models always better than empirical knowledge, nor should empirical knowledge always be preferred over expert opinion. Based on a systematic documentation of uncertainty in a monitoring and evaluation tool for marine spatial planning, Stelzenmüller et al. (forthcoming) conclude that quantitative uncertainty assessment approaches need to be complemented by qualitative approaches, including problem framing from multiple perspectives and stakeholder involvement. Both approaches combined should "provide enough background knowledge on the nature of uncertainty to stimulate decision makers whose decisions are particularly sensitive to the uncertainty to dive deeper into the subject" ([84]:161).

If the state (quality) of science and knowledge is premature, uncertain, or relies on too many assumptions, then science moves into the post-normal science domain [28,36,16,92] calling e.g. for transdisciplinary, collaborative knowledge production and extended peer review (e.g. [35,82]). An expected benefit of joint knowledge production is to get a better mutual understanding of the problems involved. Furthermore, interaction between the different stakeholder groups about the knowledge basis and considering traditional local ecological knowledge in addition to scientific knowledge can add transparency or even reduce (or at least reframe) uncertainties, by realising that a particular contested issue is irrelevant for the management question to be dealt with. For example, in a joint science-industry collaboration on modelling herring fisheries, scientists realised after several joint meetings that the main management question was not to get a better catch quota estimate but how to split the total catch quota over the different countries [90]. This improved problem understanding needed different scientific skills and knowledge, which was less uncertain than that for the original question [90,82].

3.4. Willingness

Urgent management decisions cannot be postponed and need to be taken despite knowledge gaps and uncertainties, since, generally speaking, "policy and science operate on different timescales" ([89]:15). Moreover, decision makers are not always willing to spend time on interacting with scientists or other actors, or are not inclined to create a transparent process with uncertain outcomes. Decision making processes dominated by politics can seriously limit the willingness to interact with science and society. An awareness of the political reality can prevent frustration and fatigue among scientists and other actors wanting to interact with decision makers.

Actors previously engaged in collaborative knowledge production or participatory processes might develop "consultation fatigue", in particular, if their participatory experiences are negative, e.g. due to badly designed processes, or "as they perceive that their involvement gains them little reward or capacity to influence decisions that affect them" ([77]:2420). Sometimes, other routes to influence decision making such as lobbying are preferred to participatory processes.

Moreover, frustration or scepticism about the intention of other actors can hamper the willingness to engage in participatory processes. Stakeholders can have their own hidden agendas [61], i.e., reasons for not collaborating or collaborating in biased and even misleading ways. In collaborative fisheries research, for example, "some fishers are reluctant to share information that they fear could lead to future quota reductions or effort restrictions" ([45]:835). Can stakeholders trust scientists to deal with the jointly produced knowledge in a reliable, impartial, independent way? At the same time, can scientists trust stakeholders to collect data in a just manner and to share correct information [45,51].

4. Conclusion

This article argues that EBM requires extra attention for interaction processes between stakeholders. Striving for sustainability (requiring trade-offs between ecological, economic and social objectives) in a multi-level governance setting and across a multitude of sectors (involving different interests and stakes) means that there are no simple solutions to an EBM challenge. Rather, each EBM case needs a context specific approach. The interaction triangle is presented as a tool to analyse, evaluate and/ or plan interactions between three stakeholder groups. Three interaction dimensions are put forward in the triangle, i.e. interaction between (A) decision makers and scientists, (B) decision makers and other actors, and (C) scientists and other actors. Following Mitchell et al. [62] and Clark et al. [12], the authors argue that effective EBM requires salient scientific input to decision making based on the interaction between decision makers and scientists, credible knowledge production based on the interaction between scientists and other stakeholder, and legitimate participatory processes based on the interaction between decision makers and other actors. Finally, the authors present context-specific factors that affect interaction depending on the specific EBM context. Available resources, trust between stakeholders, state of available knowledge, and willingness are factors that determine the positioning on each of the three interaction dimensions. As not every EBM challenge requires the same 'degree' of interaction, context awareness and understanding is crucial and represents the first step towards efficient EBM in terms of salience, credibility and legitimacy. Moreover, the three interaction dimensions are related, so the positioning on one interaction spectrum can affect the positioning on one or both of the other two interaction spectra. Hence, some EBM situations might require strong interaction on all three dimensions; for other situations, one, two or all interaction dimensions might need only minimal attention for interaction. It all depends on the context, including the objective of the specific EBM challenge, the context-specific factors, and the willingness of the EBM initiator to achieve a legitimate, credible, and salient EBM process.

The authors conclude with recommendations from a normative perspective: (a) Stakeholder participation is a key element of successful EBM. (b) Depending on the context of an EBM question, the initiators of, as well as participants in EBM processes should decide and negotiate on how much and what kind of interaction is necessary, appropriate and desirable. (c) Roles of all stakeholders in the process should be clarified. (d) A common vision and the objectives for EBM should be defined. In summary, process clarity and transparency enhance the joint understanding of the management question to be solved. Conscious and transparent choices about the way and degree of interaction are expected to improve the quality of EBM processes.

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